



ANTENNAS AND PROPAGATION

UNIVERSITY OF MICHIGAN
APR 16 1998
MEDIA UNION LIBRARY



A PUBLICATION OF THE IEEE ANTENNAS AND PROPAGATION SOCIETY

APRIL 1998 VOLUME 46 NUMBER 4 IETPAK (ISSN 0018-926X)

PAPERS

Physical Interpretation of the Phase Asymmetry of a Slant-Path Transmission Matrix	<i>N. J. McEwan, Z. A. A. Rashid, and S. M. R. Jones</i>	465
A Wide-Band Single-Layer Patch Antenna	<i>N. Herscovici</i>	471
Multiport Network Model for CAD of Electromagnetically Coupled Microstrip Patch Antennas	<i>R. P. Parrikar and K. C. Gupta</i>	475
Simultaneous Time- and Frequency-Domain Extrapolation	<i>R. S. Adve and T. K. Sarkar</i>	484
Scattering from Structures Formed by Resonant Elements	<i>V. Veremey and R. Mittra</i>	494
Normalization and Interpretation of Radar Images	<i>J. P. Skinner, B. M. Kent, R. C. Wittmann, D. L. Mensa, and D. J. Andersh</i>	502
Perfectly Matched Layer Mesh Terminations for Nodal-Based Finite-Element Methods in Electromagnetic Scattering ...	<i>J. Tang, K. D. Paulsen, and S. A. Haider</i>	507
On the Behavior of the Sierpinski Multiband Fractal Antenna	<i>C. Puente-Baliarda, J. Romeu, R. Pous, and A. Cardama</i>	517
On Modeling and Personal Dosimetry of Cellular Telephone Helical Antennas with the FDTD Code	<i>G. Lazzi and O. P. Gandhi</i>	525
Study of Impedance and Radiation Properties of a Concentric Microstrip Triangular-Ring Antenna and Its Modeling Techniques Using FDTD Method	<i>I. S. Misra and S. K. Chowdhury</i>	531
Analysis of Stripline-Fed Slot-Coupled Patch Antennas with Vias for Parallel-Plate Mode Suppression	<i>A. Bhattacharyya, O. Fordham, and Y. Liu</i>	538
Blindness Removal in Arrays of Rectangular Waveguides Using Dielectrically Loaded Hard Walls	<i>S. P. Skobelev and P.-S. Kildal</i>	546
Near-Field Scattering by Physical Theory of Diffraction and Shooting and Bouncing Rays	<i>S.-K. Jeng</i>	551
Method of Moments Solution for a Wire Attached to an Arbitrary Faceted Surface	<i>I. Tekin and E. H. Newman</i>	559
Forward-Scattering Analysis in a Focused-Beam System	<i>R. Shavit, T. Wells, and A. Cohen</i>	563
High-Frequency Analysis of an Array of Line Sources on a Truncated Ground Plane	<i>F. Capolino, M. Albani, S. Maci, and R. Tiberio</i>	570
A UTD Solution for the Scattering by a Wedge with Anisotropic Impedance Faces: Skew Incidence Case	<i>G. Pelosi, G. Manara, and P. Nepa</i>	579
On the Use of Cavity Modes as Basis Functions in the Full-Wave Analysis of Printed Antennas	<i>G. Vecchi, P. Pirinoli, and M. Orefice</i>	589

LETTERS

Time-Domain Spherical Near-Field Formulas in the Case Where the Radial Components of the Electromagnetic Field Are Measured	<i>I. Christiansen</i>	595
A Compact PIFA Suitable for Dual-Frequency 900/1800-MHz Operation	<i>C. R. Rowell and R. D. Murch</i>	596
Scattering by a Dielectric-Loaded Nonplanar Slit—TM Case	<i>J.-W. Yu and N.-H. Myung</i>	598
Partial Control for Wide-Band Interference Suppression Using Eigen Approach	<i>M. J. Mismar and T. H. Ismail</i>	600



All members of the IEEE are eligible for membership in the Antennas and Propagation Society and will receive this TRANSACTIONS upon payment of the annual Society membership fee of \$12.00. For information on joining, write to the IEEE at the address below. *Member copies of Transactions/Journals are for personal use only.*

R. J. MARHEFKA, *President*

ADMINISTRATIVE COMMITTEE

D. H. SCHAUBERT, *Vice President*

O. B. KESLER, *Secretary-Treasurer*

1998

- *D. G. BODNAR
- R. J. MARHEFKA
- E. K. MILLER
- J. W. MINK
- J. L. VOLAKIS

1999

- *Y. RAHMAT-SAMII
- C. A. BALANIS
- M. F. ISKANDER
- D. R. JACKSON
- D. V. THIEL

2000

- *S. A. LONG
- J. J. LEE
- M. PIKET-MAY
- R. J. POGORZELSKI
- G. S. SMITH

2001

- *E. S. GILLESPIE

Honorary Life Member: R. C. HANSEN

*Past President

Committee Chairs and Representatives

- EAB/TAA: E. K. MILLER
- Energy Committee: Vacant
- European Representatives: P. J. B. CLARRICOATS, A. G. ROEDERER
- Finance: O. B. KESLER
- Historian: W. F. CROSWELL
- IEEE Magazine Committee: W. R. STONE
- IEEE Press Liaison: R. J. MAILLOUX
- IEEE Transactions Committee: P. L. E. USLENGHI
- International Radio Consultative Cmte (CCIR): E. K. SMITH
- Institutional Listings: C. C. ALLEN
- Long-Range Planning: A. C. SCHELL
- Magazine Editor: W. R. STONE
- Meetings: J. A. MOELLERS
- Meetings Coordination: S. A. LONG
- Meetings Workshops: W. G. SCOTT

- Membership: S. D. GEDNEY
- New Technology: A. I. ZAGHLOUL
- Nominations: E. S. GILLESPIE
- Professional Activities (PACE): K. L. VIRGA
- Publications: R. J. MARHEFKA
- R&D Committee—Aerospace: G. HYDE
- R&D Committee—Defense: A. C. SCHELL
- R&D Committee—Engineering: C. W. BOSTIAN
- Standards—Antennas: E. A. URBANK
- Standards—Propagation: W. A. FLOOD
- Superconductivity Committee: K. MEI, J. WILLIAMS
- USNC/URSI: L. P. B. KATCHI
- TAB Magazines Committee: W. R. STONE
- TAB New Technology Directions Committee: A. I. ZAGHLOUL
- TAB Public Relations Committee: W. R. STONE
- TAB Transactions Committee: P. L. E. USLENGHI

Chapter Chairs

<i>Albuquerque</i> D. P. McLEMORE	<i>Dallas</i> T. LOGAN	<i>Houston (Texas A&M)</i> R. D. NEVELS	<i>Michigan, S. E.</i> J. W. BURNS	<i>Philadelphia</i> E. HOLZMAN	<i>Singapore</i> M. S. LEONG	<i>Tokyo</i> T. SHIOKAWA
<i>Atlanta</i> G. HOPKINS	<i>Dayton</i> K. NAISHITURA	<i>Hungary</i> I. FRIGYES	<i>Milwaukee</i> J. RICHIE	<i>Phoenix</i> B. EL SHARAWY	<i>South Africa</i> D. B. DAVIDSON	<i>Toronto</i> T. E. VAN DEVENTER
<i>Baltimore</i> H. B. SEQUEIRA	<i>Denver</i> R. P. GEYER	<i>Huntsville</i> H. L. BENNETT	<i>Montreal</i> G. L. YIP	<i>Poland</i> C. W. K. GWAREK	<i>South Australia</i> B. D. BATES	<i>Tucson</i> H. C. KOHLBACHER
<i>Beijing</i> Z. SHA	<i>Egypt</i> M. N. I. FAHMY	<i>Indonesia</i> S. NATENAGARO	<i>Nanjing</i> W. X. ZHANG	<i>Princeton</i> W. R. CURTICE	<i>South Bay Harbor</i> M. SALAZAR-PALMA	<i>Turkey</i> A. ALTINAS
<i>Benelux</i> W. X. ZHANG	<i>Finland</i> K. NIKOSKINEN	<i>Israel</i> A. MADJAR	<i>New Jersey Coast</i> R. A. ZIEGLER	<i>Rio de Janeiro</i> J. R. BERGMANN	<i>Spain</i> C. W. WILSON	<i>Ukraine</i> A. NOSICH
<i>Boston</i> K. V. T. KLOOSTER	<i>Florida W. Coast</i> T. WELLER	<i>Italy (Central & S.)</i> P. BERNARDI	<i>New South Wales</i> T. BIRD	<i>Russia</i> D. SAZONOV	<i>Spokane</i> J. B. MEAD	<i>Uzbekistan</i> N. N. VOITOVICH
<i>Buffalo</i> M. R. GILLETTE	<i>Foothill</i> D. A. PAUL	<i>Switzerland</i> Y. L. CHOW	<i>North Italy</i> C. N. NALDI	<i>St. Louis</i> R. W. KIEFEL	<i>St. Petersburg</i> S. TRETIVAKOV	<i>United Kingdom/Ireland</i> T. H. OXLEY
<i>Bulgaria</i> H. D. HRISTOV	<i>Fl. Worth</i> G. C. MAY	<i>Lithuania</i> B. LEVITAS	<i>North Jersey</i> C. GUPTA	<i>Salt Lake City</i> M. F. ISKANDER	<i>Sweden</i> J. JOHANSSON	<i>Utah</i> M. F. ISKANDER
<i>Chicago</i> J. PHILLIPS	<i>Germany</i> N. J. KEEN	<i>Long Island/NY</i> H. AHN	<i>Orlando</i> T. G. IVANOV	<i>Santa Clara Valley</i> J. ROUSSOS	<i>Switzerland</i> W. BACHTOLD	<i>Vancouver</i> L. SHAFAI
<i>Columbus</i> R. BURKHOLDER	<i>Hong Kong</i> K. K. MEI	<i>Los Angeles</i> P. RAMANUJAM	<i>Ottawa</i> D. H. REEKIE	<i>Santa Clara Valley</i> A. SABO	<i>Syracuse</i> W. Q. SONG	<i>Washington/Northern VA</i> D. T. AUCLAND
<i>Czechoslovakia</i> M. ZEMAN	<i>Houston</i> J. T. WILLIAMS			<i>Seattle</i> J. McCARDLESS	<i>Thailand</i> N. YOOTHANOM	<i>Winnipeg</i> L. SHAFAI

IEEE TRANSACTIONS® ON ANTENNAS AND PROPAGATION

is a publication devoted to theoretical and experimental advances in antennas including design and development, and in the propagation of electromagnetic waves including scattering, diffraction, and interaction with continuous media; and applications pertinent to antennas and propagation, such as remote sensing, applied optics, and millimeter and submillimeter wave techniques.

See inside back cover for Editorial Board.

THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

Officers

- JOSEPH BORDOGNA, *President*
- KENNETH R. LAKER, *President-Elect*
- ANTONIO C. BASTOS, *Secretary*
- BRUCE A. EISENSTEIN, *Treasurer*
- ARTHUR WINSTON, *Vice President, Educational Activities*
- FRIEDOLF M. SMITS, *Vice President, Publication Activities*
- DANIEL R. BENIGNI, *Vice President, Regional Activities*
- L. JOHN RANKINE, *Vice President, Standards Association*
- LLOYD A. MORLEY, *Vice President, Technical Activities*
- JOHN R. REINERT, *President, IEEE USA*

WILLIAM G. DUFF, *Director, Division IV — Electromagnetics and Radiation*

Executive Staff

- DANIEL J. SENESE, *Executive Manager*
- RICHARD D. SCHWARTZ, *Business Administration*
- W. THOMAS SUTTLE, *Professional Activities*
- MARY WARD-CALLAN, *Technical Activities*
- JOHN WITSGEN, *Information Technology*
- DONALD CURTIS, *Human Resources*
- ANTHONY J. FERRARO, *Publications*
- JUDITH GORMAN, *Standards Activities*
- CECELIA JANKOWSKI, *Regional Activities*
- PETER A. LEWIS, *Educational Activities*

IEEE Periodicals

Transactions/Journals Department

- Staff Director: FRAN ZAPPULLA
- Editorial Director: VALERIE CAMMARATA
- Production Director: ROBERT SMREK
- Transactions Manager: GAIL S. FERENC
- Electronic Publishing Manager: TOM BONTRAGER
- Managing Editor: ROBERT W. DAVIDSON
- Associate Editor: HELENE DORTHEIMER

IEEE TRANSACTIONS ON ANTENNAS AND PROPAGATION (ISSN 0018-926X) is published monthly by the Institute of Electrical and Electronics Engineers, Inc. Responsibility for the contents rests upon the authors and not upon the IEEE, the Society/Council, or its members. **IEEE Corporate Office:** 345 East 47 Street, New York, NY 10017-2394. **IEEE Operations Center:** 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331. **NJ Telephone:** 732-981-0060. **Price/Publication Information:** Individual copies: IEEE Members \$10.00 (first copy only), nonmembers \$20.00 per copy. (Note: Add \$4.00 postage and handling charge to any order from \$1.00 to \$50.00, including prepaid orders.) Member and nonmember subscription prices available upon request. Available in microfiche and microfilm. **Copyright and Reprint Permissions:** Abstracting is permitted with credit to the source. Libraries are permitted to photocopy for private use of patrons, provided the per-copy fee indicated in the code at the bottom of the first page is paid through the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923. For all other copying, reprint, or republication permission, write to Copyrights and Permissions Department, IEEE, P.O. Box 1331, Piscataway, NJ 08855-1331. © 1998 by The Institute of Electrical and Electronics Engineers, Inc. All rights reserved. Periodicals postage paid at New York, NY, and at additional mailing offices. Postmaster: Please send address changes in this journal to IEEE Transactions on Antennas and Propagation, P.O. Box 1331, Piscataway, NJ 08855-1331.



Abstract mission consisting of propagating that the

Index

SWR matrix calibrated the population revealed This phase of Olympiad Using matrix medium ment of in which along t asymm indicat particle

Duri matrix angles behavi the ma somev mean : (thoug each l The altitud occur satisf of me no ge conce

Man The ing, U Publ

Study of Impedance and Radiation Properties of a Concentric Microstrip Triangular-Ring Antenna and Its Modeling Techniques Using FDTD Method

Iti Saha Misra and S. K. Chowdhury, *Senior Member, IEEE*

Abstract— A concentric microstrip triangular-ring antenna structure using the log-periodic principle for increasing the impedance bandwidth of the microstrip patch antenna is described. The finite-difference time-domain (FDTD) method is applied to analyze the proposed structure. A special technique to model the slanted metallic boundaries of the triangular ring has been used in the general FDTD algorithm to avoid the staircase approximation. The method improves the accuracy of the original FDTD algorithm without increasing the complexity. The radiation patterns at different frequencies over wide-band width are obtained experimentally.

Index Terms—FDTD methods, microstrip antennas.

I. INTRODUCTION

A three-element concentric microstrip triangular-ring antenna (CMTRA) has been designed using a log-periodic principle and fabricated on a polytetra fluoroethylene (PTFE) substrate. The elements of the CMTRA are fed electromagnetically by a 50- Ω microstrip line. The impedance and radiation characteristics have been measured and compared with those of two single triangular-ring antennas (STRA) having the largest and the smallest element dimensions of the CMTRA. The impedance variation for the CMTRA has been measured at different feed locations. Results show that the bandwidth of the CMTRA is increased with respect to the STRA and the maximum bandwidth obtained for a particular feed location away from the center. The measured radiation characteristics at different feed location show its invariant nature. The measured impedance pattern for two feed locations are verified by FDTD method. This method is similar to the method described for concentric microstrip circular-ring antenna (CMCRA) in [1]. A special technique to model the slanted metallic boundaries of the triangular ring has been used in the general FDTD algorithm to avoid the staircase approximation [2], [3]. The method improves the accuracy of the original FDTD algorithm without increasing the complexity.

II. DESIGN OF THREE-ELEMENT CMTRA

The three-element CMTRA is shown in Fig. 1(a). The width “ w ” and spacing “ d ” between the elements are specified in

Manuscript received September 6, 1996; revised May 30, 1997.
The authors are with the Department of Electronics and Telecommunication Engineering, Jadavpur University, Calcutta, 700 032 India.
Publisher Item Identifier S 0018-926X(98)02680-5.

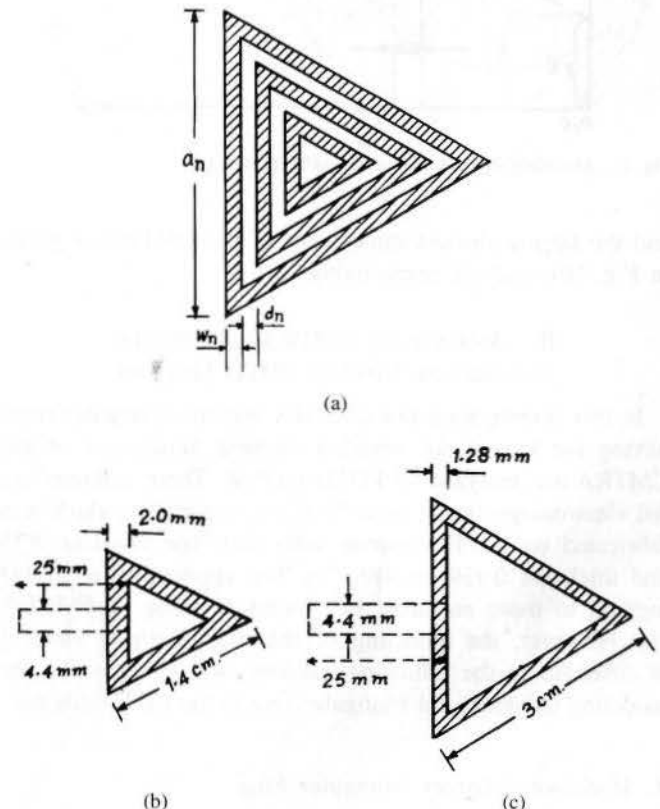


Fig. 1. Geometry of (a) three-element CMTRA, (b) STRA investigation of the smallest element dimensions, and (c) STRA investigation of the largest element dimensions.

this figure. First, the innermost element was chosen with side $a = 1.4$ cm and width $w = 0.2$ cm. The spacing between the adjacent elements and their widths are then chosen maintaining the following relation:

$$\tau = d_{n+1}/d_n = w_{n+1}/w_n = 1.25 \quad (1)$$

where n is the suffix of the n th number of patch as indicated in Fig. 1(a). The ring width and spacing decrease from the innermost element to the outermost element. Maintaining this relation the outermost ring has the sides $a = 3.0$ cm and width $w = 0.128$ cm. The STRA's investigated have the smallest

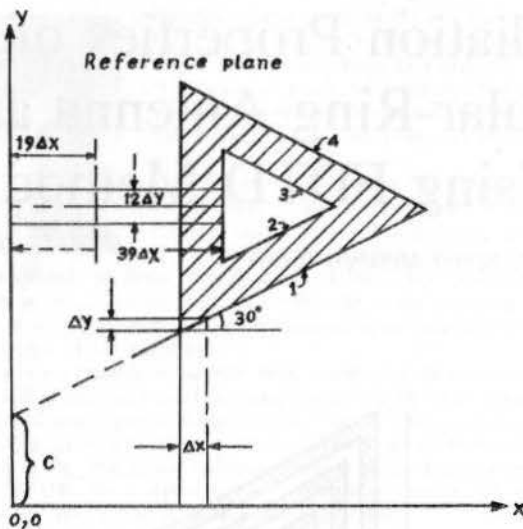


Fig. 2. Modeling of triangular ring in FDTD domain.

and the largest element dimensions of the CMTRA as given in Fig. 1(b) and (c), respectively.

III. ANALYSIS OF CMTRA AND SINGLE TRIANGULAR RING BY FDTD METHOD

In this investigation one CMTRA and two triangular rings having the largest and smallest element dimensions of the CMTRA are analyzed by FDTD method. These antennas are fed electromagnetically by a 50-Ω microstrip line which was fabricated on PTFE substrate with dielectric constant 2.55 and thickness 0.159 cm (Fig. 1). The application of FDTD method to these antennas are similar to those of CMTRA [1]. However, the modeling of the triangular-ring element is different. In the following sections, we will describe the modeling techniques of triangular ring in the FDTD domain.

A. Modeling of Larger Triangular Ring

Fig. 2 shows the actual dimension of the triangular ring antenna in the X - Y plane of the FDTD domain. Since the ring is an equilateral triangle the angle between the X axis and slanting plane is 30° . All the slanting sides of this ring can be represented by the equation of a line as

$$y = mx + C \dots \quad (2)$$

where $m = \tan \theta$, $\theta =$ angle between the X axis and slanting plane.

Putting the value of θ and any coordinate (x, y) passing through the line, the value of C can be found out.

Now, if one can select the proper aspect ratio of each cell in the FDTD domain, then the slanted plane wall can be modeled exactly, i.e., it is possible to locate the boundary nodes of the mesh exactly on the slanted planes [3]. In this particular case if we select $\Delta x = 0.64$ mm and, hence, $y = \Delta x \tan \theta$ then for every space increment along X and Y direction the equation

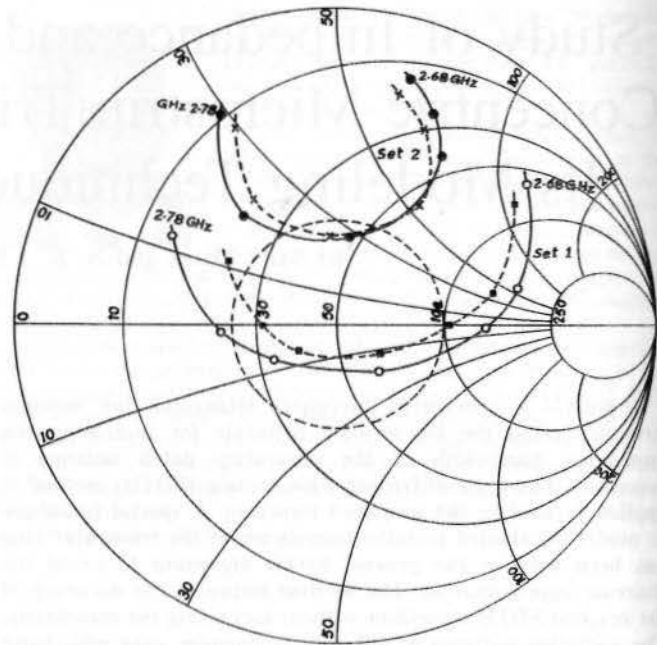


Fig. 3. Impedance plot of largest triangular ring of Fig. 1(c) at different feed location—set 1 for center feed, set 2 for 0.35 cm off-center feed.

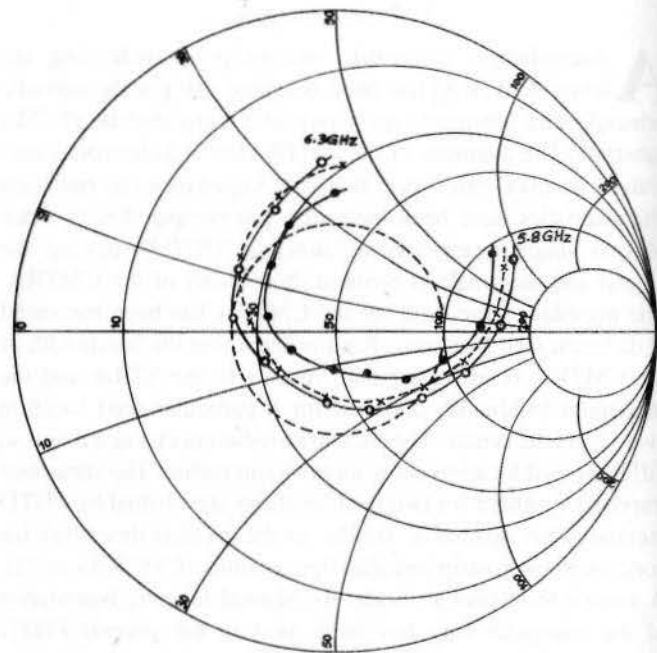


Fig. 4. Impedance plot of smallest triangular ring of Fig. 1(b) for center feed.

The tangential electric field components E_x and E_y and normal component of magnetic field H_z were made equal to zero on the triangular-ring patch bounded by the six lines. The FDTD parameters for this ring were: $\Delta x = 0.64$ mm, $\Delta y = 0.57735\Delta x = 0.3694$ mm, and $\Delta z = 0.5926$ mm, $\Delta t = \Delta y/2C_0$ ($C_0 =$ free-space velocity of light), and Gaussian half-width $\tau = 18$ ps. The distance between the source plane to microstrip antenna was $39\Delta x$ and the reference

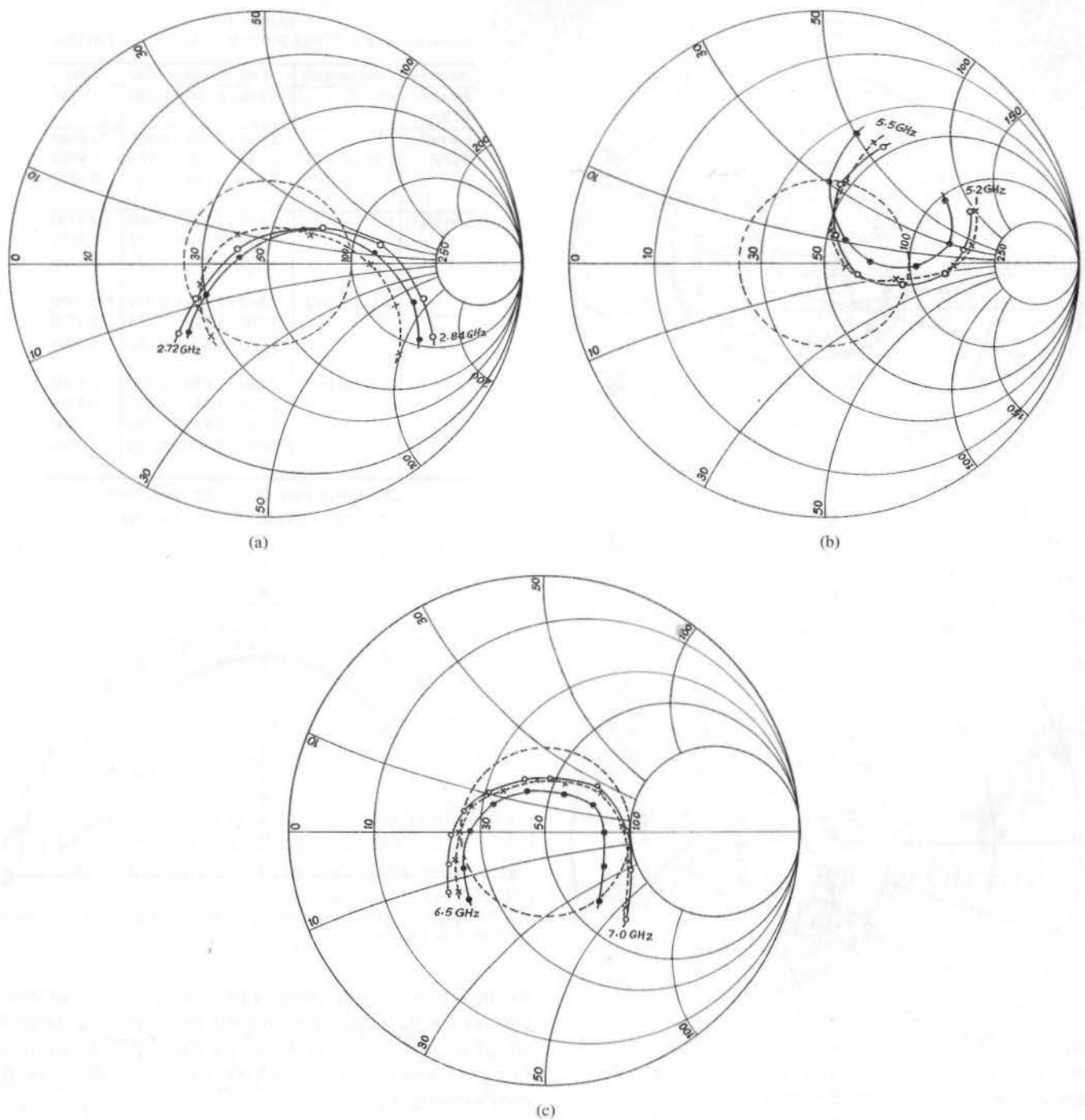


Fig. 5. (a) and (b) Impedance plot of three-element CMTRA at different frequency band for center feed. (c) Impedance plot of three-element CMTRA at different frequency band for center feed.

50- Ω microstrip line width and the ring width were modeled as $12\Delta y$ and $2\Delta x$, respectively.

B. Modeling of Small Triangular Ring

The actual dimensions of the small triangular ring is shown in Fig. 1(b). The FDTD parameters were $\Delta x = 1.0$ mm, $\Delta y = 0.57735\Delta x = 0.57735$, $\Delta z = 0.5296$ mm, $\Delta t = \Delta z/2C_0$, and Gaussian half-width = 16 ps. Microstrip line width was modeled as $7\Delta y$, the reference plane was set at a distance

C. Modeling of Three-Element CMTRA

The application of FDTD method is similar to the application of single rings. The mesh size was considered such that it can model the actual dimensions of the CMTRA. The FDTD parameters were $\Delta x = 0.4$ mm, $\Delta y = 0.23094\Delta z = 0.5296$ mm, $\Delta t = \Delta y/2C_0$, and Gaussian half-width = 20 ps.

In all three cases Mur's first-order absorbing boundary condition had been applied at the end, side, and top walls [4]. The total and incident E field were stored at the ref-

Explore Litigation Insights

Docket Alarm provides insights to develop a more informed litigation strategy and the peace of mind of knowing you're on top of things.

Real-Time Litigation Alerts



Keep your litigation team up-to-date with **real-time alerts** and advanced team management tools built for the enterprise, all while greatly reducing PACER spend.

Our comprehensive service means we can handle Federal, State, and Administrative courts across the country.

Advanced Docket Research



With over 230 million records, Docket Alarm's cloud-native docket research platform finds what other services can't. Coverage includes Federal, State, plus PTAB, TTAB, ITC and NLRB decisions, all in one place.

Identify arguments that have been successful in the past with full text, pinpoint searching. Link to case law cited within any court document via Fastcase.

Analytics At Your Fingertips



Learn what happened the last time a particular judge, opposing counsel or company faced cases similar to yours.

Advanced out-of-the-box PTAB and TTAB analytics are always at your fingertips.

API

Docket Alarm offers a powerful API (application programming interface) to developers that want to integrate case filings into their apps.

LAW FIRMS

Build custom dashboards for your attorneys and clients with live data direct from the court.

Automate many repetitive legal tasks like conflict checks, document management, and marketing.

FINANCIAL INSTITUTIONS

Litigation and bankruptcy checks for companies and debtors.

E-DISCOVERY AND LEGAL VENDORS

Sync your system to PACER to automate legal marketing.