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Designing BT Antenna for RFID Systems

Ahmad Bayat
Department of Electrical Engineering , K.N.Toosi University of technology, Tehran, Iran

Abstract: *This paper is about designing and optimizing a new antenna employed for RFID applications at microwave frequencies. The structure is designed in a way that it resonates at 2.45GHz, which is one of the RFID frequencies. The new patch is derived from BT(Bow-Tie) antenna. It results in a reduction of the size by more than 70%, as compared to monopole patch, alongside with having an acceptable gain and directivity. Based on a model of triangular antenna, a correspondent resonant model is presented. Simulation results achieved using our method show that the antenna and its model have the same resonant frequency at 2.45GHz. However, there was a little difference in Bandwidth.*

Key Terms: *Radio Frequency Identification RFID, Tag, Readable Range R, BT Antenna*

I. INTRODUCTION

In recent years, microstrip antennas are being used for fine tuning light weight, low cost manufacturing, reliability and simplicity of the structure, making them widely applicable in research and engineering applications have been used.

Bow tie microstrip antennas are designed for wireless LANs operating frequency at 2.45 GHz applications. Visual Patch combines fantasy bow in two triangular patches, which are built on a single substrate. Figure (1) shows a ribbon bow that is a bow tie microstrip antenna. Bow tie microstrip antennas are attractive options because of their compact nature than rectangular patch for communication. Growing demand for compact wireless communication equipment increases the need for further research to more antenna option and this demand has led many researchers to the field of microstrip antennas bow tie option. However, few previous studies have addressed the analysis of this type of antennas and empirical formulas have been proposed for the frequency cohort of this new Geodesy.

To reach integrated transmit / receive modules, microstrip antennas should be mounted on a board that is consistent MMIC structures. Moreover, changing a strip line on a board to a coaxial cable or antenna feed waveguide is difficult. However, flat panel antenna can solve these problems, but they have limited bandwidth. Up to now broadband microstrip antennas have been studied. Recently printed dipole antennas and bow tie antennas are presented. Regardless of the good results of the bandwidth and radiation pattern of the antenna, microstrip structures are examined.

Microstrip lines widely used in manufacturing transistor microwave amplifiers because it is not difficult to make and it can also be used as inductors and capacitors.

It should be noted that the lines usually are used at high frequencies because its length gets long in the low frequency and making circuit will be impractical [13].

Microstrip line is a line that has a conductive strip of land and a home which are separated by a dielectric medium.

Figure (1) shows the structure of a Microstrip. Dielectric material acts as a medium between the conductors and the earth. The typical dielectric substrate, including two contact points with alumina and silicon, makes the dielectric wavelength higher and thereby, the whole circuit will be smaller.

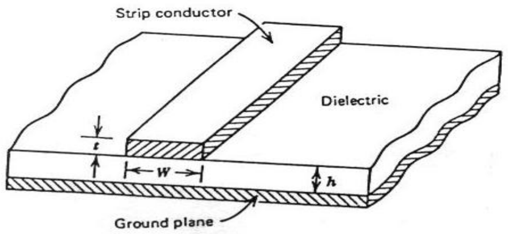

Figure 1. the physical structure of a Microstrip line

All lines of magnetic field in microstrip are not in bed. Therefore it cannot be considered a pure TEM because it has such a structure which is not true in the TEM.

Therefore, when choosing the antenna, some points should be considered. First, different types of antenna should be used in the reader and the tag for different applications. Second, the antenna should be small, easy to make and also cheap. Third, the RF characteristics of the antenna should be acceptable regarding impedance, gain and directivity.

On one hand, reducing the size of the antenna results in a small tag which can be placed anywhere, without occupying a large space. On the other hand, one of the main features of RFID systems is the readable range R, which is the maximum distance that the Interrogator can read from the tag. This distance basically depends on the gain of both the Tag antenna and the reader antenna, as represented in equation 1 [2]:

$$R = \frac{\lambda_0}{4\pi} \sqrt[4]{\frac{P_1 \cdot G_{reader}^2 \cdot G_T^2}{P_3}} \tag{1}$$

With: P_3 = Power received in the tag

P_1 = Power transmitted by the interrogator

G_{reader} = The Gain of interrogator antenna

G_T = The Gain of Tag antenna

A new small tag antenna is proposed in this article. The patch is designed based on a bow tie antenna, and is simulated using Advanced Design System (ADS 2009). The significance of this new patch is that it results in the reduction of the size of the original antenna that resonates at 2.45GHz by more than 70%. I simulated an electrical model of the structure to validate our work. Then I compared it with the ADS results of the physical patch.

II. A BT SMALL ANTENNA

A. Geometry of triangular antenna

The geometry of an equilateral triangular microstrip patch on a dielectric substrate with a ground plane is presented in Figure (2). The antenna is mounted on a substrate material with the thickness of h=3.2mm, a dielectric constant 0f $\varepsilon_r = 2.6$ and the loss tangent of (tanδ =) 0.002.

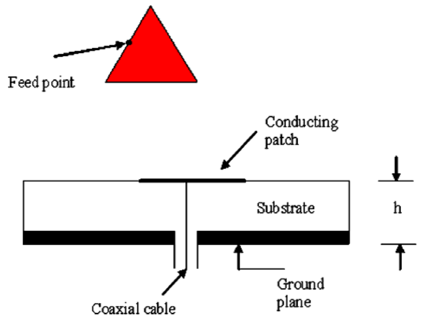

Figure 2. Triangular Antenna structure

B. Electrical model of triangular patch

The recent studies on microstrip patch have shown that the triangular patch has a radiation characteristic similar to a rectangular patch, but with reduced dimensions [3], [5], [6]. Due to this reason and in order to study our antenna, the triangular electrical model can be replaced by its equivalent electrical rectangular model, as shown in figure (3).

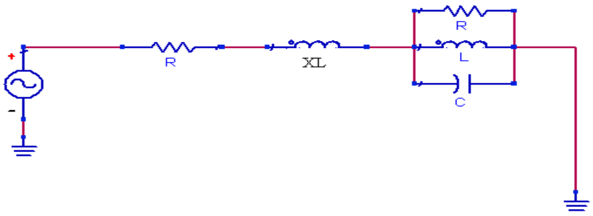

Figure 3. Electrical model of Triangular antenna

The formula presented in [4] is applied to every triangle in order to calculate the parameters of the model.

$$Z_{in} = R + jX \tag{2}$$

$$Z_{in} = \frac{R}{1 + Q_T^2\left[\frac{f}{f_r} - \frac{f_r}{f}\right]} + j\left[X_L - \frac{RQ_T\left[\frac{f}{f_r} - \frac{f_r}{f}\right]}{1 + Q_T^2\left[\frac{f}{f_r} - \frac{f_r}{f}\right]^2}\right]$$

Resonant resistance R:

Employing equation (3), the resonant resistance is calculated, as in [4]:

$$R = \frac{Q_T H}{\pi f_r \varepsilon_{dyn} \varepsilon_0 A} \cos^2\left(\frac{\pi x_0}{a}\right) \tag{3}$$

f_r : Resonant frequency

Q_T : Quality factor

ε_{dyn} : Dynamic permittivity

x_0 : the distance of the feed point from the edge of the patch.

a: length of triangle

H : thickness of dielectric

A: air of triangle1

$$Q_T = \left(\frac{1}{Q_R} + \frac{1}{Q_C} + \frac{1}{Q_D}\right)^{-1} \tag{4}$$

$$Q_R = \frac{c_0\sqrt{\varepsilon_{dyn}}}{4 f_r H} \tag{5}$$

$$Q_D = \frac{1}{Tan(\delta)} \tag{6}$$

$$Q_c = \frac{0.786\sqrt{f_r Z_{a0}(W) H}}{p_a} \tag{7}$$

Q_R : Radiation quality factor

Q_D : Losses in the dielectric

Q_C : Losses in the conductor

$$Z_a(W) = \frac{60\pi}{\sqrt{\varepsilon_r}}\left[\frac{W}{2H} + 0.441 + 0.082\left(\frac{\varepsilon_r - 1}{\varepsilon_r^2}\right) + \frac{(\varepsilon_r + 1)}{2\pi\varepsilon_r}\left(1.451 + Ln\left(\frac{W}{2H} + 0.94\right)\right)\right] \tag{8}$$

The impedance of an air filled microstrip line is as below.

$$Z_{a0}(W) = Z_a(W, \varepsilon_r = 1)$$

$$p_a = \frac{2\pi\left(\frac{W}{H} + \frac{W/(\pi H)}{W/2H + 0.94}\right)\left(1 + \frac{H}{W}\right)}{\left(\frac{W}{H} + \frac{2}{\pi} Ln\left(2\pi \exp\left(\frac{W}{2H} + 0.94\right)\right)\right)^2} \tag{9}$$

$W/H > 2$

$$\varepsilon_{dyn} = \frac{C_{dyn}(\varepsilon)}{C_{dyn}(\varepsilon_0)} \tag{10}$$

$$C_{dyn}(\varepsilon) = \frac{\varepsilon_0\varepsilon_r A}{H\gamma_n\gamma_m} + \frac{1}{2\gamma_n}\left(\frac{\varepsilon_{reff}(\varepsilon_r, H, W)}{c_0 Z(\varepsilon_r = 1, H, W)} - \frac{\varepsilon_0\varepsilon_r A}{H}\right) \tag{11}$$

$$\gamma_j = \begin{cases} 1, & j = 0 \\ 2, & j \neq 0 \end{cases}$$

$$Z(W, H, \varepsilon_r = 1) = \frac{377}{2\pi} Ln\left(\frac{f(W/H)}{w_h} + \sqrt{1 + \left(\frac{2}{W_H}\right)^2}\right) \tag{12}$$

$$f(W/H) = 6 + (2\pi - 6)\exp\left(-\left(\frac{30.666}{W_H}\right)^{0.758}\right) \tag{13}$$

Capacitance C, Inductance L:

For calculating the capacitance C, the formula of C_{dyn} is used.

To calculate the inductance L, we have:

$$\omega_{res} = 2\pi f_r \tag{14}$$

$$\omega_{res} = \frac{1}{\sqrt{LC}} \Rightarrow L = \frac{1}{\omega_{res}^2 C} \tag{15}$$

Inductive reactance of Coax:

Inductive reactance of Coax is determined using the following equation:

$$X_L = \frac{377\, fH}{c_0} Ln\left(\frac{c_0}{\pi f d_0 \sqrt{\varepsilon_0}}\right) \tag{16}$$

The model was simulated, then compared to the physical patch. Its results are shown in figure (4). The triangular patch and its electrical model show a resonant frequency of about 2.45GHz.However, they have different bandwidths, which is because of the difference between calculated and simulated losses. The gain and directivity are 8.1dB and 8.2dB, respectively.

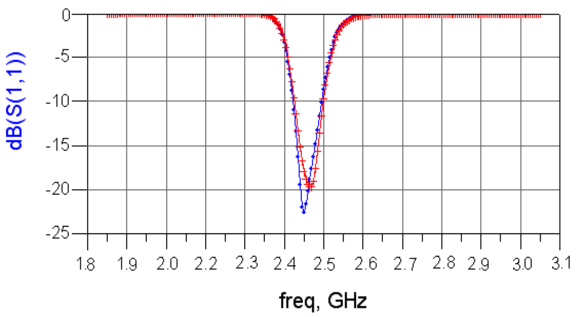

Figure 4. Return loss of both physical and model of triangular patch

C. *Geometry of proposed bow tie antenna*

The proposed patch consists of four triangle patches disposed on planar structure as shown in figure (5).

This structure is inspired by the bow tie patch antenna, in which only one transmission line links the four triangles, and the patch is mounted on a dielectric with a thickness of h = 0.65mm and the permittivity of $\varepsilon_r = 2.3$.

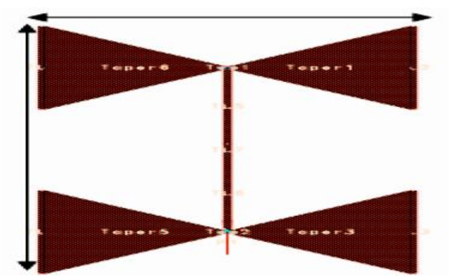

Figure 5. Figure 5. Proposed bow tie antenna structure

Figure 6.

D. *Electrical model*

An electrical model was developed for analyzing this antenna, which was inspired from the electrical model of the triangular patch described by Nasimuddin and A. K. Verma in [3]. In fact, they substituted the triangular patch by its equivalent rectangular patch and built the triangular electrical model. The transmission line was modeled by an RLC circuit. Figure (6) represents this electrical model.

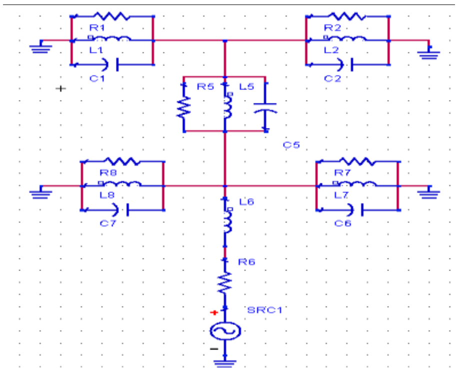

Figure 7. Electrical model of proposed bow tie antenna

The RLC parameters were determined by means of the formulas developed in section 1.

III. Results and Discussion

E. *Dimensions*

The patch proposed in this paper is designed in a way that it resonates at 2.45GHz (one of the RFID frequencies). The typical antenna is of the dimension of about 5.8cm × 5.8cm. The dimension of the antenna presented here is about 10.4mm×6.2mm, which is more than 70% smaller than the typical antenna. It leads to a very small tag with a good quality.

Return loss

Figure (7) shows the return loss with the resonant frequency of 2.45 GHz. The antenna represents a band width of about 80 MHz which is satisfactory for RFID system. Also, the magnitude |S11| attainted 25dB.

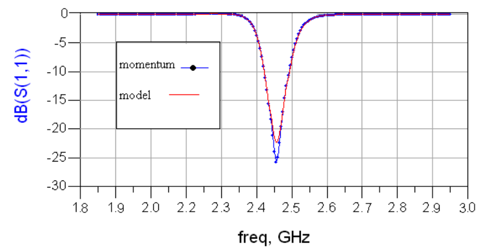

Figure 8. Return loss of both physical and model of proposed bow tie antenna

F. *Gain and Directivity*

Since the readable range, R, depends on Gain and Directivity, it should be assured that suitable ones are gained. In the bow tie antenna proposed here, the gain and he directivity are 2.1dB and 5.2dB respectively which are acceptable for an RFID system.

Finally, by comparing the physical patch and electrical model, it can be seen that the resonant frequency is the same. Furthermore, there is a little difference in band width which is due to the difference between losses in theory and real.

IV. CONCLUSION

Reducing the size of the antenna and the tag is greatly favored for many applications. Hence, many techniques are applied for reaching to a very small patch. Reducing the antenna size by more than 70% in this study is a very important achievement. Ameliorating antenna parameters and decreasing antenna cost are the priorities in our future research.

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