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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 fluroethylene (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

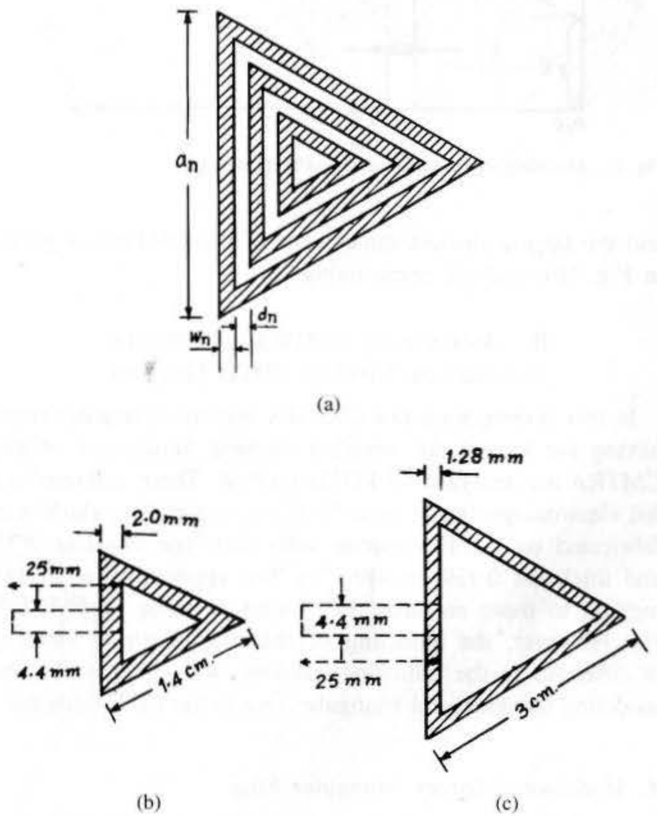

Fig. 1. Geometry of (a) three-element CMTRA, (b) STRA investigation of the smallest element dimensions, and (c) STRA investigation of the largest element dimensions.

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 nth 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

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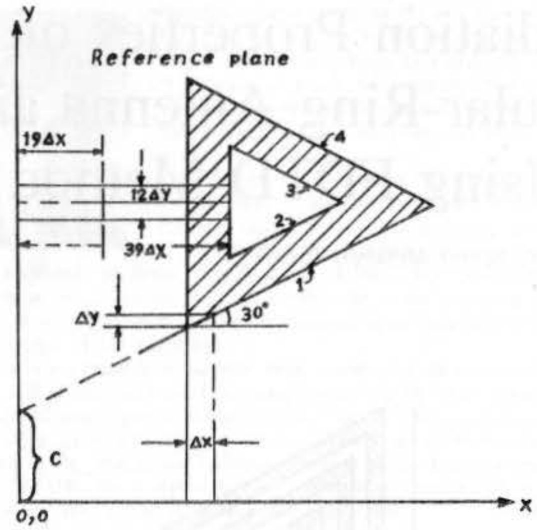

Fig. 2. Modeling of triangular ring in FDTD domain.

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 CMCRA [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

$$y = mx + C \cdots \tag{2}$$

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

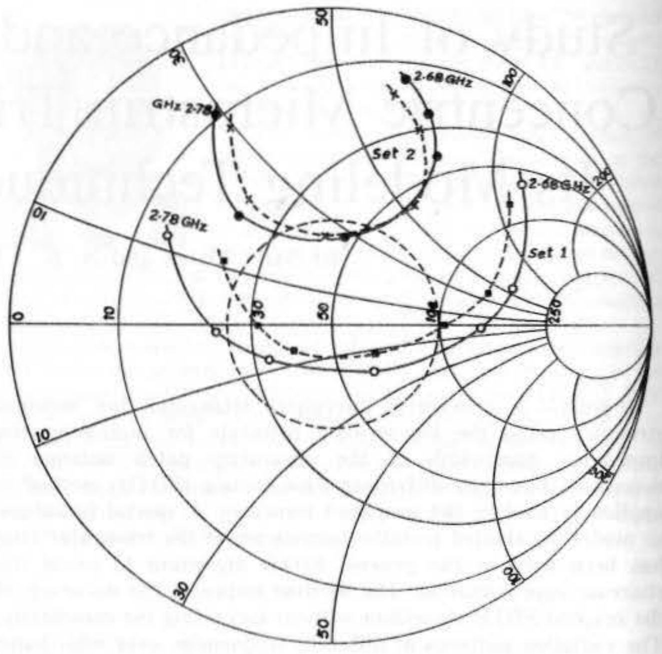

Fig. 3. Impedance plot of largest triangular ring of Fig. 1(c) at different feed location—set 1 for center feed, set 2 for 0.35 cm off-center feed.

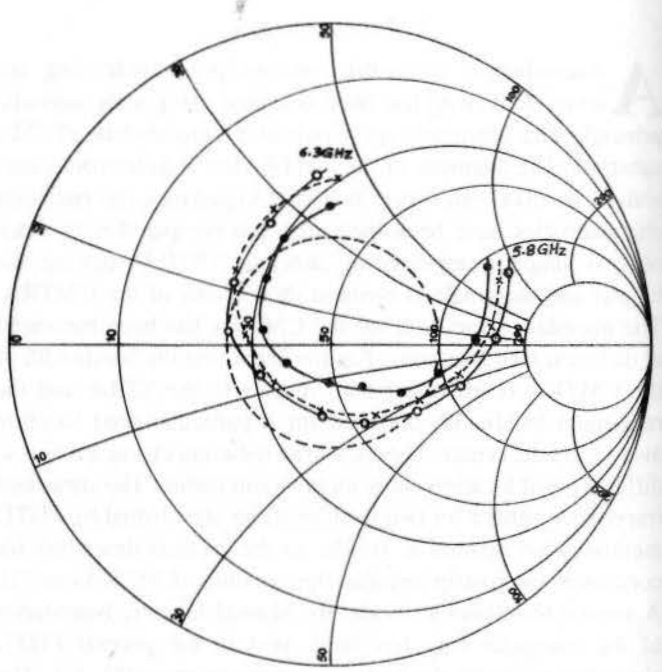

Fig. 4. Impedance plot of smallest triangular ring of Fig. 1(b) for center feed.

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 Guassian half-width $\tau = 18$ ps. The distance between the source plane to microstrip antenna was $39\Delta x$ and the reference

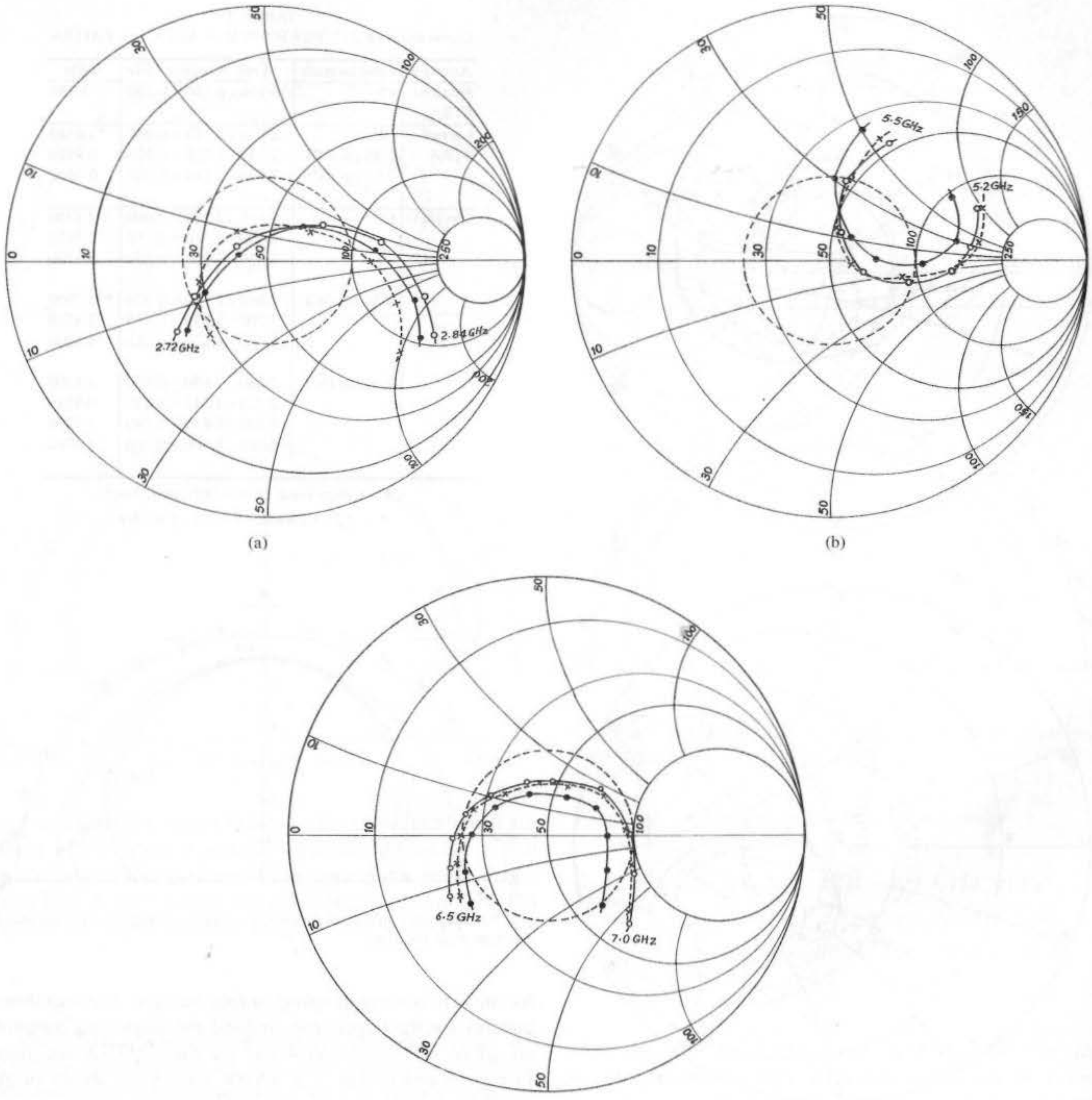

Fig. 5. (a) and (b) Impedance plot of three-element CMTRA at different frequency band for center feed. (c) Impedance plot of three-element CMTRA at different frequency band for center feed.

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, $\Delta y = 0.577\,35\Delta x = 0.577\,35$, $\Delta z = 0.5296$ 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, $\Delta y = 0.230\,94\Delta z = 0.5296$ 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-

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