International Journal of Communication Systems and Network Technologies
ISSN-2053-6283

A CPW-Fed Circular Microstrip Patch Antenna for UWB Applications

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***Abstract*— A design of circular microstrip patch antenna with Coplanar Waveguide (CPW) feeding for Ultra-Wide Band (UWB) applications has been presented. The proposed antenna is designed in CST simulation software for frequency range between 3.1 GHz and 10.6 GHz. The proposed antenna contains a circular radiation patch modified with a U-shape and an inverted U-shape slot and provided with CPW feeding for ease of integration with other microwave components. The antenna is of compact size 70 mm × 70 mm × 0.794 mm and obtains a maximum gain of 5.01 dBi and peak directivity of 7.58 dB at 8.72 GHz frequency. The antenna achieves a radiation efficiency of 99% and a VSWR of smaller than 2 across the UWB frequency range. Thus, the suggested antenna is suitable for UWB applications, offering a wide bandwidth, compact size, and stable radiation characteristics.**

Keywords*— circular microstrip patch antenna, CPW fed, ultra-wide band, gain, directivity.

I. INTRODUCTION

Antennas play a crucial role in modern communication systems by enabling the transfer of electromagnetic waves between different devices. Antennas serve as the interface between the transmission and reception of electromagnetic waves, enabling efficient and reliable communication between devices. [1] In recent years, the demand for high-performance antennas has grown significantly due to the increasing need for high-speed data transfer and connectivity in various industries. Antenna technology has evolved rapidly to meet these demands, with advancements in design, fabrication, and testing methods. Antennas have become an indispensable part of modern communication systems, enabling seamless connectivity and communication across different devices and networks. [2]

A circular MPA (microstrip patch antenna) is a type of antenna which contains a circular patch of conductive material mounted on the combination of ground plane and dielectric substrate. The circular shape of patch offers several advantages over other patch antenna shapes, such as rectangular or square. The circular shape provides a wider bandwidth, better impedance matching, and better radiation patterns.[3-5] Additionally, circular MPA can be easily designed to work in broad frequency ranges, including the UWB freq range. Circular MPA are commonly used in present day communication systems due to properties like low profile, small size, and simplicity of fabrication. They are commonly used in wireless communication systems, satellite communication systems, and radar systems.[6-7]

In March 2002, the US American FCC Standard approved the low power communicative devices for short distances in range between 3.1 GHz and 10.6 GHz.[8] Ultra-wideband (UWB) antennas are essential components of modern communication systems that require high-speed data transfer and connectivity. UWB antennas are particularly important in applications where high data transfer rates are required, such as in wireless communication systems.[9] UWB antennas enable high-speed data transfer rates by allowing the transmission of signals over a large frequency range. This capability is especially important in applications such as multimedia streaming, where large amounts of data need to be transmitted quickly and efficiently. In addition to high-speed data transfer, UWB antennas also offer several other advantages. They are highly resistant to interference and can penetrate obstacles such as walls, making them suitable for indoor communication applications.[10] UWB antennas can also be used for precise location tracking, such as in asset tracking and monitoring applications. For these reasons, the circular MPA is designed for the UWB range applications.[11-12]

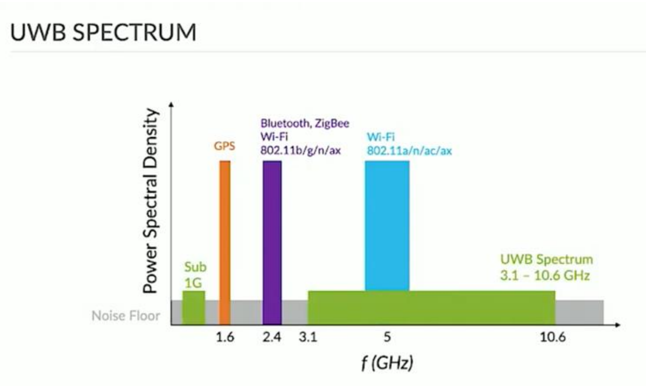

Fig. 1. Ultra-Wide Band Spectrum[13]

In this proposed research work, the circular MPA designed for UWB applications is provided with CPW feeding technique. CPW-fed (Coplanar Waveguide-fed) refers to a type of feeding mechanism used in microstrip antennas, where the signal is fed to the antenna through a coaxial probe, which is connected to the antenna through a coplanar waveguide transmission line. In this configuration, the signal is transmitted along the centre conductor of the coaxial probe and then is coupled into the CPW transmission line. The CPW transmission line is a type of transmission line that comprises of a conducting strip placed between two ground planes. The ground planes and strip are made of copper or other conductive material. CPW-fed antennas have several advantages over other feeding mechanisms.[14-15] They provide a wider bandwidth, improved impedance matching, and better radiation patterns. They also have a low profile, making them suitable for use in compact electronic devices.

This research paper aims to present a study on the design and implementation of a circular MPA provided with coplanar waveguide feeding for UWB applications. The demand for UWB systems has been growing rapidly in current era because of their unique features and advantages in wireless communication systems. The proposed antenna is designed to work in UWB freq. range, which spans from 3.1 GHz to 10.6 GHz.

The paper will provide an overview of the fundamental concepts of microstrip patch antennas and CPW-fed structures, along with the analysis of the present research works in UWB antennas. The proposed antenna design will be presented, including the dimensions and specifications necessary for its construction. The performance characteristics of the antenna will also be evaluated through various simulations and measurements, such as s-parameters, gain, return loss and radiation pattern. Finally, the results will be discussed, and the potential applications of the antenna will be highlighted, showing its suitability for UWB systems in various communication applications, like radar system, wireless comm systems & medical imaging.

II. Literature Survey

In recent times, circular microstrip patch antennas have drawn lot of interest because of its low profile, simplicity in construction and suitability for various applications. Additionally, these antennas have several advantages over other patch antenna shapes, like broader bandwidth, better impedance matching, and superior emission patterns.

CPW-fed (Coplanar Waveguide-fed) antennas have become popular due to their wide bandwidth, improved impedance matching, and better radiation patterns.

Several studies have investigated the design and performance of CPW-fed circular patch antennas for UWB applications. For example, the study in [16] shows a circular MPA that was suggested for use in UWB application.

In another study by KM Jyoti Singh[17], a circular MPA with single band notch characteristic was designed and fabricated. The antenna was created on FR4 Epoxy substrate with suitable dimensions and € of 4.3.

The research work of various researchers [18-19] shows the structure and working of circular MPA for different applications. In summary, CPW-fed circular patch antennas have gained significant attention due to their wide bandwidth, improved impedance matching, and better radiation patterns. So, the presented circular MPA is provided with CPW feeding and operates on 3.1GHz to 10.6GHz which makes it suitable for various UWB applications.

III. Antenna Design And Geometrical Details

The proposed circular microstrip patch antenna is made on an epoxy substrate made of FR-4 (Flame Retardant material) measuring 0.794 mm in height, with a permittivity of 4.3 and tan ξ of 0.025. Dimensions of the substrate are 70 mm × 70 mm × 0.794 mm. The upper radiating portion consists of a circular patch with a radius of 18 mm determined by the following formula[20] :

$$a = \frac{F}{\left[1 + \frac{2h}{\pi \varepsilon_r F}\left[l_n\left[\frac{\pi F}{2h}\right] + 1.7726\right]\right]^{1/2}}$$

The feeding technique used is CPW feeding(Coplanar Waveguide feeding), due to its small design and good impedance matching. The main feed line is 4 mm wide and the side feeds are of 30 mm × 20.2 mm. After this patch is modified by inserting a U and an inverted U shape structure into it. By optimising the various parameters, antenna for ultra-wide band (3.1-10.6 GHz) applications can be attained. Using the above method, the parameters for the designed antenna can be computed, and the results are displayed in the table drawn below.

TABLE 1 Proposed Antenna Dimensions

Name	Value
wg	70
lg	70
hg	0.035
hs	0.794
r1	18
r2	0
xc	0
yc	6
xf	4
fl	-11
k	15

Below Figure 2 depicts the design of suggested circular MPA.

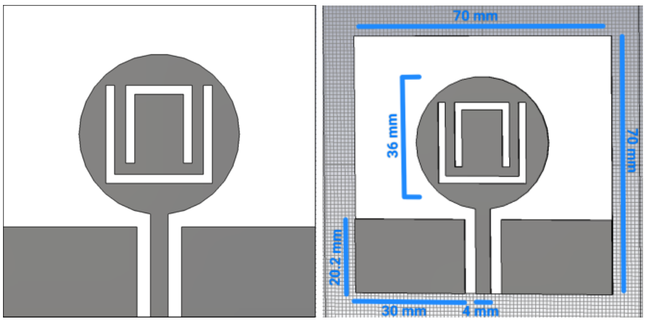

Fig. 2. (a) Circular MPA & (b) proposed antenna with CPW feeding and dimensions

IV. Result And Discussion

The suggested CPW-fed circular MPA is developed and simulated by use of CST Studio Suite simulation software. The simulated results in graphical form like s11 (return loss), RE (radiation efficiency), TE (total efficiency), VSWR, gain, directivity, and RP (radiation pattern) for the developed antenna are as follows:

A. RL (Return Loss)

RL is the graph depicting S11(dB) vs frequency (GHz). The deduced result after simulation shows that the suggested antenna resonates at the three frequencies namely 3.76 GHz, 6.24 GHz and 8.72 GHz which has a return loss of -17.10 dB, -16.06 dB and -22.34 dB respectively and the resonant frequency bandwidth starts from 3.1 GHz and ends with 10.6 GHz. The return loss plot obtained after simulation is as follows:

$$F = \frac{8.791 \times 10^9}{f_r\sqrt{\varepsilon_r}}$$

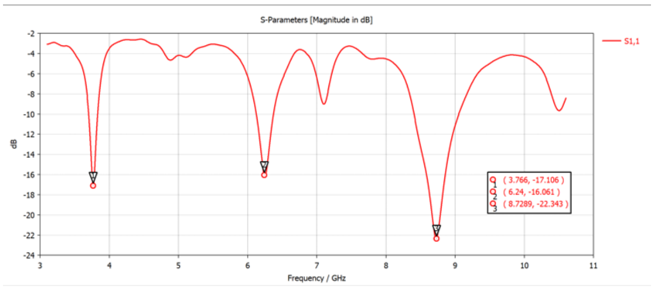

Fig. 3. s11 Parameter of the designed antenna in CST studio suite

B. *VSWR*

When a wave gets reflect because of an impedance mismatch, VSWR is the fraction of the maximum voltage to the minimum voltage along a transmission line is created. For an effective performance, the VSWR range must be between values 1 and 2. The VSWR measured at the intended antenna's resonant frequencies are 1.32, 1.36 and 1.16 for the frequencies of 3.76 GHz, 6.24 GHz and 8.72 GHz respectively. The VSWR plot obtained after simulation is as follows:

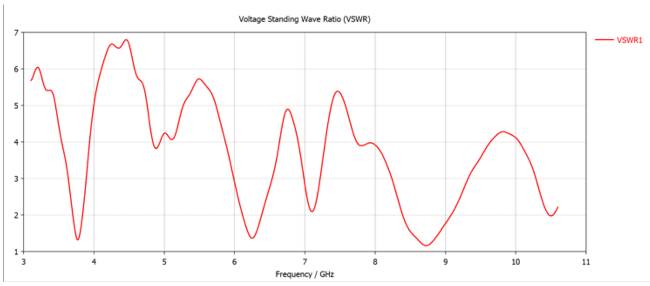

Fig. 4. VSWR plot of the designed antenna

C. *Gain and Directivity*

Gain is defined as the difference between the power density an antenna emits in one direction and the power density an isotropic radiator will emit if the same total power is applied to both. Its unit is dBi, which signifies the logarithmic value of power based on Isotropic Antenna.

Directivity of an antenna is to radiate electromagnetic waves in a particular direction, relative to an ideal isotropic radiator that radiates equally in all directions. It is usually expressed in decibels (dB) and denoted as D or D_o.

The proposed design obtains 4.85dBi of gain and 7.45dB of directivity at 3.76 GHz, 5.01dBi of gain and 7.52dB of directivity at 6.24GHz and 4.92dBi of gain and 7.58dB of directivity at 8.72 GHz. Below figure depicts the change in gain and directivity (in dB) vs frequency.

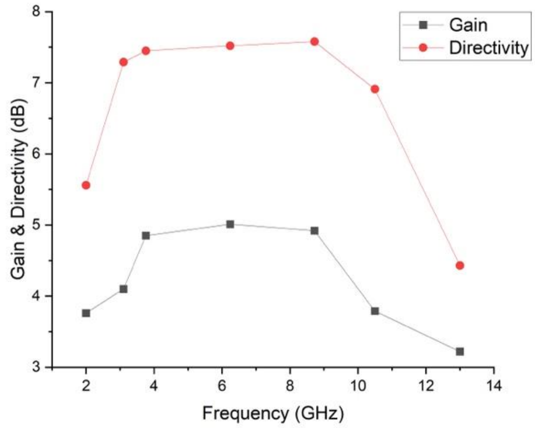

Fig. 5. Proposed antenna gain and directivity plot

D. *Radiation Efficiency (RE) and Total Efficiency (TE)*

RE measures the radiated power by the antenna in relation to the input power to antenna whereas TE is the comparison of the radiated power by the antenna to the total power delivered to antenna, including losses in transmission line and any matching network. From the obtained graph after simulation, we can conclude that for 3.76 GHz RE is 82% & TE is 73%, for 6.24 GHz RE is 91% & TE is 86%, for 8.72 GHz RE is 99% & TE is 91%.

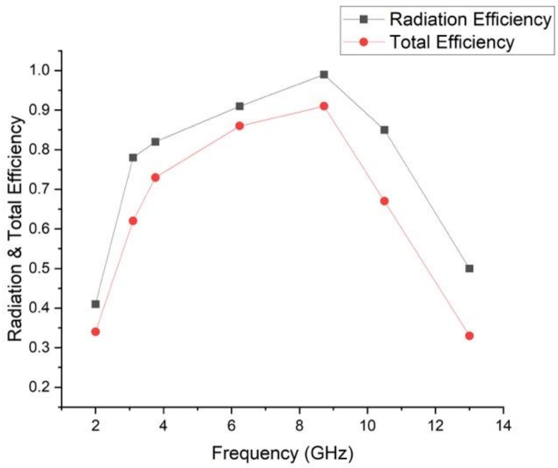

Fig. 5. Proposed antenna radiation and total efficiency plot

E. *RP (Radiation Pattern)*

The RP shows the relative strength and direction of the EM (electro-magnetic) field radiated by the antenna in different directions, as a function of angle or distance from the antenna. The graph attached below depicts the proposed antenna's calculated far field RP for Ø = 90° at the resonant frequencies. The radiation patterns assumed to be steady and omnidirectional.

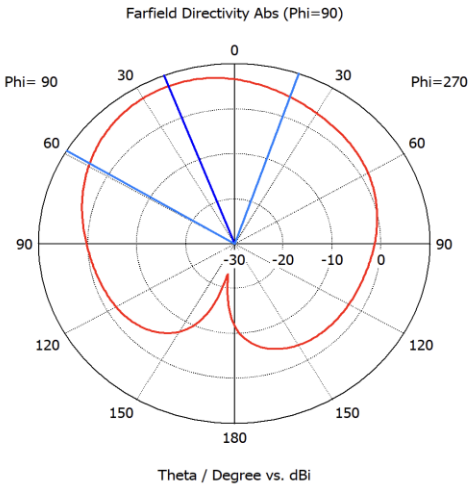

Fig. 7. Presented antenna's far-field emission plot

V. Conclusion

A design of CPW-fed CMPA is suggested in the paper for UWB applications. The proposed antenna has small size, broader bandwidth and stable. RP for the ultra-wide band frequency range.

The simulated results concludes that the suggested antenna has a broad bandwidth from 3.1 to 10.6 GHz, which covers the entire UWB frequency range. The antenna depicts max gain of 5.01 dBi, directivity of 7.58 dB and 99% RE at 8.72 GHz freq. The antenna also shows an excellent RP which is almost omnidirectional in nature. Thus, the designed antenna is acceptable for use in various UWB applications such as radar, imaging, medical, automotive and communication systems. Further research can focus on optimizing the antenna design for specific UWB applications and increasing the antenna's efficiency with respect to gain and directivity.

Acknowledgment

The first author wishes to express their gratitude to the Rajasthan Technical University in Kota, India, for their assistance during the research project and the drafting of the paper.

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