WIDEBAND MICROSTRIP ANTENNA USING HOOK-SHAPED FEED

**B. Lethakumary, Sreedevi K. Menon, Priya Francis,
C. K. Aanandan, K. Vasudevan, and P. Mohanan**
Centre for Research in Electromagnetics and Antennas
Department of Electronics
Cochin University of Science and Technology
Cochin 682 022, India

ABSTRACT: *In this paper, we introduce a novel feeding technique for
bandwidth enhancement of a rectangular microstrip antenna. This an-
tenna offers an impedance bandwidth of 22% without degrading the effi-
ciency. The effect of the feed parameters upon patch characteristics
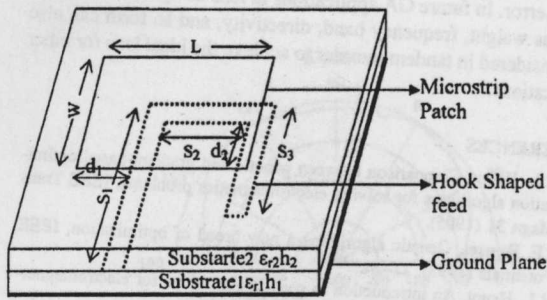such as resonant frequency, impedance bandwidth, and radiation pattern*

Figure 1 Geometry of the microstrip hook-excited microstrip antenna

TABLE 1 Variation of Impedance Bandwidth with Feed-Segment Length and Hook-Arm Length

Feed Length (S_1) [cm]	Feed-Segment Length (S_2) [cm]	Hook-Arm Length (S_3) [cm]	%Bandwidth (experiment)	%Bandwidth (IE3D)
6	4.0	2.5	18.9	15.0
	3.5	3.0	21.99	16.12
	3.0	2.5	18.5	12.3
	2.5	3.0	15.0	12.0
	2.0	3.5	12.33	9.08
	1.5	3.5	12.3	12.12
	1.0	3.5	11.2	9.5

are studied in detail. The experimental results are verified using the FDTD results. © 2004 Wiley Periodicals, Inc. Microwave Opt Technol Lett 44: 169–171, 2005; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.20578

Key words: *rectangular-microstrip antenna; impedance bandwidth; hook-shaped feed; electromagnetic coupling; FDTD*

1. INTRODUCTION

Much intensive research has been done in past years to develop enhancement techniques for broadband microstrip antennas. Several bandwidth-enhancement techniques are found in literature. Some of these techniques include the use of thick substrates with a low dielectric constant [1], and stacked or co-planar parasitic patches [2]. The use of thick substrates introduces a large inductance due to the increased length of the probe. Stacked patch geometry increases the complexity. The addition of a U-shaped slot and use of the L-probe [3, 4] are some other methods introduced for wide bandwidth. However, these techniques will increase the volume of the antenna substantially. L-strip and T-strip feeds for bandwidth enhancement of rectangular patches have been reported recently [5, 6]. In this paper, we introduce a hook-shaped microstrip feed to excite a rectangular microstrip-patch antenna. This antenna has an impedance bandwidth of 22%.

2. ANTENNA GEOMETRY

A rectangular-patch antenna of dimensions $L \times W$ is fabricated on a substrate with dielectric constant $\varepsilon_{r2} = 4.28$ and thickness $h_2 = 0.16$ cm. The antenna is fed by electromagnetic coupling, using a hook-shaped microstrip feed, and fabricated on another substrate with the same dielectric constant and thickness. The antenna geometry is illustrated in Figure 1.

3. RESULTS AND DISCUSSIONS

The variation of the return loss of the antenna is studied for different feed-segment lengths and hook-arm lengths for a particular feed length. The parameters of the hook-shaped feed are optimized for maximum bandwidth. With this feeding technique, a rectangular patch of dimensions $L = 4$ cm and $W = 2$ cm has a 2:1 VSWR bandwidth of 22%. The hook-arm length S_3 is varied from 0.5 to 4 cm for the variation of the feed-segment length S_2 from 1 to 4 cm for a fixed feed-length S_1. The variation in percentage bandwidth for different S_2 and S_3, keeping S_1 constant, are shown in Table 1. For each S_1 and S_2 combination, S_3 is varied from 0.5 to 4 cm in order to optimize the maximum impedance bandwidth. From the table, it is found that the maximum bandwidth is obtained when $S_2 = 3.5$ cm and $S_3 = 3$ cm. The optimum impedance bandwidth is obtained when $S_1 = 6$ cm, $S_2 = 3.5$ cm, $S_3 = 3$ cm, and with $d_1 = 0.5$ cm and $d_2 = 1.7$ cm. The

typical return loss at the optimum position of the antenna is shown in Figure 2.

The experimentally optimized antenna is analyzed theoretically using FDTD. For theoretical analysis, a Gaussian pulse is used as the source to excite the antenna [7]. The half-width of the pulse and the time delay t_0 is kept as 15 ps and 3 T, respectively, in order to suit the frequency band of interest. The entire computational volume is descretized into small cells of dimensions $\Delta x = 1$ mm, $\Delta y = 1$ mm, and $\Delta z = 0.4$ mm in the x, y, and z directions, respectively, in order to fit the structure exactly. To ensure Courant stability criteria, the time step is taken as 1.159 ps. An external source impedance of 50Ω is used for fast convergence [8].

The return loss and the radiation patterns of the antenna at the optimum position are calculated numerically. The theoretical and experimental variation of the return loss with frequency is shown in Figure 2. The theoretical operating band of the antenna is 3 to 3.558 GHz, while the experimental operating band is 3 to 3.7 GHz.

To analyze the radiation characteristics, the antenna is excited with a sinusoid at the theoretical resonant frequency. The iteration is carried out until the sinusoid reaches steady state. The tangential E-fields are sampled from an aperture area just above the patch surface. The far-field patterns corresponding to that frequency are calculated by taking the Fourier transform of the aperture fields sampled over one period.

Figure 3 shows the theoretical and experimental E-plane and H-plane patterns of the antenna. The cross polarization level is
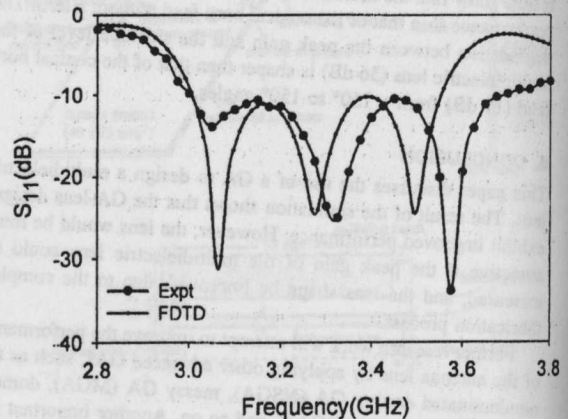

Figure 2 Variation of S_{11} with antenna frequency ($L = 4$ cm, $W = 2$ cm, $h_1 = h_2 = 0.16$ cm, $\varepsilon_{r1} = \varepsilon_{r2} = 4.28$, $S_1 = 6$ cm, $S_2 = 3.5$ cm, $S_3 = 3$ cm, $d_1 = 0.5$ cm, $d_2 = 1.7$ cm)
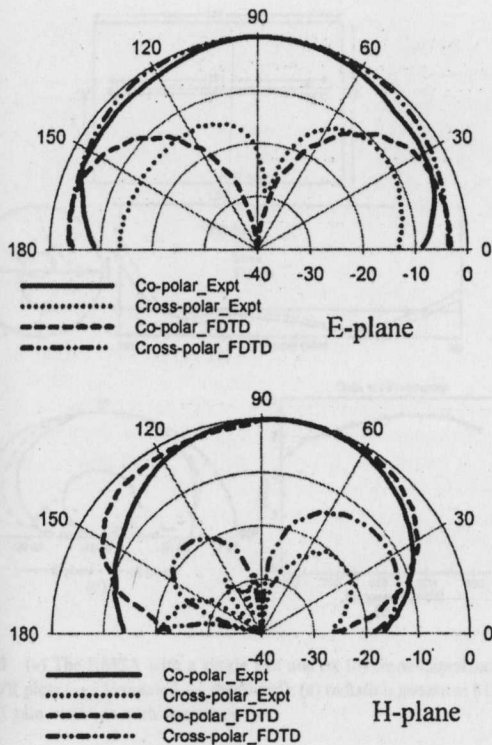
E-plane

H-plane

Figure 3 Radiation patterns of the antenna with the optimum feed parameters at the resonant frequency ($h_1 = h_2 = 0.16$ cm, $\varepsilon_{r1} = \varepsilon_{r2} = 4.28$, $L = 4$ cm, $W = 2$ cm, $S_1 = 6$ cm, $S_2 = 3.5$ cm, $S_3 = 3$ cm, $d_1 = 0.5$ cm, $d_2 = 1.7$ cm)

found to be -35 dB in the principal planes in both theory and the experiment. The half-power beam widths in the E-plane and H-plane are given in Table 2.

The gain of the antenna is compared with that of a standard circular patch resonating at the same resonant frequency of the antenna. The gain variation of the antenna with that of a standard circular patch is shown in Figure 4.

4. CONCLUSION

The effect of a hook-shaped microstripline feed on the characteristics of a circular microstrip antenna has been studied. It was observed that the hook-shaped feed enhances the bandwidth of the antenna by 22% without significantly deteriorating the volume and gain of the antenna. The antenna is analyzed numerically using the FDTD technique and excellent agreement with the experiment results is obtained. This feeding technique is a simple and effective method for improving the bandwidth, as compared to other methods. This antenna may find applications in high-speed personal communication systems, where large bandwidth is required.

TABLE 2 Comparison of the Antenna Radiation Characteristics

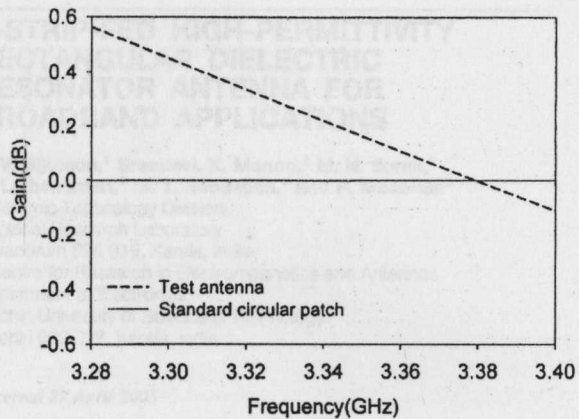| Half-Power Beamwidth		
	E-plane	H-plane
Experiment	100°	82°
Theory (FDTD)	132°	100°

Figure 4 Relative gain of the antenna with reference to the standard circular patch antenna

REFERENCES

1. W. Chenand and K.F. Lee, Input impedance of coaxially fed rectangular microstrip antenna on electrically thick substrate, Microwave Opt Technol Lett 6 (1993), 387–390.
2. R.Q. Lee, K.F. Lee, and J. Bobinchak, Characteristics of a two-layer electromagnetically coupled rectangular patch antenna, Electron Lett 23 (1987), 1070–1072.
3. T. Huynh and K.F. Lee, Single-layer single-patch wideband microstrip antenna, Electron Lett 31 (1995), 1310–1312.
4. C.L. Mak, K.M. Luk, K.F. Lee, and Y.L. Chow, Experimental study of a microstrip patch antenna with an L-shaped probe, IEEE Trans Antennas Propagat AP-48 (2000), 777–782.
5. B. Lethakumary, S.K. Menon, C.K. Anandan, K. Vasudevan, and P. Mohanan, L-strip excited wideband rectangular microstrip antenna, Microwave Opt Technol Lett 42 (2004), 173–175.
6. S.K. Menon, B. Lethakumary, K. Vasudevan, and P. Mohanan, Wideband rectangular microstrip antenna using symmetric T-shaped feed, Microwave Opt Technol Lett 35 (2002), 235–236.
7. D.M. Sheen, S.M. Ali, M.D. Abouazhra, and J.A. Kong, Application of the three-dimensional finite-difference time-domain method to the analysis of planar microstrip circuits, IEEE Trans Microwave Theory Tech MTT-38 (1990), 849–857.
8. R.J. Lubbers and H.S. Langdon, A simple feed model that reduces time steps needed for FDTD antenna and microstrip calculations, IEEE Trans Antennas Propagat 44 (1996), 1000–1005.
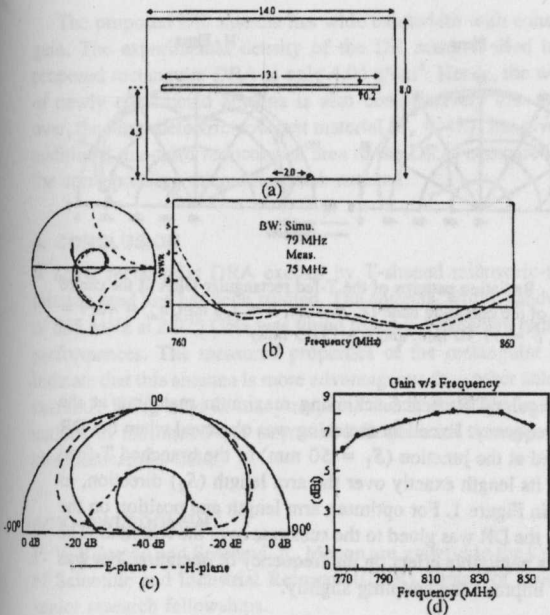
Figure 6 (a) The RMSA with a single slot and its (b) input-impedance and VSWR plots (- - - simulated, —— measured); (c) radiation pattern at 815 MHz; (d) gain variation with frequency

in Figure 6(d). The reduced gain, as compared to its dual-slot counterpart, is due to the reduced width.

5. CONCLUSION

A broadband RMSA with a pair of rectangular slots has been proposed. Its BW is further increased either by increasing the number of pairs of slots or by using a pair of bow-tie slots. The even-mode-equivalent RMSA with a pair of slots, which is a compact RMSA with a single slot, exhibits broader BW with half the patch size.

REFERENCES

1. G. Kumar and K.P. Ray, Broadband microstrip antennas, Artech House, Boston, 2003.
2. T. Huynh and K.F. Lee, Single layer single patch wideband microstrip antenna, Electron Lett 31 (1995), 1310–1312.
3. K.L. Wong, Compact and broadband microstrip antennas, Wiley, New York, 2002.
4. IE3D 7.1, Zeland Software Inc., Fremont, CA, 2000.
5. Ensemble 6.1, Ansoft Software Inc., USA.