BOW-TIE MICROSTRIP ANTENNA DESIGN

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ABSTRACT

In this paper, the bow-tie microstrip antennas have been designed with two different angles of 40° and 80°. An investigation on the effect of the angle to the return loss and radiation patterns had been carried out. The impedance matching network with the microstrip transmission line feeding was used in this study. Simulation and measurement results for the return loss and radiation patterns were presented.

I. INTRODUCTION

In recent years, microstrip antennas have been widely used in both theoretical research and engineering applications due to their light weight and thin profile configurations, low cost of fabrication, reliability, conformal structure and ease of fabrication.

The bow-tie microstrip antennas have been designed for wireless LAN application, where the operating frequency is at 2.4 GHz. The bow-tie patch actually is the combination of imaginary image of two triangular patches which are fabricated in a single substrate. Figure 1 shows the bow-tie strip of a bow-tie microstrip antenna. Bow-tie microstrip antennas have become attractive candidates in the present day communication scenario due to their compact nature compared to rectangular patches. The ever increasing demand for compact wireless communication equipment explicitly necessitates research in compact antenna options and which sparked interests of many researchers world wide in the field of bow-tie microstrip antennas.

However in the literature, only very few attempts have been made towards the analysis of this type antenna. The bow-tie patch microstrip antenna as a compact one, and suggested an empirical formula for the resonant frequency of this new geodesy. The past research work on bow-tie antenna can be seen in [1-6]

II. DESIGN CONSIDERATION OF BOW TIE ANTENNA

Figure 1 shows the dimension of a bow-tie microstrip antenna, where a is the side length of the bow-tie strip, θ is the angle of equilateral triangular, L_1, L_2, W_1, and W_2 are the dimensions of the matching network. Resonant frequency corresponding to the various modes described by [7]:

$$f_r = \frac{ck_{mn}}{2\pi\sqrt{\varepsilon_r}} \qquad (1)$$

$$f_r = \frac{2c\sqrt{m^2 + mn + n^2}}{3a\sqrt{\varepsilon_r}} \qquad (2)$$

where

f_r is the resonance frequency

k_{mn} is the resonating modes

m and n are nombor of modes

c is the velocity of light in free space.

a is the side length of the bow tie strip

The above expression is valid when the triangular resonator is surrounded by a perfect magnetic wall. The effect of a non perfect magnetic wall on the resonant frequency can be included in an empirical fashion for easy calculation.

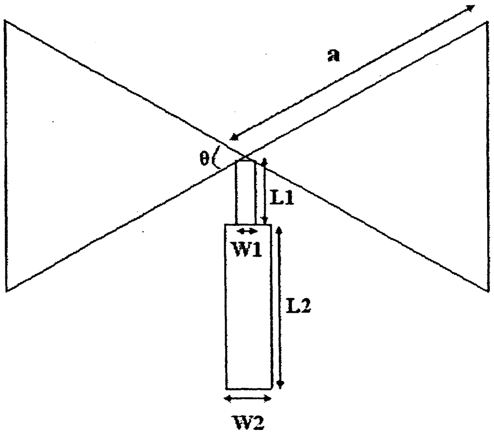


Figure 1 Dimension of Bow Tie Microstrip Antenna

A number of suggestions have been made with regard to how to modify [8] to yield an accurate expression for a triangular microstrip patch antenna that is not enclosed by a perfect magnetic wall. Most of the suggestions are about replacing the side length a by an effective value a_{eff} and leaving the substrate dielectric constant unchanged. The other set of suggestions proposes replacing both a and ε_r with their effective values. An expression for a_{eff} has been arrived at by curve fitting the experimental and theoretical results for the resonant frequency for TM_{10} mode. It is given by

Resonant frequency dominant mode is:

$$f_{10} = \frac{2c}{2f_r\sqrt{\varepsilon_r}} \qquad (3)$$

Side length:

$$a = \frac{2c}{2f_r\sqrt{\varepsilon_r}} \qquad (4)$$

Effective value of side length:

$$a_{eff} = a + \frac{h}{\sqrt{\varepsilon_r}} \qquad (5)$$

Effective dielectric constant:

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{4\sqrt{1 + \frac{12h}{a}}} \qquad (6)$$

Accuracy of this empirical expression is claimed to be within 1 % when compared with the value obtained from the moment method analysis. Knowing f_{10} from above, the resonant frequency for higher order modes is calculated from (1), that is

Resonant frequency for mn mode:

$$f_{mn} = f_{10}\sqrt{m^2 + mn + n^2} \qquad (7)$$

Wavelength in free space:

$$\lambda_o = \frac{c}{f} \qquad (8)$$

Wavelength of the antenna:

$$\lambda_g = \frac{\lambda_o}{\sqrt{\varepsilon_{eff}}} \qquad (9)$$

$$L_1 = d\lambda_g \qquad (10)$$

Where d is the value of "wavelength towards load" in the Smith chart

$$L_2 = \frac{\lambda_g}{4} \qquad (11)$$

$$\frac{W}{d} = \frac{8e^A}{e^{2A} - 2}, \qquad \text{for } \frac{W}{d} < 2 \qquad (12)$$

$$\frac{W}{d} = \frac{2}{\pi}\left[B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left\{\ln(B-1) + 0.39 - \frac{0.61}{\varepsilon_r}\right\}\right]$$
$$\text{for } \frac{W}{d} > 2 \qquad (13)$$

Where $A = \frac{Z_o}{60}\sqrt{\frac{\varepsilon_r + 1}{2}} + \frac{\varepsilon_r - 1}{\varepsilon_r + 1}(0.23 + \frac{0.11}{\varepsilon_r})$

$$B = \frac{377\pi}{2Z_o\sqrt{\varepsilon_r}}$$

III. SIMULATION AND EXPERIMENTAL RESULT

(A) Return Loss Result

The input return loss is shown in figure 2 and 3 with different value of angle (θ). Figure 2 shows the simulation result for angle θ = 40° with a return loss of -23.6dB at the operating frequency of 2.4 GHz, while the measurement return loss is -

27.71dB at 2.48GHz.The BW from the measurement and simulation result is nearly 3%.

Figure 3 shows -19.91 dB return loss from simulation at operating frequency of 2.42GHz, while the measurement return loss is -28.92dB at 2.48GHz. The angle is at θ = 80°. In considering that all the simulation and measurement return loss for both antenna having the return of lower than -20dB, therefore the incoming signal is strong enough to be received at the receiver.
The shifting of the frequency is due to the substrate of FR4 which has dielectric constant between 4.0 and 4.7. In this design the dielectric constant is 4.7. The shifting of the frequency is also from the fabrication process of the hardware

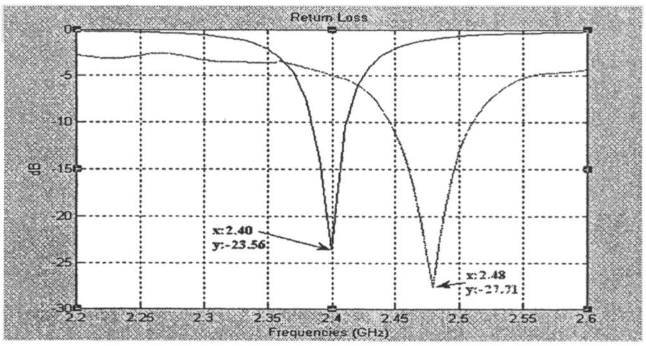


Figure 2 **Simulation and measurement return loss of the antenna with θ = 40°**

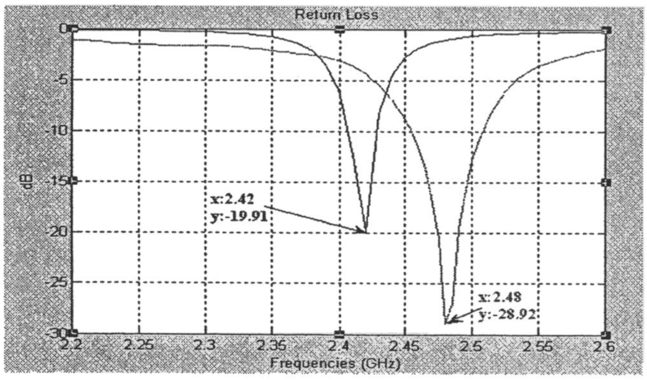
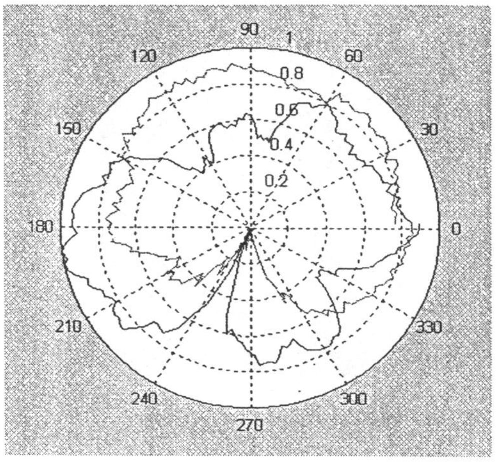


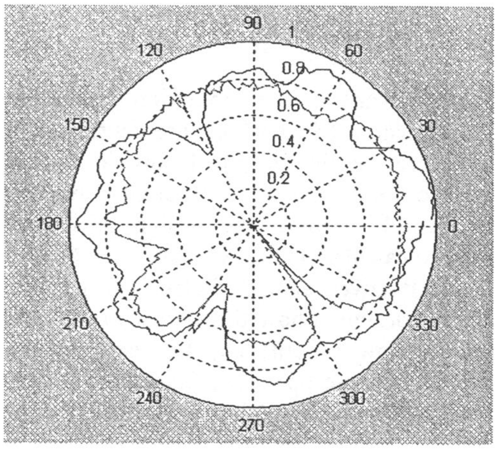
Figure 3 **Simulation and measurement return loss of the antenna with θ = 80°**

(B) Radiation pattern characteristic

Figure 4 and 5 show the radiation pattern for two different angle for E and H Plane. The cross-polar isolation radiation pattern for θ = 40° is nearly 20 dB for E Plane while for the H Plane has a very low cross polarization isolation. The beamwidth is 70 ° to 80°. The result for θ = 80° is slightly different in term of the radiation pattern. It has a narrow bandwidth compared with aan angle θ = 40°. The cross polar isolation for both plane has a higher value than when θ = 40°. The plotting in red colour is a co polarization while in blue colour is a cross polarization.

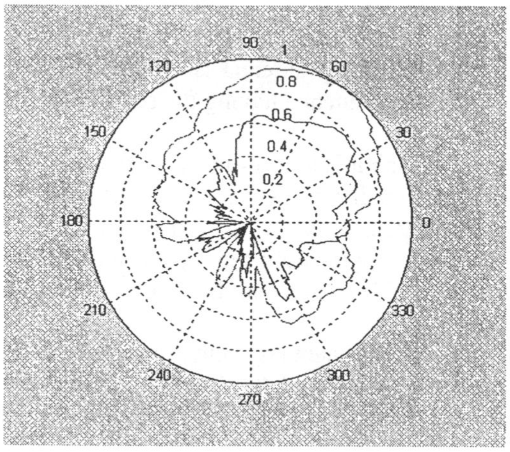


(a) E Plane

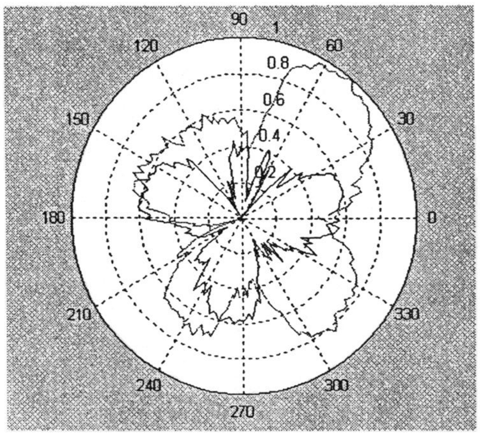


(b) H Plane

Figure 4 **Radiation patterns of the antenna with θ = 40°**



(a) E Plane



(b) H Plane

Figure 5 Radiation patterns of the antenna with θ= 80°

IV. DISCUSSION

The bow-tie patch antenna is a combination of imaginary image of two triangular patches which are fabricated in a single substrate. Therefore, the design of bow-tie microstrip antenna is based on the design of triangular microstrip antenna. Those formula used in the design of triangular microstrip antenna to calculate the side length, effective value of side length and effective value of dielectric constant, are also applicable in the design of bow-tie microstrip antenna.

For the design of bow-tie antenna, the side length is calculated and fix at a certain operating frequency. While the length is depends on the angle of the equilateral triangular, where the angle, θ is not less than 0° and not bigger than 180°. Therefore, the bow-tie microstrip antenna can be design at any degree of θ.

There is an impedance matching network with the microstrip transmission line feeding which are fabricated simultaneously with the antenna structure. The impedance matching network is the most important part in the design of a microstrip antenna in order to minimize the return loss. The acceptable return loss for a microstrip antenna is -10dB or below. It is better if the microstrip antenna having the return loss of lower than -20dB.

By comparing the simulation results and the measurement results, we can notice that the return loss of the antennas with same angle is different. It is may be caused by these factors, they are: inaccurate in preparing the layout, impurities of the equipment used for fabrication and the quality of the substrate and connector.

The bow-tie microstrip antennas which have been fabricated are with the angle of 40° and 80°.The simulation results of these designed antennas having the return loss of -23.6dB and -19.9dB respectively. While for the fabricated antennas with the angle of 40° and 80°, the return losses are -27.71dB and -28.91dB respectively.

V. CONCLUSION

The BW from the measurement and simulation result is nearly 3% with a return loss more than 20 dB. The angle of the bow-tie microstrip antennas does not affect its return loss. As long as the design of the matching network is correct, the desired return loss can be obtained. The radiation pattern for higher value of angle (θ) give a radiation pattern more directional with a HPBW of 40 ° to 50° for E plane and 20 ° to 30° for H plane.

REFERENCES

[1] Yu-De Lin and Syh-Nan Tsai, "*Coplanar waveguide-fed uniplanar bow-tie antenna,*" *IEEE Trans. On Antennas and Propagation*, vol. 45, Issue 2, pp. 305-306, Feb. 1997.

[2] Yu-De Lin and Syh-Nan Tsai, "*Analysis and design of broadside-coupled striplines fed bow-tie antennas,*" *IEEE Trans. On Antennas and Propagation*, Vol. 46, Issue 3, pp. 459-460. March 1998.

[3] K. Iwami, T. Ono, E. Oesterschulze and M. Esashi, "*Electrostatic actuator integrated optical near field probe with bow-tie antenna for high transmission efficiency,*" *12th International Conference on Actuators and Microsystem*, Vol 1, pp. 548-551, 8-12 June 2003.

[4] A. A. Lestari, A. G. Yarovoy and L.P Ligthart, "*Adaption capabilities of a wire bow-tie antenna for ground penetrating radar,*" *IEEE Antennas and Propagation Society International Symposium*, Vol 2, pp 564-567, 8-13 July 2001.

[5] K.L Shlager, G.S Smith, J.G Maloney, "*Optimization of bow-tie antennas for pulse radiation,*" *IEEE Trans. On Antennas and Propagation* Vol 42, Issue 7, pp 975-982, July 1984.

[6] Z. Guiping, A.A Kishk, A.B Yakovlev and A.W Glisson, "*A Broadband printed bow-tie antenna with a simplified feed,*" *IEEE Ant. and Propagation Society International Sysmposium*, Vol. 4, pp. 4024-4027, 20-25 June 2004.

[7] X. Gang, *"On the resonant frequencies of microstrip antennas," IEEE Trans. Antennas Propagat.*, vol.37, no. 2, pp. 245-247, 1989.

[8] J.S. Dahele and K.F. Lee, *"On the resonant frequencies of the triangular patch antenna," IEEE Trans. Antennas Propagat.*, vol. AP-35, no. 1, pp.100-101, 1987.

[9] R. Garg and S.A. Long, *"An improved formula for the resonant frequency of the triangular microstrip antenna," IEEE Trans. Antennas Propagat.*, vol. 36, pp. 570, 1988.

[10] R. Singh, A. De, and R. S. Yadava, *" Comments on an improved formula for the resonant frequency of the triangular microstrip patch antenna," IEEE Trans. Antennas Propagat.*, vol. 39, pp. 1443-1445, 1991.

[11] K. Guney, *"Resonant frequency of a triangular microstrip antenna," Microwave and Optical Technology Letters*, vol. 6, no. 9, pp. 555-557, 1993.

[12] I.J. Bahl and P. Bhartia, *Microstrip Antennas.* Dedham, MA: Artech, 1980.