INTERNATIONAL JOURNAL OF COMPUTATIONAL MATHEMATICAL IDEAS (IJCMI)
A Monthly Journal of Engineering
ISSN 0974-8652

COMPACT UWB ANTENNA DESIGN USING ROUNDED INVERTED L SHAPED SLOTS AND BEVELED ASYMMMETRICAL PATCH

ANUMOLU BHANUPRIYA [1] M SUSEELA [2]
[1] M.Tech Student, Dept of ECE, Mandava Institute of Engineering & Technology, Krishna, A.P., India
[2] Associae Professor, Dept of ECE, Mandava Institute of Engineering & Technology, Krishna, A.P., India

Volume 21 Issue-1 NOV-DEC 2020

ABSTRACT

A compact ultra-wideband (UWB) antenna with simple structure is presented. To achieve UWB performance with a compact size, two open ended rounded inverted L-shaped slots are etched on the square ground plane. Moreover, further bandwidth enhancement is obtained by cutting a bevel on the asymmetrical radiating patch. The antenna is fed by a 50Ω microstrip line and has a small size of 28 × 28 × 1.6mm3. The simulation time- and frequency-domain results obtained from HFSS simulator package are verified by experimental measurements. Both simulated and measured results show that the antenna can provide a wide impedance bandwidth of more than 129% from 2.7 to 12.55 GHz with −10- dB reflection coefficient. Besides, it is shown that by introducing several antenna designs, the impedance bandwidth can be enhanced from 58% to 129%. The effects of the key design parameters on the antenna impedance bandwidth are also investigated and discussed. Measured results for the reflection coefficient,far-field radiation patterns, radiation efficiency, gain, and group delay of the designed antenna over the UWB spectrum are presented and discussed. Measured data show good concordance with the numerical results. Also, the fidelity factor is calculated in both *E*- and *H*-plane by using CST Microwave Studio. The obtained results in both time- and frequency-domain indicate that the antenna is a good optionfor UWB applications.

INTRODUCTION

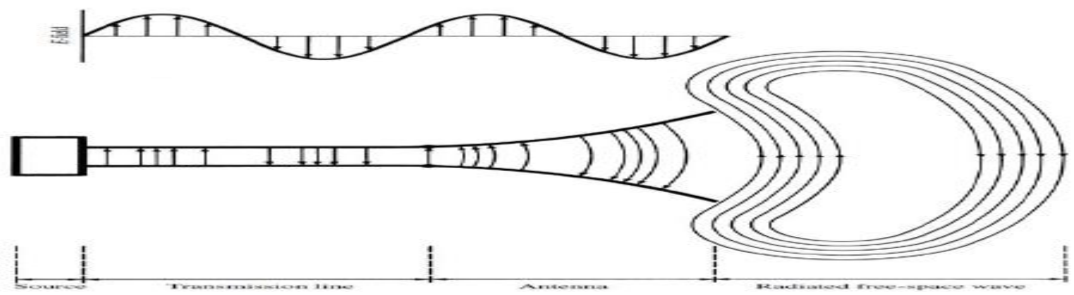
Over the past decade ultra-wideband (UWB) technology has attracted much attention of large number of researchers. UWB wireless communication system covers a very wide spectrum of frequencies that ranges from 3.1 to 10.6GHz [1]. As antennas are key components of any UWB wireless system, it is essential that they have UWB performance particularly with respect to impedance and radiation characteristics. Also, in these systems, high-performance antennas are required to have the characteristic of low- profile [2–4]. Compared with the traditional wide band antennas such as Vivaldi, log-periodic and spirals, slot antenna becomes an attractive candidate to realize a broadband and UWB characteristics due to its low profile, wide bandwidth, compact size, low cost, and ease of fabrication as well as easy integration in active components and monolithic microwave integrated circuits [5–8].

In the last few years, to improve the impedance bandwidth of planar slot antennas, several techniques have been proposed. One method is to use different geometries of slots [9–16], and the other techniques use several tuning stubs to achieve wideband performance [17, 18]. Among different slot geometries, those worthwhile mentioning are binomial-curve [9], annular-ring [10], fractal [11], rhombus [12], elliptical and circular [13], rectangle [14], triangle [15], and square [16]. The impedance bandwidths of these antennas are less than 104%. In [17], by using a coplanar waveguide (CPW) feed with a widened tuning stub, a square slot antenna with dimensions of 72mm × 72mm can yield a bandwidth of 60%. The design of a UWB CPW-fed slot antenna etched on a 0.813-mm-thick substrate with a U-shaped tuning stub for bandwidth enhancement is presented in [18]. It features an impedance bandwidth of 110% and bidirectional radiation patterns with an average gain of about 2 dBi. A round corner rectangular wide-slot antenna with a size of 68×50mm2 is proposed in [19]. The impedance bandwidth of the antenna with −10-dB reflection coefficient is almost two octaves form 2.08 to 8.25 GHz. In [20], a printed slot antenna loaded with small heptagonal slots is investigated. The small perturbations are added in the corners of the main slot antenna to provide a multi-resonance operation. As a result, a wide impedance bandwidth of 105.3% is achieved. Two printed slot antennas with equal sizes of 110mm × 110mm and impedance bandwidths of 120% (1.82 to 7.23GHz) and 110% (2.42 to 8.48GHz) are presented in [21]. In [22], based on a rotated square slot resonator a printed slot antenna with a parasitic patch for bandwidth enhancement is proposed. By properly choosing the suitable slot shape, embedding the similar parasitic patch shape, and tuning their dimensions, a wide operating bandwidth ranging from 2.225 to 5.355GHz is obtained. An open-slot antenna with a wide impedance bandwidth of 122% is designed in [23]. Two bevels are cut on the patch to enhance the impedance bandwidth. A compact CPW-fed antenna with a half-elliptical-edged monopole radiator and two symmetrical open circuit stubs extended from the ground plane is proposed in [24]. Its impedance bandwidth ranges from 3.7 to 10.1GHz. Two UWB CPW-fed printed antennas with dimensions of 50mm×50mm and 48mm×42mm and impedance bandwidths of 118.8% and 125% are reported in [25] and [26], respectively. Recently, a bandwidth-enhancement method of using a new radiator with a hybrid square-circular configuration and a rectangular open slotted ground plane with a pair of symmetrical I-shaped tuning stubs was introduced to implement a CPW-fed planar monolayer UWB antenna with a size of 44mm × 32mm × 1.6mm [27].

In this work, a low-profile asymmetrical microstrip-fed UWB antenna with a simple structure is designed and successfully implemented. The novelty of the proposed design lies in its simple configuration and simplicity to obtain the desired antenna characteristics in both time- and frequency domain. Multiple resonances and consequently UWB performance with a compact size are achieved by etching two open ended rounded inverted L-shaped slots on the square ground plane. Also, further bandwidth enhancement is obtained by cutting a bevel on the asymmetrical radiating patch. The simulation time- and frequency-domain results obtained from CST simulator package are verified by experimental measurements. Measured results show that the proposed antenna has a wide impedance bandwidth of more than 129% from 2.7 to 12.55 GHz (for $|S11| < -10$ dB) which can cover the whole UWB spectrum (3.1–10.6 GHz). In addition, the antenna has a simple structure with a small size of 28mm×28mm×1.6mm. Compared with the recent designs presented in [25] and [26], the designed antenna has a smaller size and wider bandwidth. This comparison reveals the advantages of the proposed antenna. The development stages of the proposed antenna are presented, and several designs are investigated. It is shown that by introducing several antenna designs, the impedance bandwidth can be enhanced from 58% to 129%. The effects of the key design parameters on the antenna impedance bandwidth are also investigated and discussed. Measured results for the reflection coefficient, far-field radiation patterns, radiation efficiency, gain, and group delay of the designed antenna over the entire frequency band of interest are presented and compared with the simulation outcomes.

ANTENNAS:

An antenna is defined by Webster's Dictionary as "a usually metallic device (as a rod or wire) for radiating or receiving radio waves." The IEEE Standard Definitions of Terms for Antennas (IEEE Std 145–1983) defines the antenna or aerial as "a means for radiating or receiving radio waves." In other words the antenna is the transitional structure between free space and a guiding device, as shown in Figure. The guiding device or transmission line may take the form of a coaxial line or a hollow pipe (waveguide), and it is used to transport electromagnetic energy from the transmitting source to the antenna, or from the antenna to the receiver. In the former case, we have a transmitting antenna and in the latter a receiving antenna. A transmission-line Thevenin equivalent of the antenna system of Figure in the transmitting mode is shown in Figure where the source is represented by an ideal generator, the transmission line is represented by a line with characteristic impedance c, and the antenna is represented by a load $Z_A[Z_A = (R_L + R_r) + jX_A]$ connected to the transmission line. The Thevenin and Norton circuit equivalents of the antenna are also shown in Figure. The load resistance *RL* is used to represent the conduction and dielectric losses associated with the antenna structure while *Rr*, referred to as the radiation resistance, is used to represent radiation by the antenna. The reactance XA is used to represent the imaginary part of the impedance associated with radiation by the antenna. Under ideal conditions, energy generated by the source should be totally transferred to the radiation resistance *Rr*, which is used to represent radiation by the antenna. However, in a practical system there are conduction-dielectric losses due to the lossy nature of the transmission line and the antenna, as well as those due to reflections (mismatch) losses at the interface between the line and the antenna. Taking into account the internal impedance of the source and neglecting line and reflection (mismatch) losses, maximum power is delivered to the antenna under conjugate matching.



antenna as a transition device

The reflected waves from the interface create, along with the traveling waves from the source toward the antenna, constructive and destructive interference patterns, referred to as standing waves, inside the transmission line which represent pockets of energy concentrations and storage, typical of resonant devices. A typical standing wave pattern is shown dashed in Figure, while another is exhibited in Figure. If the antenna system is not properly designed, the transmission line could act to a large degree as an energy storage element instead of as a wave guiding and energy transporting device. If the maximum field intensities of the standing wave are sufficiently large, they can cause arching inside the transmission lines.

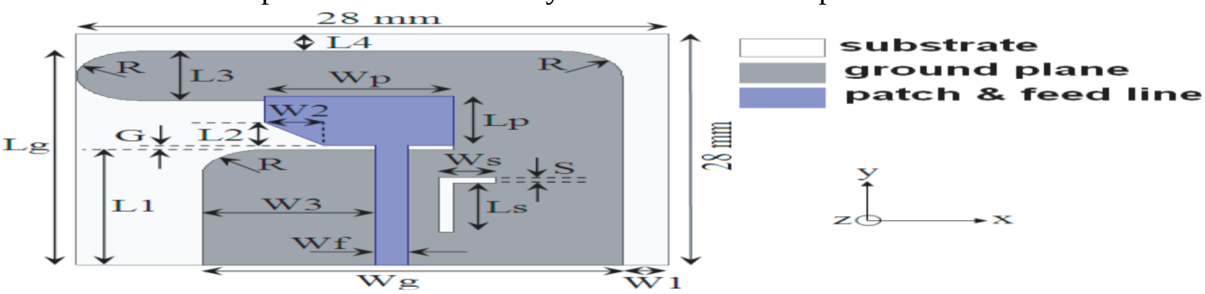
ANTENNA DESIGN

Figure shows the geometry and design parameters of the proposed antenna. As shown in this figure, the proposed structure has a truncated rectangular radiator which is fed asymmetrically by a 50Ω microstrip line. In order to accomplish UWB performance of the antenna two open ended inverted L-shaped slots are etched on the square ground plane and the corners of the open-ended L-shaped slots are rounded. Moreover, to improve the impedance matching of the antenna, a small inverted L-shaped slot is etched on the ground plane in the bottom side of the antenna. The designed antenna with the total area of 28mm × 28mm was printed on an FR4 substrate with a relative permittivity of $\varepsilon r = 4.4$, thickness of 0.8mm, and loss tangent of 0.02. The geometrical parameters of the radiator and ground plane are as follows: *Lg* = 26 mm, *Wg* = 20 mm, *Wf* = 1.53 mm, *Lp* = 6 mm, *Wp* = 9 mm, *Ls* = 6mm, *Ws* = 2.7 mm, *S* = 0.7

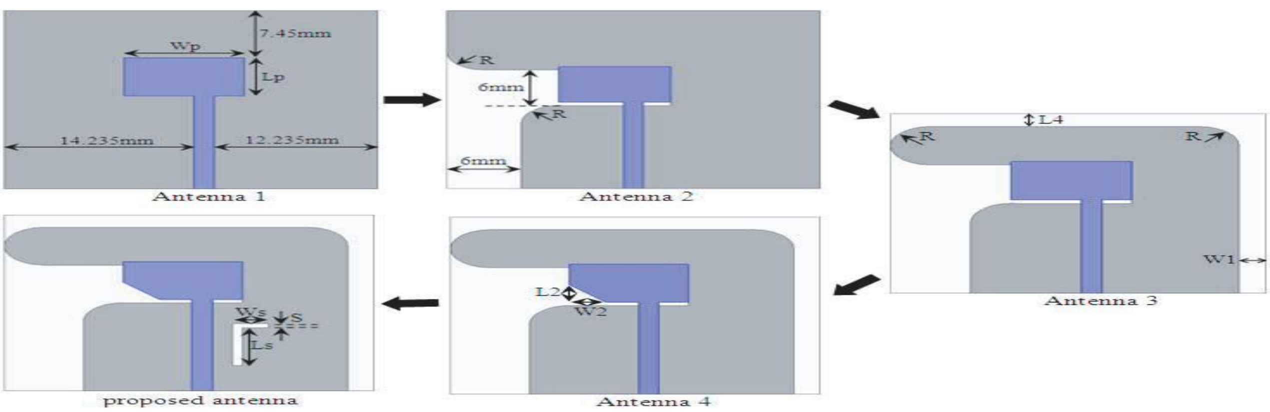
mm, $L1$ = 14 mm, $L2$ = 2.75, $L3$ = 6 mm, $L4$ = 2 mm, $W1$ = 2 mm, $W2$ = 2.75 mm, $W3$ = 8.235mm, R = 3 mm, and G = 0.55mm. The numerical analysis and geometry refinement of the proposed antenna are performed by using CST, a full-wave electromagnetic simulator package which is based on the finite element method. As will be shown in the following, by using the aforementioned techniques, multiple resonances and consequently a broad bandwidth of 129% (2.7 to 12.55 GHz for $|S11| < -10$ dB) can be obtained.

The development stages of the proposed antenna are illustrated in Figure 6.2, and the corresponding simulated reflection coefficient curves are plotted in Figure 6.3. The design procedure begins with the design of Antenna 1. As shown in Figure 6.2, Antenna 1 consists of square ground plane (28mm × 28mm) and a rectangular radiator which is asymmetrically fed by a 50Ω microstrip line. Referring to Figure 6.3, it can be observed that Antenna 1 provides a −10-dB reflection coefficient bandwidth of about 4.5% from 7.6 to 7.95GHz. After etching the first open ended inverted L-shaped slot on the square ground plane and rounding the corners of the slot (Antenna 2), multiple resonances are generated and the antenna can get multiband operation with −10-dB impedance bandwidths of about 19% (2.8–3.4GHz), 58% (4.6–8.4GHz), 9.8% (9.7–10.7 GHz), and 9.1% (11.5–12.6 GHz), respectively. In the next step, the second open ended inverted L-shaped slot is etched on the ground plane (Antenna 3), and as depicted in Figure 6.3, dual-band operation with two impedance bandwidths of 120% (2.7–10.8GHz) and 4.8% (12.1–12.7 GHz) is resulted. In this case, Antenna 3 satisfies the requirement for UWB systems.

Afterwards, to enhance the impedance bandwidth of the antenna, one corner of the radiator is truncated (Antenna 4) and as shown in Figure 3, the fourth resonant frequency is occurred at about 11 GHz. As a result, Antenna 4 can cover the broad frequency range of 2.7–12.55 GHz. However, in the last step of the antenna design, to improve the impedance matching of the antenna at the middle frequencies (6.5 and 9.5GHz), a small inverted L-shaped slot is etched on the ground plane (proposed antenna). As illustrated in Figure 3, the proposed antenna features good impedance matching over the entire frequency range of 2.7–12.55 GHz. Its impedance bandwidth is more than 129% for $|S11| < -10$ dB. The evolution procedure discussed above clearly shows that the two open ended inverted L-shaped slots corner truncated radiator, and small inverted L-shaped slot collaboratively establish the UWB performance of the antenna.

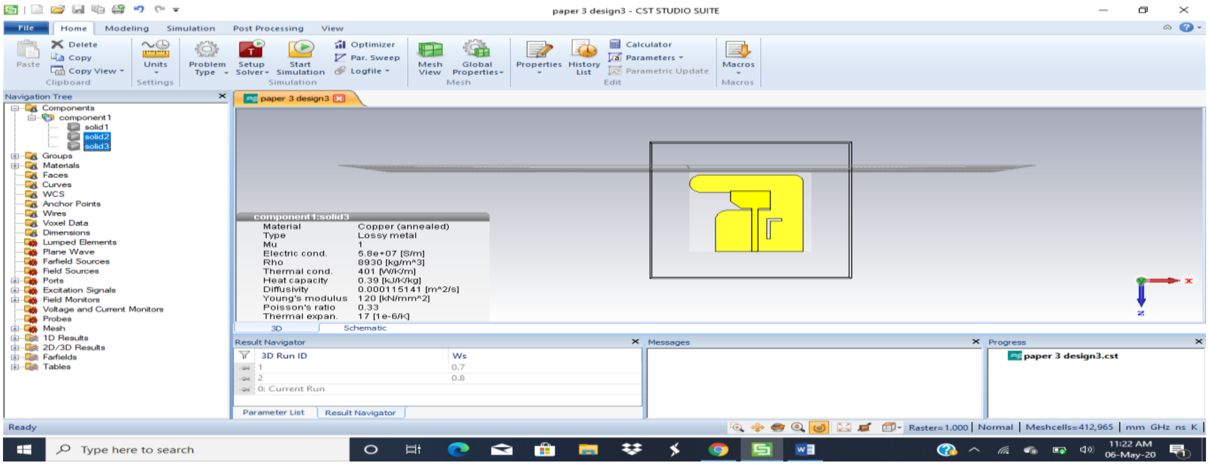


Geometry and design parameters of the proposed antenna.

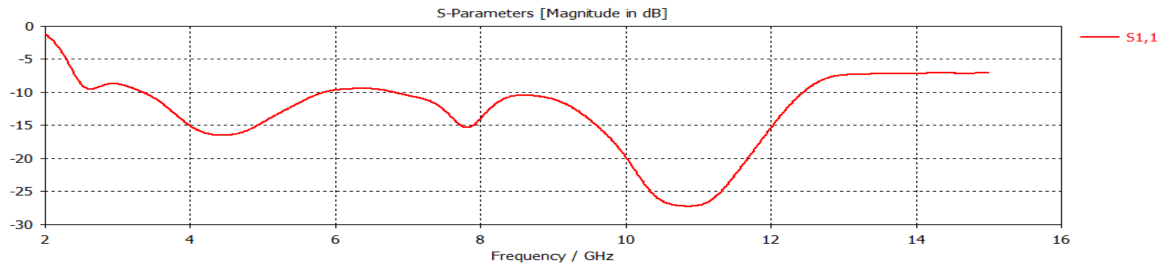


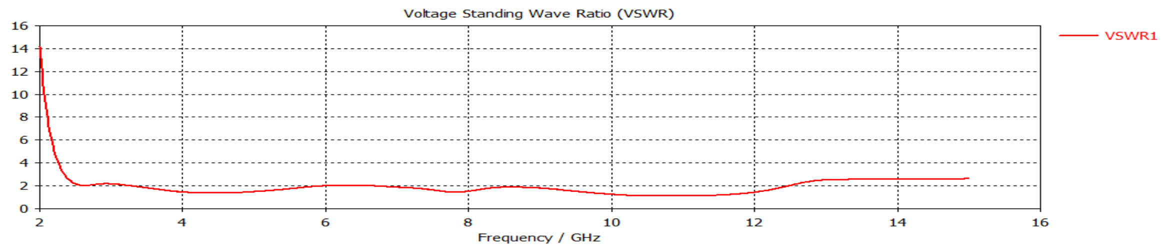
Stages of the antenna design.

DESIGN



RESULTS :





CONCLUSION

This paper presents a compact planar UWB antenna with simple structure. In order to jointly achieve UWB performance with a compact size, two open ended rounded inverted L-shaped slots are etched on the square ground plane. Further bandwidth enhancement is obtained by cutting a bevel on the asymmetrical radiating patch. Moreover, to improve the impedance matching of the antenna at the middle frequencies, a small inverted L-shaped slot is etched on the ground plane. The experimental and numerical results of the proposed antenna in both time- and frequency-domain have been presented and discussed. Measured results show that the proposed antenna with a small size of 28× 28× 1.6 mm3 has a wide impedance bandwidth of more than 129% from 2.7 to 12.55 GHz (for $|S11| < -10$ dB). The evolution procedure of the proposed antenna is presented and several designs are investigated. It is shown that by introducing several antenna designs, the impedance bandwidth can be enhanced from 58% to 129%. A numerical sensitivity analysis has been carried out to understand the effects of the key design parameters on the antenna impedance bandwidth. Experimental results for the reflection coefficient, far-field radiation patterns, radiation efficiency, gain, and group delay of the designed antenna are presented and compared with the simulation data. Also, the fidelity factor is calculated in both E- and H-planes by using CST Microwave Studio. Compared with the recent designs presented in [25] and [26], the designed antenna has a smaller size and wider bandwidth. The measured outcomes show that the antenna is a competent option for the use in UWB communication systems.

REFERENCES:

[1] Siwiak K, McKeown D, pp. 97–111 Ultra wideband radio technology; 2005.
[2] Latif SI, Shafai L, Sharma SK. Bandwidth enhancement and size reduction of microstrip slot antennas. IEEE Trans Antennas Propag 2005;53: 994–1003.
[3] Ma TG, Tseng CH. An ultra wide band coplanar waveguide-fed tapered ring slot antenna. IEEE Trans Antennas Propag 2006;54:1105–11.
[4] Behdad N, Sarabandi K. A multiresonant single element wide-band slot antenna. IEEE Trans Antennas Propag 2005;53:994–1003.
[5] Jan JY, Su JW. Band width enhancement of a printed wide slot antenna with a rotated slot. IEEE Trans Antennas Propag 2005;53:2111–4.
[6] MaTG, Jeng SK. Planar miniature tapered slot fed annular slot antennas for ultra wide band radios. IEEE Trans Antennas Propag 2005;53:1194–202.
[7] JoongHan Yoon. Triangular slot antenna with a double T shaped tuning stub for wide band operation. Microw Opt Technol Lett 2007;49:2123–8.
[8] Ma TG, Jeng SK. A printed dipole antenna with tapered slot for ultra wide band applications. IEEE Trans Antennas Propag 2005;53:3833–6.
[9] Lin YC, Hung KJ. Compact ultrawideband rectangular aperture antenna and band-notched designs. IEEE Trans Antennas Propag 2006;54:3075–81.
[10] Garg R, Bhartia P, Bahl I, Ittipiboon A. Microstrip antenna design handbook. Norwood, MA: Artech House; 2001.