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Design of a Very Compact Ultra wideband Printed Antenna with Rounded Corners

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Abstract

In this paper, a very compact UWB microstrip-fed antenna is presented. By only sequentially inserting the three notches with proper sizes and tuning their dimensions in two corners of the rectangular radiating patch, very good radiation and impedance characteristics are obtained. The proposed antenna has a very wide impedance bandwidth measured at about 15 GHz (3 up to18 GHz, bandwidth ratio about 1:6) for S11 <-10 dB. Moreover, the stability of the H-plane radiation patterns of the proposed antenna is maintained in omnidirectional form within the frequency bandwidth up to 16GHz.

Keywords: Compact Antenna, Rounded Corners, Ultra Wide-Band(UWB)

INTRODUCTION

Recently, the accelerating growth of UWB communications and systems, has led to the development of novel communication devices such as novel antennas to satisfy the UWB systems requirements. UWB systems use ultra-short pulses in the order of nanoseconds to occupy a huge frequency band. Especially, USA Federal Communications Commission (USFCC) has assigned the frequency band of 3.1–10.6 GHz with respect to these emerging UWB activities. The aim of UWB systems is to increase the data bit rate of different applications due to limitations in current wireless systems.Among the various existing antennas, printed slot antennas featured with good radiation performance, low cost, low profile and good impedance matching have gained great popularity among antenna designers. It is well known, however, that its bandwidth is inherently narrow. Thus, many researchers have been attempted to widen the bandwidth of the conventional printed antennas [2]. In these designs, the wide impedance bandwidth produced with different shapes and structures such as: increasing ellipticity ratio of the ellipse-shaped patch to widen the impedance bandwidth [2], carving a circular/elliptical hole in the patch to improve the impedance matching in the middle frequency band, [3] and [4], rounding ground plane to decrease the lower frequency band-edge and improve the impedance matching and impedance bandwidth in the upper frequency band, [5] and [6] and recently the hybrid monopole antennas was presented to increase the freedom degree of them.

This letter focuses on a square monopole antenna for UWB applications, which combines the square-patch approach with a truncated ground plane and achieves a fractional bandwidth of more than 140%. In order to achieve wider operation bandwidth, the designed antenna has round corners on the radiated patch. The size of the designed antenna is much smaller than the UWB antennas reported recently. Good return loss and radiation pattern characteristics are obtained in the frequency band of interest. Simulated and measured results are presented to validate the usefulness of this proposed small antenna structure for UWB applications.

ANTENNA STRUCTURE AND DESIGN

Fig. 1 shows the geometry of the compact antenna which is symmetrical with respect to the longitudinal direction (y -axis) the antenna basically consists of a radiating patch, connected to a 50Ω feed line on the ground plane. The antenna is printed on a 16×14mm2 FR4 substrate with permittivity of 4.4, loss tangent of 0.024, and thickness of 1mm(=h). By etching of three notches from the rectangular patch and two elliptical slots from the ground plane, the bandwidth of the antenna is improved up to 143%. The antenna covers the frequency range of 3 – 18 GHz for VSWR < 2.

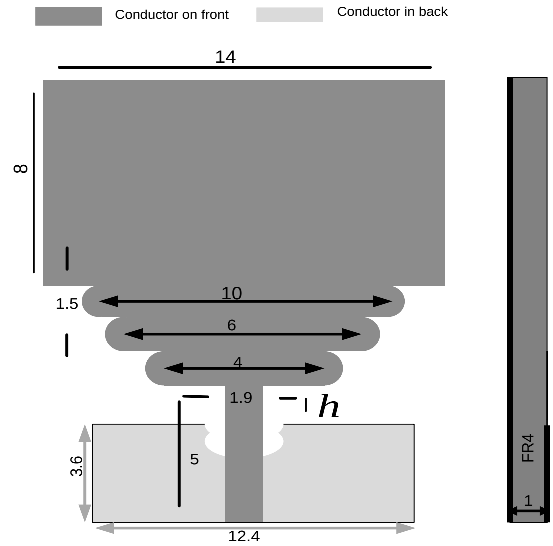

Fig. 1. Configuration and photography of the fabricated antenna with optimal parameters

The truncated ground plane plays an important role in the broadband characteristics of this antenna because it helps match the patch with the feed line in a wide range of frequencies [7].

RESULTS AND DISCUSSIONS

Radiation characteristics

Ansoft HFSS (Ver.13) simulation tool is employed to perform the design and optimization process. The antenna with the given values in Fig.1 has been fabricated and tested. The photo of the fabricated antenna is shown in Fig.2. To investigate the process of enhancement the bandwidth of proposed antenna, five antennas numbered from 1 to 5, are introduced in Fig. 3. Ant 1, without three pairs of notches (the quasi-square patch); Ant 2, the square patch with just one pair of notch (A slot); Ant3, the square patch with two pairs of notches (A, and B); Ant 4 (the proposed antenna), with three pairs of notches (A, B and C, simultaneously). Note that the height of three notches are similar to each other and corresponds to 1.5mm and in Ant 5two elliptically-shaped notches are removed from the upper side of the ground plane. To clear more, the distributed surface currents of two antennas (Ant.1 and Ant.5) at 15 GHz are shown in Fig. 4. It is observed that the sharp and sudden discontinuity, detected in Ant 1, is completely degraded in Ant 5. In this case, the sudden variation in surface currents at two corners of the patch that is the active areas at high frequencies is not seen [8].In Ref. [8] the author discusses the effects of unequal slots on the radiated patch. In this study, the other effective parameter is feed gap (h); meanwhile, all other parameters that have not been mentioned are fixed to the values shown in Fig. 1. The simulated reflection coefficient for different lengths of the feed gap (h) is shown in Fig. 5. It can be seen thatthe impedance bandwidth is decreased with increasing h. Furthermore, Fig.5 shows the best value for h is equal to 1.4mm and in this case the antenna has three different resonances due to the existence of three serial discontinuities in direction of the microstrip-fed line.

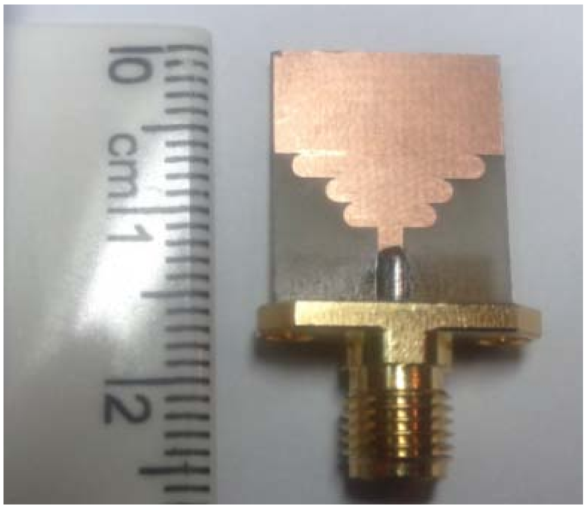

Fig. 2. Photo of the fabricated antenna

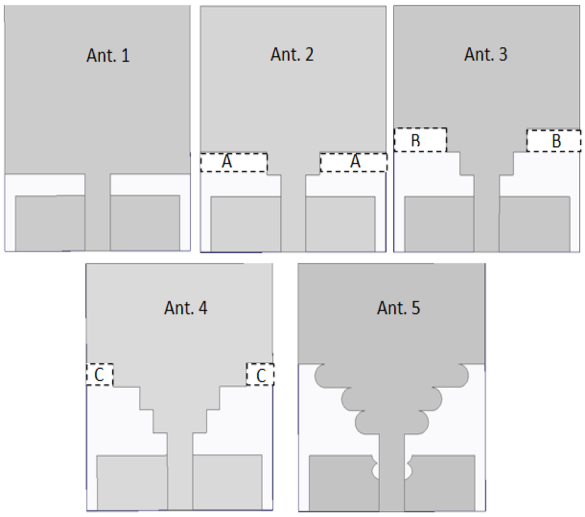

Fig.3. The configuration of the five proposed antenna

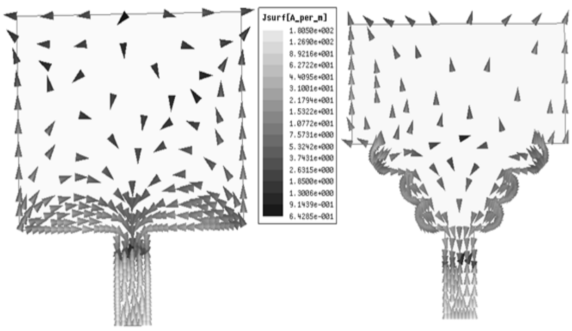

Fig.4. Simulated distribution of surface currents for Ant I and IV at 15 GHz.

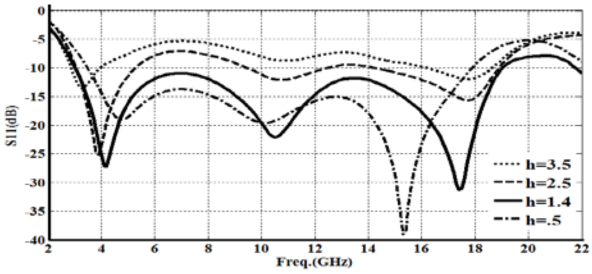

Fig. 5. Simulated return loss characteristics of the proposed antenna with different values of h (unit: mm)

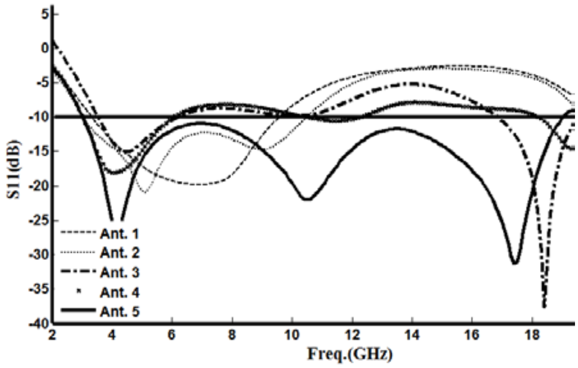

Fig.6. return loss for the antennas in Fig.2

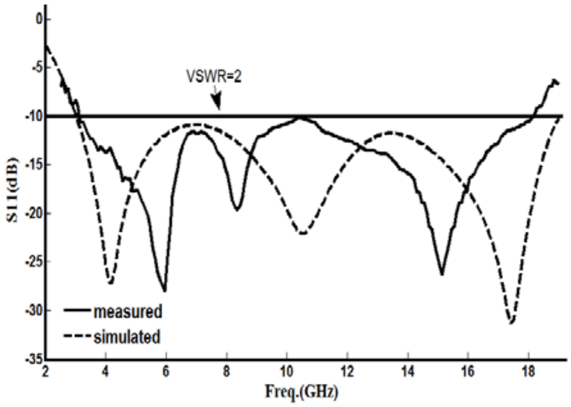

Fig.7. Measured and simulated return loss curves versus frequency for the proposed antenna

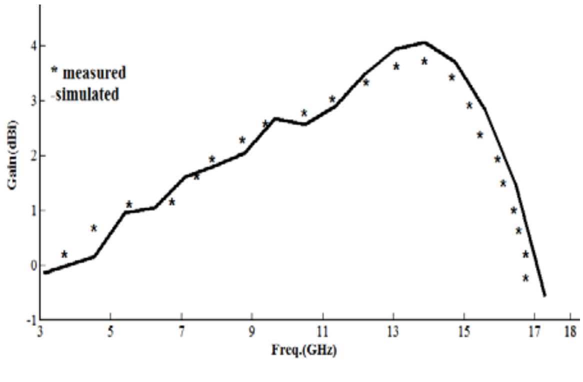

Fig.8. Measured and simulated gain of the proposed antenna

Fig.6 shows that the simple structure of the Ant 1, with only one resonance in return-loss curve, covers the frequency band of 3-9.5GHz. In Ant 1, the current encounters with the sharp points of the rectangular patch, which is a factor of the bandwidth limitation. In Ant 2, when two notches are cut from the lower corners of the rectangular patch (that nominated by section A), the sharp point are smoothed to some raised. As a result, the impedance matching has improved the bandwidth specially at higher frequencies. Two rectangular slots on the patch of Ant 3, lead to three resonances in return-loss curve are created but due to these resonances are far from each other and can't overlap with together the impedance matching are narrower than Ant. 2. In Ant 4 impedance matching is promising to enhance and in Ant. 4 by inserting two elliptical slots instead of rectangular slot the impedance bandwidth is really enhanced. It is noticeable to be mentioned that the coupling between the strip and the ground plane provides the necessary capacitive loading whereas the strip itself contributes to the inductance value of the resonator [9].In order to achieve wider operation bandwidth of the designed antenna has round corners on the radiated patch[10]. Meanwhile, the proposed antenna exhibits almost omnidirectional radiation pattern, and low cross polarization.An Agilent 8722ES Vector Network Analyzer has been applied to measure S11 and impedance bandwidth. The simulated and measured return loss of the realized antenna is plotted.Fig. 7.illustrates that the fabricated antenna operated over the wide frequency band of 3-18GHz. Great agreement is observed between the simulated and measured results. The small difference may be due to the SMA connector and soldering effects. For the fabricated antenna, gain and radiation patterns at sampling frequencies of 9 and 13GHz are also measured. The measured gain of the antenna is seen in Fig.8. The antenna gain is varying from about1.6 to 4.25 dBi across the entire bandwidth. Note that due to skin effect at higher frequencies, the radiation efficiency decreased and the gain is decreased by increasing the frequencies.The y–z plane and the x–z plane are selected to show the antenna radiation patterns referred to as E–plane and H–plane, respectively. Fig. 9.depicts the antenna normalized radiation pattern co-polar at 9 and 13 GHz. It is clear that the proposed antenna has an acceptable quasi omnidirectional pattern required to receive information signals from all directions.

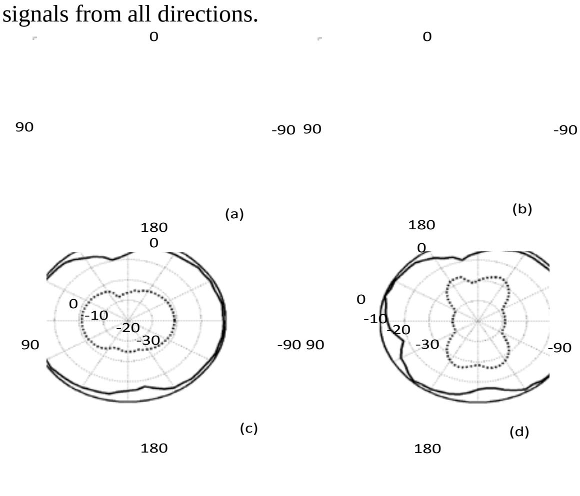

Fig. 9. Normalized patterns of the fabricated antenna in H-plane at (a) 9GHz (b) 13GHz, and E-plane at (c) 9GHz (d) 13GHz. solid lines: Co-Polar, dash lines: Cross-polar.

Time-Domain Analysis

In this portion, more is used from CST software to analyse the antenna in time domain. In UWB systems, the information is transmitted using short pulses. Hence, it is important to study the temporal behavior of the transmitted pulse. The communication system for UWB pulse transmission must limit distortion, spreading and disturbance as much as possible. Group delay is an important parameter in UWB communication, which represents the degree of distortion of pulse signal. The key in UWB antenna design is to obtain a good linearity of the phase of the radiated field because the antenna should be able to transmit the electrical pulse with minimal distortion. The group delay is usually used to evaluate the phase response of the transfer function because it is defined as the rate of change of the total phase shift with respect to angular frequency. Ideally, when the phase response is strictly linear, the group delay is constant.

$$\text{groupdelay} = -\frac{d\theta(w)}{dw} \qquad (1)$$

As depicted from Fig.10, the group delay variation is less than 0.8ns over the frequency band which ensure us pulse transmitted or received by the antenna will not distort seriously and will retain its shape.

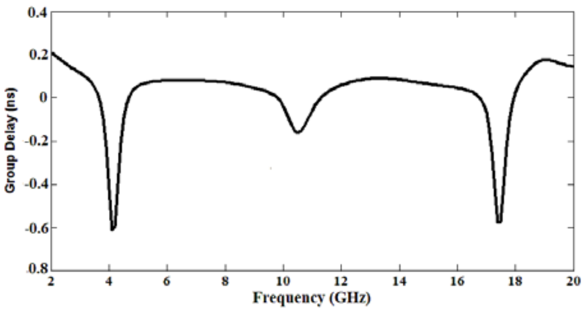

Fig. 10.Simulated group delay versus frequency for the proposed antenna.

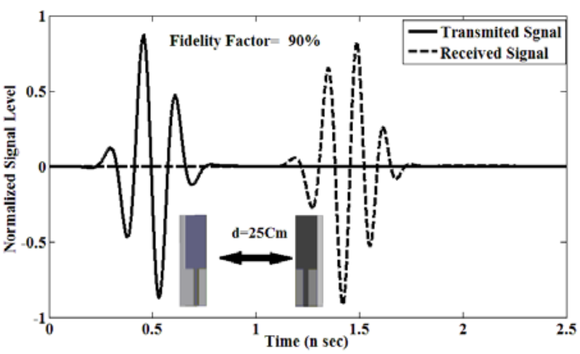

Fig. 11.Simulated transmitted and received pulses by the simulator CST in the position face to face

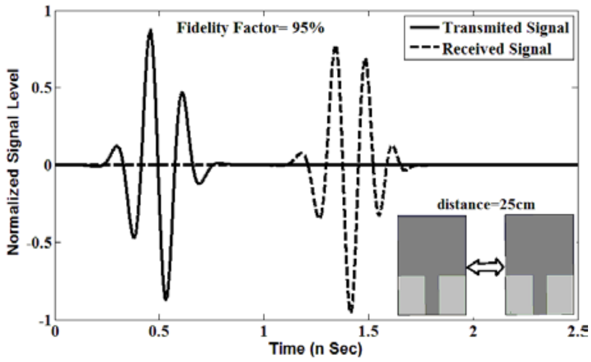

Fig. 12.Simulated transmitted and received pulses by the simulator CST in the position side by side.

In spite of it, therefore, the proposed antenna is suitable for modernUWB communication systems. Transient response of the antenna is studied by modeling the antenna by its transfer function. The transfer function is transformed to time domain by performing the inverse Fourier transform. Seventh derivative of a Gaussian function is selected as the transmitted pulse. Therefore the output waveform at the receiving antenna terminal can therefore be expressed by convoluting the input signal and the transfer function. The input and received wave forms for the face-to-face and side-by-side orientations of the antenna are shown in Fig.11 ,12. It can be seen that the shape of the pulse is preserved in all the cases. Using the reference and received signals, it becomes possible to quantify the level of similarity between signals. In telecommunication systems, the correlation between the transmitted (TX) and received (RX) signals is evaluated using the fidelity factor (1)

$$F = \max_{\tau}\left|\frac{\int_{-\infty}^{+\infty} S(t)r(t-\tau)dt}{\sqrt{\int_{-\infty}^{+\infty} S(t)^2 \cdot \int_{-\infty}^{+\infty} r(t)^2\, dt}}\right| \qquad (1)$$

Where S(t) and r(t) are the TX and RX signals, respectively. For impulse radio in UWB communications, it is necessary to have a high degree of correlation between the TX and RX signals to avoid losing the modulated information. However for most other telecommunication systems, the fidelity parameter is not that relevant. In order to evaluate the pulse transmission characteristics of the proposed UWB antenna, two configurations (side-by-side and face-to-face orientations) were chosen. The transmitting and receiving antennas were placed in a d=250 mm distance from each other. As shown in Fig. 11,12 although the received pulses in each of two orientations are broadened, a relatively good similarity exists between the RX and TX pulses. Using (1), the fidelity factor for the face-to-face and side-by-side configurations were obtained equal to 0.90 and 0.95, respectively. Values the fidelity factor show that the antenna imposes negligible effects on the transmitted pulses. The pulse transmission results are obtained using CST.

CONCLUSIONS

A new compact monopole microstrip antenna is proposed for UWB applications. We showed that by sequentially embedding three pairs of notches with the proper dimensions and positions and use round corners, in the square patch, very good impedance matching and improved bandwidth are obtained. The measured results illustrate that the proposed antenna offers a very wide bandwidth from 3.1 to 18 GHz for VSWR <2 and stably omnidirectional H-plane patterns up to 16 GHz. This antenna has a simple structure, compact size and low cost, therefore it will be an attractive candidate for UWB applications.

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