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Design of Modified Bowtie Antenna for Wireless Applications

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Abstract

Design of modified bowtie antenna for bandwidth enhancement characteristics using CADFEKO software is reported in this paper. In a bowtie antenna, by using triangular elements instead of rods, the bandwidth is greatly increased. The basic bowtie antenna is modified using a coplanar waveguide feed (CPW). The main issue with CPW-fed antennas is to provide an easy impedance matching to the CPW-fed line. The proposed antenna can exhibit minimum return loss, Omni-directional radiation pattern, wide impedance bandwidth, and VSWR<2. Furthermore, the modified antenna is analyzed using different substrate materials.The results portray significant losses in gain when the loss tangent of the material is included in the simulations. From the simulation results it is concluded thatthe bandwidth of the antenna is improved using the substrate of lower dielectric constant or by increasing the substrate thickness.

Keywords: Bow-tie antenna; CPW; VSWR

1. INTRODUCTION

The commercial pressure of ever-higher data rates and increases in user density are driving the antenna design for mobile wireless communicators to have wide-band response with spatial ability. In radio systems, a biconical antenna is a broad-bandwidth antenna made of two roughly conical conductive objects, nearly touching at their points. Biconical antennas are broadband dipole antennas, typically exhibiting a bandwidth of 3 octaves or more. A bowtie antenna is a wire approximation in two dimensions of a biconic dipole antenna (used, for example, for UHF television reception). The biconical antenna has a broad bandwidth because it is an example of a travelling wave structure; the analysis for a theoretical infinite antenna resembles that of a transmission line. Bow-tie and bow-tie slot antennas are planar-type variations of the biconical antenna that has wideband characteristics as in [5] and [10]. A number of bow-tie slot designs are introduced, which demonstrate wide BW that range from 17% to 40%. The WIFI frequency is divided into two bands: 2400-2484 MHz and 5150-5850 MHz; Because WIFI is the highest frequency on the mobile device; the WIFI antenna will be the smallest antenna.

The design is carried in FEKO, which is a Method of Moments (MoM) tool that can be used to calculate the radiation pattern, impedance and gain of an antenna while mounted on some defined geometry. In addition, it can calculate the isolation or mutual coupling (S12) between pairs of antennas, the near fields around an antenna and the electric currents that flow on an antenna or the surrounding structure as in [9].

2. DESIGN FORMULATION

An empirical formula of resonant frequency of bow-tie antennas is presented, which is based on the cavity model of microstrip patch antennas as in [2]. A procedure to design a bow-tic antenna using generic algorithm (GA) in whichthe formula is taken as a fitness function is also given. An optimized bow-tic antenna by genetic algorithm is measured. Numerical and experimental results are used to validate the formula and GA.

The design formulae of a bow-tie patch, for the dominant TM_{10} mode, can be obtained using the equations that follow

$$f_r = \frac{c}{2\sqrt{\epsilon_e}L}\left[\frac{1.152}{R_t}\right] \quad (1)$$

$$R_t = \frac{L}{2}\frac{(W+2\Delta l)+(W_c+2\Delta l)}{(W+2\Delta l)(S+2\Delta l)} \quad (2)$$

$$\Delta l = h\,\frac{0.412\,(\epsilon_e+0.3)\left(\frac{w_i}{h}+0.262\right)}{(\epsilon_e-0.258)\left(\frac{w_i}{h}+0.813\right)} \quad (3)$$

$$\epsilon_e = \left(\frac{\epsilon_r+1}{2}\right)+\left(\frac{\epsilon_r-1}{2}\right)\left[1+\frac{12h}{w_i}\right]^{-1/2} \quad (4)$$

$$W_i = \frac{(W+W_c)}{2} \quad (5)$$

Where, W_c is the central gap between the bows, which is made 0 because the antenna is designed from the origin (0,0,0) for the basic bowtie antenna, R_t, is the terminating resistance of the bowtie antenna and Δl is the extension length due to the fringing effect of the radiating antenna also the parameters, ε_r, h and $\varepsilon_e$are the permittivity of dielectric constant of the substrate, thickness of the substrate and effective permittivity of the substrate respectively and c is the velocity of electromagnetic wave in free space.

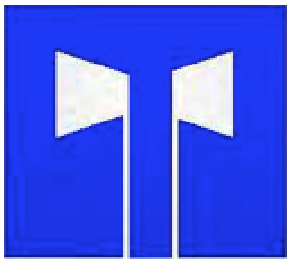

Figure 1. CPW fed bowtie antenna

The basic bowtie design is designed in FEKO and shown in figure 2. The simulated CPW feed bowtie is shown in figure 3.

3. CPW FEED

Antennas using CPW-fed line as shown in figure 1, have many attractive features including low radiation loss, less dispersion, easy integration for monolithic microwave circuits (MMICs) and a simple configuration with single metallic layer, since no backside processing is required for integration of devices as in [4],[8],[11]. Therefore, the designs of CPW-fed antennas have recently become more and more attractive. CPW-fed slot antennas with modified shape reflectors have been proposed. By shaping the reflector, noticeable enhancements in both bandwidth and radiation pattern, which provides unidirectional radiation, can be achieved while maintaining the simple structure. Here, the possibility of covering some the standardized WiFi and WiMAX frequency bands while cling to the class of simply structured and compact antennas.

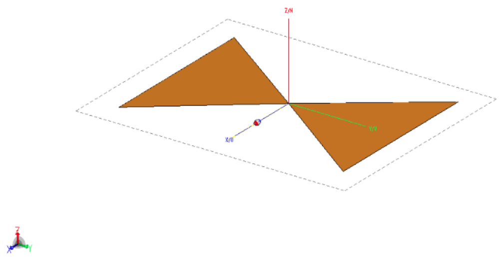

Figure 2. Basic bowtie antenna in FEKO

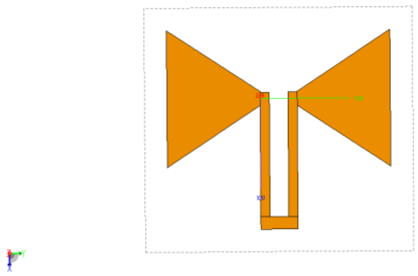

Figure 3. Proposed bowtie antenna in FEKO

4. SUBSTRATE MATERIAL ANALYSIS

Substrate materials play vital in antenna design, production and finished product performance. A simple method that can be employed to modify the different properties of the antenna is by changing the substrate's parameters such as height and dielectric constant of thesubstrate influence the antenna properties. All of the parameters in an antenna design (L, W, h, permittivity) control the properties of the antenna.

4.1.LENGTH VARAITION

First, the length of the patch L controls the resonant frequency. This is true in general, even for more complicated antennas that weave around the length of the longest path on the microstrip controls the lowest frequency of operation. Following equation gives the tolerance quotient

$$f_c \approx \frac{c}{2L\sqrt{\varepsilon_r}} = \frac{1}{2L\sqrt{\varepsilon_0 \varepsilon_r \mu_0}} \qquad (6)$$

4.2.WIDTH VARAITON

Second, the width *W* controls the input impedance and the radiation pattern. The wider the patch becomes the lower the input impedance. The permittivity $\varepsilon_r$of the substrate controls the fringing fields lower permittivity have wider fringes and therefore better radiation. Decreasing the permittivity also increases the antenna's bandwidth. Following equation gives the tolerance factor

$$L \approx \frac{1}{2f_c\sqrt{\varepsilon_0 \varepsilon_r \mu_0}} \qquad (7)$$

4.3. HEIGHT VARAITION

The height of the substrate *h* also controls the bandwidth increasing the height increases the bandwidth. The fact that increasing the height of a patch antenna increases its bandwidth can be understood by principle: "an antenna occupying more space in a spherical volume will have a wider bandwidth." The following equation roughly describes how the bandwidth scales with these parameters:

$$B \propto \frac{\varepsilon_r - 1}{\varepsilon_r^2}\frac{W}{L}h \qquad (8)$$

The simulations are performed for different substrate configurations of bowtie antenna with Duroid, FR4 and benzo-cyclobuten substrates.

5. RESULTS AND DISCUSSIONS

The radiation pattern of the proposed bowtie antenna with CPW feed is having high directivity compared to conventional antenna and the results are shown in figures 4 and 5.

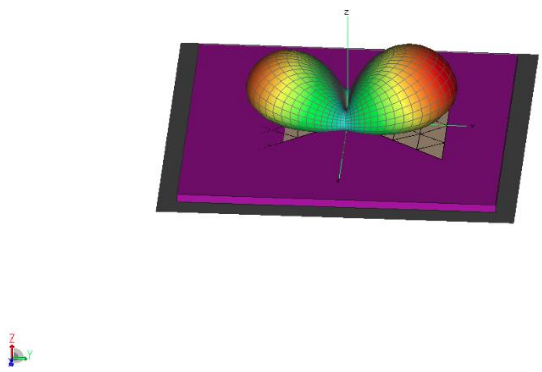

Figure 4. Radiation pattern of the basic bowtie antenna

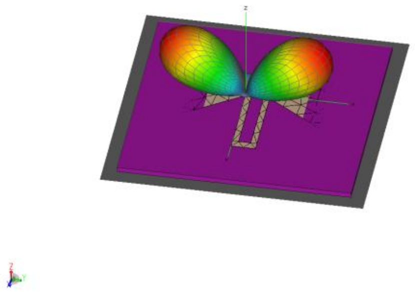

Figure5. Radiation pattern of the proposed bowtie antenna

The S-parameters of the basic antenna is given in the figure 6. It gives nearly -15dB respectively.

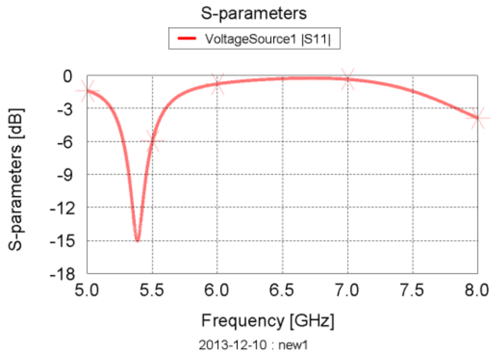

Figure 6. S11 parameters of the basic bowtie antenna

From the proposed antenna's S-parameter graphshown in figure 7, it is shown that the proposed antenna gives a wider bandwidth than the basic antenna structure. Table 1 shows the comparison of bandwidth achieved by the basic bowtie antenna and the proposed bowtie antenna.There is bandwidth enhancement achieved up to 50% in figure 7.

Table 1. Bandwidth Comparison of the basic bowtie antenna and proposed bowtie antenna

Parameters	Basic antenna	Proposed antenna
Application	Wi-Max	Wi-Max
Fractional bandwidth %	7.08	13.57

The proposed antenna is analyzed on three different substrate materials as mentioned earlier. The S11 characteristics curve for the first substrate - benzo-cyclobuten is shown in Figure8. The S11 value in dB is about -7.

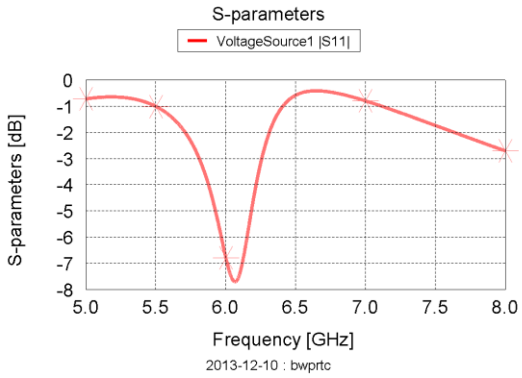

Figure 7. S11 parameters of the proposed bowtie antenna

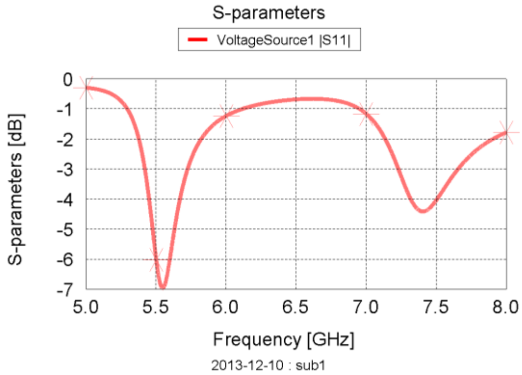

Figure 8.S11 characteristics of substrate1

The S11 characteristics curve for the second substrate - Glass is shown in Figure 9. The S11 value in dB is about -7.5

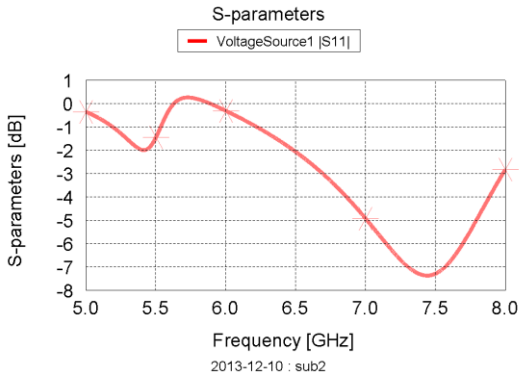

Figure 9. S11 characteristics of substrate2

The S11 characteristics curve for the third substrate - Duroid 6010 is shown in Figure10. The S11 value in dB is about -7.8.

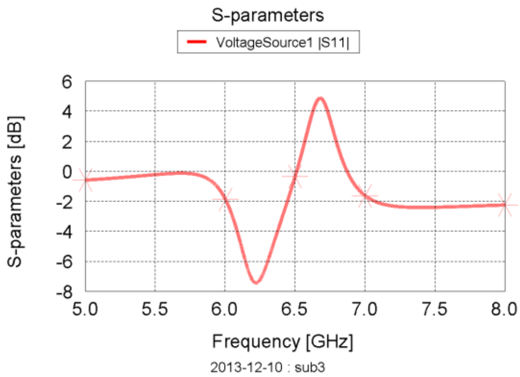

Figure 10. S11 characteristics of substrate3

Table 2. Comparison of the modified bowtie antenna simulated results on different Dielectric Constants

Name of the substratematerial	**Permittivity of the dielectric, ε_r**	**Thickness of the substrate, h**	**Loss tangent, δ**	**Fractional B.W %**	**Min VSWR**	**S11 in dB**
Benzo - cyclobuten	2.6	1.6	0	5	1.2	-7
Glass	5.5	1.6	0	27	1.5	-7.5
Duroid 6010	10.2	1.6	0.0023	7	2	-7.8

The wider bandwidth is due to the δ lowering the quality factor of the antenna. Both bandwidth and gain decrease as $\varepsilon_r$increases for perfect dielectric. A linear relationship of 2 dB drops per decade is observed between the gains and ideal $\varepsilon_r$evaluated in the range of this study. The bandwidth does not vary for lossy substrates. However, the gains drop linearly by 1.5 dB per decade for increasing ε_r. The results portray significant losses in gain when the loss tangent of the material is included in the simulations

6.CONCLUSION

It is analyzed that the CPW feed for the antenna has achieved bandwidth enhancement double the original value. Also the substrates on which the antennas are constructed show that the lower permittivity valued substrate helps in achieving a good antenna performance.

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