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Design of Notched Rounded Bowtie Antenna for Ultra-Wideband Communication Systems

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Abstract

In this paper, a modified bowtie antenna structure is proposed for Ultra-Wideband communication systems. This antenna is obtained by rounding and notching the edges of antenna arms. Antenna parameters for the designed structure are examined according to the restrictions specified by Federal Communications Commission. Thus, Return Loss (S_{11}), Voltage Standing Wave Ratio (VSWR), gain, radiation pattern and impedance are observed in the 3.1 GHz - 10.6 GHz frequency range. Additionally, the effect of arm length and dielectric material on antenna performance are interpreted in the same range. According to obtained results, the proposed structure satisfies the bandwidth requirements for Ultra-Wideband systems. Gain and impedance variations are also in acceptable limits for Ultra-Wideband applications. The proposed antenna is analyzed through CST Microwave Studio program.

Keywords: Antenna design, Notched bowtie antenna, Ultra-wideband

Ultra Geniş Bantlı Haberleşme Sistemleri için Çentikli Yuvarlatılmış Kelebek Anten Tasarımı

Öz

Bu çalışmada, Ultra-Geniş Bant haberleşme sistemleri için modifiye edilmiş kelebek anten yapısı önerilmiştir. Bu anten kelebek antenin kollarının yuvarlatılması ve çentik atılması ile oluşturulmuştur. Tasarlanan yapının anten parametreleri, Federal İletişim Komisyonu tarafından belirlenen kısıtlamalara göre incelenmiştir. Böylece, Geri Dönüş Kaybı (S_{11}), Duran Dalga Oranı (VSWR), kazanç, ışıma örüntüsü ve anten empedansı 3,1 GHz -10,6 GHz frekans aralığında gözlenmiştir. Ayrıca, anten kol uzunluğunun ve dielektrik malzemenin anten performansına etkisi aynı frekans aralığında yorumlanmıştır. Elde edilen sonuçlara göre, önerilen yapı Ultra-Geniş Bant sistemleri için bant genişliği gereksinimlerini karşılamaktadır. Kazanç ve empedans değişimleri de Ultra-Geniş Bant uygulamaları için kabul edilebilir sınırlardadır. Önerilen anten CST Microwave Studio programı ile analiz edilmiştir.

Anahtar Kelimeler: Anten tasarımı, Çentikli kelebek anten, Ultra-geniş bant

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1. INTRODUCTION

As it is well known, antenna is a significant component in communication systems for transmitting and receiving the signals effectively. Especially in Ultra-Wideband (UWB) systems, antenna design is a crucial task due to broadband system characteristics. The challenging issue in the modelling of UWB antennas is to maintain the desired performance throughout the UWB frequency range. According to the regulations specified by Federal Communications Commission (FCC) for UWB communications, Return Loss (S_{11}) should be below -10 dB and Voltage Standing Wave Ratio (VSWR) should be less than 2 over the 3.1 GHz - 10.6 GHz frequency range [1]. Arm length, feed gap, substrate length, substrate width, and flare angle are important for obtaining the required bandwidth and directional characteristics in UWB systems. Moreover, thickness and dielectric constant of the substrate have considerable effect on antenna performance.

Bowtie antenna is a commonly used structure in many applications including wireless communication, Ground Penetrating Radar (GPR), Ultra-Wideband (UWB) systems and medical imaging. This antenna type has advantageous properties such as small size, low weight, low cost and ease of implementation. There are several bowtie antenna structures designed for different applications in the literature [2-14]. In general, most studies focus on improving antenna performance by using simulation programs. Some of these studies additionally include experiments to verify simulation results.

This study proposes a modified bowtie antenna structure for Ultra-Wideband communications. The modification is performed by rounding and notching the edges of antenna arms. The proposed antenna is examined in the 3.1 GHz -10.6 GHz frequency range according to the restrictions specified by FCC regulations. Antenna performance is analysed by observing Return Loss (S_{11}), Voltage Standing Wave Ratio (VSWR), gain, radiation pattern and impedance in the frequency range of interest. Additionally, the effect of arm length and substrate material are examined on the antenna performance. The proposed structure is simulated by using CST Microwave Studio program.

2. ANTENNA DESIGN

Antenna configuration is composed of a modified bowtie structure printed on a dielectric substrate. The modification is carried out by rounding and notching the arm edges of a classical bowtie antenna. The geometry of the proposed antenna is depicted in Figure 1. Designed antenna lies in the *xy* plane. Notched bowtie is made of copper and the substrate material is Rogers RT5870 with relative permittivity of 2.33. Substrate dimensions are 137.5 mm × 137.5 mm with h = 0.5 mm thickness. Flare angle is 60^o and the notch radius is 10 mm.

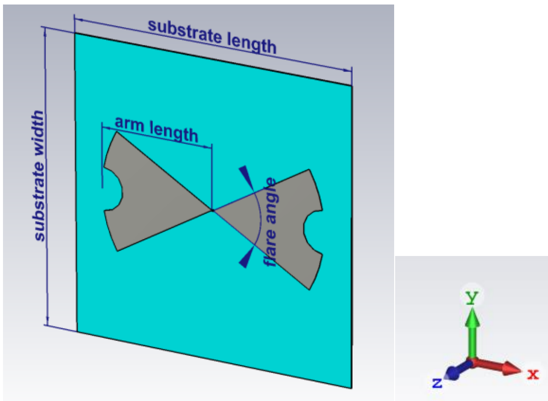

Figure 1. Notched rounded bowtie antenna configuration

3. ARM LENGTH EFFECT

The proposed antenna is designed with three different arm lengths to see the effect of arm length on antenna performance. All of the other physical parameters are kept constant in the structure. Figure 2 shows Return Loss plots for arm lengths of 35 mm, 45 mm, and 55 mm. According to the figure, when the arm length is 35 mm, S_{11} is not below -10 dB in the ranges of 4.2-5.4 GHz and 7.5-9.03 GHz. Therefore, this antenna has triple-band characteristics in the 3.1-10.6 GHz frequency range. However, as the arm length increases to 55 mm, the bandwidth improves significantly since S_{11} is below -10 dB throughout the whole frequency range. Additionally, when the arm length is 55 mm, the best resonance occurs at 6.62 GHz with Return Loss value of -27.79 dB. Similarly, in Figure 3, when the arm length is 55 mm, VSWR is smaller than 2 for the whole UWB range. Here, the minimum VSWR is 1.09 at 6.62 GHz. Then, it can be concluded that, 55 mm arm length yields the best bandwidth performance for UWB applications.

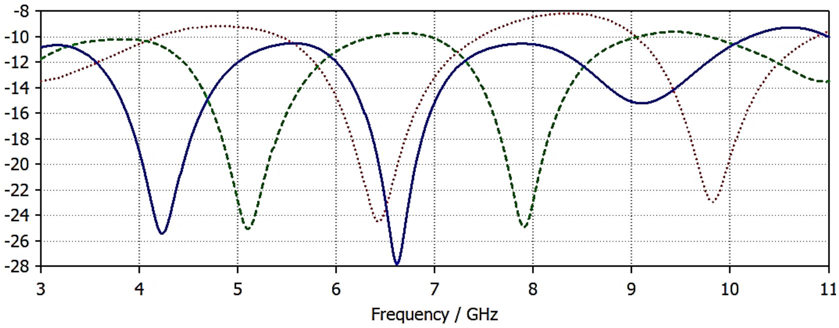

Figure 2. Return Loss (S_{11}) of the antenna for different arm lengths; ····· 35 mm, – – – 45 mm, ——— 55 mm

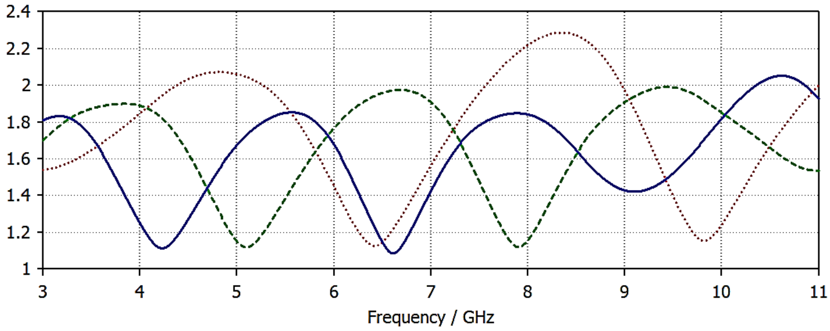

Figure 3. VSWR of the antenna for different arm lengths; ····· 35 mm, – – – 45 mm, ——— 55 mm

4. EFFECT OF DIELECTRIC MATERIAL

In order to observe the effect of dielectric material, antenna performance is compared for Rogers RT5870 and FR4 substrates. The dielectric constant for FR4 material is 4.3. Arm length is selected as 55 mm for both antennas since it gives the best Return Loss and bandwidth characteristic. All the other dimensions of the antennas are selected the same as in the previous section. Figure 4 shows Return Loss plots for both substrates. According to figure, the structure with Rogers RT5870 substrate has Return Loss below -10 dB throughout the UWB frequency range. However, the antenna with FR4 substrate does not satisfy -10 dB bandwidth requirement. Rather, it shows triple-band characteristics in this range.

Similarly, VSWR graphs for the antennas with Rogers RT5870 and FR4 substrates are illustrated in Figure 5. Although the structure with Rogers RT5870 substrate has VSWR below 2, the structure with FR4 substrate does not satisfy this condition at all frequencies throughout the UWB range. Hence, RT5870 is appropriate to be used for UWB applications. On the other hand, it is not as cost effective as FR4 material. This is a compromise that should be considered in the design of UWB antennas.

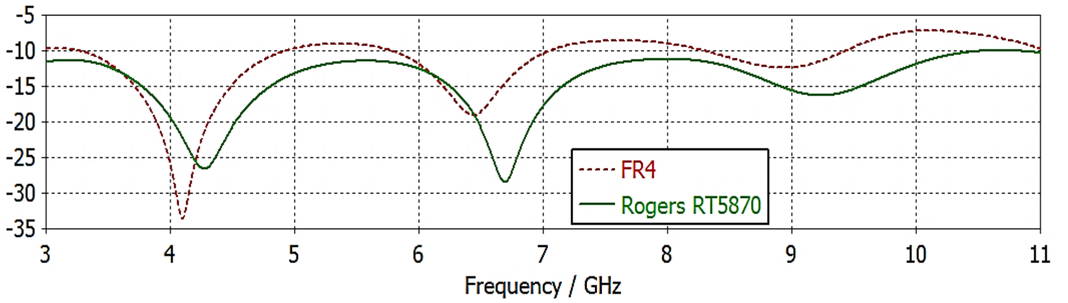

Figure 4. S_{11} Return Loss for the proposed antenna with substrates ----- FR4 and —— Rogers RT5870

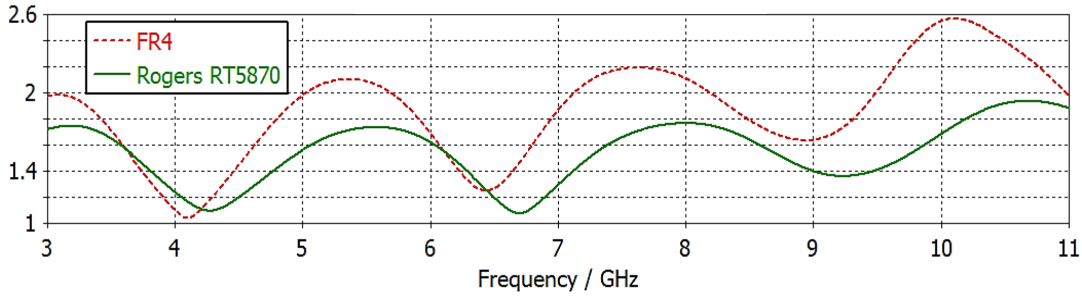

Figure 5. VSWR for the proposed antenna with substrates ----- FR4 and —— Rogers RT5870

5. RADIATION PATTERN AND GAIN

One of the main concerns for antenna design in UWB communications is the radiation pattern. It is not an easy task to control the radiation pattern at all frequencies since the pattern deteriorates with increasing frequency. Figure 6 illustrates the radiation pattern at three different frequencies with Rogers RT5870 substrate. According to the figure, the radiation pattern is omnidirectional at 3.1 GHz. However, as the frequency increases, more lobes start to appear and deteriorations occur in the omnidirectional pattern characteristic.

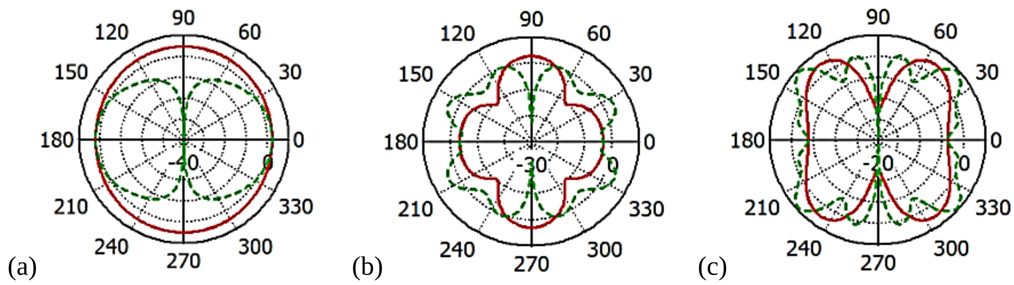

Figure 6. Radiation pattern for —— Phi=90°, ----- Theta=90° at a) 3.1 GHz, b) 6.85 GHz, c) 10 GHz.

The gain over the frequency range is illustrated in Figure 7. According to the graph, the gain is almost uniform from 3.1 GHz to 5 GHz. It increases after 5 GHz until it reaches the maximum value of 4.96 dB at 7 GHz. The gain starts to decrease again after this frequency until it reaches the minimum, that is, 3.36 dB at 8.73 GHz. The gain variation is only 1.6 dB over the entire frequency range, which is tolerable and therefore quite reasonable for UWB systems.

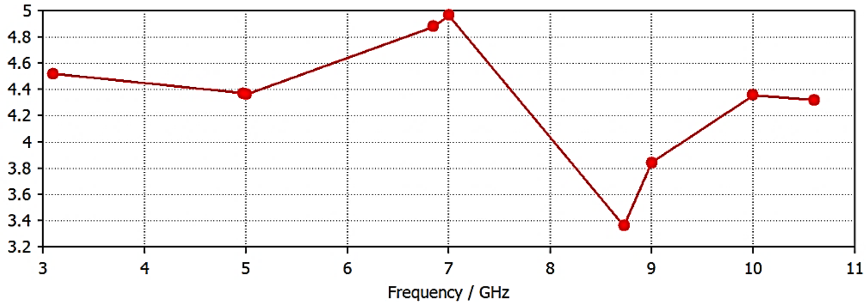

Figure 7. Gain over the range 3.1 GHz - 10.6 GHz

6. ANTENNA IMPEDANCE

Antenna impedance with respect to frequency is examined in Figure 8. The magnitude Z_{11} does not change significantly throughout the frequency range. Additionally, the imaginary part is considerably small as compared to the real part. Thus, it appears that the proposed antenna has an appropriate impedance characteristic for UWB applications.

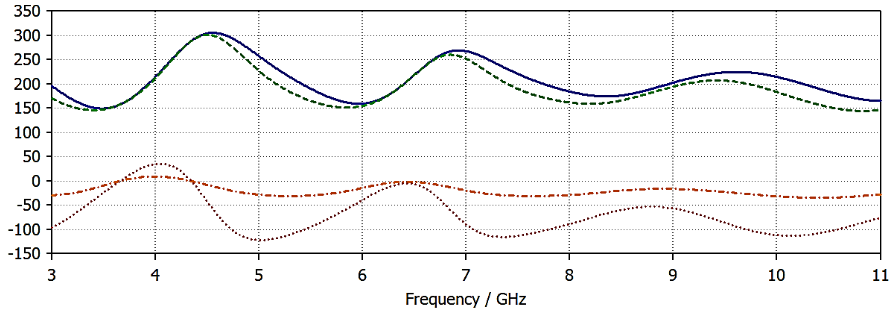

Figure 8. Impedance of the proposed antenna with frequency for Rogers RT5870 substrate, —— Mag(Z_{11}), ----- Re(Z_{11}), ····· Im(Z_{11}), – · – · – Arg(Z_{11})

7. CONCLUSION

In this paper, a notched rounded bowtie antenna is proposed for Ultra-Wideband communication systems. The structure is obtained by rounding and notching the arm edges of classical bowtie antenna. Antenna performance is analysed by observing Return Loss (S_{11}), Voltage Standing Wave Ratio (VSWR), gain, radiation pattern and impedance in the 3.1 GHz - 10.6 GHz frequency range. The effect of arm length and dielectric material are examined on antenna performance. CST Microwave Studio is used for designing and analyzing the antenna. According to obtained results, the structure designed with RT5870 substrate satisfies the bandwidth requirements for UWB systems. In fact, Return Loss is below - 10 dB and VSWR < 2 over the UWB frequency range. Additionally, gain and impedance variations are relatively small and these variations are in acceptable limits for UWB applications. Although the radiation pattern is omnidirectional at the lowest frequency, it tends to deteriorate as the frequency increases. It is aimed to improve the radiation pattern also at higher frequencies by further modifying the proposed structure in the future work.

8. ACKNOWLEDGEMENT

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