Exhibit DD

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

Huizhou TCL Mobile Communication Co. Ltd., TCT Mobile (US) Inc., TCL Mobile Communication (HK) Co., Ltd.
Petitioners

v.

WI-LAN INC.,
Patent Owner

INTER PARTES REVIEW OF U.S. PATENT NO. 9,854,577 B2
Case IPR No.: IPR2020-00304

DECLARATION OF DR. TITUS LO
EX 1003

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I. INTRODUCTION

1. My name is Titus Lo, and I have been retained by counsel for Petitioner TCT Mobile, Inc., TCT Mobile US Holdings Inc., TCL Communication Inc. ("TCL" or "Petitioner" or "Petitioners") as an expert witness to provide my opinion regarding certain prior art references and U.S. Patent No. 9,854,577 (the "'577 patent").

2. I have been asked to consider the validity of claims 1-22 of the '577 patent in view of the understanding of a person of ordinary skill in the art ("POSITA") as it relates to the '577 patent. I have personal knowledge of the facts and opinions set forth in this declaration, and believe them to be true. If called upon to do so, I would testify competently thereto.

3. I am being compensated for my time at my standard consulting rate. I am also being reimbursed for expenses that I incur during the course of this work. My compensation is not contingent upon the results of my study, the substance of my opinions, or the outcome of any proceeding involving the challenged claims. I have no financial interest in the outcome of this matter or on the pending litigation between Petitioner and Patent Owner.

4. My opinions are based on my years of education, research and experience, as well as my investigation and study of relevant materials, including those cited herein.

5. I may rely upon these materials, my knowledge and experience, and/or additional materials to rebut arguments raised by the Patent Owner. Further, I may also consider additional documents and information in forming any necessary opinions, including documents that may not yet have been provided to me.

6. My analysis of the materials produced in this proceeding is ongoing and I will continue to review any new material as it is provided. This declaration represents only those opinions I have formed to date. I reserve the right to revise, supplement, and/or amend my opinions stated herein based on new information and on my continuing analysis of the materials already provided.

II. BACKGROUND AND QUALIFICATIONS

7. I am an expert in the field of telecommunication systems. I have studied, researched, and practiced in this field for over thirty years. I have summarized in this section my educational background, work experience, and other relevant qualifications. A true and accurate copy of my curriculum vitae can be found in Appendix A.

8. I earned my Bachelor of Applied Science degree in Electrical Engineering from the University of British Columbia in Vancouver, British Columbia, Canada in 1986. I earned my Master of Engineering degree in 1989 and Doctor of Philosophy (Ph.D.) degree in 1995, both in Electrical Engineering from McMaster University in Hamilton, Ontario, Canada. My Ph.D. dissertation, entitled "MLE and RBF for AOA estimation in a Multipath Environment", is about the concept and principle for application of artificial intelligence to antenna signal processing.

9. From 1989 to 1997, I had worked full time, first as a research engineer and then as a senior research engineer/project manager, at Communications Research Laboratory, McMaster University, where I had been involved in numerous research and development projects related to antenna beamforming technology applied to mobile communications, satellite communications, and spaceborne radar systems. It was during this period that, foreseeing the important role of beamforming technology in future wireless communications, I was able to establish my international leading position in this field. I had co-authored technical reference book, entitled *Digital Beamforming in Wireless Communications*, the first of its kind in the field, published in 1996 by Artech House. After more than twenty years later, it is now a well-known fact that

antenna beamforming is one of the cornerstone technologies employed in the 5th generation (5G) wireless communications networks.

10. It was because of both of the importance of antenna beamforming technology to its wireless business and my exceptional expertise in the field that AT&T Wireless Services had persuaded me to join its Strategic Technology Group (STG) in 1997. At AT&T, as part of system design and engineering, I led the research and development of advanced radio technologies in an orthogonal frequency division multiplexing (OFDM) system, including antenna array processing, signal acquisition, synchronization, channel estimation, space-time coding, and transmission diversity, all of which were the critical elements to AT&T's fixed wireless network – the world's first carrier-grade and commercially deployed orthogonal frequency division multiple access (OFDMA) system.

11. From 2001, I had embarked on my startup endeavor in pursuing the development of advanced technologies to telecommunications. I had worked in a number of startups subsequently. In 2001, I joined NextComm, Inc., a Kirkland, WA based startup that designed and developed application-specific integrated circuits (ASICs) for wireless local area network (WLAN) devices, where I was responsible for system engineering, including the design, implementation, and test, of IEEE 802.11a (OFDM-based) and 802.11b (spread spectrum-based) standard

(a.k.a. Wi-Fi) compliant chipsets. During the tenue in NextComm, I participated in and contributed to the IEEE 802.11 Standard Working Group in the development of 802.11g amendment. In 2003, I served as the vice president of engineering and operations at Waltical Solutions, Inc., Bellevue, WA, where I directed a engineering team in the design and development of broadband wireless communications technologies (including 801.11e/WiMax) and systems. In 2006, I served as the vice president, Neocific, Inc., a 4G pioneer based at Bellevue, WA, where I managed and mentored a team of researchers and engineers in the research and development of 4^{th} generation (4G) wireless technologies, including key radio functionalities such as synchronization, random access, inter-cell interference mitigation, power control, and control signaling. In 2011, I engaged in consulting services to my clients by providing (i) the analysis, evaluation, and due diligence investigation of wireless-technology intellectual property portfolios and (ii) the analysis and evaluation of technology markets and industry ecosystems.

12. Throughout my professional career, I have been granted more than 120 US and foreign patents in the area of wireless communications. I have published more than 80 technical papers in peer-reviewed international journals (e.g., IEEE Transactions and IEE Proceedings) and conference proceedings (e.g., IEEE International Conferences and Spie's International Symposiums). I have been

invited to present and lecture many times at a broad array of industry and professional venues and to various technical and industrial communities in the fields of antennas, RF, and wireless communications.

13. I was appointed as an affiliated professor in the Department of Electrical & Computer Engineering at the University of Washington, Seattle, WA from 2008 to 2012. I have also served or been serving various leadership positions in the Institute of Electrical and Electronics Engineers (IEEE). For example, I have been serving as an organization committee member for IEEE 5G World Forum since its inception in 2018. I have been a senior IEEE member since 1998 and have been inducted in to the IEEE Eta Kappa Nu Honor Society in 2019.

III. PRIORITY DATE AND ONE OF ORDINARY SKILL

14. In rendering the opinions set forth in this declaration, I was asked to consider the patent claims and the prior art through the eyes of a POSITA at the time of the alleged invention, which I understand is March 7, 2007. I understand that the factors considered in determining the ordinary level of skill in a field of art include the level of education and experience of persons working in the field; the types of problems encountered in the field; the teachings of the prior art, and the sophistication of the technology at the time of the alleged invention. I understand that a POSITA is not a specific real individual, but rather is a hypothetical

individual having the qualities reflected by the factors above. I understand that a POSITA would also have knowledge from the teachings of the prior art, including the art cited below.

15. Taking these factors into consideration, in my opinion, on or before March 7, 2007 a POSITA relating to the technology of the '577 patent would have had a Bachelor's degree in electrical engineering, computer engineering, computer science, or a related field, and around two years of experience in the design or development of telecommunication systems, or the equivalent. Individuals with additional education or additional industrial experience could still be of ordinary skill in the art if that additional aspect compensates for a deficit in one of the other aspects of the requirements stated above.

16. Well before March 7, 2007, my level of skill in the art was at least that of a POSITA. I am qualified to provide opinions concerning what a POSITA would have known and understood at that time, and my analysis and conclusions herein are from the perspective of a POSITA as of March 7, 2007.

IV. MATERIALS RELIED UPON

17. In reaching the conclusions described in this declaration, I have relied on the documents and materials cited herein as well as those identified in the exhibit list submitted with the petition. Each of these materials is a type of

document that experts in my field would have reasonably relied upon when forming their opinions.

18. My opinions are also based upon my education, training, research, knowledge, and personal and professional experience.

V. LEGAL STANDARDS

19. I have been informed that there are two ways in which prior art may render a patent claim unpatentable. First, the prior art can be shown to "anticipate" the claim. Second, the prior art can be shown to have made the claim "obvious" to a POSITA. I have been asked to evaluate whether claims 1-22 of the '577 Patent are obvious.

A. Obviousness

20. I have been informed that a claim may be invalid under 35 U.S.C. § 103(a) if the subject matter described by the claim as a whole would have been obvious to a hypothetical person of ordinary skill in the art in view of a prior art reference or in view of a combination of references at the time the claimed invention was made. I have been informed that obviousness is determined from the perspective of a hypothetical POSITA and that the asserted claims of the patent should be read from the point of view of such a person at the time the claimed invention was made. I have been informed that a hypothetical POSITA is assumed

to know and to have all relevant prior art in the field of endeavor covered by the patent in suit.

21. I have been informed that there are two criteria for determining whether prior art is analogous and thus can be considered prior art: (1) whether the art is from the same field of endeavor, regardless of the problem addressed, and (2) if the reference is not within the field of the patentee's endeavor, whether the reference still is reasonably pertinent to the particular problem with which the patentee is involved. I have also been informed that the field of endeavor of a patent is not limited to the specific point of novelty, the narrowest possible conception of the field, or the particular focus within a given field. I have also been informed that a reference is reasonably pertinent if, even though it may be in a different field from that of the patentee's endeavor, it is one which, because of the matter with which it deals, logically would have commended itself to a patentee's attention in considering his problem.

22. I have also been informed that an analysis of whether a claimed invention would have been obvious should be considered in light of the scope and content of the prior art, the differences (if any) between the prior art and the claimed invention, and the level of ordinary skill in the pertinent art involved. I have been informed as well that a prior art reference should be viewed as a whole.

23. I have also been informed that in considering whether an invention for a claimed combination would have been obvious, I may assess whether there are apparent reasons to combine known elements in the prior art in the manner claimed in view of interrelated teachings of multiple prior art references, the effects of demands known to the design community or present in the market place, and/or the background knowledge possessed by a person having ordinary skill in the art. I have been informed that other principles may be relied on in evaluating whether a claimed invention would have been obvious, and that these principles include the following:

- A combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results;
- When a device or technology is available in one field of endeavor, design incentives and other market forces can prompt variations of it, either in the same field or in a different one, so that if a person of ordinary skill can implement a predictable variation, the variation is likely obvious;
- If a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar

devices in the same way, using the technique is obvious unless its actual application is beyond his or her skill;

- An explicit or implicit teaching, suggestion, or motivation to combine two prior art references to form the claimed combination may demonstrate obviousness, but proof of obviousness does not depend on or require showing a teaching, suggestion, or motivation to combine;
- Market demand, rather than scientific literature, can drive design trends and may show obviousness;
- In determining whether the subject matter of a patent claim would have been obvious, neither the particular motivation nor the avowed purpose of the named inventor controls;
- One of the ways in which a patent's subject can be proved obvious is by noting that there existed at the time of invention a known problem for which there was an obvious solution encompassed by the patent's claims;
- Any need or problem known in the field of endeavor at the time of invention and addressed by the patent can provide a reason for combining the elements in the manner claimed;

- "Common sense" teaches that familiar items may have obvious uses beyond their primary purposes, and in many cases a person of ordinary skill will be able to fit the teachings of multiple patents together like pieces of a puzzle;
- A person of ordinary skill in the art is also a person of ordinary creativity, and is not an automaton;
- A patent claim can be proved obvious by showing that the claimed combination of elements was "obvious to try," particularly when there is a design need or market pressure to solve a problem and there are a finite number of identified, predictable solutions such that a person of ordinary skill in the art would have had good reason to pursue the known options within his or her technical grasp; and
- One should be cautious of using hindsight in evaluating whether a claimed invention would have been obvious.

24. I have further been informed that, in making a determination as to whether or not the claimed invention would have been obvious to a person of ordinary skill, the Board may consider certain objective factors if they are present, such as: commercial success of products practicing the claimed invention; long-felt but unsolved need; teaching away; unexpected results; copying; and praise by

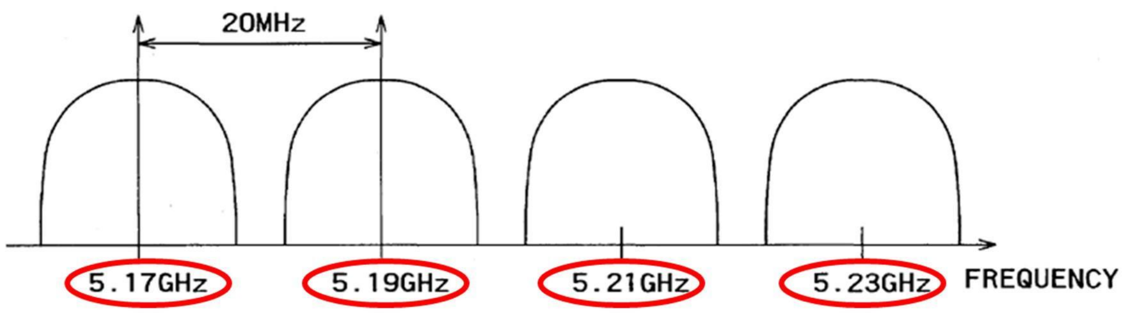
others in the field. These factors are generally referred to as "secondary considerations" or "objective indicia" of nonobviousness. I have been informed, however, that for such objective evidence to be relevant to the obviousness of a claim, there must be a causal relationship (called a "nexus") between the claim and the evidence and that this nexus must be based on what is claimed and novel in the claim rather than something in the prior art. I have also been informed that even when they are present, secondary considerations may be unable to overcome primary evidence of obviousness (*e.g.*, motivation to combine with predictable results) that is sufficiently strong.

25. I have been asked to consider the validity of the challenged claims. I have been informed that for *inter partes* reviews, invalidity must be shown under a preponderance of the evidence standard. I have been informed that to establish something by a preponderance of the evidence one needs to prove it is more likely true than not true. I have concluded that each of claims 1-22 are invalid, according to the grounds described herein, under both the preponderance of the evidence standard as well as the higher standard of clear and convincing evidence.

VI. BACKGROUND OF THE ART

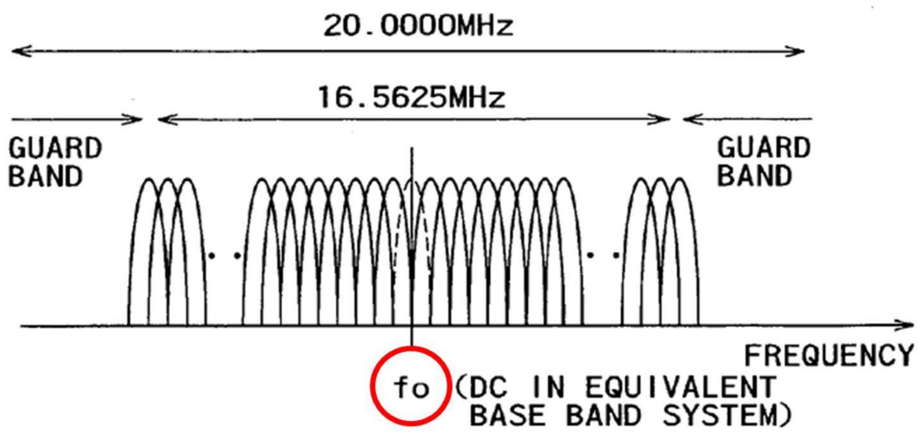
26. Orthogonal frequency division multiplexing (OFDM) is a type of transmission technique that partitions the overall channel bandwidth into multiple overlapping orthogonal subcarriers, each of which are transmitted simultaneously.

27. Individual channels in OFDM systems take up a specific bandwidth of frequency. They are separated by guard bands, which are simply portions of the frequency spectrum where no signal is transmitted. This is demonstrated in Fig. 29 of Yamaura, below, where each channel's carrier frequency is annotated in red. As can be seen from the below, each channel is spaced 20 MHz apart, and is separated by a guard band.



28. Each OFDM channel comprises a set of OFDM subcarriers. See Yamaura at [0006] and [0141]. For example, each 20 MHz band illustrated above in Fig. 29 is centered around a center carrier frequency and has a plurality of OFDM subcarriers. Yamaura at [0006] and [0004] ("one transmission channel … is divided into a plurality of subcarriers"). This is demonstrated in annotated Fig. 30, below, where a series of subcarriers are centered around a "central frequency f0

[(annotated red)] in the carrier frequency band." Yamaura at [0006]; *see also id.* at [0141] and Figs. 16, 20, 22, 24. Each terminal in an OFDM system may be assigned one or more time slots and subcarrier combinations to transmit and receive data.



VII. ANALYSIS OF THE '577 PATENT

A. Overview of the '577 Patent

29. The '577 Patent is directed to aggregating multiple channels. '577 Patent at Abstract. Data for transmission is divided, and then transmitted on a first and second channel simultaneously. *Id.* at 5:55-61. Identification of the channels which are to be aggregated is transmitted to the terminal device via control channels. *Id.* at 23:39-49.

B. Claim Construction of the '577 Patent Claims

30. I have been informed that for purposes of this *Inter Partes* Review, the standard for claim construction is the same as the standard used in federal

district court litigation: claim terms should generally be given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the invention and after reading the patent and its prosecution history.

31. I have been informed that the following terms may be construed by the Board:

- "receive unit" (claims 1 and 9)
- "transmit unit" (claim 4)
- "control data via control channels" (claims 1 and 12)
- "medium access control (MAC) layer" (claims 5 and 16)

1. "receive unit" (claims 1 and 9)

32. In my opinion, a "receive unit," in the context of wireless communications described in the '577 Patent, would have been well-known to a POSITA to be circuitry that receives and processes wireless signals. I do not believe that construction is necessary because it is well understood to a POSITA.

33. I understand that claim terms can be construed as a means plus function term. I understand that, if the Board construes "receive unit" as a means plus function term, that they will look at the particular structure disclosed in the specification, that the recited function that the structure performs.

34. If the Board construes "receive unit" as a means plus function term, the structure is "circuitry that receives and processes wireless signals in conjunction with the processor" and the function that it performs is: (a) "receive control data via control channels over at least a first communication channel or a second communication channel" ('577 Patent at 24:25–31) and (b) "receive downlink data on the assigned OFDM subcarriers of the first communication channel and the assigned OFDM subcarriers of the second communication channel." (*id.* at 24:40–44).

35. The above-described structure is described in the specification, which discloses a "receiving unit" that "may include one or more … receivers … or receiving chains." '577 Patent at 9:1-4, Figs. 3A-3B, Element 304(R); *see also id.* at 9:58-60. The receiver can have "one or more radios." *Id.* at 9:4-6, 9:63-65, 3:54-63. A radio is circuitry that receives and processes wireless signals. The receiving unit 304(R) (annotated yellow, below) receives wireless signals from the wireless communication link 106 (aqua). *Id.* at Fig. 3B, 4:32-35.

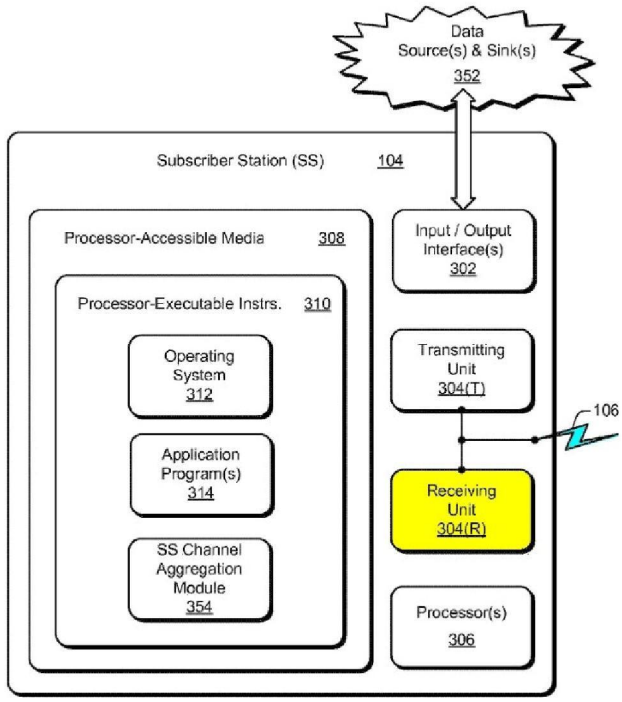


FIG. 3B

Example Subscriber Station

36. The above-described structure performs the function. The embodiments of Fig. 3B, which illustrate the receivers, are "utilized to implement embodiments of channel aggregation." '577 Patent at 2:56-59. The receivers receive control data via control channels over at least a first or second communication channel. *Id.* at 23:40-42, Figs. 5-6, 24:25-31. The data is received by the receiver on the assigned OFDM subcarriers. *Id.* at 15:42-49, 6:65-7:3, 24:40-44.

2. "transmit unit" (claim 4)

37. Claim 4 recites a "transmit unit" that is configured to transmit "to a base station, an indication that the wireless device is capable of channel aggregation."

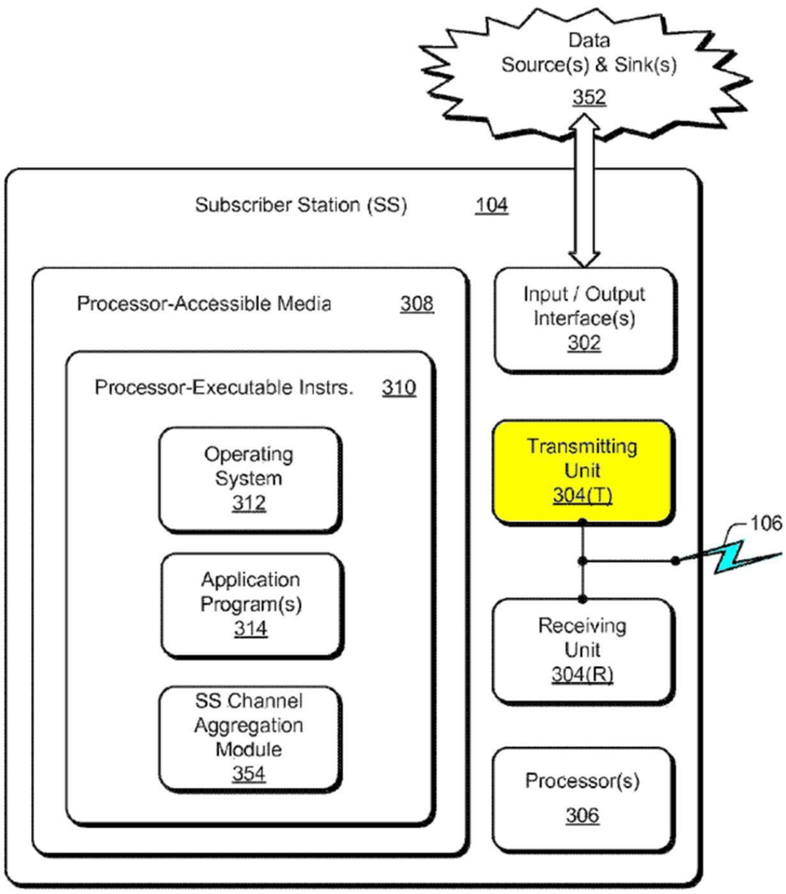
38. In my opinion, a "transmit unit," in the context of wireless communications described in the '577 Patent, would have been well-known to a POSITA to be circuitry that transmits and processes wireless signals. I do not believe that construction is necessary.

39. I understand that claim terms can be construed as a means plus function term. I understand that, if the Board construes "transmit unit" as a means plus function term, that they will look at the particular structure disclosed in the specification, that the recited function that the structure performs.

40. If the Board determines that "transmit unit" should be construed as a means plus function term, the structure is "circuitry that transmits and processes wireless signals in conjunction with the processor" and the function is "transmits to a base station, an indication that the wireless device is capable of channel aggregation."

41. The structure is supported by the specification. The '577 Patent discloses a "transmitting unit" that "may include one or more … transmitters … or transmitting chains." '577 Patent at 9:1-4, Figs. 3A-3B, Element 304(T), 9:58-60.

The transmitter can have "one or more radios." *Id.* at 9:4-6, 9:63-65, 3:54-63. A radio would be understood to be circuitry that transmits and processes wireless signals. The transmitting unit 304(T) (annotated yellow, below) transmits wireless signals from the wireless communication link 106 (aqua). *See id.* at Fig. 3B, 4:32-35.



Example Subscriber Station

FIG. 3B

42. The above-described structure performs the function. The embodiments of Fig. 3B are "utilized to implement embodiments of channel aggregation." '577 Patent at 2:56-59. The transmitters are used to "notify a base station of a channel-aggregating capability during capabilities negotiation." *Id.* at 10:18-20. The circuitry that transmits and processes wireless signals performs the function.

3. "control data via control channels" (claims 1 and 12)

43. In light of the '577 Patent specification, a POSITA would have understood "control data via control channels" to mean "data that is recognizable by the wireless device to be for the purposes of control."

44. A POSITA would understand that "control data via control channels" would mean any type of data, so long as it is understood by the system to be control data. This construction is supported by the specification, which describes its control data with reference to setting up channel aggregation, and without specific reference to any specific type of channel or data structure. Additionally, the '577 Patent specification itself only mentions control channels twice in a single paragraph ('577 Patent at 23:39-49), but this section generically references assignment in control channels. A POSITA would understand that the '577 Patent's control data and control channels are not directed to any specific data or

channel structure, but is "data that is recognizable by the wireless device to be for the purposes of control."

VIII. OVERVIEW OF THE PRIOR ART REFERENCES

45. I have been asked to evaluate the grounds of unpatentability listed below. In my opinion, claims 1-22 of the '577 Patent are invalid based on the below grounds.

Grounds	References	Challenged Claims
1A.	Gorokhov	1, 3-6, 8-12, 14-17, and 19-22
1B.	Gorokhov and Jung	2 and 13
1C.	Gorokhov and Zhao	7 and 18
1D.	Gorokhov and Walton	10 and 21
2A.	Ryu and Yamaura	1, 3-5, 11-12, 14-16, and 22
2B.	Ryu, Yamaura, and Jung	2 and 13
2C.	Ryu, Yamaura, and Zhao	7 and 18
2D.	Ryu, Yamaura, and Walton	10 and 21

IX. PRIORITY OF GOROKHOV

46. I have been asked to determine whether Gorokhov's claims have written description support in the provisional applications that Gorokhov claims priority to. *See* Gorokhov at 1:6-16. I understand that these provisional

applications have been submitted as Exhibits 1005-1007, and have been referenced accordingly. It is my opinion that the provisional applications do support the claims of Gorokhov. An example claim is provided below, along with the support that can be found in Gorokhov's provisional applications.

Claim language of Gorokhov	Support in Provisional Applications
13. A communications apparatus for assigning resources in a wireless communication system, the apparatus comprising:	EX1006 at pg. 15, claim 1; Figs. 1 and 6, pg. 15, claim1; EX1007 at pg. 14, claim 1; Figs. 1 and 6.
a wireless transmitter configured to transmit, on a control channel formed from a group of contiguous subcarriers in bandwidth including at least some discontinuous subcarriers,	EX1006 at [0032]-[0036] and [0042]-[0048], Figs. 4-5, pg. 15, claim1; EX1007 at [0034]-[0047], Figs. 4-5.
guard subcarrier information, said guard subcarrier information indicating both the number and location of guard subcarriers in a plurality of discontinuous portions of bandwidth corresponding to a first carrier that may be assigned by said control node;	EX1006 at [0039], [0043], Claims 4 and 5; EX1005 at §§ 2.3.12.7 and 3.1; EX1007 at [0025], [0038], [0041]-[0042].
a selection module for selecting a first wireless terminal to be assigned a communications resource:	EX1006 at [0004], [0026]-[0034], [0041], pgs. 15-16, claims 1, 6-10, Fig. 3; EX1007 at [0004], [0040]; EX1005 at 2 and 8.

a resource assignment module for assigning the first wireless terminal selected by said selection module a resource including at least two discontinuous portions of bandwidth corresponding to the first carrier for a period of time, said at least two discontinuous portions of bandwidth being discontinuous portions of bandwidth from said plurality of discontinuous portions of bandwidth, said at least two discontinuous portions of bandwidth including a first portion of bandwidth and a second portion of bandwidth,	EX1006 at [0004], [0026]-[0034], [0041], pgs. 15-16, claims 1, 6-10, Fig. 3; EX1007 at [0004], [0040]; EX1005 at 2 and 8.
said first and second portions of band width being separated by a third portion of bandwidth corresponding to another carrier not included in said resource, said third portion of bandwidth being larger than either of said two discontinuous portions of bandwidth and being a portion of bandwidth which is not used by said communications apparatus;	EX1006 at [0004], [0026]-[0034], [0041], pgs. 15-16, claims 1, 6-10, Fig. 3; EX1007 at [0004], [0040]; EX1005 at 2 and 8.
wherein said wireless transmitter is further configured to transmit a single assignment message communicating the assignment of the resource including the at least two discontinuous portions of bandwidth to the first wireless terminal,	EX1006 at [0033] *see also* EX1006 at [0004], [0026]-[0034], [0041], pgs. 15-16, claims 1, 6-10, Fig. 3; EX1007 at [0004], [0040]; EX1005 at 2 and 8.
said assignment message including a node identifier corresponding to a set of subcarriers including at least one guard subcarrier from each of the at least two discontinuous portions of bandwidth corresponding to the resource; and	EX1006 at [0033], claim 9; EX1005 at 46-47; *see also* EX1006 at [0004], [0026]-[0034], [0041], pgs. 15-16, claims 1, 6-10, Fig. 3; EX1007 at [0004], [0040]; EX1005 at 2 and 8.

memory for storing information.	EX1006 at pg. 15, claim 1, [0060]; *see also id.* at Figs. 1 and 6, pg. 15, claim1; EX1007 at pg. 14, claim 1; Figs. 1 and 6.

47. I also understand that the subject matter disclosed by Gorokhov must also have been disclosed by Gorokhov's provisional applications. Because of this, for each citation to Gorokhov provided, I have also provided citation to sections in the provisional applications that support the citation.

X. SPECIFIC GROUNDS OF CHALLENGE

A. Gound 1A: Claims 1, 3-6, 8-12, 14-17, and 19-22 are rendered obvious by Gorokhov

48. Gorokhov is a Qualcomm patent that teaches an OFDM wireless system that performs channel aggregation by combining different channels—each with their own bandwidths of frequency—for downlink traffic. *See* Gorokhov at Abstract; EX1006 at [0016]-[0017]. As explained in Gorokhov, Gorokhov "[e]ach carrier is a portion of a larger bandwidth in which the system can operate…" Gorokhov at 4:55-57; *see also* EX1006 at [0016]. As explained in Gorokhov, the "bandwidth … is divided into multiple carriers" (Gorokhov at 6:45-46; EX1006 at [0027]) and downlink traffic for the wireless device is "scheduled on multiple carriers simultaneously." Gorokhov aggregates these channels in order to support

higher data rates for OFDM systems. Gorokhov at 2:29-42; EX1006 at [0004]; *see also* EX1005 at 3-4.

49. Gorokhov recognizes that contiguous portions of bandwidth are sometimes unavailable for downlink transmission. For instance, sometimes certain bands are unlicensed and unavailable to a carrier's base station. Gorokhov at 13:15-19; *see also id.* at Fig. 3; 2:43-51; *see also* EX1006 at [0041]. Because the usable bands may be disjoint—and separated by a contiguous portion of unusable spectrum (*e.g.,* Gorokhov at 2:43-51; EX1006 at [0041])—they must be specifically identified so that they can be aggregated. Gorokhov provides an assignment message that assigns multiple disjoint portions of bandwidth that are used to simultaneously transmit downlink data. Gorokhov at 2:57-60, 7:35-38, 12:32-44, 13:24-31, 15:64-16:22, 17:1-10; EX1006 at [0033], [0035], and [0042].

a. Claim 1 is rendered obvious by Gorokhov

[1.PRE] A wireless device comprising:

50. Gorokhov teaches a wireless terminal which is the claimed wireless device. *See, e.g.,* Gorokhov at 12:35; *see also id.* at 7:36, Figs. 1, 6, 10; EX1006 at Fig. 1. An example wireless device is annotated yellow below.

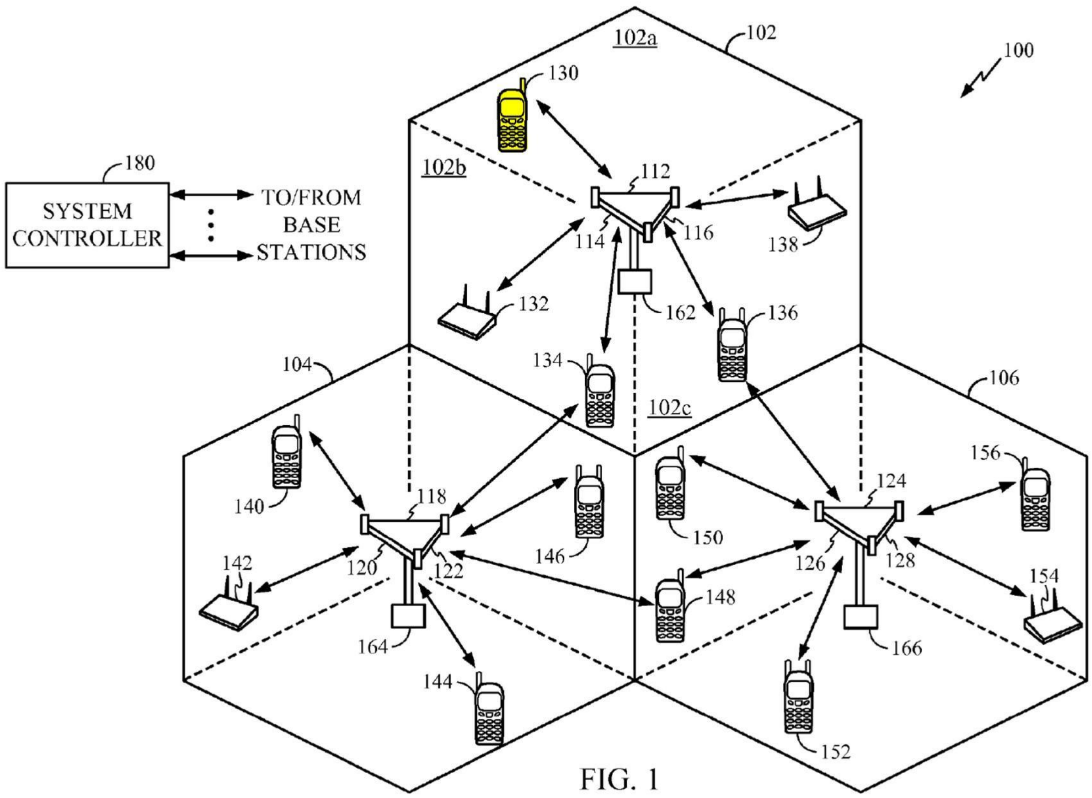


FIG. 1

[1.A] a receive unit; and

51. Gorokhov teaches a receiver (which is the claimed receive unit) on the wireless terminal. *See, e.g.,* Gorokhov at 10:16-42, Fig. 6; EX1006 at [0052]-[0056]. An embodiment of the receive unit for a MIMO system is annotated below. *See also* Gorokhov at 9:49-59; EX1006 at Fig. 6. The MIMO system is provided as an example, and a POSITA would have understood that Gorokhov is not limited to MIMO systems.

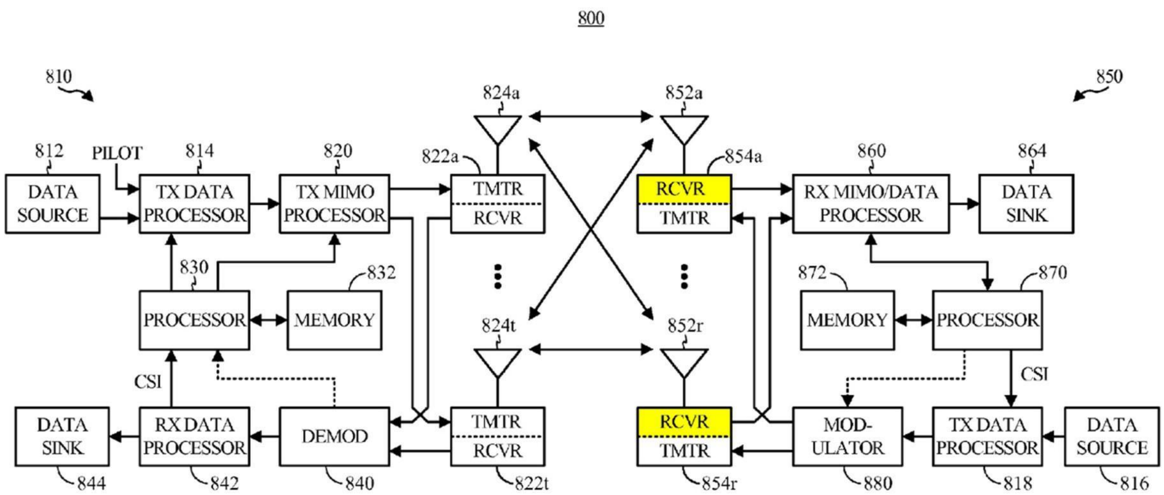


FIG. 6

[1.B] a processor; and

52. Gorokhov's wireless terminal has a processor. *See, e.g.,* Gorokhov at 10:25, Fig. 6; *see also id.* at 10:26-11:13. Both the RX data processor 860 and processor 870 (both of which can be the claimed processor) are annotated below in blue. *See* Gorokhov at 10:37-62; *see also* EX1006 at Fig. 6 and [0054]-[0055].

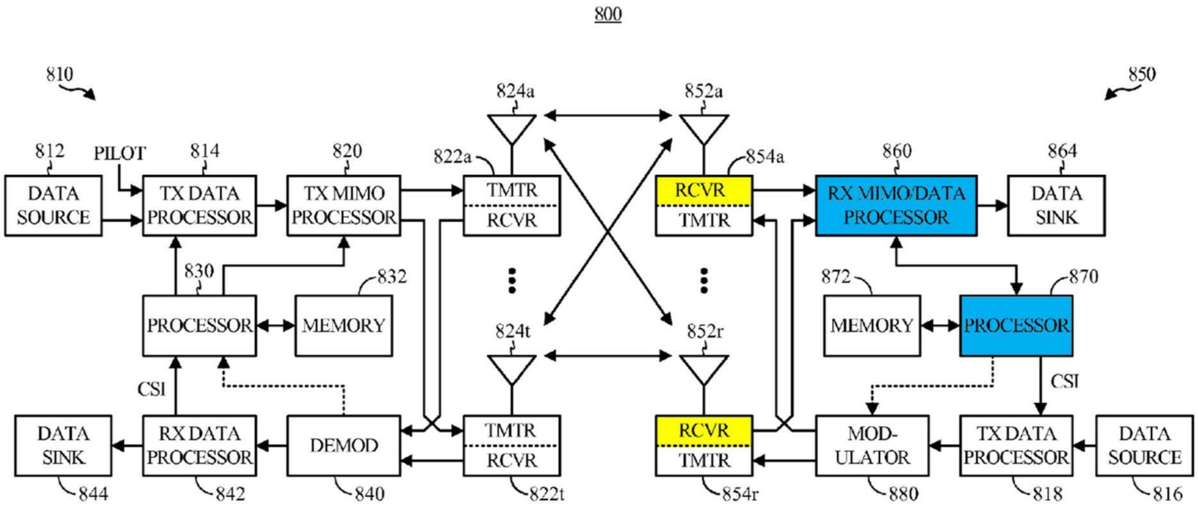


FIG. 6

[1.C] the receive unit and the processor are configured to receive control data via control channels over at least a first communication channel or a second communication channel,

53. Gorokhov teaches a signaling channel 516 which is the claimed control data. This is annotated in aqua below. The signaling channel 516 is received via a control channel 406 which is the claimed control channels. This is annotated in yellow. Gorokhov at 8:65-9:3 and Fig. 5A; *see also id.* at 7:53-63 (stating that control channels have forward link assignments); 9:42-48; EX1006 at [0035], [0042], and Figs. 5A-5B. Gorokhov teaches that the signaling channel 516 contains channel assignment and other control data. *See, e.g., id.* at 8:67-9:3; *see also id.* at 6:47-51; EX1006 at [0035], [0042], and Figs. 5A-5B.

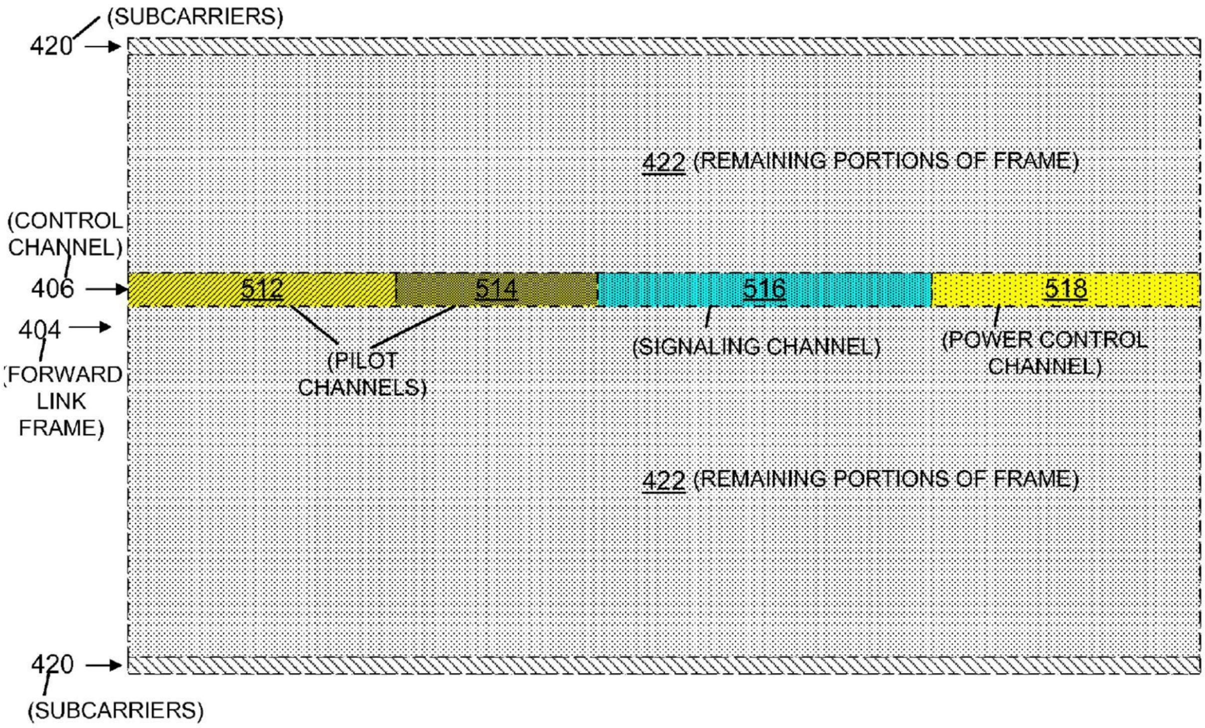


Fig. 5A

54. The signaling channel 516 of the control channel 406 is transmitted over one of the disjoint portions of bandwidth. *See* Gorokhov at 6:47-51 (stating that the control channels can be transmitted over each carrier), 8:46-51 (stating that the control channel can be sent over portions of the carrier), 8:55-59 (stating that the control channel can be assigned a set of subcarriers); EX1006 at [0027], [0041]-[0042]. The disjoint portions of bandwidth are the claimed first and second communications channels.

55. Finally, Gorokhov's receiver and processor are configured to receive incoming data. *See* Gorokhov at 3:28–31, 10:4–37, Fig. 6; EX1006 at Fig. 6 and [0054]-[0055].

[1.D] the control data including a first assignment of downlink resources for the first communication channel and a second assignment of downlink resources for the second communication channel;

56. Gorokhov teaches this limitation because it teaches an assignment message that assigns two separate communication channels for downlink transmission. The signaling channel 516 has assignment data which assigns the disjoint portions of bandwidth. *See* Gorokhov at 8:67-9:3; EX1006 at [0042]. Gorokhov uses different portions of bandwidth at the same time to transmit downlink resources. *See* Gorokhov at Abstract, 2:33-42; 2:57-60; EX1006 at [0004].

57. Gorokhov teaches:

> "a single assignment message [that] communicat[es] the assignment of a resource including the at least t[wo] discontinuous portions of bandwidth to the first wireless terminal." Gorokhov at 16:12-15, 12:32-44, 19:65-20:5; *see also id.* at Fig. 7, Element 712, Abstract, 2:57-60, 3:22-38, 7:35-43, 12:6-12, 12:32-44, 13:24-31, and 17:7-10; EX1006 at [0004], [0032]-[0035].

58. The assignment can also include "a node identifier corresponding to a set of sub-carriers, the set of sub-carriers including at least one sub-carrier from each of at least two discontinuous portions of bandwidth." Gorokhov at 16:15-20; *see also id.* at 12:37-44 (describing a channel tree being sent to the wireless terminal), 13:37-44, 17:56-64 (describing a sub-carrier mapping that is transmitted), 7:35-42; EX1006 at [0033], Claim 9.

59. Gorokhov demonstrates the assignment of two discontinuous portions of bandwidth in flow-chart form, where the assignment message is annotated in yellow. *See* Gorokhov at Fig. 7 (annotated below); *see also* EX1006 at [0033] (describing transmitting single assignment to device).

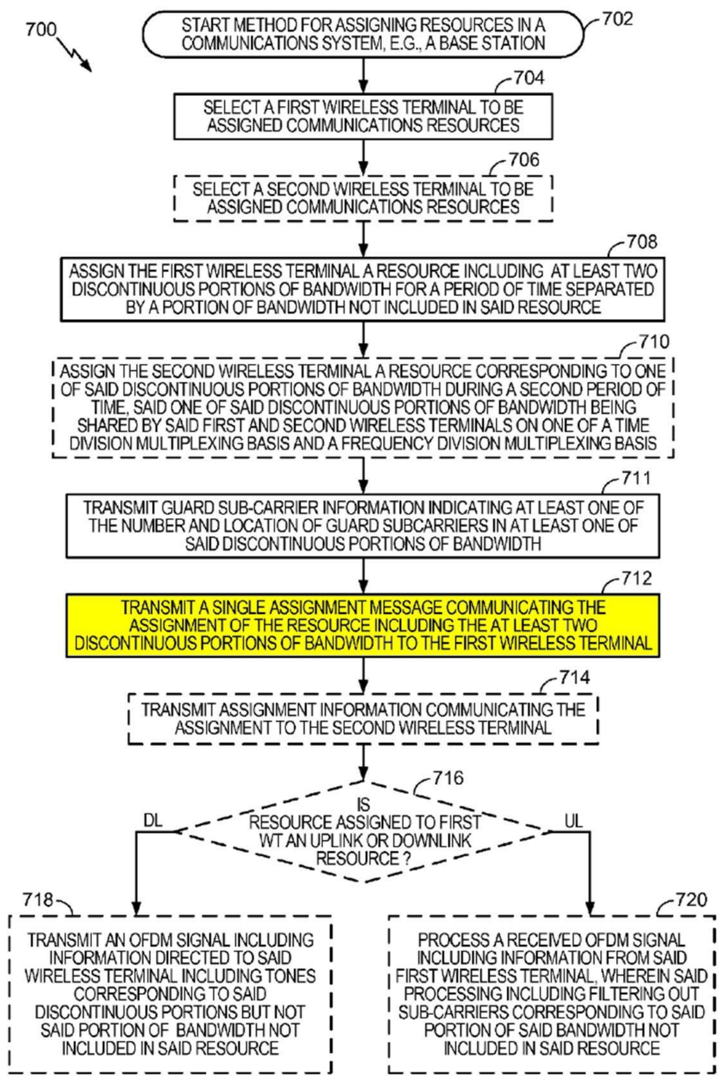
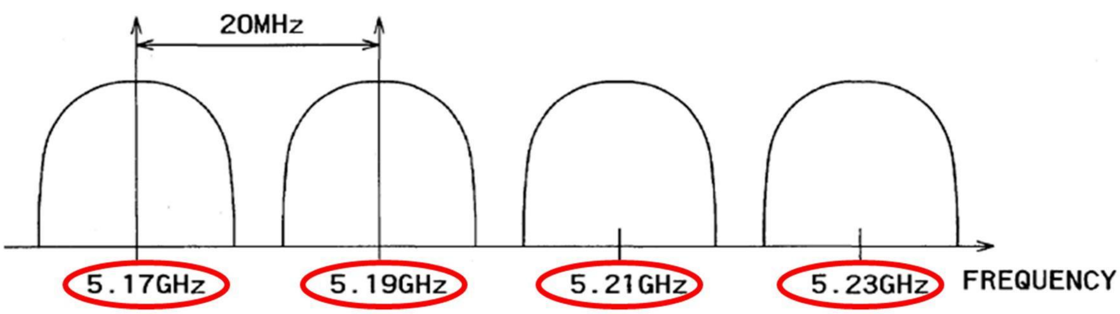


FIG. 7

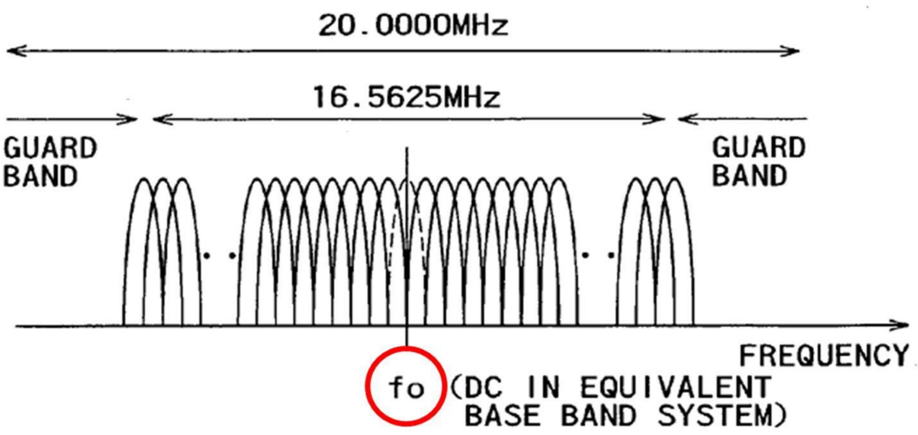
60. The two or more discontinuous portions of bandwidth that are allocated by Gorokhov are the claimed communications channels. As described

above, Gorokhov teaches using two separate portions of bandwidth (Gorokhov at Abstract; EX1006 at [0016]-[0017]), which a POSITA would understand to be two separate channels, each occupying a different bandwidth of frequency. Furthermore, each portion of bandwidth has guard subcarriers separating it from other portions. *See e.g.*, Gorokhov at 19:40-47, 14:48-51, and 17:13-17; *see also id.* at 2:60-64 (stating that each bandwidth portion has guard subcarriers); EX1006 at pg. 15, Claim 5.

61. A POSITA would understand that guard subcarriers are used to separate OFDM channels. This is well-known in the art, and this well known understanding is demonstrated in the art, *e.g.*, Yamaura, where the below Fig. 29 demonstrates that each channel is spaced 20 MHz apart, and is separated by a guard band.



62. This is also demonstrated in annotated Fig. 30, below, where a channel has OFDM subcarriers separated by a guard band.



63. Gorokhov's carrier discussion also demonstrates that it teaches multiple different channels. Gorokhov teaches that the total available "bandwidth … is divided into multiple carriers" (Gorokhov at 6:45-46; EX1006 at [0027]) and downlink traffic for the wireless device is "scheduled on multiple carriers simultaneously." Gorokhov at 4:60-61; *see also id.* at 4:55-57 ("[e]ach carrier is a portion of a larger bandwidth in which the system can operate…"), Fig. 3; *see also* EX1006 at [0016], Fig. 3. The bandwidth of each disjoint carrier is 1.25 MHz, and each carrier is separated by at least a bandwidth of 1.25 MHz. Gorokhov at 7:15-26; EX1006 at [0030]-[0031]; *see also* Gorokhov at 2:37-51 (stating that 1.25 MHz may represent a different service providers carrier); *see also id.* at 7:15-27. And, each carrier has guard bands separating it. *See* Gorokhov at 7:28-34; EX1006 at pg. 15, Claim 5.

64. Gorokhov's teaching of channel aggregation matches the '557 Patent's teachings. The '577 Patent aggregates "non-adjacent channels in … different frequency bands." '577 Patent at 3:38-41. Each channel occupies a frequency bandwidth (*e.g.*, *id.* at 6:3-5, 6:13-14) having a number of OFDM subcarriers (*e.g.*, *id.* at 7:1-3). Gorokhov aggregates "disjoint portions of bandwidth." Gorokhov at Abstract; EX1006 at [0030]. Gorokhov teaches that each portion of bandwidth spans different frequency bandwidths (*e.g.*, bands of 1.25 MHz each)—spanning a set of OFDM sub-carriers (*e.g.*, 128 sub-carriers for 1.25 MHz) (*see, e.g.,* Gorokhov at 10:38-41; EX1006 at [0054])—over the total available bandwidth (*e.g.*, 20 MHz) (*see* Gorokhov at 6:45-46 and 7:15-27; *see also id.* at Fig. 3; EX1006 at [0027], [0030]). The portions of bandwidth used are disjoint because they are separated by a certain bandwidth (e.g., 1.25 MHz). *See* Gorokhov at 15:34-36; EX1006 at [0030].

65. The '577 Patent's assignment description also matches Gorokhov's teachings. Gorokhov teaches an assignment message that assigns disjoint carriers to the wireless terminal (*e.g.*, Gorokhov at 12:32-35; EX1006 at [0033]) and further teaches that the assignment message can use subcarrier resource mappings (*e.g.*, Gorokhov at 17:56-64; EX1006 at [0032]-[0033], [0039]). The '577 Patent

teaches control channels and/or downlink maps for assigning aggregated channels (*e.g.*, *id.* at 23:39-49). The ’577 Patent and Gorokhov are substantially similar.

66. Gorokhov teaches that its control data is communicated over its first or second communication channel. The control channels can “exist in each of the carriers.” Gorokhov at 6:47-49; *see also id.* at 8:46-51 (stating that the control channel can be sent over portions of the carrier), 8:55-59 (stating that the control channel can be assigned a set of subcarriers); EX1006 at [0027], [0041]-[0042].

67. Finally, Gorokhov’s single assignment message contains two assignments, it assigns: (1) the first portion of bandwidth, and (2) the second portion of bandwidth. Thus, Gorokhov’s single assignment message is a first/second assignment of downlink resources for the first/second communication channels.

68. Even if Patent Owner were to argue that two separate assignments are required, it would have been an obvious modification because a POSITA would have viewed having an assignment in a single chunk of data or two (or in a data structure having two separate entries) would have been an obvious and trivial difference. Indeed, the ’577 Patent itself does not describe having assignments in separate chunks, or describe having one or two separate assignment messages as having any novel distinction.

[1.E] wherein the first communication channel and the second communication channel have different carrier frequencies;

69. Gorokhov teaches that each of its disjoint portions of bandwidth have different carrier frequencies. Gorokhov's wireless device is "scheduled on multiple carriers simultaneously." Gorokhov at 4:60-61; *see also id.* at 4:55-57 ("Each carrier is a portion of a larger bandwidth in which the system can operate…"); EX1006 at [0016], [0030]-[0031]. Gorokhov explains that the available "bandwidth … is divided into multiple carriers." Gorokhov at 6:45-46; EX1006 at [0027]. And the carriers have non-contiguous frequency bandwidths (*e.g.*, 1.25 MHz) of the total available bandwidth (*e.g.*, 20 MHz) (*see* Gorokhov at Abstract, 6:45-46, and 7:15-27; *see also id.* at Fig. 3; EX1006 at Fig. 3, [0026]-[0027], [0030]-[0031]). Gorokhov explains that 1.25 MHz is an example section of bandwidth that corresponds to the bandwidth of a service provider's carrier. *See, e.g.*, Gorokhov at 2:49–51, 2:64–66; Gorokhov at [0026].

[1.F] wherein the first assignment of downlink resources indicates assigned orthogonal frequency division multiple access (OFDM) subcarriers of the first communication channel and the second assignment of downlink resources indicates assigned OFDM subcarriers of the second communication channel; and

70. Gorokhov's assignment message meets this limitation because it assigns OFDM subcarriers for each of the disjoint portions of bandwidth that it uses for simultaneous transmission of downlink data. Gorokhov's disclosure is

related to an OFDM system. Gorokhov at 3:1-6; EX1006 at [0025]. Gorokhov teaches providing a "single assignment message [that] communicat[es] the assignment of a resource including the at least t[wo] discontinuous portions of bandwidth to the first wireless terminal." *See* Gorokhov at 16:12-15, 12:32-44, 19:65-20:5; *see also id.* at Fig. 7, Element 712, Abstract, 2:57-60, 3:22-38, 7:35-43, 12:6-12, 12:32-44, 13:24-31, and 17:7-10; EX1006 at [0033]. The two discontinuous channels span a set of OFDM subcarriers—for example, if the portion of bandwidth is 1.25 MHz (*e.g.*, Gorokhov at 7:15-17; EX1006 at [0030]-[0031]), then the two discontinuous portions of bandwidth would span 128 sub-carriers (*e.g.*, Gorokhov at 10:38-41); EX1006 at [0054]. The disjoint portions of bandwidth are aggregated and used for downlink traffic. Gorokhov at Abstract; EX1006 at [0016]-[0017].

71. Gorokhov teaches an additional embodiment that further demonstrates that the OFDM subcarriers for the two disjoint portions of bandwidth are assigned. Gorhokov teaches that the assignment message provides "a node identifier corresponding to a set of sub-carriers, the set of sub-carriers including at least one sub-carrier from each of at least two discontinuous portions of bandwidth." *See, e.g.,* Gorokhov at 16:15-20 (emphasis added); *see also id.* at 12:37-44, 13:37-44, 17:56-64, 7:35-42; EX1006 at [0032]-[0033], Claim 9. Gorokhov's disclosure of

this embodiment matches the '577 Patent's disclosure of providing downlink maps for its subcarriers. *See, e.g.,* '577 Patent at 23:39-49.

[1.G] the receive unit and the processor are further configured to receive downlink data on the assigned OFDM subcarriers of the first communication channel and the assigned OFDM subcarriers of the second communication channel;

72. Gorokhov's receiver and processor receives downlink data on both disjoint portions of bandwidth. Gorokhov teaches using these "portions of bandwidth … at the same time[] as a[] … downlink band." *See, e.g.,* Gorokhov at Abstract, 2:57-60, 4:60-61, 13:34-35, 16:5-8; EX1006 at [0004], [0016], [0025]. Downlink traffic is transmitted on these assigned bands. *See, e.g.,* Gorokhov at 17:1; *see also id.* at 6:60–7:5, 10:25-37; EX1006 at [0004], [0016], [0025]. Data is transmitted over two separate channels simultaneously to increase downlink data rates. *See* Gorokhov at 2:36–42; EX1006 at [0004], [0016], [0025]. As described immediately above, these bands comprise a set of OFDM subcarriers.

[1.H] wherein at least a portion of the downlink data is received at least in part simultaneously on the first communication channel and the second communication channel; and

73. Gorokhov teaches using the two disjoint portions of bandwidth at the same time to transmit and receive downlink data. Gorokhov at 2:57-60, 2:32-42, 4:60-61, 20:22-25; EX1006 at [0004], [0016], [0025]. This is done in order to

increase downlink data rates. *See, e.g.,* Gorokhov at 2:36-42; EX1006 at [0004], [0016], [0025].

[1.I] the processor is configured to combine at least a portion of the received downlink data from the first communication channel and the second communication channel to produce data for a single service.

74. Gorokhov's processor combines the downlink data from the disjoint portions of bandwidth to produce data for a single service. The wireless terminal receives an assignment message assigning it two disjoint portions of bandwidth to receive downlink data on. *See* Gorokhov at 16:12-15, 12:32-44, 19:65-20:5; *see also id.* at Fig. 7, Element 712, Abstract, 2:57-60, 3:22-38, 7:35-43, 12:6-12, 12:32-44, 13:24-31, and 17:7-10; EX1006 at [0004], [0032]-[0035]. The wireless terminal receives the data streams on the disjoint portions of bandwidth, and demodulates, deinterleaves, and decodes the stream to recover the transmitted traffic data. *See* Gorokhov at 10:31-34; *see also id.* at 16:39-44, 18:7-13, 3:36-37; EX1006 at [0053], Fig. 6. And the data received is from a single service—a service provider's base station uses non-contiguous channels to transmit to a wireless terminal because there are sometimes gaps in the licensed spectrum that a specific provider can use (*e.g.*, a different provider uses it). *See, e.g.,* Gorokhov at 13:15-19, 2:49-51; EX1006 at [0030]-[0031]. Furthermore, Gorokhov teaches performing FFTs on the input data streams (*e.g.*, Gorokhov at 7:32-37; EX1006 at

[0031]), and a POSITA would understand that the data would need to be combined in some form (whether to perform a single FFT or two FFTs).

75. Finally, Fig. 6 demonstrates how two separate channels received by receivers (yellow) can be combined (red) by the processor (blue). Gorokhov at Fig. 6; EX1006 at Fig. 6.

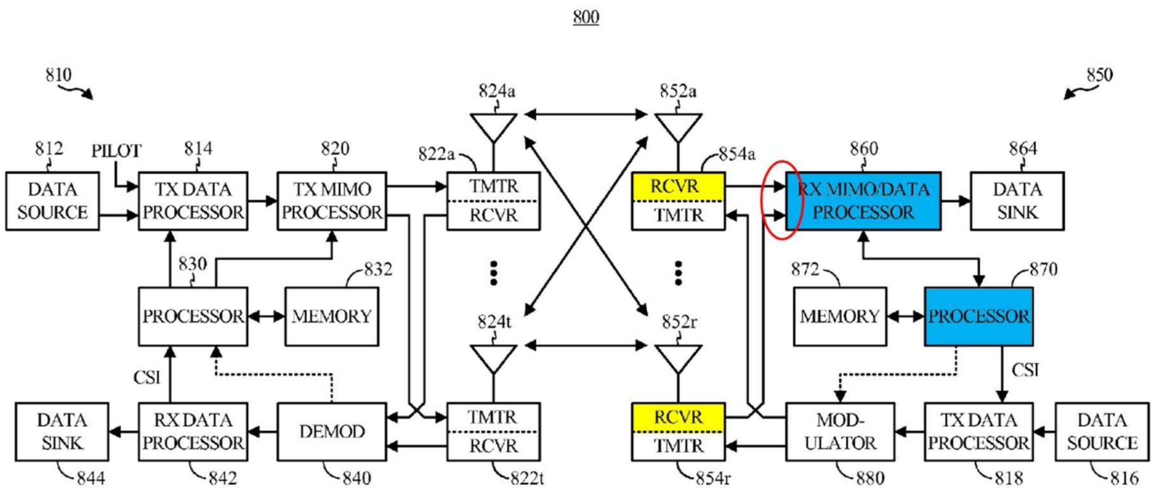


FIG. 6

b. Claim 3 is rendered obvious by Gorokhov

[3] The wireless device of claim 1 wherein the first communication channel and the second communication channel are in different frequency bands.

76. Gorokhov teaches that each of its two disjoint portions of bandwidth are in different frequency bands. *See, e.g.,* Gorokhov at 13:7-19 and 15:14-29; *see also id.* at 2:20-28, 2:49-51, 2:64-66; EX1006 at Fig. 3, [0026]-[0027], [0030]-[0031].

c. Claim 4 is rendered obvious by Gorokhov

[4.A] The wireless device of claim 1 further comprising a transmit unit;

77. Gorokhov teaches a wireless terminal that has a processor. *See, e.g.*, Gorokhov at 12:35; *see also id.* at 7:36, Figs. 1, 6, 10, 10:25-11:13. Gorokhov's wireless terminal has a transmitter. *See, e.g.*, 10:16-37, Fig. 6, Element 852a and 854a. EX1006 at [0052]-[0056], Fig. 6. The transmitter is annotated below in Fig. 6. *See also* EX1006 at Fig. 6.

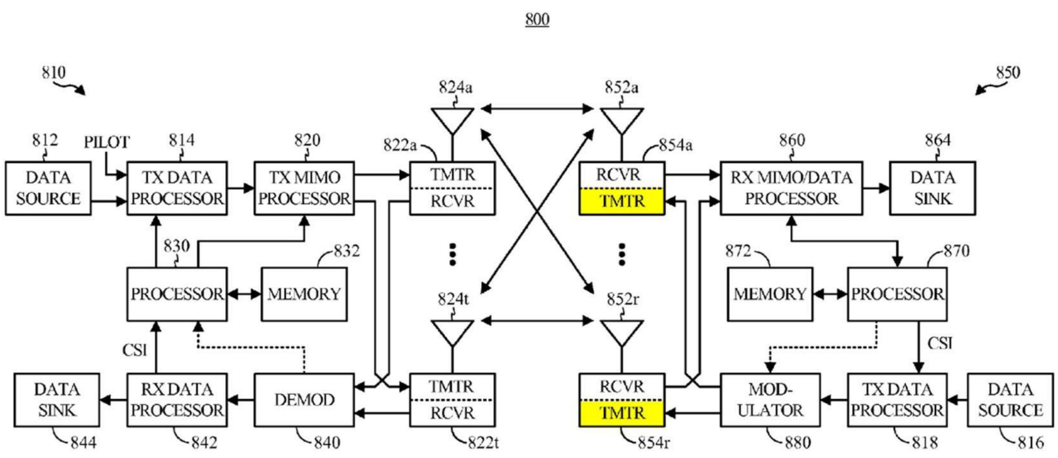


FIG. 6

[4.B] wherein the transmit unit and the processor are configured to transmit, to a base station, an indication that the wireless device is capable of channel aggregation.

78. Gorokhov's wireless terminal, with a transmitter and a processor, transmits identification information stating whether the device can utilize multiple channels to the base station. A wireless device is "scheduled in one carrier or more than one carrier according to its capabilities." Gorokhov at 4:62-63; *see also id.* at

6:60-63; EX1006 at [0017]. The wireless terminal's capabilities are communicated by the wireless terminal when it transmits identification information to the base station. *See id.* at 4:63-5:5; *see also id.* at Fig. 1, 5:6-12, 11:29-35; EX1006 at [0017]. A POSITA would understand that, when a terminal transmits its capabilities, it transmits whether it can be scheduled to only one channel or to more, which would be an indication regarding whether it can perform channel aggregation.

d. Claim 5 is rendered obvious by Gorokhov

[5] The wireless device of claim 1 wherein the processor uses a single medium access control (MAC) layer for processing the downlink data from both the first communication channel and the second communication channel.

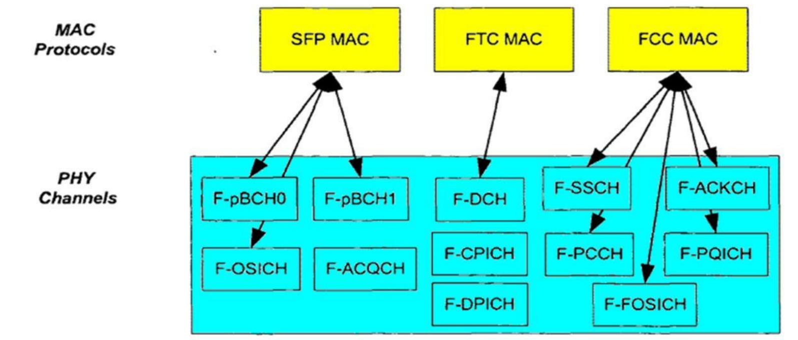
79. Gorokhov teaches transmitting data over a physical layer on two separate portions of bandwidth. *See e.g.*, Gorokhov at Abstract; *see also id*. at Fig. 6 (showing hardware); EX1006 at [0004], [0032]-[0035]; *see also* Gorokhov at Fig. 10 (showing data/info 1020 which has identifiers that a POSITA would understand to be for a MAC layer); 16:15-20 (saying that the assignment can include "a node identifier corresponding to a set of sub-carriers"); *see also id.* at 12:37-44 (describing a channel tree being sent to the wireless terminal), 13:37-44, 17:56-64 (describing a sub-carrier mapping that is transmitted), 7:35-42; EX1006 at [0033], Claim 9. A POSITA would understand that the physical layer would necessitate a

MAC layer in order for the channels to be aggregated and for data to pass to higher abstraction layers for use in the mobile terminal.

80. Gorokhov's provisional application teaches using the MAC layer (annotated yellow) to receive data from the physical layer (aqua) in forward link channels. *See* EX1005 at p. 10, Fig. 7.

2.1.2 Forward Link Channels

The FL channels are shown in Figure 7, and described in Table 3.



81. As demonstrated below, the above figure and structure matches the disclosure of the '577 patent's annotated Fig. 4A-B.

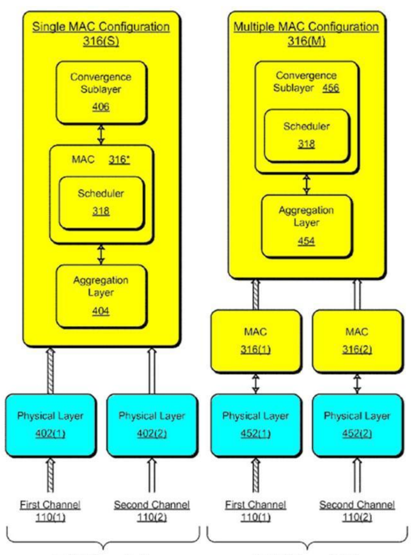
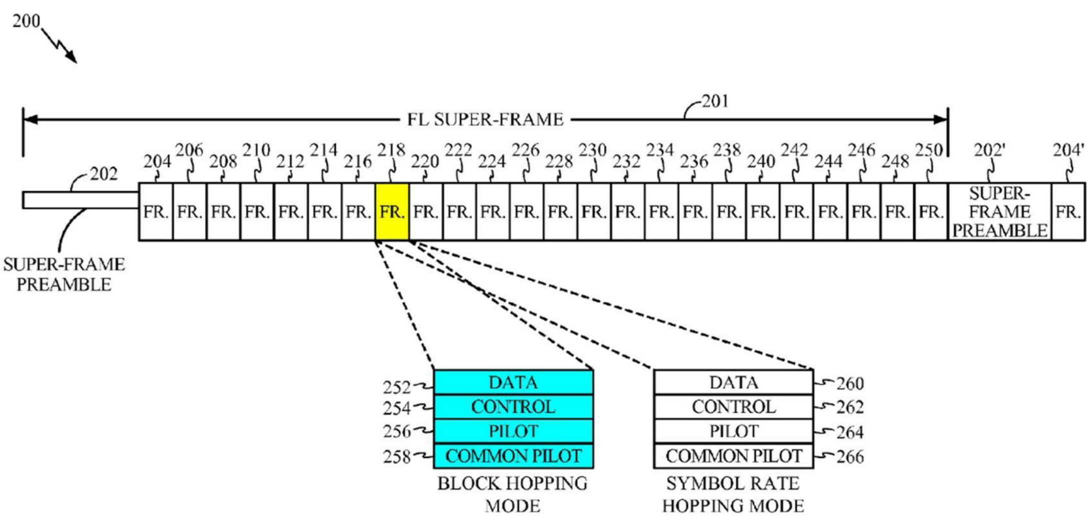


FIG. 4A FIG. 4B

e. Claim 6 is rendered obvious by Gorokhov

[6] The wireless device of claim 1 wherein transmission of downlink data is scheduled on a subframe basis.

82. Gorokhov's "forward link transmission is divided into units of superframes." Gorokhov at 5:30-31, 4:57-61 (stating that terminals are scheduled on a frame or superframe basis); EX1006 at [0021]; EX1007 at [0018]. A superframe comprises frames (*id.* at 5:30-42, 6:30-40), which a POSITA would understand to be a subframe. *See* Gorokhov at 5:30-31, EX1006 at [0021], EX1007 at [0018]. As shown in annotated Fig. 2A below, a super-frame is divided into frames (*e.g.*, Frame 218, annotated yellow), which have a data portion 252, control portion, 254, pilot portion 256, and a common pilot portion 258. *See, e.g.,* Gorokhov at 5:43-55; EX1006 at Fig. 2A, [0020]-[0023].



f. Claim 8 is rendered obvious by Gorokhov

[8] The wireless device of claim 1 wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the first communication channel is Frequency Division Duplexed (FDD) and a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the second communication channel is Time Division Duplexed (TDD).

83. The only '577 Patent support for using both TDD and FDD—one for each portion of bandwidth—is that its disclosure is applicable to both TDD and FDD systems. *See* EX1001 at 5:30-35. Gorokhov likewise teaches that its systems is applicable to both TDD and FDD systems, and describes the frame structure for each. Gorokhov at 5:20-42; EX1006 at [0020]. A POSITA would have found it obvious to use both frame structures, and that using one channel for TDD, and another for FDD, would have been obvious.

g. Claim 9 is rendered obvious by Gorokhov

[9] The wireless device of claim 1 further comprising one or more receive antennas, wherein the receive unit and the processor are further configured to receive the downlink data via the one or more receive antennas.

84. Gorokhov's wireless device has one or more receive antennas that the receiver receives downlink data from. *See* Gorokhov at Fig. 6, Elements 852 and 854, 10:16-41; *see also id.* at 11:29-35; EX1006 at [0049], Fig. 6.

h. Claim 10 is rendered obvious by Gorokhov

[10] The wireless device of claim 1, wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the

first communication channel is received from a first cell, and wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the second communication channel is received from a second cell.

85. Gorokhov teaches a terminal that simultaneously connects to two separate cells, where each cell transmits downlink data to the terminal on separate OFDM channels. Gorokhov teaches terminals 134, 136, and 148 (annotated red, below) that are connected to two separate cells (annotated aqua/yellow/green) at the same time. *See* Gorokhov at 4:36-42, Fig. 1; EX1006 at [0013], Fig. 1.

86. Each carrier is a communication channel. *See, e.g.*, Gorokhov at 19:40-47, 14:48-51, and 17:13-17, 2:60-64, 6:45-46, 4:60-61, 4:55-57, 7:15-34, Abstract; EX1006 at [0004], [0016]-[0017], [0032]-[0035], [0042], pg. 15, claim 5.

87. Each channel has assigned OFDM subcarriers. *See, e.g.,* Gorokhov at 3:1-6, 16:12-15, 12:32-44, 19:65-20:5, Fig. 7, Element 712, 7:15-17, 10:38-41, 16:15-20, 12:37-44, 13:37-44, 17:56-64, 7:35-42; EX1006 at [0025], [0030]-[0033], [0054], [0016]-[0017].

88. Gorokhov also teaches that cells sometimes operate with a single carrier only (Gorokhov at 4:54-57; EX1006 at [0016]), and that a terminal is scheduled on multiple carriers at the same time (Gorokhov at 4:60-61; EX1006 at [0016]). A POSITA would understand that a terminal connected to a single-carrier

cell, would need to receive data from a separate cell in order to perform multi-carrier aggregation.

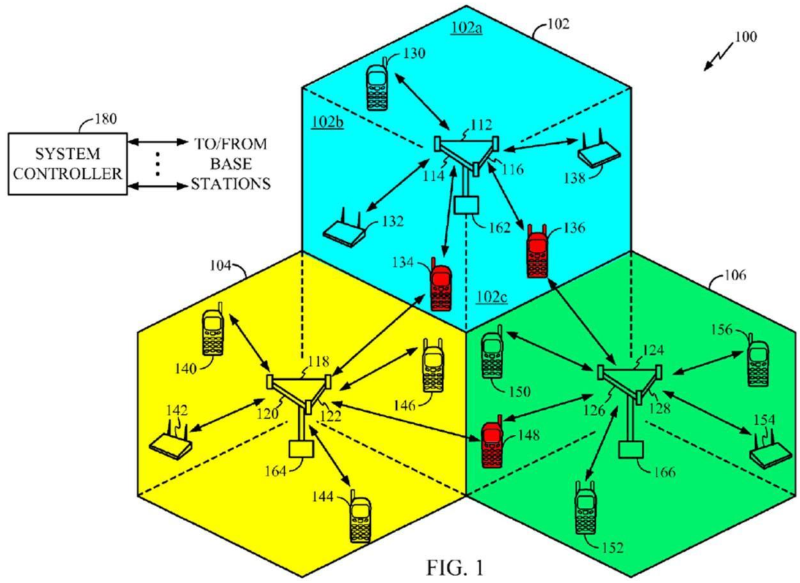


FIG. 1

89. Furthermore, a POSITA would understand that this limitation is taught during handover because, during handover, an on-going session is handed off from one cell to the next without any interruption in service. During handover, each cell that the terminal is connected to would transmit downlink data on the terminal's assigned channels. As demonstrated above, terminals 134/136/148 are connected to two cells at the same time, and each cell would transmit a device's assigned channels during a handover event.

i. Claim 11 is rendered obvious by Gorokhov

[11] The wireless device of claim 1, wherein the control data received via the control channels is received over the first communication channel and is not received via the second communication channel.

90. Gorokhov teaches this limitation. Gorokhov teaches a single assignment message. Gorokhov at 7:35-37; EX1006 at [0004], [0032]-[0035]. A POSITA would understand that, because there is a single assignment message, that it would be transmitted only on one carrier and not another.

91. Furthermore, Gorokhov teaches that allocation of non-contiguous carriers may be provided in "one or more overhead channels." Gorokhov at 7:28-34; EX1006 at [0032]. Because it is allocated in only one channel, a POSITA would understand that it is transmitted via only one communication channel.

j. Claim 12 is rendered obvious by Gorokhov

92. Claim 12 is taught for the same reasons as described with respect to claim 1.

[12.PRE] A method for use by a wireless device, the method comprising:

93. Gorokhov teaches a method to use by a wireless device. Gorokhov teaches a wireless device (*see also* Gorokhov at 12:35) and a method that it performs to assign two disjoint portions of bandwidth to transmit data on (*see also* Gorokhov at Abstract).

[12.A] receiving control data via control channels over at least a first communication channel or a second communication channel,

94. [12.A] is taught for the same reasons as described in [1.B].

[12.B] the control data including a first assignment of downlink resources for

the first communication channel and a second assignment of downlink resources for the second communication channel;

95. [12.B] is taught for the same reasons as described in [1.D].

[12.C] wherein the first communication channel and the second communication channel have different carrier frequencies;

96. [12.C] is taught for the same reasons as described in [1.E].

[12.D] wherein the first assignment of downlink resources indicates assigned orthogonal frequency division multiple access (OFDM) subcarriers of the first communication channel and the second assignment of downlink resources indicates assigned OFDM subcarriers of the second communication channel; and

97. [12.D] is taught for the same reasons as described in [1.F].

[12.E] receiving downlink data on the assigned OFDM subcarriers of the first communication channel and the assigned OFDM subcarriers of the second communication channel;

98. [12.E] is taught for the same reasons as described in [1.G].

[12.F] wherein at least a portion of the downlink data is received at least in part simultaneously on the first communication channel and the second communication channel; and

99. [12.F] is taught for the same reasons as described in [1.H].

[12.G] combining at least a portion of the received downlink data from the first communication channel and the second communication channel to produce data for a single service.

100. [12.G] is taught for the same reasons as described in [1.I].

k. Claim 14 is rendered obvious by Gorokhov

[14] The method of claim 12 wherein the first communication channel and the second communication channel are in different frequency bands.

101. Claim 14 is identical to claim 3 and is taught for the same reasons.

l. Claim 15 is rendered obvious by Gorokhov

[15] The method of claim 12 further comprising transmitting, to a base station, an indication that the wireless device is capable of channel aggregation.

102. Claim 15 is substantively similar to claim 4 and is taught for the same reasons.

m. Claim 16 is rendered obvious by Gorokhov

[16] The method of claim 12 further comprising using a single medium access control (MAC) layer for processing the downlink data from both the first communication channel and the second communication channel.

103. Claim 16 is substantively similar to claim 5 and is taught for the same reasons.

n. Claim 17 is rendered obvious by Gorokhov

[17] The method of claim 12 wherein transmission of downlink data is scheduled on a subframe basis.

104. Claim 17 is substantively similar to claim 6 and is taught for the same reasons.

o. Claim 19 is rendered obvious by Gorokhov

[19] The method of claim 12 wherein data received via the first communication channel is Frequency Division Duplexed (FDD) and data received via the second communication channel is Time Division Duplexed

(TDD).

105. Claim 19 is substantively similar to claim 8 and is taught for the same reasons.

p. Claim 20 is rendered obvious by Gorokhov

[20] The method of claim 12, wherein the receiving the downlink data includes receiving the downlink data via one or more receive antennas.

106. Claim 20 is substantively similar to claim 9 and is taught for the same reasons.

q. Claim 21 is rendered obvious by Gorokhov

[21] The method of claim 12, wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the first communication channel is received from a first cell, and wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the second communication channel is received from a second cell.

107. Claim 20 is substantively similar to claim 10 and is taught for the same reasons.

r. Claim 22 is rendered obvious by Gorokhov

[22] The method of claim 12, wherein the control data received via the control channels is received over the first communication channel and is not received via the second communication channel

108. Claim 22 is substantively similar to claim 11 and is taught for the same reasons.

B. Gound 1B: Claims 2 and 13 are rendered obvious by Gorokhov and Jung

109. Claims 2 and 13 are directed to using ARQ sequence numbers. The ’577 Patent recognizes that the usage of ARQ sequence numbers was very common and already implemented in the art. *See* ’577 Patent at 16:8-16 (“automatic retransmit request (ARQ) numbering sequence protocol [] is already included along with the data in some wireless communication schemes”). Jung (a Samsung publication) teaches using ARQ sequence numbers to combine downlink data from different services for an OFDMA wireless communication system. *See, e.g.*, Jung at 1:10-12, 9:31-32, 15:2-6, 15:34-16:4, 23:6-20, 24:7-9.

s. Claim 2 is rendered obvious by Gorokhov and Jung

[2.A] The wireless device of claim 1 wherein the downlink data is received with automatic repeat request (ARQ) sequence numbers;

110. Jung’s wireless device includes receiving downlink data with ARQ sequence numbers. Jung at 15:2-6; *see also id.* at 14:15-17. Jung teaches an “ARQ Identifier Sequence Number (AISN) field” (*id.* at 15:3-5), which indicates the sequence information of transmitted broadcast packets. *Id.* at 15:33-16:1. The AISN filed is annotated below from Table 3.

Table 3

Syntax	Size
Broadcast_DL-MAP_IE {	
Extended DIUC	4 bits
Length	4 bits
For(i=0;i<N_CID;i++){	
CID	16bits
SPID	4 bits (or 2 bits used)
ACID	2 bits
AISN	1 bits
OFDMA Symbol Offset	8bits
Subchannel Offset	6bits
No. OFDMA Symbols	7 bits
No. Subchannels	6 bits
DIUC	4 bits
}	

[2.B] wherein the processor is further configured to combine the at least a portion of the downlink data using the ARQ sequence numbers.

111. Jung uses the ARQ sequence numbers to combine downlink data. The AISN field identifies the sequence information of received packets. Jung at 16:3-4. The AISN field will be checked to determine whether a subpacket is a first subpacket and, if not, it will be combined with previous subpackets. *See id.* at 23:9-16; *see also id.* at 24:7-9 (stating that an AISN could be used where the SPID is described). Jung accordingly teaches claim 2.

112. A POSITA would have been motivated to combine the teachings of Jung with the teachings of Gorokhov because doing so would have been the application of a known technique to improve similar devices. Both Jung and Gorokhov teach different data streams for OFDM systems. *See, e.g.,* Gorokhov at Abstract; Jung at 9:31-32. Both publications teach combining their data streams. *See, e.g.,* Gorokhov at Fig. 6 (showing data from RCVR 854a/854r being

combined in RX MIMO/DATA PROCESSOR 860); Jung at Fig. 3. Both publications describe segmenting the transmitted data. *See* Gorokhov at Figs. 2A-B (showing subframes) and Fig. 4 (showing combined signals). And, Jung teaches an improved method to ensure that the data is correctly combined—an ARQ sequence number.

113. Furthermore, the usage of ARQ sequence numbers would have provided predictable results. A POSITA would have understood that ARQ sequence numbers provide an indication as to ordering in a data stream, and that using an ARQ sequence would have ensured that the data stream would have been appropriately ordered.

t. Claim 13 is rendered obvious by Gorokhov and Jung

[13.A] The method of claim 12, further comprising: receiving the downlink data with automatic repeat request (ARQ) sequence numbers; and

114. [13.A] is substantively similar to [2.A] and is rendered obvious for the same reasons.

[13.B] combining the at least a portion of the downlink data using the ARQ sequence numbers.

115. [13.B] is substantively similar to [2.B] and is rendered obvious for the same reasons.

C. Gound 1C: Claims 7 and 18 are rendered obvious by Gorokhov and Zhao

116. Claims 7 and 18 are directed to using different FFTs on the receiver for each communication channel. This is an obvious variant of what a POSITA would have typically expected from an OFDM system. The '577 Patent itself treats using one or two FFTs as an unimportant and well-known option. *See, e.g.*, '577 Patent at 6:65-7:9.

117. It was standard in the art for OFDM systems to perform an FFT on the receiver, and an IFFT on the transmitter. If there are disjoint portions of bandwidth, there were effectively two options to a POSITA: (1) perform a single FFT for the combined signal, or (2) perform an FFT for each physical channel. Claims 7 and 18 require a separate FFT for each physical channel, and this was well known in the art and one of the two options that could be employed.

118. Zhao describes an OFDM system, that teaches multiplexing two separate paths into a single FFT engine. *See, e.g.*, Zhao at Fig. 5 and [0046]. Shown below is a RX Port Mux 81 (yellow) receiving two physical channels 41 and 43 (red), going into a single FFT engine 82 (aqua). *Id.* at [0046].

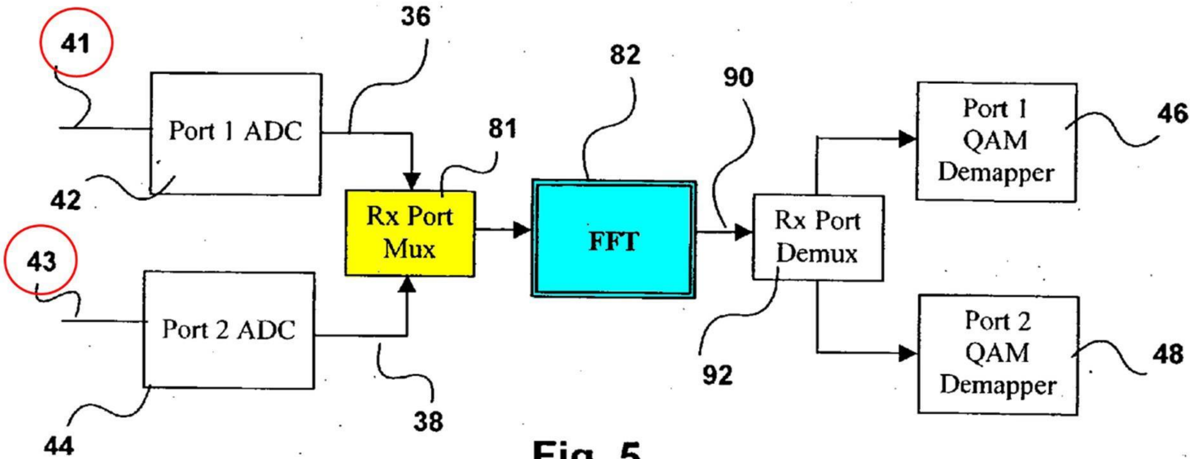


Fig. 5

119. The above demonstrates one option—using a single FFT engine for two physical channels. Zhao demonstrates, however, that using two FFT engines for two physical channels was also well-known. Shown below are two separate FFT engines 32 (orange) and 34 (green), that receive data from two separate physical channels 41 and 43. *See* Zhao at [0043].

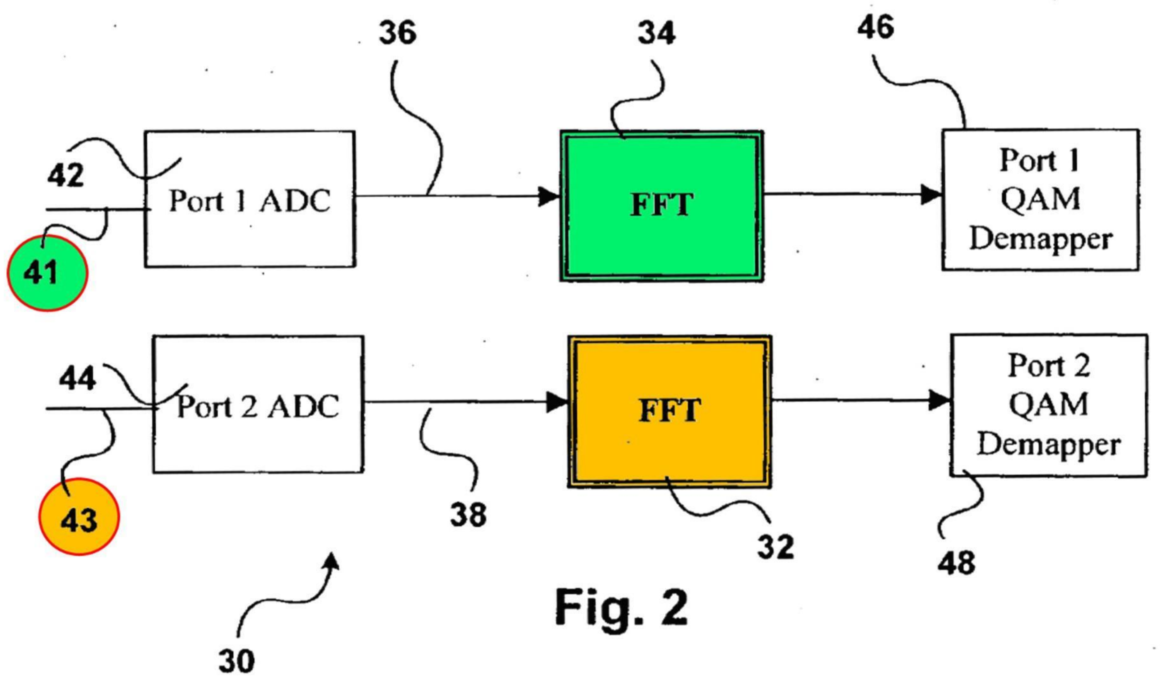


Fig. 2

PRIOR ART

120. A POSITA would have been motivated to combine Zhao with Gorokhov. Gorokhov explains that an FFT is performed on the received signal, and that the FFT size can be the same size as each assigned portion of bandwidth. *See* Gorokhov at 7:22-27; *see also id.* at 6:41-44; EX1006 at [0031]; EX1005 at 4-5. And, Gorokhov teaches using disjoint portions of bandwidth for downlink data. Gorokhov at Abstract; EX1006 at [0029]. A POSITA would have understood that the data from the separate channels could either be combined then FFTed, or separately FFTed, then combined.

121. Zhao demonstrates that both were well known in the art. *See* Zhao at [0043] and [0046]. A POSITA would have found that using two separate FTTs,

one for each physical channel, would have been a known method to yield predictable results. A POSITA would have found that using one FFT (or two) would have been a simple substitution.

a. Claim 7 is rendered obvious by Gorokhov and Zhao

[7.A] The wireless device of claim 1 wherein a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the first communication channel is processed using a first Fast Fourier Transform (FFT) and

122. Gorokhov teaches receiving downlink data on a first communication path. As demonstrated below, Zhao teaches receiving data from a first physical channel 41 (green/red) and performing an FFT with an FFT engine 34 (green). *See* Zhao at [0043].

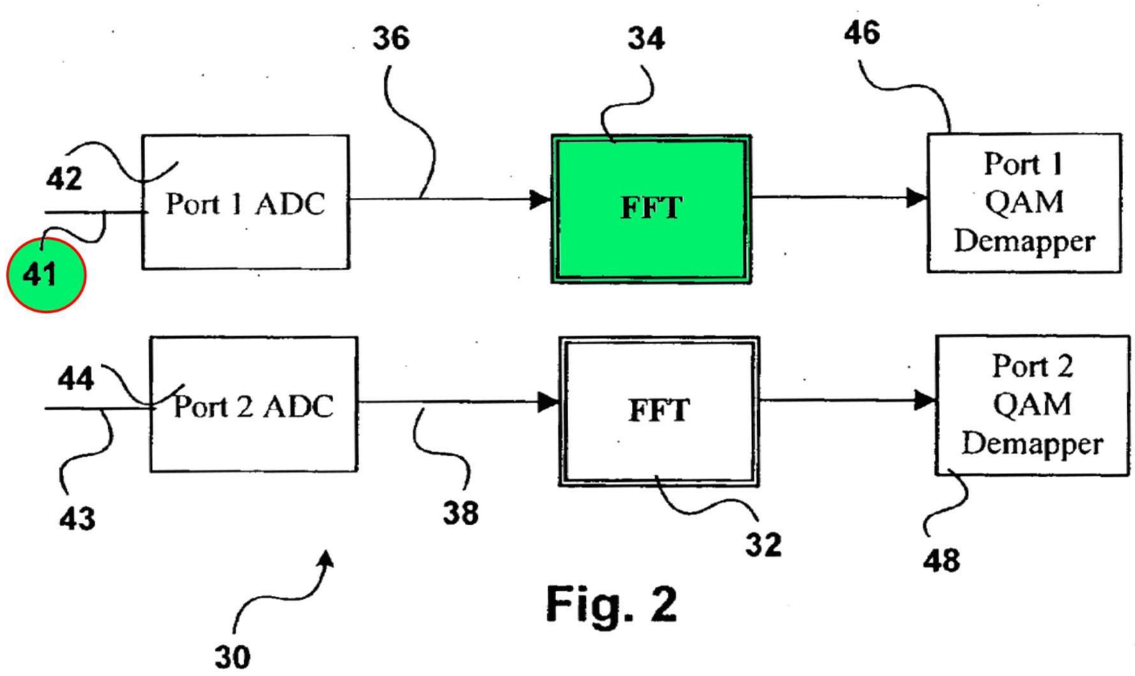


Fig. 2

PRIOR ART

[7.B] a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the second communication channel is processed using a second FFT that is different than the first FFT.

123. As described in Ground 1A, Gorokhov teaches receiving downlink data on a second communication path. As demonstrated below, Zhao teaches receiving data from a second physical channel 43 (orange/red) and performing an FFT with a separate FFT engine 32 (orange) that is different from the first. *See* Zhao at [0043].

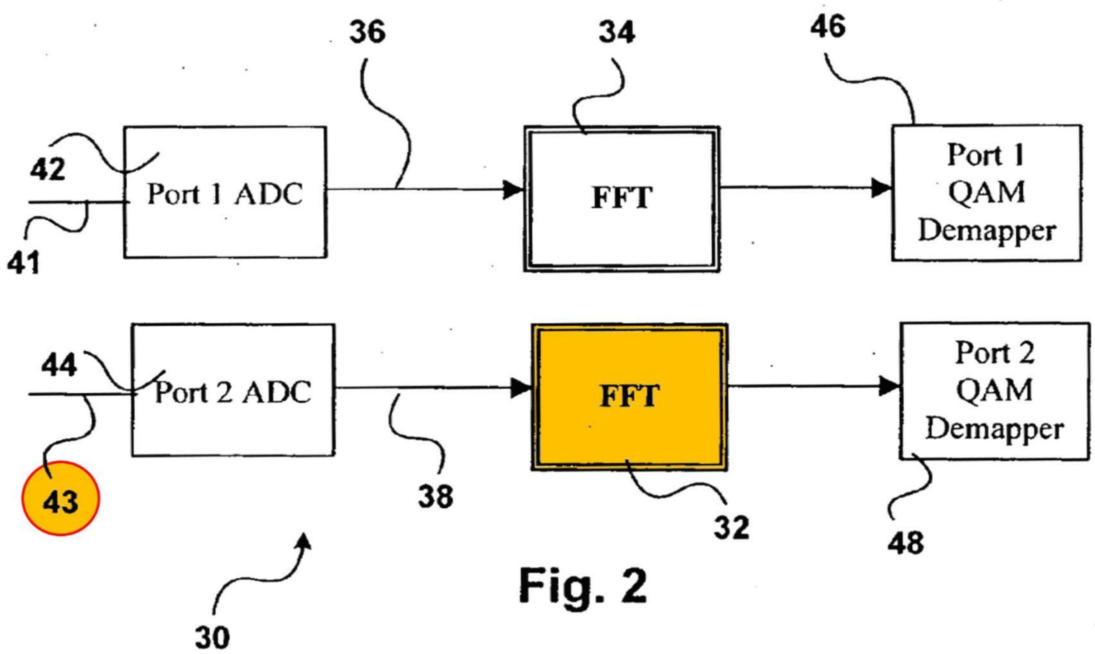


Fig. 2

PRIOR ART

b. Claim 18 is rendered obvious by Gorokhov and Zhao

[18.A] The method of claim 12, further comprising processing a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the first communication channel using a first Fast Fourier Transform (FFT) and

124. [18.A] is substantially similar to [7.A] and is rendered obvious for the same reasons.

[18.B] processing a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the second communication channel using a second FFT that is different than the first FFT.

125. [18.B] is substantially similar to [7.B] and is rendered obvious for the same reasons.

D. Gound 1D: Claims 10 and 21 are rendered obvious by Gorokhov and Walton

126. As described in Ground 1A, Gorokhov renders obvious claims 10 and 21. Gorokhov and Walton also render these claims obvious.

127. Walton teaches that each cell has dedicated frequency bandwidths that it transmits. *See, e.g.*, Walton at 12:19-39, Figs. 5-6. As demonstrated below, cell 1 has a particular bandwidth (yellow), and cell 2 has an entirely separate bandwidth. *Id.*

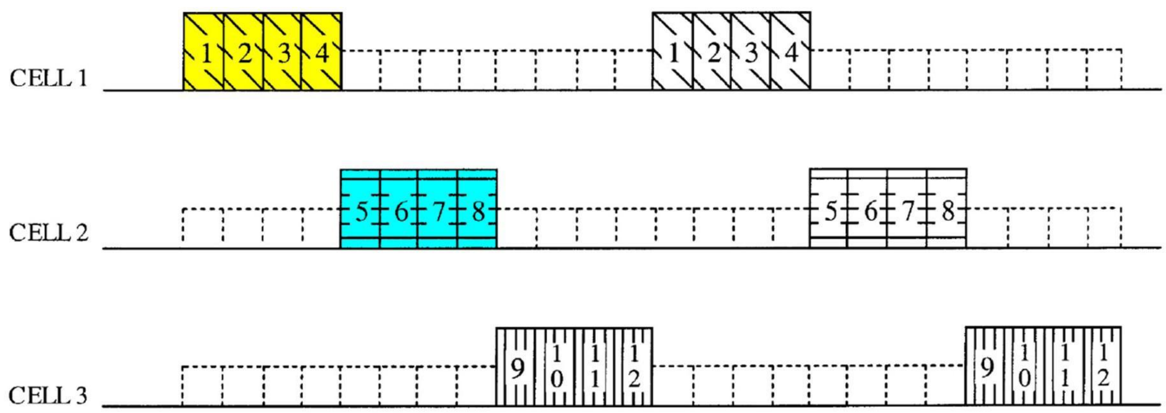


FIG. 6

128. And, Walton teaches that a device can simultaneously connect to two separate cells. *See, e.g.,* Walton at Fig. 1, 35:16-57. This is done to increase throughput through concurrent downlink transmissions from separate cells. *See id.* at 35:19-24. The data from each individual cell is synchronized and combined. *Id.* at 35:30-35, 54-57.

129. A POSITA would have been motivated to combine Gorokhov and Walton. Walton provides an improvement—it teaches that throughput can be increased by having concurrent transmission of downlink resources through two separate cells. Gorokhov at 35:16-57. Like Walton, Gorokhov also teaches that its devices connect to two separate cells at the same time. *See* Gorokhov at 4:36-42, Fig. 1; EX1006 at [0013], Fig. 1. Gorokhov further teaches that cells sometimes operate with a single carrier only (Gorokhov at 4:54-57; EX1006 at [0016]), and that a terminal is scheduled on multiple carriers at the same time (Gorokhov at 4:60-61; EX1006 at [0016]). A POSITA would have been motivated to increase throughput of Gorokhov, and retaining its aggregation of disjoint portions of bandwidth, by simultaneously transmitting the portions of bandwidth from multiple cells. This would have provided an improvement to Gorokhov, and would have led to predictable results. Further, both Gorokhov and Walton are Qualcomm patents directed toward OFDM systems. A POSITA would have been

motivated to look at the research and development of one Qualcomm OFDM patent, while reviewing the teachings of another.

a. Claim 10 is rendered obvious by Gorokhov and Walton

The wireless device of claim 1, wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the first communication channel is received from a first cell, and wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the second communication channel is received from a second cell.

130. As described in Ground 1A, Gorokhov teaches aggregating disjoint portions of bandwidth. As demonstrated below, Walton teaches that cell 1 and cell 2 are assigned different portions of bandwidth (yellow and aqua, respectively). *See, e.g.,* Walton at 12:19-39, Figs. 5-6. Walton further teaches that a device can simultaneously connect to two separate cells to receive the downlink data. *See, e.g.,* Walton at Fig. 1, 35:16-57. As described immediately above, a POSITA would have been motivated to combine Gorokhov and Walton to transmit the disjoint portions of bandwidth at the same time from separate cells to increase throughput.

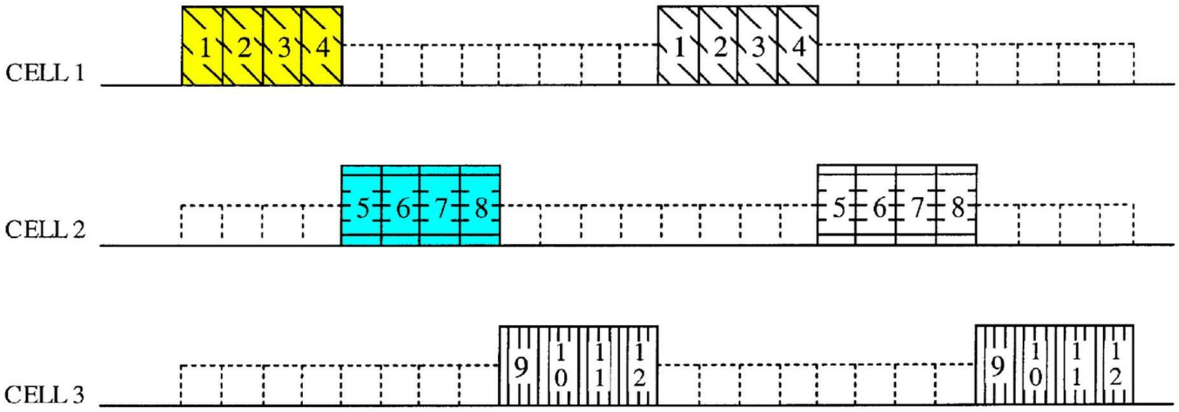


FIG. 6

b. Claim 21 is rendered obvious by Gorokhov and Walton

The method of claim 12, wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the first communication channel is received from a first cell, and wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the second communication channel is received from a second cell.

131. Claim 21 is substantially similar to claim 10 and is taught for the same reasons.

E. Gound 2A: Claims 1, 3-5, 11-12, 14-16, and 22 are rendered obvious by Ryu and Yamaura

132. Ryu teaches "channel aggregation … in order to increase throughput." Ryu at Summary. Each channel "compris[es] a carrier with a frequency bandwidth of a specific section." *Id.* at [0013]. To aggregate channels, Ryu teaches transmitting a message to a terminal for "simultaneous allocation of a plurality of traffic channels to a specific terminal." *Id.* at Summary.

133. Ryu teaches every critical aspect of the invention claimed in the '577 Patent. And, this is apparent from Ryu's summary of its claimed invention:

> "In order to achieve the object as described above, … performing carrier aggregation to allocate a plurality of additional traffic channels to a terminal with an allocated channel, … a step of configuring the information on channels to be aggregated in a control message; a step of allocating a plurality of channels by transmitting the configured control message to the terminal; and a step of transmitting data between the terminal and the base station via the allocated channels."

Ryu at [0035].

134. The only difference between Ryu and the claimed invention of the '577 Patent, is that Ryu is explicitly directed to TDMA, CDMA, SDMA, and FDMA systems (Ryu at [0041]), while the '577 Patent claims OFDM. But the usage of OFDM is an obvious variant of Ryu's teachings.

135. Yamaura discloses a multi-carrier OFDM system. Yamaura at Abstract. Yamaura teaches OFDM channels centered around a carrier (*e.g.*, *id.* at Fig. 29) that comprise a frequency band of subcarriers (*e.g.*, *id.* at 30). Yamaura further teaches control data in control channels (FCH) "to inform each terminal station of the traffic channel allocation." *Id.* at [0143].

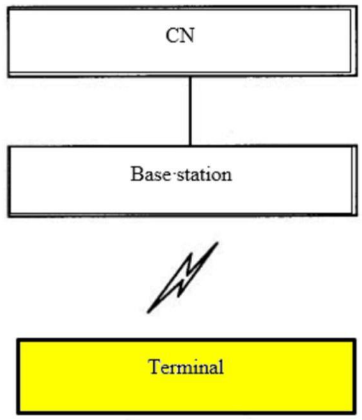
136. A POSITA would have been motivated to combine Ryu and Yamaura. As noted, Ryu is directed to TDMA, CDMA, SDMA, and FDMA systems (Ryu at

[0041]), but it states that its "invention can also be applied to communication systems operating according to other standards." *Id.* at [0040]. Ryu states that its invention "can be applied to a wide range of wireless systems that allow data exchange." *Id.* at [0066]. OFDM was very well known at the time, and a POSITA would have found it obvious to apply Ryu's teachings to OFDM, which Yamaura teaches.

(a) Claim 1 is rendered obvious by Ryu and Yamaura

[1.PRE] A wireless device comprising:

137. Ryu teaches an end user device. *See, e.g.*, Ryu at Figs. 1-2; *see also id.* at [0016] (describing an "end user device (EUD)"). Shown in annotated Fig. 1 below, the terminal device (yellow) communicates with a core network through a base station. *Id.* at Fig. 1. Yamaura also teaches a wireless device. *See* Yamaura at Abstract.



[1.A] a receive unit; and

138. Ryu's end user device has a physical layer for the radio interface and a wireless modem. Ryu at [0007], [0009], [0042], and [0065]-[0066]; *see also id.* at Fig. 2. Yamaura teaches an RF receiver. See Yamaura at Fig. 32, Element 331, [0069].

[1.B] a processor; and

139. Ryu's end user device can be a cellular handset or a laptop computer (*see, e.g.,* Ryu at [0042] and [0057]), which a POSITA would have understood to include a processor. Yamaura teaches a control unit, which a POSITA would understand to be a processor. Yamaura at [0024].

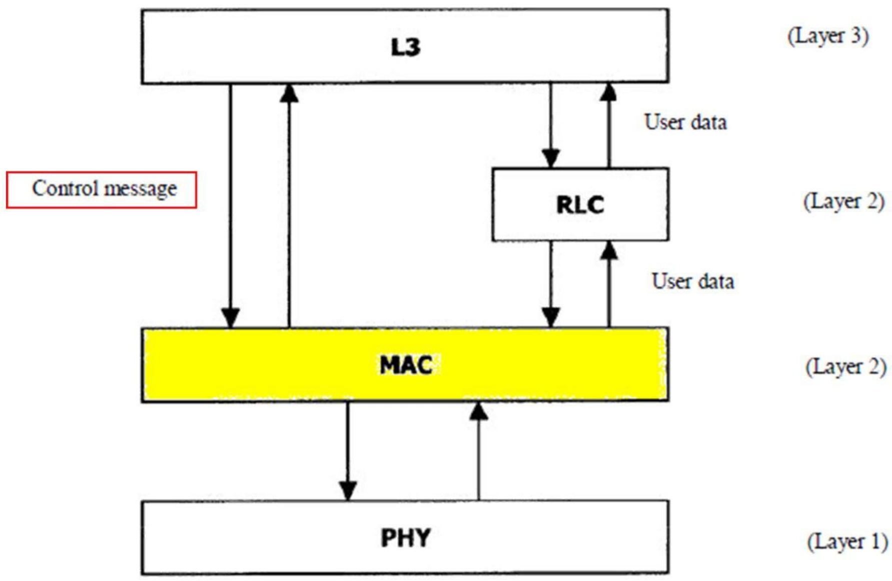
[1.C] the receive unit and the processor are configured to receive control data via control channels over at least a first communication channel or a second communication channel,

140. Ryu's end user device receives data through its physical layer and wireless modem and its processor.

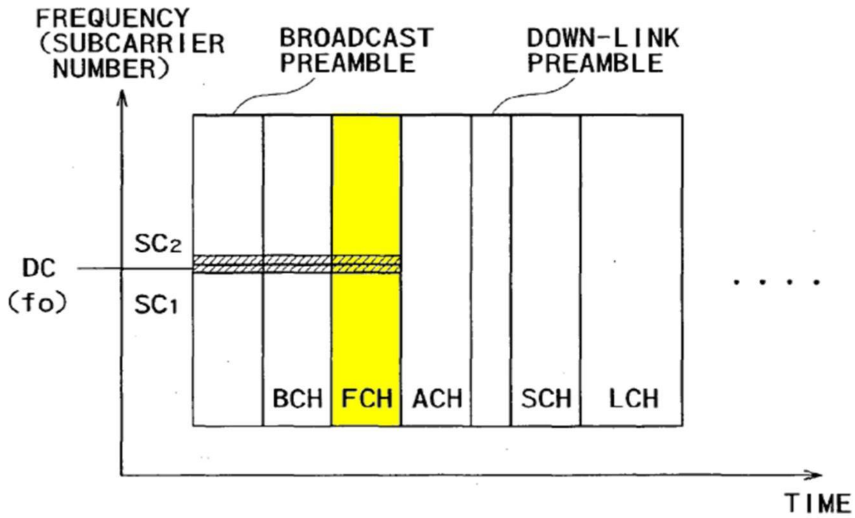
141. Ryu teaches receiving control data, because its end user device receives an "aggregation control message" from a base station. Ryu at [0051], [0059]; *see also id.* at Fig. 4 (describing the format of the aggregation control message) and Fig. 6. The base station transmits the aggregation control message over a traffic channel (TCH), which is the claimed first or second communication channel. Ryu at [0051].

142. The "aggregation control message" that is sent over the traffic channel TCH is received via control channels. The traffic channel TCH is a physical channel, "comprising a carrier with a frequency bandwidth of a specific section," (Ryu at [0013]) that all data—including both control and data payload—is carried on. A POSITA would have understood that the portion of the physical traffic channel that provides control data is the control channel. Further, a POSITA would have understood that a portion of the traffic channel would need to be logically designated as a control channel for the control data to be interpreted at the receiver. Otherwise, a receiver may confuse control for payload data, and the system would not operate properly. Accordingly, a POSITA would have understood that Ryu teaches that the aggregation message is received via control channels.

143. Furthermore, Ryu also teaches a medium access control (MAC) layer that recognizes and interprets control data—it provides "radio resource allocation." Ryu at [0010]. The MAC layer, at both the base station and terminal device, recognizes the aggregation control message as control data for channel aggregation and channel allocation. Ryu at [0017] and [0051]. This is illustrated in Fig. 2 (below), where the MAC (annotated yellow) interprets control messages (red) obtained from the physical layer PHY. Ryu at [0007]-[0011], Fig. 2. In order for the terminal's MAC to decipher the aggregation control message as control data from the physical layer, a POSITA would have understood that the control message would need to be sent over a recognizable portion of the traffic channel in time or frequency. A POSITA would understand that recognizable portion to be a control channel. If the control data were not sent in a control channel, then the MAC layer would be unable to recognize it as control data.

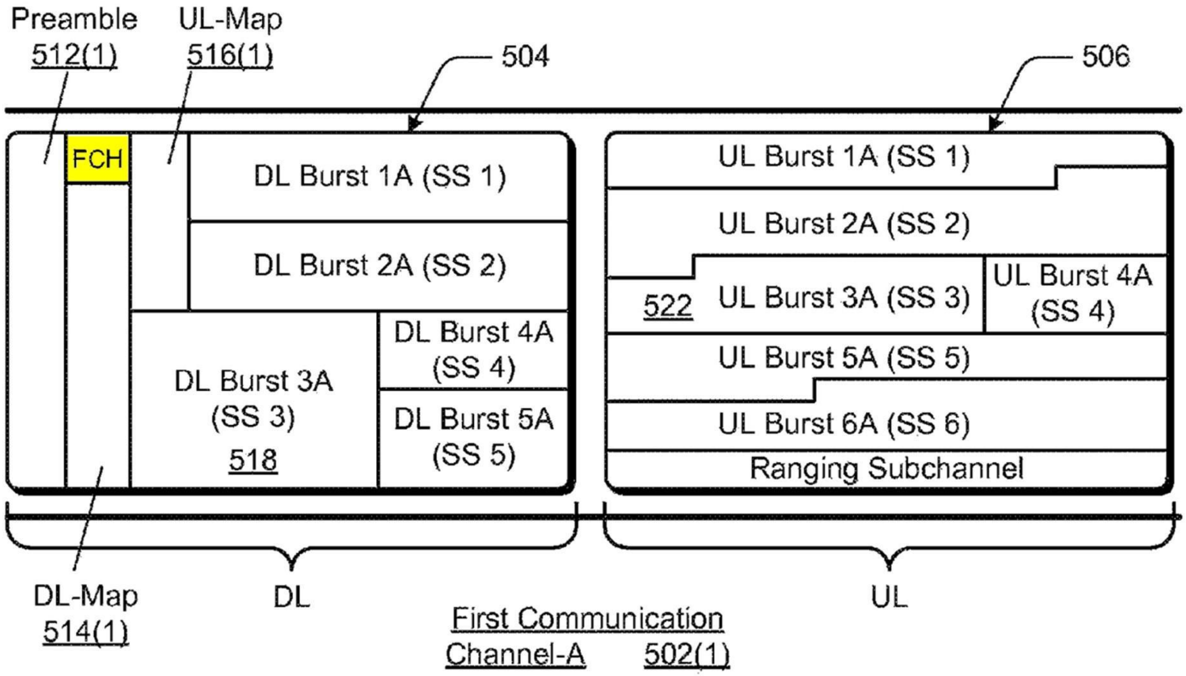


144. Even if Patent Owner were to argue that Ryu's aggregation control message is not received via control channels, this limitation is nonetheless obvious in view of Yamaura. Yamaura teaches an OFDM system, where "traffic channel allocation information" is sent over the FCH (*see, e.g.,* Yamaura at ¶¶11 and 143), which a POSITA would have understood to be a Frame Control Header. The FCH—as part of a transmitted frame and part of control channels—is illustrated below in yellow in annotated Fig. 17. *See also* Yamaura at Figs. 4, 21, 23, 25, 28, 31.



145. As can be seen from the above, FCH occupies control channels. A POSITA would recognize the FCH to be a control channel, and that the combination of Ryu/Yamaura would have provided Ryu's aggregation control message in a dedicated control channel that is part of an OFDM frame structure, like Yamaura's FCH.

146. Further, usage of the FCH matches the '557 patent's description. As shown below, an annotated excerpt of Fig. 5 of the '577 Patent depicts a channel structure of the first/second communication channels, which includes a FCH and downlink map. *See, e.g.*, '577 Patent at Figs. 5-6; *see also id.* at 23:39-49. In light of the '577 Patent, a POSITA would have understood that the claimed "control channels" could include the FCH.



147. As will be described in [1.F], POSITA would have been motivated to combine Ryu's description of channel aggregation with Yamaura's teachings of OFDM. With that combination, a POSITA would have been motivated to provide an OFDM frame structure which would utilize an FCH to allocate frequency bands for the purposes of carrier aggregation.

148. A POSITA would have been further motivated to provide Ryu's aggregation control message in a dedicated control channel for an OFDM frame, like Yamaura's FCH. Ryu teaches a MAC on a terminal device that receives and processes messages. To function, the MAC needs to understand control data for it to set up certain channel allocations. In the context of carrier aggregation, the MAC would need to know what channels to aggregate, and would need to be able

to access control data setting up that carrier aggregation. Providing a dedicated control channel in the TCH for an OFDM system would ensure that the MAC layer would be able to obtain and process control data. A POSITA would have been motivated to provide Ryu's aggregation control message in a dedicated control channel, like Yamaura's FCH. Even if Patent Owner argues that Ryu does not teach the "control channels," it is nonetheless obvious in view of the combination of Ryu and Yamaura.

[1.D] the control data including a first assignment of downlink resources for the first communication channel and a second assignment of downlink resources for the second communication channel;

149. Ryu's aggregation control message has "the number of channels to aggregate and the information on timeslots and carriers to aggregate" which is the claimed assignment of first/second downlink resources for first/second communication channel. *See* Ryu at [0058] (emphasis added); *see also id.* at [0049]. Ryu states that its control message has "all information" needed to aggregate channels. *Id.* at [0043].

150. The aggregation control message contains a first and second assignment because it aggregates "all information" including "timeslot**s** and carrier**s**" plural. Ryu at [0043] and [0058] (emphasis added); *see also* Fig. 4 (demonstrating channels to allocate and offsets); *see also id.* at [0047] (stating that

the "aggregation control message … [is] not … bound to the format [of Fig. 4]). The aggregation control message contains more than one assignment of carriers because it contains at least two, *i.e.*, at least the first and second assignment. Further, the purpose of Ryu is "to provide carrier aggregation … by allocat[ing] a ***plurality*** of traffic channels to the terminal simultaneously." Ryu at [0028] (emphasis added).

151. The physical traffic channel that receives the aggregation control message is one of the plurality of traffic channels that is aggregated. *See* Ryu at Summary (stating that "carrier aggregation [is] applied when a base station allocates an ***additional*** traffic channel," meaning that the previous traffic channel is also allocated) and [0060] (stating that the additional traffic channel is "newly allocated," meaning same). Even if Patent Owner were to argue that this limitation was not disclosed, it would have been obvious for a POSITA to use the same previously allocated traffic channel as one of the traffic channels allocated for carrier aggregation. It would have made sense to a POSITA to have a system that uses already allocated physical resources, instead of allocating a new set of physical resources never-before used.

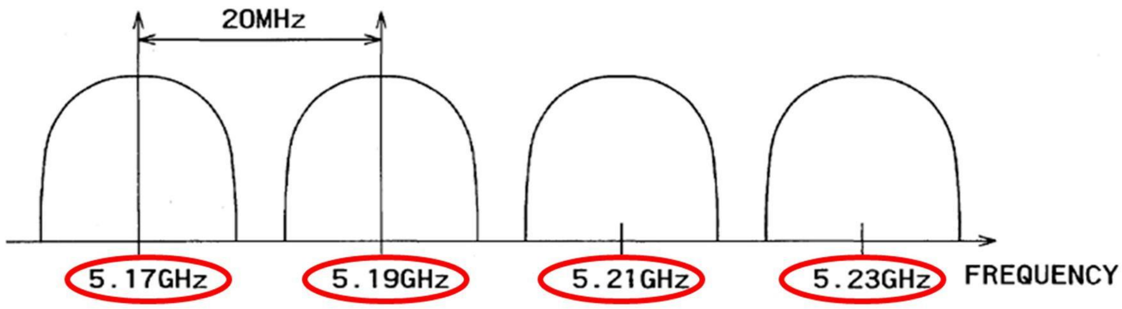
[1.E] wherein the first communication channel and the second communication channel have different carrier frequencies;

152. As described in [1.D], Ryu's aggregation control message has information regarding the "carriers to aggregate." *See* Ryu at [0050] (stating that "aggregation [is] between different carriers"); *see also id.* at [0063] (stating that "multiple traffic channels" are "simultaneously allocated"). Ryu's teaching provides a single device that "may use the multi-carrier at the same time." *Id.* at [0004]. A POSITA would understand that each of these channels have different carrier frequencies.

[1.F] wherein the first assignment of downlink resources indicates assigned orthogonal frequency division multiple access (OFDM) subcarriers of the first communication channel and the second assignment of downlink resources indicates assigned OFDM subcarriers of the second communication channel; and

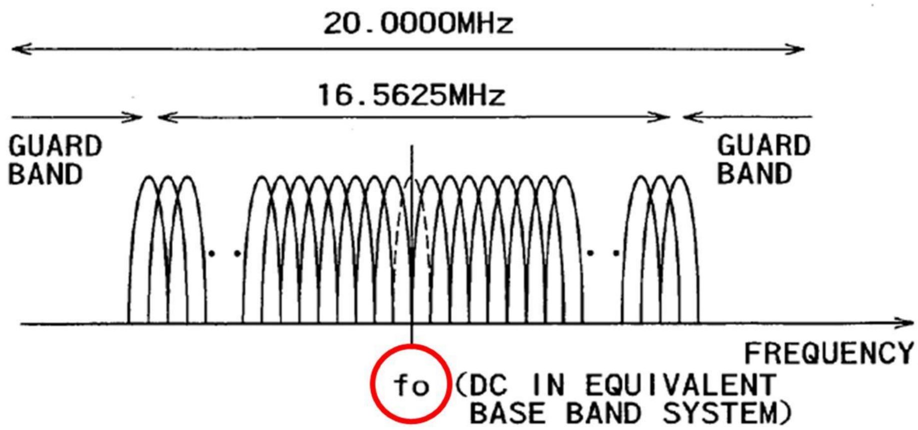
153. Ryu teaches an aggregation control message that contains "all information" on the "carriers to aggregate" which is the claimed assignment of first/second downlink resources for first/second communication channel (Ryu at [0043] and [0058]). Ryu does not explicitly state that its carriers are used for an OFDM system, while [1.F] requires that the resource assignment be specific to an OFDM system, *i.e.*, assignment of OFDM subcarriers. But using OFDM would have been obvious.

154. Yamaura teaches OFDM channels—surrounded around a central carrier frequency—that have a frequency band of OFDM subcarriers. It would have been obvious for a POSITA to have Ryu's aggregation control message to contain assignments for a first/second OFDM channel, each channel occupying a frequency band of subcarriers around a center carrier frequency. As Yamaura explains, the frequency bands of OFDM systems are surrounded around carrier frequencies. *See, e.g.,* Yamaura at [0005]. This is demonstrated in Fig. 29, below, where each channel's carrier frequency is annotated in red. *See also id.* at Fig. 3.



155. Yamaura teaches that OFDM channels comprise frequency band of OFDM subcarriers. *See* Yamaura at [0006] and [0141]. For example, each 20MHz band illustrated above in Fig. 29 is centered around a carrier frequency and has a plurality of OFDM subcarriers. Yamaura at [0006]; *see also* [0004] ("one transmission channel … is divided into a plurality of subcarriers"). This is demonstrated in annotated Fig. 30, below, where a series of subcarriers are

centered around a "central frequency f0 [(annotated red)] in the carrier frequency band." *Id.* at [0006]; *see also id.* at [0141] and Figs. 16, 20, 22, 24.



156. A POSITA would have been motivated to apply Yamaura's teachings with Ryu's teachings. Ryu contains motivations for a POSITA to look at other wireless systems, like Yamaura's OFDM systems. Ryu states that its invention is directed to, among others, "frequency division multiple access (FDMA)." Ryu at [0041]. A POSITA would understand that an FDMA system is a type of frequency division system, and that OFDM is also a type of frequency division system. A POSITA would have been motivated to look at OFDM systems because it is similar to the types of system that Ryu is directed to.

157. Further, Ryu provides additional suggestions to take its teachings, and apply it to other systems, like OFDM. It states that "the present invention can also be applied to communication systems operating according to other standards."

Ryu at [0040]; *see also id.* at [0066] (stating that the "invention can be applied to a wide range of wireless systems that allow data exchange"). Yamaura also describes the basics of OFDM systems, relating to its carriers/channels/subcarriers, that a POSITA would have known. A POSITA, looking at Ryu's suggestion, would have applied Ryu's teachings to well-known wireless systems, like OFDM.

158. A POSITA would have found that combining Yamaura's teachings with Ryu's teachings would provide an improvement to Ryu. Ryu explains the usage of different traffic channels surrounding a carrier and aggregating those channels. Ryu explains that carrier aggregation increases throughput. Yamaura teaches a plurality of channels in an OFDM system. A POSITA would have been motivated to improve upon Ryu by expanding its breadth to OFDM systems to increase their throughput.

159. Furthermore, a POSITA would have found it obvious to try a combination of Ryu with Yamaura because of their similarities. Ryu teaches a FDMA system, where different channels occupy different frequency bandwidths. Yamaura teaches an OFDM system, where different channels occupy different frequency bandwidths. Given the like-disclosure, a POSITA would have found it obvious to try to take Ryu's teachings, and combine it with Yamaura's. Because of their similarities, a POSITA would have seen it as a simple substitution of one

known element (FDMA) with another (OFDM) to yield predictable results—carrier aggregation to increase throughput.

[1.G] the receive unit and the processor are further configured to receive downlink data on the assigned OFDM subcarriers of the first communication channel and the assigned OFDM subcarriers of the second communication channel;

160. This limitation describes sending downlink traffic on the assigned channels.

161. Ryu's end user device receives downlink traffic on the allocated channels. Ryu at Fig. 5; *see also id.* at [0004] (stating that the device "use[s] the multi-carrier at the same time"); *see also* summary. Yamaura also teaches downlink data that is sent across its allocated channels. *See, e.g.,* Yamaura at Fig. 31.

[1.H] wherein at least a portion of the downlink data is received at least in part simultaneously on the first communication channel and the second communication channel; and

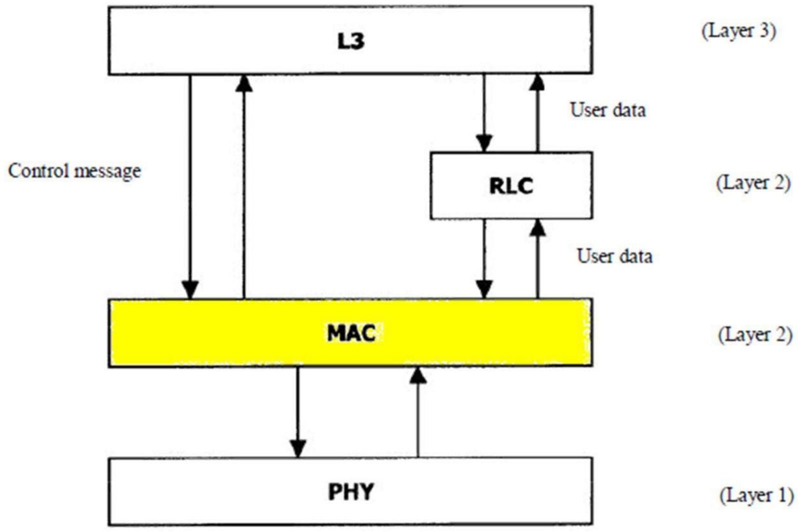
162. Ryu's end user device "uses[s] the multi-carrier at the same time." *Id.* at [0004]. This is done to increase throughput. Ryu at Summary and Claim 1. A POSITA would understand that, to increase throughput, data would be simultaneously sent across allocated traffic channels.

[1.I] the processor is configured to combine at least a portion of the received downlink data from the first communication channel and the second communication channel to produce data for a single service.

163. Ryu teaches this limitation. Ryu's core network transmits data that is recombined at the end user device. Ryu teaches an aggregation control message that is sent to aggregate traffic channels to send data over. Before the aggregation message is sent, the "core network … transmits user data to the L3 layer of the base station … [and] [t]he base station … determines whether to perform carrier aggregation." Ryu at [0058]. If carrier aggregation is to be performed, the base station sends an aggregation control message, and sends the data that it received from the core network. *Id.* A POSITA would understand that the carrier aggregated data would be combined at the end user device, and would have been from a single service from the core network. Otherwise, the data would be unusable and the transmission scheme would not work.

164. Furthermore, a POSITA would understand that the data is combined at the end user device due to its teaching of a MAC layer. The end user device's MAC maintains an allocation of traffic channels. *Id.*; *see also id.* at [0010] (stating that the MAC "provides radio resource allocation and is connected to the radio link control layer through a logical channel to provide user data transfer service"). A

POSITA would understand that the MAC layer provides resource allocation for higher layers in the OSI stack (*i.e.*, provides combination).



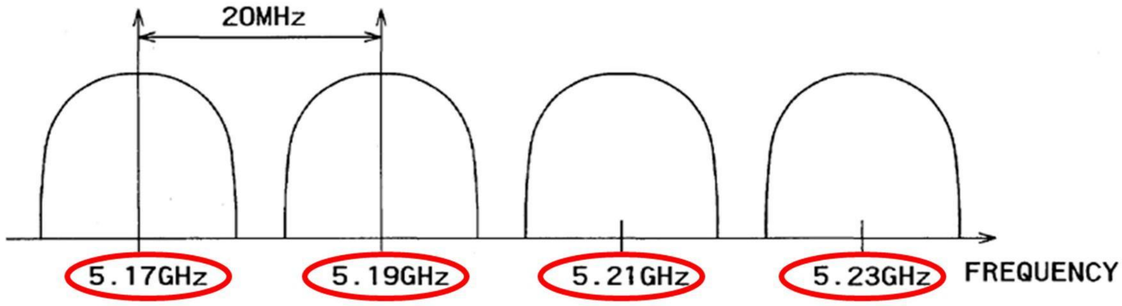
165. Finally, like Ryu, Patent Owner's own patent specification support for combining data is a MAC layer that combines data for higher level services. *Compare* '577 Patent at Figs. 4A-B *with* Ryu at Fig. 2. Yamaura further teaches a demodulator 337 that can combine received downlink data. See, e.g., Yamaura at Fig. 32. [0015]-[0016], [0021].

(b) Claim 3 is rendered obvious by Ryu and Yamaura

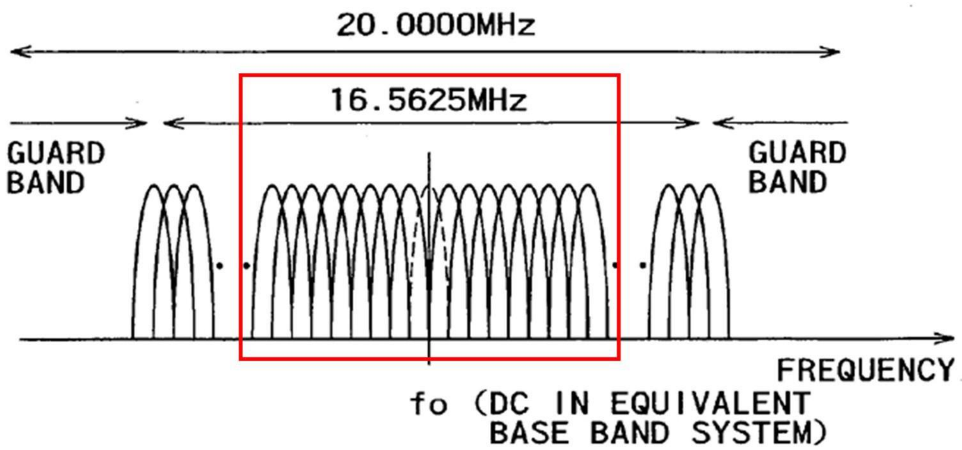
[3] The wireless device of claim 1 wherein the first communication channel and the second communication channel are in different frequency bands.

166. Ryu teaches that the "aggregation [is] between different carriers." Ryu at [0050]. Further, Yamaura teaches different OFDM frequency bands

centered around different carrier frequencies. *See, e.g.,* Yamaura at [0005], Fig. 29 (annotated below).



167. Yamaura explains that "[t]he ***frequency band*** used for information transmission is 16.5625 MHz, and both sides of the band are isolated from adjacent carriers by a guard band of about 1.7MHz." Yamaura at [0006] (emphasis added), Fig. 30 (annotated).



168. And, as explained in [1.F], a POSITA would have combined Ryu/Yamaura to transmit across different frequency bands.

(c) Claim 4 is rendered obvious by Ryu and Yamaura

[4.A] The wireless device of claim 1 further comprising a transmit unit;

169. Ryu teaches an end user device that has a physical layer for the radio interface and a wireless modem. Ryu at [0065]-[0066]; *see also id.* at Fig. 2.

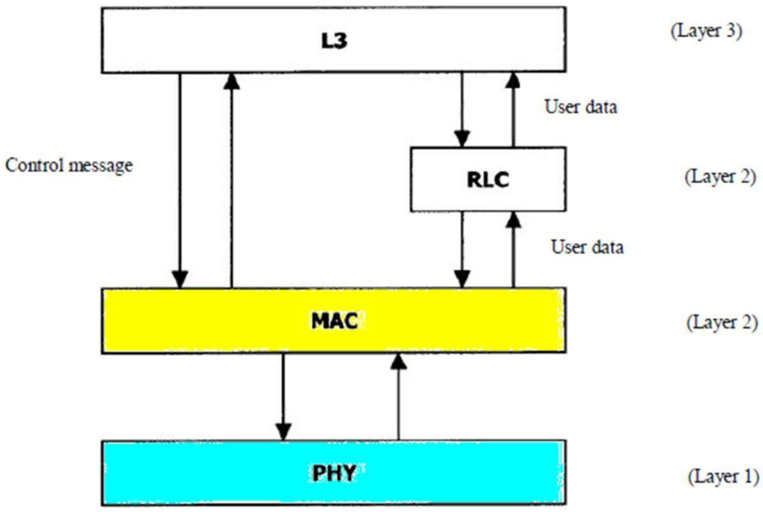
[4.B] wherein the transmit unit and the processor are configured to transmit, to a base station, an indication that the wireless device is capable of channel aggregation.

170. Ryu's transmit unit transmits to the base station a channel allocation request S26. Ryu at [0052], Fig. 5. A POSITA would understand that, if the terminal were capable of aggregation, that it would request aggregated channels. Conversely, if the terminal were incapable of aggregation, it would not request aggregated channels. Consequently, this limitation is taught.

(d) Claim 5 is rendered obvious by Ryu and Yamaura

[5] The wireless device of claim 1 wherein the processor uses a single medium access control (MAC) layer for processing the downlink data from both the first communication channel and the second communication channel.

171. As described in [1.H], Ryu teaches receiving downlink data on a first/second communication channel. The downlink data from the physical layer is processed by the MAC for higher layers. *See* Ryu at Fig. 2; *see also id.* at [0009] ("[t]he physical layer is connected to the medium access control (MAC) layer through a transport channel to exchange data").



172. As demonstrated below, the above figure and structure matches the disclosure of the '577 patent's annotated Fig. 4A-B.

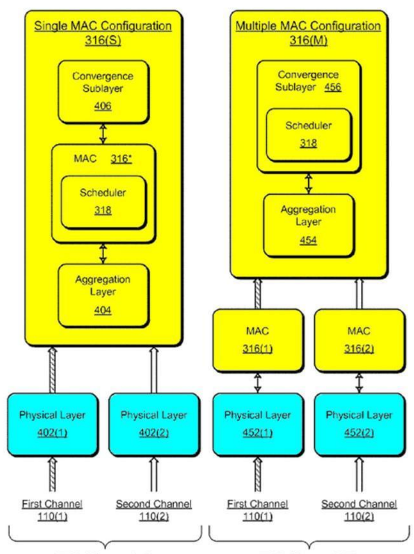


FIG. 4A FIG. 4B

(e) Claim 11 is rendered obvious by Ryu and Yamaura

[11] The wireless device of claim 1, wherein the control data received via the control channels is received over the first communication channel and is not received via the second communication channel.

173. Ryu teaches that its control data is received via its previously allocated traffic channel (*e.g.*, Ryu at [0051]), and that an additional channel is added. *Id.* Ryu at Summary (stating that "carrier aggregation [is] applied when a base station allocates an ***additional*** traffic channel," meaning that the previous traffic channel is also allocated) and [0060] (stating that the additional traffic channel is "newly allocated," meaning same). A POSITA would understand that the control data would be communicated over only one channel.

(f) Claim 12 is rendered obvious by Ryu and Yamaura

174. Claim 12 is taught for the same reasons as described with respect to claim 1.

[12.PRE] A method for use by a wireless device, the method comprising:

175. Ryu teaches a method for use by a wireless device. *See* Ryu at Summary.

[12.A] receiving control data via control channels over at least a first communication channel or a second communication channel,

176. [12.A] is taught for the same reasons as described in [1.B].

[12.B] the control data including a first assignment of downlink resources for the first communication channel and a second assignment of downlink resources for the second communication channel;

177. [12.B] is taught for the same reasons as described in [1.D].

[12.C] wherein the first communication channel and the second communication channel have different carrier frequencies;

178. [12.C] is taught for the same reasons as described in [1.E].

[12.D] wherein the first assignment of downlink resources indicates assigned orthogonal frequency division multiple access (OFDM) subcarriers of the first communication channel and the second assignment of downlink resources indicates assigned OFDM subcarriers of the second communication channel; and

179. [12.D] is taught for the same reasons as described in [1.F].

[12.E] receiving downlink data on the assigned OFDM subcarriers of the first communication channel and the assigned OFDM subcarriers of the second communication channel;

180. [12.E] is taught for the same reasons as described in [1.G].

[12.F] wherein at least a portion of the downlink data is received at least in part simultaneously on the first communication channel and the second communication channel; and

181. [12.F] is taught for the same reasons as described in [1.H].

[12.G] combining at least a portion of the received downlink data from the first communication channel and the second communication channel to produce data for a single service.

182. [12.G] is taught for the same reasons as described in [1.I].

(g) Claim 14 is rendered obvious by Ryu and Yamaura

[14] The method of claim 12 wherein the first communication channel and the

second communication channel are in different frequency bands.

183. Claim 14 is identical to claim 3 and is taught for the same reasons.

(h) Claim 15 is rendered obvious by Ryu and Yamaura

[15] The method of claim 12 further comprising transmitting, to a base station, an indication that the wireless device is capable of channel aggregation.

184. Claim 15 is substantively similar to claim 4 and is taught for the same reasons.

(i) Claim 16 is rendered obvious by Ryu and Yamaura

185. Claim 16 is substantively similar to claim 5 and is taught for the same reasons.

(j) Claim 22 is rendered obvious by Ryu and Yamaura

[22] The method of claim 12, wherein the control data received via the control channels is received over the first communication channel and is not received via the second communication channel.

186. Claim 22 is identical to claim 11 and is taught for the same reasons.

F. Gound 2B: Claims 2 and 13 are rendered obvious by Ryu, Yamura, and Jung

187. As described in Ground 1B, claims 2 and 13 are directed to using ARQ sequence numbers, which are commonly known in the art as demonstrated by both Jung and the ’577 Patent. *See* ’577 Patent at 16:8-16; Jung at 1:10-12, 9:31-32, 15:2-6, 15:34-16:4, 23:6-20, 24:7-9.

a. Claim 2 is rendered obvious by Ryu, Yamaura, and Jung

[2.A] The wireless device of claim 1 wherein the downlink data is received with automatic repeat request (ARQ) sequence numbers;

188. Jung's wireless device includes receiving downlink data with ARQ sequence numbers. Jung at 15:2-6; *see also id.* at 14:15-17. Jung teaches an "ARQ Identifier Sequence Number (AISN) field" (*id.* at 15:3-5), which indicates the sequence information of transmitted broadcast packets. *Id.* at 15:33-16:1. The AISN filed is annotated below from Table 3.

Table 3

Syntax	Size
Broadcast_DL-MAP_IE {	
Extended DIUC	4 bits
Length	4 bits
For(i=0;i<N_CID;i++){	
CID	16bits
SPID	4 bits (or 2 bits used)
ACID	2 bits
AISN	1 bits
OFDMA Symbol Offset	8bits
Subchannel Offset	6bits
No. OFDMA Symbols	7 bits
No. Subchannels	6 bits
DIUC	4 bits
}	

[2.B] wherein the processor is further configured to combine the at least a portion of the downlink data using the ARQ sequence numbers.

189. Jung uses the ARQ sequence numbers to combine downlink data. The AISN field identifies the sequence information of received packets. Jung at 16:3-4. The AISN field will be checked to determine whether a subpacket is a first subpacket and, if not, it will be combined with previous subpackets. *See id.* at

23:9-16; *see also id.* at 24:7-9 (stating that an AISN could be used where the SPID is described).

190. A POSITA would have been motivated to combine the teachings of Jung with the teachings of Ryu and Yamaura because doing so would have been the application of a known technique to improve similar devices. Jung, Ryu, and Yamaura teach different data streams for FDM systems. *See, e.g.,* Ryu at [0041]; Yamaura at Abstract; Jung at 9:31-32. Ryu and Jung teach combining their data streams. *See, e.g.,* Ryu at [0019]; Jung at Fig. 3. And, Jung teaches an improved method to ensure that the data is correctly combined—an ARQ sequence number.

191. Furthermore, the usage of ARQ sequence numbers would have provided predictable results. A POSITA would have understood that ARQ sequence numbers provide an indication as to ordering in a data stream, and that using an ARQ sequence would have ensured that the data stream would have been appropriately ordered.

b. Claim 13 is rendered obvious by Ryu, Yamaura, and Jung

[13.A] The method of claim 12, further comprising: receiving the downlink data with automatic repeat request (ARQ) sequence numbers; and

192. [13.A] is substantively similar to [2.A] and is rendered obvious for the same reasons.

[13.B] combining the at least a portion of the downlink data using the ARQ sequence numbers.

193. [13.B] is substantively similar to [2.B] and is rendered obvious for the same reasons.

G. Gound 2C: Claims 7 and 18 are rendered obvious by Ryu, Yamura, and Zhao

194. Claims 7 and 18 are directed to using different FFTs on the receiver for each communication channel. This is an obvious variant of what a POSITA would have typically expected from an OFDM system. The '577 Patent itself treats using one or two FFTs as an unimportant and well-known option. *See, e.g.,* '577 Patent at 6:65-7:9.

195. It was standard in the art for OFDM systems to perform an FFT on the receiver, and an IFFT on the transmitter. If there are disjoint portions of bandwidth, there were effectively two options to a POSITA: (1) perform a single FFT for the combined signal, or (2) perform an FFT for each physical channel. Claims 7 and 18 require a separate FFT for each physical channel, and this was well known in the art and one of the two options that could be employed.

196. Zhao describes an OFDM system, that teaches multiplexing two separate paths into a single FFT engine. *See, e.g.,* Zhao at Fig. 5 and [0046].

Shown below is a RX Port Mux 81 (yellow) receiving two physical channels 41 and 43 (red), going into a single FFT engine 82 (aqua). *Id.* at [0046].

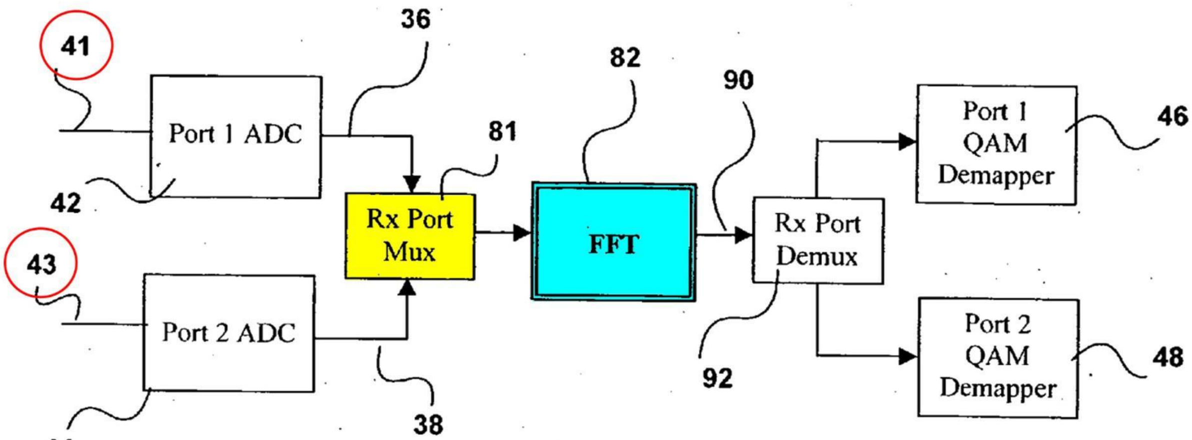


Fig. 5

197. The above demonstrates one option—using a single FFT engine for two physical channels. Zhao demonstrates, however, that using two FFT engines for two physical channels was also well-known. Shown below are two separate FFT engines 32 (orange) and 34 (green), that receive data from two separate physical channels 41 and 43. *See* Zhao at [0043].

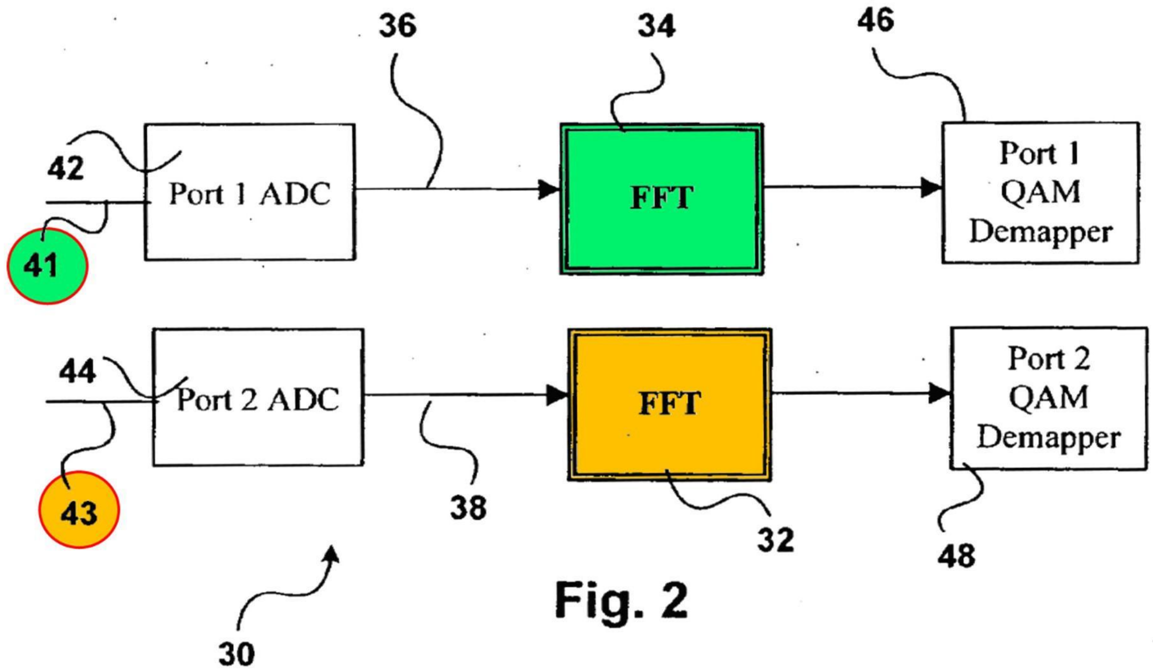


Fig. 2

PRIOR ART

198. A POSITA would have been motivated to combine Zhao with Ryu and Yamaura. Ryu teaches aggregating two separate physical channels. Ryu at [0018]. Yamura teaches performing FFTs at the receiver. Yamaura at [0020], [0100], Figs. 6 and 18. A POSITA would have understood that the data from the separate channels could either be combined then FFTed, or separately FFTed, then combined. Zhao demonstrates that both were well known in the art. *See* Zhao at [0043] and [0046]. A POSITA would have found that using two separate FTTs, one for each physical channel, would have been a known method to yield predictable results. A POSITA would have found that using one FFT (or two) would have been a simple substitution.

(a) Claim 7 is rendered obvious by Ryu, Yamaura, and Zhao

[7.A] The wireless device of claim 1 wherein a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the first communication channel is processed using a first Fast Fourier Transform (FFT) and

199. As described in Ground 2A, Ryu teaches receiving downlink data on a first communication path. As demonstrated below, Zhao teaches receiving data from a first physical channel 41 (green/red) and performing an FFT with an FFT engine 34 (green). *See* Zhao at [0043].

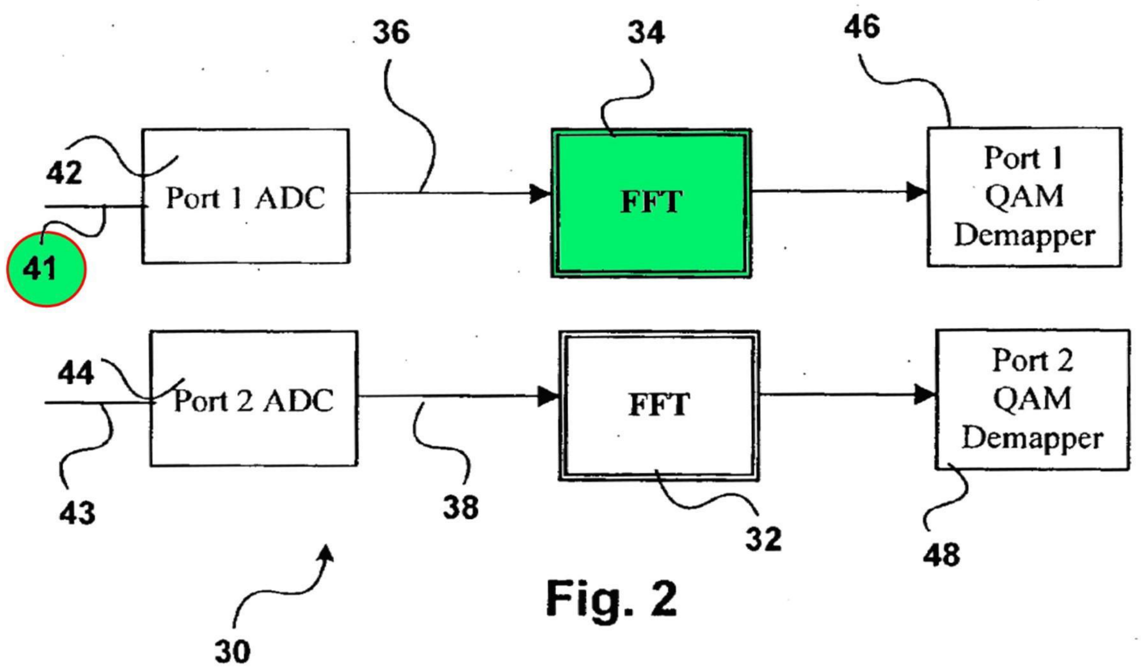


Fig. 2

PRIOR ART

[7.B] a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the second communication channel is processed using a second FFT that is different than the first FFT.

200. As described in Ground 2A, Ryu teaches receiving downlink data on a second communication path. As demonstrated below, Zhao teaches receiving data from a second physical channel 43 (orange/red) and performing an FFT with a separate FFT engine 32 (orange). *See* Zhao at [0043].

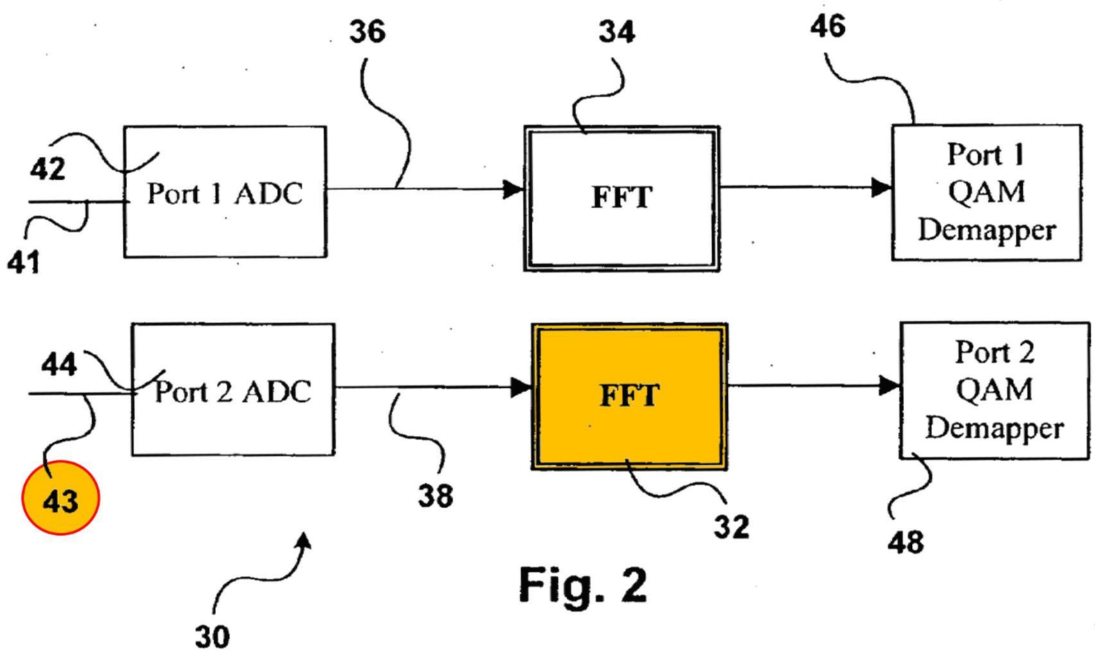


Fig. 2

PRIOR ART

(b) Claim 18 is rendered obvious by Ryu, Yamaura, and Zhao

[18.A] The method of claim 12, further comprising processing a portion of the downlink data that is received on at least a portion of the assigned OFDM subcarriers of the first communication channel using a first Fast Fourier Transform (FFT) and

201. [18.A] is substantially similar to [7.A] and is rendered obvious for the same reasons.

[18.B] processing a portion of the downlink data that is received on at least a

portion of the assigned OFDM subcarriers of the second communication channel using a second FFT that is different than the first FFT.

202. [18.B] is substantially similar to [7.B] and is rendered obvious for the same reasons.

H. Gound 2D: Claims 10 and 21 are rendered obvious by Ryu, Yamura, and Walton

203. Walton teaches that each cell has dedicated frequency bandwidths that it transmits. *See, e.g.,* Walton at 12:19-39, Figs. 5-6. As demonstrated below, cell 1 has a particular bandwidth (yellow), and cell 2 has an entirely separate bandwidth (aqua). *Id.*

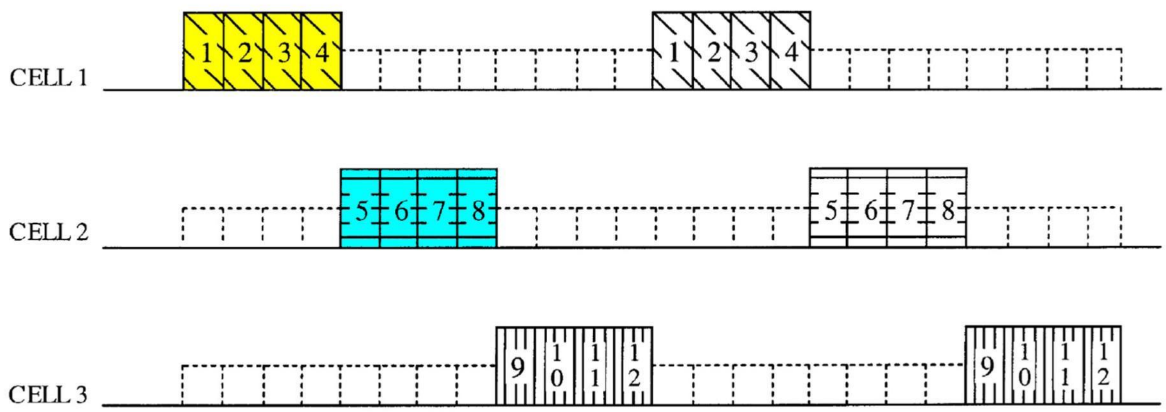


FIG. 6

204. And, Walton teaches that a device can simultaneously connect to two separate cells. *See, e.g.,* Walton Fig. 1, 35:16-57. This is done to increase throughput through concurrent downlink transmissions from separate cells. *See id.*

at 35:19-24. The data from each individual cell is synchronized and combined. *Id.* at 35:30-35, 54-57.

205. A POSITA would have been motivated to combine Ryu, Yamaura, and Walton. Walton provides an improvement—it teaches that throughput can be increased by having concurrent transmission of downlink resources through two separate cells. Walton at 35:16-57. Ryu teaches increasing throughput by aggregating traffic channels. Ryu at [0019]. A POSITA would have been motivated to increase throughput of Ryu, and retaining its aggregation of traffic channels, by simultaneously transmitting the portions of bandwidth from multiple cells. This would have provided an improvement to Ryu, and would have led to predictable results.

(a) Claim 10 is rendered obvious by Ryu, Yamaura, and Walton

The wireless device of claim 1, wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the first communication channel is received from a first cell, and wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the second communication channel is received from a second cell.

206. As described in Ground 1A, Ryu teaches aggregating different traffic channels. As demonstrated below, Walton teaches that cell 1 and cell 2 are assigned different traffic channels (yellow and aqua, respectively). *See, e.g.,*

Walton at 12:19-39, Figs. 5-6. Walton further teaches that a device can simultaneously connect to two separate cells to receive the downlink data. *See, e.g.,* Walton Fig. 1, 35:16-57. As described immediately above, a POSITA would have been motivated to combine Ryu, Yamaura, and Walton to transmit traffic channels at the same time from separate cells to increase throughput.

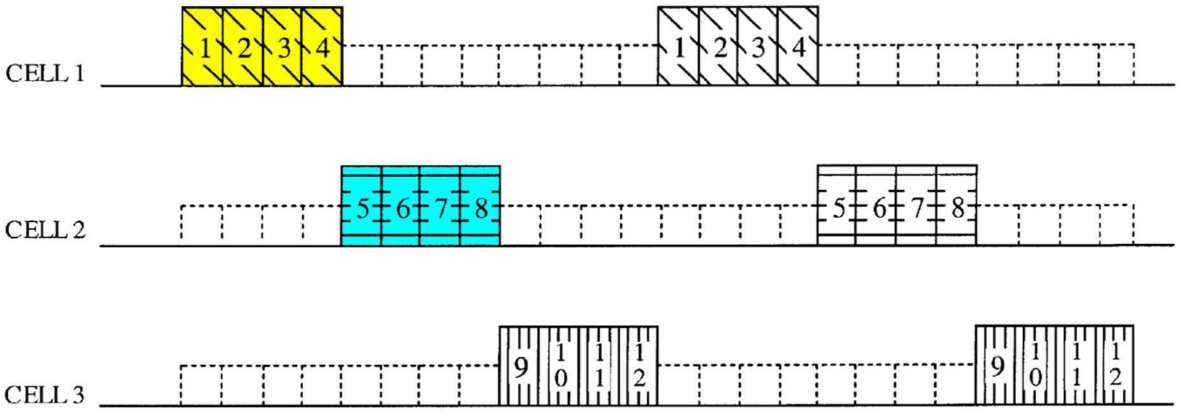


FIG. 6

(b) Claim 21 is rendered obvious by Ryu, Yamaura, and Walton

The method of claim 12, wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the first communication channel is received from a first cell, and wherein a portion of the downlink data that is received on a least a portion of the assigned OFDM subcarriers of the second communication channel is received from a second cell.

207. Claim 21 is substantially similar to claim 10 and is taught for the same reasons.

XI. SECONDARY CONSIDERATIONS

208. At this time, after review of the documents and materials cited herein, such as the prosecution history of the ’577 Patent, as well as those referenced herein, I have found no evidence of secondary considerations or objective factors of non-obviousness, and it is my opinion that claims 1-22 of the ’577 patent are obvious over the prior art. And to the extent Patent Owner alleges secondary considerations in this proceeding, it is my opinion that they would not outweigh the strong evidence of obviousness of the ’577 patent’s claims, as set forth herein.

XII. CONCLUSION

209. In summary, I have concluded that each of the Challenged Claims is invalid as obvious in light of the prior art references as discussed above and the knowledge of one of ordinary skill in the art, as described in this Declaration.

210. I reserve the right to supplement my opinions in the future to respond to any arguments that Patent Owner or its expert(s) may raise and to take into account new information as it becomes available to me.

I declare under penalty of perjury that the foregoing is true and correct. I declare that all statements made herein of my knowledge are true, and that all statements made on information and belief are believed to be true, and that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code. Executed this 22nd day of December, 2019.

Dr. Titus Lo

APPENDIX A

Titus Lo, Ph.D.
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Bellevue, WA 98006

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SUMMARY

Dr. Lo is currently an independent consultant in the areas of wireless communications. He is a veteran in wireless industry, with more than 30 years of experiences in various telecomm, satellite communications, and wireless communications technologies. In particular, he is an expert in including antennas, RF, modulation/coding, radio protocols, wireless standards (including 3G, 4G, 5G, and 802.11). Having worked in different sectors of the industry such as intellectual property (IP) development and support, R&D, product development, network deployment, and design services, he has a deep understanding of the telecommunications and wireless industry ecosystem. From 2000 to 2007 had participated in the IEEE 802.11 and 802.16 Working Groups in setting the standard specifications.

Dr. Lo is a pioneer in the field of smart antenna technology for wireless communications and satellite communications. He is the co-author of *Digital Beamforming in Wireless Communications*, the first technical reference book on smart antennas, published in 1996 by Artech House. He has been granted more than 120 US and foreign patents in the area of wireless communications. He has published more than 80 technical papers in international journals and conferences, presented and lectured many times at a broad array of industry and professional venues in the fields of antennas, RF, and wireless communications. He has provided numerous lectures on the same topics to various technical and industrial communities.

Dr. Lo have worked in a number of startups, where he engaged in research and development of OFDM/OFDMA technologies and products, especially 3GPP LTE/LTE-A and IEEE 802.11. Prior to his startup ventures, he worked at AT&T Wireless, where he led a cross-division team of researchers and engineers in research and development of key technologies for the world's first carrier-grade and commercially deployed OFDMA wireless system. He was a project/program manager at Communications Research Laboratory, McMaster University, leading a 20-member team of research engineers, scientists, and graduated students, in R&D of wireless and satellite communications technologies.

Dr. Lo received his B.A.Sc. degree from the University of British Columbia, Vancouver, Canada, M.Eng. and Ph.D. degrees, from McMaster University, Hamilton, Ontario, Canada, all in electrical engineering. He was appointed as an affiliated professor at the University of Washington, Seattle, WA from 2008 to 2012. He has served or been serving various leadership positions in the Institute of Electrical and Electronics Engineers (IEEE). He is a senior IEEE member and a member of IEEE Eta Kappa Nu Honor Society.

EDUCATION

Ph.D., Department of Electrical and Computer Engineering, McMaster University, Hamilton, Ontario, Canada

M.Eng., Department of Electrical and Computer Engineering, McMaster University, Hamilton, Ontario, Canada

B.A.Sc., Department of Electrical Engineering, the University of British Columbia, Vancouver, British Columbia, Canada

EMPLOYMENT HISTORY

Jan. 2014 – present — **Freelance Wireless Technology Consultant**, Bellevue, Washington

Responsibility: Providing consulting services to clients in various industries in the following aspects:

- Analysis, evaluation, and legal procedure support of wireless-technology IP portfolios
- Analysis and evaluation of technology markets and industry ecosystems

Jan. 2006 – present — **VP of Technology and Operations**, Neocific, Inc., Bellevue, Washington

Responsibility: Managing development and maintenance of intellectual property portfolio

Managing and mentoring a team of engineers in the design and development of 4G technologies:

- Technology research and development
- Engineering management

Directing company's daily operations and business development

Dec. 2003 – Dec. 2005 — **VP of Engineering and Operations**, Waltical Solutions, Inc., Bellevue, Washington

Responsibility: Managing engineering teams in both the US HQ and an oversea subsidiary in the design and development of broadband wireless and wire communication systems (802.11, 802.16e, WiMAX, WiBro, etc.):

- Product development
- Technology development
- Engineering management

Directing company's daily operations at both US and oversea sites and business development

Mar. 2001 – Aug. 2003 — **Principal Member of Technical Staff**, Nextcomm, Inc., Bellevue, Washington

Responsibility: Leading in R&D of WLAN technologies and products and providing support and supervision to a team of engineers:

- The development of baseband signal processor for *IEEE 802.11a/g* wireless local area networks (WLAN): from conceptual design to fixed-point model to FPGA prototype realization.
- The system architecture of the *IEEE 802.11a/g* baseband signal processor: from radio front end to interface with MAC

Leading in intellectual property development:

- Internal R&D projects to develop enabling technologies
- Participation and contribution in *IEEE802.11*

Apr. 1997 – Mar. 2001	**Principal Member of Technical Staff**, AT&T Wireless, Redmond, Washington
Responsibility:	Leading a cross-division team of researchers and engineers from AT&T Labs-Research and AT&T Wireless technology development and business units in R&D of key technologies for the world's first carrier-grade and commercially deployed OFDMA wireless system; accomplished major projects and activities including:

- Definition of technology roadmap for wireless digital broadband data services
- Development and analysis of space-frequency processing techniques for current and future products
- Analysis of system bandwidth scalability, coverage, and capacity of wireless digital broadband data services
- Development and analysis of array antenna technologies for both base stations and subscriber units
- Development and analysis of MIMO channel compensation techniques
- Propagation channel measurement and modeling
- Principal authorship of Air-Interface Design Documents

July 1993 – June 1997	**Project/Program Manager and Senior Research Engineer**, the Communications Research Laboratory, McMaster University, Hamilton, Ontario, Canada
Responsibility:	Managing industrial and governmental R&D contracts as well as academic research programs; leading a cross-discipline team of engineers, scientists and scholars to carry out independent studies, analyses, interpretations, conclusions and recommendations on various engineering projects that require highly specialized knowledge; providing supervision to research engineers, technicians, visiting scientists, graduate students, and post-doctoral fellows; accomplished major projects and activities including:

Communications:

- LMDS/LMCS system design evaluation
- Intelligent signal processing for wireless communications
- Smart antennas for wireless communications
- Digital beamforming for wireless communications
- Regenerative digital satellite system
- Design study of digital beamforming for L-band and Ka-band mobile satellite communications
- Development of software for communications receiver (early concept of SDR)

Signal Processing:

- Intelligent multi-sensor data fusion
- Digital beamforming for advanced spaceborne synthetic aperture radar
- Fractal modeling of radio wave propagation over trees and bushes
- Robust multi-sensor Multiple-target tracking techniques
- Neural networks for multi-sensor data fusion
- Multiple-target tracking using artificial neural networks

Jan. 1990 – March 1997	**Principal Consultant**, TL Associates, Hamilton, Ontario, Canada
Responsibility:	Providing consulting services to both industrial companies and governmental research and development agencies; accomplished major projects and activities including:

- Ongoing expert consultation to Ministry of Industry, Canada, on smart antenna technology
- Radarsat antenna elevation pattern restoration for Canadian Space Agency
- Radarsat receiver test data analysis methodology for Canadian Space Agency
- Antenna signal processing techniques to provide multipath immunity for a high accuracy direction finding system for electronic support measures for Department of National Defense

May 1988 – June 1993 **Research engineer**, the Communications Research Laboratory, McMaster University, Hamilton, Ontario, Canada

Responsibility: Carrying out industrial and governmental R&D contracts as well as academic research programs; making independent studies, analysis, interpretations, conclusions and recommendations on various engineering projects, including:

- High accuracy direction finding
- Development of robust and effective processing schemes for multifunctional radar applications
- Development of software and hardware for an RF communication link system for measuring and analyzing real multipath signals
- Modelling of microwave scattering from sea surfaces; development and validation of the computer sea-scattering model for a communication link system
- Digital adaptive beamforming for a wires communication system using modern spectrum estimation and adaptive filtering techniques
- Antenna array pattern synthesis and the design of the subarray in a microwave landing system

Sept. 1986 - Apr. 1988 **Teaching assistant**, Department of Electrical and Computer Engineering, McMaster University, Hamilton, Ontario, Canada

Responsibility: Giving undergraduate tutorial lectures; coordinating course experiments; grading laboratory reports, assignments, and examinations

June 1986 - Aug. 1986 **Biomedical Researcher**, Mount Sinai Hospital, Toronto, Ontario, Canada

Responsibility: Carrying out research activities on biomedical signal processing and realization of biomedical systems using both software and hardware

MEMBERSHIP AND PROFESSIONAL ACTIVITIES

Current:

- Senior Member of the Institute of Electrical and Electronics Engineers (IEEE)
- Member of IEEE Eta Kappa Nu Honor Society
- Startup subcommittee chair of the Industry Outreach Board of the IEEE Communications Society since 2017
- Finance chair of the IEEE Global Humanitarian Technology Conference since 2019
- Vice Chair of IEEE Seattle Communications Joint Chapter from 2019

Past:

- Co-Chair of Startup Forum in the second IEEE 5G World Forum in 2019
- Technical program coordinator for the IEEE Seattle 5G Workshop 2019

- Chair of IEEE Seattle Joint Chapter of Communications Society, Vehicular Technology Society, Broadcast Technology Society, Information Theory Society, and Intelligent Transportation Systems Society from 2011 to 2018
- Treasurer of IEEE Seattle Section in 2017 and 2018
- Audit Committee of IEEE Seattle Section from 2014 to 2018
- Co-Chair of Startup Forum in the first IEEE 5G World Forum in 2018
- General co-Chair of IEEE 5G Summit Seattle 2016
- Award Committee of IEEE Seattle Section in 2015
- Organization committee 2013 IEEE Seattle Metro Area Workshop “Vision of the Future”
- Technical publication referee for IEEE transactions and Journals
- Technical publication referee for IEE proceedings
- Participant and contributor in the IEEE 802.11 and IEEE802.16 Standard Work Groups
- Short Course Committee Chair, IEEE Northcon’98
- Research grant referee for Natural Science and Engineering Research Council (NSERC) of Canada

AWARDS

2000 — **Outstanding Achievement Awards**, by AT&T Wireless

1999 — **Outstanding Achievement Awards**, by AT&T Wireless

1998 — **Award for technology innovation**, by AT&T Labs — Research

1997 — **CITO Innovation Award For Excellence in Strategic Research for Beam-Forming and Smart-Antenna Concepts**, by the Communications and Information Technology Ontario (CITO), Ontario Centers of Excellence

1994 — **the Mountbatten Premium**, by the Institution of Electrical Engineers (IEE), London, England

1986 to 1988 — **the Graduate Study Scholarship**, McMaster University, Hamilton, Ontario, Canada

1983 — **the University of British Columbia Scholarship**, the University of British Columbia, Vancouver, B. C., Canada

PUBLICATIONS

A. BOOKS

1. Henry Leung and Titus Lo, "Array signal processing using radial-basis function neural network," in S. Haykin, Editor, *Advances in Spectrum Analysis and Array Processing: Volume III*, Prentice-Hall, 1995.
2. John Litva and Titus Lo, *Digital Beamforming in Wireless Communications*, Artech House, 1996.
3. John Litva, Anupreet Sandhu, Keizo Cho, and Titus Lo, “Adaptive Beamforming in Wireless Communications” in T. Rappaport, B. Woerner, J. Reed, W. Tranter, Editors, *Wireless Personal Communications: The Evolution of Personal Communications Systems*, Springer, 1996.

B. PATENTS

1. Vahid Tarokh and Titus Lo, “Near-optimal low complexity decoding of space-time codes for fixed wireless applications,” US6,188,736, US6,470,043, US6,741,635, US7,046,737, US7,526,040, US8,179,991

2. Titus Lo, Dennis Rosenauer, and Doug Stolarz, "Method for combining communication beams in a wireless communication system," US6,377,783, US6,987,958
3. Titus Lo and Vafa Ghazi, "Method for error compensation in an OFDM system with diversity," US6,442,222, US6,901,125, US7,428,285, US8,223,903, US8,532,239
4. Titus Lo, "Maximum ratio transmission," US6,459,740, US6,826,236, US7,274,752, US7,362,823, US7,609,771, US8,520,746
5. Titus Lo, Adnan Abu-Dayya, and Mike Hirano, "Multicarrier transmission using polarized antennae," PCT/US2001/018993
6. Titus Lo and Ruifeng Wang, "Turbo channel estimation for OFDM systems", US6,940,914, US7,440,507, US7,656,958, US8,503,548, US8,681,887, US9,148,326
7. Titus Lo, "Adaptive communications system and method," US7,181,246
8. Xiaodong Li, Titus Lo, Kemin Li, Haiming Huang, "Methods and apparatus for multi-carrier communication systems with adaptive transmission and feedback," US7,693,032, US8,027,367, US9,301,296, US10,075,941, CN200580004761.3, KR10-0804651
9. Xiaodong Li, Titus Lo, Kemin Li, Haiming Huang, "Methods and Apparatus for Multi-Carrier Communications with Variable Channel Bandwidth," US7,787,431, US8,953,641, US10,511,417
10. Xiaodong Li, Titus Lo, Kemin Li, Haiming Huang, "Methods and apparatus for overlaying multi-carrier and direct-sequence spread spectrum signals in a broadband wireless communication system," US7,864,725, EP1712019B1, EP2723003, EP3208985B1, CN200580003185.0, CN201010576020.5, KR10-0818774
11. Xiaodong Li, Haiming Huang, Titus Lo, Ruifeng Wang, "Method and apparatus for multi-carrier packet communication with reduced overhead," US7,948,944, US8,634,376, US8,693,430, US9,042,337, US9,735,944, US10,447,450, CN200680009811.1, CN201210111079.6
12. Xiaodong Li and Titus Lo, "Frequency correction in multi-carrier communication systems," US7,957,341, US8,526,411, US9,326,262, US10,045,319
13. Xiaodong Li, Kemin Li, Titus Lo, Hamining Huang, "Methods and apparatus for random access in multi-carrier communication systems," US7,995,967, US8,467,366, US9,565,700, US10,390,369, CN200580007552.4 KR10-804667
14. Xiaodong Li, Titus Lo, Kemin Li, and Haiming Huang, "Methods and apparatus for multi-carrier, multi-cell wireless communication networks," EP1712089B1, CN200580001222.4, CN201010154096.9, KR10-808462
15. Xiaodong Li, Titus Lo, Kemin Li, and Haiming Huang, "Methods and apparatus using cell-specific and common pilot subcarriers in multi-carrier, multi-cell wireless communication networks," US8,009,660, US8,934,473, US9,065,614, US9,749,168
16. Xiaodong Li, Titus Lo, Kemin Li, Haiming Huang, "Methods and apparatus for communication systems with time-division duplexing," US8,014,264, CN200580013366.1
17. Xiaodong Li, Kemin Li, Titus Lo, Haiming Huang, Jun Meng, "Methods and apparatus for power control in multi-carrier wireless systems," US8,031,686
18. Titus Lo and Xiaodong Li, "Methods and apparatus for multiple-antenna systems in cellular communication and broadcasting," US8,041,395, US8,116,822, US8,326,366, US9,048,540, CN200680016367.6
19. Haiming Huang, Xiaodong Li, Titus Lo, Kemin Li, "Methods and apparatus for cellular broadcasting and communication system," US8,089,911, US8,374,115, US8,634,375, US10,044,517, CN200680000320.0, CN201210195003.6
20. Xiaodong Li, Titus Lo, Kemin Li, Haiming Huang, "Methods and apparatus for signal transmission and reception in a broadband communication system," US8,094,611, US8,428,009, US8,767,522

21. Haiming Huang, Xiaodong Li, Titus Lo, Kemin Li, "Methods and apparatus for a power efficient broadcasting and communication system," US8,155,098, US8,457,081, US8,934,394, US9,780,959, CN200680000425.6, CN201010557763.8
22. Xiaodong Li, Titus Lo, Kemin Li, and Haiming Huang, "Method, apparatus, and system for mitigating pilot signal degradation by employing cell-specific pilot subcarrier and common pilot subcarrier techniques in a multi-carrier cellular network," US8,432,891
23. Titus Lo and Xiaodong Li, "Methods and apparatus for flexible use of frequency bands," US8,547,884, US9,363,066, US9,839,037
24. Titus Lo and Xiaodong Li, "Multiple receivers in an OFDM/OFDMA communication system," US8,548,086, US9,025,650, US9,882,759
25. Titus Lo and Xiaodong Li, "Methods and apparatus for multi-carrier communications with efficient control signaling," US8,565,181, US9,843,468
26. Xiaodong Li, Haiming Huang, Titus Lo, Kemin Li, "Methods for multi-carrier communication systems with Automatic Repeat Request (ARQ)," KR10-818243
27. Xiaodong Li, Haiming Huang, Titus Lo, Kemin Li, "Methods and apparatus for multi-carrier communication systems with ARQ," US8,571,057, US9,083,500, US9,509,451, US10,313,061, CN201210020099.2, KR10-818771
28. Xiaodong Li, Kemin Li, Titus Lo, Haiming Huang, Jun Meng, "Method and apparatus for interference control in a multi-cell communication system," US8,675,563, US9,755,809
29. Xiaodong Li and Titus Lo, "Transmission of synchronization and control signals in a broadband wireless system," US8,705,399, US9,014,128, US9,781,730
30. Xiaodong Li, Titus Lo, Kemin Li, Haiming Huang, "Methods and apparatus for subframe configuration and generation in a multi-carrier communication system," US8,724,443, US9,198,179, US9,750,012, US10,368,347
31. Xiaodong Li and Titus Lo, "Methods and systems for correlated information services," PCT/US2007/084174
32. Xiaodong Li and Titus Lo, "Multi-carrier modulation with hierarchical resource allocation," US9,036,573, US9,730,205
33. Titus Lo and Xiaodong Li, "Methods and apparatus for contingency communications," US9,275,540, US9,773,406, US10,325,483, EP2813063B1
34. Titus Lo and Xiaodong Li, "Multiple-antenna system for cell-specific and user-specific transmission," US9,344,313, US10,149,173
35. Xiaodong Li and Titus Lo, "Methods and apparatus for signal conditioning in ofdma systems," US9,363,123
36. Xiaodong Li, Titus Lo, Kemin Li, and Haiming Huang, "Channel probing signal for a broadband communication system" US9,948,488
37. Xiaodong Li, Titus Lo, Kemin Li, and Haiming Huang, "Differential randomization of cell-specific and common pilot subcarriers in multi-carrier, multi-cell wireless communication networks" US10,326,631

C. REFEREED JOURNAL PAPERS

1. Titus Lo and John Litva, "Adaptive beam-space nulling of multipath signals," *IEEE Transactions on Antenna and Propagation*, vol. 37, no. 1, Jan.1990.
2. Titus Lo, Henry Leung, and John Litva, "Non-linear beamforming," *Electronics Letters*, vol. 27, no. 4, Feb. 1991.
3. Titus Lo, Tim Wong, and John Litva, "A new technique for low-angle radar tracking," *Electronics Letters*, vol. 27, no. 6, March 1991.
4. Titus Lo and John Litva, "Use of a highly deterministic multipath signal model in low-angle tracking," *IEE Proceedings Part F*, vol. 138, no. 2, Apr. 1991.

5. Titus Lo and John Litva, "Low-angle tracking using a multi-frequency sampled aperture radar: An experimental investigation," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 27, no. 5, Sept. 1991.
6. Titus Lo and John Litva, "Angles of arrival of indoor multipath," *Electronics Letters*, vol. 28, no. 18, Aug. 1992.
7. Ji Chen, Titus Lo, and John Litva, "Scattering of electromagnetic waves from a time-varying fractal surface," *Microwave and Optical Technology Letters*, vol. 6, no. 1, Jan 1993.
8. Henry Leung, Titus Lo, and John Litva, "Angle-of-arrival estimation in multipath environment using chaos theory," *Signal Processing*, **31** (1993) pp. 57-68.
9. Titus Lo, John Litva, and Henry Leung, "Estimating the impulse response of indoor radio channels using signal subspace techniques," *IEE Proceedings Part I*, vol. 140, no. 3, June 1993.
10. Henry Leung and Titus Lo, "Chaotic signal processing over the sea," *IEEE Journal Oceanic Eng.*, vol. 18, no.3, July 1993.
11. Titus Lo, Henry Leung, John Litva, and Simon Haykin, "Fractal characterization of sea scattered signals," *IEE Proceedings* Part F, vol.140, no. 4, Aug. 1993. (The authors of this paper won the 1993/1994 Mountbatten Premium awarded by the Institute of Electrical Engineers, London, England.)
12. Tim Wong, Titus Lo, Henry Leung, John Litva, and Eloi Bosse, "Low angle target tracking using radial basis function neural networks," *IEE Proceedings Part F*, vol.140, no. 5, Aug. 1993.
13. Henry Leung, Titus Lo, and John Litva, "Nonlinear Adaptive Signal Processing Based on Rational Function," *Signal Processing*, **38** (1994), pp. 153-168.
14. Titus Lo, Henry Leung, and John Litva, "Radial basis function neural network for direction-of-arrivals estimation," *IEEE Signal Processing Letters*, vol. 1, no. 2, Feb. 1994.
15. Fengzhen Wang, Titus Lo, John Litva, and William Read, "VHF antenna array processing: High accuracy direction finding and performance evaluation with real data," *IEE Proceedings - Radar, Sonar, Navig.*, vol. 141, no. 3, June 1994.
16. Titus Lo, Henry Leung, and John Litva, "Low-angle radar tracking in a naval environment using for-ward-backward nonlinear prediction method," *IEEE Journal Oceanic Eng*. vol. 19 no. 3, July 1994.
17. Ji Chen, Chen Wu, Titus Lo, Keli Wu, and John Litva, "Using linear and nonlinear predictors to improve the computational efficiency of FD-TD algorithm," *IEEE Transactions on Microwave Theory and Tech.*, vol. 42, no. 10, Oct. 1994.
18. Titus Lo, John Litva, and Henry Leung, "A new approach for estimating indoor radio propagation characteristics," *IEEE Transactions on Antenna and Propagation*, vol. 42, no. 10, Oct. 1994.
19. Titus Lo, Henry Leung, and John Litva, "Artificial neural network for AOA estimation in a multipath environment over the sea," *IEEE Journal Oceanic Eng.*, vol. 19 no. 4, Oct. 1994.
20. Henry Leung and Titus Lo, "A spatial temporal dynamical model for sea scattered signals," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 33, no.2, March 1995.
21. Fengzhen Wang, Titus Lo, John Litva, and William Read, "Performance of DF techniques with a real VHF array," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 31, no. 2, April 1995.
22. Ji Chen, Henry Leung, Titus Lo, John Litva, and Matin Blachette, "A modified probabilistic data association filter in real clutter," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 32, no. 1, Jan. 1996.
23. Fengzhen Wang, John Litva, Titus Lo, Eloi Bosse, and Henry Leung, "Feature-mapping data fusion," *IEE Proceedings - Radar, Sonar and Navigation,* vol. 143, no.1 Feb. 1996.

24. Fengzhen Wang, John Litva, Titus Lo, and Eloi Bosse, "Performance of neural data association," *IEE Proceedings - Radar, Sonar and Navigation*, vol. 143, no.1 Feb. 1996.
25. Ji Chen, Titus Lo, Henry Leung, and John Litva, "The use of fractal for modeling EM waves scattering from rough sea surface," *IEEE Transactions on Geoscience and Remote Sensing*, vol. 34, no. 4, July 1996.
26. Ying Zhang, Henry Leung, Titus Lo, and John Litva, "A distributed sequential nearest neighbor multitarget tracking algorithm," *IEE Proceedings - Radar, Sonar and Navigation*, vol. 143, no. 4, Aug. 1996.
27. Shiping He, Titus Lo, and John Litva, "A spread spectrum system with a time domain processing device," *IEEE Transactions on Circuits and Systems II: Analog and Digital Signal Processing,* Special Issue on Low Power Wireless Communications, vol. 44, no. 6, June, 1997.
28. Ying Zhang, Henry Leung, Martin Blanchette, Titus Lo, and John Litva, "An efficient decentralized multiradar multitarget tracker for air surveillance," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 33, no. 4, Oct. 1997.
29. Vahid Tarokh and Titus Lo, "Principal ratio combining for fixed wireless applications when transmitter diversity is employed," *IEEE Comm. Letters*, vol. 2, no. 8, Aug. 1998.
30. Titus Lo, "Maximum Ratio Transmission", *IEEE Trans. Commun.,* vol. 47, no. 10, Oct. 1999.
31. Henry Leung, Titus Lo, and Sichun Wang, "Prediction of Noisy Chaotic time series using an optimal radial basis function neural network," *IEEE Trans. Neural Networks*, vol. 12, no. 5, Sept. 2001.
32. Titus Lo, "Adaptive space-time transmission with side information," *IEEE Trans. Wireless Communications,* Vol. 3, no. 5, Sept. 2004.

D. CONFERENCE/SYMPOSIUM PRESENTATIONS

1. Titus Lo and John Litva, "Adaptive beam-space nulling of multipath signals," IEEE AP-S International Symposium, June, 1988
2. Titus Lo, Jian Wang, and John Litva, "An optimization approach to pattern synthesis in the design of microstrip phased array antenna," IEEE AP-S International Symposium, June 1989.
3. Titus Lo and John Litva, "Early results of multipath measurements on Lake Ontario," IEEE AP-S International Symposium, June 1989.
4. Titus Lo, Larry Lai, and John Litva, "Multipath propagation effects on low-angle radar tracking: An experimental evaluation," IEEE AP-S International Symposium, May 1990.
5. John Litva, Titus Lo and Tim Wong, "A new technique for low-angle radar tracking", Proc IEEE Pacific Rim Conf. on Communications, Computers and Signal Processing, Victoria B. C., May 9-10, 1991 (invited).
6. Titus Lo and John Litva, "Characteristics of diffuse forward-scattering signals," Proc. IEEE IGARSS'91, Espoo, Finland, June 1991.
7. Titus Lo, John Litva, and Robert J. C. Bultitude, "High-resolution spectral analysis techniques for estimating the impulse of indoor radio channels," 1992 IEEE International Conference on Selected Topics in Wireless Communications, Vancouver, B. C., June 25-26, 1992.
8. John Litva, Titus Lo and Shen Ying, "Combining electromagnetic and digital signal processing: Moving towards the intelligent antenna," Symposium on Antenna Technology and Applied Electromagnetics, Winnipeg, MN, Aug. 5-7 1992.
9. Titus Lo, John Litva, and Henry Leung, "Determination of optimal network structure by canonical subspace analysis," Spie's International Symposium on Optical Engineering and Photonics in Aerospace and Remote Sensing, April 1993.

10. Ji Chen, Titus Lo, Henry Leung, John Litva, Albert Bridgewater, and Matin Blanchette, "A study of track initiation and the modified probabilistic data association filter for multiple target tracking using real data," Proc IEEE Pacific Rim Conf. on Communications, Computers and Signal Processing, Victoria B. C., May 9-10, 1993.
11. Ji Chen, Titus Lo, and John Litva, "Time-varying fractal surface Scattering," Progress In Electromagnetic Research Symposium, JPL, Pasadena, CA., July 1993.
12. Fengzhen Wang, Titus Lo, and John Litva, "Performance analysis of broadband adaptive digital beamforming," IEEE AP-S International Symposium, June 1993.
13. Fengzhen Wang, Titus Lo, John Litva, and William Read, "Spatio-temporal Approach for real data with multipath propagation," 1993 Canadian Conference on Electrical and Computer Engineering, Vancouver, B.C., Sept. 1993..
14. Fengzhen Wang, John Litva, and Titus Lo, "Performance of broadband adaptive digital beamforming in communications," 23 rd European Microwave Conference, Madrid, Spain, Sept. 1993.
15. Fengzhen Wang, Titus Lo, John Litva, and William Read, "VHF sensor array real data processing techniques for direction finding," The international Conference on Signal Processing Applications & Technology'93, Santa Clara, CA, Sept. 1993.
16. Titus Lo, Henry Leung, W. Bridgewater, and John Litva, "Multitarget tracking initiation using a modified Hough transform," NATO Advisory Group for Aerospace Research & Development Conference Proceedings 539, Guidance and Control Panel 57th Symposium, Seattle, Washington, Oct. 12-15, 1993.
17. Fengzhen Wang, Titus Lo, John Litva, and Eloi Bosse, "Multisensor automatic target classification with neural networks," IEEE Seventh SP Workshop on Statistical Signal and Array Processing, Quebec City, June 1994.
18. Ban Quach, Henry Leung, Titus Lo, and John Litva, " Hopfield network approach to beamforming in spread spectrum communication," IEEE Seventh SP Workshop on Statistical Signal and Array Processing, Quebec City, June 1994.
19. Albert Chan, Titus Lo, and John Litva, "Detection in array receiver using radial basis function network," IEEE Seventh SP Workshop on Statistical Signal and Array Processing, Quebec City, June 1994.
20. Titus Lo, Henry Leung, John Litva, "A comparative study of statistical and neural DOA estimation Techniques," IEEE Seventh SP Workshop on Statistical Signal and Array Processing, Quebec City, June 1994.
21. Fengzhen Wang, Titus Lo, John Litva, and William Read, "High accuracy direction finding antenna array system," IEEE AP-S International Symposium, Seattle, WA, June 1994.
22. Charles Laperle, Titus Lo, and John Litva, "Modelling of nonlinearities and their effects on digital beamforming," IEEE AP-S International Symposium, Seattle, WA, June 1994.
23. Nagula Sangary, Keli Wu, Titus Lo, and John Litva, "Beamforming with spiral antennas," URSI Radio Science Meeting, Seattle, WA, June 1994.
24. Titus Lo, Fengzhen Wang, Ji Chan, Henry Leung, and John Litva, "Neural networks for Multisensor Multitarget tracking," Dedicated Conf. on Robotics, Motion, and Machine Vision, Aachen, Germany, Oct. 1994 (invited).
25. Fengzhen Wang, Titus Lo, John Litva, and Eloi Bosse, "A new energy function of mean field Hopfield network for measurement data association," 5th International Conference on Signal Processing and Technology'94, Dallas, Taxes, Oct. 1994.
26. Ying Zhang, Henry Leung, Titus Lo, and John Litva, "A distributed multi-sensor multi-target tracking algorithm," Spie's International Symposium on Optical Engineering and Photonics in Aerospace and Remote Sensing, April 1995.

27. Yifeng Li, Henry Leung, Titus Lo, and John Litva, "New architectures for centralized multisensor multitarget tracking," Spie's International Symposium on Optical Engineering and Photonics in Aerospace and Remote Sensing, April 1995.
28. Henry Leung, Ban Quach, Titus Lo, and John Litva, "Chaotic neural beamforming for wireless communications," IEEE Pacific Rim 1995 conference, Victoria, B.C., May 1995.
29. John Litva, Anupreet Sandhu, Keizo Cho, and Titus Lo, "Adaptive beamforming for wireless communications," 5th Virginia Tech symposium on Wireless Personal Communications, Blacksburg, VA, June 1995.
30. Keizo Cho, Titus Lo, and John Litva, "BER performance comparisons between a Diversity Receiver and a LMS beamforming receiver operating with cochannel interference," Wireless'95, Calgary, Alta., July 1995.
31. Anupreet Sandhu, Titus Lo, Henry Leung, and John Litva, "Hopfield neurobeamformer for spread spectrum communications," The 6th IEEE International symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 95), Toronto, ON., Sept. 1995.
32. Wei Zhang, Titus Lo, and John Litva, "Fractal modelling of forest surface for electromagnetic wave scattering research," The 6th IEEE International symposium on Personal, Indoor and Mobile Radio Communications (PIMRC 95), Toronto, ON., Sept. 1995.
33. Jean-Yves Carrier, John Litva, Henry Leung, and Titus Lo, "Genetic algorithm for multiple target tracking data association," Spie's International Symposium on Optical Engineering and Photonics in Aerospace and Remote Sensing, April 1996.
34. Titus Lo, Henry Leung, and John Litva, "Separation of a mixture of chaotic signals," IEEE International Conference on Acoustic, Speech and Signal Processing (ICASSP'96), Atlanta, May 1996.
35. Titus Lo and John Litva, "Radarsat antenna elevation pattern restoration," IEEE AP-S International Symposium, June 1996.
36. Titus Lo, Henry Leung, and Keith Chan, "Data fusion using dynamic associative memory," Spie's International Symposium on Optical Engineering and Photonics in Aerospace and Remote Sensing, April 1997.
37. Shiping He, Titus Lo, and John Litva, "Performance analysis of CDMA with an adaptive antenna array," International Wireless and Telecommunications Symposium, Shah Alam, Malaysia, May 1997.
38. Ming Lu, Titus Lo, John Litva, "A physical spatio-temporal model of multipath propagation channels," IEEE VTC, Phoenix, AZ, May 1997.
39. John Litva, Anupreet Sandhu and Titus Lo, "Adaptive beamforming for CDMA wireless communications using correlated codes," IEEE AP-S International Symposium, June 1997.
40. Ming Lu, Titus Lo, John Litva, "Downlink capacity of a cellular CDMA system configured with multibeam cell-site antenna in multipath fading channels," Wireless'97, Calgary, AB, July 1997.
41. Ming Lu, Titus Lo, and John Litva, "Effect of transmit antenna pattern on rake reception in multipath fading channels", IEEE International Conference on Universal Personal Communications (ICUPC'97), San Diego, CA, Oct. 12-16, 1997
42. Shiping He, Titus Lo, and John Litva, "A new spread spectrum system using spectral correlation technology", IEEE MILCOM'97, Monterey, CA, Nov. 2-5, 1997.
43. Shiping He, Titus Lo, and John Litva, "A spread spectrum system with a time-domain processing device", IEEE MILCOM'97, Monterey, CA, Nov. 2-5, 1997.
44. Ming Lu, Titus Lo, and John Litva, "A smart antenna array for CDMA systems with non-coherent M-ary orthogonal modulation", IEEE CLOBECOM'97, Phoenix, AZ, Nov. 4-8, 1997.

45. Donghai Qiao, John Litva, Titus Lo, and Shiping He, "Effects of frequency selective fading on performance of an adaptive antenna array", 1997 IEEE Pacific Rim Conference on Volume: 1, Page(s): 366 -369 vol.1
46. Vahid Tarokh and Titus Lo, "Principal ratio combining for fixed wireless applications when transmitter diversity is employed," IEEE ICUPC'98, Florence, Italy, Oct. 5-9, 1998.
47. Titus Lo, "Maximum Ratio Transmission," IEEE ICC'99, Vancouver, Canada, June 1999.
48. Titus Lo and Vahid Tarokh, "Space-time block coding – From a physical perspective," IEEE WCNC'99, New Orleans, LA, Sept. 1999.
49. Titus Lo, "Adaptive space-time transmission with side information" Wireless Communications and Networking, 2003. WCNC 2003. 2003 IEEE, Volume: 1, 16-20 March 2003.

E. INVITED LECTURES AND SEMINARS

1. Special guest speaker, "Propagation over Fractal Trees," Spectrum Research Seminar Series, Ministry of Industry, Canada, June 1995. (Video tape for the entire lecture is available through the Ministry)
2. Invited speaker, "Fixed Wireless Communications," AT&T Labs-Research, Nov. 1998.
3. Invited speaker, "Optimizing system capacity in wireless communications systems," IEEE Intercomm'99, Vancouver, B.C., Feb. 1999
4. Invited speaker, "IEEE802.16e: Technical Overview", Seminar at the University of British Columbia, sponsored by IEEE Joint Communications Chapter – Vancouver, July 25 2005
5. Invited speaker, "Mobile WiMAX – Technical Overview and Market Opportunity," MITACS Seminar Series on Analog Wideband Communications, University of Calgary, Mar. 7 2008
6. Invited speaker, "LTE – A technical overview," Seminar at University of Washington, sponsored by IEEE Seattle Communications Society Chapter, May 19, 2009
7. Invited speaker, "Key Technologies in 3.5G and 4G," IEEE Pacific Northwest Wireless Workshop 2009, Oct. 30, 2009
8. Invited speaker, "LTE – An infotainment," Seminar at Microsoft Research, sponsored by IEEE Seattle Communications Society Chapter, Sept. 30, 2010
9. Invited speaker, "LTE – An introduction," Seminar for executives at Intermec Corporation, Nov. 16, 2010
10. Invited speaker, "The "ABCs" of LTE," Seminar at Microsoft Research, sponsored by IEEE Seattle Section, May 12, 2015
11. Moderator, panel discussion, "Current State of 5G" sponsored by IEEE Seattle Communications Joint Chapter, Nov. 19, 2019

F. IEEE802-16 STANDARD CONTRIBUTIONS

1. IEEE C802.16e-04/97, "Changes to DL-MAP-IE and UL-MAP-IE to support AMC Subchannel in OFDMA PHY"
2. IEEE C802.16e-04/121, "Changes to subchannel group in DL PUSC zone to support scalable FFT in OFDMA PHY"
3. IEEE C802.16e-04/268, "Downlink Power Control to reduce multi-cell interference"
4. IEEE C802.16e-04/472, "Clarification of CDMA handover ranging process"

G. REPORTS AND WHITE PAPERS

1. Paul Bauman, John Litva, Larry Lai, and Titus Lo, "Sea swell modelling, collection and analysis of data," CRL No. 199, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, March 1989.

2. Titus Lo, Larry Lai, and John Litva, "Validation of a sea swell model, analysis of real multipath data, and testing of the CHA technique with real and simulated data," Department of National Defense Contract no. 052SS w7714-8-5674, April, 1990.
3. Titus Lo, Larry Lai, and John Litva, "Characterization and computer modelling of multipath signals in naval environments," Department of National Defense Contract no. w7714-9-9181/01-SZ, Nov. 1990.
4. John Litva and Titus Lo, "A study to investigate algorithms to provide multipath immunity for high accuracy direction finding systems." LAE Report, Lockheed Canada Inc., 1991.
5. Larry Lai, Titus Lo, Albert Chan, and John Litva, "Portable multipath measurement system," CRL Report no. 233, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, July 1991.
6. Ji Chen, Titus Lo, and John Litva, "A study of track Initiation and data association for multiple target tracking," CRL Report no. 271, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, June 1993.
7. Titus Lo, Fengzhen Wang, and John Litva, "High accuracy direction finding trials," CRL Report no. 273, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Nov. 1993.
8. Titus Lo, Charles Laperle, Ying Shen, Minya Zhang, and John Litva, "Digital beamforming for mobile satellite communications--Technology assessment and design study," CRL Report no. 284, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Dec. 1993.
9. Charles Laperle, Titus Lo, and John Litva, "Modelling of nonlinearities and a study of their effects on beamforming," CRL Report no. 285, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Apr. 1994.
10. John Litva, Fengzhen Wang, and Titus Lo, "Neural networks for multisensor data fusion," CRL Report no. 298, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Apr. 1995.
11. Wei Zhang, Tony Tam, Titus Lo, and John Litva, "Fractal modelling of forest surface for electromagnetic wave scattering research," CRL Report no. 299, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, March 1995.
12. Ying Zhang, Titus Lo, and John Litva, "Distributed multi-sensor multi-target track fusion," CRL Report no. 301, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, April 1995.
13. Yifeng Li, Titus Lo, and John Litva, "The centralized multisensor multitarget tracking systems," CRL Report no. 318, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Jan. 1996.
14. Fengzhen Wang, Titus Lo, and John Litva, "Neural networks for multisensor data fusion -- feature mapping approach," CRL Report no. 322, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, March 1996.
15. Titus Lo, Xiaoming Yu, Nader Obeid, and John Litva, "Radarsat antenna elevation pattern restoration," LAE Report, Canadian Space Agency, March 1996.
16. Tony Tam, Titus Lo, and John Litva, "Forest propagation modelling utilizing a cellular automata-fractal approach," CRL Report no. 329, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, May 1996.
17. Ming Lu, Titus Lo, John Litva, "A physical spatio-temporal model of multipath propagation channels," CRL Report no. 342, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Feb. 1997.
18. Ming Lu, Titus Lo, John Litva, "Downlink capacity of a cellular CDMA system configured with multibeam cell-site antenna in multipath fading channels," CRL Report no. 343, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Feb. 1997.

19. Ming Lu, Titus Lo, and John Litva, "Effect of transmit antenna pattern on rake reception in multipath fading channels", CRL Report no. 344, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Feb. 1997.
20. Ming Lu, Titus Lo, and John Litva, "A smart antenna array for CDMA systems with non-coherent M-ary orthogonal modulation", CRL Report no. 345, The Communications Research Laboratory, McMaster University, Hamilton, Ontario, Feb. 1997.
21. Titus Lo and John Litva, "Smart antenna technology – An overview", LAE Report, Ministry of Industry, Canada, March 1997.
22. John Litva, Titus Lo, Shiping He, and Donghai Qiao, " Investigation of the impact of frequency-selective fading on adaptive antennas", LAE Report, The Communications Research Centre, Ministry of Industry, Canada, July 1997.