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Study of Microstrip Slotted Antenna for Bandwidth Enhancement

By Kapil Goswami
Singhania University, Jhunjhunu (Rajasthan)

Abstract - Two printed wide-slot antennas with E-shaped patches and slots, for broadband applications, are proposed. They are fed by a coplanar waveguide (CPW) and a microstrip line with almost the same performances. Detailed simulation and experimental investigations are conducted to understand their behavior and optimize for broadband operation. Good agreement between the measurement and simulation has been achieved. The impedance bandwidths, determined by 10-dB reflection coefficient, of the proposed slot antennas fed by microstrip line and CPW are examined from both measurement and simulation. We have obtained the large operating bandwidth by choosing suitable combinations of feed and slot shapes. In order to achieve wider operation bandwidth both of the designed antennas have round corners on the wide slot and patch. Meanwhile, the proposed antennas exhibit almost omnidirectional radiation patterns, relatively high gain, and low cross polarization. A comprehensive numerical sensitivity analysis has been done to understand the effects of various dimensional parameters and to optimize the performance of the designed antennas. Results for reflection coefficient, far-field E and H-plane radiation patterns, and gain of the designed antennas are presented and discussed. At the end, we compare the simulated and measured results and found the enhancement of bandwidth of E-shape microstrip antenna.

Indexterms : *Bandwidth, Directivity, Microstrip Antenna, Method of Moment (MOM).*

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STUDY OF MICROSTRIP SLOTTED ANTENNA FOR BANDWIDTH ENHANCEMENT

Strictly as per the compliance and regulations of:

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Kapil Goswami

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I. Introduction

Modern wireless systems are placing greater emphasis on antenna designs for future development in communication technology because of antenna being the key element in the whole communication system. The antenna in a system serves as the transducer between the controlled energy residing within the system and the radiated energy existing in free space. For the design of the antenna for next generation we are trying to reduce the size of antenna with enhanced bandwidth, so that we can use this type of antenna in any compact device like mobile phones, WLL and other devices. The microstrip antenna is very good for wireless communication due to it's light weight, low volume and low profile planer configuration which can be easily made conformal to host surface. Additionally, it has the low fabrication cost. It's supportive nature for both linear and circular polarization and low sensitivity to manufacturing tolerance makes this antenna very important for next generation. But major disadvantage of this type of antenna is that it has a very narrow bandwidth.

Antenna is one of the important elements in the RF system for receiving or transmitting the radio wave signals from and into the air as the medium. Without proper design of the antenna, the signal generated by the RF system will not be transmitted and no signal can be detected at the receiver. The development of MIC and HF semiconductor devices and printed circuits has drawn the maximum attention of the antenna community in recent years. In spite of its various attractive features like light weight, low cost, easy fabrication, conformability on curved surface etc, the microstrip element suffers from an inherent disadvantage of narrow impedance bandwidth and low gain. In principle, bandwidth enhancement can be achieved by several approaches [1].

In this paper, we remove such type of disadvantage of simple microstrip antenna by designing the E- Shape Microstrip antenna. The coaxial feed technique is used for the analysis of this antenna because it occupies less space and has low spurious radiations by using Teflon connector. The Method of Moment (MOM) [2] is used to discuss the electromagnetic radiation characteristics of the microstrip antenna.

II. Theoretical Background Of Microstrip Patch Antenna

E-shape microstrip patch antenna can be designed by using a cavity model [3] suitable for moderate bandwidth antennas. The lowest order mode, TM_{10}, resonates when effective length across a patch is half of wavelength. Radiations occur due to fringing field. A brief description of resonant frequency and cavity model is given as follows;

a) Designing equations

Because of the fringing effects, electrically the patch of the antenna looks larger than its physical dimensions. The enlargement on L (Patch length) is given by:

Author : Research Scholar, Singhania University, Jhunjhunu (Rajasthan). E-mail : kapilgswami@yahoo.com

$$\Delta L = 0.412h(\varepsilon_{reff}+0.3)(Wh^{-1}+0.264)/[(\varepsilon_{reff}-0.258)(Wh^{-1}+0.8)] \quad (1)$$

Where h is the height and W is the width of patch.

Where the effective (relative) permittivity(ε_{reff}) is:

$$\varepsilon_{reff} = \frac{\varepsilon_e+1}{2} + \frac{\varepsilon_r-1}{2\sqrt{1+12hW^{-1}}} \quad (2)$$

This is related to the ratio of h/W. The larger the h/W, the smaller the effective permittivity .
The effective length of the patch is given by:

$$L_{eff} = L + 2\Delta L \quad (3)$$

The resonant frequency for the TM_{100} mode is:

$$f_r = \frac{1}{2L_{eff}\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} = \frac{1}{2(L+2\Delta L)\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} \quad (4)$$

An optimized width for an efficient radiator is:

$$W = \frac{1}{2f_r\sqrt{\mu_0\varepsilon_0}}\sqrt{\frac{2}{\varepsilon_r+1}} \quad (5)$$

The length L for the antenna is:

$$L = \frac{1}{2f_r\sqrt{\varepsilon_{reff}}\sqrt{\varepsilon_0\mu_0}} - 2\Delta L \quad (6)$$

b) Cavity model

Transmission line model ignores field variations along the radiating edges. This disadvantage can be overcome by using cavity model in which interior region of dielectric substrate is modeled as cavity bounded by electric walls on the top and bottom. The basis for the assumption is the following observations for thin substrate ($h \ll \lambda$). Since the substrate is thin; the field in interior region does not vary much in Z direction that is normal to the path.

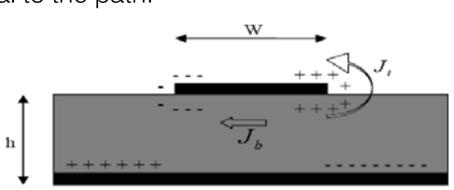

Figure 1 : Charge distribution and current density creation on the patch.

Consider Fig 1, When the microstrip patch is provided power, a charge distribution is seen on the upper and lower surfaces of the patch and at the bottom of the ground plane. This charge distribution is controlled by two mechanisms, an attractive mechanism and a repulsive mechanism. The attractive mechanism applies between the opposite charges on the bottom side of the patch and the ground plane, which helps in keeping the charge concentration intact at the bottom of the patch. The repulsive mechanism holds between the like charges on the bottom surface of the patch, which causes pushing of some charges from the bottom, to the top of the patch. As a result of this charge movement, currents flow at the top and bottom surface of the patch. The cavity model assumes that the height to width ratio (i.e. height of substrate and width of the patch) is very small and as a result of this the attractive mechanism dominates and causes most of the charge concentration and the current to be below the patch surface. Much less current would flow on the top surface of the patch and as the height to width ratio further decreases, the current on the top surface of the patch would be almost equal to zero, which would not allow the creation of any tangential magnetic field components to the patch edges. Hence, the four sidewalls could be modeled as perfectly magnetic conducting surfaces.

III. Design Parameters Of Proposed Antenna

Consider a Microstrip E-SHAPE ANTENNA shown in Fig-2 and Fig-3:

Using above equations(1-6) the dimensions of the proposed antenna is summarized below:

Parameters	Dimensions
Resonant frequency(f_r)	2.5 GHz
Dielectric constant (ε_r)	4.2
Substrate thickness (h)	1.6 mm
Width of patch (W)	37.21 mm
Width between two slots (W_1)	7.44 mm
Slot width (W_s)	7.44 mm
Length of patch (L)	28.89 mm
L_1	14.445 mm
Slot length (L_s)	14.445 mm

Table 1 : Proposed antenna parameter

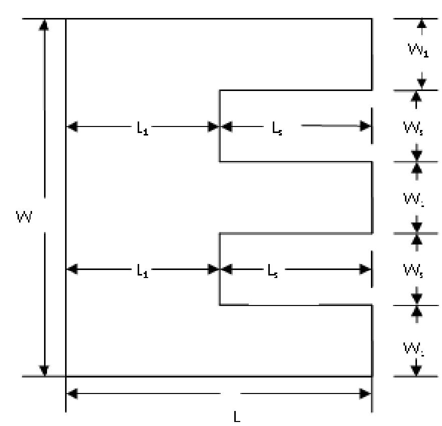

Figure 2 : Geometry of proposed E-shape antenna

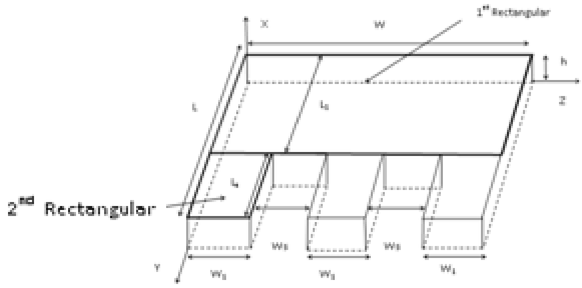

Figure 3 : E-shape microstrip antenna

IV. Result Analysis by Simulation and Discussion

All the antenna parameters are firstly calculated and plotted by using MATLAB coding and then simulated by IE3D based on Method of Moment. By using MATLAB [4], we find the values of return loss and VSWR on feeding points (27, 2.5) and also simulate the proposed antenna with IE3D [5]. Finally we compare output of simulated and theoretical results with the support of various graphs and charts given below. The probe feed antenna is shown in Figure 3. The E-shaped antenna is formed by inserting the coordinate. The coordinate of the antenna for the analysis is found out by using the total length and width of E-shape antenna. The probe feed is inserted in such a way so that maximum -10 dB bandwidth obtained. The probe is feed at point (27, 2.5) as shown in Fig 4.

E-SHAPE Microstrip Patch Antenna with feed point (27, 2.5) :

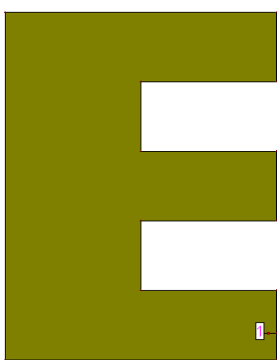

Figure 4 : Antenna shape with feed point

a) *Theoretical analysis using MATLAB based on cavity model*

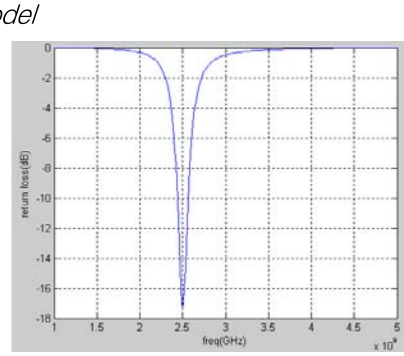

Figure 5 : Return loss of E-shape microstrip antenna

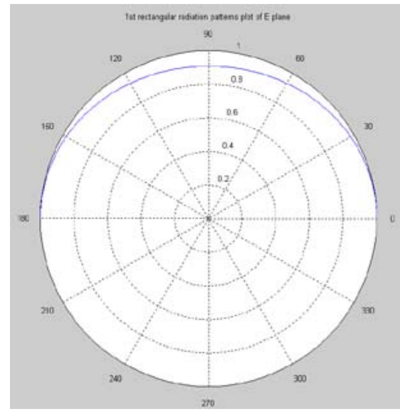

Figure 6 : Radiation pattern of 1st rectangle E-plane

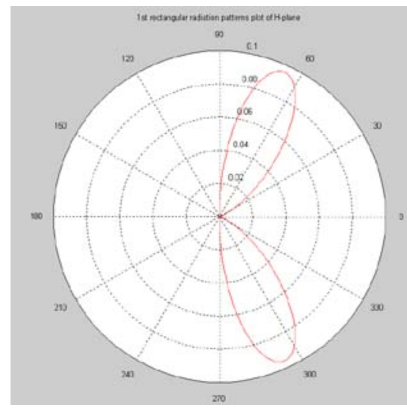

Figure 7 : Radiation pattern of 1st rectangle H-plane

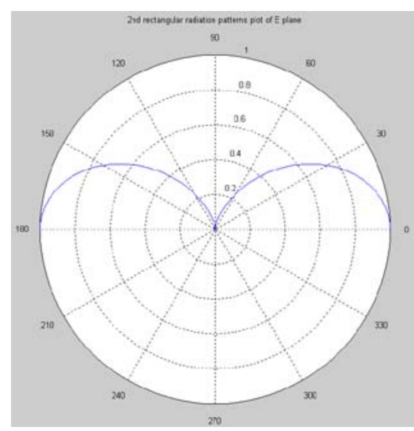

Figure 8 : Radiation pattern of 2nd rectangle E-plane

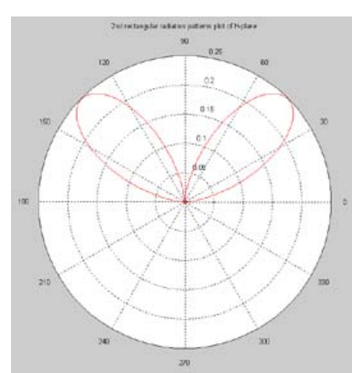

Figure 9 : Radiation pattern of 2nd rectangle H-plane

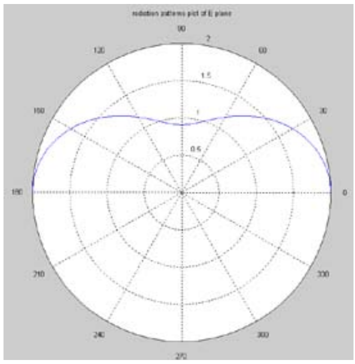

Figure 10 : Radiation pattern of E-shape microstrip antenna (E-plane)

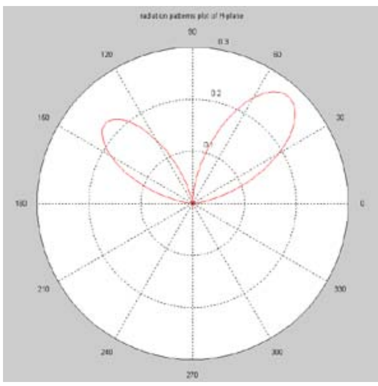

Figure 11 : Radiation pattern of E-shape microstrip antenna (H-plane)

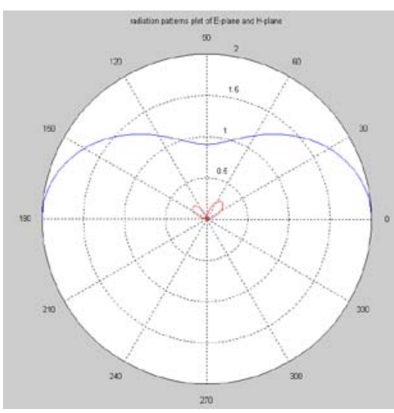

Figure 12 : Radiation pattern of E-shape microstrip antenna (E-plane & H-plane)

b) Simulated result by IE3D based on MOM Method

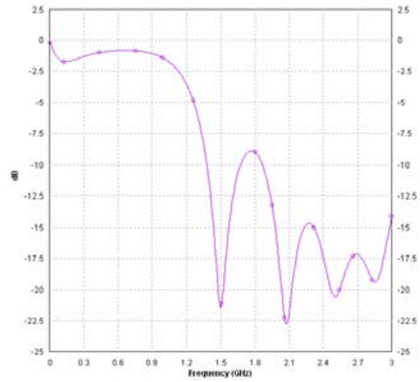

Figure 13 : Return loss versus frequency

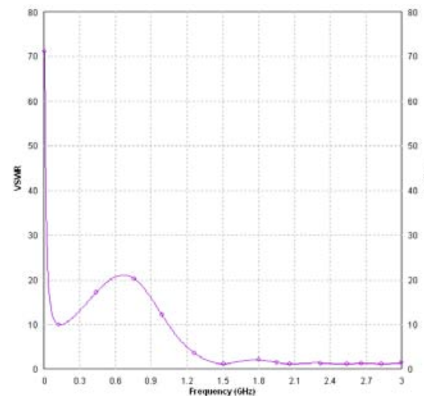

Figure14 : VSWR versus frequency

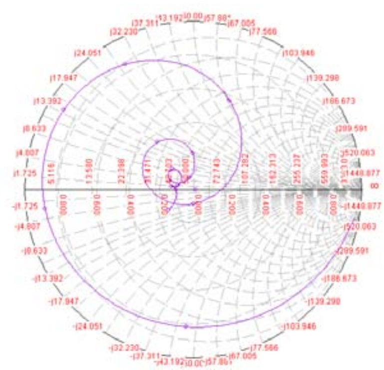

Figure 15 : Input impedance(Smith Chart) loci

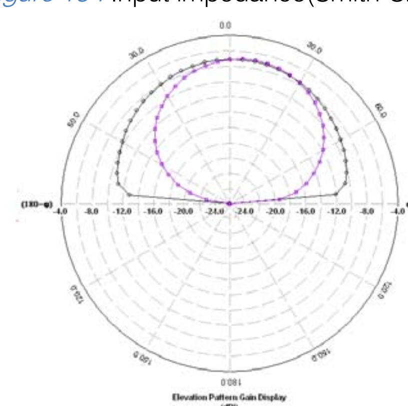

Figure 16 : Radiation pattern of E-shape microstrip antenna

V. Discussion

On measurement, the proposed microstrip antenna (Fig-3) resonates at 2.46 GHz with return loss -13.5 dB and 2.886 GHz with return loss -14.7 dB(Fig-17). The measured -10 dB return loss bandwidth of antenna is 90 MHz or about 3.65% with respect to centre frequency 2.463 GHz. While on simulation, antenna resonates at 2.082 GHz with return loss -22.77 dB, 2.514 GHz with return loss -20.54 dB and 2.874 GHz with return loss -19.27 dB(Fig-13).The obtained impedance bandwidth also covers the frequency band of wireless systems.

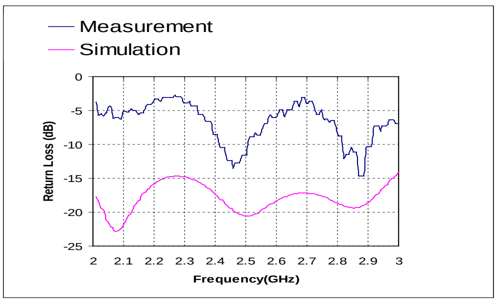

Figure 17 : Simulated and measured return loss versus frequency

Through simulated and measurement analysis (figure 2- 9), we observe that the bandwidth increases when resonance frequency is greater than working frequency.

VI. Conclusion

Based on the theoretical, simulated and analysis of the E-shape microstrip antenna, we have discussed the size and design parameters. Then we simulated the antennas that can run at 2.5 GHz frequency and calculated its return loss by using IE3D based on Method of Moment and spectrum analyzer. Through theoretical, simulated and measured analysis, we find the bandwidth increases when resonance frequency is greater than the working frequency in microstrip antenna and the E type shape of this antenna is very helpful for the enhancement of bandwidth.

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