IPR2020-01302
U.S. Patent No. 7,539,474

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Intel Corporation

Petitioner

v.

ParkerVision, Inc.

Patent Owner

U.S. Patent No. 7,539,474

Issue Date: May 26, 2009
Title: DC OFFSET, RE-RADIATION, AND I/Q SOLUTIONS USING UNIVERSAL FREQUENCY TRANSLATION TECHNOLOGY

Inter Partes Review No. IPR2020-01302

DECLARATION OF DR. MICHAEL STEER

TABLE OF CONTENTS

I have personal knowledge of the facts set forth in this declaration and, if called to testify as a witness, would testify under oath as follows:

I. BACKGROUND

1. I have been retained as an expert on behalf of ParkerVision, Inc. ("ParkerVision") in the above-captioned matter (IPR2020-01302).

2. I have been asked by ParkerVision to provide my expert opinion regarding the validity of claims 1, 3, 4, 7, and 9-11 of U.S. Patent No. 7,539,474 ("the '474 patent"). For the reasons set forth below, it is my opinion that claims 1, 3, 4, 7, and 9-11 of the '474 patent are valid.

II. PROFESSIONAL QUALIFICATIONS

3. I am the Lampe Distinguished Professor of Electrical and Computer Engineering at North Carolina State University.

4. I received my Bachelor of Engineering with Honors (B.E. Hons) and Ph.D. in Electrical Engineering from the University of Queensland, Brisbane, Australia, in 1976 and 1983 respectively.

5. I was a pioneer in the modeling and simulation of nonlinear radio frequency and microwave circuits. To put this in perspective, the first commercial cellular phone became available in 1983, and in that same year, I began teaching classes in radio frequency circuit design. Specifically, I joined the Electrical Engineering Department at North Carolina State University, Raleigh, North

Carolina, as a Visiting Assistant Professor in August 1983. I became an Assistant Professor in 1986 when the department was renamed the Department of Electrical and Computer Engineering. I have been promoted throughout the years, first becoming an Associate Professor in 1991, a Professor in 1996, a Named Professor in 2005, and a Distinguished Professor in 2010.

6. During the 1990s, I began working very closely with the U.S. Department of Defense, and in particular with the U.S. Army, on radio frequency communications and advanced radio frequency circuits. Between 1996 and 1998, I also worked as a consultant for Zeevo, Inc., a Silicon Valley-based provider of semiconductor and software solutions for wireless communications.

7. In 1999, I moved to the United Kingdom to become Professor and Director of the Institute of Microwaves and Photonics at the University of Leeds, one of the largest university-based academic radio frequency research groups in Europe. I held the Chair in Microwave and Millimetrewave Electronics. I also continued my work with the U.S. Army and worked with the European Office of the U.S. Army Research Office. I returned to the United States in 2000, resuming the position of Professor of Electrical and Computer Engineering at North Carolina State University.

8. Further details on various aspects of my professional experience and qualifications can be found in my curriculum vitae, which is attached hereto as Appendix A.

9. Based on my experience in the wireless communications industry, I have a detailed understanding of radio frequency circuit design, including the radio frequency front end of cellular phones.

III. MATERIAL CONSIDERED

10. In preparing this declaration, I have reviewed the specification, claims and prosecution history of the ’474 patent.

11. I understand that the ’474 patent (a) issued on May 26, 2009, (b) is a continuation of U.S. Application No. 09/526,041 (now U.S. Patent No. 6,879,817), filed on Mar. 14, 2000, and (c) claims priority from U.S. Provisional Application Nos. 60/180,667, filed on Feb. 7, 2000; 60/177,705, filed on Jan. 24, 2000; 60/177,702, filed on Jan. 24, 2000; 60/171,496, filed on Dec. 22, 1999; 60/171,502, filed on Dec. 22, 1999; 60/171,349, filed on Dec. 22, 1999; 60/158,047, filed on Oct. 7, 1999; and 60/129,839, filed on Apr. 16, 1999.

12. I have reviewed and understand the following documents.

Exhibit	Description
	Petition for *Inter Partes* Review of U.S. Patent No. 7,539,474 Challenging Claims 1, 3, 4, 7, 9-12 (“Petition”)
1001	U.S. Patent No. 7,539,474 (“the ’474 patent”)
1002	Declaration of Vivek Subramanian Regarding U.S. Patent No. 7,539,474
1003	’474 patent file history
1004	U.S. Patent No. 6,879,817 (“’817 patent”)
1005	Lawrence E. Larson, *RF and Microwave Circuit Design for Wireless Communications* (Artech House 1996) (“Larson”)
1006	U.S. Patent No. 4,603,463 (“Butler”)
1007	U.S. Patent No. 6,192,225 (“Arpaia”)
1008	U.S. Patent No. 4,639,619 (“Baldwin)
1009	U.S. Patent No. 4,712,070 (“Clark”)
1010	U.S. Patent No. 5,796,304 (“Gentzler”)
1011	U.S. Patent No. 5,263,196 (“Jasper”)
1012	U.S. Patent No. 6,014,054 (“Kawakita”)
1013	U.S. Patent No. 5,621,323 (“Larsen”)
1014	U.S. Patent No. 5,430,893 (“Myer”)
1015	U.S. Patent No. 6,230,000 (“Tayloe”)
1016	S. Patent No. 4,705,967 (“Vasile”)
1017	U.S. Patent No. 5,818,243 (“Wakamatsu”)
1018	E.U. Patent No. 1,016,209 (“Ferris”)
1019	Chris Bowick, *RF Circuit Design* (1982) (“Bowick”)
1020	Richard B. Curtin, Technique for Measuring Electric Field Signals Using a Differential Antenna System, IEEE TRANSACTIONS ON ELECTROMAGNETIC COMPATIBILITY (Mar. 1967) (“Curtin”)
1021	Declaration of Sylvia Hall-Ellis Regarding the Authenticity of *RF and Microwave Circuit Design for Wireless Communications* (“Hall-Ellis Decl.”)
1022	Declaration of Christopher Ernst Regarding the Authenticity of *RF and Microwave Circuit Design for Wireless Communications* (“Ernst Decl.”)
1025	Patent Owner’s Preliminary Infringement Contentions, *ParkerVision, Inc. v. Intel Corp.*, No. 6:20-cv-00108 (June 26, 2020)
1026	Asad A. Abidi, Low-Power Radio-Frequency IC’s for Portable Communications, PROCEEDINGS OF THE IEEE, Vol. 83, No. 4 (Apr. 1995) (“Abidi”)
1027	Asad A. Abidi, Direct-Conversion Radio Transceivers for Digital

	Communications, IEEE Journal of Solid-State Circuits, Vol. 30, No. 12 (Dec. 1995) ("Abidi2")
1028	David H. Shen, et al., A 900-MHz RF Front-End with Integrated Discrete-Time Filtering, IEEE Journal of Solid-State Circuits, Vol. 30, No. 12 (Dec. 1996) ("Shen")
1029	U.S. Patent No. 6,438,366 ("Lindfors")
1030	Jim Williams, Application Note 47, *High Speed Amplifier Techniques*, Linear Technology (Aug. 1991) ("Williams")
2009	"Transistor," *The American Heritage College Dictionary* (3rd ed. 1997)
2010	U.S. Patent No. 5,969,545
2011	U.S. Patent No. 6,531,931
2012	U.S. Patent No. 5,614,855
2013	Rudolf Graf, *Modern Dictionary of Electronics* (7th ed. 1999)
2014	J. Crols, "A 1.5 GHz Highly Linear CMOS Downconversion Mixer, IEEE J. Solid-State Circuits, Vol. 30, No.7, pp. 736-742, July 1995
2015	A. Rofougaran, J. Chang, M. Rofougaran, and A. Abidi, "A 1 GHz CMOS RF Front-End IC for a Direct-Conversion Wireless Receiver," IEEE J. Solid-State Circuits, Vol. 31, No. 7, pp. 880-889, July 1996
2016	B. Razavi, "Challenges in Portable RF Transceiver Design," IEEE Circuits and Devices, Vol. 12, No. 5, pp. 12-25, Sept. 1996
2017	Mehmet Özgür, "MMIC Mixers" (1996) (Bilkent University)
2018	Sedra/Smith, *Microelectronic Circuits* (4th ed. Oxford University Press 1998)
2019	S. M. Sze, *Physics of Semiconductor Devices*, (2nd ed. John Wiley & Sons, Inc. 1981).
2020	U.S. Patent No. 6,061,551
2021	Claim Construction Order, *ParkerVision, Inc. v. Intel Corp.*, No. 6:20-cv-108-ADA (W.D. Tex.)
2022	B. Razavi, "CMOS RF receiver design for wireless LAN applications," IEEE Radio and Wireless Conference, pp. 275-280, Aug. 1999
2023	Qualcomm Email dated Aug. 11, 1998
2024	Qualcomm Email dated Feb. 2, 1999
2025	Qualcomm Email dated Oct. 7, 1998
2026	Qualcomm Email dated Feb. 4, 1999

IV. LEGAL STANDARDS

13. I am not an attorney and I have not independently researched the law. ParkerVision's counsel has explained certain legal principles to me that I have relied on in forming my opinions set forth in this declaration. I have applied these legal principles in arriving at my opinions expressed in this declaration.

A. Anticipation.

14. I have been informed and understand that a patent claim is invalid as anticipated if each and every element as set forth in the claim is found, either expressly or inherently, in the teachings and disclosures of a single prior art reference.

15. I also understand that a reference inherently discloses an element if that element is necessarily present in the disclosure of the reference and would be so recognized by one of ordinary skill in the art. I further understand that inherency cannot be established by probabilities or possibilities, and that the mere fact that an element may result from a certain set of circumstances – that is, an element might be present – is insufficient to establish inherency.

B. Obviousness.

16. I have been informed and understand that an invention cannot be patented if the subject matter as a whole would have been obvious to a person of ordinary skill in the art at the time of the invention. Also, I understand that while the prior art is compared to each claim on an element-by-element basis, the claimed

invention as a whole must have been obvious to one of ordinary skill in order for a claim to be invalid.

17. I understand that the fundamental question in analyzing obviousness is whether, at the time of the invention, the subject matter of the claimed invention as a whole would have been obvious to a person of ordinary skill in the art to which the subject matter pertains, taking into account: (a) the scope and content of the prior art; (b) the differences between the prior art and the claims at issue; (c) the level of ordinary skill in the art; and (d) any objective indicia of non-obviousness referred to as secondary considerations.

18. It is my understanding that objective indicia of non-obviousness (secondary considerations) include industry praise, commercial success, long-felt but unresolved need, copying, failure of others, and/or unexpected results. I also understand that there should be a nexus between the objective indicia and the claimed invention.

19. I understand that multiple references can be combined, with one another and/or with the knowledge of a person of ordinary skill in the art, in rendering a claim obvious. I also understand, however, that obviousness cannot be established by simply demonstrating that each element was independently known in the prior art. Rather, it may be necessary to identify a reason, such as a teaching, suggestion,

or motivation, that would have prompted a person of ordinary skill in the art to combine the elements in the way the claimed invention does.

20. I also understand that obviousness cannot be established through hindsight. I understand this to mean that the claimed invention cannot be used as a roadmap to combine elements from different pieces of prior art, or different embodiments of a single prior art reference, to create the claimed invention. I understand that the claimed invention as a whole must be compared to the prior art as a whole, and one must avoid aggregating pieces of prior art through hindsight that would not have been combined absent the patent inventor's insight.

C. "Means-plus-function" claim elements.

21. I have been informed and understand that a claim term using the word "means" is presumed to be a "means-plus-function" term. I also have been informed that a term used as a substitute for "means" (referred to as a "nonce" word) (e.g., the term "element" or "module" used by itself) that fails to connote structure (from the point of view of a person of ordinary skill in the art at the time of the invention) to perform the claimed function(s) is also a means-plus-function term.

22. I understand that a means-plus-function term is limited to the function recited in the claim and the specific structure disclosed in the patent's specification for performing that function and structures that are equivalent to the disclosed structures. As such, it is my understanding that if a term is a means-plus-function

term, the term is defined by its function (as set forth in the claim) and the specific structure disclosed in the patent's specification for performing that function and structures that are equivalent to the disclosed structures.

23. I also understand that a claim term that does not use the word "means" is presumed not to be a "means-plus-function" term. I understand that in order for a term that does not use the word "means" to be deemed a "means-plus-function" term, the term must not connote structure to a person of ordinary skill in the art at the time of the invention. In other words, if the term connotes structure, it is not deemed to be a "mean-plus-function" term.

24. I have been informed and understand that for a means-plus-function term, a prior art reference or combination of references must disclose the identical function set forth in the claim and must disclose a structure that performs the function that is either identical to or the equivalent of the structure in the specification of the challenged patent that performs the claimed function. I understand that a structure disclosed in a prior art reference can be equivalent if (a) the prior art element performs the identical function specified in the claim in substantially the same way, and produces substantially the same result as the corresponding element disclosed in the specification, (b) a person of ordinary skill in the art would have recognized the interchangeability of the element shown in the prior art for the corresponding element disclosed in the specification, or (c) there are

insubstantial differences between the prior art element and the corresponding element disclosed in the specification.

V. LEVEL OF ORDINARY SKILL IN THE ART

25. I have been informed and understand that claims are construed from the perspective of a person of ordinary skill in the art ("POSITA") at the time of the claimed invention.

26. In my opinion, a POSITA with respect to the '474 patent would have (a) a Bachelor of Science degree in electrical or computer engineering (or a related academic field), and at least two (2) additional years of work experience in the design and development of radio frequency circuits and/or systems, or (b) at least five (5) years of work experience and training in the design and development of radio frequency circuits and/or systems.

27. In view of my qualifications, experience, and understanding of the subject matter of the claimed invention, I believe that I meet the above-mentioned criteria and consider myself a person with at least ordinary skill in the art pertaining to the '474 patent.

VI. GENERAL OVERVIEW OF THE TECHONOLOGY

28. The '474 patent relates to wireless communication and, more particularly, to frequency up-conversion and down-conversion of electromagnetic (EM) signals.

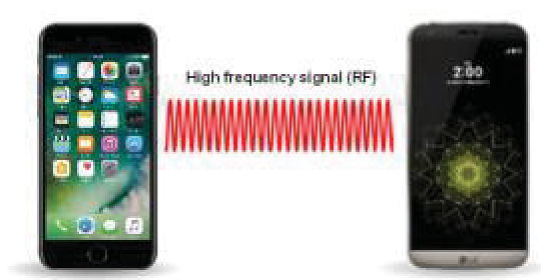
A. Wired communications.

29. Traditional wired communications networks transmit audio signals over wire lines by converting audio signals to electrical signals and back to audio signals.

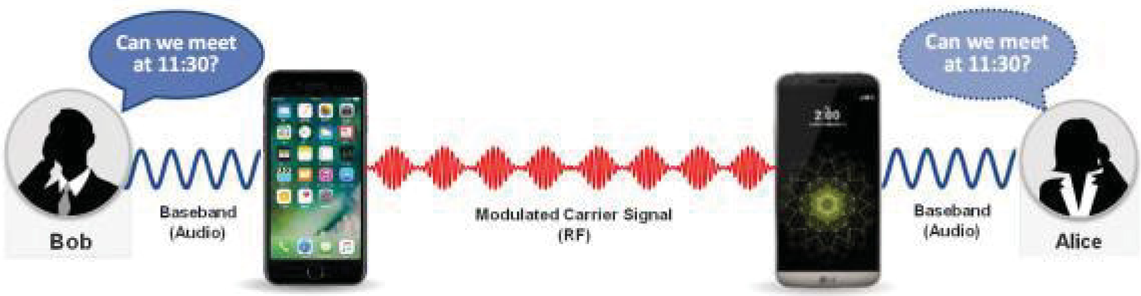
30. When Bob speaks into a phone, Bob's phone converts his voice (low frequency audio signals) into electrical signals. Electrical signals are transmitted over wires to Alice's phone, which converts the electrical signals back into audio signals so that Alice can hear Bob's voice.

B. Wireless communications.

31. Similar to wired communications, in wireless communications, low frequency audio signals are converted into electrical signals. In wireless communications, instead of travelling through wires, the signals are transmitted through air as radio waves (electromagnetic (EM) waves).



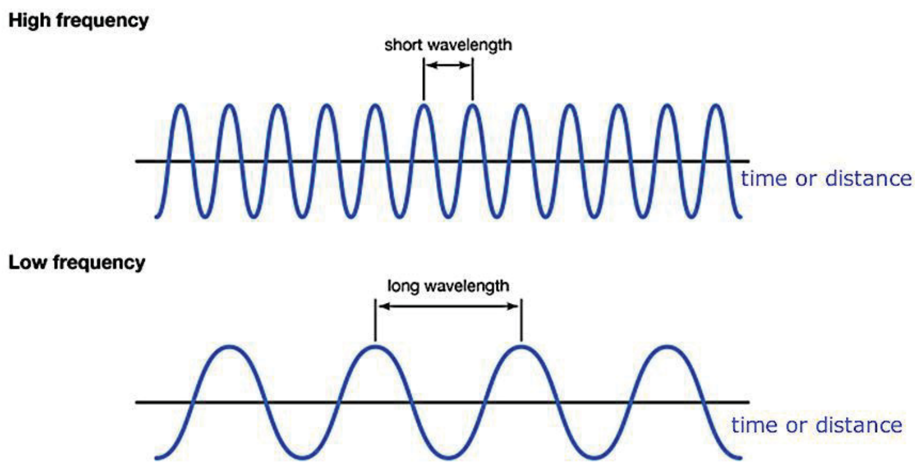
32. As shown above, wireless devices use high radio frequency (RF) signals (e.g., above 300 MHz (red)) because high frequency signals can carry more information and because high frequency antennas can physically fit within small devices such as cellular phones.



33. In a wireless communication, when Bob speaks into his cell phone, Bob's cell phone converts his voice (low frequency audio signal) into a high frequency RF signal. The RF signal is transmitted over the air to Alice's cell phone. Alice's cell phone then converts the RF signal back into a low frequency audio signal and Alice can hear Bob's voice.

C. Frequency.

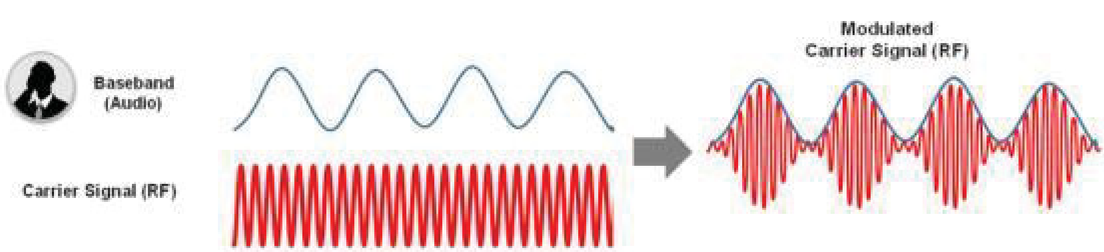
34. Frequency is the number of cycles of a wave per unit time (second).



35. As shown above, a high frequency signal has more cycles of a wave per second than a low frequency signal. Notably, the frequency of an audio wave can be one thousand cycles per second whereas the frequency of a radio wave can be one billion cycles per second.

D. Up-conversion.

36. In order to transmit an audio signal over air, a wireless device must transform the audio signal to an RF signal. Since the RF signal is used to carry the information in the audio signal, the RF signal is referred to as a "carrier signal." And since audio waves are at a low frequency, they are referred to as "baseband," a "baseband signal" or at a "baseband frequency."

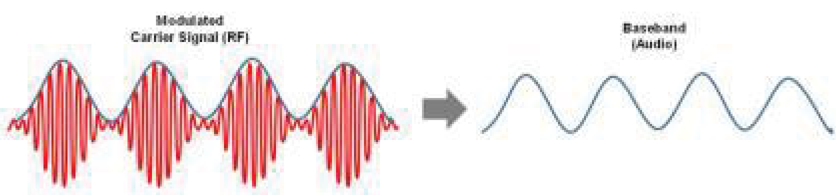


37. In order to transport the baseband (audio) signal, the transmitting

wireless device (e.g., Bob's cell phone) modifies the carrier signal. As shown above, the baseband signal is impressed upon the carrier signal (above left), thereby modulating/changing the shape of the carrier signal to approximate the shape of the baseband (audio) signal (above right).[1] The modified signal is referred to as a "modulated carrier signal." The process is referred to as "up-conversion" because the low frequency signal is being up-converted to a high frequency signal.

E. Down-conversion.

38. In order for the receiving wireless device (e.g., Alice's cell phone) to recover the baseband (audio) signal from the modulated carrier signal, the receiving wireless device must transform the modulated carrier signal back to an audio signal. This process is referred to as "down-conversion" because a high frequency signal is being down-converted to a low frequency signal.



39. As shown above, "down-conversion" is the process by which the

---

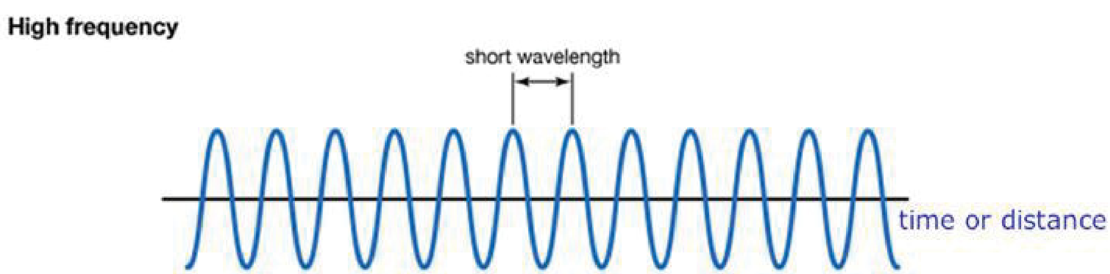
[1] This type of modification is referred to as amplitude modulation. Modulation can also occur by modifying other properties of the carrier signal such as frequency or phase.

baseband (audio) signal is recovered from the carrier signal. Down-conversion is the subject of claims 1, 3, 4, 7, and 9-11 of the ’474 patent.[2]

VII. DETAILED TECHNOLOGY BACKGROUND

A. Radio frequency.

40. The term “radio frequency” or “RF” refers to the frequency at which a radio transmits an electromagnetic (EM) signal over the air. While “radio frequency” is abbreviated as RF, RF itself is used as a term which acquires specific meaning in context. For example, if the context is referring to a signal, then “RF” means “radio frequency signal.” If, however, the context is referring to a circuit, then “RF” means “radio frequency circuit.” RF as a modifier always is referring to an element that exists at a frequency of a radio signal that is transmitted or received as a wireless electromagnetic signal.



[2] While Section VI provides an overview of the technology using voice/audio signals, this is for illustrative purposes only. The technology of the ’474 patent can be used to up-convert or down-convert any type of electromagnetic signal that carries information, such as video, web, and other types of data.

41. As shown above, the RF signal transmitted over the air is a sinusoidal wave. As discussed in Section VII.I below, in order to transmit information (e.g., voice, data) in the wave, certain characteristics (amplitude, frequency, and/or phase) of the wave are varied (modulated).

42. The RF spectrum is part of the electromagnetic (EM) spectrum. A broad categorization of the EM spectrum is shown in the table below.

Name or band	Frequency	Wavelength
Radio frequency	3 Hz – 300 GHz	100 000 km – 1 mm
Microwave	300 MHz – 300 GHz	1 m – 1 mm
Millimeter (mm) band	110 – 300 GHz	2.7 mm – 1.0 mm
Infrared	300 GHz – 400 THz	1 mm – 750 nm
Far infrared	300 GHz – 20 THz	1 mm – 15 μm
Long-wavelength infrared	20 THz – 37.5 THz	15–8μm
Mid-wavelength infrared	37.5 – 100 THz	8–3 μm
Short-wavelength infrared	100 THz – 214 THz	3–1.4 μm
Near infrared	214 THz – 400 THz	1.4 μm – 750 nm
Visible	400 THz – 750 THz	750 – 400 mm
Ultraviolet	750 THz – 30 PHz	400 – 10 nm
X-Ray	30 PHz – 30 EHz	10 – 0.01 nm
Gamma Ray	> 15 EHz	< 0.02 nm

Gigahertz, GHz = 10^9 Hz; terahertz, THz = 10^{12} Hz; pentahertz, PHz = 10^{15} Hz; exahertz, EHz = 10^{18} Hz.

43. RF signals and RF circuits are identified by the frequencies at which information is coherently generated, radiated by a transmit antenna, propagated through air, and collected by a receiver antenna. Today, the RF spectrum is recognized as being between 3 hertz (Hz) and 300 gigahertz (GHz). For example, radios operating at very low frequencies of a few hertz are used for submarine and underground mine communication since electromagnetic waves at these frequencies can penetrate water and earth. As another example, radios at 10s and 100s of

gigahertz (GHz) are used for radar and very high data rate, almost beam-like communications. Cellular phones, for example, mostly operate at frequencies from 300 MHz to 6 GHz.

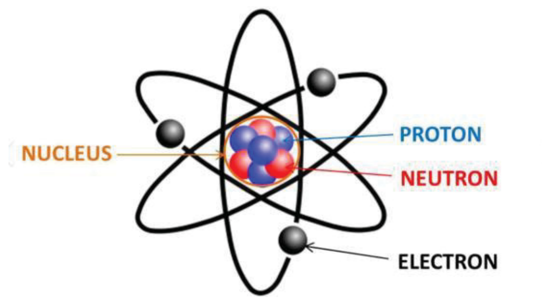
44. The frequency of an RF signal determines the size of the antenna needed to transmit the signal and the amount of information that can be transmitted in the signal. High frequencies, such as the frequencies used by cellular phones, are ideal for mobile communications. The higher the frequency, the smaller the size of an antenna and the greater the capacity to carry information. At frequencies between 300 MHz and 6 GHz, the size of the antenna can fit within the physical confines of a mobile device and the radio waves can bend around objects (e.g., buildings) (known as diffraction) and pass through walls. Frequencies above 6 GHz can also be used e.g., for 5G mobile devices, but there are trade-offs. For example, frequencies above 6 GHz allow for high data rates, but these signals cannot penetrate buildings and do not bend around buildings as well as the lower cellular frequencies.

B. Basic circuit concepts.

45. RF signals are created using electronic circuits. To understand circuits, it is important to understand the concepts of charge, voltage, current, energy, power,

resistance, impedance, and inductance.[3]

46. Charge: In a circuit, there are two physical types of charge – positive charge and negative charge. Protons have a positive charge (+), and electrons have a negative charge (–).



47. As shown above, protons and electrons are components of an atom. Protons are fixed in position in the center of an atom (in the atom's nucleus). Electrons orbit the nucleus. Atoms are locked into a conductor's (such as a wire/metal) crystal lattice. Generally, the number of electrons balances the number of protons so that the overall charge on an atom is neutral.

48. In an electrical conductor, while most electrons are bound to an atom, some of the electrons are free to roam/move through the conductor. These so-called free electrons can be forced to move by the application of an electric field. If a number of free electrons bunch together in a region of a material, then that region is

[3] In circuits, information can be conveyed either as charge, voltage, or current.

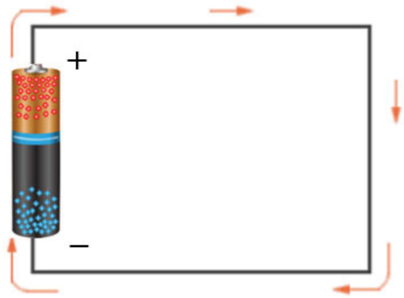
said to have a net negative charge. If free electrons are forced out of a region, then that region is said to have a net positive charge as the number of electrons in the region will be less than the number of protons.

49. Circuits operate based on the movement of electrons and the movement of charge transfers energy. An electron has potential energy, also called electric potential energy or just electrical energy. When charges move, the potential energy can be maintained or some of it can be converted to another form such as thermal energy. Charge may build up to establish a voltage signal. Here, a voltage signal refers to information that is almost entirely conveyed as a voltage. Alternatively, the movement of charge, the rate of which is current, may itself be the signal. Most circuits convey information, i.e., present signals, as a voltage or as a current.

50. Voltage: Voltage is the difference in an electron's potential energy, per unit charge, between two points. In other words, voltage is the amount of potential (electrical) energy available, per unit charge. Negative charges (electrons) are pulled towards higher voltages, while positive charges (protons) are pulled towards lower voltages. Since protons are fixed in position, the negative charges (electrons) are pushed away from lower voltages.

51. Electric current: An electric current is the movement/flow of charge in a circuit (in a conductor or into, out of, or through an electrical component). As shown by the arrows below, current (the net rate of movement of positive charges)

flows from positive voltage to negative voltage.



52. Electric energy: Electric energy is energy that results from the movement of a charge in a circuit. The faster the charges move and the more charges that move, the more energy they carry. The only way to transfer energy is by transferring charge. So, movement of a charge indicates movement of energy.

53. I will explain energy in the context of a resistor (*see* Section VII.E.3 for discussion of resistors). As electrons travel through a resistor, some of the potential energy of the electrons is converted to thermal energy and the resistor heats up. The difference in the potential energy of the electrons before and after passage through the resistor is the voltage V. It is the passage of electrons through the resistor that forms the voltage V.

54. The rate of movement of the electrons (that is, charge) is the current I. As such, the energy E transferred to a resistor (as heat) is a product of current I, voltage V, and time t, and is calculated using the formula: $E = I \times V \times t$.

55. Energy is not the same as voltage. Energy can be retained as electrical energy or it can be converted to thermal energy. Voltage is the difference in electric

potential energy between two points and there can be a voltage whether or not energy is converted from electrical form to thermal form. Generally, when we are talking about electrical circuits, we are referring to electrical energy only and we talk about energy being dissipated where dissipated is short-hand for electrical energy being converted to thermal energy. Energy and voltage are used in circuits in different ways.

56. Power: Power is the amount of energy transferred per unit time. Power is the average rate at which energy is transferred by charges. For a resistor, for example, charges transition from one potential energy to another as they pass through the resistor. Energy is transferred to the resistor (as heat) and the rate of energy transfer is power P. P is a product of voltage V and current I and is calculated using the formula: $P = V \times I$.

57. Resistance: Resistance is a measure of the difficulty of passing an electric current through a conductor. Physically what happens is that a moving electron bumps into the crystal structure of a resistor and causes the crystal to vibrate, thus, transferring electrical energy to heat.

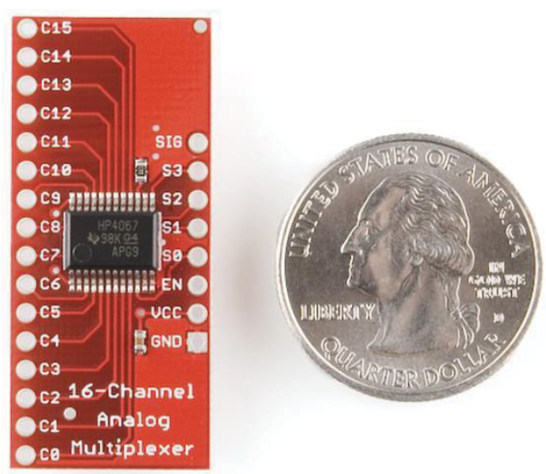
58. Impedance: Impedance is the measure of the opposition that a circuit presents to a current when a voltage is applied. Impedance is related to, but not the same as, resistance. Resistance is one component of impedance. In addition, impedance describes the ability of a circuit element to store and/or return electrical

energy (referred to as reactance). A circuit component with high resistance has high impedance.

59. Inductance. Inductance is the potential of a conductor to create voltage when an electrical current is flowing through it.

C. Integrated circuits.

60. An integrated circuit is a set of electronic circuits formed and interconnected on a small piece (chip) of semiconductor substrate (silicon).



61. As shown above, an integrated circuit(s) (inside the black chip) can be very small. Yet, an integrated circuit can contain millions or billions of circuit elements including, for example, transistors, capacitors, resistors, etc. Because of their small size, integrated circuits are used in cellular and wireless devices to create and process RF signals.

62. Integrated circuits are expensive to design. Designing a single integrated circuit can involve hundreds or thousands of circuit designers/engineers.

In addition, research and development can cost hundreds of millions of dollars per year.

63. When integrated circuits are manufactured in large volumes, the fabrication cost per chip can be under $1.00 USD. As such, the cost of design of an integrated circuit is considerably more than the cost of actually building an integrated circuit. Thus, it is extremely important to simplify the design of integrated circuits and to develop architectures that minimize design costs. In the cellular/wireless industry, solutions that simplify integrated circuit design (e.g., reduce or eliminate the number of components) have significant value because such solutions allow companies to manage design costs.

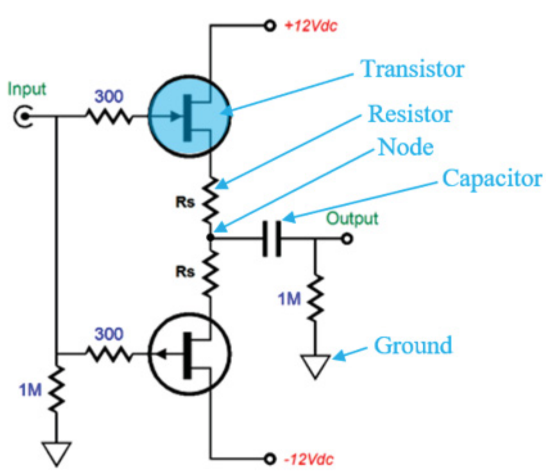
64. Ultimately, chips containing integrated circuits are incorporated into devices such as cellular phones or Wi-Fi devices. As such, adopting innovations in the chips that result in reducing or eliminating components internal or external to the integrated circuits not only reduces design costs but also reduces manufacturing costs. This is also of significant value to manufacturers of integrated circuits and devices. Since reducing or eliminating components from a device (e.g., cellular phone) results in device manufacturers (e.g., cellular phone manufacturers) reducing their manufacturing cost, chip/integrated circuit manufacturers can charge higher prices for innovative integrated circuit designs that allow for such reduction/elimination of components.

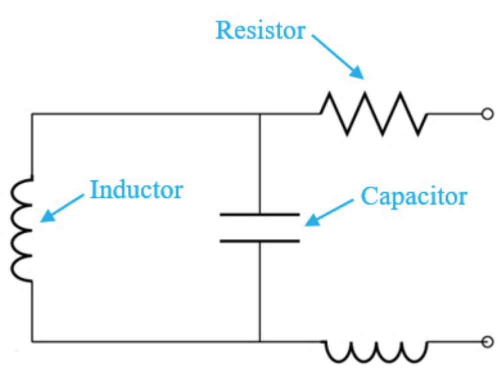
65. Moreover, innovative integrated circuit designs that allow for improvements to integrated circuits and the devices into which they are incorporated (e.g., cellular phone) have significant value. For example, in the cellular phone industry, there is significant value in an integrated circuit design that reduces device power requirements, increases device battery life, improves performance, and/or reduces the size of integrated circuits and devices.

66. The claimed invention of the '474 patent allows for the reduction and/or elimination of components in radio frequency integrated circuits (and devices incorporating such circuits) (e.g., eliminate filters, reduce battery size, eliminate matching circuits, etc.), while simultaneously enabling high-performance communication protocols.

D. Circuit diagrams.

67. Circuit designers/engineers use circuit diagrams to illustrate how circuit elements are connected together.





68. The exemplary circuit diagrams above show various circuit elements and how they can be connected together by wires/traces (shown by lines). Transistors, capacitors, resistors, and inductors shown in the diagrams above are described in Section VII.E below. As shown above, "ground" (shown as an upside-down triangle) is a connection to a fixed potential which is defined as zero volts and a "node" (shown as a dot) is a location where three or more wires/leads come together.

69. Each circuit element has a particular effect(s) on voltage, current, charge, and energy. By combining circuit elements in different numbers and/or ways and using circuit elements that have certain values, circuit designers/engineers can create circuits that perform a wide variety of different functions.

E. Circuit components.

1. Transistor.

70. A transistor is a semiconductor device used to switch, detect, or amplify electronic signals and electrical power. Ex. 2009 at 1437 ("A small electronic device containing a semiconductor and having at least three electrical contacts, used in a circuit as an amplifier, a detector, or a switch.").

71. A transistor has at least three terminals for connection to an external circuit. Key to the functionality of a transistor is that a controlling voltage or current at one terminal can control a current between two of the other terminals.

72. Some types of transistors can be used as a switch whereas others can be used as a continuous time-varying resistor. *See* Section VIII. Transistors, however, can also be used to provide other functions (e.g., amplification). Whether a transistor is used as a switch, a continuous time-varying resistor, or performs another function depends on the signals applied to the terminals of the transistor, and on the circuit in which the transistor is embedded.

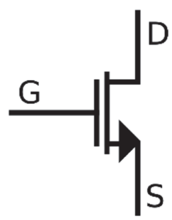
73. Indeed, at the time of the invention of the '474 patent, a POSITA understood that a transistor behaves/can be used in different ways and operates as different circuit elements depending on how it is set-up. I provide citations to some patents from industry leaders at the time of the invention. *See, e.g.,* Ex. 2010 at 6:35-37 ("For accurate operation, it is important that the pair 602 of differentially-coupled transistors operate as an *amplifier*, and <u>*not*</u> as a *switch*."); Ex. 2011 at 9:56-57 ("transistors . . . *behave as switches* in the low impedance 'On' state."); Ex. 2012 at 7:19; 8:10-11, 14-15 ("transistor [] is used as a switch . . . .").[4]

74. A field-effect transistor (FET) is one type of transistor. Not all transistors are FETs. Most FETs are classified into junction-gate field-effect transistors (JFETs) and metal–oxide–semiconductor field-effect transistors (MOSFETs). One of the characteristics of a FET is that controlling a voltage at one

[4] Unless otherwise noted, I have added all emphasis in this declaration.

terminal controls a current between two of the other terminals. A JFET or MOSFET can therefore be used as a switch, a continuous time-varying resistor, or can be used in other ways, such as to provide amplification.

75. The symbol for one type of FET is shown below.



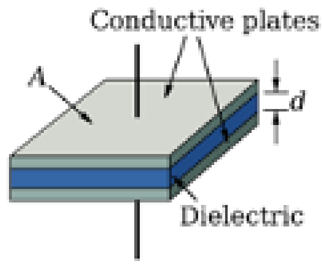
76. A FET has three terminals: (1) source (S), (2) drain (D), and (3) gate (G). In a FET, a voltage at the gate (G) controls the current flow between the drain (D) and source (S).

2. Capacitor.

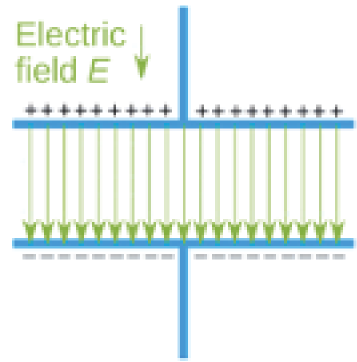
77. A capacitor is one type of circuit element used to store (accumulate) energy. A capacitor stores electric energy in an electric field by separating charges over a distance.

78. The symbol for one type of capacitor is shown below.

79. A capacitor stores energy in an electric field established between two plates.



(a)



(b)

80. As shown above left in (a), a capacitor is constructed with two conductive (metal) plates with a dielectric (or air) separating the plates by a distance *d*. The dielectric/air does not allow current to pass.

81. The operation of a capacitor is shown above right in (b). When current flows towards the top plate of the capacitor, a positive charge (indicated by the "+" symbol) will accumulate on the top plate. An equal current will leave the bottom plate and a negative charge (indicated by the "–" symbol) will accumulate on the bottom plate. The positive charge accumulation on the top plate is due to the uncovered protons that are revealed by free electrons that have left the conductive plate. The negative charge accumulation on the bottom plate is due to the free electrons that arrive at the bottom plate. No charges and, thus, no current can travel from the top plate to the bottom plate, because the dielectric or air between the plates does not allow for movement of electrons.

82. As positive charge accumulates on the top plate and negative charge accumulates on the bottom plate, an electric field is formed between the two plates. Energy equal to the difference of the potential energies of the charges on the top and bottom plates is stored in the electric field. The larger the plate area A the greater the number of charges that can accumulate and the more energy that can be stored in the electric field. Also, the smaller the distance d between the plates, the stronger the electric field and the more energy that can be stored in the electric field.

83. The time rate of change of the electric field is sometimes referred to as a displacement current, which is directed through the region between the plates. However, displacement current is not a real current but sometimes it is a convenient mathematical abstraction.

84. The ability of a capacitor to store energy is described by its capacitance. The capacitance C of a capacitor is equal to the charge Q stored on the plates (with a positive charge $+Q$ on one plate and a negative charge $-Q$ on the other plate) divided by the voltage V between the plates and is calculated using the formula: $C = Q/V$. The capacitance of a capacitor is proportional to plate area and inversely proportional to the distance between the plates.

85. The formula for the energy E stored in a capacitor is set forth below (where C is the capacitance of the capacitor and V is the voltage across the capacitor).

$$E_{cap} = \frac{C \text{ x } V^2}{2}$$

86. As such, the energy stored in a capacitor is proportional to (a) the square of the voltage across the capacitor and (b) the capacitance of the capacitor.

87. Given that energy stored in a capacitor is proportional to its capacitance, a capacitor with a small capacitance cannot store much energy, whereas a capacitor with a larger capacitance can store more energy for a given voltage.

88. A capacitor can be used in different *ways* within a circuit. In particular, the capacitance of a capacitor and the electric elements connected to a capacitor dictate how the capacitor operates in a circuit. That a capacitor can be used in different *ways* within a circuit is key to understanding why the claimed invention of the '474 patent is distinguishable from Intel's prior art references.

3. Resistor.

89. A resistor is a circuit element that introduces resistance into a circuit. The symbol for one type of resistor is shown below.

90. Resistors are used, for example, to reduce current flow, adjust signal levels, divide voltages, bias active elements, and terminate transmission lines.

91. When a constant voltage *V* is placed across the resistor, the potential on one side of the resistor is higher than the potential on the other side and there will be a constant current *I* through the resistor. Charges lose electric potential energy as they pass through the resistor and the difference in potential energy forms the voltage

V.

92. A resistor dissipates power *P* which, in turn, results in the generation of heat. The power dissipated by a resistor can be calculated using the formula: $P = V \times I$.

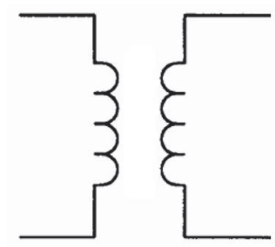
4. Inductor.

93. An inductor is a passive two-terminal electrical element that stores energy in a magnetic field when electric current flows through it. The symbol for one type of inductor is shown below.

94. An inductor is a conductor that is wound into a coil. When electricity flows through the coil, a magnetic field is generated. The electromagnetic field generated by the current causes a voltage to form, which opposes changes in current through the inductor.

5. Transformer.

95. A transformer is a passive electrical component consisting of two or more coils of wire. A transformer is used to transfer electric energy from one coil to another coil by changing a magnetic field (i.e., through electromagnetic induction). The symbol for one type of transformer is shown below.



96. Varying current in one of the coils of a transformer changes the magnetic field in the transformer. This, in turn, results in a varying electromotive force across any other coil of the transformer. Through this process, electrical energy is transferred from the coil receiving current to another coil without the need for a direct metallic (conductive) connection between the coils.

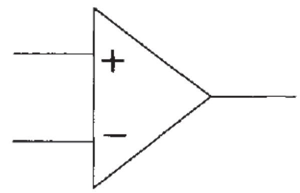
6. Low-pass filter.

97. A low pass filter is an electrical circuit that allows low frequency signals, including direct current (DC), while blocking high frequency signals.

7. Differential amplifier.

98. A differential amplifier is an electrical element that amplifies voltage or current. It has two input terminals and either one or two output terminals. The input to the differential amplifier is the difference of the voltages, or the difference of the currents, at the two input terminals. If the differential amplifier has one output terminal, then the output of the differential amplifier is the voltage or current at that output terminal. If the differential amplifier has two output terminals, then the output of the differential amplifier is the difference of the voltages or currents at the two output terminals.

99. The symbol for a single-output differential amplifier is shown below.



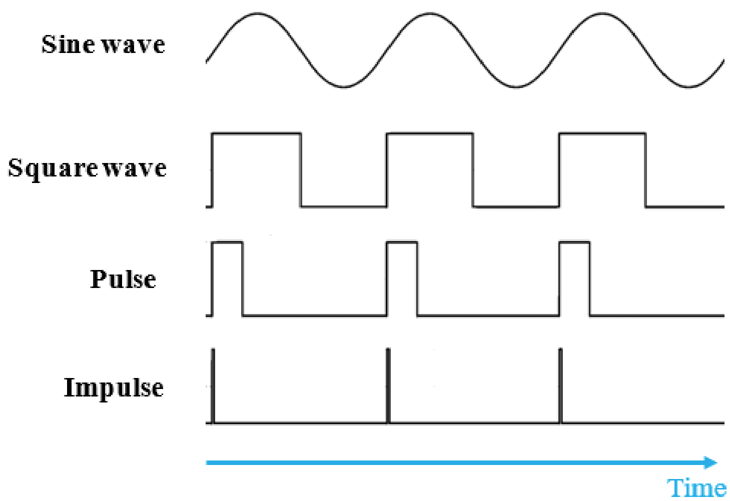
100. This differential amplifier has a positive (+) input terminal, a negative (–) input terminal, and a single output terminal. The positive input terminal is also called the non-inverting input and the negative input terminal is also called the inverting input. Some differential amplifiers present a low impedance load at the inputs while other types of differential amplifiers present a high impedance load at the inputs. One type of differential amplifier that presents high impedance loads is an operational amplifier (usually abbreviated "op-amp"). A circuit using an op-amp as its active element is called an "op-amp circuit."

F. Local oscillators

101. An oscillator is "[s]omething that oscillates," i.e., "repeat[s] a cycle of motions or to pass through a cycle of state with strict periodicity." Ex. 2013 at 527. "In particular, [an oscillator is] a self-excited electronic circuit whose output voltage or current is a periodic function of time [and is a] generator of an alternating signal, continuous, sinusoidal or pulsed." *Id.*

102. A local oscillator is "[a]n oscillator used in a … circuit to reproduce a sum or difference frequency equal to the intermediate frequency of the receiver. This

is done by mixing its output with the received signal." *Id*. at 433. The terms "local oscillator," "LO," or "LO circuit" are used to refer to the local oscillator circuit. The output signal of a local oscillator is commonly referred to as the "LO," "LO signal," or "local oscillator signal."



103. The diagram above shows different types of signals that can be generated by a local oscillator. The signal can be (1) a sine or sinusoidal wave, (2) a square wave, (3) a pulse, or (4) an impulse. A square wave, pulse and impulse are each periodic repetition of pulses.

104. A sine or sinusoidal wave is "a wave that can be expressed as the sine of a linear function of time, space, or both." *Id*. at 698. In the context of circuits, a sine wave is a voltage or current that varies sinusoidally with time. The sine wave is a continuous signal with a value that changes smoothly over time.

105. A square wave is a "square- or rectangular-shaped periodic wave that

alternately assumes two fixed values for equal lengths of time, the transition time being negligible in comparison with the duration of each fixed value.” *Id.* at 725. A square wave is a signal that has two values, and unlike a sine wave, has abrupt transitions between those values.

106. A pulse is defined by “[a] sudden and abrupt jump in an electrical quantity from its usual level to a higher or lower value, quickly followed by an equally abrupt return.” *Id.* at 597. In other words, a local oscillator producing a pulse is actually producing a train of pulses, which repeat periodically in time. A train of pulses is a signal that has two values, and unlike a sine wave, has abrupt transitions between those values.

107. An impulse is “[a] pulse that begins and ends within so short a time that it may be regarded mathematically as infinitesimal.” *Id.* at 365. In other words, a local oscillator producing an impulse is actually producing a train of impulses, which repeat periodically in time. A train of impulses is a signal that has two values, and unlike a sine wave, has abrupt transitions between those values.

108. An impulse and a square wave are particular types of pulses.

G. Electrical load, high impedance loads and low impedance loads.

109. The concept of a “load” is a key concept to the claimed invention of the ’474 patent. Connecting a load to a capacitor affects the operation of the capacitor and, thus, the way the capacitor is used in a circuit.

110. An electrical load is an electrical element or portion of a circuit that absorbs power and converts it into a desired form. *Id.* at 431. Whereas a power source supplies energy, a load extracts/uses energy. For example, a resistor is a type of load and a differential amplifier is another type of load.

111. There are high impedance loads and low impedance loads. A high impedance load inhibits current from moving in a circuit and absorbs very little electrical energy. A low impedance load provides little constraint to current moving in a circuit and absorbs electrical energy. Thus, a low impedance load must have a low resistance, whereas a load with a high resistance is a high impedance load.

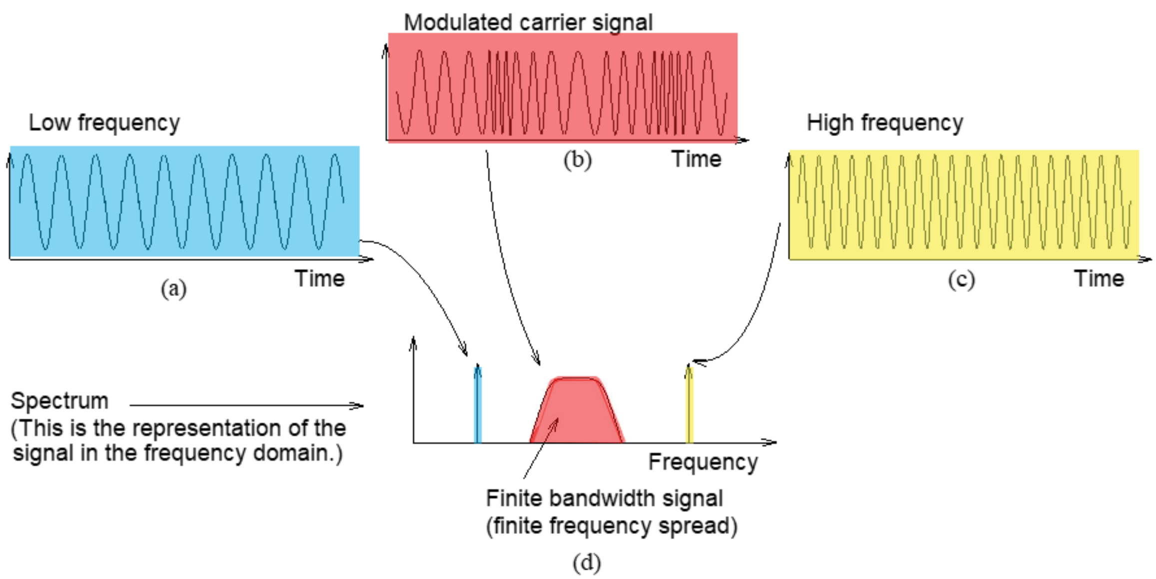
112. Since a load is connected to the output of other circuitry, the circuitry (e.g., capacitor, source, transistors) is said to be driving the load (when substantial current flows from the circuitry to the load). For example, when circuitry is connected to a low impedance load, the circuitry is said to be driving a low impedance load.

H. Signals; time domain and frequency domain representations of a signal.

113. In circuit design, signals can be expressed in a digital or an analog form and as a voltage, current or energy. The term "waveform" is used to describe a signal's shape and variations over time.

114. Signals can be looked at from the point of view of time or frequency i.e., in the time domain or the frequency domain. The time domain refers to a

description of a signal with respect to time and the signal is shown as a waveform. The frequency domain refers to a description of a signal with respect to frequency. The frequency domain is an abstraction which enables some of the attributes of a signal to be simply represented. For example, the frequency domain describes how a signal repeats itself over a long period of time but does not inform one about how a signal changes over a short period of time.



115. The diagram above illustrates three signals – a low frequency signal (blue), a modulated carrier signal (red) and a high frequency signal (yellow). Diagrams (a), (b), (c) illustrate these signals in the time domain and show the signals as sinusoidal waveforms. The low frequency signal (a) has a constant amplitude and repeats 9.5 times. The high frequency signal (c) has a constant amplitude and repeats 20 times over the same interval of time as the low frequency signal. The modulated

carrier signal (b) has a constant amplitude, but its frequency varies over time – from left to right, the signal varies from a lower frequency, to a higher frequency, to a lower frequency, to a higher frequency and so on. How the frequency changes over time in (c) conveys information.

116. Diagram (d) above illustrates each of the three signals (a), (b), (c) in the frequency domain in a plot called a spectrum. While a spectrum plot does not have all the information about a signal, it is useful in guiding RF circuit design.

117. In the plot of diagram (d), the vertical axis represents the amplitude of the signal and the horizontal axis represents frequency. In the frequency domain, since the low frequency signal has a constant amplitude and a constant frequency, the low frequency signal is shown as a single, vertical line on the plot (d). The height of the vertical line corresponds to the amplitude of the low frequency signal. The low frequency signal is also referred to as a single-tone signal.

118. In the plot of diagram (d), since the high frequency signal also has a constant amplitude and a constant frequency, it is also shown as a single, vertical line on the plot.

119. The vertical lines representing the low and high frequency signals are the same height because both signals have the same amplitude. In the plot of diagram (d), however, the low frequency signal is shown on the left of the plot and the high frequency signal is shown to the right on the plot to illustrate that the low frequency

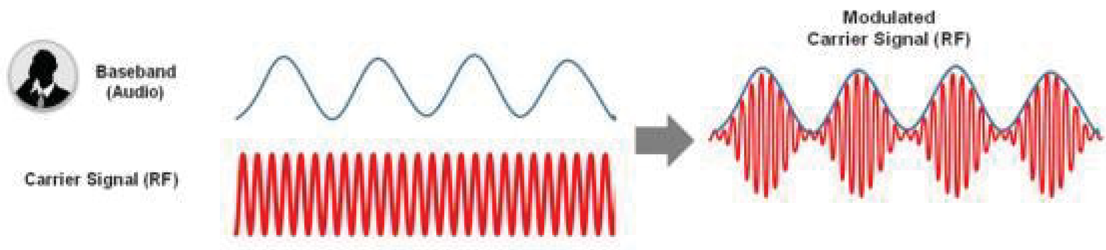
signal is at a lower frequency than the high frequency signal.

120. With regard to the carrier signal shown in diagram (b), the frequency of the signal varies over time. In wireless communications, this is referred to as a modulated signal. Here, the signal is frequency modulated; it has a range of frequencies. The range is called a bandwidth. As such, in the plot of diagram (d), the modulated carrier signal is not shown as a single, vertical line but, instead, is shown as a trapezoidal shape indicating that the modulated carrier signal is spread over a range of frequencies.

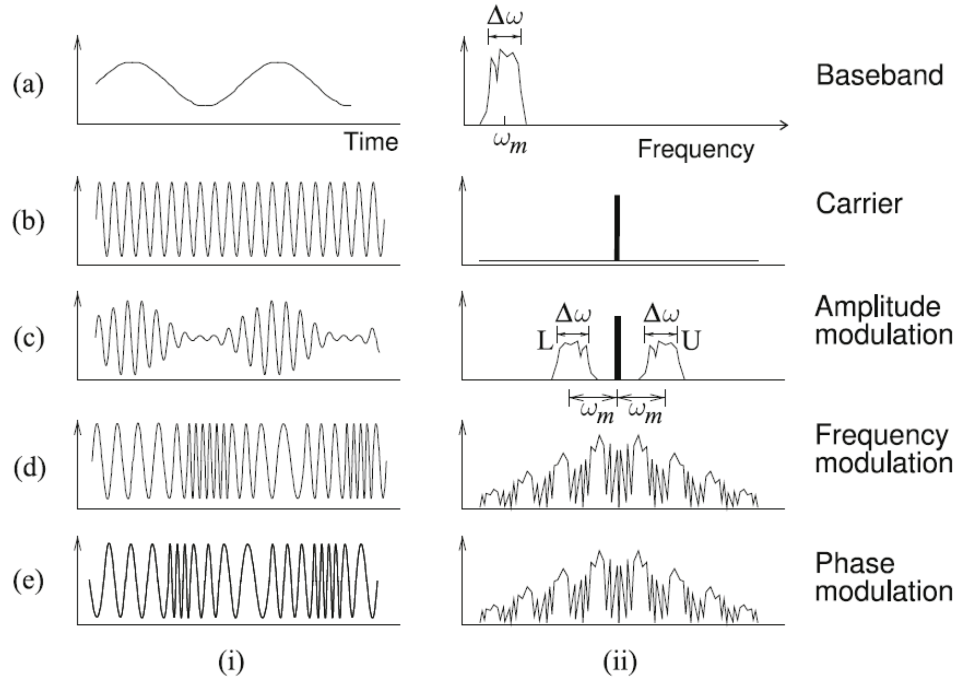
I. Baseband signals, carrier signals, modulation and up-conversion.

121. Information such as voice or digital data cannot be directly transmitted through air because such information exists at a low frequency. This low-frequency signal is referred to as "baseband," a "baseband signal" or at a "baseband frequency." The baseband signal has a frequency range extending from almost 0 Hz up to several megahertz in some cases.

122. In order to transmit information over air, a wireless device must transform a baseband signal (which carries the information) to an RF signal (a higher frequency signal). Since the RF signal is used to carry the information over the air, the RF signal is referred to as a "carrier signal."



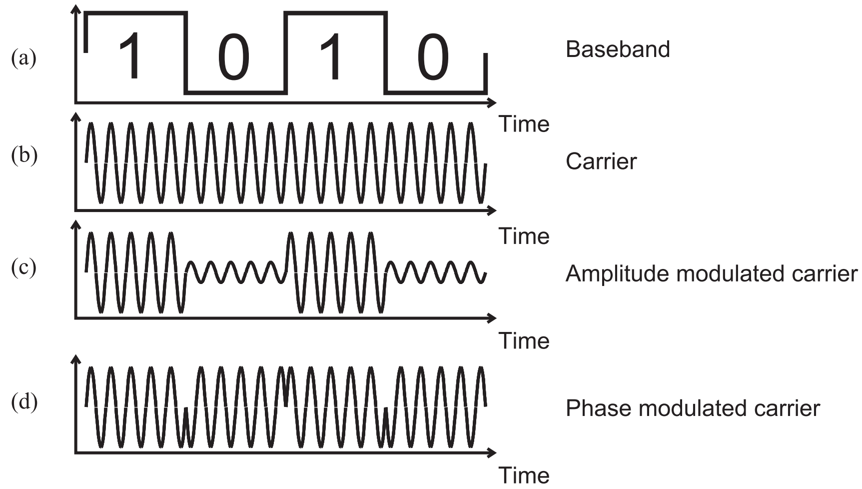
123. In particular, in order to transport the baseband signal, a transmitting wireless device modifies (modulates) the carrier signal. The carrier signal without modulation is also called an "unmodulated carrier signal". As shown above, the baseband signal is impressed upon the carrier signal (above left), thereby modulating/changing the shape of the carrier signal to approximate the shape of the baseband signal (above right). The modified signal is referred to as a "modulated carrier signal." In this specific example, the amplitude is being modulated. The process is referred to as "modulation" or "up-conversion" because the low frequency signal is being up-converted to a high frequency signal.



124. One or more characteristics of the carrier signal can be modulated – amplitude, frequency and/or phase. Modulating the amplitude is referred to as amplitude modulation; modulating the frequency is referred to as frequency modulation; modulating the phase is referred to as phase modulation.

125. The diagrams above illustrate the relationship between the baseband, carrier, and modulated carrier signals. Column (i) illustrates signals in the time domain. Diagram (a) shows a low frequency baseband signal; diagram (b) shows a high frequency carrier signal; diagram (c) shows an amplitude modulated carrier signal that results from impressing the low frequency baseband signal onto the carrier signal; diagram (d) shows a frequency modulated carrier signal that results from modulating the frequency of the carrier signal based on the changing baseband signal; and diagram (e) shows a phase modulated carrier signal that results from

modulating the phase of the carrier signal based on the changing baseband signal.



126. The diagram above shows an amplitude modulated carrier signal (c), which is formed by modulating the amplitude of the carrier signal (b) based on a square wave baseband signal (a). The diagram also shows a phase modulated carrier signal (d), which is formed by modulating the phase of the carrier signal (b) based on a square wave baseband signal (a).

J. I/Q Modulation.

127. For at least three decades, radios have used new communication protocols that simultaneously modulate the amplitude and phase of a carrier signal. One approach is to first change the phase of the carrier signal and then modulate the amplitude of the resulting signal. Another approach is to first change the amplitude of the carrier signal and then modulate the phase of the resulting signal. An alternative approach is to modulate the amplitude and phase of the carrier signal at the same time. This modulation process is called I/Q modulation. The result of the

approaches set forth above is what is called an I/Q modulated carrier signal.

128. The desired modulated carrier signal can be decomposed into, or synthesized from, two amplitude-modulated sinusoids that are offset in phase by 90 degrees. One of these sinusoids is called the in-phase (or I-phase or just I) component of the I/Q modulated carrier signal, and the phase-offset component is called the quadrature-phase (or Q-phase or just Q) component of the I/Q modulated carrier signal. The modulating signals at baseband are called the I baseband and Q baseband, respectively.

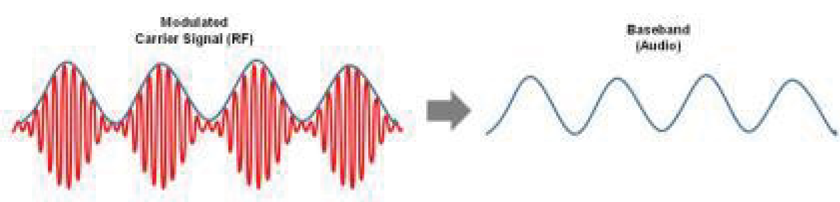
129. The advantage of I/Q modulation is that the I baseband can carry one set of information and the Q baseband can carry another set of information. Having separate I and Q baseband information streams greatly expands the information that can be transmitted as compared to the I and Q components carrying the same information, or, alternatively, compared to using amplitude or phase modulation on their own.

130. A receiver of an I/Q modulated RF signal must separately extract I baseband and Q baseband signals. In older communication protocols (e.g., 1G cellular radio), I/Q modulation was not used. In those older communication protocols, if a receiver separately extracts I and Q down-converted signals, these I and Q signals are not baseband. As such, the baseband signal had to be derived as a combination of the I down-converted signal and a 90 degree phase-shifted Q down-

converted signal.

K. Demodulation.

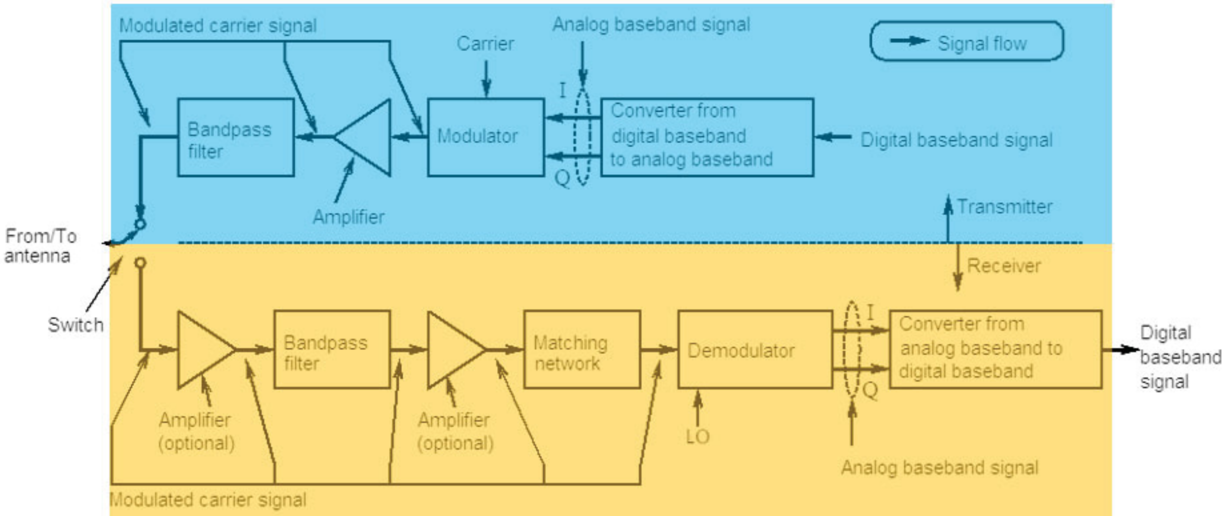
131. As shown in the diagram below, in order for the receiving wireless device (e.g., cellular phone) to recover the baseband signal (and the information that it carries) from the modulated carrier signal, the receiving wireless device must transform the modulated carrier signal back to a baseband signal. This process is referred to as "demodulation" or "down-conversion" because a high frequency signal is being down-converted to a low frequency signal.



132. Demodulation is the inverse of modulation and results in the extraction of a baseband signal from the modulated carrier signal.

L. Transceiver.

133. A transceiver is a device that can transmit and receive RF signals.



134. The diagram above illustrates the general architecture of a transceiver that has been used since at least 1999. The transceiver has a transmitter side (blue) and a receiver side (orange).

135. On the transmitter side (when an RF signal is being transmitted), the transmitter converts the digital baseband signal (which carries information) into two signals – analog in-phase (I-phase or just I) signal and analog quadrature-phase (Q-phase or just Q) signal.

136. Once separated out, the I and Q signals are combined with/impressed upon a carrier signal (in a modulator), which, in single-stage up-conversion, results in an analog modulated carrier (RF) signal. The I baseband signal modulates one version of the carrier signal (called the in-phase carrier signal) and the Q baseband signal modulates a time-shifted version of the carrier signal (called the quadrature-phase carrier signal). The outputs of these modulation portions are combined to yield

the final RF signal. The RF signal is then amplified, filtered, and sent to an antenna where it is radiated (over air) into the environment as a RF signal.

137. On the receiver side (when an RF signal is being received), the receiver filters the received RF signal and sends the signal to a down-converter. The down-converter separates analog in-phase (I) signal and analog quadrature-phase (Q) signals from the RF signal. These I and Q signals are converted into a digital baseband signal, which can then be processed to extract the information that was sent by the transmitted device.

M. Direct conversion and intermediate frequencies.

138. Today, a receiver can down-convert from an RF signal to a baseband signal in one stage or multiple stages. In a one stage configuration, the RF signal is directly converted to a baseband signal. This is referred to as direct down-conversion. In a multiple stage configuration, the RF signal is first down-converted to an intermediate frequency (IF) signal (which is at a lower frequency than the RF signal but higher frequency than a baseband signal) and the IF signal is then down-converted to a baseband signal.

139. In the late 1990s through March 2000, however, direct down-conversion was not well developed. At that time, receivers generally used multiple stage conversion. There was, however, significant research and development dedicated to finding ways to accomplishing direct down-conversion using a single

conversion stage. Many companies failed in this endeavor and the solutions that were developed had significant technical and practical limitations.

140. In the late 1990s through March 2000, the direct conversion schemes used non-linear or time-varying devices to effect conversion. But these schemes had difficulty handling signals (RF or baseband) that varied widely in amplitude. With direct down-converters, there was a problem of too much noise and interference being inserted into the down-converted signal. These problems required many additional circuit components and also resulted in direct conversion schemes that could not be used with advanced communication protocols that have wide variations in the baseband characteristics such as having large amplitude variations.

141. There was the additional problem that the non-linear and time-varying elements consumed considerable battery power thus reducing battery lifetime. ParkerVision's inventions addressed these problems.

142. The technology of claims 1, 3, 4, 7, and 9-11 of the '474 patent (a) introduced switches to replace nonlinear and time-varying devices, and (b) introduced energy storage elements so that discharged energy from the storage elements form the down-converted signal.

143. The technology of claims 1, 3, 4, 7, and 9-11 of the '474 patent simultaneously a) operates efficiently, b) can be realized in an integrated circuit, c) achieves performance that enables high-performance protocols, d) can be mass

produced with excellent yield, and e) eliminates/reduces many expensive and bulky external components (i.e., components (e.g., filters) that device manufacturers (e.g., cellular phone manufacturers) must include in their device external to the RF chip).

N. History of RF receivers.

144. Claims 1, 3, 4, 7, and 9-11 of the ’474 patent is related to RF *receiver* technology and *down*-conversion. As such, my discussion of the history of RF technology will focus on RF receivers and down-conversion.

145. In the mid-1990s through March 2000, the industry was focused on the use of mixers and heterodyned receivers for down-conversion (discussed below). *See* Ex. 2014, Ex. 2015 at 884, and Ex. 2016 at 15.

146. Transistors, including FETs, were being used in mixers. Transistors are inherently nonlinear, and most mixers prior to March 2000 exploited this nonlinearity for down-conversion. One type of such mixer used a continuous time-varying element, e.g., where the FET is made to present a continuous time-varying resistance.

147. In the mid-1990s through March 2000, with regard to the transistors used in mixers, the industry was focused on three types of FET mixer configurations: a gate mixer, a drain mixer and a resistive mixer. *See, e.g.,* Ex. 2017 at 6-7.

148. In a gate mixer, “[b]oth the RF and the LO signals are applied to the gate of the device . . . . This results in efficient mixing since . . . the FET’s

transconductance is very sensitive to the modulation of the externally applied LO signal." *Id.* at 6. In a gate mixer configuration, the FET is very nonlinear and the RF and LO signals are multiplied together.

149. In a drain mixer, "[t]he RF signal is applied to the gate, and the LO signal is applied to the drain of a FET." *Id.* at 7. The device/FET is very nonlinear. *Id*.

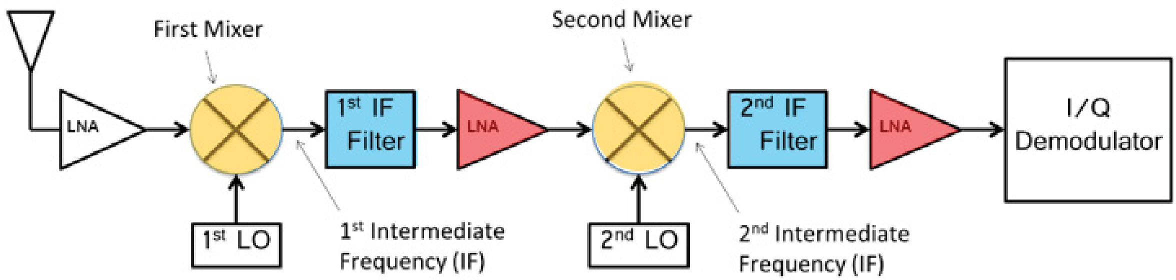
150. In a resistive mixer, "the unbiased channel of the device is used as a time-varying resistor whose resistance is modulated by the LO signal applied at the gate … [and there is] weak nonlinearity of the FET's channel resistance." *Id*. A circuit referred to as a Gilbert analog multiplier is a type of resistive mixer. In such a circuit, the LO signal is applied to the gate of a FET and the RF signal is applied to the source of the FET. *See* Ex. 2015 at 884.

151. In the mid-1990s through March 2000, many of the efforts in the industry related to down-conversion were directed to developing mixers using MOSFET (metal-oxide-semiconductor field-effect transistor) transistors. Ex. 2016 at 25. While MOSFET-based mixers had problems, other factors motivated continued design efforts around MOSFETs. *Id*. ("MOS (metallic oxide semiconductor) [FET] devices were considered noisy, slow devices … [but t]he lower cost and faster advance of complementary MOS (CMOS) … has motivated great efforts in designing RF CMOS [FET] circuits … .").

1. Heterodyne receivers.

152. In the late 1990s through March 2000, heterodyne receivers, which used a decades-old RF technology called heterodyning, dominated the cellular/wireless industry for receiving and processing RF signals. This technology utilized nonlinear and time-varying elements (e.g., transistors or diodes) in a nonlinear or time-varying mixer to effect translation of information centered at one frequency to information centered at another frequency. For example, the mixer resembled an analog multiplier. But this technology had problems – the circuity was large and required significant power. The size and power requirements of heterodyne receivers were, at least in part, the result of the number of components these receivers used in order to perform down-conversion.

153. One type of heterodyne mixer architecture was a superheterodyne receiver which uses two heterodyning stages. A superheterodyne receiver used frequency mixing to convert a received signal to a fixed intermediate frequency (IF) signal, because an IF was more easily processed than the RF signal that was received. Superheterodyne receivers did not perform direct down-conversion but, rather, used two stages for down-conversion.



154. The diagram above illustrates a typical dual IF superheterodyne receiver architecture. As shown above, nonlinear or time-varying mixers (shown in orange above) are used to provide frequency translation. A first mixer down-converts the RF signal (received over the air) to a first intermediate frequency (IF) signal, which is at a lower frequency than the received RF signal. A second mixer down-converts the first intermediate frequency (IF) signal to a second intermediate frequency (IF) signal, which is at a lower frequency than the first intermediate frequency. The second intermediate frequency (IF) signal is then sent to an I/Q demodulator, which converts the I and Q signals into a digital baseband signal. The digital baseband signal can be processed to extract information (1s and 0s representing voice, data, etc.).

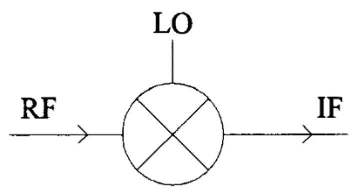
155. There are, however, significant disadvantages to using nonlinear or time-varying mixers (e.g., Gilbert analog multiplier). These mixers require the use of additional components, which increase the size and power requirements of the circuit. *First*, these mixers create noise, which is unwanted disturbances in an electrical signal. As a result of mixing using a multiplier, mixers also create large

unwanted signals at frequencies other than the desired frequency. As such, a filter (shown in blue above) is needed after each mixer to filter out the noise created by the mixer in order to clean up a signal for further processing. *Second*, when a mixer is used for down-conversion, the output frequency (the frequency of the signal leaving the mixer) is typically less than the input frequency (the frequency of the signal entering the mixer) but still at high enough in frequency and with a wide bandwidth that an amplifier (e.g., low-noise amplifier (LNA)) (shown in red above) is needed after the filter to amplify the signal leaving the filter for further processing.

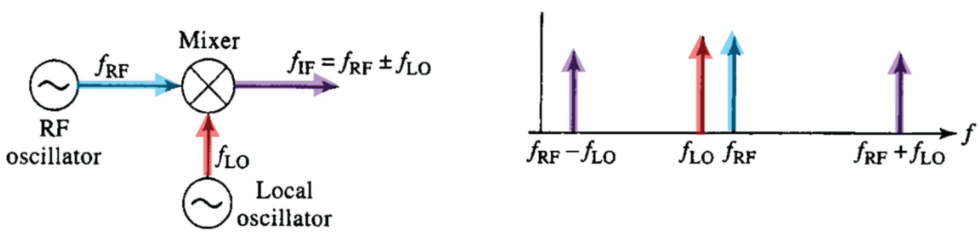
156. When nonlinear or time-varying mixers (e.g., Gilbert analog multiplier) are used for down-conversion, only a small portion of the energy from the received RF signal is converted to the desired signal. Further, most of the available energy of the RF signal is converted to unwanted frequencies. *See, e.g.,* Ex. 2015 at 884 ("[T]the Gilbert analog multiplier … downconverts a fraction of the RF current to the IF, and the remaining RF current upconverts around one or more harmonics of the LO.") The reduced down-converted energy level compared to the available RF energy is called conversion loss. Conversion loss, in turn, negatively impacts mixer performance. *Id.* ("The internal current conversion-loss penalizes mixer noise [performance]. . . .").

2. Mixers.

157. The typical symbol for a mixer is shown below.



158. The function of a mixer is to convert a signal received at one frequency to another frequency. As shown above, an input signal (here, an RF signal (modulated carrier signal)) enters a mixer and an output signal (here, an intermediate frequency (IF) signal) leaves the mixer. A component referred to as a local oscillator (LO) sends a signal to the mixer to effect down-conversion by the mixer.



159. As shown in the diagrams above, an RF signal is down-converted by frequency shifting the RF signal (blue arrow) to an IF signal (purple arrows). The frequency shift is accomplished by using a local oscillator to send a signal with a frequency f_{LO} (red arrow) to the mixer. The mixer mixes the RF signal having a frequency f_{RF} and the LO signal having a frequency f_{LO} to produce an IF signal having frequencies at $f_{RF} - f_{LO}$ and $f_{RF} + f_{LO}$. As shown in the frequency domain (above right), down-conversion by the mixer replicates the RF signal frequency

(blue arrow) at two frequencies: $f_{RF} - f_{LO}$ and $f_{RF} + f_{LO}$ (purple arrows).[5] The circuitry after the mixer filters out the higher frequency $f_{RF} + f_{LO}$ signal, thus, leaving just the lower frequency $f_{RF} - f_{LO}$ signal. The mixer exploits the non-linearity of circuit elements to achieve the multiplication, i.e., mixing, of the RF and LO signals.

160. In view of the foregoing, the mixer described in this section is inherently a nonlinear circuit (i.e., the frequency that is outputted from the mixer is not the same as the frequency received by the mixer). Because of this non-linearity, mixers have traditionally been the limiting factor in the performance of radio receivers.

161. In the late 1990s through March 2000, the dominant type of mixer was based on using nonlinearity to implement multiplication of an RF signal and an LO signal. A mixer based on a nonlinear mixing uses negligible energy from the RF source, and then noise generated by the mixer becomes significant compared to the down-converted signal level. *See, e.g.,* Ex. 2015 at 884 ("The … more conventional … mixer resembles the Gilbert analog multiplier. It consists of a linear RF voltage-to-current (V-I) converter, or RF transconductor, whose output current is

---

[5] The mixer described in this section is an ideal mixer/multiplier. As such, while not shown, in practice there will be many other unwanted frequency components in the IF signal leaving the mixer (i.e., there will be noise).

commutated by the local oscillator (LO). As commutation conserves the total current, it downconverts a fraction of the RF current to the IF, and the remaining RF current upconverts around one or more harmonics of the LO. … [This] internal current conversion-loss penalizes mixer noise.”).[6] This high level of noise and low level of signal makes it difficult to distinguish the signal from noise.

162. In the late 1990s through March 2000, mixers could not efficiently handle baseband signals that varied widely in amplitude such as the range of amplitudes used in advanced communication protocols. In addition, with mixers, there was a problem of too much noise and interference being inserted into the down-converted signal. Addressing this noise and interference required many additional circuit components such as filters to eliminate unwanted signals. But no component could remove noise near the frequency of the down-converted signal. There was yet another problem with mixers in that the non-linear and time-varying elements consumed considerable battery power, thus reducing battery lifetime. As a result, research and design of mixers based on a nonlinear mixing was pursued extensively in order to address these issues.

163. The term “mixer” has changed meaning over time and has lost its

---

[6] In this context, “commutated” means to change the direction of electric current; “commutation” means the change of electric current direction.

original meaning. Prior to the time of the invention of the ’474 patent, a “mixer” referred to the configuration set forth above, which was not an energy sampler. After the time of the invention of the ’474 patent, companies began to develop energy samplers and refer to them as “mixers.” As such, the term “mixer” has become a generic term to refer to different configuration that performs down-conversion or up-conversion. As used today, the term “mixer” really says nothing about how a circuit operates or the specific configuration of the circuit. As such, when analyzing a component referred to as a “mixer” one needs to look at the operation and configuration of the circuit to determine the technology that is being implemented.

3. Sample-and-hold (*voltage* sampling).

164. In the late 1990s through March 2000, a technology being considered for direct down-conversion (to recover the baseband signal directly from the RF signal without using IF) was sample-and-hold (voltage sampling).

165. In the late 1990s through March 2000, the radio (cellular/wireless) industry was exploring direct down-conversion solutions that replicated the *voltage* of the RF signal and introduced as little *voltage* distortion as possible. At this time, it was thought that the best (and most accurate) way to accomplish this was to sample the voltage of the RF signal itself. Such a solution was quite logical – replicate voltage as faithfully as possible and hold the sampled voltage on a capacitor. Holding the voltage level for an interval of time required that there should be no

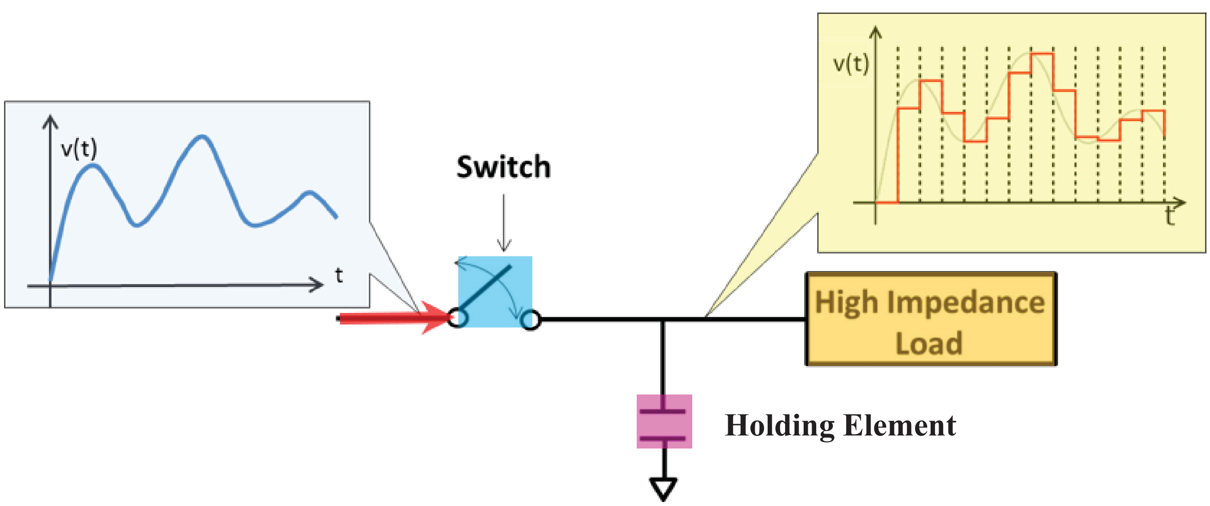
charge leaving (i.e., discharging from) the capacitor. As such, the state-of-the-art at that time was to use a sample-and-hold (voltage sampling) system to accomplish this.

166. One implementation of sample-and-hold was based on sampling the RF signal using an impulse sampling concept. Impulse sampling attempts to replicate the *voltage* of the RF signal at the sampling instant with as little distortion as possible. The sampled voltage of the RF signal, in turn, is a representation of the original baseband signal sent from a transmitting device. The technique that was being explored at the time was impulse sample-and-hold. A switch was used to connect the RF signal to a small holding capacitor which held the sampled voltage for long enough for its value to be slowly read. It was critical that the holding capacitor was small so that relatively few charges were transferred during sampling so that the source RF voltage signal was not distorted.

167. Another implementation of sample-and-hold is track-and-hold. In track-and-hold, the same or equivalent circuit configuration to an impulse sample-and-hold circuit is used. In track-and-hold, the switch is connected to the holding capacitor for a tracking interval and the *voltage* that is sampled (and held on the holding capacitor) is the voltage at the end of the tracking interval. Thus, the sampling aperture is the instant, i.e., negligible aperture, at the end of the tracking interval. Track-and-hold is a type of *voltage* sampling because track-and-hold uses

readings of *voltage* across a capacitor in order to down-convert, and energy is not discharged from the capacitor to form the down-converted signal. A track-and-hold voltage sampling mixer circuit, "fundamentally suffers from a large noise figure, because while tracking the narrowband signal, it also tracks and aliases wideband noise. This, and the difficulty of buffering such a switched mixer to the inductive load of an integrated LNA, make it inappropriate in a sensitive receiver." Ex. 2015 at 884. The above quoted description and analysis applies to voltage sampling in general.

168. The diagram below illustrates an exemplary sample-and-hold (*voltage* sampling) system.



169. As shown above, a sample-and-hold (*voltage* sampling) system

includes a switch (blue), a holding element (capacitor)[7] (pink) coupled to ground, and a *high* impedance load (orange). The '474 patent specifically *reserves* the term "*holding*" module/element to refer to an element (e.g., capacitor) used in a sample-and-hold (voltage sampling) system because, as discussed below, the use of a *high* impedance load causes the capacitor to *hold* energy (i.e., *prevent* energy in the capacitor from being discharged to form the down-converted signal).

170. The system takes a *sample* of the RF signal (red arrow)[8] by turning the switch ON (closing the switch) and OFF (opening the switch). The switch is turned ON and OFF by a control signal received from a local oscillator (not shown).

171. When the switch is turned ON, the switch closes and a tiny portion of energy from the RF signal (i.e., a sample of the RF signal) is sent to the capacitor.[9]

---

[7] In order to limit distortion of the RF signal (and have as little effect as possible on voltage of the RF signal), a *small* capacitor (i.e., a capacitor having low capacitance) was generally used in a sample-and-hold system.

[8] The voltage of the RF signal is shown by the blue line in the graph (above left).

[9] The switch is generally ON (closed) for a very short (negligible) period of time and, thus, the capacitor is only connected to the RF signal for a very short period of time. Since energy E is equal to voltage V x current I x time t and time is very short (close to zero), the energy transferred to the capacitor is tiny. As such, a small

When the switch is turned OFF, the switch opens and the capacitor *holds* the energy. In particular, the *high* impedance load causes the capacitor to *hold* the energy so that an accurate voltage across the capacitor could be determined. Without a *high* impedance load, energy would be discharged from the capacitor toward the load and the system could not accurately determine the voltage (i.e., the system would not work properly).

172. As the energy is being held, the system determines the voltage across the capacitor (i.e., the voltage level) and, using that reading, the system derives a small portion of a baseband signal (which is a representation of a small portion of the original baseband signal sent from a transmitting device). After the voltage is determined, the energy in the capacitor is subsequently dissipated as heat and forever lost. Because of the way in which sample-and-hold systems work (e.g., using a high impedance load), there should be no energy from the RF signal itself that becomes part of the baseband signal.

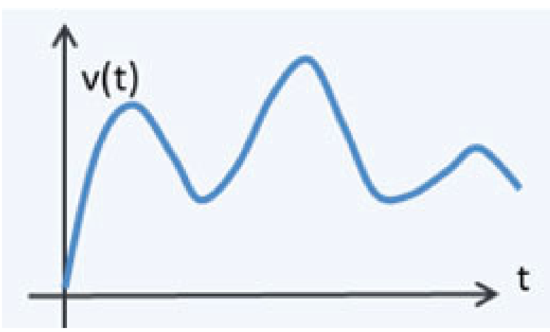
173. When the switch is turned ON again, the switch closes and, once again, energy from the RF signal (i.e., a second sample of the RF signal) is sent to the capacitor. When the switch is turned OFF, the switch opens and the capacitor holds

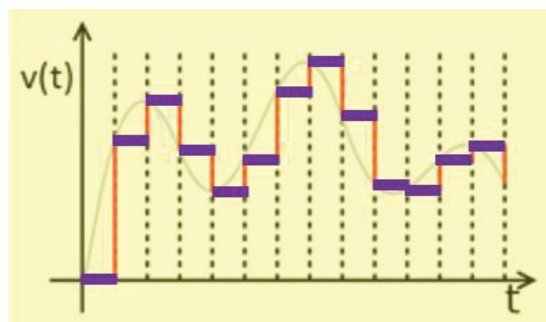
---

capacitor is needed to store the tiny amount of energy transferred.

energy from this second sample. Again, the circuit determines the voltage across the capacitor and, using that reading, the system derives another small portion of a baseband) signal (which is a representation of another small portion of the original baseband signal sent from a transmitting device). Once again, the energy in the capacitor is subsequently dissipated as heat and forever lost.

174. This process repeats and the system takes numerous samples of the voltage of the RF signal. As each sample is taken, the system reads more and more voltages and derives more and more of the baseband signal. The process continues until the entire baseband signal has been derived.

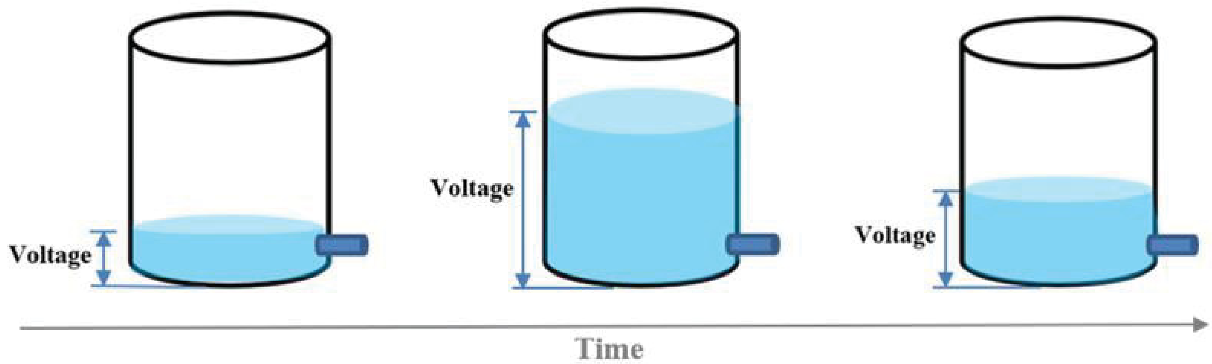




175. As shown in the diagram above left, the blue line is the voltage of the RF signal received by the sample-and-hold system. The voltage represents the information on baseband signal that is carried in the RF signal.

176. The diagram above right illustrates how the blue line is recreated using a capacitor. As the capacitor holds energy for a sample of the RF signal, a reading of voltage in the capacitor for that sample (purple horizonal line) is captured by the system. As voltage is continuously captured, a pattern emerges, and the voltage

readings (purple horizonal lines) approximate the shape of the voltage of the original RF signal (shown as a light gray line in the right diagram).



177. One can think of a sample-and-hold system as a water tank with a drain. A high impedance load is equivalent to the drain being shut tight in order to prevent the flow of water out of the water tank. Voltage is the level of the water in the water tank. Over time, water is added to the tank (causing the water level to increase) and water evaporates from the tank (causing the water level to decrease) (similar to how energy in sample-and-hold dissipates at heat). If one wanted to track the changes in the water level, one would take a reading of the water level periodically over time such as every minute (as it increases and decreases) and plot the water levels on a

graph. Sample-and-hold (voltage sampling) systems work similarly.

4. Energy Sampling.[10]

178. In the late 1990s through March 2000, persons of ordinary skill in the art were *not* looking into energy sampling as an alternative to heterodyning (non-linear mixing) or voltage sampling in order to perform down-conversion. So, a POSITA would not look at the problems with non-linear mixing or sample-and-hold and turn to energy sampling for a solution. To the contrary, using energy sampling to form a baseband signal was counter-intuitive and against the thinking in the radio (cellular/wireless) industry at the time.

179. Energy transfer (energy sampling) was/is a *fundamentally different and competing* method to mixing as discussed above in Section VII.N.2. Energy samplers, unlike mixers, do not mix (i.e., multiply) two signals together in order to down-convert a signal. As such, at the time of the invention of the ’474 patent, a POSITA would not simply substitute or consider using an energy transfer (energy sampling) system in place of a mixer and vice versa.

180. Energy transfer (energy sampling) was/is a *fundamentally different and*

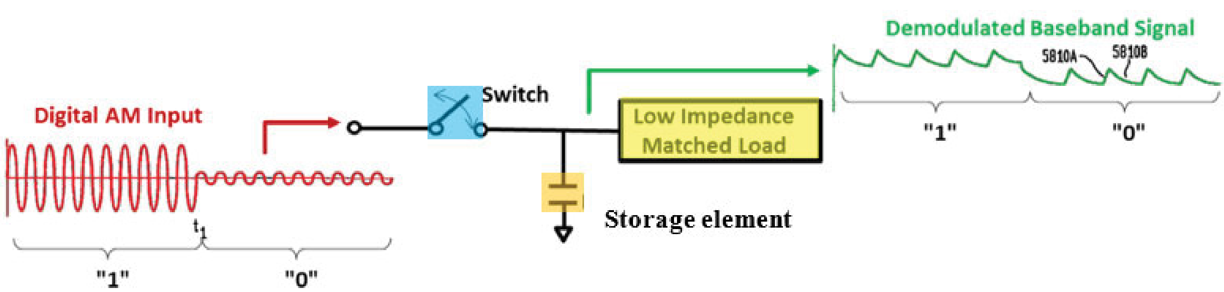
---

[10] Throughout this declaration I use the term “energy sampling” as shorthand to describe an energy transfer system (i.e., system that sample energy, instead of voltage, to obtain the baseband signal).

competing method to voltage sampling. Energy samplers do not attempt to replicate or sample the voltage of an RF signal. As such, at the time of the invention of the '474 patent, a POSITA would not simply substitute or consider using an energy transfer (energy sampling) system in place of a sample-and-hold (voltage sampling) system and vice versa.

181. Only through hindsight (with knowledge of the '474 patent) would a POSITA have looked into using energy sampling instead of non-linear mixing or voltage sampling. Indeed, by the late 1990s through March 2000, nothing is written about circuits that function as energy samplers as related to radio technology. For example, articles written in the late 1990s describing the state of down-conversion technology at the time do not describe energy sampling. *See* Exs. 2014, 2015, 2016.

182. The diagram below illustrates ParkerVision's implementation of an energy transfer (*energy* sampling) system for radio communications. *See* Section XI for a detailed discussion of the '474 patent.



183. ParkerVision's energy transfer (energy sampling) system includes a switch (blue), a storage element (capacitor) (orange) coupled to ground, and a *low*

impedance load (yellow). As discussed below, using a *low* impedance load is significant in the design of ParkerVision's energy transfer (energy sampling) system.

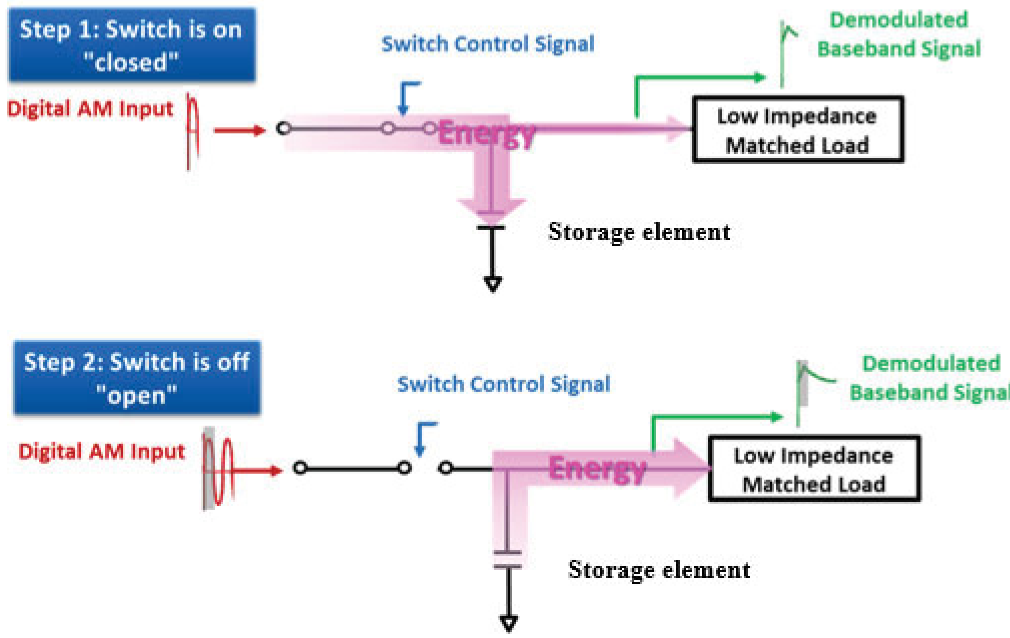
184. In energy transfer (energy sampling), a "switch" is critical and necessary to the operation of an energy transfer system. As the name implies and as discussed below, an *energy sampling* system operates by taking *samples* of (i.e., some of the *energy* from) the RF signal (red signal) and using those samples (energy) to form a down-converted signal. In particular, the switch of an energy sampler is repeatedly opened (turned OFF) and closed (turned ON) to obtain samples, which is known as "sampling." It is the ability of a switch to repeatedly open and close that enables an energy sampler to work. As such, use of a switch is critical to ParkerVision's invention. The operation of an energy sampler is *fundamentally different* than the operation of a mixer as discussed in Section VII.N.2 above. The mixer (a) uses a continuous time-varying *resistor*, not a *switch* and (b) forms a down-converted signal by mixing two signals (an RF signal and an LO signal) together instead of only using energy from the RF signal as is done in energy sampling.

185. Moreover, the '474 patent specifically *reserves* the term "*storage*" element to refer to an element (e.g., capacitor) used in an energy sampling system because, as discussed below, the use of a *low* impedance load enables the capacitor to *store* energy and subsequently *discharge* the energy to form the baseband signal (i.e., the discharged energy itself becomes part of the baseband signal). The ability

to store and discharge energy to form the down-converted signal is critical to ParkerVision's invention. As such, the use of the term "storage" element by the '474 patent is tied to an element's (e.g., capacitor's) ability to discharge stored energy to a low impedance load. This is the opposite of how the "holding" element (e.g., capacitor) works in sample-and-hold (voltage sampling). Indeed, the '474 patent uses *different* names for the capacitors in the two systems (energy sampling, which requires a "storage" element, and sample-and-hold (voltage sampling), which requires a "holding" element) to distinguish between the *different* function/operation of the capacitors and *different* type of loads used with the capacitors. As shown above, the energy transfer (energy sampling) system receives an RF signal (here, a digital amplitude modulated (AM) signal (red signal)) and creates a baseband signal (green signal), which represents the information sent by the transmitting device (1s and 0s).

186. In order to accomplish this, the system takes a sample of the RF signal (red signal) by turning the switch ON (closing the switch) and OFF (opening the switch). The switch is turned ON and OFF by a control signal received from a local

oscillator (not shown).



187. As shown in Step 1 above, upon receiving a control signal, the switch is turned ON (closed).[11] When the switch is ON, (a) *some* of the energy from the

[11] In energy sampling, the switch is generally ON (closed) for a longer period of time than in voltage sampling and, thus, the capacitor is connected to the RF signal for a longer period of time. Since energy *E* is a function of voltage *V* and current *I* over time (*E*=*V* x *I* x *t*) and the switch is ON (closed) for a longer period of time, the energy transferred to the capacitor in energy sampling is greater than in voltage sampling. As such, a larger capacitor (a capacitor with a higher capacitance) is generally used in energy sampling than is voltage sampling.

RF signal is sent to the storage element (capacitor) and (b) *some* of the energy passes through the system towards the low impedance load. The storage element stores the energy that it receives. As shown above in the Step 1 diagram, when the switch is ON, the energy from the switch forms a portion of a baseband signal (green signal on the right) (which is a representation of a portion of the original baseband signal sent from a transmitting device).

188. I note that energy flow in an energy transfer system can be significant (as compared to sample-and-hold) and close to all of the energy available from the RF input signal. The reason for this is the inclusion of the *low* impedance load and a large capacitor as a storage element. The energy transfer system is designed to efficiently transfer energy rather than accurately sample a voltage as is done in a sample-and-hold system.

189. As shown in Step 2 above, when the switch is turned OFF (closed), the capacitor *discharges* the stored energy towards the low impedance load. As shown above in the Step 2 diagram, when the switch is OFF, the discharged energy from the capacitor forms another portion of the baseband signal (green signal on the right) (which is a representation of a portion of the original baseband signal sent from a transmitting device). The reason why the energy in the energy transfer system is

discharged and included as part of the baseband signal is, once again, the inclusion of the *low* impedance load.

190. Steps 1 and 2 repeat. And as the switch is turned ON and OFF, the system forms more and more of the baseband signal *from the energy of the RF signal*. The process continues until the entire baseband signal has been formed. By using energy sampling, the energy from the RF signal itself (pass through energy from the switch and discharged energy from the capacitor) becomes the baseband signal (and thus complete down-conversion of the RF signal). Since the energy itself becomes the baseband signal, energy is not being wasted as it is in a sample-and-hold where the energy is disposed of after the hold is completed.

191. In energy sampling, the RF signal drives the low impedance load when the switch is closed and the capacitor continues to drive the low impedance load when the switch is opened. If the capacitor did not continue to drive the low impedance load, there would be gaps in the baseband signal. As such, the system would not work properly and information would be lost.

192. Whereas the high impedance load in sample-and-hold (voltage sampling) causes a capacitor to *hold* energy (i.e., *prevent* energy in the capacitor from being discharged to form the down-converted signal), the *low* impedance load in energy sampling has the opposite effect, enabling a capacitor to *store* energy and then *discharge* the stored energy in between samples to form the down-converted

signal (i.e., the discharged energy itself becomes part of the down-converted signal).

193. The technique used in energy sampling enables direct down-conversion with advantages over other techniques including sample-and-hold and mixing. *See* Section XIII.C. Indeed, prior to the invention of the '474 patent, the radio (cellular/wireless) industry did not realize that an energy transfer system (which does not accurately replicate the input voltage of the carrier signal and does not perform mixing) would work to effectively direct down-convert an RF signal nor did the industry realize the advantages of implementing such a system.

194. Energy sampling is an accurate way to form a baseband signal (which is a representation of the original baseband signal sent from a transmitting device). And what ParkerVision realized, and others did not, was that accurately capturing the voltage of the RF signal and mixing was not critical. ParkerVision realized that using the available energy was the best way to form the baseband signal. An advantage of ParkerVision's energy sampling system is that the energy stored on the capacitor is accumulated over multiple cycles of the RF signal. This accumulation enabled the random noise fluctuations on the RF signal to average out even further than would be obtained by averaging out over just one sampling aperture.

195. There are significant advantages to using energy sampling instead of voltage sampling or mixing. For example, use of energy sampling to down-convert an RF signal improves RF receiver performance, lowers power consumption,

reduces size of integrated circuits/devices and has other integration benefits. In other words, by using energy sampling, RF receivers can be built smaller, cheaper and with improved performance.

VIII. OPERATION OF FETS

196. All passages in this section are written from the point of view of a POSITA in the late 1990s through March 2000 and describe how the technology worked at that time.

A. Overview.

197. A FET is a type of transistor. Since a FET is relevant to the analysis of the prior art, I will focus my discussion on FETs.

198. A FET can amplify, oscillate, or switch the flow of current between two terminals by varying the current or voltage at a third terminal. In other words, a FET can perform different functions depending on how it is set up. In electronics, the term "biasing" refers to the setting of the operating conditions (current or voltage) of a device.

199. A FET is a non-linear device, i.e., its parameters can be varied with respect to current and voltage. Varying the parameters of a FET causes the FET to behave in different ways and, thus, a FET can be used in different ways in a circuit (e.g., as a switch or a continuous time-varying resistor). In other words, the same FET can function as completely different devices.

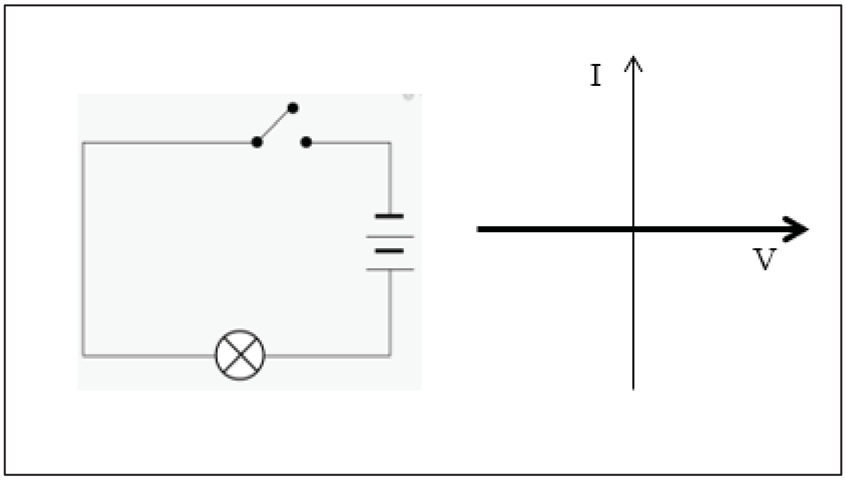
200. The way in which a FET behaves (and is used) depends on the LO signal (e.g., independent control input) that is received by the FET, how it is biased, and the circuit in which the FET is located.

201. For example, if a FET receives a *sinusoidal wave* (i.e., a sinusoidal, continuous time-varying voltage) across its input terminals, a continuous time-varying current flows between its output terminals. In this biasing arrangement, the FET functions as a continuous time-varying *resistor*. This mode of operation is referred to as time-varying transconductance (the reciprocal of time-varying resistance). A transconductance means that a voltage at one place causes the conductance to change elsewhere. I note that conductance (the ease with which an electric current passes) is the reciprocal of resistance (opposition to the flow of electric current).

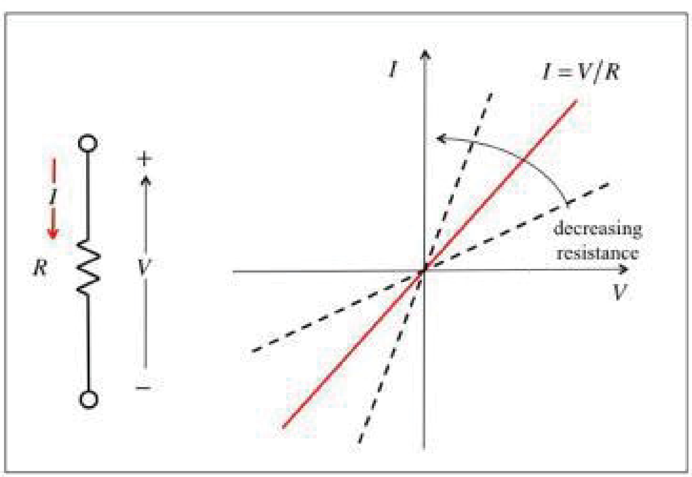
202. If, however, a large and fast voltage variation, such as a *square* or a train of *pulses*, is applied at the gate of a FET, the FET acts as a *switch* between the output pair of terminals.

203. The operation of a FET can best be described using its current-voltage characteristic (or I-V curve). A current-voltage characteristic is a relationship, typically represented as a graph (such as that shown below), between the current (I) flowing through an electronic device and the voltage (V) applied across its terminals. The shape of the I-V characteristic and the magnitude of the current are controlled

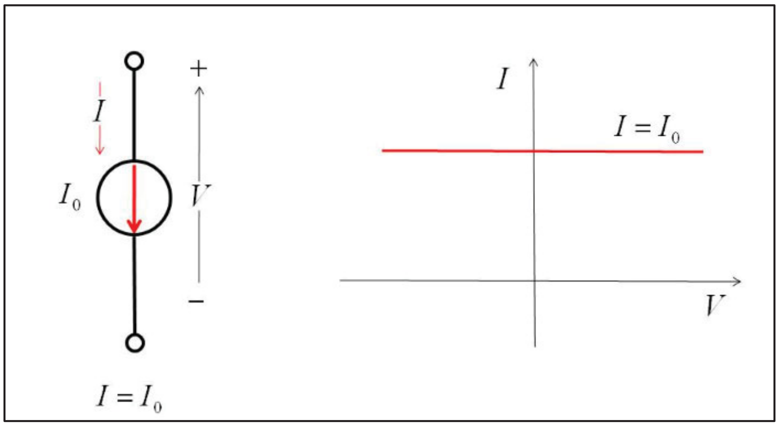
by the physics of the device.



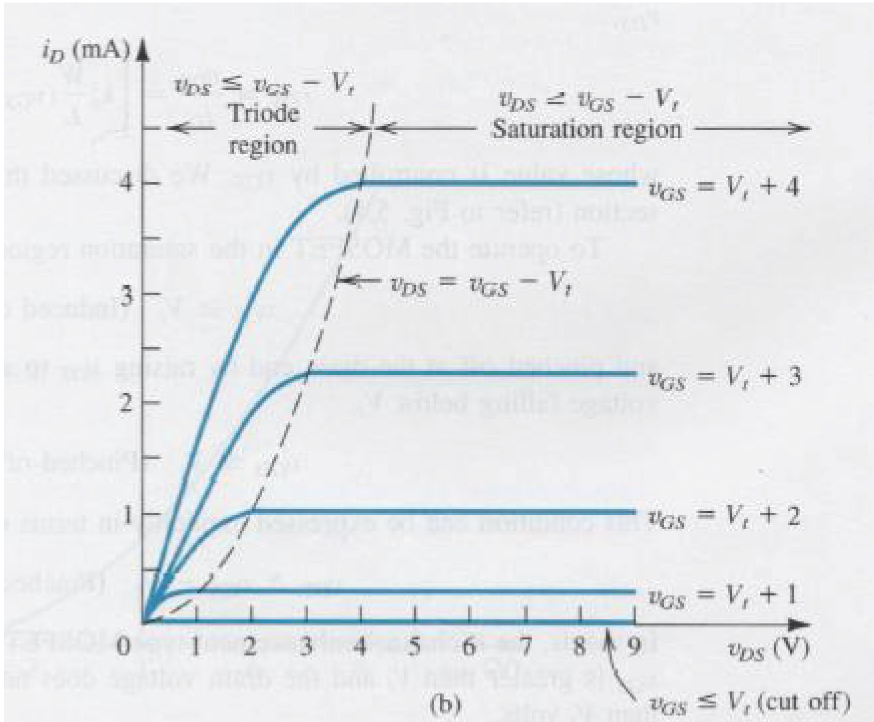
204. The I-V characteristic describes how a device works. For example, consider the circuit shown above. In this circuit, a switch is open; the switch is an open circuit. As shown above, an open circuit is the absence of a connection between two terminals. The open circuit maintains zero current, I=0, and can have any voltage drop, V, across it. Therefore, its I-V characteristic is a horizontal line at I=0, as shown above.



205. Another example of an I-V curve is that of a resistor, as shown above. An ideal resistor is a component with a linear relationship between voltage and current according to Ohm's law, i.e., V=I×R, where V is the voltage across the terminals, I is current through the resistor, and R is resistance. As shown in the graph above, the I-V curve of the resistor passes through the origin and has a slope 1/R.



206. An ideal current source, as shown above, is a component that provides a fixed current regardless of the voltage across the component itself. As shown in the figure above, the I-V curve for an ideal current source is a horizonal line at I = I_0.



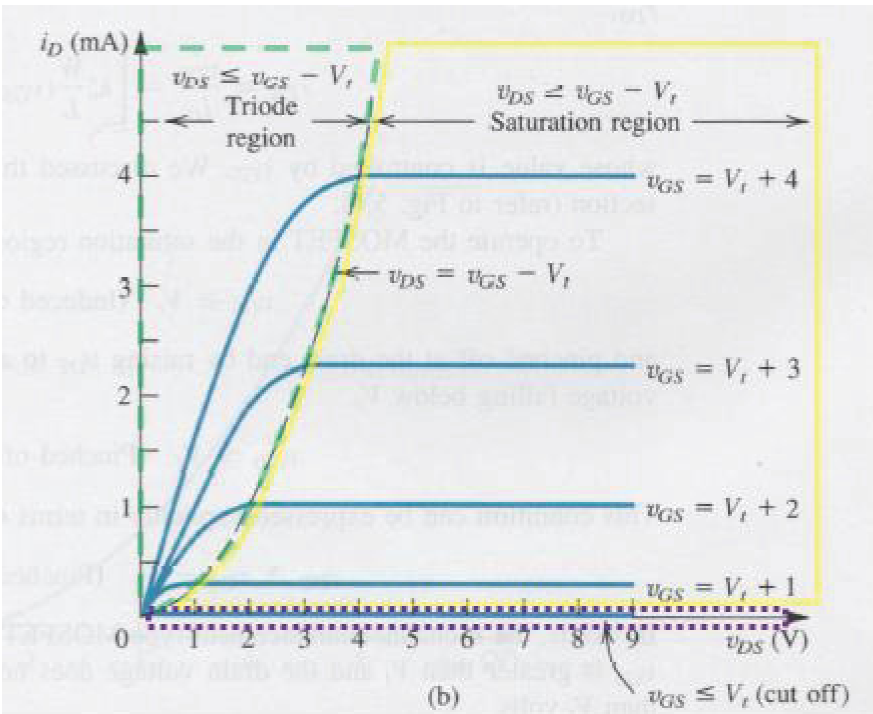
Ex. 2018 at 367.

207. In order to explain how a FET works, I will use a current-voltage characteristic graph for a MOSFET as shown above. In particular, the figure above shows several current-voltage (I-V) curves (blue lines) of an enhancement-type NMOS transistor (a type of MOSFET). Each blue line corresponds to a different controlling voltage, i.e., gate to source voltage (V_{GS}). The vertical axis is the current (I_{DS}) that flows between the drain (D) and source (S) terminals, and the horizontal axis is the voltage (V_{DS}) between the drain and source. Other types of FETs (e.g., JFETs) differ in the details of the characteristic but the essential characteristic is the same.

208. Because a MOSFET is a non-linear device, it has non-linear I-V

characteristics and is said to have three regions of operation – cutoff region, triode region, and saturation region.

209. As shown below, I have annotated the MOSFET current-voltage characteristic graph to show these regions – cutoff region (dotted purple box), triode region (dashed green area) and saturation region (yellow area).



Id.

210. When operating in different regions, a MOSFET (and FETs in general) exhibits different behaviors and, thus, the MOSFET will act as *different* devices.

211. The cutoff region (dotted purple box) is the operating region in which V_{GS} is less than a critical voltage, which is the threshold voltage of the transistor. In this region, the conductive channel is closed and there is no flow of current between

the drain and source.

212. The triode region (dashed green area) is the operating region in which V_{GS} is greater than the threshold voltage, and V_{DS} is less than the saturation voltage of the MOSFET. In the triode region, there is a roughly linear relationship between V_{DS} and I_{DS} because there is a very small value of the applied drain-source potential. As such, the triode region is referred to as a linear region or linear region of operation. When a FET is described as operating entirely in its triode or linear region (i.e., only in the triode or linear region), this means that the FET is operating as a voltage-controlled or continuous time-varying *resistor* (with the resistance being determined by a continuous time-varying voltage V_{GS} of the FET).

213. The saturation region (yellow area) is the operating region in which I_{DS} remains constant regardless of any increase in V_{DS}, and occurs once V_{DS} exceeds the value of the saturation voltage. In this region, the space between the blue lines in the graph is increasing for the same change in the controlling voltage simply because of the physics of the transistor. As such, the saturation region is referred to as a non-linear region. When operating in this region, the MOSFET behaves and operates as a voltage-controlled current source.

214. Another type of FET is the JFET. A JFET has similar characteristics to a MOSFET. Similar to a MOSFET, a JFET is said to operate in three regions of operation – a pinch off region, linear region, and saturation region.

215. As shown below, I have annotated a JFET current-voltage characteristic graph to show these regions – pinch off region (dotted purple box), linear region (dashed green area) and saturation region (yellow area).

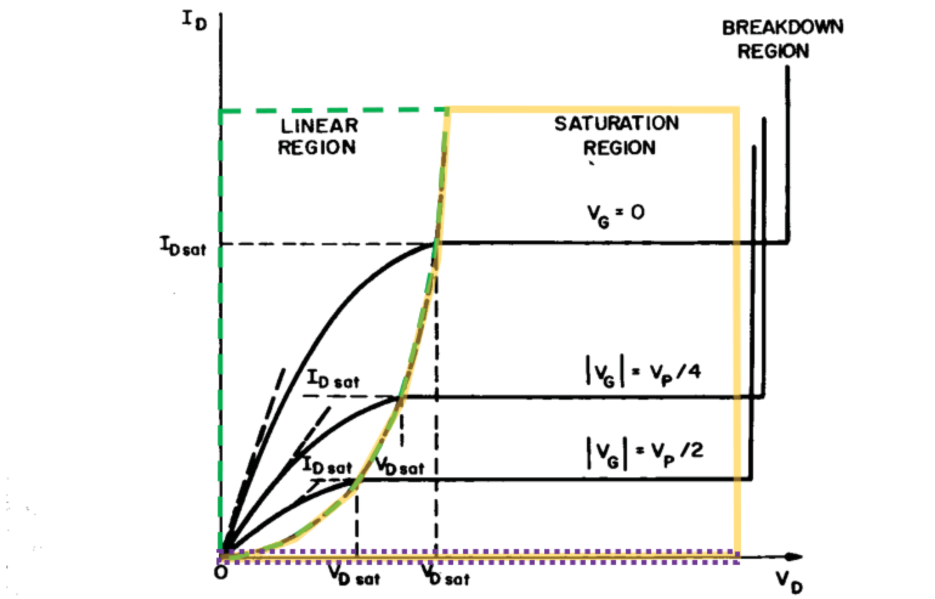


Fig. 3 Basic *I–V* characteristics of a JFET, which include the linear region, saturation region, and breakdown region. V_P is the pinch-off voltage. For a given voltage V_G, the current and voltage at the point where saturation occurs are designed by I_{Dsat} and V_{Dsat}, respectively.

Ex. 2019 at 315.

216. The pinch off region is another name for the cut-off region as shown in the MOSFET diagram above; the linear region is equivalent to the triode region of a MOSFET. Also shown is the breakdown region. The breakdown region represents when too high a voltage is applied to the JFET and the JFET breaks down and is usually destroyed. Breakdown also occurs with a MOSFET if the voltages are too high.

217. The region in which a FET operates and, thus, the way in which a FET

behaves (and is used) depends on the LO signal (e.g., independent control input) that is received by the FET, how it is biased, and the circuit in which the FET is located. If the FET in a FET resistive mixer receives a *sinusoidal wave* across its input terminals, the FET operates entirely in the triode region and functions as a continuous time-varying *resistor*. If, however, a large and fast voltage variation, such as a *square* or train of pulses, is applied at the gate of a FET, the FET alternates operation between the cutoff and triode regions and functions as a *switch*. A less common type of FET mixer is one that operates in the saturation region exploiting the nonlinear relationship between the input voltage and the output current.

218. In other words, the way in which a FET behaves (and is used) depends on the LO signal (e.g., independent control input) that is received by the FET, how it is biased, and the circuit in which the FET is located.

B. Different uses of transistors.

219. In order to understand the operation of a circuit, one must view the circuit as a whole and also look at the electrical signals in the circuit. One cannot simply look at individual components of the circuit. This is because the same components (e.g., transistor) used in different circuits can be used in different ways depending on a number of characteristics or parameters that can be varied, such has dimensions and materials, which can affect the operation. As such, the way in which

the components are used is critical.

220. That FETs have many modes of operation depending on circuit topology and signals is well known. *See* Section VIII.A above. FETs are used in different ways in different circuits/systems depending on the needs of the circuit/system.

1. Transistors used in a *sampling* system.

221. In the late 1990s through March 2000, FETs were used in *sampling* systems – sample-and-hold (voltage sampling) systems. In such a system, the FET was used as a wideband analog switch to sample the voltage of the RF signal. The reason that a FET is used as a switch in a sampling system is because, when used as a switch, the open and closing of the FET allows for a sample of voltage to be captured.

222. When a FET is used as a switch, the FET opens and closes. When the FET is ON (closed), current can pass through the FET; when the FET is OFF (opened), current cannot pass through the FET. Said another way, a FET used as a switch has two states – either ON (closed) or OFF (opened); allowing all current through or preventing current from flowing.

2. Transistors used in a non-linear mixer.

223. In the late 1990s through March 2000, another way FETs were used was in a non-linear *mixer*. In such a system, the FET was mostly used as a continuous

time-varying resistor (but not as a switch) to effectuate down-conversion of a signal (i.e., translate information centered at one frequency to information centered at another frequency). The reason that a FET is used as a continuous time-varying resistor in a non-linear mixer is because, when used as a continuous time-varying resistor, the FET operates as a good multiplier to mix the RF and LO signals.

224. Non-linear mixers, which use mixing (multiplying), are a *fundamentally different and competing* system to energy transfer (energy sampling) systems, which use sampling.

225. In the late 1990s through March 2000, a POSITA understood that a FET used as a continuous time-varying resistor is not a switch nor does it act as a switch. Instead, as a continuous time-varying resistor, the FET acts like a completely *different* circuit component – a resistor. In such a configuration, the FET operates entirely in its linear region (i.e., triode region). Ex. 1005 at 273 ("In a FET resistive mixer, the time-varying channel resistance is used for frequency conversion. The LO is applied to the gate, but no dc bias is applied to the channel (the gate may be dc biased, usually near pinch off). The FET then *operates entirely in its linear region,* where the channel is effectively a gate-voltage-controlled resistor.").

226. Unlike a FET used as a switch, a FET used as a continuous time-varying resistor does not open and close; it does not have two states. Importantly, as a continuous time-varying resistor, a FET can reduce the flow of current or allow

current to increase back up. One can think of a FET used in this way as throttling the current. Throttling of current cannot be achieved using a switch.

227. The resistance of the FET (known as time-varying resistance) can be changed/varied over time. Depending on the control signal sent to the FET, the resistance of the FET can be, for example, continuously and smoothly varying from a low resistance to a high resistance and back again.

228. The resistance of the FET is modulated by applying an LO to the gate. The resistance is varied by varying the voltage at the gate of the FET.

229. That a FET can be used in different ways within a circuit is key to understanding why the claimed invention of the ’474 patent is distinguishable from Intel’s prior art references.

IX. INTEL’S EXPERT MAKES A CRITICAL ERROR IN HIS ANALYSIS

230. I have reviewed the Declaration of Dr. Vivek Subramanian. Ex. 1002. There are errors in Dr. Subramanian’s declaration. I discuss one of the most critical errors below.

231. In his discussion of transistors, Dr. Subramanian simply states that “[a] transistor acts like a switch that either completes a circuit (which allows current to flow) or breaks a circuit (which stops the flow of current). If the transistor is turned ON, it will allow current to flow from source to drain (or from drain to source, depending on the type of transistor). If the transistor is turned OFF, it will not allow

current to flow. The state of the transistor—ON or OFF—is controlled by a signal applied at the gate." Ex. 1002 ¶52. As such, Dr. Subramanian suggests that if a transistor is in a circuit, the transistor is a switch. This is wrong. As discussed in Section VIII.A above, transistors have different modes of operation and act as different devices depending on circuit topology and the signals input to the transistor. As such, just because a transistor is used in a circuit does not mean that the transistor is being used as a switch. One must look at how the transistor is driven and the type of the controlling signal(s) to determine whether the transistor is, for example, being used as a switch or a continuous time-varying resistor. This is a critical error and results in Dr. Subramanian providing a flawed analysis of Larson and, thus, an incorrect conclusion with regard to validity of the '474 patent.

232. For this reason, I disagree with Dr. Subramanian's characterization of Larson as disclosing a "switch." As discussed in Sections XIV.A and XV.A.1 below, the transistors (FETs) disclosed in Larson operate as continuous time-varying *resistors*. The FETs of Larson are *not* switches nor are they operating as switches i.e., the FETs are not opening and closing.

X. ENERGY SAMPLING V. VOLTAGE SAMPLING

233. In order to understand the operation of a circuit, one must view the circuit as a whole. One cannot simply look at individual components of the circuit. This is because the same components used in different circuits can be used in

different ways depending on the value of the component (e.g., resistor with low or high resistance, capacitor with low or high capacitance) and/or the other components in the circuit. As such, the *way* in which the components are used is critical.

234. While energy sampling and voltage sampling use similar components (e.g., switches, capacitors and loads), these components are used (operated) in different *ways* in a circuit to create a desired result. In energy sampling, a switch, capacitor and *low* impedance load are used. In such a circuit, energy stored in the capacitor is discharged to the load and discharged energy itself forms the down-converted signal (i.e., the discharged energy itself becomes part of the down-converted signal). In voltage sampling, a switch and a capacitor are also used. But, voltage sampling uses a *high* impedance load. The use of a high impedance load instead of a low impedance load causes the circuit to behave in a different way than in energy sampling. For example, unlike in energy sampling, a voltage sampling circuit discards energy held in the capacitor without using the energy as part of the baseband signal.

235. Moreover, in voltage sampling, the discrete sampled voltages are used to derive the baseband signal. In energy sampling, the continuous flow of current/energy, both during and in between samples, forms the baseband signal.

236. Indeed, it is the different way that energy is used that results in energy sampling providing significant and unexpected advantages over voltage sampling as

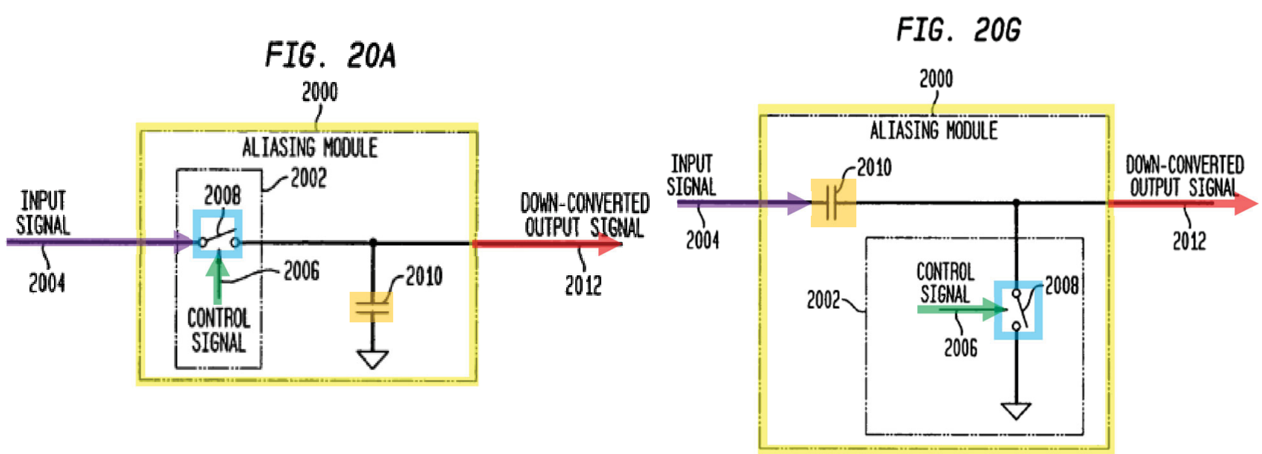
set forth in Section XIII.C.

237. As such, energy sampling and voltage sampling are *fundamentally different and competing* systems.

XI. U.S. PATENT NO. 7,539,474

A. Overview

238. The ’474 patent relates to a system and method for up-converting and down-converting electromagnetic signals (radio frequency signals). Ex. 1001 at 10:35-39. Claims 1, 3, 4, 7, and 9–11 only relate to down-conversion and, thus, my discussion in this section focuses on down-conversion.



239. Figure 20A of the ’474 patent (above left) shows the basic configuration of an aliasing module 2000 according to an embodiment of the invention. *Id*. at 11:38-40. Aliasing module 2000 (yellow) includes (1) a universal frequency translation (UFT) module 2002 (implemented as a switch 2008 (blue) with a control signal 2006 (green) for controlling the switch) and (2) a capacitor 2010 (orange) for

storing and discharging energy. *Id.* at 11:41-42.

240. The specification specifically refers to the aliasing module 2000 as "energy transfer module" and the capacitor 2010 as a "storage module." *See id.* at 15:14-18; 16:30-33.

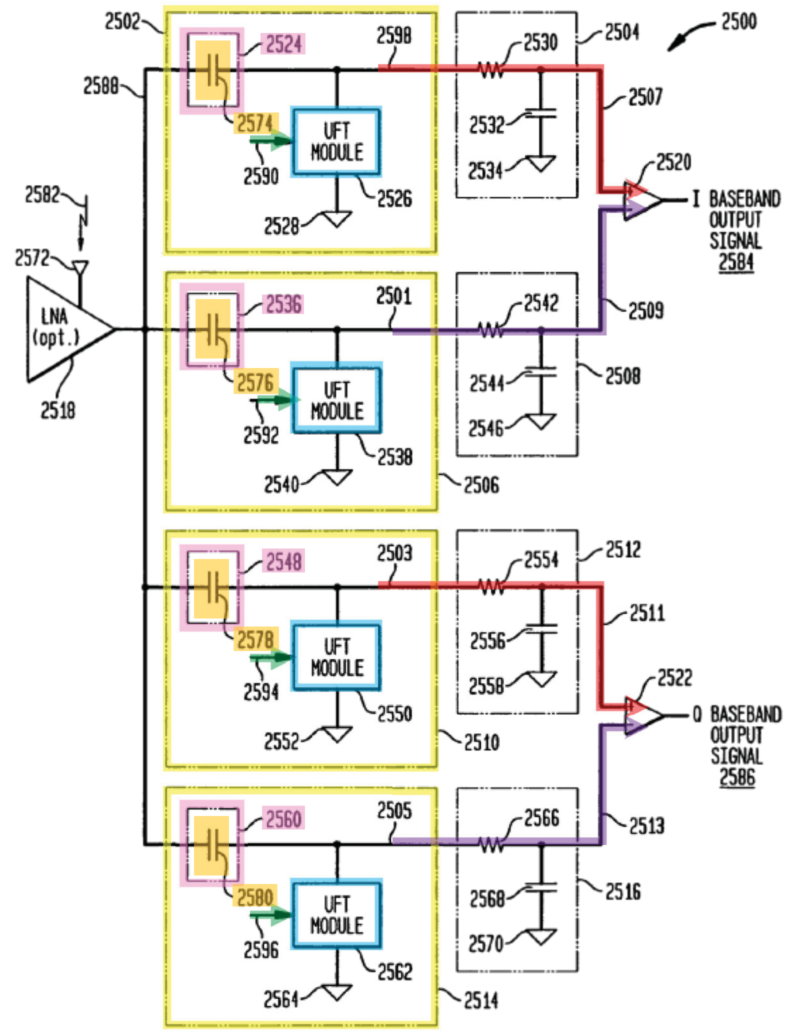
241. The switch receives an input signal 2004 (purple arrow), processes the signal as discussed below, and outputs a down-converted output signal 2012 (red arrow). In this configuration, the switch 2008 is in series with the input signal 2004 and the capacitor 2010 is shunted to e.g., ground. *Id.* at 11:43-47.

242. Figure 20G of the '474 patent (above right) shows an alternative configuration of the aliasing module of Figure 20A. In Figure 20G, the capacitor 2010 is in series with the input signal 2004 and the switch 2008 is shunted to e.g., ground. *Id.* at 11:47-50.

243. Nevertheless, the configurations of Figures 20A and 20G will operate in the same way.

244. The '474 patent discloses various embodiments of receivers into which the aliasing module of Figures 20A and 20G can be incorporated such as, for example, into receiver 2500 of Figure 25.

FIG. 25



245. Figure 25 of the '474 patent illustrates an exemplary I/Q modulation receiver 2500. *Id.* at 77:23-24. The I/Q modulation receiver 2500 receives, down-converts, and demodulates an I/Q modulated RF input signal 2582 to an I baseband output signal 2584, and a Q baseband output signal 2586. *Id.* at 77:35-38.

246. RF input signal 2582 comprises a first and second information signal that are I/Q modulated onto an RF carrier signal. *Id.* at 77:38-40. I baseband output

signal 2584 comprises the first baseband information signal and Q baseband output signal 2586 comprises the second baseband information signal. *Id.* at 77:40-43.

247. In particular, antenna 2572 receives I/Q modulated RF input signal 2582, which is sent to a low-noise amplifier (LNA) 2518. *Id*. at 77:44-46. The LNA 2518 amplifies I/Q modulated RF input signal 2582 and outputs the amplified I/Q modulated RF input signal 2588 to UFD modules 2502, 2506, 2510, 2514. *Id*. at 77:46-50; 78:20-21; 79:16-17, 55-56.

248. UFD modules 2502, 2506 down-convert an I-phase signal portion of the I/Q modulated RF input signal 2582 and UFD modules 2510, 2514 down-convert a Q-phase signal portion. Other than processing signals at relative phase shifts, UFD modules 2502, 2506 and 2510, 2514 operate the same, and thus the operation of the circuits will be explained in the context of UFD modules 2502, 2506.

249. Figure 25 (above) includes UFD (aliasing) modules 2502, 2506 (yellow) (aliasing modules having the configuration as shown in Figure 20G). The UFD modules 2502, 2506 (yellow) include UFT modules 2526, 2538 (blue), respectively, which can include a switch such as shown in Figure 20G. *Id.* at 77:54-57; 78:25-28. UFD modules 2502, 2506 also include storage modules 2524, 2574 (another name for "storage element"). *Id.* The specification specifically refers to and identifies storage modules 2524, 2536, 2548, 2560 (pink) *separately* from capacitors 2574, 2576, 2578, 2580 (orange), respectively. *Id.* at 77:65-66; 78:37-38. As

discussed in Section XI.B below, the term "storage" module/element is specifically reserved by the '474 patent to refer to a module/element of an energy transfer (energy sampling) system.

250. In operation, a switch in the UFT module 2526 is turned ON (closes) and OFF (opens) based on I control signal 2590 (green). *Id.* at 77:56-58. As a result of the opening and closing of the switch, a down-converted signal (I output signal 2598) is formed (the details of such formation are discussed in Section XI.B.1 below). *Id.* at 77:58-62. The I output signal 2598 is (optionally) received by a filter 2504, which filters the signal. *Id.* at 78:7-10.

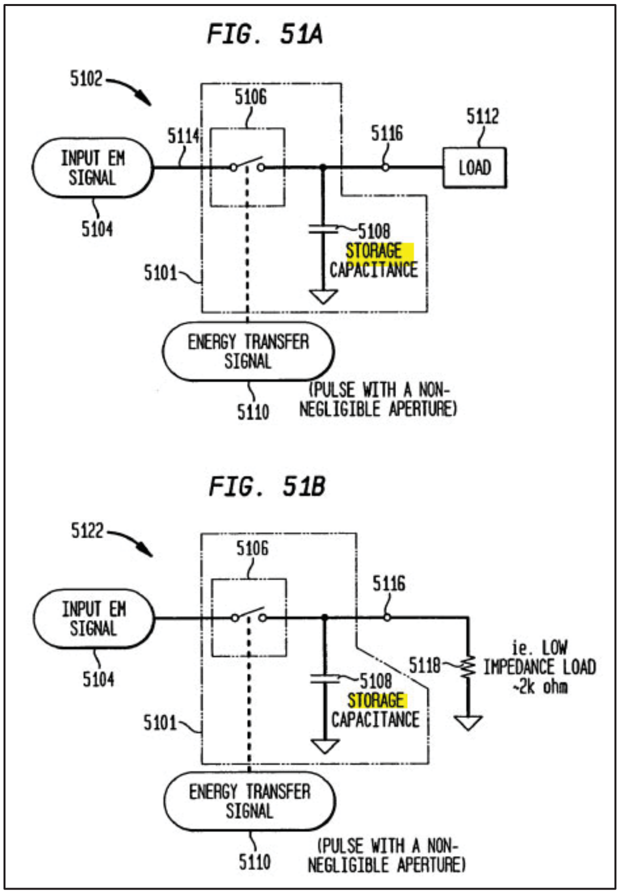
251. Similarly, a switch in the UFT module 2538 is turned ON (closes) and OFF (opens) based on an inverted I control signal 2592 (green). *Id.* at 78:27-29. As a result of the opening and closing of the switch, a down-converted signal (inverted I output signal 2501) is formed (the details of such formation are discussed in Section XI.B.1 below). *Id.* at 78:29-33. The inverted I output signal 2501 is (optionally) received by a filter 2508, which filters the signal. *Id.* at 78:46-49.

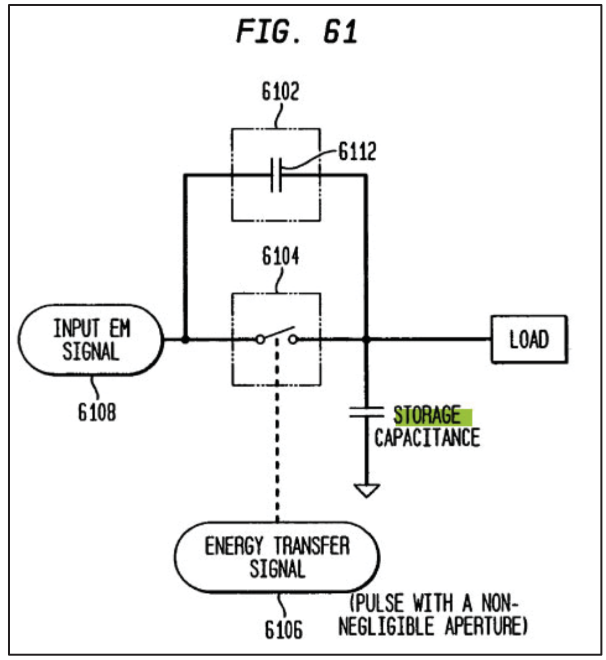
252. As shown by the red arrow, UFD module 2502 (yellow) outputs an I output signal 2598, which can be filtered to produce a filtered I output signal 2507. As shown by the purple arrow, UFD module 2506 (yellow) outputs an inverted I output signal 2501, which can be filtered to produce a filtered inverted I output signal 2509. Regardless of whether a filter is used, the I output signal and inverted I output

signal are sent to a combining module (differential amplifier 2520). The differential amplifier 2520 subtracts the inverted I output signal from the I output signal, amplifies the result, and outputs I baseband output signal 2584. *Id*. at 78:61-66.

253. Similar to Figure 25, Figures 95 and 105 also refer to storage modules 9534, 10520, *separately* from capacitors 9526, 10522. *Id.* at 60:6-9; 74:58-60.

254. The reason the ’474 patent describes a “storage” module/element and a capacitor separately is because a capacitor used as a “storage” module/element is a *specific* implementation where a capacitor is used as an element of an *energy* transfer (*energy* sampling) system (where energy itself becomes part of the baseband/down-converted signal). *See* Section XI.B.1 below.





255. For example, Figures 51A, 51B (above) are described as energy transfer systems ('474 patent, 5:13-14) and disclose "a *storage* module, illustrated here as a *storage* capacitance 5108" (*id*. at 20:3-6).

256. In other words, whether a capacitor is a "storage" module/element depends on the way in which the capacitor is being used. Just because a capacitor is being used does not mean that the capacitor is a "storage" module/element.

3. Frequency Down-conversion

The present invention is directed to systems and methods of universal frequency down-conversion, and applications of same.

In particular, the following discussion describes down-converting using a Universal Frequency Translation Module. The down-conversion of an EM signal by aliasing the EM signal at an aliasing rate is fully described in co-pending U.S. patent application entitled "Method and System for Down-Converting Electromagnetic Signals," Ser. No. 09/176,022, filed Oct. 21, 1998, the full disclosure of which is incorporated herein by reference. A relevant portion of the above mentioned patent application is summarized below to describe down-converting an input signal to produce a down-converted signal that exists at a lower frequency or a baseband signal.

Exemplary systems and methods for generating and optimizing the control signal **2006** and for otherwise improving energy transfer and s/n ratio, are disclosed in the co-pending U.S. patent application entitled "Method and System for Down-converting Electromagnetic Signals," Ser. No. 09/176,022.

See id. at 11:20-37; 15:8-13.

257. As shown above (yellow highlights), the specification of the '474 patent specifically states that the details regarding down-conversion and control signals for improving energy transfer are set forth in U.S. Patent Application No. 09/176,022 (now U.S. Patent No. 6,061,551 ("the '551 patent")) (Ex. 2020). As such, a POSITA would look to and review the '551 patent in order to further his/her understanding of the technology of the '474 patent.

B. The patent discloses two *fundamentally different and competing* systems for down-conversion.

258. The '551 patent and, thus, the '474 patent goes into great detail regarding the difference between "storage" module/element, which the '551 patent explains is an element of an *energy* transfer (*energy* sampling) system, and a

"holding" module/element, which the '551 patent explains is an element of a sample-and-hold (*voltage* sampling) system.

259. The '551 patent and, thus, the '474 patent discloses two systems for down-conversion: (1) *energy* transfer (i.e., *energy* sampling) and (2) sample-and-hold (i.e., *voltage* sampling). Independent claim 1 (and claims 3, 4, 7, and 9-11 which depend upon claim 1) of the '474 patent is directed to *energy* transfer because it uses a term that the patentees *reserved* specifically to connote energy transfer (energy sampling) – "*storage* element." The patent draws a sharp contrast between a "storage" module/element, which connotes energy transfer (energy sampling), and a "holding" module/element, which connotes sample-and-hold (voltage sampling). *See, e.g.,* Ex. 2020 at 66:55-67.

260. As discussed below, energy transfer (energy sampling) and sample-and-hold (voltage sampling) are distinctly different technologies. In energy transfer, the down-converted signal includes the *energy* from the RF signal; in sample-and-hold, the down-converted signal is derived from reading discrete points of *voltage* of the RF signal. *Compare id.* at 66:33-68:15 (describing an energy transfer system) *with id.* at 54:45-55:29 (describing a sample-and-hold system). And while energy transfer and sample/hold both result in down-converted signals, an energy transfer system results in a higher quality baseband signal and, therefore, allows for wireless devices with fewer components, reduced size and cost, and increased battery life. *Id.*

at 62:60-63, 66:34-54.

261. As disclosed in the ’551 patent (and, thus, the ’474 patent) and in more detail below, the following table identifies key features that distinguish energy transfer (energy sampling) from sample-and-hold (voltage sampling).

Energy Transfer (*Energy* Sampling)	**Sample-and-Hold (*Voltage* Sampling)**
Non-negligible sampling aperture	Negligible sampling aperture[12]
“*Storage*” element	“*Holding*” element
Low impedance load	*High* impedance load
Down-converted signal includes the *energy* transferred from the RF signal to the load (i.e., energy sent to the load makes up the down-converted signal)	Down-converted signal is based on discrete *voltage* measurements of the RF signal

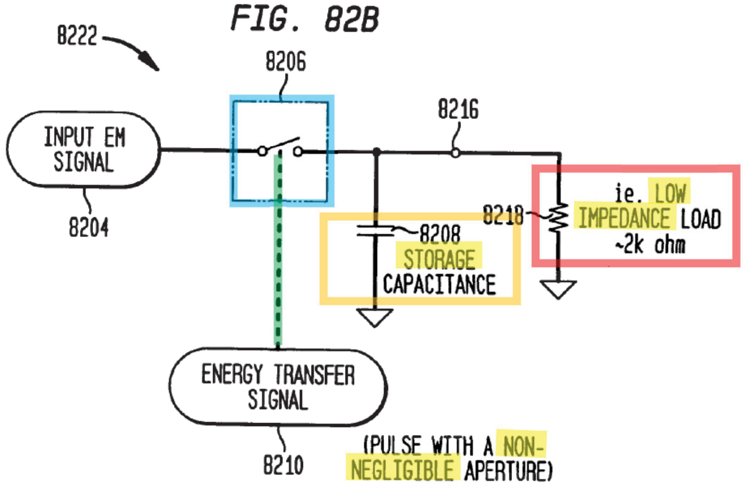
1. Energy transfer (*energy* sampling).

262. Figure 82B of the ’551 patent (below) illustrates an energy transfer (energy sampling) system, which would be incorporated into a transceiver chip of a

[12] I note that in impulse sample-and-hold (voltage sampling), negligible sampling apertures are being used. In track-and-hold (another type of sample-and-hold (voltage sampling)), tracking intervals are used. The voltage sampled is at the end of the tracking interval and, thus, the sampling aperture is the instant, i.e. negligible aperture, at the end of the tracking interval. Nevertheless, track-and-hold is *voltage* sampling because track-and-hold uses readings of voltage across a capacitor in order to down-convert, and energy is not discharged from the capacitor to form the down-converted signal.

wireless device.

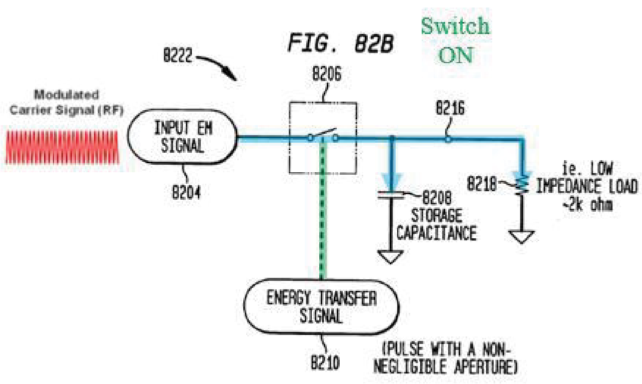
FIG. 82B

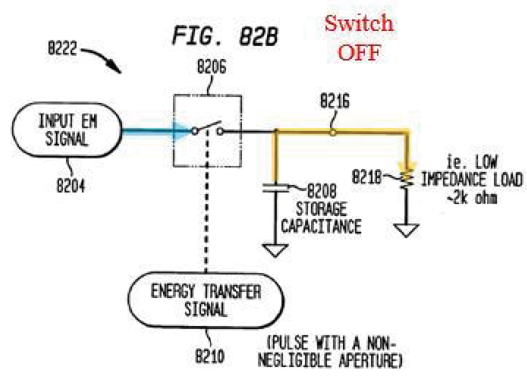


263. The system includes a switch 8206 (blue), a control signal 8210 (green) for controlling the switch, a "storage" capacitor 8208 (orange) for storing and discharging energy, and a low impedance load (red). Notably, there are several key features (yellow highlights) that distinguish an energy transfer system from sample-and-hold. In particular, an energy transfer system uses (1) a control signal having a pulse with a non-negligible aperture/duration, and (2) a "storage" capacitor for storing and discharging non-negligible amounts of energy for driving a *low* impedance load.[13] Indeed, *low* impedance is what enables a "storage" capacitor to

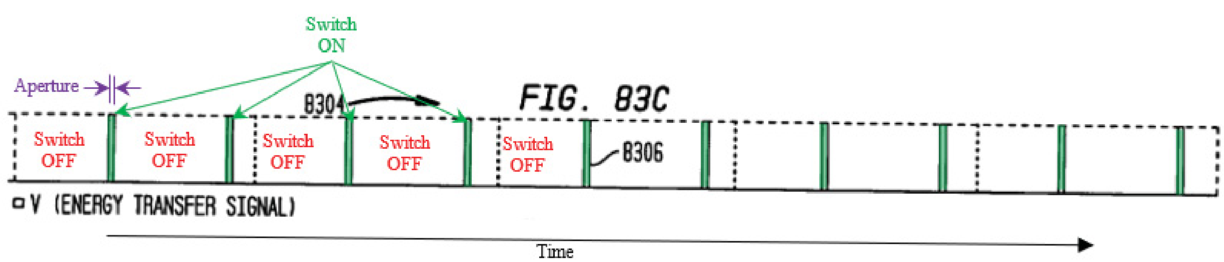
[13] Unlike a battery that produces energy, a load is an electrical component (e.g., resistor) that consumes energy (similar to how a light bulb consumes energy). Impedance refers to the opposition that a component presents to the flow of electrical

discharge its energy when the switch is OFF (open). If the impedance were high, the "storage" capacitor could *not* discharge sufficient energy for the system to perform energy transfer (energy sampling) and form a down-converted signal from energy transferred to the low impedance load.





264. The annotations in Figure 82B above illustrate how an energy transfer system down-converts a high frequency input EM signal 8204 (e.g., modulated carrier signal (red)) to a baseband signal. In particular, down-conversion occurs by repetitively opening and closing the switch 8206.

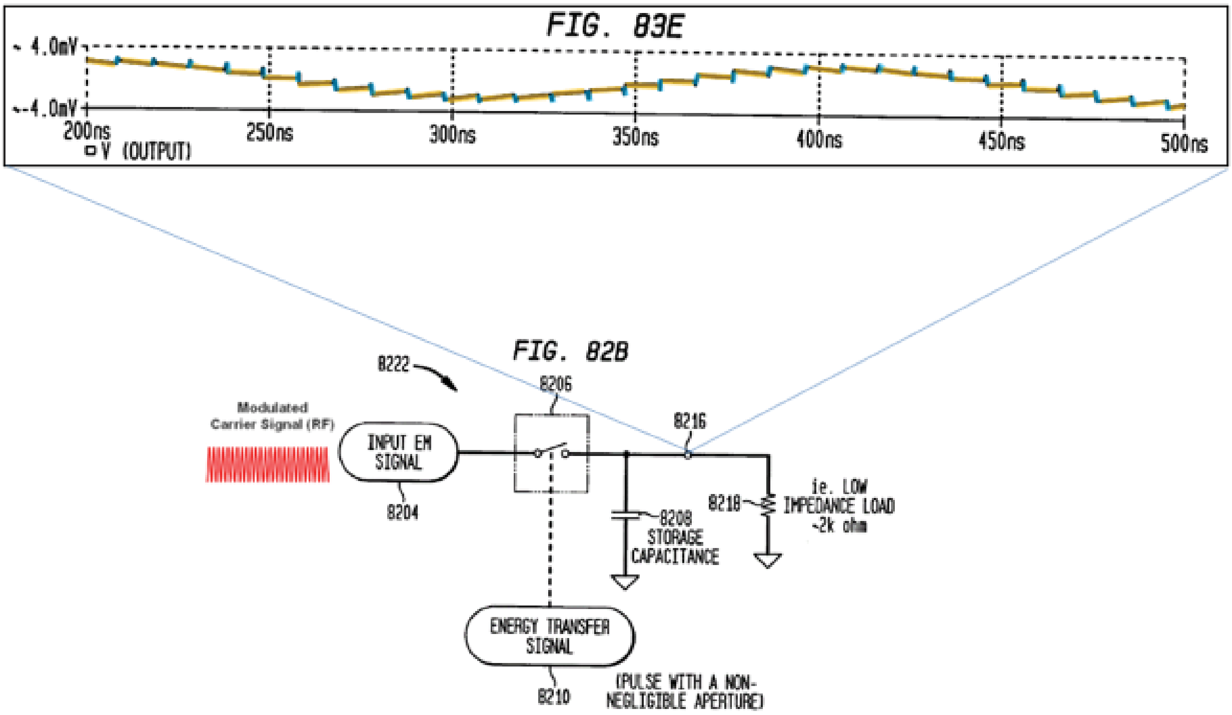


current. A low impedance load is an electrical component that consumes energy and provides low resistance to the flow of current.

265. As shown in Figure 83C above, the switch is turned ON (closed) by sending a pulse 8306 (green) to the switch. The switch is kept ON (kept closed) for the duration of the pulse (i.e., a non-negligible aperture (purple) of the pulse). As shown by the repetitive pulses 8306, this opening and closing of the switch repeats continuously over time.

266. As shown in Figure 82B above (left), when the switch is ON (during the aperture), a portion of the input EM signal 8204 (blue) passes to the "storage" capacitor 8208 and the low impendence load 8218. When the pulse 8306 (green) stops, the switch is turned OFF (opened), and the input EM signal is prevented from passing through the switch. Since the load is low impedance, when the switch is OFF (opened), as shown in Figure 82B above (right), energy (orange) stored in the "storage" capacitor 8208 is discharged to the low impedance load 8218. For this

reason, the "storage" capacitor is said to "drive the load." Ex. 2020 at 67:42-46.



267. The repetitive opening and closing of the switch results in the waveform (blue/orange) shown above in Figure 83E at terminal 8216. The waveform is made up of energy (blue) from the EM signal and discharged energy (orange) from the "storage" capacitor. Indeed, the discharged energy (orange) from the "storage" capacitor is essential. Without the discharged energy, the waveform of Figure 83E would be incomplete (the orange portions would be missing), thereby producing a degraded and/or unusable signal that could not be properly processed by a receiving wireless device.

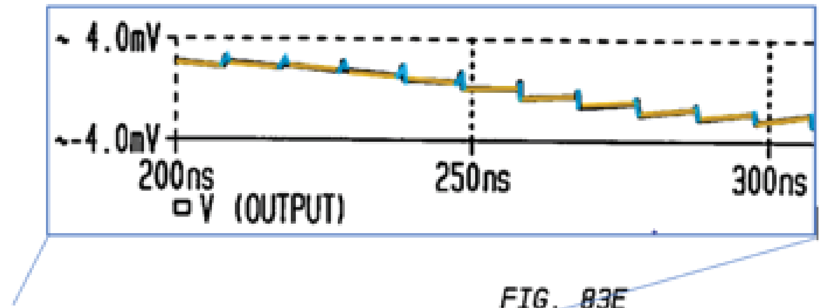


FIG. 83E

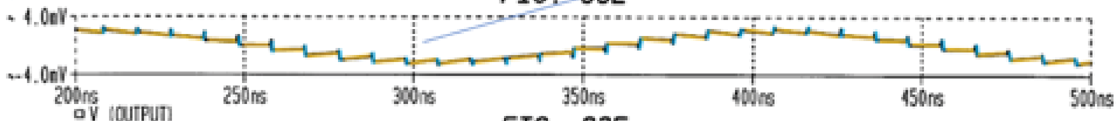
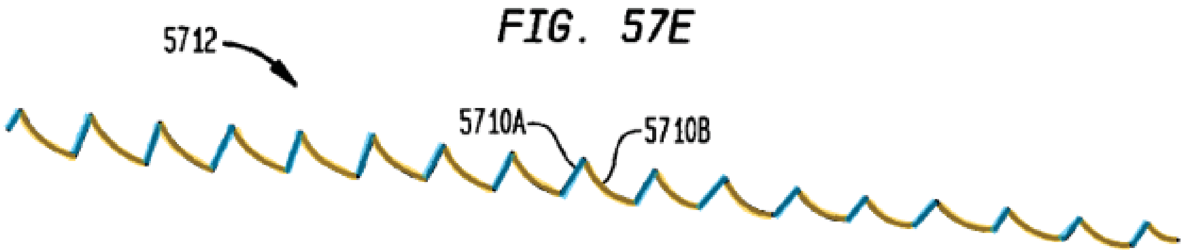
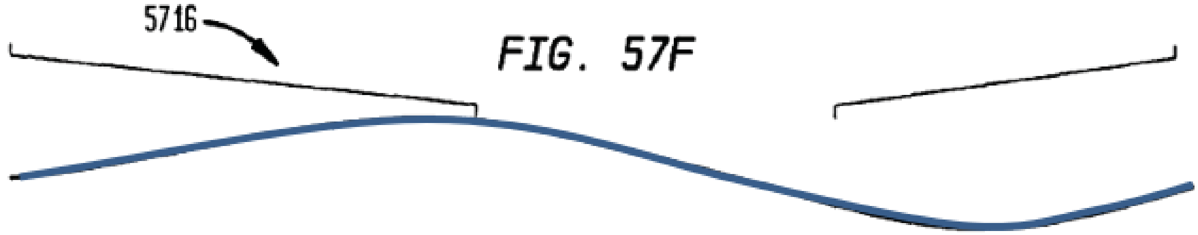


FIG. 83F

268. As shown above, the waveform of Figure 83E is filtered to created a smooth waveform (dark blue) as shown in Figure 83F. *Id.* at 68:2-4. The smooth waveform is the baseband (audio) signal that was sent from the transmitting wireless device (e.g., Bob's cell phone). The baseband signal can be processed by the receiving wireless device (e.g., Alice's cell phone) and Alice can hear Bob's voice.

269. The figures below illustrate a close-up view of another embodiment of a down-converted signal in an energy transfer system.



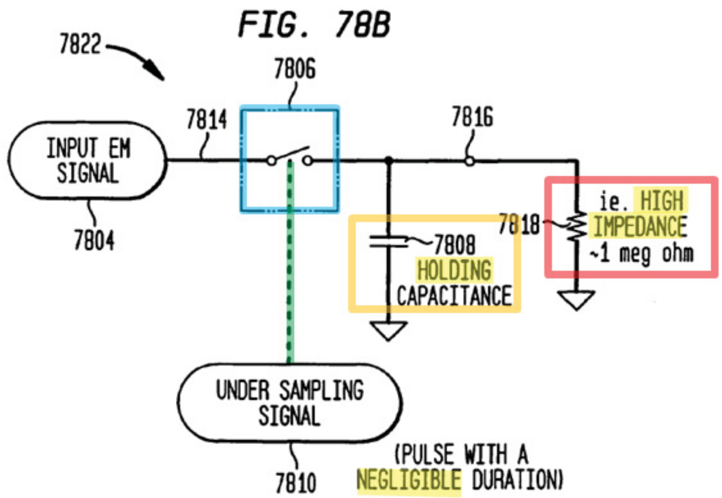


270. Figure 57E shows a segment 5712 of the down-converted signal 5716 of Figure 57F. The down-converted signal of Figure 57E is made up of *two* portions - portion 5710A (i.e., energy (blue) from the EM signal) and portion 5710B (i.e., discharged energy (orange) from the "storage" capacitor). *Id.* at 85:48-58.

2. Sample-and-hold (*voltage* sampling).

271. Figure 78B of the '551 patent illustrates a sample-and-hold (*voltage*

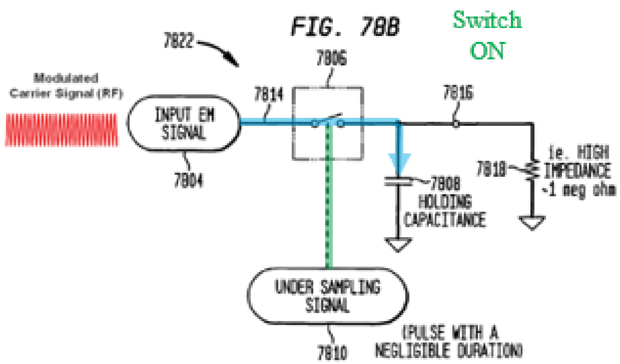
sampling) system.

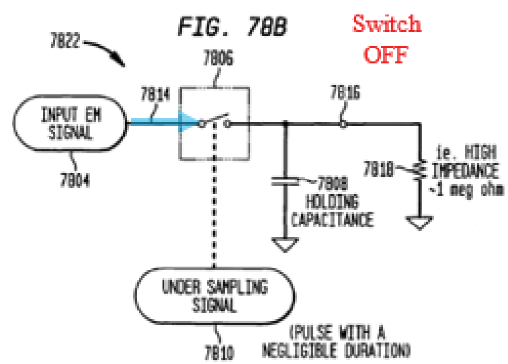


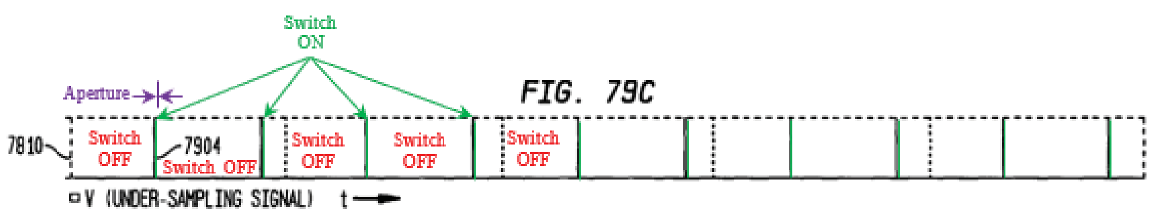
272. The system includes a switch 7806 (blue), a control signal 7810 (green) for controlling the switch, a "holding" capacitor 7808 (orange) for *holding* a voltage across the capacitor, and a *high* impedance load (red). Unlike an energy transfer system, a sample-and-hold system uses (1) a control signal having a pulse with a *negligible* aperture/duration, (2) a "holding" capacitor for *holding* a constant voltage across the capacitor and (3) a *high* impedance load (yellow highlights). The capacitor is referred to as a "holding" capacitor because, unlike the "storage" capacitor in an energy transfer system, a "holding" capacitor does *not* discharge any significant energy to the load. Indeed, the *high* impedance load is specifically included to *prevent* the holding capacitor from discharging energy, which would degrade the discrete voltage measurements and adversely affect the system performing sample-

and-hold (voltage sampling).

273. The annotations in Figure 78B (below) illustrate how a sample-and-hold system down-converts a high frequency input EM signal 7804 (e.g., modulated carrier signal (red)) to a baseband signal.



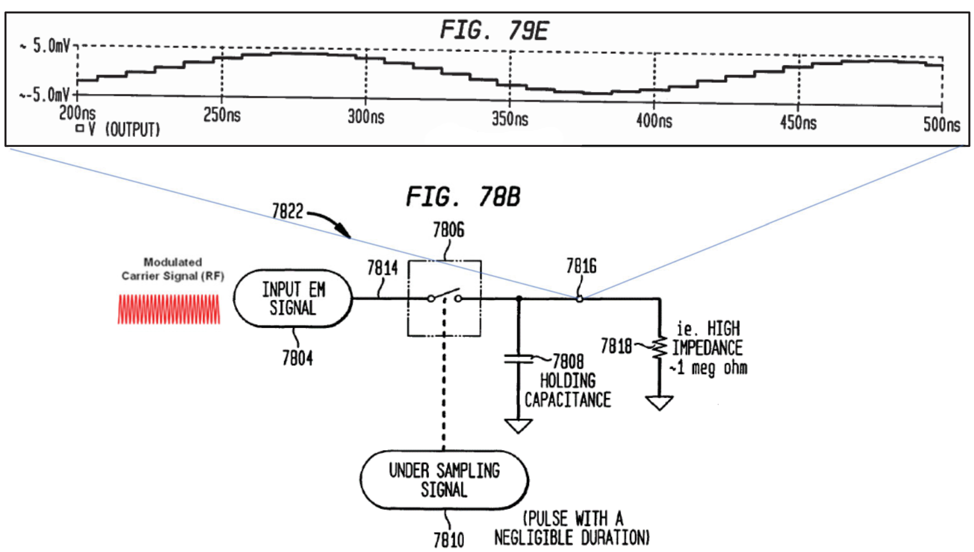




274. As shown in Figure 79C (above), the switch is turned ON (closed) by sending a pulse 7904 (green vertical line) of an extremely short/negligible duration to the switch. Thus, the aperture (purple) of a pulse is referred to as a *negligible* aperture because the pulse width "tend[s] toward zero time." Ex. 2020 at 63:45-47. As shown by the repetitive pulses 7904, this opening and closing of the switch repeats continuously over time.

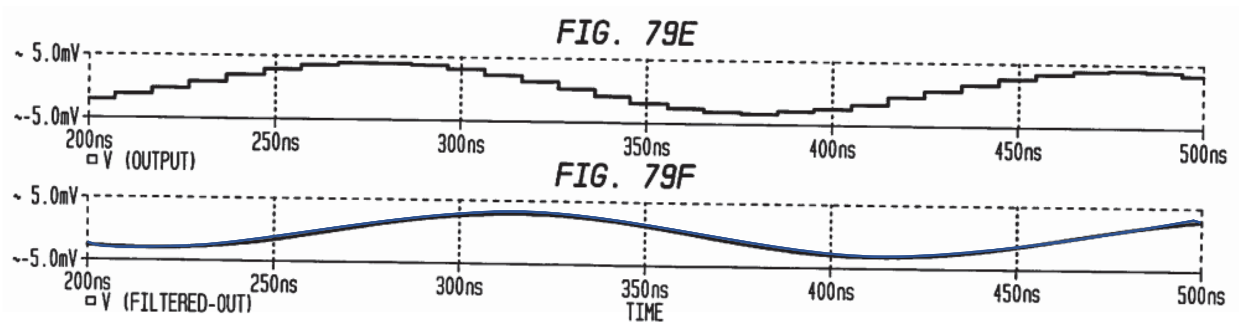
275. As shown in Figure 78B above, when the switch is ON (closed) (during the aperture), the EM signal 7804 (blue) is sent to the "holding" capacitor 7808.

When the pulse 7904 (green) stops, the switch is turned OFF (opened). But unlike energy transfer (energy sampling), since sample-and-hold uses a *high* impedance load, when the switch is OFF (opened), there is *high* resistance to the flow of current and, thus, the "holding" capacitor holds a constant voltage value. Because there is no significant energy discharge between pulses, the terminal 7816 maintains a constant voltage value until the next pulse. *Id.* at 64:21-26. The voltage value serves as the "sample" of a discrete voltage value that the system uses to recover the baseband signal. In particular, the system uses each discrete change (increase/decrease) in the *voltage* value over time to recover the baseband. This is unlike energy transfer (energy sampling) which uses the *energy* from the input EM signal provided to a low impedance load to recover the baseband.



276. As shown in Figure 79E, sample-and-hold produces a voltage wave with a stair step pattern. The vertical part of the step represents the "sample" of the

voltage value which occurs at the time of pulse 7904. The horizontal portion of the step represents the "holding" of that voltage value until the next pulse when the next sample of voltage is taken. *Id.* at 64:26-30.



277. As shown above, the waveform of Figure 79E is filtered to create a smooth waveform (dark blue) as shown in Figure 79F. *Id.* at 64:32-34. The smooth waveform is the baseband (audio) signal that was sent from the transmitting wireless device (e.g., Bob's cell phone). The baseband signal can be processed by the receiving wireless device (e.g., Alice's cell phone) and Alice can hear Bob's voice.

C. Prosecution history of the '474 patent.

278. The '474 patent was filed on February 17, 2005. The applicants filed a preliminary amendment that same day. Ex. 1003 at 308-333. Claim 2 (shown below) was added in the preliminary amendment. *Id.* at 321-322.

2. (New) An apparatus for down-converting an input signal, comprising:

a first frequency down-conversion module that receives an input signal, wherein the first frequency down-conversion module down-converts the input signal according to a first control signal and outputs a first down-converted signal;

a second frequency down-conversion module that receives the input signal, wherein the second frequency down-conversion module down-converts the input signal according to a second control signal and outputs a second down-converted signal; and

a subtractor module that subtracts the second down-converted signal from the first down-converted signal and outputs a single channel down-converted signal;

wherein the first frequency down-conversion module comprises a first switch and a first storage element, wherein the first switch is coupled to the first storage element at a first node and coupled to a first reference potential; and

wherein the second frequency down-conversion module comprises a second switch and a second storage element, wherein the second switch is coupled to the second storage element at a second node and coupled to a second reference potential;

279. On March 6, 2008, the U.S. Patent Office issued an Office Action rejecting claims 2 on the ground of non-statutory obviousness-type double patenting as being unpatentable over claims of U.S. Patent No. 6,879,817 ("the '817 patent"), assigned to ParkerVision, Inc. *Id.* at 893-902. On April 15, 2008, the applicants responded to the March 6th Office Action, amending claim 2 (as shown below). *Id.* at 993-1007. Applicants also filed a terminal disclaimer over the '817 patent on August 25, 2008. *Id.* at 1060.

> 2. (Currently Amended) An apparatus for down-converting an input signal, comprising:
>
> a first frequency down-conversion module that receives an input signal, wherein the first frequency down-conversion module down-converts the input signal according to a first control signal and outputs a first down-converted signal;
>
> a second frequency down-conversion module that receives the input signal, wherein the second frequency down-conversion module down-converts the input signal according to a second control signal and outputs a second down-converted signal; and
>
> a ~~subtractor~~ combining module that ~~subtracts~~ combines the second down-converted signal [[from]] with the first down-converted signal and outputs a single channel down-converted signal;
>
> wherein the first frequency down-conversion module comprises a first switch and a first storage element, wherein the first switch is coupled to the first storage element at a first node and coupled to a first reference potential; and
>
> wherein the second frequency down-conversion module comprises a second switch and a second storage element, wherein the second switch is coupled to the second storage element at a second node and coupled to a second reference potential;

280. On December 22, 2008, the U.S. Patent Office issued a Notice of Allowance. *Id.* at 1112-1117. Claim 2 was allowed and later issued as independent claim 1 of the '474 patent, which is the subject of this IPR Petition.

XII. CLAIM CONSTRUCTION

281. I understand that claim construction is the process of determining the meaning of words used in a patent claim in order to understand the meaning of the claim. I have been informed that claim construction is a matter of law and that claim construction will be determined by the Patent Trial and Appeal Board. I understand that the proper construction of a term is how a POSITA, at the time of the invention,

would have understood the term based on its use in the claims, specification, and prosecution history of the patent. I further understand that the claims are not to be reviewed in this proceeding under the "broadest reasonable interpretation" standard.

282. My understanding of the legal standard for determining whether a term is a means-plus-function term and for construing such a term is set forth in Section IV.C above.

283. I have reviewed claims 1, 3, 4, 7, and 9-11, the specifications of the '474 patent and '551 patent and the prosecution history of the '474 patent.

A. "switch" (claim 1)

284. Claim 1 (and claims 3, 4, 7, and 9-11 which depend upon claim 1) recites a "switch."

285. As I have discussed in Section XI.A above, the '474 patent specifically discloses the use of a switch and independent claims 1 (and claims 3, 4, 7, and 9-11 which depend upon claim 1) of the '474 patent is directed to *energy* transfer. As I discussed in Section VII.N.4, a "switch" (and its ability to open and close) is critical and necessary to the operation of an energy transfer system. Indeed, it is the ability of a switch to repeatedly open and close that enables an energy sampler to work.

286. I have reviewed the construction of the U.S. District Court for the Western District of Texas, which construed a "switch" as having its plain and ordinary meaning wherein the plain and ordinary meaning is "an electronic device

for opening and closing a circuit as dictated by an independent control input." Ex. 2021 at 6. It is my opinion that the District Court's construction is correct and accurately captures the meaning of "switch" as understood by a POSITA. I note that in the District Court case, Intel agreed that a switch is "an electronic device for opening and closing a circuit." *See id.*

B. "storage element" (claim 1)

287. Claim 1 (and claims 3, 4, 7, and 9-11 which depend upon claim 1) recites a "storage element."

288. As I have discussed in Section XI above, the '474 patent specifically *reserves* the term "storage" element for an element of an energy transfer system that stores non-negligible amounts of energy. The specification distinguishes a "storage" element from a "holding" element. In particular, a "holding" element is an element of a *sample-and-hold* (*voltage* sampling) system.

289. I have reviewed the construction of the U.S. District Court for the Western District of Texas, which construed a "storage element" as "an element of an *energy transfer system* that stores non-negligible amounts of energy from an input electromagnetic signal." Ex. 2021 at 5. It is my opinion that the District Court's construction is correct and accurately captures the meaning of "storage element" as

understood by a POSITA.

C. "frequency down-conversion module" (claim 1)

290. Claim 1 (and claims 3, 4, 7, and 9-11 which depend upon claim 1) recites a "frequency down-conversion module." The term does *not* use the word "means." As such, it is my understanding that there is a presumption that "frequency down-conversion module" is *not* a means-plus-function term. Accordingly, in order to determine whether "frequency down-conversion module" is a mean-plus-function term, it is my understanding that the question becomes whether the term "frequency down-conversion module" connotes structure to a POSITA at the time of the invention. It does.

291. A POSITA at the time of the invention would have understood that the term "frequency down-conversion module" connotes structure including, for example, a switch and a storage element (physical circuit components). Indeed, claim 1 itself recites that the "frequency down-conversion module" includes "a [] switch and a [] storage element."

D. "combining module" (claim 1)

292. Claim 1 recites a "combining module." The term does *not* use the word "means." As such, it is my understanding that there is a presumption that "combining module" is *not* a means-plus-function term. Accordingly, in order to determine whether "combining module" is a mean-plus-function term, it is my understanding

that the question becomes whether the term "combining module" connotes structure to a POSITA at the time of the invention. It does.

293. A POSITA at the time of the invention would have understood that the term "combining module" connotes structure including, for example, a differential amplifier (a physical circuit element). I note that Intel's expert, Dr. Subramanian, identifies a specific type of circuit element – a differential amplifier – as the structure of a "combining module." Ex. 1002 ¶¶83-84.

E. "the [] switch is coupled to the [] storage element at a [] node and coupled to a [] reference potential" (claim 1)

294. Claim 1 recites a "first frequency down-conversion module compris[ing] a first switch and a first storage element, wherein the first switch is coupled to the first storage element at a first node and coupled to a first reference potential." Claim 1 repeats the same language for a "second frequency down-conversion module."

295. I have reviewed claim 1, the specifications of the '474 patent and '551 patent and the prosecution history of the '474 patent.

296. In my opinion, the claim language is straightforward and should be given its plain and ordinary meaning. The language simply describes the structural connection/relationship between a switch, storage element, and reference potential (e.g., ground). A POSITA would not have any difficulty understanding the structural

connection/relationship between components set forth in the term.

297. I have reviewed the construction of the U.S. District Court for the Western District of Texas, which construed "the [] switch is coupled to the [] storage element at a [] node and coupled to a [] reference potential" as plain-and-ordinary meaning "wherein 'coupled' is directly connected or connected through ha conductor (or a closed switch)." Ex. 2021 at 4. It is my opinion that the District Court's construction is correct and accurately captures the meaning of the phrase as understood by a POSITA.

XIII. SECONDARY CONSIDERATIONS

A. Long-felt need.

298. In the late 1990s through March 2000, there was a long felt, but unresolved, need for direct down-conversion. Numerous companies in the industry were looking for ways to accomplish direct down-conversion. While heterodyning (non-linear mixing) solutions were being used in commercial products and other non-linear mixing and sample-and-hold (voltage sampling) solutions were being explored, such solutions had their own problems (e.g., high energy requirements and noisy) that made them poor solutions for commercial products. In the late 1990s through March 2000, there was a long-felt need for a solution for direct down-conversion.

299. Indeed, by the mid-2000s, with the rise in popularity of smartphones,

there was still a critical need for smaller, more efficient, higher-performance receivers capable of supporting multiple frequency bands and advanced communication protocols. The down-conversion technology – energy transfer (energy sampling) system – of claims 1, 3, 4, 7, and 9-11 of the ’474 patent addressed this need in ways (and providing benefits) that heterodyning solutions and sample-and-hold (voltage sampling) solutions could not.

B. Others tried and failed.

300. In the late 1990s through March 2000, others tried and failed to figure out a way to implement direct down-conversion in a commercially viable way. During this time, a number of different solutions were being used and/or explored by those in the industry such as heterodyning (non-linear mixing) and sample-and-hold (voltage sampling). *See* Exs. 2014, 2015, 2016, 2022. Heterodyning was commercially used but had problems (e.g., high energy requirements and noisy). After ParkerVision’s invention, heterodyning was ultimately abandoned in favor of energy sampling as set forth in claims 1, 3, 4, 7, and 9-11 of the ’474 patent. Other technologies including sample-and-hold (voltage sampling) were never widely implemented commercially (if they were implemented at all) because of problems with the technology (e.g., too much noise).

C. Unexpected results.

301. In the late 1990s through March 2000, superheterodyne receivers,

which used a decades-old RF technology called heterodyning, dominated the cellular/wireless industry for receiving and processing RF signals. During this time, heterodyning (non-linear mixing) was being used for direct down-conversion but there were significant problems with this technology. For example, heterodyning consumed too much battery power, was noisy and susceptible to interference (e.g., from other signals, channels, or users), and required expensive and bulky external components (i.e., components (e.g., filters) that device manufactures (e.g., cellular phone manufactures) must include in their device external to the RF chip).

302. In the late 1990s through March 2000, the radio (cellular/wireless) industry was looking to replicate the voltage of the RF signal and use that voltage to derive a baseband signal (which was a representation of the original baseband signal sent from the transmitting device). The industry was looking to sample-and-hold (voltage sampling) and mixing using nonlinear or time-varying elements to solve the direct down-conversion problem. Energy sampling was not being considered nor was it an obvious approach because energy sampling did not accurately replicate the voltage of an RF signal. As such, using energy sampling at that time was counter-intuitive and against the thinking in the radio (cellular/wireless) industry at the time.

303. Using energy sampling to down-convert (i.e, using a "*storage element*"), as set forth in claims 1, 3, 4, 7, and 9-11 of the '474 patent, had

unexpected results.

304. One unexpected result of energy sampling as set forth in claims 1, 3, 4, 7, and 9-11 of the '474 patent is that an energy sampling downconverter selects one channel from a band. In cellular communications there are multiple channels in a band. For example, a channel could be 1.4 MHz wide, but the band could be 10 MHz wide with multiple channels within a single band. One or several users occupy one channel. Whereas a conventional filter has fixed characteristics and allows all channels in a band to pass, the energy sampling downconverter is able to select just one channel in the band. Because of this, an energy sampling downconverter is able to achieve results that simply cannot be obtained any other way even if the cell phone manufacturer uses additional components.

305. Another unexpected result of energy sampling as set forth in claims 1, 3, 4, 7, and 9-11 of the '474 patent is that it overcomes issues with noise. With energy sampling, a downconverter can use nearly all of the available RF energy so that the level of the desired baseband signal is enhanced with respect to the noise. In this way, the desired signal stands out from the noise. Unknown prior to the invention of the '474 patent, this, in turn, improves RF receiver performance, lowers power consumption, allows for reduction/elimination of expensive and bulky external components (i.e., components (e.g., filters) that device manufactures (e.g., cellular

phone manufactures) must include in their device external to the RF chip), etc.

306. Yet another unexpected result of energy sampling as set forth in claims 1, 3, 4, 7, and 9-11 of the '474 patent is that down-conversion using energy sampling is surprisingly linear since the switch goes from one definite state, e.g., "ON", to a second definite state, e.g., OFF. Prior to ParkerVision's invention, the common understanding was that a switch was a nonlinear device. Without the superior linearity of ParkerVision's invention, it would not be possible to support the high linearity demands of advanced communication protocols in 4G and 5G.

307. In the late 1990s through March 2000, all of the advantages of using the energy transfer (energy sampling) system as set forth in claims 1, 3, 4, 7, and 9-11 of the '474 patent were unexpected by industry and academia. Unknown at this time by industry and academia was that, by using the energy transfer (energy sampling) system of claim 1 of the '474 patent, RF receivers could be built smaller, cheaper and with improved performance. Indeed, the use of energy sampling for down-conversion allowed manufactures to reduce and/or eliminate components in integrated circuits (and devices incorporating such circuits) (e.g., eliminate filters, reduce battery size, eliminate matching circuits, etc.) while simultaneously enabling high-performance communication protocols. Using the energy transfer (energy sampling) system of claim 1 of the '474 patent resulted in improved RF receiver performance, lower power consumption, reduced size of integrated circuits/devices,

reduction/elimination of expensive and bulky external components, etc.

D. Praise by others.

308. In the late 1990s, ParkerVision began meeting with companies such as Qualcomm, an industry leader in RF chip technology. Qualcomm quickly recognized the significance of ParkerVision's energy transfer (energy sampling) system as set forth in claims 1, 3, 4, 7, and 9-11 of the '474 patent. In internal communications, Qualcomm engineers and senior executives lauded ParkerVision's technology: "This is virtually the holy grail of RF receiver designs –- achievable and within practical limits!" (Ex. 2023); "[w]e are very impressed with the performance! We can make a phone with [ParkerVision's] parts with higher dynamic range than today's phones" and "[t]he truth is Parker Vision have [sic] stumbled on something revolutionary." Ex. 2024. After testing ParkerVision's technology, a Qualcomm senior executive and former engineer stated "[t]o tell you the truth, I am more of a believer now than when I started talking with [ParkerVision]" (Ex. 2025) and Qualcomm's then-division President stated "this is critical technology that we must land based on what we have seen so far. It offers revolutionary rf versus power performa[n]ce based on early te[s]t resul[t]s." Ex. 2026.

E. Copying and commercial success.

309. Sample-and-hold (voltage sampling) solutions never became the solution used for commercial products. And subsequent to March 2000,

heterodyning (non-linear mixing) was abandoned in favor of the energy sampling system as set forth in claims 1, 3, 4, 7, and 9-11of the ’474 patent. In particular, Qualcomm and others in the industry transitioned away from superheterodyne receivers and mixer technology and began to use the energy transfer (energy sampling) system set forth in claims 1, 3, 4, 7, and 9-11 of the ’474 patent. Today, energy transfer (energy sampling) systems as set forth in claim 1 of the ’474 patent have been adopted by nearly the entire industry. Companies have enjoyed great commercial and financial success by using the energy transfer (energy sampling) systems set forth in claims 1, 3, 4, 7, and 9-11 of the ’474 patent.

XIV. INTEL’S PRIOR ART REFERENCES

A. RF and Microwave Circuit Design for Wireless Communications,” by Lawrence E. Larson (“Larson”).

310. Larson (Ex. 1005) is an edited book and has a copyright date of 1997. Intel relies on Chapter 5 of Larson which was written by Stephen A. Maas.

311. As discussed above in Section VII.N, at this time, the radio industry was focused on heterodyning (e.g., non-linear mixing resulting in multiplication of an RF and LO) and sample-and-hold (voltage sampling) solutions for the down-conversion (including direct down-conversion) of RF signals.

312. Consistent with the direction of the industry in the late 1990s, Chapter 5 of Larson presents a review of the design and fabrication of RF and microwave *mixers*. The FET resistive mixers disclosed in Larson does not use a “switch” (i.e.,

an electronic device for opening and closing a circuit) as set forth in claims 1, 3, 4, 7 and 9-11 of the '474 patent. Nor is Larson an energy transfer system and, thus, does not disclose "*storage* elements" (a term *reserved* for elements of *an energy* transfer (*energy* sampling) system) as set forth in claims 1, 3, 4, 7 and 9-11 of the '474 patent.

313. Chapter 5 of Larson begins by discussing the properties of mixers. As discussed above in Section VII.N.2, the function of a mixer is to convert a signal received at one frequency to another frequency. As discussed in the excerpt below, "[a] mixer is fundamentally a multiplier. An ideal mixer multiplies a signal by a sinusoid, shifting it to both a higher and lower frequency, and selects one of the

resulting sidebands."

5.2.1 Frequency Mixing

A mixer is fundamentally a multiplier. An ideal mixer multiplies a signal by a sinusoid, shifting it to both a higher and lower frequency, and selects one of the resulting sidebands. A modulated narrowband signal, usually called the *RF signal*,[1] represented by

$$S_{RF}(t) = a(t)\sin(\omega_s t) + b(t)\cos(\omega_s t) \quad (5.1)$$

is multiplied by the function called the *local oscillator* (LO) signal

$$f_{LO}(t) = \cos(\omega_p t) \quad (5.2)$$

to obtain the *IF signal*[2]

$$\begin{aligned} S_{IF}(t) = {} & \frac{1}{2}a(t)(\sin((\omega_s + \omega_p)t) + \sin((\omega_s - \omega_p)t)) \\ & + \frac{1}{2}b(t)(\cos((\omega_s + \omega_p)t) + \cos((\omega_s - \omega_p)t)) \end{aligned} \quad (5.3)$$

[1]RF was originally an abbreviation for radio frequency. Like many technical abbreviations and acronyms (e.g., radar, laser, FET), the term has evolved into a word in itself, and has lost most of its original meaning. Thus, we regularly use terms like RF frequency to distinguish from RF port, RF voltage, etc. Some of these terms may seem redundant or illogical to grammatical bluestockings who insist that RF have only its original meaning. For better or worse, language evolves; this is an example.

[2]IF originally meant intermediate frequency. The above footnote applies here as well.

Ex. 1005 at 226.

314. In particular, as set forth above, a modulated carrier signal (RF signal) is multiplied by a component referred to as the local oscillator (LO) signal to obtain the intermediate frequency signal. *Id*.

315. In an ideal mixer, two sinusoidal IF components, referred to as "mixing products," result from each sinusoid (sin) and co-sinusoid (cos) in s(t). The mixer mixes the RF signal having a frequency f_{RF} and the LO signal having a frequency f_{LO} to produce an IF signal having frequencies at $f_{RF} - f_{LO}$ and $f_{RF} + f_{LO}$. In receivers, the difference-frequency component is usually desired, and the sum-frequency

component is rejected by filters.

316. As shown below, Section 5.7.2 of Larson describes a type of mixer referred to as a balanced FET *resistive* mixer.

5.7.2 Balanced FET Resistive Mixers

Balanced FET resistive mixers have essentially the same advantages mixers as balanced diode or active-FET mixers: inherent port isolation, rejection of AM LO noise, and rejection of certain spurious responses and IM products. Figure 5.36 shows a singly balanced FET resistive mixer. At low frequencies, the LO balun can be realized by a transformer, as shown; at higher frequencies, a 180-deg transmission line or one of the structures in Figures 5.16 to 5.19 could be used. The LO pumps the two FETs 180-deg out of phase, but the RF is applied in phase at the drains. The IF currents in the FETs' channels therefore have a 180-deg phase difference, and an output hybrid or balun is necessary to subtract them. Of course, the two FETs generally require twice the LO power of a single FET, and have 3-dB greater IM intercept points. The mixer rejects all (2, 2) and (1, 2) spurious responses; (2, 1) responses are not rejected.

As with other types of gate-driven FET mixers, the LO input impedance at low frequencies is virtually an open circuit, and is thus almost impossible to match.

Ex. 1005 at 276.

317. In Section 5.7.2, Larson shows a configuration of a balanced FET *resistive* mixer in Figure 5.36 (below). *See id.* Intel relies on the circuit of Figure 5.36 to invalidate the claims of the ’474 patent.

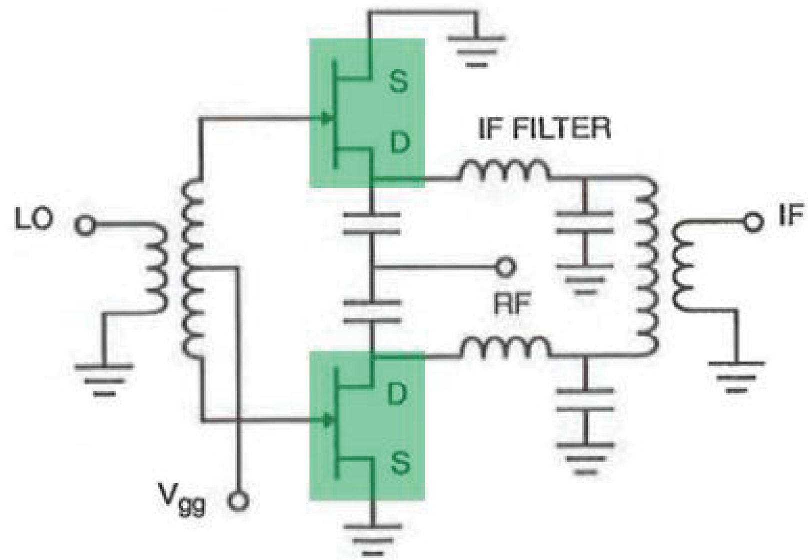


Figure 5.36 Singly balanced FET resistive mixer. The RF connection is a virtual ground for both the LO and the IF.

318. As shown below, the FETs of the FET *resistive* mixer is shown in green. Notably and highly relevant to the validity analysis, as shown below, Larson discloses that that a "FET *resistive* mixer" (such as the mixer in Figure 5.36 of Larson above) uses "time-varying channel resistance" and "operates *entirely in its linear region*, where the channel is effectively a gate-voltage-controlled resistor."

5.7 PASSIVE FET MIXERS

Passive FET mixers, often called *FET resistive mixers*, are used frequently in wireless applications. They have a number of advantages over diode and active FET mixers.

In a FET resistive mixer, the time-varying channel resistance is used for frequency conversion. The LO is applied to the gate, but no dc bias is applied to the channel (the gate may be dc biased, usually near pinchoff). The FET then operates entirely in its linear region, where the channel is effectively a gate-voltage-controlled resistor. The RF signal is applied to the drain, and IF currents are filtered from the drain or source.

Ex. 1005 at 273-274. As the name implies, a POSITA would understand this passage to mean that in a FET *resistive* mixer, the FETs are working in the linear (triode) region and, thus, are operating and being used as continuous time-varying *resistors*. *See* Section VIII.A and VIII.B.2 above. The FETs are *not* operating or being used as switches. In other words, the FETs do *not* opening and closing.

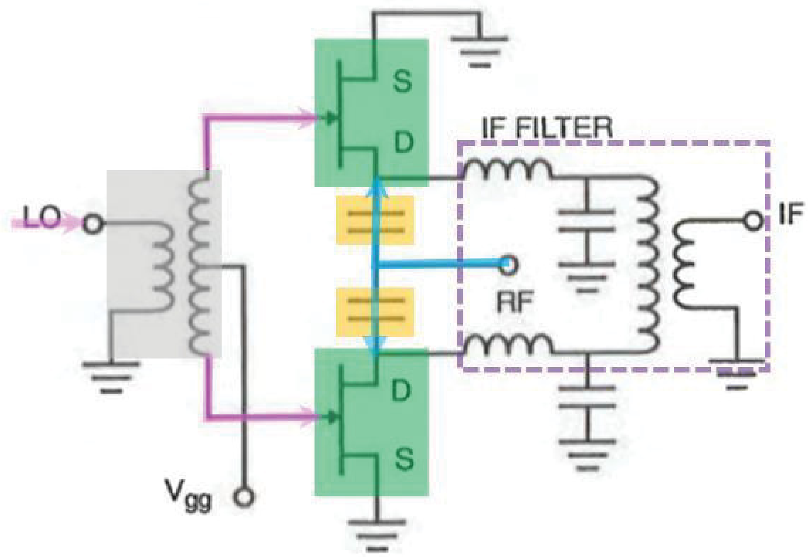


Figure 5.36 Singly balanced FET resistive mixer. The RF connection is a virtual ground for both the LO and the IF.

319. The FET resistive mixer of Figure 5.36 includes an LO connection, a transformer (gray), FETs (green), capacitors (orange) and an output circuit (dashed purple box).

320. The LO signal (pink arrows) is sent to the gate (G) of the FETs (green) through transformer (gray). The RF signal (blue arrows) is sent from the RF connection to the drains (D) of the FETs (green) through the capacitors (orange).

The capacitors (orange) allow the RF signal to pass to the FETs.

321. Given that Larson states that a FET resistive mixer uses "time-varying channel resistance" and "operates *entirely in its linear region*, where the channel is effectively a gate-voltage-controlled resistor," the LO signal will be a sinusoidal signal, which will cause the FETs to act and operate as gate-voltage-controlled *resistors* i.e., continuous sinusoidal time-varying *resistors*. In other words, the FETs are ***not*** operating or being used as switches i.e., the FETs are not opening and closing.

322. The above statement is consistent with how a POSITA would understand the RF resistive mixer to work. In particular, the LO signal (pink arrows) is applied to the gates G of the FETs (green) 180-degrees out of phase. Larson discloses "[a]t low frequencies, the LO balun can be realized by a transformer, as shown; at higher frequencies, a 180-deg transmission line [hybrid] … could be used." Ex. 1005 at 276. Since 180-degree transmission line hybrid is a narrow band element, the hybrid will only let a sinusoidal signal through. Thus, Larson is describing that the controlling voltage at the gates of the FETs is a sinusoid (i.e., it is not a pulse).

323. The continuous resistance variation of the FETs resulting from receiving a sinusoidal LO signal will cause the FETs to down-convert the RF signal to an IF signal.

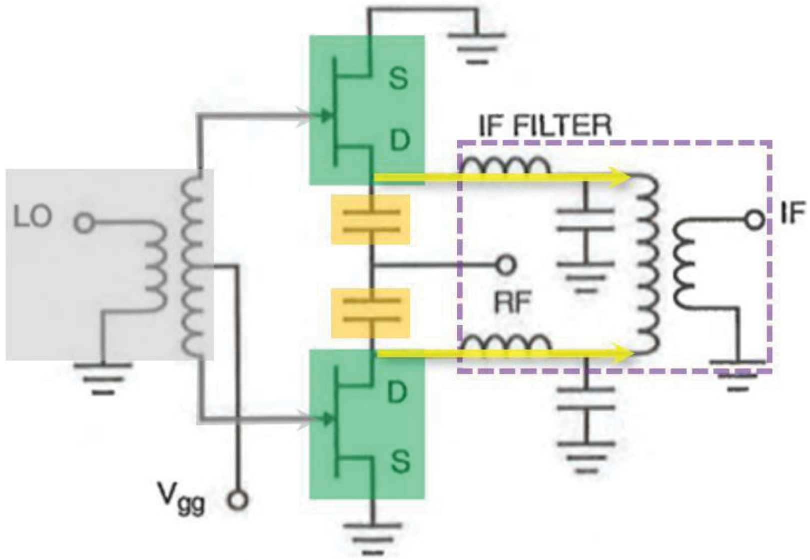


Figure 5.36 Singly balanced FET resistive mixer. The RF connection is a virtual ground for both the LO and the IF.

324. The IF signal leaves the drains (D) of the FETs. The capacitors (orange) prevent/block the IF signal from passing from the drain (D) of the FETs towards the RF connection. As such, as shown above, the IF signal (yellow arrows) is sent towards the output circuit (dashed purple box).

325. I note that the capacitors (orange) essentially act as one-way valves – allowing the RF signals to pass in one direction but not allowing the IF signals to pass in the other direction. In particular, the capacitors (orange) allow the RF signal to pass from the RF connection to the FETs but prevent/block the IF signal from passing from the FET to the RF connection. I note that the capacitors (orange) are not elements of an energy transfer system because the capacitors do not store energy

which forms the down-converted signal.

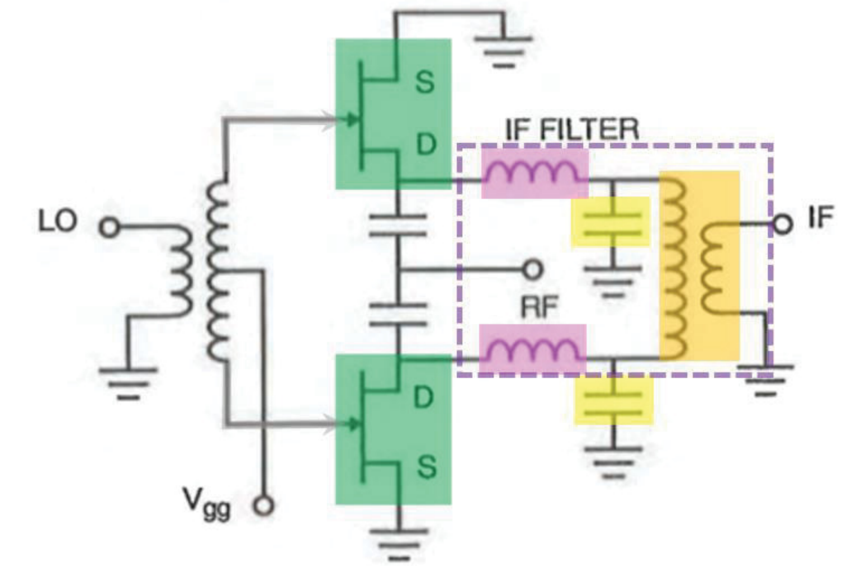


Figure 5.36 Singly balanced FET resistive mixer. The RF connection is a virtual ground for both the LO and the IF.

326. As shown above, a POSITA would understand that the output circuit (dashed purple box) includes the inductors (pink), capacitors (yellow), and a common 2:1 transformer (orange). The transformer (orange) combines the IF signals. A POSITA would understand that the elements of the output circuit interact with each other and cannot be considered independently or in isolation.

327. Figure 5.36 includes the term "IF FILTER." A POSITA would understand that the interacting elements of the output circuit work together to provide the IF FILTER.

328. When the interacting elements of the output circuit are considered together, the output circuit does not pass DC. For example, the input of the

transformer (orange) is a short circuit at 0 Hz. Thus, the capacitor (yellow) is shorted out at DC. As such, while the output circuit will filter signals, the output circuit is not a low pass filter.

B. U.S. Patent No. 4,603,436 ("Butler")

329. Butler (Ex. 1006) was filed on August 20, 1984. Butler discloses a microwave mixer and, more particularly, a double balanced mixer for frequency conversion. Figure 1 of Butler (shown below) illustrates a circuit diagram of a microwave mixer.

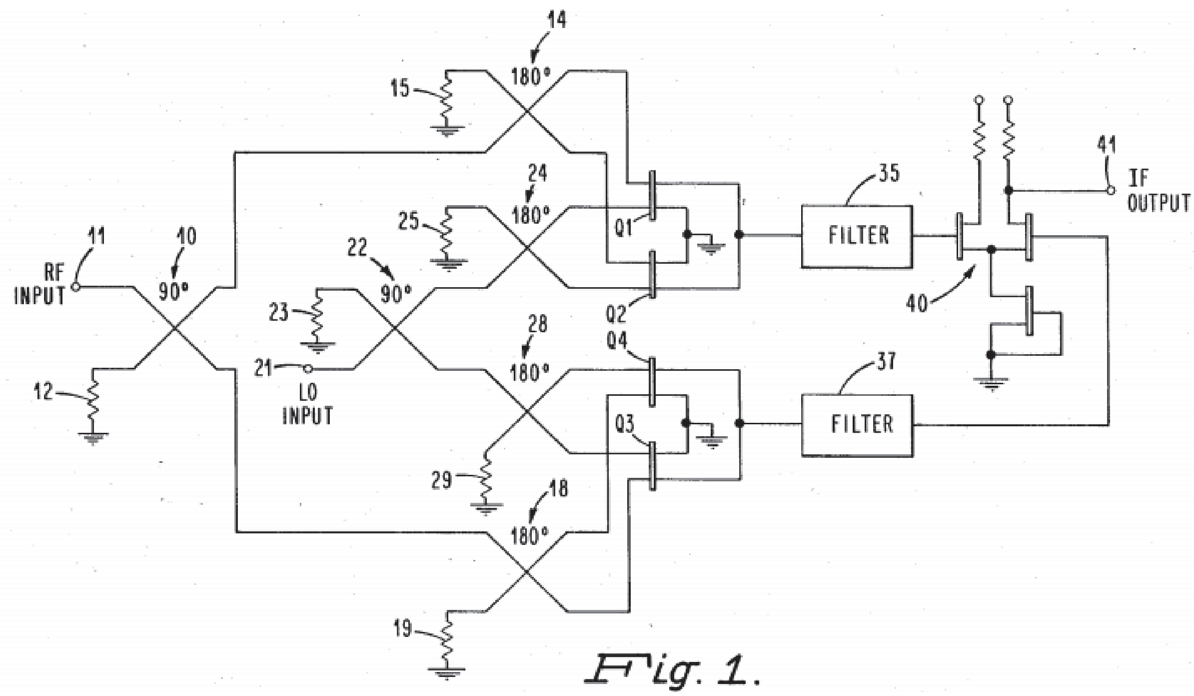


Fig. 1.

330. The mixer includes a first and second quadrature coupler 10, 22 connected to RF input terminal 11 and local oscillator input terminal 21, respectively. The quadrature couplers 10, 22 are connected to antiphase power

dividers 14, 18, 24, 28.

331. The mixer also includes four dual-gate field effect transistors (FET's) Q1, Q2, Q3, and Q4. Ex. 1006 at 5:34-35. The first output of the first antiphase power divider 14 is connected to the first gate of FET Q1, and the second output is connected to the first gate of FET Q2. *Id.* at 5:36-39. The first output of the second antiphase power divider 18 is connected to the first gate of FET Q3, and the second output is connected to the first gate of FET Q4. *Id.* at 39-42. The connections of the signal distribution networks to the FETs are such that the RF signals appearing at the first gates may be expressed as: FET Q1: A cos $(\omega_{RF}t-\pi/4)$; FET Q2: A cos $(\omega_{RF}t+\pi/4)$; FET Q3: A cos $(\omega_{RF}t-\pi/2)$; FET Q4: A cos $(\omega_{RF}t)$. *Id.* at 42-48. Here, ω is called the radian frequency and is equal to 2π times the frequency in hertz.

332. Similarly, the first output of the third antiphase power divider 24 is connected to the second gate of FET Q1, and the second output is connected to the second gate of FET Q2. *Id.* at 5:49-52. The first output of the fourth antiphase power divider 28 is connected to the second gate of FET Q3, and the second output is connected to the second gate of FET Q4. *Id.* at 5:52-55. The connections of the signal distribution networks are such that the resultant local oscillator (LO) signals appearing at the second gates of the FET's may be expressed as: FET Q1: B cos $(\omega_{LO}t)$; FET Q2: B cos $(\omega_{LO}t-\pi/2)$; FET Q3: B cos $(\omega_{LO}t+\pi/4)$; FET Q4: B cos $(\omega_{LO}t-$

$\pi/4$). *Id.* at 5:55-62. That is, the LO is a sinusoidal signal and not a pulse.

333. The mixing action performed by each of the dual-gate FETs produces an intermediate frequency (IF) such that $\omega_{IF} = \pm (\omega_{RF} - \omega_{LO})$. *Id.* at 5:63-65. Accordingly, the IF signals appearing at the drains of the FETs may be expressed as: FET Q1: C cos ($\omega_{IF}t\pm\pi/4$); FET Q2: C cos ($\omega_{IF}t\pm\pi/4$); FET Q3: C cos ($\omega_{IF}t\pm3\pi/4$); FET Q4: C cos (ω_{IF} $t\pm3\pi/4$). *Id.* at 5:65-68.

334. The drains of FETs Q1 and Q2 are connected together and to the input of a low pass filter 35. *Id.* at 6:3-4. Similarly, the drains of FETs Q3 and Q4 are connected together and to the input of a second low pass filter 37. *Id.* at 6:4-6. The outputs of the low pass filters 35 and 37 may be applied to the two input connections of a differential amplifier 40. The differential amplifier 40 functions as an antiphase power combiner which also provides gain resulting in a single unbalanced IF output signal at an IF output terminal 41.

XV. VALIDITY OF THE '474 PATENT

A. Larson does not anticipate claims 1, 3, 4, 7, and 9-11.

1. Larson does not disclose a "switch."

335. Claims 1, 3, 4, 7, and 9-11 recite a "switch." As set forth in Section XII.A above, the proper construction of "switch" is "an *electronic device for* <u>*opening and closing*</u> *a circuit* as dictated by an independent control input."

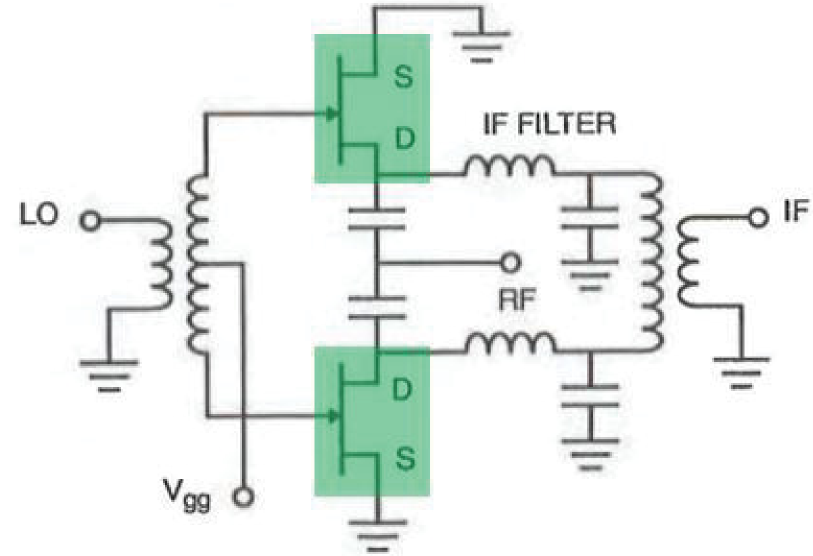


Figure 5.36 Singly balanced FET resistive mixer. The RF connection is a virtual ground for both the LO and the IF.

336. As shown above, Intel identifies the FETs (green) of Figure 5.36 of Larson as "switches." Intel is wrong.

337. As set forth in Section XIV.A above, Figure 5.36 discloses a singly balanced FET resistive mixer. As set forth in Section VIII.B.2 above, the FETs in a FET resistive mixer are operating as continuous time-varying *resistors*. Each FET is *not* a *switch* nor is it operating as a switch i.e., the FETs are not *opening and closing* a circuit. As such, neither of the FETs in Larson is "an *electronic device for opening and closing a circuit* as dictated by an independent control input."

338. There is no teaching, suggestion, or motivation in Larson to use a FET as a switch for down-conversion nor would it have been obvious or inherent to a POSITA to modify the FETs in Larson (which operate as continuous time-varying

resistors) to operate as a *completely different* device – a switch. Indeed, since Larson pertains to mixer technology and, in particular, a FET resistive mixer (which does not involve sampling), a POSITA would not see any reason or be motivated to use a FET as a switch. *See* Section VIII.N.4. Indeed, mixing and sampling are *fundamentally different and competing* technologies. Moreover, Larson specifically discusses mixers using FETs as continuous time-varying resistors and makes no mention or suggestion of using a FET as a switch. Indeed, if the FETs in Larson was modified to be switches, there would be more LO harmonics and undesired signals so that the performance of the circuit is Larson would be further compromised.

339. As such, to get the invention of the ’474 patent using Larson, one would have to ignore all of the disclosure in Larson, abandon all of the teachings and suggestions of Larson, and ignore that *mixing* was the state-of-the-art for down-conversion at the time of the invention of the ’474 patent. In other words, one would have to use hindsight (knowledge of the ’474 patent) to modify Larson to arrive at the claimed invention of claims 1, 3, 4, 7, and 9-11. In addition, the secondary considerations set forth in Section XIII above demonstrate that the invention of claims 1, 3, 4, 7, and 9-11 of the ’474 patent are not obvious or inherent in view of Larson.

2. Larson does not disclose a “storage element.”

340. Claims 1, 3, 4, 7, and 9-11 recites a “storage element.” As set forth in

Section XI.B, the term "storage element" is *reserved* by the '474 patent for an element of an *energy transfer* (*energy* sampling) systems. As set forth in Section XII.B above, the proper construction of "storage element" is "an element of an *energy transfer system* that stores non-negligible amounts of energy from an input electromagnetic signal."

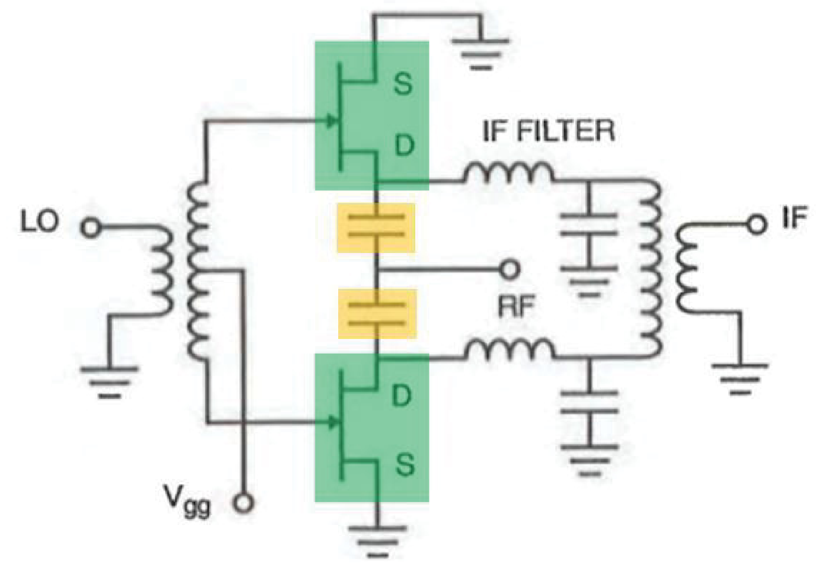


Figure 5.36 Singly balanced FET resistive mixer. The RF connection is a virtual ground for both the LO and the IF.

341. As shown above, Intel identifies the capacitors (orange) of Figure 5.36 of Larson as the "storage elements." Intel is wrong.

342. As discussed in Section XIV.A above, the capacitors (orange) merely operate to allow the RF signal to pass from the RF connection to the FETs but prevent/block the IF signal from passing from the FET to the RF connection. The capacitors, however, do not store energy which forms the down-converted signal as

is done in an energy transfer system. As such, for this reason alone, the capacitors are not elements of an energy transfer system.

343. As set forth in Section XIV.A above, Larson discloses a *mixing* system. The operation of an energy sampling system is *fundamentally different* than the operation of a mixer/mixing system. As discussed in Section VII.N.2 above, the mixer forms a down-converted signal by mixing two signals (an RF signal and an LO signal) together. As discussed in Section VII.N.4 above, an energy transfer system, on the other hand, uses *sampled* energy from the RF signal to form a down-converted signal.

344. There is no teaching, suggestion, or motivation to Larson to use *sampled* energy from the RF signal to form a down-converted signal as is done in an energy transfer system. Indeed, as discussed above in Section XI.A, all teaching, suggestion, and motivation in Larson demonstrates that Larson only relates to a *mixing* system, which mixes two signals together. As such, none of the capacitors in Larson is an "element of an *<u>energy transfer</u> system* that stores non-negligible amounts of energy from an input electromagnetic signal."

345. Moreover, it would not have been obvious or inherent to a POSITA to use Larson as an energy transfer system. Larson specifically discusses mixing and makes no mention or suggestion of using an energy sampling solution. There is no teaching, suggestion, or motivation in Larson to use energy sampling to down-

convert a signal. Indeed, mixing and energy sampling systems are *fundamentally different and competing* technologies.

346. As such, to get to the invention of the ’474 patent using Larson, one would have to ignore all of the disclosure in Larson, abandon all of the teachings and suggestions of Larson, and ignore that *mixing* was the state-of-the-art for down-conversion at the time of the invention of the ’474 patent. In other words, one would have to use hindsight (knowledge of the ’474 patent) to modify Larson to use *energy* sampling and, thus, a “storage” element to get to the claimed invention of claims 1, 3, 4, 7, and 9-11. In addition, the secondary considerations set forth in Section XIII above demonstrate that the invention of claims 1, 3, 4, 7, and 9-11 of the ’474 patent was not obvious or inherent in view of Larson.

347. For the foregoing reasons in Sections XV.A.1 and 2, Larson does not anticipate claims 1, 3, 4, 7, and 9-11 of the ’474 patent.

B. Larson does not anticipate claim 7.

348. Claim 7 recites down-converting an input signal according to a first and second control signal where “the first control signal comprises a first *pulse*; and the second control signal comprises a second *pulse*.” As set forth in Section XIV.A above, Larson uses a sinusoidal signal, *not* a pulse signal.

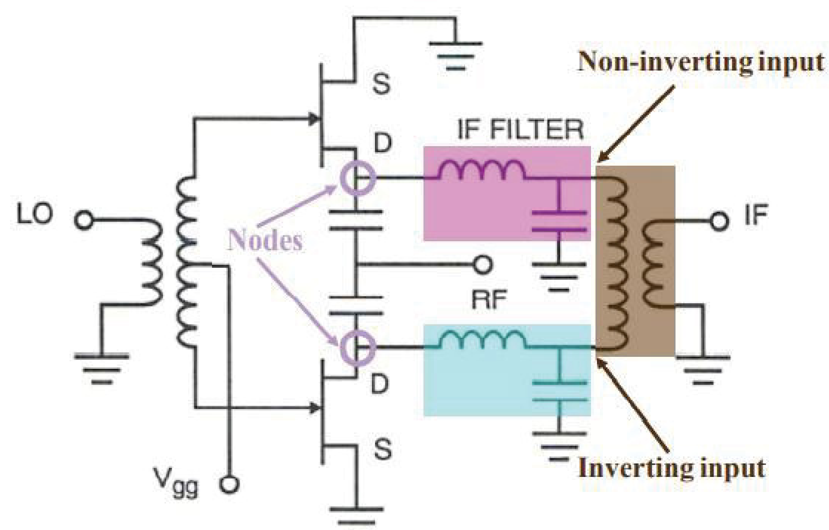
349. For the same reason discussed in Section XV.A.1 with regard to a switch, there is no teaching, suggestion, or motivation in Larson to use a pulse signal

with the FETs nor would it have been obvious or inherent to a POSITA to modify Larson to use a pulse signal. Indeed, a POSITA would understand that using a pulse signal would cause the FETs of Larson to operate in a completely different manner than disclosed in Larson and there would be no reason to do so.

350. For this additional reason, Larson does not anticipate claim 7 of the ’474 patent.

C. Larson does not anticipate claims 11.

351. Claim 11 discloses a first and second filter where “the first filter comprises a first *low pass* filter; and so the second filter comprises a second *low pass* filter.” As set forth in Section XIV.A above, the transformer in the output circuit of Larson presents a short circuit at DC and, thus, the output circuit is not a *low pass* filter.



352. As shown above (which is an annotated diagram prepared by Dr.

Subramanian (*see* Ex. 1002 ¶143), Dr. Subramanian identifies two low pass filters (a) the inductor and capacitor in the pink area and (b) the inductor and capacitor in the blue area. Ex. 1002 ¶¶146-149. I disagree with Dr. Subramanian's analysis.

353. In particular, in his analysis, Dr. Subramanian fails to take into account the effect that transformer (shown in brown above) will have on the other components of the output circuit. In particular, at DC, the transformer will short out the capacitors and, thus, the filters identified by Dr. Subramanian are not low pass filters.

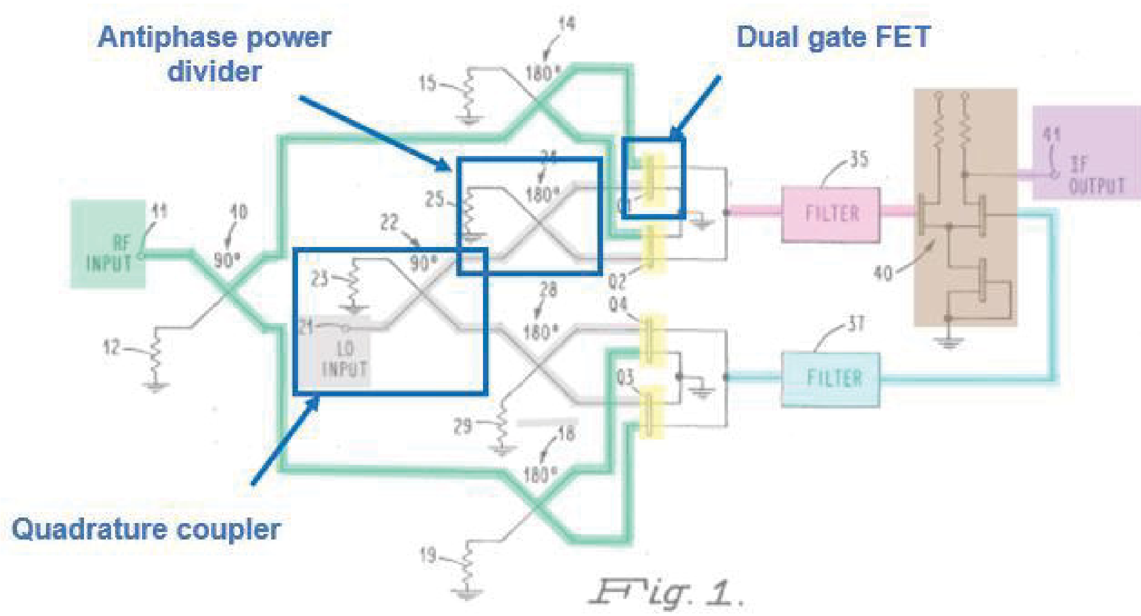
354. For this additional reason, Larson does not anticipate claim 11 of the '474 patent.

D. Butler does not resolve the deficiencies with Larson.

355. Butler does not change my analysis set forth above with regard to Larson. Indeed, Butler also discloses the use of nonlinear mixing technology for frequency down-conversion. In particular, Butler discloses the use of dual-gate FETs and, thus, similar to Larson, Butler is using a continuous time-varying resistors to achieve mixing. Indeed, Larson explains that dual-gate FETs (as disclosed in Butler) operate as continuous time-varying resistors in a mixer. Ex. 1005 at 269 ("The operation of a dual-gate mixer … the FET provides mixing by a combination of time-varying transconductance and drain-source resistance."). The combination of Larson and Butler does not resolve the deficiencies of Larson. As such, the

combination does not change the fundamental nature of Larson as a FET resistive mixer, which uses FETs as continuous time-varying resistors and does not have storage elements.

356. Dr. Subramanian asserts that the transistors in Butler are used as switches. Ex. 1002 ¶¶91-92. Dr. Subramanian is wrong.



357. As shown above (which is an annotated diagram prepared by Dr. Subramanian (*see id.* at ¶90), Dr. Subramanian identifies the dual gate FETs as switches. I have added annotations in dark blue to explain why Dr. Subramanian is wrong.

358. In Butler, the quadrature coupler and the antiphase power divider are transmission line structures and, thus, they are narrow band elements. A transmission

line in a quadrature coupler will only be 90 degrees long, i.e., a quarter-wavelength long, at exactly one center frequency. It only approximates being 90 degrees long for a narrow range of frequencies, e.g., 10%, around that center frequency. The same is true for an antiphase power divider. A pulse, which contains a fundamental frequency component and its harmonics, will not be able to travel through a quadrature coupler nor an antiphase power divider as disclosed in Butler. In view of the foregoing, the quadrature coupler and antiphase power divider as disclosed in Butler only pass sinusoidal LO signals. Thus, the LO signals presented to the dual gate FETs are sinusoids. Accordingly, Butler is describing a circuit with a sinusoidal LO and not an LO that is a pulse.

359. Furthermore, Butler explicitly shows that the LO signal presented to the FETs are sinusoids, not pulses.

> (LO) signals appearing at the second gates of the FET's may be expressed as:
> FET Q1: B cos (ω_{LO}t)
> FET Q2: B cos (ω_{LO}t$-\pi/2$)
> FET Q3: B cos (ω_{LO}t$+\pi/4$)
> FET Q4: B cos (ω_{LO}t$-\pi/4$)

Ex. 1006 at 5:57-62.

360. A POSITA would not be motivated to combine Butler with Larson because Larson specifically states that mixers with dual-gate FETs (such as disclosed in Butler) are "inferior." Ex. 1005 at 269 ("the dual-gate FET mixer is

inferior in terms of conversion gain and noise fi

mixer.").

361. Moreover, while the output circuit

pass filters, unlike Larson, Butler does not incorp

disclosure of Larson and Butler, it would not be o

output circuit of Larson to use the differential

transformer of Larson. Such modifications would

Moreover, there is no teaching, suggestion, or mo

to do so. For the foregoing reasons, the claims 1,

are not obvious in view of the combination of La

XVI. SUPPLEMENTATION

362. I reserve the right to supplemen

APPENDIX A

Michael B. Steer

Curriculum Vitae
August 7, 2020

Michael Steer is the Lampe Distinguished Professor of Electrical and Computer Engineering at North Carolina State University (NC State). He received his B.E. and Ph.D. in Electrical Engineering from the University of Queensland, Brisbane, Australia, in 1976 and 1983 respectively. Professor Steer is a Fellow of the Institute of Electrical and Electronic Engineers cited for contributions to the computer aided engineering of non-linear microwave and millimeter-wave circuits. In 1999 and 2000 he was Professor and Director of the Institute of Microwaves and Photonics at the University of Leeds where he held the Chair in Microwave and Millimeterwave Electronics. He has authored more than 500 publications on topics related to antenna arrays, electromagnetic fields, circuit-electromagnetic field interactions, circuit-electromagnetic-acoustic interactions, microwave and millimeter-wave systems; nonlinear RF effects; RF, analog and digital behavioral modeling; RF circuit simulation; high-speed digital design; and RF/microwave design methodology. He has authored three books *Microwave and RF Design: A Systems Approach*, SciTech, 2010; *Foundations of Interconnect and Microstrip Design*, John Wiley, 2000 (with T.C. Edwards); *Multifunctional Adaptive Microwave Circuits and Systems*, SciTech, 2009 (with W. D. Palmer). He is a 1987 Presidential Young Investigator (USA) and was awarded the *Bronze Medallion* by U.S. Army Research for "Outstanding Scientific Accomplishment" in 1994 and 1996. He received the Alcoa Foundation Distinguished Research Award in 2003 from the College of Engineering at NC State for distinguished research accomplishment. He also received the RJ Reynolds Award for Excellence in Teaching Research and Extension from the College of Engineering in 2013, and the Alexander Quarles Holladay Medal for Excellence in 2017, all from North Carolina State University. The Holladay Medal is the highest honor bestowed on a faculty member by NC State. He was the 2003 Jack S. Kilby Lecturer.

He served as a member of the Administrative Committee of the IEEE Microwave Theory and Techniques (MTT) Society (1998–2000, 2003–2006, 2016–2018), as Secretary of the Society (1997), as Associate Editor of the IEEE Microwave Magazine (1999–2000), and as Editor-In-Chief of the society's flagship publication the *IEEE Transactions on Microwave Theory and Techniques* (2003–2006). He received Service Recognition Awards from the IEEE Microwave Theory and Techniques Society in 1998 and in 2001, and a Distinguished Service Award from the Society in 2007.

In 2009 he received a U.S. Army medal, the "Commander's Award For Public Service," awarded to a private citizen from the Commanding General of the U.S. Army Research, Development and Engineering Command (RDECOM). Citation: "For outstanding public service during the period September 2002 through December 2009 as Principal Investigator on U.S. Army basic research initiatives directed at countering improvised explosive devices. During this time, Prof. Steer led innovative theoretical and experimental research programs, developed and sustained strong working relationships with Army scientists and engineers, and aggressively transitioned research breakthroughs into important electronic warfare applications in support of the warfighter."

He received the 2010 Microwave Prize from the IEEE Microwave Theory and Techniques Society. Citation: for a significant contribution to the field of endeavor of the IEEE MTT Society in the paper entitled "Electro-Thermal Theory of Intermodulation Distortion in Lossy Microwave Components," IEEE Transactions on Microwave Theory and Techniques, Vol. 56, No. 12, December 2008. The work showed that the underlying limit to the performance of communication systems is signal distortion resulting from electro-thermal effects. The performance of communication systems, as well as of high power radar systems, can be improved through appropriate measures to remove heat, and by the choice of materials with particular thermal characteristics. The Microwave Prize recognizes the authors of the most significant paper on microwave engineering published in the preceding year in any IEEE publication. In 2011 he received the Distinguished Educator Award from the IEEE Microwave Theory and Techniques Society, and was inducted into the Electronic Warfare Technology Hall of Fame (sponsored by the Association of Old Crows). Also in 2011 he was named one of the Most Creative Teachers in the South by Oxford American Magazine.

In 2010 he was promoted to the rank of Distinguished Professor at North Carolina State University and is now the Lampe Distinguished Professor with an endowment from the Lampe Family.

He has lead three large Multidisciplinary University Research Initiatives; MARRS: Multifunctional Adaptive Radio Radar and Sensors, 2002–2007; SIAMES: Standoff Inverse Analysis and Manipulation of Electronic Systems, 2005–2011; and SEMIWAVE: Sound and Electromagnetic Interacting Waves, 2010–2015. He has been the principal investigator of projects funded at $35.7M. He has conducted large research programs in antenna arrays, multifunctional systems, electromagnetic theory, applied electromagnetics, circuit design, and multifunctional microwave circuits and systems. He has taught courses in electromagnetic fields, transmission lines and antennas for wireless, electronic circuits, RF and microwave circuit and system design, cellular radio design, and computer aided design.

Dr. Steer is principal investigator of Department of Defense research projects related to new radio architectures, antenna arrays, adaptive circuits, electronic warfare (counter-IED technologies), and acoustic and electromagnetic remote sensing. He has worked on projects with industry, the Army Research Office, JIEDDO (the Joint Improvised Device Defeat Organization), the Army Research Laboratory, the Office of Naval Research, the Air Force Research Laboratory, AMC-FAST (Army Materiel Command, Field Assistance in Science and Technology), Army V (fifth) Corps, I2WD (Information and Intelligence Warfare Directorate, a Directorate of CERDEC, the U.S. Army Research, Development and Engineering Command), CIA, SPAWAR San Diego (Space and Naval Warfare Systems Command), Naval EOD Tech Div (The Naval Explosive Ordnance Disposal Technology Division, a division of NAVSEA, the Naval Sea Systems Command), and NRL, the Naval Research Laboratory.

APPENDIX A

Michael B. Steer

BRIEF RESUME

1. Education background:

- University of Queensland, Australia - 1983, PhD in Electrical Engineering
- University of Queensland, Australia - 1976, BE in Electrical Engineering

2. Professional experience:

2010 - now	Lampe Distinguished Professor
1983 - 2010	Lampe Professor of Electrical and Computer Engineering North Carolina State University, Department of Electrical and Computer Engineering, Raleigh, North Carolina, USA, NC 27695-7911. (2005–2010) Professor: North Carolina State University, (1996–2005) Associate Professor: North Carolina State University. (1991 - 1996) Assistant Professor: North Carolina State University. (1986 - 1991) Visiting Assistant Professor: North Carolina State University (1983 - 1986)
1999 - 2000	Professor, Chair of Microwave and Millimeterwave Electronics Director of the Institute of Microwaves and Photonics School of Electronic and Electrical Engineering, University of Leeds, United Kingdom.

2. Scholarly and creative activities:

Area	**Cumulative**
Books	12
Book Chapters	24
Refereed Publications	512
Refereed Journal Papers	175
Refereed Conference Papers	301

4. Membership in professional organizations:

IEEE, Fellow, 1976 to present.
Association of Old Crows, Member, 2010 to present

5. Scholarly and Professional Honors:

1. Alexander Quarles Holladay Medal for Excellence 2017, the highest award made by North Carolina State University in recognition of faculty career achievement, 2017.
2. R.J. Reynolds Tobacco Company Award for Excellence in Teaching, Research, and Extension, College of Engineering, NC State University, 2013.
3. Named one of the “Most Creative Teachers in the South” by Oxford American Magazine, September 2011.
4. Inducted into the Electronic Warfare Technology Hall of Fame (sponsored by the Association of Old Crows), 2011
5. 2011 Distinguished Educator of the IEEE Microwave Theory and Techniques Society
6. Distinguished Professor, 2010.
7. Certificate of Appreciation for Distinguished Service to his College, University and Nation, College of Engineering, North Carolina State University, 2010.
8. 2010 Microwave Prize from the IEEE Microwave Theory and Techniques Society. Citation: for a significant contribution to the field of endeavor of the IEEE MTT Society in the paper entitled “Electro-Thermal Theory of Intermodulation Distortion in Lossy Microwave Components,” IEEE Transactions on Microwave Theory and Techniques, Vol. 56, No. 12, December 2008, pages 2717-2725.
9. US Army Research, Development and Engineering Command (RDECOM), December 2009. Citation: “For outstanding public service during the period September 2002 through December 2009 as Principal Investigator on U.S. Army basic research initiatives directed at countering improvised explosive devices. During this time, Prof. Steer led innovative theoretical and experimental research programs, developed and sustained strong working relationships with Army scientists and engineers, and aggressively transitioned research breakthroughs into important electronic warfare applications in support of the warfighter.”
10. Best Paper Award, Government Microelectronics and Technology Conference, 2009, for paper presented in 2008.
11. Distinguished Service Recognition Award, IEEE Microwave Theory and Techniques Society, 2007.
12. Named Professor, North Carolina State University, 2005.
13. Alcoa Foundation Distinguished Research Award, North Carolina State University, 2003.
14. Jack S. Kilby Lecturer, Government Microelectroniocs and Applications Conference, 2003
15. Fellow, Institute of Electrical and Electronic Engineers, 1999. Citation: `For contributions to the computer aided engineering of non-linear microwave and millimeter-wave circuits.'
16. Service Recognition Award from the IEEE Microwave Theory and Techniques Society in 1998 and in 2001.
17. Bronze Medallion awarded by U.S. Army Research for `Outstanding Scientific Accomplishment,' 1996.
18. Bronze Medallion awarded by U.S. Army Research for `Outstanding Scientific Accomplishment,' 1994
19. Presidential Young Investigator Award, 1987.
20. Commonwealth Postgraduate Research Award (Australia), 1977.

6. Professional service on campus:

Member, University Research Committee, 2005 to 2017
Member, Peer Review of Teaching Committee, ECE Department, 2016–present
Member, Awards Committee, ECE Department, 2016–present
Member, College of Engineering Research Committee, 2005 to 2017
Member, University Bookstore Committee, 2015 to 2016
Faculty Senator, North Carolina State University, 2014 to 2016
Chair, North Carolina State University Defense Application Group, 2011 to 2013
Member, University of North Carolina Defense Application Group, 2011 to 2015
Member, ECE Reappointment Promotion and Tenure Committee, 2012 to 2013.
Member, ECE Post Tenure Review Committee, 2012 to 2013.
Member, North Carolina State University Defense Interactions Committee, 2012
Member ECE Course and Curriculum Committee, 2011.
Member ECE Faculty Search Committee, 2011
Chair, College of Engineering Research Committee, 2009–2016
Member, ECE Post Tenure Review Committee, 2008 to 2010, 2012–2013
Chair, University Research Committee, 2007–2008
Chair, ECE Post Tenure Review Committee, 2007 to 2008
Member, Chancellor's Faculty Team Preparing NC State's Response to UNC-tomorrow. 2007–2008
Member, Alumni Distinguished Research Award Selection Panel, 2007–2008
Member of Selection Panel for College of Engineering Faculty Research and Professional Development Individual Award, 2007–2008
Member, Awards committee selecting Alcoa Foundation Distinguished Research Award, 2007–2008
Member, Awards committee selecting Alcoa Foundation Research Achievement Award, 2007–2008
Member College of Engineering Research Committee, Member 2005–2009
ECE Post-Tenure Review Committee, Chair, 2006–2008.
University Research Committee, Chair-elect 2006–2007
Analog RF and Mixed Mode Faculty Group, Chair, 2003–2006.
ECE Executive Committee, Member, 2003–2006.
University Research Committee, Member 2005–2006.
College of Engineering Building Committee, Member, 2002–2004.
ECE Building Committee, Chair, 2001–2004.
ECE Graduate Programs Committee, Member, 2003–2005.
ECE Advisory Committee, Member, 2001–2003.
ECE Space Committee, Chair, 2001.
ECE Open House Committee, Chair, 1987–1988.

7. Professional service off campus:

- IEEE Fellow Committee, Member, 2016 to 2017.
- IEEE Microwave Theory and Techniques Society Publications Committee, Chair, 2016 to 2018

- IEEE Microwave Theory and Techniques Society Administrative Committee, Member, 2016 to 2018
- Steering Committee of the IEEE Journal of Electromagnetics, RF and Microwaves in Medicine and Biology, Chair, 2016 to 2018
- Steering Committee of the IEEE Journal on Multiscale and Multiphysics Computational Techniques, Member, 2016 to 2018
- Member of the Strategic Planning Committee of the IEEE Microwave Theory and Techniques Society, Member, 2016 to 2018
- IEEE Microwave Theory and Techniques Society Publications Committee, Member, 2013 to 2014
- IEEE Microwave Theory and Techniques Society Fellow Evaluation Committee, Chair, 2011 to 2015
- IEEE Microwave Theory and Techniques Society Publications Committee, Member, 2003 to 2007.
- Technical Committee on Microwave Systems, Microwave Theory and Techniques Society., Member, 2006 to 2010
- IEEE Microwave Theory and Techniques Society Fellow Evaluation Committee, co-Chair, 2008 to 2010
- Member of the Editorial Board of the IEEE Transactions on Microwave Theory and Techniques, 1985–present
- Member of the Editorial Board of the International Journal of Microwave and Millimeter Wave Computer Aided Engineering and International Journal of Numerical Modeling.
- Proposal Reviewer for U.S. Army Research Office.
- Proposal Reviewer for the National Science Foundation.
- Reviewer for the IEEE Transactions on Microwave Theory and Techniques
- Reviewer for the IEEE Microwave and Wireless Component Letters
- Reviewer for the IET Microwaves and Antennas and Propagation
- Reviewer for the International Journal on Numerical Modeling
- Reviewer for the IEEE Microwave magazine
- Reviewer for the International Journal of RF and Microwave Computer Aided Engineering
- Reviewer for the IEEE Transactions on Circuits and Systems
- Reviewer for the International Journal of Circuit Theory and Applications
- Reviewer for the Journal of Vacuum Science and Technology
- Reviewer for the International Journal of Computer Aided Engineering
- Reviewer for the IET Circuits Devices and Systems, IEEE Transactions on Computer Aided Design, IEEE Transactions on Advanced Packaging, IEEE Transactions on Electron Devices, Analog Integrated Circuits and Signal Processing
- Book Proposal and Book Reviewer for Scitech Publishing , John Wiley
- Editor-in-Chief, IEEE Trans. on Microwave Theory and Techniques, 2003–2006.
- Member of Professional Group G12 Committee of IEE 1999-2000
- Member, Administrative Committee, IEEE Microwave Theory and Techniques Society, 1998–2000, 2003–2006

- Member of the Engineering and Physical Sciences Research Council College (UK), 2000–2006.

II. TEACHING AND MENTORING OF UNDERGRADUATE AND GRADUATE STUDENTS

TEACHING EFFECTIVENESS

List courses taught, with an evaluation of teaching effectiveness, including a summation of data from student evaluations for the past three years and summary of available peer evaluations.

1. Courses Commonly Taught

ECE422 Transmission Lines and Antennas for Wireless
An undergraduate course on microwave circuits and antennas.

ECE549 RF Design for Wireless
This is a modern RF and microwave engineering class which presents a system level view of RF and microwave engineering.

ECE719 Advanced Microwave Circuit Design
This is an advanced circuit theory class in which students learn how to model electronic components such as transistors, and learn how circuit simulators work.

APPENDIX A

A. MENTORING ACTIVITIES

Include undergraduate academic advising and assessments thereof, if applicable, graduate committees, postdoctoral advising, advising student organizations, special projects with students, and Department of Public Instruction assessments of supervising student teaching.

GRADUATE STUDENT SUPERVISION

PhD, Chair of the Current Students

ELBADRY Mohamed

GRADUATE COMMITTEES

Currently, member of __**10**__ PhD and __**0**___MS committees.

Student name	**Degree**	**Chair**	**Member**
ELBADRY Mohamed	PhD	x	x
HARRIS William	PhD		x
WANG Meng	PhD		x
SHRIVASTAVA, Shruti	PhD		x
SHEN Junyu	PhD		x
SHREEPATHI BHAT Avinash	PhD		x
CHANG Yuan	PhD		x
WANG Meng	PhD		x
YANG Binbin	PhD		x
BONNER-STEWART Jeffrey	PhD		x

B. DOCTORAL THESES DIRECTED

Doctoral Dissertaions Directed (38)

Student name	Degree [date]	Organization
Michael Chen	2017	Northrop Grumman
Spencer Johnson	2014	MIT/Lincoln Laboratories
Austin Pickles	2014	Consultant (NC)
Josh Wetherington	2013	Vadum, Inc. (NC)
Vrinda Haridasan	2012	Physical Devices (NC)
Glenwood Garner III	2011	Vadum, Inc. (NC)
Christopher Saunders	2011	Chalmer's University
Mustafa Yelten	2011	Intel
T. Rob Harris	2011	UNC Charlotte (NC)
Miao DING	2011	RFMD (NC)
T. Rob HARRIS	2011	UNC Charlotte (NC)
Alan Victor	2010	Nitronex (NC)
Jonathan WILKERSON	2010	Physical Devices (NC)
Greg MAZZARO	2009	The Citadel
Frank HART	2009	GreenWave Scientific (NC)
Minsheng LI	2008	Intel
Mark, BUFF	2006	Greenwave Scientific (NC)
Sonali LUNIYA	2006	Petagonia Health (NC)
Nikhil KRIPLANI	2006	Vadum, Inc. (NC)
Wonhoon JANG	2006	University of Aviero
Jayesh NATH	2006	Apple
Aaron WALKER	2006	Vadum, Inc. (NC)
Khaled GHARAIBEH	2004	Yarmouk University
Steven LIPA	2004	NC State University (NC)
Chris HICKS	2002	US Navy, Navsea
Carlos CHRISTOFFERSON	2000	Lakehead University
Ahmed I. KHALIL	1999	Hitite Corporation
Mostafa N. ABDULLAH	1999	Intel
Huan-Shen H. HWANG	1997	Kyocera
Todd NUTESSON	1996	Aerospace Corporation
Gregory MONAHAN	1995	Portland Community College
Sharad MEHROTRA	1994	Cadence
Hoda BOGHDADY	1993	University of Cairo
Patrick L. HERON	1993	Cadence (NC)
Phil LUNSFORD	1993	East Carolina University (NC)
Mark BASEL	1993	Mentor Graphics
Chao-Ren CHANG	1990	Ansoft
George W. RHYNE	1988	RFMD (NC)

Master's Theses Directed

Chaired 36 Master of Science in Electrical Engineering with thesis.

Student name	Degree
Shivam Priyadarshi	2010
Seung Kyun Heo	2010
JoAnna Vetreno	2007
Ravi Vijayaraghavan	2003
Kuldip Gothi	2003
Aditya Goswami	2003
Rajesh Bollapragada	2003
Rahul Ghosh	2003
Mark Buff	2003
Houssam Kanj	2003
Senthil Velu	2002
Sonali Luniya	2002
Ramya Mohan	2002
Rachana Shah	2002
Shubha Vijaychand	2002
Jayanthi Suryanarayanan	2002
Satish Uppathil	2002
Nikhil Kriplani	2002
Nikolaos Vardalahos	2000
Shunmin Wang	1999
Satoshi Nakazawa	1999
Usman Mughal	1999
Mete Ozkar	1998
Baribrata Biswas	1998
Carlos Christoffersen	1998
Mark Summers	1997
Jaee Patwardhan	1997
Steve Lipa	1993
Cliff Barfield	1992
Jeff Kasten	1992
Steve Goldberg	1991
Steven Skaggs	1991
Dan Winklestein	1990
Jeyhan Karaoguz	1989
Richard J. Bishop	1989
Greg T. Brauns	1988

APPENDIX A

PostDoctoral Fellows

1. Sonali Luniya, 2006–2008. Patagonia Health, NC USA
2. Zhiping Feng, 2005–2010, HuaWei, NC USA
3. Nikhil Kriplani, 2005–2010, Vadum, Inc., NC USA
4. Wael Fathelbab, 2001–2006. RS Microwave Inc., NJ, USA
5. Khaled Gharaibeh, 2004–2005. Yarmouk University, Jordan
6. Robert Johnson, 1999–2000. University of Leeds , UK
7. Michael Roberts, 1999–2000. Filtronic plc., UK
8. Carlos Christoffersen, 2000. Lakehead University , Canada
9. Alexander Yakovlev, 1998–2001. University Mississippi , USA
10. Hector M. Gutierrez, 1997–1999. University of Florida, USA

Academics Trained (PhD Chaired and Postdoctoral fellows)

1. Wael Fathelbab, South Dakota School of Mines, 2007–2010
2. Khaled Gharaibeh, Yarmouk University, Jordan
3. Robert Johnson, University of Leeds, UK
4. Phil Lunsford, East Carolina University, USA
5. Carlos Christoffersen, Lakehead University, Canada
6. Gregory Mazzaro, The Citadel, USA
7. Alexander Yakovlev, University of Mississippi, USA
8. Gregory Monahan, Portland Community College, USA
9. Hector M. Gutierrez, University of Florida, USA
10. Hoda Boghdady, University of Cairo, Egypt

APPENDIX A

Michael B. Steer

III. SCHOLARSHIP

A. PUBLICATIONS AND AWARDS

List items as applicable, e.g., original research articles and research review articles in peer-reviewed journals, refereed articles that are pedagogy or extension-related, research abstracts, books; interdisciplinary/multidisciplinary works; invited and contributed research presentations; appointments or election to study sections and editorial boards; creative or professional works; exhibitions; juried shows, honors; awards, fellowships, prizes, competitions, and other pertinent evidence.

JOURNAL PUBLICATIONS

1. J. F. Harvey, M. B. Steer, T. S. Rappaport, “Exploiting high millimeter wave bands for military communications, applications, and design,” *IEEE Access*, 2019, pp. 52350–52359.
2. W. Palmer, D. Kirkwood, S. Gross, M. Steer. H. S. Newman, and S. Johnson, “An attractive future for integrated magnetics,” *IEEE Microwave Magazine*, Vol. 20, No. 6, June 2019, pp. 36–50.
3. M. Chen, M. Zikry, and M. B. Steer, “Microwave excitation of crystalline energetic composites,” *IEEE Access*, Vol. 6, No. 1, Dec. 2018, pp. 24596–24605.
4. Meng Wang, I. M. Kilgore, M. B. Steer and J. J. Adams, “Analysis of intermodulation distortion in liquid metal antennas,” *IEEE Antennas and Propagation Letters*, Vol. 17, No. 2, Feb. 2018, pp. 279–282.
5. P. Ansuinelli, A. G. Schuchinsky, F. Frezza, and M. B. Steer, “Passive intermodulation due to conductor surface roughness,” *IEEE Trans. Microwave Theory and Techniques*, Vol. 66, No. 2, Feb. 2018, pp. 688–699.
6. M. Chen and M. B. Steer, “Abstracted random mediums for electromagnetic hotspot observation in finite difference time domain simulation,” *IEEE Trans. Microwave Theory and Techniques*, Vol. 65, No. 5, May 2017, pp. 1873–1879.
7. I. M. Kilgore, S. A. Kabiri, A. W. Kane, M. B. Steer, “The effect of chaotic vibrations on antenna characteristics,” *IEEE Antennas and Wireless Propagation Letters*, Vol. 15, 2016, pp. 1242–1244
8. D. S. Kozlov, A. P. Shitvov, A. G. Schuchinsky, and M. B. Steer “Passive intermodulation of analog and digital signals on transmission lines with distributed nonlinearities: modelling and characterization,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. 64, No. 5, May 2016, pp. 1383–1395.
9. Jianguo Ma, M.B. Steer, and Xiaoning Jiang, “An acoustic filter based on layered structure,” Applied Physics Letters, Vol. 106, No. 11, Mar. 16, 2015, pp. 111903-1–3.
10. L.W.Y. Liu, B. S. Virdee, J. Inal, and M. B. Steer, “Microfabrication of Conical Micro-funnels for Drug Delivery Applications,” *IET Micro & Nano Letters*, Vol. 10, No. 7, Jul. 2015, pp. 355–357.
11. J. R. Wilkerson, I. M. Kilgore, K. G. Gard, and M. B. Steer, “Passive Intermodulation Distortion in Antennas,” *IEEE Transactions on Antennas and Propagation,* Vol. 63, No. 2, Feb. 2015, pp. 474–482
12. S. Priyadarshi, W. R. Davis, P. D. Franzon, and M. B. Steer, “Thermal Pathfinding for 3D ICs,” *IEEE Trans. on Components, Packaging and Manufacturing Technology*, Vol. 4, No. 7, July 2014, pp. 1159–1168.
13. S. J. Johnson and M. B. Steer, “An Efficient Approach to Computing Third-Order Scattering of Sound by Sound with Application to Parametric Arrays,” *IEEE Transactions on Ultrasonics, Ferroelectrics and Frequency Control*, Vol. 61, No. 10, Oct. 2014, pp. 1729–1741.

14. J.M. Wetherington, and M.B. Steer. “Sensitive vibration detection using ground-penetrating radar,” *IEEE Microwave and Wireless Component Letters*, Vol. 23, Iss. 12, Dec. 2013, pp. 680–682.
15. A. J. Pickles and M. B. Steer, “Electromagnetic properties of disordered three-dimensional mixtures,” *IEEE Access*, November 2013, pp. 778–788.
16. A. J. Pickles, I. M. Kilgore, and M. B. Steer, “Automated creation of complex three-dimensional composite mixtures for use in electromagnetic simulation,” *IEEE Access*, Vol. 1, 10 May 2013, pp. 248–251.
17. Ting Zhu, M. B. Yelten, M. B. Steer, and P. D. Franzon, “Variation-Aware Circuit Macromodeling and Design Based on Surrogate Models,” *Simulation and Modeling Methodologies, Technologies and Applications: Advances in Intelligent Systems and Computing*, Vol. 197, 2013, pp. 255–269.
18. E.J. Wyers, M. B. Steer, C. T. Kelley and P. D. Franzon, “A Bounded and Discretized Nelder-Mead Algorithm Suitable for RFIC Calibration,” *IEEE Transactions on Circuits and Systems I: Regular Papers*, Vol. 60, No. 7, 2013, pp. 1787–1799.
19. A. J. Pickles and M. B. Steer, “Effective permittivity of three-dimensional periodic Composites with regular and irregular inclusions,” *IEEE Access*, 2013.
20. G. Garner and M. B. Steer, “A cascaded second-order approach to computing third-order scattering of noncollinear acoustic arrays,” *Applied Acoustics*, Vol. 73, No 12, Dec. 2012, pp. 1220–1230.
21. J. M. Wetherington and M. B. Steer, “Standoff acoustic modulation of radio frequency signals in a log-periodic dipole array antenna,” *IEEE Antennas and Wireless Propagation Letters*, Vol. 11, Nov. 2012, pp. 885–888.
22. S. Priyadarshi, C. S. Saunders, N. M. Kriplani, H. Demircioglu, W. R. Davis, P. D. Franzon, and M. B. Steer, “Parallel transient simulation of multi-physics circuits using delay-based partitioning,” *IEEE Trans. on Computer Aided Design of Integrated Circuits and Systems*, Oct. 2012, pp.1522–1535.
23. T. Zhu, M. Steer, and P. Franzon, “Surrogate model-based self-calibrated design for process and temperature compensation in Analog/RF Circuits,” *IEEE Design & Test of Computers*, On-Line, Sept. 2012.
24. M. Ding, K. G. Gard and M. B. Steer, “A highly linear and efficient CMOS RF power amplifier with a 2-D circuit synthesis technique,” *IEEE Trans. Microwave Theory and Techniques*, Sept. 2012, pp. 2851–2862.
25. Z. Feng, M. Lueck, D. Temple, and M.B. Steer, “High performance solenoidal radio frequency transformers on high resistivity silicon substrate,” *IEEE Trans. Microwave Theory and Techniques*, Vol. 60, No. 7, pp. 2066–2072, July 2012.
26. W. Jang, N.M. Kriplani, A. Walker, and M.B. Steer, “Behavioral modeling of power amplifier asymmetry in the time domain,” *International Journal on Numerical Modeling: Electronic Networks, Devices and Fields*, On-line, June 2012.
27. J. M. Wetherington and M. B. Steer, “Robust analog cancellor for high dynamic radio frequency range measurement,” *IEEE Transactions on Microwave Theory and Techniques*, Vol. 60, No. 6, pp.1709–1719, June 2012.
28. S. Melamed, T. Thorolfsson, T. R. Harris, S. Priyadarshi, M. B. Steer, P. D. Franzon, and W. R. Davis, “Junction-level thermal analysis of three dimensional integrated circuits using high definition power blurring,” *IEEE Transactions on Computer Aided Design of Integrated Circuits and Systems*, pp. 676–689, May 2012.
29. M. B. Yelten, P. D. Franzon, and M. B. Steer, “Comparison of modeling techniques in circuit variability analysis,” *International Journal of Numerical Modelling: Electronic Networks, Devices and Fields*, Vol. 25, No. 3, pp. 288–302, May/June2012.

30. G. Garner and M. B. Steer, "Third-order parametric array generated by distantly spaced primary ultrasonic tones," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, pp. 776–784, April 2012.
31. T. R. Harris, S. Priyadarshi, S. Melamed, C. Ortega, R. Manohar, S. R. Dooley, N. M. Kriplani, W. R. Davis, P. D. Franzon, and M. B. Steer, "A transient electrothermal analysis of three-dimensional integrated circuits," *IEEE Transactions on Advanced Packaging*, Vol. 2, No. 4, pp. 660–667, April 2012.
32. M. B. Yelten, P. D. Franzon, and M. B. Steer, "Analog negative bias temperature instability (NBTI) monitoring circuit," *IEEE Trans. on Device and Materials Reliability*, Vol. 12, No. 1, March 2012, pp. 177–179.
33. P. Lam, V. Haridasan, Z. Feng; A. Kingon, M. B. Steer and J. P. Maria, "Scaling issues in ferroelectric barium strontium titanate tunable planar capacitors," *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, , Vol. 59, No. 2, Feb. 2012, pp. 198–204.
34. M. B. Yelten, Ting Zhu, S. Koziel. P. D. Franzon, and M. B. Steer, "Demystifying surrogate modeling for circuits and systems," IEEE Circuits and Systems Magazine, First Quarter, 2012, pp. 45–63.
35. S. Priyadarshi, T. R. Harris, S. Melamed, C. Otero, N. Kriplani, C. E. Christoffersen, R. Manoharx, S. R. Dooley, W. R. Davis, P. D. Franzon, and M. B. Steer, "Dynamic electrothermal simulation of three dimensional integrated circuits using standard cell macromodels," IET Circuits, Devices & Systems, Vol. 6, Iss. 1, Jan. 2012, pp. 35–44.
36. C. S. Saunders and M. B. Steer, "Passivity enforcement for admittance models of distributed networks using an inverse eigenvalue method," *IEEE Transactions on Microwave Theory and Techniques*, Vol. 60, Iss. 1, Jan. 2012, pp. 8–20.
37. J. A. Kosinski, W. D. Palmer, and M. B. Steer, "Unified understanding of RF remote probing," *IEEE Sensors Journal*, Vol. 11, No. 12, Dec. 2011, pp. 3055–3063.
38. J. Hu, J. Q. Lowry, K. G. Gard, and M. B. Steer, "Nonlinear radio frequency model identification using a hybrid genetic optimizer for minimal user intervention," *Institute of Engineering and Technology Microwaves, Antennas, & Propagation*, Vol. 5, Iss. 15, 2011.
39. M. B. Yelten, P. D. Franzon, and M. B. Steer, "Surrogate model based analysis of analog circuits – Part I: variability analysis," *IEEE Transactions on Device and Materials Reliability*, Vol. 11, No. 3, September 2011, pp. 458–465.
40. M. B. Yelten, P. D. Franzon, and M. B. Steer, "Surrogate model based analysis of analog circuits – Part II: reliability analysis," *IEEE Transactions on Device and Materials Reliability*, Vol. 11, No. 3, September 2011, pp. 466–473.
41. T. Zhu, M. B. Steer, and P. D. Franzon, "Accurate and scalable IO buffer macromodel based on surrogate modeling," *IEEE Trans. on Components, Packaging and Manufacturing Technology*, Vol. 1, No. 8, August 2011, pp. 1240–1249.
42. V. Haridasan, P.G. Lam, Z. Feng, W.M. Fathelbab, J.-P. Maria, A.I. Kingon, and M.B. Steer, "Tunable ferroelectric microwave bandpass filters optimized for system-level integration," *Institute of Engineering and Technology Microwaves, Antennas, & Propagation*, Vol. 5, Iss. 10, July 14 2011, pp. 1234–1241.
43. J. R. Wilkerson, P. G. Lam, K. G. Gard, and M. B. Steer, "Distributed passive intermodulation distortion on transmission lines," *IEEE Trans. Microwave Theory and Techniques*, May 2011, pp. 1190–1205.
44. J. Hu, K. G. Gard, and M. B. Steer, "Calibrated nonlinear vector network analyzer without using a multi-harmonic generator," *Institute of Engineering and Technology Microwaves, Antennas, & Propagation*, , Vol. 5, No. 5, April 2011, pp. 616–624.
45. N. M. Kriplani, S. Bowyer, J. Huckaby and M. B. Steer, "Modeling an Esaki tunnel diode in a circuit simulator," *Active and Passive Electronic Components*, Volume 2011, 2011, Article ID 830182, 8 p.

46. C. S. Saunders, J. Hu, C. E. Christoffersen, and M. B. Steer, "Inverse singular value method for enforcing passivity in reduced-order models of distributed structures for transient and steady-state simulation," *IEEE Trans. Microwave Theory and Techniques*, April 2011, pp. 837–847.
47. M. Li, L. Hoover, K.G. Gard, and M. B. Steer, "Behavioral modeling and impact analysis of physical impairments in quadrature modulators," Institute of Engineering and Technology Microwaves, Antennas, & Propagation, Vol. 2, Iss. 12, December 2010, pp. 2144 –2154.
48. G. J. Mazzaro, M. B. Steer, and K. G. Gard, "Intermodulation distortion in narrowband amplifier circuits," Institute of Engineering and Technology Microwaves, Antennas, & Propagation, April 2010, pp. 1149–1156.
49. C. Saunders, G.J. Mazzaro, and M.B. Steer, "Robust reduced-order modeling of distributed linear networks," Institute of Engineering and Technology Microwaves, Antennas, & Propagation, Vol. 4, Iss. 7, July 2010, pp. 962–973.
50. G. J. Mazzaro, K.G. Gard, and M.B. Steer, "Linear amplification by time-multiplexed spectrum," Institute of Engineering and Technology Circuits, Devices, and Systems, Vol. 4, Iss. 5, May 2010, pp. 392–402.
51. J.R. Wilkerson, K.G. Gard and M.B. Steer, "Automated broadband high dynamic range nonlinear distortion measurement system," IEEE Trans. Microwave Theory and Techniques, Vol. 58, Iss. 5, May 2010, pp.1273–1282.
52. M. Li, L. Hoover, K.G. Gard, and M. B. Steer, "Behavioral modeling and impact analysis of physical impairments in quadrature modulators," *Institute of Engineering and Technology Microwaves, Antennas, & Propagation*, In Press, 2010.
53. G. J. Mazzaro, M. B. Steer, and K. G. Gard, "Intermodulation distortion in narrowband amplifier circuits," *Institute of Engineering and Technology Microwaves, Antennas, & Propagation* , In Press, 2010.
54. C. Saunders, G.J. Mazzaro, and M.B. Steer, "Robust reduced-order modeling of distributed linear networks," *IEEE Trans. Microwave Theory and Tech.,* In Press, 2010.
55. G.J. Mazzaro, K.G. Gard, and M.B. Steer, "Linear amplification by time-multiplexed spectrum," *Institute of Engineering and Technology* to *Circuits, Devices, and Systems*, In Press 2010.
56. J.R. Wilkerson, K.G. Gard and M.B. Steer, "Automated broadband high dynamic range nonlinear distortion measurement system," *IEEE Trans. Microwave Theory and Tech.,* Vol. 58, Iss. 5, May 2010, pp.1273–1282.
57. P. Lam, Z. Feng, V. Haridasan, A. Kingon, M. Steer, J.-P. Maria, "The impact of metallization thickness and geometry for X-band tunable microwave filters**,"** *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, May 2009, pp. 2808–2814.
58. G. J. Mazzaro, M. B. Steer, K. G. Gard, and A. L. Walker, "Response of RF networks to transient waveforms: interference in frequency-hopped communications," IEEE Trans. Microwave Theory and Tech., Vol. 56, Iss. 12, Part 1, December 2008, pp. 2808–2814.
59. J. R. Wilkerson, K. G. Gard, A. G. Schuchinsky, and M. B. Steer, "Electro-thermal theory of intermodulation distortion in lossy microwave components," IEEE Trans. Microwave Theory and Tech., Vol. 56, Iss. 12, Part 1, December 2008, pp. 2717–2725.
60. G. J. Mazzaro, M. B. Steer, and K. G. Gard, "Filter characterization using one-port RF measurements," Institute of Engineering and Technology Microwaves, Antennas, & Propagation, Vol. 3, Iss. 2, March 2009, pp. 303–309.
61. N. M. Kriplani, S. Luniya and M. B. Steer, "Integrated deterministic and stochastic simulation of electronic circuits: application to large signal noise analysis,"Int. J. Numerical Modeling: Electronic Networks, Devices and Fields, Vol. 21, Iss. 6, Nov. 2008, pp. 303–309.
62. A. Varma, P. D. Franzon and M. B. Steer, "Improving behavioral IO buffer modeling based on IBIS," IEEE Transactions on Advanced Packaging, Vol. 31, Iss. 4, November 2008, pp. 711–721.
63. A. Victor and M. B. Steer, "Reflection coefficient shaping of a 5 GHz voltage-tuned oscillator for improved tuning," IEEE Trans. Microwave Theory and Tech., Vol. 55, Iss. 12, Dec. 2007, pp. 2488–2494.

64. F. P. Hart and M. B. Steer, "Modeling the nonlinear response of multitones with uncorrelated phase," *IEEE Trans. Microwave Theory and Tech*., October 2007, pp. 2147–2156.
65. W. Fathelbab and M. B. Steer, "Filter prototypes comprising singlet and/or inline sections," *Int. Journal of Electronics*, Vol. 94, Iss. 9, Oct. 2007, pp. 925–934.
66. N. M. Kriplani, S. Bowyer, J. Huckaby and M. B. Steer, "Modeling a tunnel diode in a circuit simulator," *IET Circuits, Devices & Systems*, In Press, 2007.
67. K. M. Gharaibeh, K. G. Gard and M. B. Steer, "Estimation of co-channel nonlinear distortion and SNDR in wireless systems," *IET Microwaves, Antennas & Propagation*, Oct. 2007, pp. 1078–1085.
68. F. P. Hart, S. Luniya, J. Nath, A. Victor and M. B. Steer, "Modeling high-order filters in a transient microwave circuit simulator," *IET Microwaves, Antennas & Propagation*, Oct. 2007, pp 1024–1028.
69. P. M. Buff, J. Nath and M. B. Steer, "Origin of the half-wavelength errors in microwave measurements using through-line calibrations," *IEEE Trans. Instrumentation and Measurement*, Oct. 2007, pp 1610–1615.
70. M. B. Steer, "Beyond 3G," IEEE Microwave Magazine, February 2007, pp. 76–82.
71. L. Katehi, W. Chappell, S. Mohammadi, A. Margomenos and M. Steer, "Heterogeneous wafer-scale circuit architectures," IEEE Microwave Magazine, February 2007, pp. 52 –69.
72. K. M. Gharaibeh, K. G. Gard and M. B. Steer, "In-band distortion of multisines," IEEE Trans. Microwave Theory and Tech., August 2006, pp. 3227–3236.
73. S. Luniya, K. G. Gard, and M. B. Steer, "Modeling nonlinear distortion of ultra wideband signals at X-band," IEEE Microwave and Wireless Component Letters, July 2006, pp. 381–383.
74. N. M. Kriplani, D. P. Nackashi, C. J. Amsinck, N. H. Di Spigna, M. B. Steer and P. D. Franzon, R. L. Rick, G. C. Solomon and J. R. Reimers, "Physics-based molecular device model in a transient circuit simulator," Elsevier Science: Chemical Physics, July 11 2006, Vol. 326, Issue 1, Special Issue on The Molecules and Methods of Chemical, Biochemical and Nanoscale Electron Transfer, pp. 188–196.
75. W. Jang, A. Walker, K. Gard and M. B. Steer, "Capturing asymmetrical spectral regrowth in RF systems using a multi-slice behavioral model and enhanced envelop transient analysis," Int. J. Microwave and Millimeter Wave Computer Aided Engineering, July 2006, pp. 400–407.
76. A. M. Victor and M. B. Steer, "Transceiver cascade system analysis and design via a contribution method," Int. J. on RF and Microwave Computer Aided Engineering. 2006, July 2006, pp. 338–345.
77. W. M. Fathelbab and M. B. Steer, "Tapped marchand baluns for matching applications," IEEE Trans. Microwave Theory and Tech, Vol. 54, June 2006, pp. 2543–2551.
78. A. Walker, M. B. Steer and K. Gard, " A vector intermodulation analyzer applied to behavioral modeling of nonlinear amplifiers with memory effect ," IEEE Trans. Microwave Theory and Tech, Vol. 54, Issue 5 , May 2006 , pp. 1991 –1999 .
79. N. B. Carvalho, J. C. Pedro, W. Jang and M. B. Steer, " Nonlinear RF circuits and systems when driven by several modulated signals," Trans. Microwave Theory and Tech, Vol. 54, Issue 2, Feb. 2006, pp. 572 – 579 .
80. M. Buff, M. B. Steer and G. Lazzi, "Cole-Cole dispersion models for an aqueous gelatin-syrup dielectric composite," IEEE Trans. On Geoscience and Remote Sensing, Vol. 44, Issue 2, Feb. 2006, pp. 351 – 355.
81. D. Ghosh, B. J. Laughlin, J. Nath, A. I. Kingon, M. B. Steer and J-P. Maria, "Tunable high Q interdigitated (Ba, Sr)TiO3 capacitors fabricated on low cost substrates with copper metallization," Thin Solid Films, Vol. 496 , Iss. 2, Feb. 21 2006, pp. 669–673 .
82. A. Walker, M. B. Steer and K. Gard, `` Capturing asymmetry in distortion of an RF system using a multislice behavioral model ," IEEE Microwave and Wireless Component Letters, Vol. 16, Issue 4, April 2006, pp. 212 – 214.

83. A. M. Victor, J. Nath, D. Ghosh, B. Boyette, Jon-Paul Maria, M. B. Steer, A. I. Kingon and G. T. Stauf, “ Noise characteristics of an oscillator with a Barium Strontium Titanate (BST) varactor ,” Proc. IEE Part H. Microwave Antennas and Propagation, Vol. 153, No. 1, Feb. 2006 , pp. 96 – 102 .
84. W. M. Fathelbab and M. B. Steer , “Parallel-coupled line filters with enhanced stopband performance,” IEEE Trans. Microwave Theory and Tech. , Dec. 2005, Issue 12, pp. 3774 – 3781.
85. W. R. Davis, J. Wilson, S. Mick, J. Xu, H, Hua, C. Mineo, A. m. Sule, M. Steer and P. D. Franzon, “ Demystifying 3D ICs: the pros and cons of going vertical ,” IEEE Design & Test of Computers , Vol. 22, Issue 6, Nov. – Dec. 2005, pp. 498 – 510.
86. D. Ghosh, B. J. Laughlin, J. Nath, A. I. Kingon, M. B. Steer and J-P. Maria, “High Q interdigitated (Ba, Sr)TiO3 interdigitated capacitors fabricated on low cost substrates with copper metallization,” Ceramic Engineering and Science Proceedings, Vol. 26, Issue 5, 2005, p. 125 .
87. J. Nath, D. Ghosh, J.-P. Maria, A. I. Kingon, W. Fathelbab, P. D. Franzon and M. B. Steer , “ An electronically-tunable microstrip bandpass filter using thin-film Barium Strontium Titanate (BST) varactors ,” IEEE Trans. Microwave Theory and Tech. , Vol. 53, No. 9, Sep. 2005, pp. 2707 – 2712.
88. N. B. Carvalho, J. C. Pedro, W. Jang and M. B. Steer, “ Nonlinear simulation of mixers for assessing system-level performance ,” Int. J. Microwave and Millimeter Wave Computer Aided Engineering, Vol. 15, Issue 4, July 2005, pp. 350 – 361.
89. K. G. Gard, L. E. Larson and M. B. Steer, “The impact of RF front-end characteristics on the spectral regrowth of communications signals ,” IEEE Trans. Microwave Theory and Tech. , June 2005, pp. 2179 – 2186.
90. W. M. Fathelbab and M. B. Steer, “New classes of miniaturized planar Marchand baluns ,” IEEE Trans. Microwave Theory and Tech. , Vol. 53, Issue 4, April 2005, pp. 1211 – 1220.
91. W. M. Fathelbab and M. B. Steer, “A re-configurable bandpass filter for RF/microwave multifunctional systems ,” IEEE Trans. Microwave Theory and Tech. , Vol. 53, Issue 3, Part 2, March 2005, pp. 1111 – 1116.
92. R. Pant, M. A. Neifeld, M. B. Steer, H. Kanj, and A. C. Cangellaris, “ Electrical package impact on VCSEL-based optical interconnects ;” Optics Communication , Vol. 245, Issue 1-6, Jan. 2005, p. 315-332.
93. W. M. Fathelbab and M. B. Steer, “A re-configurable bandpass filter for RF/microwave multifunctional systems,” IEEE Trans. Microwave Theory and Tech., Vol. 53, Issue 3, Part 2, March 2005, pp. 1111 – 1116.
94. M. B. Steer, “Multi scale multi physics modeling of microwave circuits and systems,” Quarterly of the Polish Academy of Sciences , In Press, 2005.
95. K. M. Gharaibeh and M. B. Steer, “ Modeling distortion in multichannel communication systems ,” IEEE Trans. Microwave Theory and Tech., Vol. 53, No. 5, pp. 1682 – 1692, May 2005.
96. W. M. Fathelbab and M. B. Steer, “ Four-port microwave networks with intrinsic broadband suppression of common-mode signals ,” IEEE Trans. Microwave Theory and Tech, Vol. 53, No. 5, pp. 1569 – 1575, May 2005.
97. R. Mohan, J. C. Myoung, S. E. Mick, F. P. Hart, K. Chandrasekar, A. C. Cangellaris, P. D. Franzon and M. B. Steer, “ Causal reduced-order modeling of distributed structures in a transient circuit simulator ,” IEEE Trans. Microwave Theory and Tech , Vol. 52, No. 9, Sept. 2004, pp. 2207 – 2214.
98. C. W. Hicks and A. B. Yakovlev and M. B. Steer, “ Aperture-coupled stripline-to-waveguide transitions for spatial power combining ,” J. Applied Computational Electromagnetics Society , Vol. 19, 2005, In Press .
99. M. B. Steer, L. P. B. Katehi, S. Mohammadi, J. F. Whitaker , A. B. Yakovlev, “ Architectures and prototyping laboratory for the development of space-based microwave power transmission systems ,” URSI Radio Science Bulletin , No. 311, Dec. 2004, pp. 7 –15 .

100. W . M. Issue 5, and M. B. Steer, “Distributed biasing of differential RF circuits ” IEEE Trans. Microwave Theory and Tech., Vol. 52, pp. 1565 – 1572, May 2004.
101. W. Y. Liu , J. Suryanarayanan, J. Nath, S. Mohammadi, L. P. B. Katehi and M. B. Steer, “Torroidal inductors for radio frequency integrated circuits,” IEEE Trans. Microwave Theory and Tech. , vol. 52, pp. 646–654, Feb. 2004 .
102. K. M. Gharaibeh and M. B. Steer, “Characterization of cross modulation in multichannel amplifiers using a statistically based behavioral modeling technique ,” IEEE Trans. Microwave Theory and Tech. , vol. 51 , pp. 2434 – 2444, Dec. 2003 .
103. F. P. Hart, D. Stephenson, C.-R. Chang, K. Gharaibeh, R. G. Johnson and M. B. Steer, M athematical foundations of frequency domain modeling of nonlinear circuits and systems using the arithmetic operator method , Int. J. on RF and Microwave Computer Aided Engineering, Dec. 2003 , pp. 473–495.
104. M. V. Lukich, A. B. Yakovlev, A. Z. Elsherbeni, C. E. Smith and M. B. Steer, “ Printed antenna design for broadband waveguide-based spatial power combiners ,” Microwave and Optical Technology Letters , , Vol. 13, pp. 411–415 , March 2003 .
105. A. B. Yakovlev, M. V. Lukich, A. Z. Elsherbeni, C. E. Smith and M. B. Steer, “ Meander-slot and U-slot antenna arrays for wideband spatial power combiners ,” IEEE Microwave and Wireless Component Letters , Vol. 36, No. 5, March 2003, pp. 125-127 .
106. W. Batty, C. E. Christoffersen, A. B. Yakovlev, J. F. Whitaker, M. Ozkar, S. Ortiz, A. Mortazawi, R. Reano, K. Yang, L. P. B. Katehi, C. M. Snowden and M. B. Steer , " Global coupled EM-electrical-thermal simulation and experimental validation for a spatial power combining MMIC array ," IEEE Trans. Microwave Theory and Tech. , Vol. 50, Dec. 2002, pp. 2820–2833 .
107. A. B. Yakovlev, S. Ortiz, M. Ozkar, A. M. Mortazawi and M. B. Steer, “ Electric dyadic Green's functions for modeling resonance and coupling effects in waveguide-based aperture-coupled patch arrays ,” The Journal of the Applied Computational Electromagnetics Society , Vol. 17, No. 2, July 2002, pp. 123 – 133.
108. W. Y. Liu, D. P. Steenson and M. B. Steer, “Organic micromachining techniques for mass production of millimeter-wave and submillimeter-wave planar circuits”, J. Microlithography, Microfabrication, and Microsystems, Vol. 1, Issue 2, 2002.
109. M. B. Steer, J. W. Bandler and C. M. Snowden, “Computer-aided design of RF and microwave circuits and systems ,” IEEE Trans. Microwave Theory Techniques, Mar. 2002, pp. 996–1005, invited paper . (NEOCAD)
110. T. Tayag, M. B. Steer, J. F. Harvey, A. B. Yakovlev and J. Davis, “ Spatial power splitting and combining based on the Talbot effect ,” IEEE Microwave and Guided Waves Letters , Vol. 12, Jan. 2002, pp. 9–11.
111. P. J. Rudge, R. E. Miles, M. B. Steer and C. M. Snowden, " Investigation into intermodulation distortion in HEMTs using a quasi-2D physical model," IEEE Trans. Microwave Theory Techniques, Vol. 49, Dec. 2001, pp. 2315–2321.
112. W. Batty, C. E. Christoffersen, A. J. Panks, S. David, C. M. Snowden and M. B. Steer, " Electrothermal CAD of power devices and circuits with fully physical time-dependent compact thermal modeling of complex non linear 3-d systems ," IEEE Transactions on Components and Packaging Technology , Dec. 2001, pp. 566–590.
113. M. B. Steer, J. Sevic and B. Geller, “ The RF power amplifier ,” IEEE Trans. Microwave Theory and Techniques , Vol. 49, June 2001.
114. W. Y. Liu, D. P. Steenson and M. B. Steer, " Membrane-supported CPW with mounted active devices ," IEEE Microwave and Guided Waves Letters , Vol. 11. April 2001, pp. 167–169.
115. C. E. Christoffersen and M. B. Steer, `` State-variable-based transient circuit simulation using wavelets ," IEEE Microwave and Guided Waves Letters , Vol. 11. April 2001, pp. 161–163.

116. M. Abdullah, and M B. Steer, " Extraction of the network parameters in the analysis of planar structures using the method of moments ," IEEE Trans. Microwave Theory Techniques, Jan. 2001. 94–103 .

117. H. Gutierrez, K. Gard, and M. B. Steer , " Nonlinear gain compression in microwave amplifiers using generalized power series and transformation of input statistics ," IEEE Trans. Microwave Theory Techniques, Nov. 2000, pp. 1774–1777.

118. C. E. Christoffersen, U. A. Mughal, and M. B. Steer, " Object oriented microwave circuit simulation," Int. J. on RF and Microwave Computer Aided Engineering, Vol. 10, Issue 3, May/June 2000, pp. 164–182.

119. A. B. Yakovlev, A. I. Khalil, C. W. Hicks, A. M. Mortazawi and M. B. Steer, " The generalized scattering matrix of closely spaced strip and slot layers in waveguide ," IEEE Trans. Microwave Theory Techniques, Vol. 48, Jan. 2000, pp. 126–137.

120. J. F. Sevic and M. B. Steer, " On the significance of envelope peak-to-average ratio for estimating the spectral regrowth characteristics of an RF/Microwave power amplifier ," IEEE Trans. Microwave Theory Techniques , Vol. 48, June 2000, pp. 1068–1071.

121. A. I. Khalil, A. B. Yakovlev, and M. B. Steer, " Efficient method of moments formulation for the modeling of planar conductive layers in a shielded guided-wave structure ," IEEE Trans. Microwave Theory Techniques, Vol. 47, Sept. 1999 , pp. 1730–1736.

122. C. E. Christoffersen and M. B. Steer, " Implementation of the local reference node concept for spatially distributed circuits ," Int. J. on RF and Microwave Computer Aided Engineering, Vol. 9, No. 5, Sept. 1999, pp. 376–384.

123. A. I. Khalil and M. B. Steer " A generalized scattering matrix method using the method of moments for the electromagnetic analysis of multi-layered structures in waveguide ," IEEE Trans. Microwave Theory Techniques, Vol. 47, Nov. 1999, pp. 2151–2157 .)

124. K. Gard, H. Gutierrez and M. B. Steer, “Characterization of spectral regrowth in microwave amplifiers based on the nonlinear transformation of a complex gaussian process,” IEEE Trans. Microwave Theory Techniques, Vol. 47, July 1999, pp. 1059–1069 .

125. M. B. Steer, J. F. Harvey, J. W. Mink, M. N. Abdulla, C. E. Christoffersen, H. M. Gutierrez, P. L. Heron, C. W. Hicks, A. I. Khalil, U. A. Mughal, S. Nakazawa, T. W. Nuteson, J. Patwardhan, S. G. Skaggs, M. A. Summers, S. Wang, and A. B. Yakovlev, " Global modeling of spatially distributed microwave and millimeter-wave systems,” *IEEE Trans. Microwave Theory Techniques*, June 1999, pp. 830–839.

126. C. E. Christoffersen, M. Ozkar, M. B. Steer, M. G. Case and M. Rodwell, “State variable-based transient analysis using convolution,” IEEE Trans. Microwave Theory Techniques, June 1999, pp. 882–889 .

127. T. W. Nuteson, M. B. Steer, S. Nakazawa and J. W. Mink, “Near-field and far-field prediction of quasi-optical grid arrays,” IEEE Trans. On Microwave Theory and Technique, Vol. 47, Jan. 1999, pp. 6–13.

128. A. I. Khalil and M. B. Steer, “Circuit theory for spatially distributed microwave circuits,” *IEEE Trans. On Microwave Theory and Techniques*, vol. 46, Oct. 1998 , pp. 1500-1502.

129. C. W. Hicks, H.-S. Hwang and M. B. Steer, J. W. Mink, and J. Harvey, “Spatial power combining for two dimensional structures,” IEEE Trans. On Microwave Theory and Techniques, June, 1998, pp. 784–791.

130. T. W. Nuteson, H. Hwang, M. B. Steer, K. Naishadham, J. W. Mink, and J. Harvey, “Analysis of finite grid structures with lenses in quasi-optical systems,” IEEE Trans. Microwave Theory Techniques , May 1997, pp. 666–672.

131. T. W. Nuteson, G. P. Monahan, M. B. Steer, K. Naishadham, J. W. Mink, K. Kojucharoff and J. Harvey, “Full-wave analysis of quasi-optical structures,” IEEE Trans. Microwave Theory Techniques , May 1996, pp. 701–710.

132. J. F. Sevic, M. B. Steer and A. M. Pavio, “Nonlinear analysis methods for the simulation of digital wireless communication systems,” Int. Journal on Microwave and Millimeter Wave Computer Aided Engineering , May 1996, pp. 197–216.
133. S. Lipa, M. B. Steer, A. C. Cangellaris and P. D. Franzon, “Experimental characterization of transmission lines in thin-film multichip modules,” IEEE Trans. on Components, Packaging, and Manufacturing Technology-Part A , Vol. 19 March 1996, pp. 122–126.
134. H. Hwang, T. W. Nutesson, M. B. Steer, J. W. Mink, J. Harvey and A. Paolella, “A quasi-optical dielectric slab power combiner,” IEEE Microwave and Guided Wave Letters , Vol. 6, Feb. 1996 pp. 73–75.
135. M.B. Steer, C.-R. Chang, G.W. Rhyne, “Simple calculation method of the intermodulation distortion of multiple-carrier amplifiers operating in weakly nonlinear region,” *Electronics and Communications in Japan (Part II: Electronics)*, Vol. 78, Iss. 10, Oct. 1995, pp. 44–51.
136. G. P. Monahan, P. L. Heron, M. B. Steer, J. W. Mink and F. W. Schwering, “Mode degeneracy in quasi-optical resonators,” Microwave and Optical Technology Letters , Vol. 8, No. 5, April 5 1995, pp. 230–232.
137. M. S. Basel, M. B. Steer and P. D. Franzon “Simulation of high speed interconnects using a convolution-based hierarchical packaging simulator ," IEEE Trans. on Components Hybrids and Manufacturing Technology, Part B: Advanced Packaging , Vol. 18, Feb. 1995, pp. 74–82.
138. S. Simovich, S. Mehrotra, P. D. Franzon, and M. B. Steer, “Delay and reflection noise macromodeling for signal integrity management of PCBs and MCMs ," IEEE Trans. on Components Hybrids and Manufacturing Technology, Part B: Advanced Packaging , Vol. 17, Feb. 1994, pp. 15-21.
139. P. L. Heron, J.W. Mink, G. P. Monahan, F. W. Schwering and M. B. Steer, " Impedance matrix of an antenna array in a quasi-optical resonator," IEEE Trans. Microwave Theory Techniques , Vol. 41, Oct. 1993, pp. 1816–1826.
140. P. L. Heron, F. W. Schwering, G. P. Monahan, J.W. Mink, and M. B. Steer, " A dyadic Green's function for the plano-concave quasi-optical resonator ," IEEE Microwave and Guided Wave Letters , Vol. 3, Aug. 1993, pp. 256–258.
141. S. Zeisberg, A. Schunemann, G. P. Monahan, P. L. Heron, M. B. Steer, J.W. Mink and F. W. Schwering, " Experimental investigation of a quasi-optical slab resonator ," IEEE Microwave and Guided Wave Letters , Vol. 3, Aug. 1993, pp. 253-255.
142. S. Lipa, M. B. Steer, A. S. Morris, and P. D. Franzon, " Comparison of methods for determining the capacitance of planar transmission lines with application to multichip module characterization," IEEE Trans. on Components Hybrids and Manufacturing Technology, Part B: Advanced Packaging , Vol. 16, May 1993, pp. 247–252.
143. M. B. Steer, " Diode characterization in a coaxial mount ," Int. J. f Microwave and Millimeter Wave Computer Aided Engin. Vol. 3, April 1993, pp. 114–117.
144. S. G. Skaggs, J. Gerber, G. Bilbro and M. B. Steer, " Parameter extraction of microwave transistors using a hybrid gradient descent and tree annealing approach ," IEEE Trans. Microwave Theory Techniques , Vol. 41, April 1993, pp. 726–729.
145. S. Simovich, P. D. Franzon, and M. B. Steer, " Method for automated waveform analysis of transient responses in digital circuits ," Electronics Letters , Vol. 29, No. 8, April 21, 1993, pp. 681-682.
146. G. P. Monahan, A. S. Morris and M. B. Steer, "A coaxial test fixture for characterizing low impedance microwave two-terminal devices," Microwave and Optical Technology Letters , Vol. 6, Mar. 1993, pp. 197-200.
147. R. B. Marks, D. F. Williams and M. B. Steer, "Accurate experimental characterization of interconnects: a discussion of 'experimental electrical characterization of interconnects and discontinuities in high-speed digital systems'," IEEE Trans. Components Hybrids and Manufacturing Technology , Vol. 15, Aug. 1992, pp. 601-604.

148. M. B. Steer, S. B. Goldberg and P. D. Franzon, " Comments on an 'Accurate measurement technique for line properties, junction effects and dielectric and magnetic parameters' ," IEEE Trans. Microwave Theory Techniques , Vol. 40, Feb. 1992, pp. 410-411.
149. S. B. Goldberg, M. B. Steer, P. D. Franzon and J. S. Kasten, " Experimental electrical characterization of interconnects and discontinuities in high speed digital systems ," IEEE Trans. on Components Hybrids and Manufacturing Technology , Vol. 14, Dec., 1991, pp. 761-765.
150. C.R. Chang, M. B. Steer, S. Martin and E. Reese, " Computer-aided analysis of free-running microwave oscillators ," IEEE Trans. Microwave Theory Techniques , Oct. 1991, pp. 1735-1745.
151. P.J. Lunsford and M. B. Steer, " The relationship between bivariate Volterra series analysis and power series analysis and application to the behavioral modeling of microwave circuits ," International Journal on Microwave and Millimeter Wave Computer Aided Engineering , Vol. 1, July 1991, pp. 253-262.
152. R. Gilmore and M. B. Steer, " Nonlinear circuit analysis using the method of harmonic balance -- a review of the art: part II, advanced concepts " International Journal on Microwave and Millimeter Wave Computer Aided Engineering , Vol. 1, April, 1991, pp. 159-180.
153. D. Winkelstein, M. B. Steer and R. Pomerleau, " Simulation of arbitrary transmission line networks with nonlinear terminations ," IEEE Trans. on Circuits and Systems , April 1991, pp.418-422. See also, IEEE Trans. on Circuits and Systems , Vol. 38, Oct. 1991.
154. M. B. Steer, C. R. Chang and G. W. Rhyne, " Computer aided analysis of nonlinear microwave circuits using frequency domain spectral balance techniques: the state of the art ," International Journal on Microwave and Millimeter Wave Computer Aided Engineering , Vol. 1, April 1991, pp. 181–200.
155. R. Gilmore and M. B. Steer, " Nonlinear circuit analysis using the method of harmonic balance -- a review of the art: part I, introductory concepts ," International Journal on Microwave and Millimeter Wave Computer Aided Engineering , Vol. 1, Jan. 1991, pp. 22–37.
156. G. L. Bilbro, M. B. Steer, R. J. Trew, C. R. Chang and S. G. Skaggs, " Extraction of the parameters of equivalent circuits of microwave transistors using tree annealing ," IEEE Trans. Microwave Theory Techniques , vol. 38, Nov. 1990, pp. 1711–1718.
157. G.P. Monahan, P.L. Heron, M.B. Steer, J.W. Mink, and F.K. Schwering, “A UTD formula for h-polarization plane wave diffraction by a wedge with impedance faces,” *Microwave and Optical Technology Letter,* Vol. 3, Iss. 10, 1990, pp. 356–359.
158. C. R. Chang and M. B. Steer, " Frequency domain nonlinear microwave circuit simulation using the arithmetic operator method ," IEEE Trans. Microwave Theory Techniques , Aug. 1990, pp. 1139–1143.
159. P. J. Lunsford, G. W. Rhyne and M. B. Steer, " Frequency domain bivariate generalized power series analysis of nonlinear analog circuits ," IEEE Trans. Microwave Theory Techniques , June 1990, pp. 815–818.
160. C.R. Chang, P. L. Heron and M. B. Steer " Harmonic balance and frequency domain simulation of nonlinear microwave circuits using the block Newton method ," IEEE Trans. Microwave Theory Techniques , April 1990, pp. 431–434.
161. H. Riedell, M. B. Steer, M.R. Kay, J.S. Kasten, M. S. Basel, and R. Pomerleau,”Dielectric characterization of printed circuit board substrates,” IEEE Trans. on Instrumentation and Measurement , April 1990, pp. 437–440.
162. P. L. Heron, and M. B. Steer, “Jacobian calculation using the multidimensional fast Fourier transform in the harmonic balance analysis of nonlinear microwave circuits,” IEEE Trans. Microwave Theory Techniques , April 1990, pp. 429–431.
163. R. J. Bishop, J. J. Paulos, M. B. Steer and S. H. Ardalan, " Table-based simulation of delta-sigma modulators ," IEEE Trans. on Circuits and Systems , March 1990, pp. 447–-451.
164. J. Kasten, M. B. Steer and R. Pomerleau, “Enhanced through-reflect-line characterization of two-port measuring systems using free-space capacitance calculation,” IEEE Trans. Microwave Theory Techniques , Feb. 1990, pp. 215–217.

165. G. T. Brauns, R. J. Bishop, M. B. Steer, S. H. Ardalan and J. J. Paulos, "Table-based modeling of delta-sigma modulators using ZSIM ," IEEE Trans. Computer Aided Design , Feb. 1990, pp. 142–150.
166. C. R. Chang, M. B. Steer and G. W. Rhyne, "Frequency domain spectral balance using the arithmetic operator method ," IEEE Trans. Microwave Theory Techniques , Nov. 1989, pp. 1681–1688.
167. G. W. Rhyne and M. B. Steer, "Comments on 'Simulation of nonlinear circuits in the frequency domain' ," IEEE Trans. on Computer Aided Design , Aug. 1989, pp. 927-929.
168. G. W. Rhyne, M. B. Steer and B. D. Bates, "Frequency domain nonlinear circuit analysis using generalized power series," IEEE Trans. Microwave Theory Techniques , Feb. 1988, pp. 379–387.
169. G.W. Rhyne and M. B. Steer, "Generalized power series analysis of intermodulation distortion in a MESFET amplifier: simulation and experiment," IEEE Trans. Microwave Theory Techniques , Dec. 1987, pp. 1248–1255.
170. R. J. Trew and M. B. Steer, "Millimeter-wave performance of state-of-the-art MESFET, MODFET and PBT transistors," Electronics Letters , 12 th Feb. 1987, pp. 149–151.
171. M. B. Steer and R. J. Trew, "High frequency limits of millimeter-wave transistors ," IEEE Electron Device Letters , vol. 7, Nov. 1986, pp. 640–642.
172. M. B. Steer, P. J. Khan and R. S. Tucker, "Relationship of Volterra series and generalised power series ," Proc. IEEE , vol. 71, Dec. 1983, pp. 1453–1454.
173. M. B. Steer and P. J. Khan, " An algebraic formula for the complex output of a system with multi-frequency excitation ," Proc. IEEE , vol. 71, Jan. 1983, pp. 177–179.
174. M. B. Steer and P. J. Khan, "Wideband equivalent circuits for radial transmission lines ," Proc. IEE Microwaves, Antennas and Propagation, Part H , vol. 128, April 1981, pp. 111–113.
175. P. J. Khan and M. B. Steer, "Analysis of bias-pin resonator diode mounts for millimeter-wave oscillators," Proc. IEEE , vol. 67, Nov. 1979, pp. 1556–1557.

PEER-REVIEWED CONFERENCE PUBLICATIONS

1. M. Elbadry, M. Steer, J. Wetherington, and M. A. Zikry, "Modeling the behavior of heterogeneous systems subjected to the coupled effects of electromagnetic and mechanical fields," *International Mechanical Engineering Congress & Exposition*, November 2019, p. IMECE2019-13021.
2. A. Schuchinsky and M.B. Steer, "Nonlinear distortion of multitone wave packets by lossy conductors," Metamaterials Conference, Sept. 2019.
3. A. Schuchinsky and M.B. Steer, "Nonlinear interference in multicarrier wave packets," *IEEE MTT-S International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization for RF, Microwave, and Terahertz Applications*, June 2019, In Press
4. A. Schuchinsky and M.B. Steer, "Nonlinear distortion of multitone wave packets by lossy conductors," Metamaterials Conference, 2019. In review
5. M. El-badry, J. Wetherington, M. Steer, M.A. Zikry, "Modeling of coupled electromagnetic-mechanical behavior," *ASME International Mechanical Engineering Congress & Exposition*, Nov. 2018.
6. J. Wetherington, G. Garner, TT. Nichols, S. Gidcumb, E. Phillips, and M. B. Steer, "Nonlinear co-site interference measurement," *MILCOM 2018 2018 IEEE Military Communications Conference*, Oct. 2018.
7. M. B. Steer, T. G. Williamson, J. Wetherington, J. Wilkerson, P. Aaen, A. G. Schuchinsky, "Power and temperature dependence of passive intermodulation distortion," *22 nd International Microwaves and Radar Conference (MIKON 2018)*, May 2018.

8. A. Schuchinsky and M.B. Steer, “Dynamics of resistive electro-thermal nonlinearity,” *IEEE MTT-S International Conference on Numerical Electromagnetic and Multiphysics Modeling and Optimization for RF, Microwave, and Terahertz Applications*, May 2017, pp. 73–75.
9. M. Chen and M. B. Steer, “Significance of randomness in establishing hotspots in crystals,” *Proceedings of IEEE SoutheastCon 2017*, March 2017.
10. I. M. Kilgore, A. W. Kane, S. A. Kabiri, and M. B. Steer, Analysis of RF interference resulting from antenna vibration,” *Government Microcircuit Applications Conf. (GOMACtech)*, March 2016.
11. D. C. Heinz, M. L. Brennan, M. B. Steer, A. W. Melber, and J. T. Cua. “Phase response of HF/VHF Metal Detector,” In *SPIE Defense+Security*, International Society for Optics and Photonics, April, 2015.
12. I. Kilgore, J. Wetherington, and M. B. Steer, Algorithmic strategies for high dynamic range analog cancellation,” *Government Microcircuit Applications Conf. (GOMACtech)*, March 2015.
13. D.C. Heinz, M.L. Brennan, M.B. Steer, A.W. Melber, and J.T. Cua. "High to very high-frequency metal/anomaly detector." In SPIE Defense+Security International Society for Optics and Photonics, pp. 907209–907209, 2014.
14. A. Shitvov, A.G. Schuchinsky, M.B. Steer, and J.M. Wetherington, “Characterisation of nonlinear distortion and intermodulation in passive devices and antennas,” 2014 8th European Conference on Antennas and Propagation (EuCAP), pp. 1454–1458, April 2014.
15. S. Priyadarshi, W.R.Davis, and P.D. Franzon. "Pathfinder3D: A framework for exploring early thermal tradeoffs in 3DIC." *2014 IEEE International Conference on IC Design & Technology (ICICDT)*, pp. 1–6, 2014.
16. M.B. Steer, J.M. Wetherington, and J.R Wilkerson, “Investigation of close-in passive intermodulation distortion on antennas,” 2013 IEEE Antennas and Propagation Society International Symposium, pp. 2251–2252, July 2013.
17. M. B Steer, J. R Wilkerson, N. M Kriplani, and J. M Wetherington, “Why it is so hard to find small radio frequency signals in the presence of large signals,” 2012 Workshop on Integrated Nonlinear Microwave and Millimetre-Wave Circuits (INMMIC), Sept. 2012, pp. 1–3.
18. J. M Wetherington and M. B Steer, “Characterization of the dynamic range of a single aperture communications system,” 2012 Workshop on Integrated Nonlinear Microwave and Millimetre-Wave Circuits (INMMIC), Sept. 2012, pp. 1–3.
19. M. Yelten, P. D. Franzon, and M.B. Steer, “Process mismatch analysis based on reduced-order models,” 13th Int. Symposium of Quality Electronic Design (ISQED, 2012, March 2012, pp. 19–21.M. Yelten, P. D. Franzon, and M. B. Steer, “Process mismatch analysis based on reduced-order models,” *Int. Symp. of Quality Electronic Design*, March 2012.
20. C. S. Saunders and M. B. Steer, “Reduced-order modeling for co-simulation of circuit and electromagnetic interactions,” *Proceedings of the XXX General Assembly of the Union of Radio Scientists International*, August 2011, pp. 1-4.
21. T. Zhu, M. Yelten, M. B. Steer, and P. D. Franzon, “Applications of surrogate modeling in circuit design and calibration,” 1st International Conference on Simulation and Modeling Methodologies, Technologies and Applications, July 2011.
22. E. J. Wyers, M. B. Steer, C. T. Kelley, and P. D. Franzon, “Application of a modified Nelder-Mead algorithm for calibrating RF analog integrated circuits,” Government Microcircuit Applications Conf. (GOMACtech), March 2011, pp. 545–548.
23. G. Sollner, J. Smolko, S. Lardizabal, R. Molfino, M. Morton, A. Kopa, C. Wang, A. Imhoff, E. Wyers, A. Leonard, S.Lipa, P. Franzon, M. SteerJ. Bardin, F. Bohn, H. Wang, K. Dasgupta, A. Hajimiri, “Tunable Receiver for 6-18 GHz with Autonomous Self-Healing,” Microcircuit Applications Conf. (GOMACtech), March 2011.
24. G. Garner and M.B. Steer, “Standoff acoustic shear wave imaging using LFM chirps,” Microcircuit Applications Conf. (GOMACtech), March 2011.

25. E. J. Wyers, M. B. Steer, C. T. Kelley, and P. D. Franzon, "Application of a modified Nelder-Mead algorithm for calibrating RF analog integrated circuits," Government Microcircuit Applications Conf. (GOMACtech), March 2011, pp. 545–548.
26. S. Priyadarshi, N. Kriplani, T. R. Harris, and M. B. Steer, "Fast dynamic simulation of VLSI circuits using reduced order compact macromodel of standard cells," Proceedings 2010 IEEE Int. Behavioral Modeling and Simulation Conference, September 2010.
27. G. Garner, J.R. Wilkerson and M.B. Steer, "Third-order distortion of sound fields," Microcircuit Applications Conf. (GOMACtech), March 2010, pp. 513–516.
28. W. Fathelbab and M. B. Steer, "Parallel-coupled and hairpin filters with enhanced stopband performance," submitted to the Int. Journal of Circuit Theory and Applications, April 2007.
29. T. R. Harris, S. Melamed, S. Luniya, L. E. Doxsee, Jr., K. Obermiller, C. Hawkinson, W. R. Davis, P. D. Franzon and M. B. Steer, "Thermal analysis and verification of a mounted monolithic integrated circuit," Proceedings of IEEE SoutheastCon 2010, March 2010, pp. 37–40.
30. G. Garner, J.R. Wilkerson and M.B. Steer, "Generation of highly directional acoustic beams," *Microcircuit Applications Conf. (GOMACtech)*, March 2010.
31. C.S. Saunders and M.B. Steer, "Robust automated modeling of distributed microwave circuits using genetic algorithms," *Microcircuit Applications Conf. (GOMACtech)*, March 2010.
32. J.R. Wilkerson and M.B. Steer, "Passive intermodulation distortion in antennas," *Microcircuit Applications Conf. (GOMACtech)*, March 2010.
33. G.J. Mazzaro, M.B. Steer and K.G. Gard, "Time-frequency effects in wireless communication systems," *Microcircuit Applications Conf. (GOMACtech)*, March 2010.
34. Z. Feng, P.G. Lam, V. Haridasan, J.P. Maria, A.I. Kingon and M.B. Steer, "Narrowband barium strontium titanate (BST) tunable bandpass filters at X-band," *2009 IEEE MTT-S Int. Microwave Symp*. June 2009, pp. 1061–1064.
35. N.M. Kriplani, J. Fletcher, S. Langdon, C.W. Penney, S.A. Fast and M.B. Steer, "Integration of FDTD EM analysis and transient circuit simulation of RF systems," *2009 IEEE MTT-S Int. Microwave Symp*. June 2009, pp. 1577–1580.
36. G. J. Mazzaro, K. G. Gard, and M. B. Steer, "Low distortion amplification of multisine signals using a time-frequency technique," *2009 IEEE MTT-S Int. Microwave Symp*, June 2009, pp. 901–904.
37. P. D. Franzon, W. R. Davis, M. Steer, T. Thorolfsson, C. Mineo, L. McIlrath, and K. Obermiller, "CAD and design application exploration of 3DICs," Government Microcircuit Applications Conf. (GOMACTech), March 2009.
38. M. B. Steer, N. M. Kriplani, K. G. Gard, J. Hu, W. Jang, and G. J. Mazzaro, "The Origins and Modeling of Co-Site Interference in Military and Commercial Radios," Government Microcircuit Applications Conf. (GOMACtech), March 2009.
39. G. Garner III, M. Wagnborg, and M. B. Steer, "Standoff acoustical analysis of natural and manmade objects," Government Microcircuit Applications Conf. (GOMACtech), March 2009.
40. M. B. Steer, T. Doxsee, K. Obermiller, W. R. Davis, P. D. Franzon, T. R. Harris, L. McIlraith, T. Thorolfsson, and S. Melamed, "Electro-thermal modeling of packaged 3D integrated circuits," Government Microcircuit Applications Conf. (GOMACTech), March 2009.
41. T. R. Harris, N. Kriplani, P. Franzon, M. B. Steer, and R. Davis, "Reduced order electrothermal modeling of three-dimensional integrated circuits using RC networks, " submitted to Government Microcircuit Applications Conf. (GOMACTech), March 2009.
42. Z. Feng, W. M. Fathelbab, P. G. Lam, V. Haridasan, J.-P. Maria, A. I. Kingon, S. Kirchoefer, R. B. Elder and M. B. Steer, "Tunable integrated (Ba,Sr)TiO3-based bandpass filter at 67 GHz using silver/copper metallization," IEEE Radio and Wireless Conf. (RAWCON), January 2009.
43. P. D. Franzon, W. R. Davis, M. B. Steer, H. Hao, S. Lipa, S. Luniya, C.Mineo, J. Oh, A. Sule, T. Thorolfsson, L. McIlrath, K. Obermiller and T. Doxsee, "Application and design automation for 3D integrated circuits," Twenty Fifth International VLSI Multilevel Interconnection (VMIC) Conference, October 2008.

44. P. D. Franzon, W. R. Davis, M. B. Steer and K. Obermiller, "Thermal design and modeling for 3D ICs," P. D. Franzon, and M. B. Steer, "Performance driven global routing and wiring rule generation for high speed PCBs and MCMs," Proc. of the 45 th Design Automation Conf., June 8–13 2008.
45. M. B. Steer, J. Lowry, T. R. Harris, and N. Kriplani, "Multi-physics simulation using compact models: EM, circuit, thermal, molecular electronics," Workshop on Computational Multi-Physics Techniques for Analysis & Design of Electromagnetic Micro/Nano-Devices, 2008 IEEE MTT-S Int. Microwave Symp. June 2008.
46. M. B. Steer, F. Hart, N. Kriplani and A. Victor, "Phase noise measurements for emerging RF systems, Workshop on Workshop on Measurements for Wireless System-Level Evaluation, 2008 IEEE MTT-S Int. Microwave Symp. June 2008.
47. M. B. Steer, N. Kriplani and S. Luniya, "What can time-domain modeling do for RF nonlinear circuit analysis,"Workshop on Getting Accurate Results with Nonlinear Circuit Analysis, 2008 IEEE MTT-S Int. Microwave Symp. June 2008.
48. P. D. Franzon, W. R. Davis, M. B. Steer, S. Lipa, S. Luniya , T. Thorolfsson, E. C. Oh, S. Melamed, K. Obermiller, S MBerkeley, and B. Shani, "Thermal modeling of 3D Integrated Circuits," Proc. of the 45 th Design Automation Conf., June 8–13 2008.
49. P. D. Franzon, W. Rhett Davis, M. B. Steer, H. Hao, S. Lipa, S. Luniya, C. Mineo, J. Oh , A. Sule, T. Thorolfsson, S. Sapatnekar, P. Chadzynski, T. Doxsee, D. Piette and K. Obermiller, "Computer-Aided Design and Application Exploration for 3D Integrated Circuits," Government Microcircuit Applications Conf. (GOMACTech), March 2008.
50. M. Steer, G. Mazzaro, J. Wilkerson, K. Gard and A. Walker, "Exploiting Device-Circuit-Field Interactions in the Time-Frequency Domain," Government Microcircuit Applications Conf. March 2008.
51. K. G. Gard and M. B. Steer , "Time-Frequency Characterization of Nonlinear Phase and Amplitude Distortion in RF Front-End Circuits," Government Microcircuit Applications Conf.), March 2008.
52. G. Garner III, M. Skeen and M. B. Steer, "Use of Parametric Ultrasonic Arrays for Standoff Analysis and Detection," submitted to Government Microcircuit Applications Conf. March 2008.
53. T. R. Harris, S. Luniya andM. B. Steer, "Efficient Electrothermal Simulation of Three-Dimensional Integrated Circuits Using Compact Modeling," Government Microcircuit Applications Conf. March 2008.
54. J. Hu, K. G. Gard and M. B. Steer, "Extraction of Behavioral Models for Power Amplifiers with Memory Effects using Vector Signal Analysis and a Dynamic Time-Frequency Signal," Government Microcircuit Applications Conf. March 2008.
55. J. Lowry, M. Steer and K. Gard, "Behavioral Modeling of Microwave RF Power Amplifiers," submitted to Government Microcircuit Applications Conf. (GOMACTech), March 2008.
56. G. Mazzaro, M. Steer, K. Gard and K. Ranney, "Remote Electronic Device Detection using Switched-Tone Probes," submitted to Government Microcircuit Applications Conf. (GOMACTech), March 2008.
57. J. R. Wilkerson, K. G. Gard, and M. B. Steer, " Broadband High Dynamic Range Inverse Standoff Analysis" Daniel Patrick, P. Mark Buff, Kevin G. Gard and Michael B. Steer, "Environment for Experimental Development of Wire-On-Ground Detection Methods," submitted to Government Microcircuit Applications Conf. (GOMACTech), March 2008.
58. J. R. Wilkerson, K. G. Gard, M. B. Steer, "Wideband high dynamic range distortion measurement," 2008 Radio and Wireless Symposium, Jan. 2008.
59. F. Hart, N. B. Carvalho, K. G. Gard and M. B. Steer, "Modeling correlated and uncorrelated distortion in communication systems," 2008 Radio and Wireless Symposium, Jan. 2008.

60. G. Garner, J. R. Wilkerson, M. M. Skeen, D. F. Patrick, R. D. Hodges, R. D. Schimizzi, S. R. Vora, Z. Feng, K. G. Gard, and M. B. Steer, "Acoustic-RF anechoic chamber construction and evaluation," 2008 Radio and Wireless Symposium, Jan. 2008.
61. M. B. Steer, G. Mazzaro, J. R. Wilkerson and K. G. Gard, "Time-frequency effects in microwave and radio frequency electronics," Int. Conf. on Signal Processing and Communication Systems (ICSPCS,2007), Dec. 2007.
62. P. D. Franzon, W. R. Davis, M. B. Steer, H. Hao, S. Lipa, C. Mineo, J. Oh, A. Sule, T. Thorolfssun, "Design for 3D integration and applications ," Int. Symp. on Signals, Systems, and Electronics, July 2007, pp. 263–266.
63. J. Hu, K. G. Gard, N. B. Carvalho and M. B. Steer, "Dynamic time-frequency waveforms for VSA characterization of PA long-term memory effects," 69 th Automatic Radio Frequency Testing Group (ARFTG), June 2007.
64. M. Steer and N. Kriplani, "Stochastic simulation as an aid to uncertainty modeling of sensors: modeling phase noise in an oscillator," Government Microcircuit Applications Conf. (GOMACTech), March 2007.
65. Z. Feng, C. A. Bower, J. Carlson, M. Lueck, D. Temple and M. B. Steer, "High-Q solenoidal inductive elements," 2007 IEEE MTT-S Int. Microwave Symp. Dig. June 2007, In Press.
66. K. Gard, J. Wilkerson and M. Steer, "Electrothermal generation of intermodulation distortion in film resistors," Government Microcircuit Applications Conf. (GOMACTech), March 2007.
67. Z. Yang, C. A. Bower, J. Carlson, M. Lueck, D. Temple and M. Steer, "High-Q solenoidal inductive elements," 2007 IEEE MTT-S Int. Microwave Symposium Workshop, June 2007.
68. D. Temple, C. A. Bower, J. Carlson, M. Lueck, Z.–P. Feng and M.B. Steer,"A stackable silicon interposer with integrated through-wafer inductors," 2007 IEEE 27 th Electronic Components and Technology Conference Digest, May 2007.
69. A. J. Vasani, K. G. Gard, J. Nath, A. M. Victor and M. B. Steer, "Low noise amplifier with tunable matching network using thin-film barium-strontium-titanate varactor," IEEE Radio and Wireless Symp. 2007, Jan.. 2007.
70. A. M. Victor, J. Nath, K. G. Gard, J.-P. Maria, A. I. Kingon and M. B. Steer, "Tracking phase lock loop characteristics with a VCO using a Barium Strontium Titanate (BST) thin-film varactor," IEEE Radio and Wireless Symp. 2007, Jan.. 2007, pp. 289–292.
71. C. E. Christoffersen, S. Luniya, W. Batty and M. B. Steer, "Full electrothermal transient simulation of an X-band GaAs MMIC with microwave excitation, TEXPO, October 2006.
72. A. Varma, P. D. Franzon and M. B. Steer, "Developing improved IO buffer behavioral modeling methodology based on IBIS," Proc. IEEE 15 th Topical Meeting on Electrical Performance of Electronic Packaging, Oct. 2006.
73. N. M. Kriplani, A. Victor and M. B. Steer, "Time-domain modelling of phase noise in an oscillator," 36 th European Microwave Conference, Sept. 2006, pp. 514–517.
74. J. Ding, D. Linton, D. Smithand M. B. Steer, "Compact electro-thermal modelling and simulation of InP HBT based on the local reference concept," The 1 st European Microwave Integrated Circuits Conference, Sept. 2006, pp. 383–386.
75. J. R. Wilkerson, K. G. Gard and M. B. Steer, "Electro-thermal passive intermodulation distortion in microwave attenuators," 36 th European Microwave Conference, Sept. 2006, pp. 157–160.
76. A. Victor, J. Nath, D. Ghosh, S. Aygum, W. Nagy, J.-P. Maria, A. I. Kingon and M. B. Steer, "Voltage controlled GaN-on-Si HFET power oscillator using thin-film ferroelectric varactor tuning," 36 th European Microwave Conference, Sept. 2006, pp. 87–90.
77. P. D. Franzon, W. R. Davis, M. B. Steer, J. M. Wilson, Jian Xu, Hua Hao, Steve Lipa, "Contactless and via'd high-throughput 3D systems," Materials Research Society Fall 06 Meeting, 2006.
78. M. Steer, A. Mantooth, N. Kriplani and W. Jang, "Advanced device modeling using automatic differentiation in a mixed domain circuit simulator," Proc. Int. Conf. on Mixed Design of Integrated Circuit and Systems, Gdynia, Poland, 22–24 June 2006.

79. K. M. Gharaibeh, K. G. Gard and M. B. Steer, “The applicability of noise power ratio (NPR) in real communication signals,” 67 th Automatic Radio Frequency Testing Group Conf. (ARTFG), June 2006.
80. S. Luniya, W. Batty, V. Caccamesi, M. Garcia, C. E. Christoffersen, S. Melamed, W. R. Davis and M. B. Steer, “Compact electrothermal modeling of an X-band MMIC,” 2006 IEEE MTT-S Int. Microwave Symp., June 2006.
81. M. B. Steer, “The relationship of signal processing, communication technologies and RF circuit design and the impact on the future of RF and microwave education,” 16 th Int. Conf. on Microwaves, Radar and Wireless Communications (MIKON 2006) Digest., Plenary Talk, May 2006, pp. 1215–1217.
82. J. Nath, W. M. Fathelbab, P. G. Lam, D. Ghosh, S. Aygün, K. G. Gard, J.-P. Maria, A. I. Kingon and M. B. Steer, “Discrete barium strontium titanate (BST) thin-film interdigital varactors on alumina: design, fabrication, characterization and applications,” 2006 IEEE MTT-S Int. Microwave Symp., June 2006.
83. M. B. Steer, fREEDA Electromagnetic and Mixed-Physics Simulation Framework,” Workshop on Advanced Methods for EM Computing at IEEE MTT-S Int. Microwave Symp., June 16, 2006.
84. M. Li, L. Hoover, K. G. Gard and M. B. Steer, “Behavioral modeling of quadrature modulators for characterization of nonlinear distortion,” 2006 IEEE MTT-S Int. Microwave Symp., June 2006.
85. K. Gard and M. B. Steer and K. M. Gharaibeh, “Modeling and measurement of nonlinear memory effects in wireless communication systems,” Workshop on Memory Effects in Power Amplifiers at IEEE MTT-S Int. Microwave Symp., June 2006.
86. M. B. Steer, S. Luniya, J. Lowry, N. Kriplani, F. Hart, C. Christoffersen, “Simulation and modeling of substrate coupling,” Workshop on Substrate Effects in Si RFIC Interconnects at IEEE MTT-S Int. Microwave Symp., June 11, 2006.
87. A. Walker, J. Wilkerson, K. Gard and M. B. Steer, “Modeling and characterization of the intermodulation response of a remote nonlinear system,” Government Microcircuit Applications Conf. (GOMACTech), March 2006.
88. M. B. Steer, N. M. Kriplani, S. Luniya, F. Hart, J. Lowry and C. E. Christoffersen, “fREEDA: an open source circuit simulator,” Proc. 2006 Workshop on Integrated Nonlinear Microwave and Millimeter-wave Circuits, Jan. 2006.
89. M. B. Steer, K. Gard, K. Gharaibeh, A. Walker and W. Jang, “Deterministic and stochastic behavioral modeling of RF front-ends,” Proc. 2006 Workshop on Integrated Nonlinear Microwave and Millimeter-wave Circuits, Jan. 2006.
90. M. Li, K. M. Gharaibeh, K. Gard and M. B. Steer, “Accurate multisine representation of digital communication signals for characterization of nonlinear circuit,” Radio and Wireless Symp. 2006, Jan. 2006.
91. K. M. Gharaibeh, K. Gard and M. B. Steer, “Characterization of in-band front-ends using multi-sine excitation,” Radio and Wireless Symp. 2006, Jan. 2006.
92. D. Ghosh, J. Nath, J.-P. Maria, M. B. Steer and A. I. Kingon, “Tunable high Q interdigitated BST thin film interdigital capacitors on low cost alumina substrates,” Proc. American Ceramic Society Conf., 2005.
93. A. Varma, M. Steer, and P. Franzon, “A new method to achieve improved accuracy with IBIS models,” IEEE 14 th Topical Meeting on Electrical Performance of Electronic Packaging, Oct. 2005, pp 119–122.
94. M. Buff, M. Steer and G. Lazzi, `` Design of a microwave dielectric surrogate using aqueous gelatin-syrup solutions," 35 th European Microwave Conference, Oct. 2005.
95. M. B. Steer, “Asia Pacific Microwave Conference Editorial,” IEEE Transactions on Microwave Theory and Techniques, September 2005.

96. N. Carvalho, J. C. Pedro, W. Jang and M. B. Steer, “Simulation of nonlinear RF circuits driven by multi-carrier modulated signals,” 2005 IEEE MTT-S Int. Microwave Symp., June 2005.
97. A. Walker, M. B. Steer and K. Gard, “ Simple, broadband relative phase measurement of intermodulation products ,” Proc. Automatic Radio Frequency Testing Group Meeting, June 2005 .
98. A. M. Victor and M. B. Steer, “ Improved Y factor noise measurement using the second stage contribution to advantage ,” Proc. Automatic Radio Frequency Testing Group Meeting, June 2005 .
99. K. M. Gharaibeh, K. Gard and M. B. Steer, “ Estimation of in-band distortion in digital communication system ,” 2005 IEEE MTT-S Int. Microwave Symp ., June 2005.
100. J. Nath, D. Ghosh, W. Fathelbab, J.-P. Maria, A. I. Kingon, P. D. Franzon and M. B. Steer, “ A tunable combline bandpass filter using barium strontium titanate interdigital varactors on an alumina substrate ,” 2005 IEEE MTT-S Int. Microwave Symp ., June 2005.
101. K. M. Gharaibeh, K. Gard and M. B. Steer, “ Accurate estimation of nonlinear distortion metrics in digital communication system — SNR, EVM and Rho ,” Proc. of the 42 th Automatic Radio Frequency Testing Group Meeting , Dec., 2004, pp. 41–63.
102. M. B. Steer and A. C. Cangellaris, “ Modeling of spatially distributed microwave circuits ,” Workshop on Rediscovering Circuit Design Techniques For Microwave Components, Circuits And Subsystems:The Efficiency And Power Of Em/Circuit Codesign at 2005 IEEE MTT-S Int. Microwave Symp ., June 2005, pp. WFG.D.1–WFG.D.27.
103. K. M. Gharaibeh, K. Gard and M. B. Steer, “Accurate estimation of nonlinear distortion metrics in digital communication system — SNR, EVM and Rho,” *Proc. of the 42 th Automatic Radio Frequency Testing Group Meeting*, Dec., 2004, pp. 41–63.
104. M. B. Steer, “Microwave engineering in the open spectrum era,” *2005 Asia Pacific Microwave Conference*, Dec. 2004.
105. D. Ghosh, B. J. Laughlin, J. Nath, A. I. Kingon, M. B. Steer and J-P. Maria, “High Q (Ba, Sr) Tio3 interdigitated capacitors fabricated on low cost polycrystalline alumina substrates with copper metallization,” *Proc. 29 th Int. Conf. on Advanced Ceramics and Composites*, Jan. 2005.
106. M. B. Steer, “Terahertz Electronics,” *IEEE Trans. Microwave Theory and Tech.*, October 2004.
107. T. Kim, J. Nath, J. Wilson, S. Mick, P. D. Franzon, M. B. Steer and A. I. Kingon, “A High K Nanocomposite for High Density Chip-to-Package Interconnections,” *Materials Research Society Fall 04 Meeting*, Boston, Dec. 2004.
108. J. Nath, D. Ghosh, J.-P. Maria, M. B. Steer, and A. I. Kingon. “A tunable combline bandpass filter using thin film Barium Strontium Titanate (BST),” *Asia Pacific Microwave Conference*, Dec. 2004.
109. K. Gard, L. E. Larson and M. B. Steer, `` Impact of amplifier characteristics on distortion of communication circuits,” *34 th European Microwave Conference*, Oct. 2004, pp. 697–700.
110. J. Nath, D. Ghosh, J.-P. Maria, M. B. Steer, A. Kingon, and G. T. Stauf, “Microwave Properties of BST Thin Film Interdigital Capacitors on Low Cost Alumina Substrates,” *34 th European Microwave Conference*, Oct. 2004, pp. 1497–1500
111. A. Varma, M. Steer, P. Franzon, “SSN issues with IBIS models,” *Electrical Performance of Electronic Packaging*, Oct. 2004, pp 87–90.
112. K. M. Gharaibeh, K. Gard and M. B. Steer, “Understanding Nonlinear Distortion — Deterministic vs. Propabalistic,” 2005 Topical Workshop on Power Amplifiers for Wireless Communications, Sept. 2004.
113. A. M. Victor, J. Nath, D. Ghosh, B. Boyette, J.-P. Maria, M. B. Steer, A. I. Kingon and G. T. Stauf, “A voltage controlled oscillator using Barium Strontium Titanate (BST) thin film varactor,” In Press, *IEEE Radio and Wireless Conf. (RAWCON)*, Sept. 2004, pp. 91–94.
114. K. M. K. Gard and M. B. Steer, “The impact of nonlinear amplifier distortion on the performance of CDMA systems,” *IEEE Radio and Wireless Conf. (RAWCON)*, Sept. 2004, pp. 83–86.

115. M. B. Steer, "Emerging Technologies for RF Communications and Radar," *Filtronic Engineering Symposium*, Sept. 2004. (Plenary Talk)
116. A. Walker, M. Steer, K. Gard, and K. M. Gharaibeh, "Multi-slice behavioral model of RF systems and devices," *IEEE Radio and Wireless Conf. (RAWCON)*, Sept. 2004, pp. 71–74.
117. S. Luniya, M. B. Steer and C. E. Christoffersen, "High dynamic range transient simulation of microwave circuits *IEEE Radio and Wireless Conf. (RAWCON)*, Sept. 2004.
118. F. Hart, N. Kriplani; S. Luniya, C. Christoffersen and M. B. Steer "Streamlined Circuit Device Model Development with fREEDA and Adol-C," *AD 2004 — Fourth International Workshop on Automatic Differentiation*, July 2004.
119. M.B. Steer, "Multi physics multi scale modeling of microwave circuits and systems hybridizing circuit, electromagnetic and thermal modeling," *15 th Int. Conf. on Microwaves, Radar and Wireless Communications (*MIKON 2004) Digest., Plenary Talk, May 2004.
120. M. B. Steer, "Editorial: Time to Publication," *IEEE Trans. Microwave Theory and Tech.*, March 2004.
121. A. Walker, P. M. Buff and M. B. Steer, "Remote detection of RF Systems via multi-tone sinusoidal excitation," *Government Microcircuit Applications Conf. (GOMACTech)*, March, 2004.
122. M. B. Steer, "Editorial: State of the Transactions," *IEEE Trans. Microwave Theory and Tech.*, March 2004.
123. P. M. Buff and M. B. Steer, "High resolution FMCW synthetic aperture radar for electronic device imaging and interrogation," *Government Microcircuit Applications Conf. (GOMACTech)*, March, 2004.
124. J. Nath and M. B. Steer, "A straight forward method of characterizing the Intrinsic Loss Characteristics of Symmetrical Two Port Networks," *Proc. of the 62 nd Automatic Radio Frequency Testing Group Meeting*, Dec., 2003.
125. A. Varma, M. B. Steer and P. D. Franzon, "Simultaneous switching oise in IBIS models," *Proc. IEEE Electromagnetic Compatibility Conference*, 2004, pp. 1000–1004.
126. M. B. Steer, "Editorial: Publishing in the Transactions," *IEEE Trans. Microwave Theory and Tech.*, January 2004.
127. A. Varma, A. Glasser, S. Lipa, M. B. Steer and P. D. Franzon, "The development of a macro-modeling tool to develop IBIS models," *Proc. IEEE 12 th Topical Meeting on Electrical Performance of Electronic Packaging*, Oct. 2003, pp. 277–280.
128. A. Varma, P. D. Franzon and M. B. Steer, "S2IBIS — past, present and future," EIA IBIS Forum Summit Meeting, October 2003, pp. 277–280.
129. K. Gard, L. Larson and M. B. Steer, AM-AM and AM-PM Measurement of Baseband to RF Integrated Circuits for ACPR Calculations," *IEEE Radio and Wireless Conf.*, August 2003.
130. K. Gharaibeh and M. B. Steer, ``Statistical modeling of cross modulation in multichannel power amplifiers using a new behavioral modeling technique,'' *2003 IEEE MTT-S Int. Microwave Symp*., June 2003, pp. 343–346.
131. M.B. Steer, "Global modeling of microwave systems combining circuit, Thermal and Electromagnetic Modeling," *1 st East-West Worhop on Advanced Techniques in Electromagnetcis*, Invited paper, April 2004.
132. M. B. Steer, "Using technology to detect local asymmetric threats," *Government Microcircuit Applications Conf.*, March, 2003.
133. M. B. Steer, "Universal Modeling for Transient, Wavelet, and Statistical Modeling," Workshop on Fundamentals of Nonlinear Behavioral Modeling:
Foundations and Applications, *2003 IEEE MTT-S Int. Microwave Sym. June 2003.*
134. M. B. Steer, "Multifunctional adaptive radio radar and sensor system exploration environment," *Government Microcircuit Applications Conf.*, March, 2003.
135. C. W. Hicks, A. B. Yakovlev and M. B. Steer, "Slotted waveguide transitions for spatial power combining," *Applied Computational Electromagnetics Society Conference*, March 2003.

136. C. W. Hicks, A. B. Yakovlev and M. B. Steer, "Planar aperture coupled waveguide amplifier array for spatial power combining," *IEEE Radar Conference 2003*, 5-8 May 2003.
137. W. Batty, C. E. Christoffersen, A. B. Yakovlev, J. F. Whitaker, A. Mortazawi, A. Al-Zayed, M. Ozkar, S. Ortiz, R. Reano, K. Yang, L. P. B. Katehi, C. M. Snowden and M. B. Steer, "Electro-thermal simulation a complex design example: the spatial power combining MMIC array," *6th International Workshop on Thermal Investigations of ICs and Systems* (Therminic), Oct. 2002.
138. W. Y. Liu, S. Mohammadi, L. P. B. Katehi and M. B. Steer, "Polymer-membrane-supported fin-line frequency multipliers," *IEEE Radio and Wireless Conference*, August 2002.
139. K. Gharaibeh, K. Gard, H. Gutierrez and M. B. Steer, "The importance of nonlinear order in modeling intermodulation distortion and spectral regrowth," *IEEE Radio and Wireless Conference (RAWCON)*, August 2002, 161–164.
140. K. Gharaibeh and M. B. Steer, ``Statistical modeling of cross modulation in multichannel power amplifiers using a new behavioral modeling technique,'' *2003 IEEE MTT-S Int. Microwave Symp*., June 2003.
141. W. Y.Liu, M. B. Steer, S. Mohammadi, L. P. B. Katehi, "Polymer frequency multipliers", *ICMMT* 2002, Aug, 2002
142. J. Suryanarayanan, W. Y. Liu, J. Nath, B. N. Johnson, S. Mohammadi, L. P. B. Katehi and M. B. Steer, ``Toroidal inductors for integrated radio frequency and microwave circuits,'' *2003 IEEE MTT-S Int. Microwave Symp*., June 2003.
143. M. B. Steer, and J. F. Harvey, "Microwave and RF technology choices and research directions," Plenary Talk, *Mediterranean Microwave Conf*., June 2002.
144. M. B. Steer, J. F. Harvey and K. Gharaibeh, "Technology choices for multifunctional adaptive radio, radar and sensors," *Mediterranean Microwave Conf*., June 2002.
145. M. B. Steer, C. E. Christoffersen, S. Velu and N. Kriplani, "Global modeling of RF and microwave circuits", *Mediterranean Microwave Conf*., June 2002.
146. C. W. Hicks, A. B. Yakovlev and M. B. Steer, "Slotted waveguide transitions for spatial power combining," *Applied Computational Electromagnetics Society Conference*, March 2003.
147. C. W. Hicks, A. B. Yakovlev and M. B. Steer, "Planar aperture coupled waveguide amplifier array for spatial power combining," *IEEE Radar Conference 2003*, 5-8 May 2003.
148. A. B. Yakovlev, M. V. Lukich, A. Z. Elsherbeni, C. E. Smith, and M. B. Steer, "Broadband printed antennas for waveguide-based spatial power combiners," *IEEE AP-S Int. Symp. and USNC/URSI National Radio Science Meeting*, June 2002
149. W. Batty, C. E. Christoffersen, A. B. Yakovlev, J. F. Whitaker, M. Ozkar, S. Ortiz, A. Mortazawi, R. Reano, K. Yang, L. P. B. Katehi, C. M. Snowden and M. B. Steer, "Global coupled EM-electrical-thermal simulation and experimental validation for a spatial power combining MMIC Array," *2002 IEEE MTT-S Int. Microwave Symp.*, June 2002.
150. C. E. Christoffersen, S. Velu and M. B. Steer, "A universal parameterized nonlinear device model formulation for microwave circuit simulation," *2002 IEEE MTT-S Int. Microwave Symp.*, June 2002.
151. W. Y. Liu, S. Mohammadi, L. P. B. Katehi and M. B. Steer, "Polymer-membrane-supported fin-line frequency multipliers," *IEEE Radio and Wireless Conference*, August 2002.
152. A. B. Yakovlev, M. V. Lukich, A. Z. Elsherbeni, C. E. Smith, and M. B. Steer, "Broadband printed antennas for waveguide-based spatial power combiners," *IEEE AP-S Int. Symp. and USNC/URSI National Radio Science Meeting*, June 2002.
153. W. Batty, C. E. Christoffersen, A. B. Yakovlev, J. F. Whitaker, M. Ozkar, S. Ortiz, A. Mortazawi, R. Reano, K. Yang, L. P. B. Katehi, C. M. Snowden and M. B. Steer, "Global coupled EM-electrical-thermal simulation and experimental validation for a spatial power combining MMIC Array," *2002 IEEE MTT-S Int. Microwave Symp.*, June 2002.
154. W. Batty, C. E. Christoffersen, C. M. Snowden and M. B. Steer, "Fully physical coupled electro-thermal modelling of power devices and circuits,"*13th Workshop on Physical Simulation of Semiconductor Devices*, March 2002.

155. M. B. Steer, "Techniques and technologies for handling multiple channels in multifunctional adaptive radio, radar and sensor (MARRS) systems, "*Government Microcircuit Applications Conf.*, March, 2002, pp. 178–181.
156. W. Batty, A. J. Panks, C. M. Snowden, C. E. Christoffersen and M. B. Steer, "Coupled electro-thermal physical device simulation in global microwave circuit modeling," *2002 IEEE MTT-S Int. Microwave Symp. Workshop*, June 2002.
157. M. B. Steer, "Design Issues for Multifunctional Adaptive Radio Radar and Sensors," *Workshop on Intelligent RF Front-Ends at the 2002 IEEE MTT-S Int. Microwave Symp.*, June, 2002.
158. M. B. Steer, "Techniques and technologies for handling multiple channels in multifunctional adaptive radio, radar and sensor (MARRS) systems, "*Government Microcircuit Applications Conf.*, March, 2002, pp. 178–181.
159. M. B. Steer, "Commercial and military RF Technology Choices," *2002 IEEE Sarnoff Symposium*, March 2002.
160. C. E. Christoffersen and M. B. Steer, "Generalized circuit formulation for the transient simulation of circuits using wavelet, convolution and time-marching techniques," ECCTD, Nov. 2001.
161. W. Batty, C. E. Christoffersen, S. David, A. J. Panks, R. G. Johnson, C. M. Snowden and M. B. Steer, "Fully analytical compact thermal model of complex electronic power devices and packages in coupled electrothermal CAD," *7th Int. Workshop on Thermal Investigations of ICs and Systems*, Sept. 2001.
162. K. Gard, L. E. Larson and M. B. Steer, "Autocorrelation analysis of distortion generated from bandpass nonlinear circuits*," Proc. Custom Integrated Circuits Conference*, 2001, pp. 345–348.
163. M. B. Steer, P. D. Franzon and A. C. Cangellaris, " Global modelling of RF and microwave systems integrating circuit, thermal and EM analyses," Proc. MIDAS Workshop, July 2001, pp. 345–348.
164. *W. Batty, C. E. Christoffersen, S. David, A. J. Panks, R. G. Johnson, C. M. Snowden, and M. B. Steer,* "Fully physical time-dependent compact thermal modelling of complex non linear 3-dimensional systems for device and circuit level electro-thermal CAD," *Seventeenth Annual IEEE Symp. On Semiconductor Thermal Measurement and Management*, 2001. pp. 71–84.
165. A. Yakovlev, S. Ortiz, M. Ozkar, A. Mortazawi, and M. B. Steer, "Electric Green's dyadics for modeling resonance surface wave effects in a waveguide-based aperture coupled patch array," *Proc. 2001 IEEE Antennas and Propagation Symposium,* June 2001, pp. 236–239.)
166. W. L. Liu, D. P. Steenson and M. B. Steer, "Organic micromachining techniques for mass production of millimeter-wave and submillimeter-wave planar circuits," *Proc. SPIE (JM3),* 2001.
167. M. B. Steer and C.E. Christoffersen, "Transient circuit simulation using wavelets," *2002 IEEE MTT-S Int. Microwave Symposium Workshop*, May 2001.
168. C. E. Christoffersen and M. B. Steer, "Comparison of wavelet- and time-marching-based microwave circuit transient analysis," *2001 IEEE MTT-S Int. Microwave Symp. Digest*. May 2001, pp. 447–450.)
169. P. J. Rudge, R. E. Miles, M. B. Steer and C. M. Snowden, "Two-tone intermodulation distortion simulations in the time domain using a quasi-2D physical pHEMT model," *2001 IEEE MTT-S Int. Microwave Symp. Digest*. May 2001, pp. 439–442.
170. K. Gard, L. E. Larson and M. B. Steer, "Generalized autocorrelation analysis of spectral regrowth from bandpass nonlinear circuits*," 2001 IEEE MTT-S Int. Microwave Symp. Digest*. May 2001, pp. 9–12. (RF MURI)
171. W. L. Liu, D. P. Steenson and M. B. Steer, "Membrane-supported copper E-plane circuits," *2001 IEEE MTT-S Int. Microwave Symp. Digest*. May 2001, pp. 539–542.
172. M. B. Steer, J. Sevic, K. Gard, and H. Gutierrez, "Adjacent channel effects of nonlinear circuits," *2001 IEEE Sarnoff Symposium*, March 2001, pp. 12–15.
173. M. B. Steer, "Technology Integration," Technion 2001, March 14 2001, Israel.

174. M. B. Steer, C. E. Christoffersen, W. Batty and C. M. Snowden, "Electro-thermal modeling of large scale active arrays," *Government Microcircuit Applications Conference*, March, 2001.
175. S. Ortiz, M. Ozkar, A. Yakovlev, A. Mortazawi and M. Steer, "Spatially combined fault tolerant millimeter-wave power amplifiers," *2001 Government Microcircuit Applications Conf.*, March 2001.
176. J. Wood, S. Lipa, P. Franzon and M. Steer, "Multi-gigahertz, low-power, low-skew rotary clock scheme," *2001 IEEE Int. Solid-State Circuits Conf. Dig. Of Tech. Papers*, Feb. 2001, pp. 400–401.
177. W. Batty, C. E. Christoffersen, S. David, A. J. Panks, R. G. Johnson, C. M. Snowden and M. B. Steer, "Predictive microwave design by coupled electro-thermal simulation based on a fully physical thermal model," *8th IEEE Int.l Symp. on Electron Devices for Microwave and Optoelectronic Applications,* Nov. 2000.
178. W. Y. Liu, M. B. Steer and D. P. Steenson*, "*Characterization of the nonlinear device capacitance in frequency domain," *8th IEEE Int. Symp. on Electron Devices for Microwave and Optoelectronic Applications,* Nov. 2000, pp. 253–258.
179. W. L. Liu, D. P. Steenson and M. B. Steer, "A simple but novel technique of micromachining for millimeter wave and submillimeter wave applications," *IWMF'2000 Workshop*, Oct. 2000.
180. W.Y.Liu, D.P.Steenson, M.B.Steer, "A technique of micromachining suitable for fabrication of submillimeter wave components", *Proc. SPIE* 4088, pp 144-147, Sept., 2000.
181. W. Batty, C. E. Christoffersen, S. David, A. J. Panks, R. G. Johnson, C. M. Snowden and M. B. Steer, "Steady-state and transient electro-thermal simulation of power devices and circuits based on a fully physical thermal model," *6th Int. Workshop on Thermal Investigations of ICs and Systems* (Therminic 2K), Sept. 2000, pp. 125–130.
182. W. L. Liu, A. Harkar, D. P. Steenson and M. B. Steer, "A novel technique to estimate the voltage-dependent capacitance of a weakly nonlinear device," *LCS2000 Symp.,* Sept. 2000, pp. 539–542.
183. W. L. Liu, D. P. Steenson and M. B. Steer, "Membrane-supported copper E-plane circuits," *2001 IEEE MTT-S Int. Microwave Symp. Digest*. May 2001, pp. 539–542.
184. K. Gard, L. E. Larson and M. B. Steer, "Bandpass techniques for modeling and analyzing spectral regrowth," *IEEE MTT-S Santa Clara Workshop.,* June 2000.
185. A. B. Yakovlev, S. Ortiz, M. Ozkar, A. Mortazawi, and M. B. Steer, "Electromagnetic modeling and experimental verification of a complete waveguide-based aperture-coupled patch amplifier array," *2000 IEEE MTT-S Int. Microwave Symp. Digest*. June 2000.
186. M. Ozkar, S. Ortiz, A. B. Yakovlev, A. Mortazawi, and M. B. Steer, "Spatially combined fault tolerant masthead power amplifiers," *2000 IEEE MTT-S Int. Microwave Symp Workshop.,* June 2000.
187. W. L. Liu, D. P. Steenson and M. B. Steer, "A technique of microfabrication suitable for machining submillimeter-wave components," *Proc. SPIE 4176-28, First Int. Symp. On Laser Precision Microfabrication*, Sept. 2000, pp. 144–147.
188. K. Gard and M. B. Steer, "Efficient simulation of spectral regrowth using nonlinear transformation of signal statistics", *IEEE Topical Workshop on Power Amplifiers for Wireless Communications,* Sept. 1999.
189. P. J. Rudge, K. Gard, H. Gutierrez, M. B. Steer and R. E. Miles, "Modelling spectral regrowth and the effect of packet size*", 4 th IEEE High Frequency Postgraduate Student Colloqium*, Sept. 1999. pp.. 68–73.
190. H. Gutierrez, C. E. Christoffersen and M. B. Steer, "An integrated environment for the simulation of electrical, thermal and electromagnetic interactions in high-performance integrated circuits," *Proc. IEEE 6 th Topical Meeting on Electrical Performance of Electronic Packaging,,* Sept. 1999, pp. 217–220. .
191. M. B. Steer, J. W. Mink and J. F. Harvey, "Strategies for modeling the interaction of device, circuits and fields," *Proc. 1999 URSI General Assembly,* Aug. 1999.)

192. M. N. Abdulla, U.A. Mughal and M. B. Steer, "Network characterization for a finite array of folded-slot antennas for spatial power combining," *Proc. 1999 IEEE Antennas and Propagation Symp.,* July 1999, pp. 2370–2373.
193. A. I. Khalil, M. Ozkar, A. Mortazawi and M. B. Steer, "Modeling of waveguide-based spatial power combining systems," *Proc. 1999 IEEE Antennas and Propagation Symp.,* July 1999, pp. 1707–1710.)
194. A. I. Khalil, A. B. Yakovlev, and M. B. Steer, "Analysis of shielded CPW spatial power combiners," *Proc. 1999 IEEE Antennas and Propagation Symp.,* July 1999, pp. 1828–1831.)
195. A. B. Yakovlev, A. I. Khalil, C. W. Hicks and M. B. Steer, "Electromagnetic modeling of a waveguide-based strip-to-slot transition module for application to spatial power combining systems," *Proc. 1999 IEEE Antennas and Propagation Symp.,* July 1999, pp. 286–289.)
196. H. Gutierrez, K. Gard, and M. B. Steer, "Spectral regrowth in microwave amplifiers using transformation of signal statistics," *1999 IEEE MTT-S Int. Microwave Symp. Digest*. June 1999, pp. 985–988.
197. A. I. Khalil, A. B. Yakovlev, and M. B. Steer, "Efficient MOM-based generalized scattering matrix method for the integrated circuit and multilayered structures in waveguide," *1999 IEEE MTT-S Int. Microwave Symp. Digest*. June 1999.pp. 2374–2377.)
198. C. E. Christoffersen, S. Nakazawa, M. A. Summers and M. B. Steer, "Transient analysis of a spatial power combining amplifier," *1999 IEEE MTT-S Int. Microwave Symp. Digest*. June 1999, pp. 791–794.
199. M. Abdullah, U. A. Mughal, H.-S. Tsai, M B. Steer and R. A. York, "A full-wave system simulation of a folded-slot spatial power combining amplifier array, *1999 IEEE MTT-S Int. Microwave Symp. Digest*. June 1999, pp. 559–562.
200. M. B. Steer, C. E. Christoffersen, H. Gutierrez, S. Nakazawa, M. Abdulla, and T. W. Nutesson, "Modelling of Large Non-Linear Systems Integrating Thermal and Electromagnetic Models," *European Gallium Arsenide and related III-V Compounds Application Symposium*, Oct. 1998, pp. 169–174.
201. M. B. Steer, and A. I. Khalil, "Integration of Electromagnetic and Circuit Analysis," *Proc. 1998 Workshop on Integrated Nonlinear Microwave and Millimeter-wave Circuits*, Oct. 1998.
202. M. B. Steer, M. Ozkar, and C. E. Christoffersen, "Circuit level modelling of spatially distributed mm and sub mm-Wave Systems," *Proc. 1998 IEEE Sixth Int. Conf. on Terahertz Electronics Proceedings*, Sept. 1998, pp. 21–24.
203. M. B. Steer, T. W. Nuteson, C. W. Hicks, J. F. Harvey and J. W. Mink "Strategies for handling complicated device-field interactions in microwave systems," *Progress in Electromagnetics Research Symposium*, July 1998.
204. M. B. Steer, M. N. Abdulla, C. Christoffersen, M. Summers, S. Nakazawa, A. Khalil, and J. Harvey, "Integrated electro-magnetic and circuit modeling of large microwave and millimeter-wave structures," *Proc. 1998 IEEE Antennas and Propagation Symp.,* June 1998, pp 478–481.
205. H.-S. Hwang, C. W. Hicks, M. B. Steer, J. Harvey and J. W. Mink, "A quasi-optical dielectric slab power amplifier with a large amplifier array," *Proc. 1998 IEEE Antennas and Propagation Symposium,* June 1998, pp 482–485.)
206. M. Steer, "Transient analysis of electrically large microwave structures," Workshop on new developments in time Domain analysis for non-linear design, *IEEE MTT-S Int. Microwave Symposium*, 1998.
207. M. Abdullah and M. B. Steer, "A finite double layer slot array structure for spatial power combing amplifier," *Proc. 1998 IEEE Antennas and Propagation Symposium,* June 1998, pp 1206–1209.
208. C. E. Christoffersen, M. B. Steer and M. A. Summers, "Harmonic balance analysis for systems with circuit-field interactions," *Proc. 1998 IEEE MTT-S International Microwave Symp.*, June 1998, pp. 1131–1134.

209. M. A. Summers, C. E. Christoffersen, A. I. Khalil, S. Nakazawa, T. W. Nuteson, M. B. Steer, and J. W. Mink, "An integrated electromagnetic and nonlinear circuit simulation environment for spatial power combining systems," *Proc. 1998 IEEE MTT-S International Microwave Symp.*, June 1998, 1473–1476.

210. J. F. Sevic, K. L. Burger and M. B. Steer, "A novel envelope-termination load-pull method for ACPR optimization of RF/microwave power amplifiers," *Proc. 1998 IEEE MTT-S International Microwave Symp.*, June 1998, pp. 723–726.

211. K. Gard, H. Gutierrez and M.B. Steer, "A statistical relationship for power spectral regrowth in digital cellular radio," *Proc. 1998 IEEE MTT-S International Microwave Symp.*, June 1998, pp. 989–992.

212. M. Abdullah and M.B. Steer, "A partitioning approach to large scale electromagnetic problems applied to an array of microstrip coupled slot antennas," *Proc. 1998 IEEE MTT-S International Microwave Symp.*, June 1998, pp. 1783–1786.

213. B. Biswas, A. Glasser, M. Steer, P. Franzon, D. Griffis, P. Russel, "Experimental electrical characterization of on-chip interconnects," *Proc. IEEE 6 th Topical Meeting on Electrical Performance of Electronic Packaging*, Oct. 1997, pp. 57–59.

214. J. W. Mink, H. Hwang, T. W. Nuteson, M. B. Steer and J. Harvey, "Spatial power combining for two-dimensional structures," Proc. 1997 Topical Symposium on Millimeter Waves, July 1997.

215. F. Nusseibeh, T. W. Nuteson, J. Patwardhan, M. A. Summers, C. E. Christoffersen, J. Kreskovsky and M. B. Steer "Computer aided engineering environment for spatial power combining systems," *Proc. 1997 IEEE MTT-S International Microwave Symp.*, Part 2, June 1997, pp. 1073–1076.

216. M. B. Steer, T. W. Nuteson, C. W. Hicks, J. F. Harvey, and J. W. Mink, "Strategies for handling complicated device-field interactions in microwave systems," *Proc. 1996 Workshop on Integrated Nonlinear Microwave and Millimeter-wave Circuits*, Oct. 1996.

217. R. Lakhani, C. Deutschle, P. Franzon and M. Steer, "High speed bus design using HSPICE optimization techniques based on the worst case design approach," *Proc. 1996 5th Topical Meeting on Electrical Performance of Electronic Packaging,* Oct. 1996, pp. 93–96.

218. M. B. Steer, T. W. Nuteson, C. W. Hicks, J. Harvey and J. W. Mink, "Strategies for handling complicated device-field interactions in microwave systems," Progress in Electromagnetics Research Sympoium, July 1996.

219. J. F. Harvey and M. B. Steer, "A Unified Electromagnetic, Nonlinear Circuit, and Thermal Analysis for Complex Spatial Power Combining Architectures," WRI Int. Symp. on Directions for the next Generation of MMIC Devices and Systems, June 1997.

220. M. Steer, "RF design for wireless," *Proc. of the 1996 International Symposium on Circuits and Systems: Emerging Technologies Designing Low Power Digital Systems,* June 1996, pp. 331–367.

221. S. Mehrotra, P. Franzon, G. Bilbro and M. Steer, "CAD tools for managing signal integrity and congestion simultaneously,"*Proc. 3rd Topical Meeting on Electrical Performance of Electronic Packaging*, Oct. 1994, pp. 30–32.

222. J. F. Harvey, T. W. Nuteson, J. Patwardhan, M.A. Summers, C. E. Christoffersen, F. Nusseibeh, J. Kreskovsky, and M.B. Steer, "A unified electromagnetic, nonlinear circuit, and thermal analysis for complex spatial power combining architectures," *Proc. WRI Int. Symp. on Directions for the next Generation of MMIC Devices and Systems*, June 1997.

223. J. Harvey, M. B. Steer, T. W. Nuteson, J. W. Mink, and A. Paolella, "Advances in quasi-optical power combiners provide path to radar and communications enhancements," *Proc. 21 st Army Science Conf.*, June 1996, pp. 121–125.

224. H. Hwang, T. W. Nutesson, M. B. Steer, J.W. Mink, J. Harvey and A. Paolella, "A 2-dimensional slab quasi-optical power combining system," *Proc. 1996 URSI Conf.*, July 1996.

225. H. Hwang, T. W. Nutesson, M.B. Steer, J. W. Mink, J. Harvey and A. Paolella, "Two-dimensional quasi-optical power combining system performance and component design," *1996 IEEE MTT-S Int. Microwave Symp. Digest*, June 1996, pp. 927–930.

226. T. W. Nuteson, M. B. Steer, K. Naishadham, J. W. Mink, and J. Harvey, "Electromagnetic modeling of finite grid structures in quasi-optical systems," *1996 IEEE MTT-S Int. Microwave Symp. Digest*, June 1996, pp. 1251–1254.

227. J. F. Sevic, M. B. Steer and A. M. Pavio, "Large-signal automated load-pull characterization of adjacent channel power for digital wireless," *1996 IEEE MTT-S Int. Microwave Symp. Digest*, June 1996, pp. 763–766.

228. H. Hwang, T. W. Nutesson, M. B. Steer, J. W. Mink, J. Harvey and A. Paolella, "Slab-based quasi-optical power combining system," *Proc. 20 th Infrared and Millimeter-Wave Conf.*, Orlando Florida, Dec. 1995., pp. 157–158.

229. H. Hwang, T. W. Nutesson, M. B. Steer, J. W. Mink, J. Harvey and A. Paolella, "Quasi-optical power combining techniques for dielectric substrates," *Int. Semiconductor Device Research Symp.*, Dec. 6-8, 1995, pp. 243–246.

230. H. Hwang, T. W. Nutesson, M. B. Steer, J.W. Mink, J. Harvey and A. Paolella, "Quasi-optical power combining in a dielectric substrate," *Int. Symp. on Signals, Systems and Electronics*, URSI Symp. Oct. 25–27, 1995, pp. 89–92.

231. M. B. Steer, "Quasi-optical power combining in a dielectric substrate," *Int. Symp. on Signals, Systems and Electronics*, October 1995.

232. J. F. Sevic, R. Baeten, G. Simpson, and M. B. Steer, "Automated large-signal load-pull characterization of adjacent channel power ratio for digital wireless communication systems," *Proc. of the 46 th Automatic Radio Frequency Testing Group Meeting*, Oct. 1995, pp. 64–70.

233. A. W. Glaser, M. B. Steer, P. D. Franzon, G. Shedd, and P. Russell, "A method for on-chip interconnect characterization," *Proc. IEEE 4 th Topical Meeting on Electrical Performance of Electronic Packaging*, Oct. 1995, pp. 108–110.

234. J. F. Sevic, and M. B. Steer, "Analysis of GaAs MESFET spectrum regeneration driven by a pi/4-DQPSK modulated source," *1995 IEEE MTT-S Int. Microwave Symp. Digest*, May 1995, pp. 1375–1378.

235. T. W. Nuteson, G. P. Monahan, M. B. Steer, K. Naishadham, J. W. Mink, and F. K. Schwering, "Use of the moment method and dyadic green's functions in the analysis of quasi-optical structures," *1995 IEEE MTT-S Int. Microwave Symp. Digest*, May 1995. pp. 913–916.

236. H. Hwang, G. P. Monahan, M. B. Steer, J. W. Mink, and F. K. Schwering, "A dielectric slab waveguide with four planar power amplifiers," *1995 IEEE MTT-S Int. Microwave Symp. Digest*, May 1995. pp. 921–924

237. F. Poegel, S. Irrgang, S. Zeisberg, A. Schuenemann, G. P. Monahan, H. Hwang, M. B. Steer, J. W. Mink, and F. K. Schwering, "Demonstration of an oscillating quasi-optical slab power combiner," *1995 IEEE MTT-S Int. Microwave Symp. Digest*, May 1995. pp. 917–920.

238. S. Mehrotra, P. D. Franzon, and M. B. Steer, "Performance driven global routing and wiring rule generation for high speed PCBs and MCMs," *Proc. of the 32nd Design Automation Conf.*, June 12–16 1995, pp. 381–387.

239. S. Mehrotra, P. D. Franzon, G. L. Bilbro and M. B. Steer, "CAD tools for managing signal integrity and congestion simultaneously," *Topical Meeting on Electrical Performance of Electronic Packaging*, Nov. 2–4, 1994.

240. P. J. Doherty, C. A. Andrews, N. R. Lenaeus, M. B. Steer and J. Dahl, "PCMCIA weather satellite receiver," *Proc. of the 1995 IEEE Southeastcon '95 Conf.*, March 26–29 1995, pp. 240–243

241. M. S. Basel, M. B. Steer, and P. D. Franzon, "Hierarchical simulation of high speed digital interconnects using a packaging simulator," *Proc. 44 rd Electronic Components and Technology Conf.*, May 1994, pp. 81–87.

242. M. Sengupta, S. Lipa, P. D. Franzon and M. B. Steer, "Crosstalk design advise," *Proc. 44 rd Electronic Components and Technology Conf.*, May 1994, pp. 687–694.
243. J. W. Mink, F. W. Schwering, P. L. Heron, G. P. Monahan, A. Schuneman, S. Zeisberg, and M. B. Steer, "A hybrid dielectric slab-beam waveguide, theory and experiment," *19 th Army Science Conf.*, June 1994.
244. M. B. Steer and S. G. Skaggs, "CAD of GaAs microwave circuits: historical perspective and future trends," invited paper, *Korea-United States Design and Manufacturing Workshop*, Nov. 17–19, 1993, pp. 109–118.
245. A. Schuneman, S. Zeisberg, P. L. Heron, G. P. Monahan, M. B. Steer, J. W. Mink, F. W. Schwering, "A prototype quasi-optical slab resonator for low cost millimeter-wave power combining," *Workshop on Millimeter-Wave Power Generation and Beam Control*, Huntsville, Alabama, Sept. 14 – 16, 1993, pp. 235–243.
246. M. B. Steer, S. Lipa, P. D. Franzon and A. C. Cangellaris, "Experimental characterization of interconnects and discontinuities in thin-film multichip module substrates," invited paper, *Electrical Performance of Electronic Packaging*, Monterrey, California, Oct. 20–22, 1993, pp. 145–147.
247. S. Simovich, S. Mehrotra, P. D. Franzon, M. B. Steer, Z. Rakib and G. Simpson, "A signal integrity advisor for automated packaging design," *Electrical Performance of Electronic Packaging*, Monterrey, California, Oct. 20–22, 1993, pp. 55–57.
248. M. B. Steer, "A prototype quasi-optical slab resonator for low cost millimeter-wave power combining, *Workshop on Millimeter-Wave Power Generation and Beam Control*, September 1993.
249. P. D. Franzon and M. B. Steer, "Macromodels for generating signal integrity and timing management advice for package design," *43 rd Electronic Components and Technology Conf.*, June 1993.
250. P. D. Franzon, S. Simovich, S. Mehrotra and M. B. Steer, "Macromodels for generating signal integrity and timing management advice for package design," *Proc. 43 rd Electronic Components and Technology Conf.*, June 1993, pp. 523–529.
251. S. Simovich, P. D. Franzon and M. B. Steer, "A simple method for noise tolerance characterization of digital circuits," *Proc. Third IEEE Great Lakes Symp. on VLSI Systems*, March 5–6, 1993, pp. 52–56.
252. A. Schuneman, S. Zeisberg, G. P. Monahan, F.W. Schwering, J. W. Mink, and M. B. Steer, "Experimental investigation of a quasioptical slab resonator," *Proc. 1993 URSI Conf.*, June 1993, p. 27.
253. P. L. Heron, G. P. Monahan, F. W. Schwering, J. W. Mink, and M. B. Steer "Multiport circuit model of an antenna array in an open quasi-optical resonator," *Proc. 1993 URSI Conf.*, June 1993, p. 84.
254. P. L. Heron, G. P. Monahan, J. E. Byrd, M. B. Steer, F. W. Schwering and J.W. Mink, "Circuit level modeling of quasioptical power combining open cavities," *1993 IEEE MTT-S Int. Microwave Symp. Digest*, June 1993, pp. 433–436.
255. S. Simovich, P. D. Franzon, and M. B. Steer, "A simple method for noise tolerance characterization of digital circuits," *Proc. of the 3rd Great Lakes Symposium on Design Automation of High Performance VLSI Systems,* 1993, pp. 52–56.
256. P. D. Franzon, S. Simovich, S. Mehrotra, and M. B. Steer, "Automatic a-priori generation of delay and noise macromodels and wiring rules for MCMs," *Proc. 1993 IEEE Multi-Chip Module Conf.*, Feb. 1993, pp. 185–190.
257. M. B. Steer, "Simulation of microwave and millimeter-wave oscillators, present capability and future directions," *Proc. 1992 Workshop on Integrated Nonlinear Microwave and Millimeter-wave Circuits*, Oct. 1992, pp. 47–60.

258. P. D. Franzon, S. Mehrotra, S. Simovich, M.B. Steer, "Automating design for signal integrity*",* *Topical Meeting on Electrical Performance of Electronic Packaging*, Tucson, Arizona, April 23, 1992, pp. 10–13.
259. M. B. Steer and P. D. Franzon, "Microwave characterization of thin-film multi-chip module substrates and printed wiring boards accounting for frequency-dependent characteristic impedance," *Topical Meeting on Electrical Performance of Electronic Packaging*, Tucson, Arizona, April 23, 1992, pp. 125–127.
260. P. D. Franzon, S. Simovich, M. B. Steer, M. Basel, S. Mehrotra, and T. Mills, "Tools to aid in wiring rule generation for high speed interconnects," *Proc. 29th Design Automation Conf.*, June 8–12 1992, pp. 466–471.
261. M. B. Steer, S. B. Goldberg, G. Rinne, P.D. Franzon, I. Turlik and J. S. Kasten, "Introducing the through-line deembedding procedure," *1992 IEEE MTT-S Int. Microwave Symp. Digest*, June 1992, pp. 1455–1458.
262. J. Karaoguz, S. H. Ardalan and M. B. Steer and C. R. Chang, "An integrated simulation environment for design and analysis of mobile communication systems," *Proc. IEEE SOUTHEASTCON '92*, April 1992, pp 650–653.
263. P. D. Franzon, M. B. Steer, R. S. Gyurcsik, M. S. Basel, S. Elassad, J.N. Hall, T. Mills, S. Simovich, "Tools and techniques for the design of high speed multichip modules," *1991 Japan IEMT Symp.*.
264. M. S. Basel, M. B. Steer, P. D. Franzon and D. Winkelstein, "High speed digital system simulation using frequency dependent transmission line network modeling," *1991 IEEE MTT-S Int. Microwave Symp. Digest*, June 10–14, 1991, pp. 987–990.
265. M. B. Steer, "Simulation of nonlinear microwave circuits-an historical perspective and comparisons," (invited), *1991 IEEE MTT-S Int. Microwave Symp. Digest*, Boston Masachussets, June 10–14 1991, pp. 599–602.
266. M. B. Steer and R.G. Hicks, "Characterization of diodes in a coaxial measurement system," *1991 IEEE MTT-S Int. Microwave Symp. Digest*, Boston Masachussets, June 10–14, 1991, pp. 173–176,
267. S. B. Goldberg, M. B. Steer, and P. D. Franzon, "Accurate experimental characterization of three-ports," *1991 IEEE MTT-S Int. Microwave Symp. Digest*, Boston Masachussets, June 10–14, 1991, pp. 241–244.
268. S. G. Skaggs, M. B. Steer and G. L. Bilbro "Parameter optimization for microwave device modeling," *The North Carolina Symp. and Exhibition-El-Tech '91.*, May 1991.
269. P D Franzon and M. B. Steer, "Interconnect modeling and simulation for high speed MCM," *1991 Multichip Module Workshop*, March 28–29, 1991, pp. 122–129.
270. M. B. Steer, "Circuit Level Modeling and Simulation of Quasi-Optical Power Combiners," *Workshop on Quasi-Optical Power Combiners*, Sept. 1991.
271. S. B. Goldberg, M. B. Steer, P. D. Franzon and J. S. Kasten, "Experimental electrical characterization of high speed interconnects," *Proc. 41 st Electronic Components and Technology Conf.*, Atlanta Georgia, May 11–16 1991, pp. 85–88.
272. M. B. Steer and P. D. Franzon "Circuit Simulation with Distributed Elements," *MCNC Workshop on Circuit and Process Simulation*, Nov. 6, 1990.
273. P. Franzon, M. B. Steer, S. Elassaad, M. S. Basel, H. A. Deshmane, L-T Hwang, I. Turlik, and D. Winkelstein, "CAD Tools for the automated design of high speed multichip modules," *Proc. Int.l Electronic Packaging Conf.*, Sept. 1990, pp. 864–583.
274. P. Franzon and M. B. Steer "CAD tools for the automated design of high speed multi-chip modules," *Proc. 1990 VLSI Educators Conf.*
275. M. B. Steer, G. L. Bilbro, R. J. Trew and S. G. Skaggs, "Parameter extraction of microwave transistors using tree annealing," *1989 IEEE/Cornell Conf. Digest*, pp. 195–200, Aug. 1989.
276. P. L. Heron, C.R. Chang and M. B. Steer, "Control of aliasing in harmonic balance analysis of nonlinear circuits," *1989 IEEE MTT-S Int. Microwave Symp. Digest*, June 1989.

277. D. Winkelstein, R. Pomerleau and M. B. Steer, "Transient simulation of complex, lossy, multi-port transmission line networks with non-linear digital device termination using a commercially available circuit simulator," *SOUTHEASTCON'89 Convention Digest*, April 1989.
278. G. Stewart, R. Pomerleau and M. B. Steer, "Microstrip discontinuity modeling," *SOUTHEASTCON'89 Convention Digest*, April 1989, pp. 107–111.
279. M. Kay, R. Pomerleau and M. B. Steer, "Emperical statistical modeling of planar transmission line structures accounting for manufacturing variations," *SOUTHEASTCON'89 Convention Digest*, April 1989.
280. C. Barfield, R. Pomerleau and M. B. Steer, "Macromodels of digital devices for high speed digital circuit simulation," *SOUTHEASTCON'89 Convention Digest*, April 1989.
281. H. Riedell, R. Pomerleau, M. B. Steer and M. S. Basel, "Dielectric characterization of printed circuit substrates," *SOUTHEASTCON'89 Convention Digest*, April 1989.
282. J. N. Hall, S. H. Ardalan, M. S. Basel, R. Pomerleau, D. O. Riddle and M. B. Steer "High-speed printed circuit board analysis and simulation in a workstation environment," *Proc. RF Expo East 88*, Oct. 1988, pp. 263–274.
283. D. Winkelstein, R. Pomerleau and M. B. Steer, "Simulation of complex PCB layouts including coupled tracks with non-linear digital device termination," *Proc. RF Expo East 88*, Oct. 1988, pp. 359–366.
284. J. Kasten, M. B. Steer and R. Pomerleau, "Calibration of a measurement system with symmetrical test fixtures," *Proc. RF Expo East 88*, Oct. 1988, pp. 367–379.
285. C. R. Chang, P. L. Heron, M. B. Steer, G. W. Rhyne, D. O. Riddle and R. S. Gyurcsik, "Computer simulation of nonlinear RF and microwave circuits," *Proc. .RF Expo East 88*, Oct. 1988, pp. 333–342.
286. G. Brauns, M. B. Steer, S. Ardalan and J. Paulos, "ZSIM: A nonlinear z-domain simulator for delta-sigma modulators," *1987 IEEE Int. Conf. on Computer Aided Design*, Nov. 1987, pp. 538–541.
287. G. W. Rhyne, M. B. Steer and B. D. Bates, "Analysis of nonlinear circuits driven by multi-tone signals using generalized power series analysis," *IEEE Int. Symp. on Circuits and Systems*, 1987, pp. 903–906.
288. G. W. Rhyne and M. B. Steer, "Generalized power series analysis of intermodulation distortion in a MESFET amplifier: simulation and experiment," *Proc. 1987 IEEE MTT-S Int. Microwave Symp. Digest*, June 1987, pp. 115–118.
289. M. B. Steer and R. J. Trew, "Comparison of the gain and frequency performance of state-of-the-art MESFET, MODFET and HBT millimeter-wave transistors," *IEEE Int. Symp. on Circuits and Systems*, 1987, pp. 19–22.
290. J. Paulos, G. Brauns, M. B. Steer and S. Ardalan "Improved signal-to-noise ratio using tri-level delta-sigma modulation," *IEEE Int. Symp. on Circuits and Systems*, 1987, pp. 463–466.
291. R. J. Trew and M. B. Steer, "Comparison of millimeter-wave MESFET, HEMT & PBT performance," Presented at the *1987 Workshop on Compound Semiconductor Microwave Materials and Devices (WOCSEMMAD - 1987)*, March 2–4, 1987.
292. M. B. Steer, "True frequency domain analysis of nonlinear circuits with multifrequency excitation," Presented at the *Workshop on Modeling High Speed GaAs Devices and Non-Linear CAD*, February 3–4, 1987.
293. R. J. Trew, M. B. Steer and D. Chamberlain, "Parasitic effects upon the high-frequency performance of three-terminal devices*," Proc. 3 rd GaAs Simulation Workshop*, Duisburg, Germany, Oct. 7–8, 1986.
294. G. W. Rhyne and M. B. Steer, "Simulation of intermodulation distortion in MESFET circuits with arbitrary frequency separation of tones,"*1986 IEEE MTT-S Int. Microwave Symp. Digest*, June 1986, pp. 547–550.
295. G. W. Rhyne and M. B. Steer, "A new frequency domain approach to the analysis of nonlinear microwave circuits," *1985 IEEE MTT-S Int. Microwave Symp. Digest*, 1985, pp. 401–404.

296. M. B. Steer, "Gain saturation in circulator coupled reflection amplifiers," *1985 IEEE MTT-S Int. Microwave Symp. Digest*, June 1985, pp. 395–398.
297. M. B. Steer, "Multifrequency analysis of nonlinear circuits," *SOUTHEASTCON'85 Convention Digest*, May 1985, pp. 116–120.
298. M. B. Steer and P. J. Khan, "Large signal analysis of nonlinear microwave systems," *1984 IEEE MTT-S Int. Microwave Symp. Digest*, June 1984, pp. 402–403.
299. M. B. Steer and P. J. Khan, "Intermodulation analysis of mixers," *IREECON International Convention Digest*, IREE, Melbourne, Australia, 24–28 Aug. 1981, pp. 97–99.
300. M. B. Steer, B. D. Bates and P. J. Khan, "Millimeter-wave resonant-cap diode mounts," *Radio Research Board Symposium on Millimeter Wave Techniques and Their Application*, Sydney, Australia, 13–15 Feb. 1980.
301. M. B. Steer and P. J. Khan, "Nonlinear and radial line considerations in parametric amplifier analysis," *IREECON International Convention Digest*, IREE Australia, Sydney, 27–31 Aug. 1979, pp. 387–390.

APPENDIX A

Michael B. Steer

APPOINTMENTS OR ELECTION TO STUDY SECTIONS AND EDITORIAL BOARDS

IEEE Transactions on Microwave Theory and Techniques. Member of the editorial board, 1990–present.
International Journal of Microwave and Millimeter Wave Computer Aided Engineering, Member of the editorial board, 1990–2003, 2007–2012.
International Journal of Numerical Modelling. Member of the editorial board, 2007–2012.
IEEE Transactions on Microwave Theory and Techniques, Editor-In-Chief, 2003–2006
IEEE Panel of Editors, 2004–2006, 2016–2018
Chair of the Publications Committee, IEEE Microwave Theory and techniques Society, 2016–2018

BOOK CHAPTERS

1. T. Zhu, M. B. Yelten, M. B. Steer, P. D. Franzon, "Model-Based Variation-Aware Integrated Circuit Design," in Surrogate-Based Modeling and Optimization, 2013, pp. 171–188.
2. T. Zhu, M. Berke Yelten, M. B. Steer, and P. D Franzon, "Variation-Aware Circuit Macromodeling and design based on surrogate models," Simulation and Modeling Methodologies, Technologies and Applications, 2014, pp. 255–269.
3. T. Zhu, M. B. Yelten, M. B. Steer, and P. D. Franzon, "Application of surrogate modeling in variation-aware macromodeland circuit design," in Advances in Intelligent and Soft Computing Series, Springer-Verlag, (In Press) , 2013.
4. T. Zhu, M. B. Yelten, M. B. Steer, and P. D. Franzon, "Variation-aware circuit macromodel and design based on surrogate models," in Simulation and Modeling Methodologies, Technologies and Applications, Advances in Intelligent Systems and Computing, Edited by N. Pina, J. Kacprzyk and J. Filipe, Springer, pp. 255–269, 2013.
5. M. B. Steer, K. G. Gard and A. Victor, "RF System Design," in Multifunctional Adaptive Microwave Circuits and Systems, Edited by M. B. Steer and W. D. Palmer, 2009.
6. W. M. Fathelbab and M. B. Steer, "Tunable Filters," in Multifunctional Adaptive Microwave Circuits and Systems, Edited by M. B. Steer and W. D. Palmer, 2009.
7. W. M. Fathelbab and M. B. Steer, "Broadband Network Design," in *Multifunctional Adaptive Microwave Circuits and Systems*, Edited by M. B. Steer and W. D. Palmer, 2009.
8. M. B. Steer, "Passive Microwave Devices," in *RF and Microwave Handbook,* Edited by M. Golio and J. J. Golio, CRC Press, 2007.
9. M. B. Steer and J. F. Sevic, "Nonlinear RF and Microwave Circuit Analysis," in RF and Microwave Handbook, Edited by M. Golio and J. J. Golio, CRC Press, 2007.
10. M. B. Steer, "Microwave Devices: Passive Microwave Devices," in Electronics, Power Electronics, Optoelectronics, Microwaves, Electromagnetics , and Radar, Edited by R. C. Dorf , 2006.
11. F. P. Hart, N. Kriplani, S. R. Luniya, C. E. Christoffersen and M. B. Steer, "Streamlined Circuit and Device Model Development with fREEDA and ADOL-C," in Automatic Differentiation: Applications, Theory, and Implementations , edited by H. M. Bucker, G. F. Corliss, P. Hovland, U. Naumann and B. Norris, Series: Lecture Notes in Computational Science and Engineering, Vol. 50, Springer, New York, NY, 2005.
12. M. B. Steer and K. M. Gharaibeh , " Volterra Modeling for Analog and Microwave Circuits," in Encyclopedia of RF and Microwave Engineering , John Wiley, 2005, pp. 5507–5514.
13. M. B. Steer and J. F. Sevic, "Nonlinear RF and Microwave Circuit Analysis," in *Commercial Wireless Circuits and Components Handbook,* Edited by M. Golio, CRC Press, 2002.
14. M. B. Steer, "Passive Microwave Devices," in Modern Microwave and RF Handbook , Edited by M. Golio and J. J. Golio, CRC Press, 2001.

15. M. B. Steer and J. F. Sevic, "RF and Microwave Circuit Simulation," in Modern Microwave and RF Handbook , Edited by M. Golio and J. J. Golio, CRC Press, 2001.
16. J. W. Mink, M. B. Steer, and J. Wiltse, "Quasi-Optical Power Combining: A Perspective," in Active Antennas & Quasi-optical Arrays , Edited by A. Mortazawi, T. Itoh & J. Harvey," IEEE Press, 1998.
17. J. F. Harvey, M.B. Steer, H.-S. Hwang, T.W. Nuteson, C.W. Hicks, and J.W. Mink, ``Distributed power combining and signal processing in a 2-D quasi-optical system," Chapter 10 in *Directions for the Next Generation of MMIC Devices and Systems,* Edited by N.K. Das and H.L. Bertoni, Plenum Press, 1997.
18. M. B. Steer, J. Mink, and H.-S. Hwang, "Planar Quasi-Optical Power Combining," in Active and Quasi-Optical Arrays for Solid-State Power Combining , Edited by R. A. York and Z. B. Popovic, 1997.
19. M. B. Steer, "Passive Microwave Devices," in The Electronics Handbook , Edited by J. Whitaker, CRC Press, 1996.
20. M. B. Steer, "RF Design for Wireless," in Emerging Technologies: Designing Low Power Digital Systems , Edited by W. Liu and R. Cavin, IEEE Press, 1996.
21. P. Franzon and M. Steer, "Tools and Techniques for the Design of High Speed Multichip Modules," in Electronics Packaging , Volume 3, Chapter 7, IEEE Press, 1993, pp. 245–264.
22. M. B. Steer, "Passive Microwave Devices," in The Electrical Engineering Handbook , Edited by R. Dorf, CRC Press, 1993, pp. 882–891.
23. R. J. Bishop, J. J. Paulos, M. B. Steer and S. H. Ardalan, "Table-based simulation of delta-sigma modulators," in Oversampling Delta-Sigma Data Converters: Theory, Design and Simulation , edited by J.C. Candy and G.C. Thames, IEEE Press 1992, pp. 163–167.
24. J. Paulos, G. Brauns, M. B. Steer, "Improved signal-to-noise ratio using tri-level delta-sigma modulation," in Oversampling Delta-Sigma Data Converter Theory, Design and Simulation , edited by J. C. Candy and G. C. Thames, IEEE Press 1992, pp. 245–248.

<u>BOOKS</u>

1. M. B. Steer, *Microwave and RF Design: Radio Systems*, NC State University, 2019, ISBN: 978-4696-5690-8 and 978-4696-5691-4.
2. M. B. Steer, *Microwave and RF Design: Transmission Lines*, NC State University, 2019, ISBN: 978-4696-5692-2 and 978-4696-5693-9.
3. M. B. Steer, *Microwave and RF Design: Networks*, NC State University, 2019, ISBN: 978-4696-5694-6 and 978-4696-5695-3.
4. M. B. Steer, *Microwave and RF Design: Modules*, NC State University, 2019, ISBN: 978-4696-5696-0 and 978-4696-5697-7.
5. M. B. Steer, *Microwave and RF Design: Amplifiers and Oscillators*, NC State University, 2019, ISBN: 978-4696-5698-4 and 978-4696-5699-1.
6. M. B. Steer, *Fundamentals of Microwave and RF Design*, NC State University, 2019, ISBN: 978-4696-5688-5 and 978-4696-5689-2.
7. T. C. Edwards and M. B. Steer, *Foundations for Microstrip Circuit Design,* John Wiley & Sons, 2016. ISBN: 978-1-11893-619-1
8. M. B. Steer, *Microwave and RF Design: A Systems Approach*, Second Edition, IET/SciTech Publishing, 2013, ISBN: 978-1-61353-021-4.
9. M. B. Steer, *Microwave and RF Design: A Systems Approach*, First Edition, SciTech Publishing, 2010. ISBN: 978-1-89112-182-1.
10. M. B. Steer and W. D. Palmer, *Multifunctional Adaptive Microwave Circuits and Systems*, SciTech Publishing, 2009. ISBN: 9781891121777.

11. T. C. Edwards and M. B. Steer, *Foundations of Interconnect and Microstrip Design,* Third Edition, John Wiley & Sons, 2000. ISBN: 978-0-47160-701-4
12. M. B. Steer, *Large Signal Analysis of Nonlinear Microwave Devices,* Ph.D. Dissertation, University of Queensland, Brisbane, Australia, March 1983.

B. GRANTS AND CONTRACTS

List externally and internally sponsored grants and contracts as well as non-sponsored and independent programs that have supported your scholarship; indicate funding levels and duration.

Complete Listing

- Co-Principal Investigator, Radio Disruption of Electronic Systems (RADES), $64,906, March 31 2020 – July 6 2020.
- Co-Principal Investigator, ROTC Research Experiences in Naval Electronic Warfare (RENEW), $249,919, September 30 2019 – September 29 2021.
- Principal Investigator, "Modeling of Vibration-Enhanced Underground Sensing (VENUS)," Vadum Inc. contracting with Army Research, Development, and Engineering Command, $300,000, October 1 2017 – September 14 2020.
- Principal Investigator, "Modeling and Radio Frequency Characterization of Magnetically Stimulated Vibrations," Vadum Inc. contracting with Army Research, Development, and Engineering Command, $49,582, August 15 2016 – February 14 2017.
- Principal Investigator, "Transient Capture of Microwave Signals," Army Research Office, $80,750, April 28 2016 – April 27 2017.
- Principal Investigator, "High Dynamic Range Measurement System," Army Research Office, $28,288, August 13 2015 – August 12 2016.
- Principal Investigator, "Exploration and Discovery of Signals in the Analog Domain," Army Research Office, $50,000, October 1 2015 – June 30 2016.
- Co-Principal Investigator, "Collaborative Research: Planning Grant: I/UCRC for Advanced Electronics Through Machine Learning," NSF, $11,499, April 15 2015 – March 31 2016.
- Co-Principal Investigator, "Leveraging Commercial Flows for Heterogeneous Integration," DARPA, $1,504,642, 6 May 2013 – 28 February 2017.
- Principal Investigator, "Exploration and Discovery of Signals in the Analog Domain" US Army Research Office, $50,000, October 1 2015 – June 30 2016.
- Principal Investigator, "Time-Frequency and Non-Laplacian Phenomena," US Army Research Office, $450,000, 9 Sept. 2012 – 30 September 2016.
- Principal Investigator, "Sound and Electromagnetic Interacting Waves," Office of Naval Research, $7,090,000, 1 Aug. 2010 – 30 June 2017.
- Principal Investigator, "Multi-Physics Field and Circuit Computational Modeling in the Time Domain," REMCOM, $300,000, 1 Oct. 2010–15 March 2013.
- Principal Investigator, "Advanced audio workshop," US Army Research Office, $16,083, 1 June 2010–31 May 2012.
- Co- Principal Investigator, "High Performance Tunable Materials Phase II," Defense Microelectronics Activity, $1,525,334, 20 June 2011 – 31 Jan. 2014.
- Co- Principal Investigator, "High Performance Tunable Materials Program," Defense Microelectronics Activity, $1,112,900, 10 October 2009 – 30 Sept. 2013.
- Co- Principal Investigator, Algorithms and Structures For Self Healing Circuits (SHAMROC), DARPA, $1,388,341, 29 July 2009 – 31 May 2013.
- Principal Investigator, Advanced Audio Workshop, US Army Research Office, 1 June 2010 – 31 May 2012.
- Principal Investigator, "Electrical Network Design and Characterization For Three Dimensional Integrated Circuits," DARPA through Boise State University, $140,000, 1/1/2007–4/30/2011.

- Principal Investigator, " Optimum Waveform Design for Electromagnetic Disruption and Probing of Remote Devices," $990,100, 1 November 2006–31 October 2010, JIEDDO through U.S. Army Research Office.
- Principal Investigator, "SIAMES: Standoff Inverse Analysis And Manipulation of Electronic Systems," $5,050,600, 1 May 2005–30 August 2011, U.S. Army Research Office.
- Principal Investigator, "Computer Aided Design of Three Dimensional Integrated Circuits," DARPA as a subcontract through PTC, Inc.," $1,820,000, 1 July 2004–10 January 2010.
- Principal Investigator, "Mixed-Signal Interposer Design and Fabrication (as subcontract to Purdue University), $743,534, 1 May 2002–28 February 2007.
- Principal Investigator, "MARRS: Multifunctional Adaptive Radio Radar and Sensors," Multidisciplinary University Research Initiative, $6,000,000, 1 May 2001–31 January 2007, U.S. Army Research Office.
- Principal Investigator, "Equipment Supporting Multifunctional, Adaptive Radio, Radar and Sensor Research," U.S. Army Research Office," $259,090, 1 May 2002–30 April 2003.
- Principal Investigator, "Remote Characterization of Electric and Electronic Devices," U.S. Army Research Office, $212,310, 1 September 2002 – August 31 2005
- Principal Investigator, "Behavioral Modeling of Narrowband Radio Frequency (RF) Circuits, National Science Foundation (as subcontract to University of Michigan), $150,000, 1 August 2001–31 July 2004.
- Principal Investigator, "Advanced Modeling of Mixed-Signal Systems, " DARPA NeoCAD, $1,746,919, 1 July 2001–30 June 2004.
- Principal Investigator, "Power Transmission Using Radio Waves, " $65,000, 1 July 2001–31 December 2002, National Science Foundation
- Principal Investigator, "Innovative Enhancements to an RF Circuit Simulator Based on a State Variable Formulation," $85,000, STAS, U.S. Army Research Office through Batelle Corporation, 1 May 2001–31 July 2002.
- Principal Investigator, "Equipment for Characterizing Millimeter-Wave Spatial and Quasi-Optical Power Combiners," U.S. Army Research Office, $231,621, 15 May 2000–14 May 2001.
- Principal Investigator, "Microwave and Millimetre-Wave Design and Instrumentation Facility," Engineering and Physical Science Research Council, (£2.2M), $4,197,600, 1 April 2000–31 March 2002.
- Principal Investigator, "Studentship: integrated design of the transmitter front end of cellular phone handsets," Filtronics, (£34,500), $65,826, 1 October 1999–30 September 2002.
- Principal Investigator, "Studentship: Ultra linear RF power amplifier design for cellular radio," Filtronics, (£34,500), $65,826, 1 October 1999–30 September 2002"
- Principal Investigator, "Studentship: Investigation of Frequency Selective Limiters," Filtronics (£34,500), $65,826, 1 October 1999–30 September 2002.
- Co-Principal Investigator, "Highly linear power amplifier design," MA/COM, $125,556, 1 July 1998 –30 June 2001.
- Principal Investigator, "Integrated electro-thermal modelling," $50,000, European Research Office of the U.S. Army Research Office, 1 July 1999 - 30 June 2000.
- Principal Investigator, "Development of an OFDM-based millimetre-wave wireless local area network system," $360,000, Cannon Research 1 July 1998 –30 June 2001.
- Principal Investigator, "Instrumentation for Quasi-Optical Power Combining Research," U.S. Army Research Office, $439,291, 1 March 1997-28 February 1998.
- Co-Principal Investigator, "Tunable Ferroelectric Thin Film Varactor," DARPA (funded as a subcontract to Advanced Technology Materials), $540,000 1 September 1998 - 15 February 2003.
- Co-Principal Investigator, "Equipment for Characterizing Millimeter-Wave Spatial and Quasi-Optical Power Combiners," US Army Research office, $230,000, 15 May 2000 - 14 May 2001.

APPENDIX A

Michael B. Steer

- Principal Investigator, Planar and Thermal Spatial Power Combining Research, Multidisciplinary University Research Initiative on Quasi-optical Power Combining, U.S. Army Research Office (funded as a subcontract to Clemson University), $1,254,084, 1 May 1997 - 30 April 2003.
- Principal Investigator, "Computer Aided Engineering of Quasi-Optical Power Combining Systems," DARPA, $1,395,000, 1 October 1996 - 31 August 1999.
- Co-Principal Investigator, "Low-Power High Performance MEMS-based Switch Fabric," DARPA, $1,047,658, 14 September 1996 - 30 September 1999.
- Co-Principal Investigator, “Three Dimensional High Density Electronic Module Design and Manufacturing,” DARPA as subcontract to the Microelectronics Center of North Carolina, Jan. 1, 1997--Dec 31, 1998, $257,285.
- Principal Investigator, Development of Laboratory Infrastructure to Support the Teaching of Hardware Oriented Wireless Courses, North Carolina State University, $49,900, 1 September 1995 - 30 June 1996.
- Co-Principal Investigator, "Workshop on Applications and Research Strategies for Quasi-optical Power Combining," U.S. Army Research Office, $4,000, 1 September 1995 - 30 December 1995.
- Principal Investigator, "Development of a second generation SPICE-to-IBIS converter," Cadence Design Systems, $3,614, 1 April 1995 - 31 July 1995.
- Principal Investigator, "Research and Development of a Quasi-Optical Dielectric Slab Power Combining System," U.S. Army Research Office, $293,977, August 14 1995 - August 13 1998.
- Principal Investigator, "Computer Aided Engineering Tools for Microwave and Millimeter-Wave Quasi-optical Oscillators and Amplifiers," Compact Software (ARPA sub-contract), $55,000, October 1 1995 - July 31 1997.
- Principal Investigator, "Experimental Determination of On-Chip Interconnect Capacitances," SEMATECH, $127,341, January 1 1995 - April 30 1996.
- Principal Investigator, "Circuit Modeling and Computer Aided Design for Quasioptical Systems," $150,000) Scientific Research Associates, 1 July 1995 - 30 June 1997.
- Co-Principal Investigator, "Methodology, tools and demonstration of MCM system optimization," $670,000) ARPA, November 1 1993 - April 30 1997.
- Co-Principal Investigator, Unrestricted Gift, Cadence, $300,000, July 1995 - June 2001.
- Co-Principal Investigator, Three Dimensional High Density Electronic Module Design and Manufacturing, MCNC as a DARPA subcontract, $250,000, Jan. 1, 1997-Dec 31, 1998,
- Principal Investigator, "Circuit-Level Modeling and Computer Aided Design Tools for Millimeter Wave Quasioptical Systems," $240,000, US Army Research Office, 16 July 1992 - 14 July 1995.
- Co-Principal Investigator, "Test Equipment for High Speed Digital VLSI Systems," National Science Foundation, $270,000.
- Principal Investigator, "Interconnect Models for Computer Aided Design of Multi-GHz Multichip Modules and Integrated Circuits," National Science Foundation, $273,466, 15 February 1991 - 31 July 1993.
- Principal Investigator, "Parameter extraction for microwave transistors using tree annealing", Compact Software, $38,006.
- Principal Investigator, "CAD of Analog Subsystems", IBM, $38,675, 1 July 1989 - 30 June 1991.
- Co-Principal Investigator, "Physical Layer" Center for Communications and Signal Processing, $110,884, 1 July 1989 - 31 June 1990.
- Principal Investigator, "Quasi-Optical Power Combining of Solid State Millimeter-Wave Sources: A Proposal for Graduate Fellowship" United States Army Research Office, $95,360, 1 August 1989 - 31 July 1992.
- Principal Investigator, "Research Experiences for Undergraduates-Computer Aided Design of Analog Circuits," National Science Foundation, $4,535, 1 May 1989 - 30 April 1990.
- Principal Investigator, "Propagation of High Speed Digital Signals in Printed Circuit Board Systems, Phase III," Bell Northern Research, $172,440, 1 August 1988 - 31 December 1989.

- Principal Investigator, "Physical Layer III-Integration of Frequency Domain Analysis of Nonlinear Systems into CAPSIM," Center for Communications and Signal Processing, $46,980, 1 July 1988 - 30 June 1989.
- Co-Principal Investigator, "Proposal To Purchase Computer Equipment," Digital Equipment Corporation, $550,000, 25 July 1987 - 31 December 1989.
- Principal Investigator, "CAD of Delta-Sigma Circuits", Center for Communications and Signal Processing, $32,000, 1 July 1987 - 30 June 1988.
- Principal Investigator, "Propagation of High Speed Digital Signals in Printed Circuit Board Systems, Phase II," Bell Northern Research, $64,680, 1 July 1987 - 30 June 1988.
- Principal Investigator, "Computer Aided Design of Nonlinear Analog Circuits," Digital Equipment Corporation, $37,500, 1 July 1987 - 30 June 1988.
- Principal Investigator, "Presidential Young Investigator Award," National Science Foundation, $316,489, 1 August 1987 - 31 July 1993.
- Principal Investigator, "University Contribution-Presidential Young Investigator Award," North Carolina State University, $143,729, 1 August 1987 - 31 July 1993.
- Principal Investigator, "Propagation of High Speed Digital Signals in Printed Circuit Board Systems," Bell Northern Research, $53,185, 1 January 1987 - 30 June 1987.
- Co-Principal Investigator, "A Proposal for Instrumentation for the Characterization and Development of Near-Millimeter Wave Components Compatible with Monolithic Integration," DoD University Equipment Instrumentation Program through the U.S. Air Force, $312,500, 1 July 1986 - 30 June 1988.
- Co-Principal Investigator, "Analytic Techniques for Sigma Delta Modulators," Center for Communications and Signal Processing, $51,800, 1 July 1986 - 30 June 1987.
- Co-Principal Investigator, "RF Microwave Measurement/Simulation System," North Carolina State University and industrial matching, $172,439, 1 August 1985 - 15 June 1986.
- Senior Investigator, "Investigation of New Materials and Structures for Magnetostatic Wave Devices," Allied Corporation, $74,900, 1 January 1984 - 31 December 1984.

Consulting:

- Goldberg-Segalla, Inc., Intellectual Property analysis on behalf of Parkervision, Inc. 10/1/2019 to present.
- McKool Smith, P.C., Intellectual Property analysis on behalf of Parkervision, Inc. 12/5/2019 to present.
- Covington & Burling LLP,
  Intellectual Property analysis on behalf of Samsung Electronics Co., Ltd. and Samsung Electronics America, Inc.
  5/3/2019 to present.
- Carlson, Caspers, Vandenburgh and Lindquist, P.A.
  Intellectual Property analysis on behalf of Commscope Technologies LLC in respect to Civil Action Nos. 18-00135 (JRG), 18-00136 (JRG) 18-00137 (JRG) and 18-00138 (JRG) in the U.S. District Court, Eastern District of Texas
  2/19/2019 to 4/30/2019.
- GroundTruth, Inc. An agricultural technology company. Member of Advisory Board 1/1/2019 to present.
- Defense Advanced Research Projects Agency (through Booz, Allen, Hamilton, Aberdeen), Subject Matter Expert for Department of Defense, 7/1/2012 to present.
- Lockheed Martin,
  Review of internal research and development programs.
  8/8/2018 to 9/10/2019.
- Covington & Burling LLP,
  Intellectual Property analysis on behalf of Tessera Advanced Technologies, Inc. Petition for Inter Partes Review of U.S. Patent No. 6,408,167 B1.
  10/5/2017 to 12/31/2017.
- Covington & Burling LLP,
  Intellectual Property analysis on behalf of Tessera Advanced Technologies, Inc., Before the United States Patent Trial and Appeal Board, Case No. IPR2017-00736.
  3/9/2017 to 12/31/2017.
- Mintz, Levin, Cohn, Ferris, Glovsky, and Popeo P.C.
  Intellectual Property analysis on behalf of Parkervision, Inc. Before the United States International Trade Commission, Investigation No. 337-TA-982.
  7/1/2015 to present.
- Information and Intelligence Warfare Directorate, U.S. Army Communications-Electronics Research, Development and Engineering Center (through Booz, Allen, Hamilton, Arlington), Subject Matter Expert for Department of Defense, 3/1/2012 to 3/30/2015.
- Mintz, Levin, Cohn, Ferris, Glovsky, and Popeo P.C.
  Intellectual Property analysis on behalf of P-wave Holdings, Inc.
  2/1/2014 to 6/10/2014
- Finnegan, Henderson, Farabow, Garrett & Dunner, LLP, 901 New York Avenue, NW Washington, DC 20001-4413. Expert witness.
  Before the United States International Trade Commission, Investigation No. 337-TA-775.
  1/11/2011 to 04/2/2012.
  For Plaintiff, Expert Report Prepared, Deposed, Investigation Terminated
  (POC: Mr. Vincent Kovalick)
- Winston & Strawn, 1700 K Street, N.W., Washington, DC, 20006.
  Expert Witness on behalf of IMPACT SCIENCE & TECHNOLOGY, INC.
  9/20/2010 to 2/15/2011. Case No. 1:07-cv-01660-JFM in the United States District Court for the

District of Maryland, Northern Division. DENNIS P. GLYNN v. IMPACT SCIENCE & TECHNOLOGY, INC. v. SALTWHISTLE TECHNOLOGY, LLC. and EDO CORPORATION For Defendant/Counter-Claimant/Appellee, Expert Report Prepared , Deposed , Summary Judgment (POC: Mr. Eric Reicher)

- Vadum, Inc. 628 Hutton St., Suite 106, Raleigh, NC 27606.
  Member of technical advisory board undertaking technical reviews of software systems to model military and commercial communication electronics.
  4/15/2008 to 6/30/2010.
- Cooley Godward Kronish LLP, 777 6th Street, NW, Washington, DC, 20001.
  Expert witness on behalf of IMPACT SCIENCE & TECHNOLOGY, INC.
  Case No. 1:07-cv-01660-JFM. In the United States District Court for the District of Maryland, Northern Division.DENNIS P. GLYNN v. IMPACT SCIENCE & TECHNOLOGY, INC. v. SALTWHISTLE TECHNOLOGY, LLC. and EDO CORPORATION. For Defendant/Counter-Claimant, Expert Report Prepared, Summary Judgment (POC: Ms. Connie Bertram, now at Proskauer Rose LLP.) 8/16/2009 to 3/15/2010.
- Greenwave Scientific, Inc., 2700 Sumner Blvd., Suite 130, Raleigh, NC, 27616.
  Antenna array design concepts. 8/16/2009 to 9/30/2010.
- Research Triangle Institute, Research Triangle Park, NC, 27709.
  Development of reports on homemade explosive ordnance. 10/1/2005 to 8/15/2009.
- Delcross Technologies, LLC, 3015 Village Office Place, Champaign, IL 61822.
  Consulting on modeling of co-site interference. 03/15/2007 to 08/15/2007.
- Myers, Bigel, Sibley and Sajovec, PA, 4140 Parklake Avenue, Raleigh, NC 27612.
  Expert Witness on behalf of Commscope, Inc. COMMSCOPE v. ORTRONICS
  For Plaintiff, Expert Report Prepared, Settled Out of Court (POC: Mr. D. Randal Ayers).
  08/16/2005 to 08/15/2007.
- Cisco Systems, Inc., 7025 -3 Kit Creek Road, Research Triangle Park, NC 27709.
  Short course. 2/28/2006 to 02/28/2006.
- Dupont, 14 T W Alexander Drive, Research Triangle Park, NC, 27709.
  Strategic consulting on applications of microwave materials. 9/9/2005 to 06/30/2006.
- Filtronic, plc, Saltaire, Shipley, England, UK.
  Member of Technical Advisory Board. 7/1/1999 to 8/15/2006.
- Battelle Memorial Institute, 50101 Governors Drive, Suite 110, Chappell Hill, NC, 27517.
  Organize workshop and reimburse speakers on behalf of the US Army and the CIA.
  9/15/2005 to 04/30/2009.
- Bell Northern Research, Research Triange Park, NC.
  Short courses on GSM to employees and customers. 1/1/2001 to 12/31/2001.
- Zeevo, Inc. (out of business).
  Bluetooth chip filter design for RF front end. 1/1/1988 to 12/31/2001
- dBTag, Inc. (out of business).
  RFID antenna design. 1/1/1998 to 12/31/2000
- Hewlett Packard, 11311 W Chinden Blvd, Boise, ID 83714.
  Short course. 11/6/1995 to 11/7/1995.
- Compact Software, Inc. (purchased by Ansoft Software that was purchased by Ansys Inc.).
  275 Technology Drive, Canonsburg, PA 15317.
  Transistor model development. 01/1/1990 to 08/15/1992.
- Carolina Medical Devices (out of business).
  Resolution of interference issues in medical equipment. 6/15/1989 to 6/15/1989.