A STUDY OF MICROSTRIP FEED DISCONTINUITY FOR OMNI-DIRECTIONAL LINEAR ARRAY ANTENNAS

(1)Amit Srivastava, (2)Dr. M Sachidananda ,
(1)*akshbti@yahoo.com,* (2) sachi@iitk.ac.in
Department of Electrical Engineering, Indian Institute of Technology,
Kanpur (U.P.) India – 208016

ABSTRACT

In this paper we present the characteristics of a feed discontinuity encountered in the design of a high gain omni-directional antenna array for WLAN applications. The main advantage in the microstrip realization is the flexibility available in terms of the control on the width of the ground plane as well as the microstrip line impedance. The analysis of the discontinuity is carried out using finite difference time domain (FDTD) formulation of the problem. A few discontinuities are fabricated in the duroid substrate and the scattering parameters are measured using a vector network analyzer. The theoretical FDTD results and measurements are compared.

INTRODUCTION

Fig. (1) shows the Omni-directional antennas using microstrip configuration. The working of the antenna is somewhat similar to the leaky wave antenna using a cable with inner and outer conductors flipped every half wavelength. In the microstrip equivalent shown, the microstrip line and the ground plane side are flipped every half wavelength. The radiation occurs at the discontinuities. The overall equivalent circuit is the discontinuity impedances interconnected by the transmission lines. In this paper we characterize this discontinuity impedance. The discontinuity impedance of a single as well as the mutual coupling between two discontinuities is studied. The finite difference time domain (FDTD) technique is used for theoretical evaluation and the results are verified by experimental evaluation using a vector network analyzer.

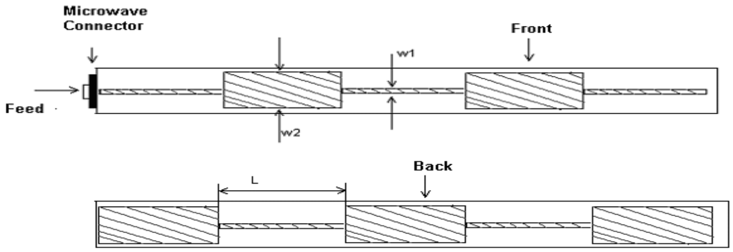


Fig.1. The microstrip omni-directional antenna configuration.

THEORY

The discontinuity encountered in the linear antenna array is characterized in terms of 2-port equivalent circuit parameters. The variation of the parameters is studied as a function of the ground plane width, substrate height and the discontinuity gap.

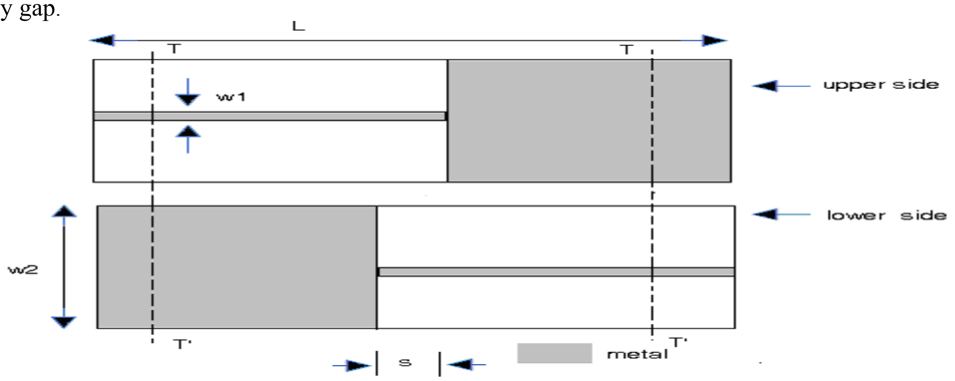


Fig. 2. A depiction of a single discontinuity.

The parameters of the structure (Fig. 2) are as follows: total length $L = 152$ mm, substrate thickness $h = 0.8$ mm, 1.6mm, width of metal strip $w1 = 2.4$ mm, dielectric constant $\varepsilon_r = 2.2$, thickness of metal strip $t = 0.0$, discontinuity gap = s, ground plane width = $w2$.

The 3D FDTD algorithm is applied to analyze the structure. The structure under study is enclosed by a PML on all the six sides. The PML is kept at a distance of half wavelength from the structure to simulate a free space condition. Non-uniform grid is used to take care of the sharp gradients in the field distribution. At discontinuities where the field gradient is expected to be sharper a finer grid is used. The size of total simulation volume is $148 \times 152 \times 81.59$ (mm^3) in *X, Y* and *Z* direction respectively. The size of the computational domain is $107\,\Delta x \times 85\,\Delta y \times 44\,\Delta z$. The simulation is performed in 7000 time steps allowing the input response to die down. A modulated Gaussian excitation is used as the incident pulse.

FABRICATION AND MEASUREMENTS

The accuracy of the computations is verified by measurements. Several discontinuities with different ground plane widths are fabricated, and the 2 port *S* parameters are measured using a vector network analyzer. The measured and theoretical results of one such discontinuity is shown in Fig. 3.

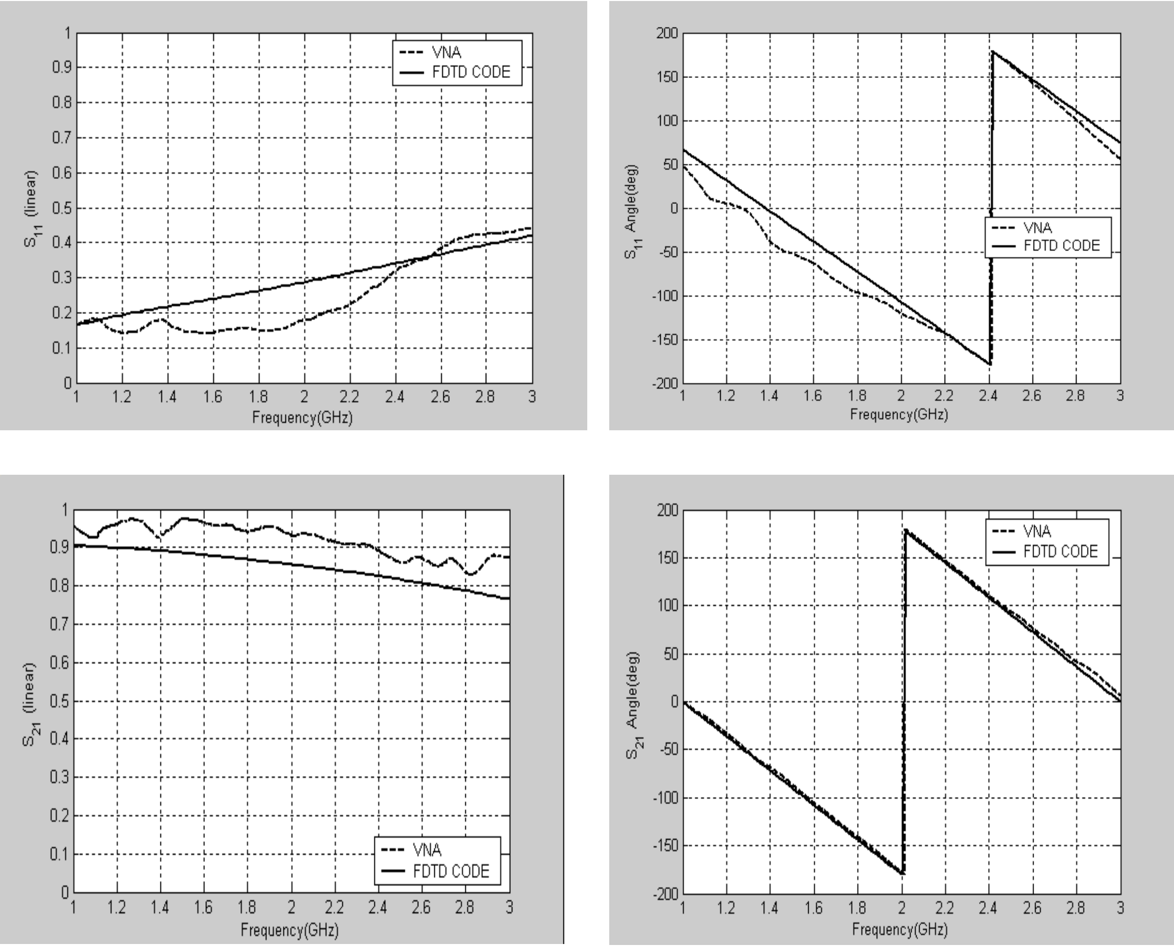


Fig. 3. S-Parameters of the discontinuity for a ground width = 20 mm.

Measured and simulation results show good agreement, within the limit of experimental error.

RESULTS

The discontinuity is characterized as a 2-port network with a T-equivalent as shown in Fig.4.

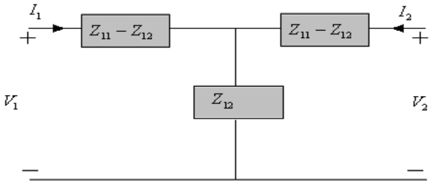


Fig. 4. T-equivalent of the single discontinuity.

Fig.5 shows the variation of Z_{12} verses ground width, w_2, with discontinuity gap *s* as a parameter element for 2.5 GHz, *h* = 0.8 mm and ε_r =2.2 and substrate thickness = 0.8 mm.

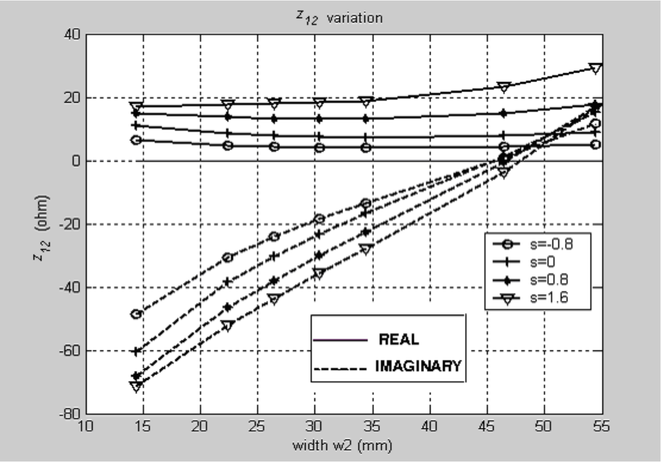


Fig. 5

Fig. 6 shows variation of $Z_{11}-Z_{12}$ (series element) verses ground width (w_2) with discontinuity gap *s* as a parameter for *f* = 2.5 GHz, *h* = 0.8 mm and ε_r = 2.2 and substrate thickness = 0.8 mm.

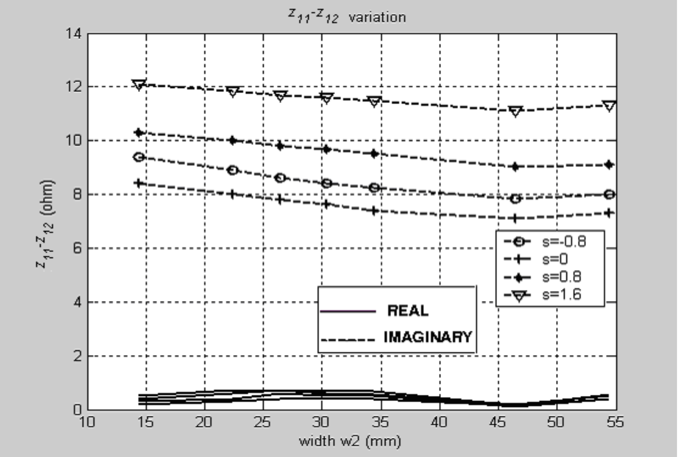
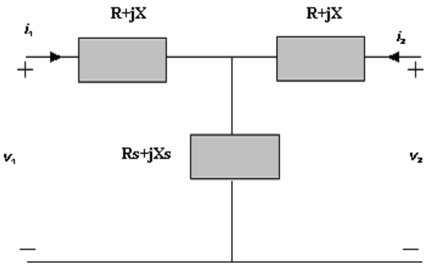


Fig. 6

The model, obtained using curve fitting procedure, representing the discontinuity is given below,



where,

$$R(w,s)=0$$

$$X(w,s) = (0.000099207s^2-0.00038909s +0.0008574)w^2+(-0.0054598s^2+0.030504s -0.092962)w +1.1469s^2+0.02225s +10.062;$$

$$Rs(w,s)= (0.00080378s^3-0.0010528s^2+0.0012956 s +.00761)w^2 +(-0.056533s^3+0.17307s^2-0.0397s -0.56297)w-2.4664s^2+6.2916s +17.491;$$

$$Xs(w,s)= (0.000096436s^3-0.00020435s^2-0.0000695s +0.00092448)w^3 +(-0.012574s^3+0.028579s^2+0.011879s -0.1103)w^2+(0.47542s^3-1.2648s^2-0.15565s +5.8242)w -4.401s^3+15.961s^2-12.252s -124.07;$$

w represents ground plane width in mm and *s* represent discontinuity gap in mm. The above equations are obtained, from curves of model parameters by curve fitting from the curves of ($Z_{11}-Z_{12}$) and Z_{12} , it can be seen that the discontinuity acts as a shunt element, like a slot and has a small inductance in series.

CONCLUSION

The FDTD method has been used to perform time domain simulations of the pulse propagation in the microstrip discontinuity. The discontinuity is characterized in terms of 2-port equivalent circuit parameters. The empirical formulas**,** for the parameters of the model have been derived as a function of ground plane width and discontinuity gap. These formulas can be used as a practical guide for designing the antenna array.

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