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Design and Performance Analysis of UWB Linearly Polarized Coaxial Fed Circular Patch Antenna for Biomedical Applications

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Abstract: **This paper demonstrates the design and performance analysis of circular patch antenna in the UWB frequency range (3.1-10.6GHz) using coaxial line feeding. The operating frequency is chosen to be at 3.3GHz which makes it perfectly fit for biomedical applications, especially in Wireless Body Area Network (WBAN). Several parameter calculations and performance measurements of this antenna have been computed using CST MW studio suite. The antenna is designed using a substrate of ARLON AD250 with a dielectric constant of 2.5 and Copper is used as patch material. Performance of the antenna is evaluated by measuring centre frequency, VSWR, return loss, radiation pattern, directivity, gain and total efficiency.**

Keywords: **UWB, Coaxial line-fed, WBAN, Return loss, Directivity.**

I. INTRODUCTION

Wireless Body Area Network (WBAN) connects different nodes of a human body with the help of sensors or antennas to a distance health monitoring system by using wireless communication channel. There are several bands available for designing a biocompatible antenna for WBAN which provides a wide range of frequency variation for biomedical applications as shown in TABLE 1.

TABLE 1: FREQUENCY BAND FOR WBAN

Service	Frequency bands
Medical Implant Communication Service (MICS)	402-405MHz
Wireless Medical Telemetry Service	420-450MHz(Japan) 863-870MHz (Europe)
Industrial, Scientific and Medical (ISM)	2.4-2.45GHz
Ultra-Wideband (UWB)	3.1-10.6GHz

The antenna designed for UWB band has small size and high frequency band and hence considered more effective for biomedical applications. Microstrip antennas, also called patch antennas, are very popular antennas in the microwave frequency range because of their simplicity and compatibility with circuit board technology. Rectangular and circular shapes are the most popular patches. The circular patch has similar properties as that of the rectangular patch regarding gain, beam position and efficiency. It has slightly narrower beam width, narrower bandwidth, and smaller physical area.

II. PHYSICAL DESCRIPTION OF ANTENNA

A. *Microstrip Patch Antenna:*

The Microstrip Patch Antenna is a single-layer design which consists generally of four parts (patch, ground plane, substrate, and the feeding part)[1]. The patch is a very thin radiating metal strip (thickness of metal$<<\lambda_0$, where λ_0 is the free space wavelength) located on one side of a non conducting substrate, the ground plane is the same metal located on the other side of the substrate. The substrate layer thickness is 0.01–0.05 of free-space wavelength. It is used primarily to provide proper spacing and mechanical support between the patch and its ground plane. It is also often used with high dielectric-constant material to load the patch and reduce its size. The Substrate material should be low in insertion loss with a loss tangent of less than 0.005.

In this work we have used Arlon AD 250 with dielectric constant of 2.5. Circular patch antennas are usually manufactured by etching the antenna patch element in a dielectric substrate as shown in the Fig.1

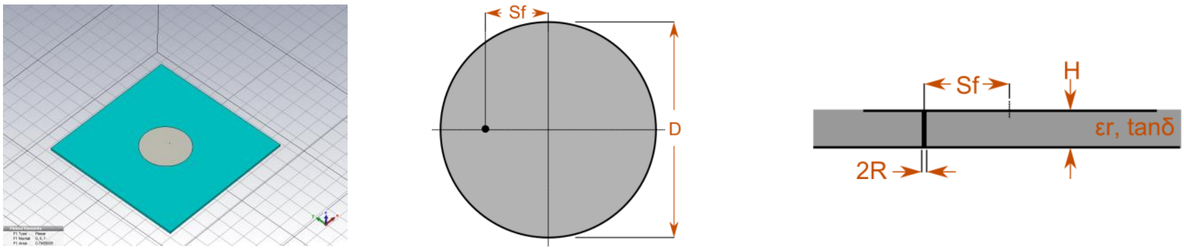

Fig 1: Top and side view of circular patch antenna

B. Feed method:

There are many methods of feeding a microstrip antenna[1]. The most popular methods are:

1. Coaxial Probe (coplanar feed)

2. Microstrip Line.

3. Proximity Coupling.

4. Aperture Coupling.

Because of the antenna is radiating from one side of the substrate, it is easy to feed it from the other side (the ground plane), or from the side of the element. The most important thing to be considered is the maximum transfer of power (matching of the feed line with the input impedance of the antenna).

In this paper, coaxial probe fed or the pin-fed version is considered because this antenna has the simplest construction among microstrip patch antennas. The outer conductor of the coaxial cable is connected to the ground-plane, while the centre conductor is fed through a hole in the substrate / ground-plane and electrically connected to the patch element. The pin-fed patch, which is simple to construct, is fed by making a circular hole in the substrate and ground plane and bringing the centre conductor of a coaxial connector or cable into ohmic contact with the patch at an appropriate point. The point of contact depends mainly on the required centre frequency and input impedance, typically 50 Ω, but also on the suppression of higher order resonant modes. By varying the contact point of the feed, the input impedance changes from a maximum at the patch edge (where voltage is maximum and current is minimum), to zero at the centre of the patch (where voltage is zero and current is maximum).

C. Antenna Design:

Fringing fields act to extend the effective diameter of the patch. Thus, the diameter of the half-wave patch (dominant TM11 mode) is usually less than a half wavelength in the dielectric medium. The electric fringing fields are responsible for radiation. The parameters used for designing the antenna [3] for simulation are as shown in TABLE II.

TABLE I1: PARAMETERS FOR DESIGNING THE ANTENNA

Name	Description	Value
r	Patch radius	15.55mm
Sf	Feed offset	3.375
R	Feed pin radius	0.1875mm
H	Height of substrate	1.5mm
€	Relative permittivity of substrate	2.5
Ls and Ws	Substrate length and width	95.7mm

D. Design guidelines:

Antennas on very thin substrates have high copper losses, while thicker and higher permittivity substrates may lead to performance degradation due to surface waves and feed-pin impedance. The maximum impedance that can be realized is governed by the impedance seen at the edge of the patch. The minimum realizable impedance is zero, at the centre of the patch [2], [4]. However, the practical minimum is governed by the rapid impedance variation as the centre is approached. The use of electrically thick substrates in designs will have degraded matching due to increased feed pin inductance.

The design equation for the actual radius of the patch is given by

$$r = \frac{F}{\left\{1+\frac{2h}{\pi F \epsilon r}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}} \qquad (1)$$

Where $F = \frac{8.791X10^7}{fr\sqrt{\epsilon r}}$ = effective radius and €r is permittivity of the substrate

- Increasing the patch's diameter will decrease the resonant frequency and vice versa.
- Increasing the substrate height will increase the bandwidth, but will decrease the resonant frequency slightly.
- Increasing the substrate height will also result in a more inductive reactance due to the feed pin.
- To increase/decrease the input impedance, increase/decrease the feed offset.
- The circular patch antenna may be fine-tuned for both impedance and centre frequency by the use of trimming stubs, as for the rectangular patch [7].

The reflection coefficient S_{11} and the radiation pattern of the antenna [5], [6] at 3.3GHz is shown in the Fig.2

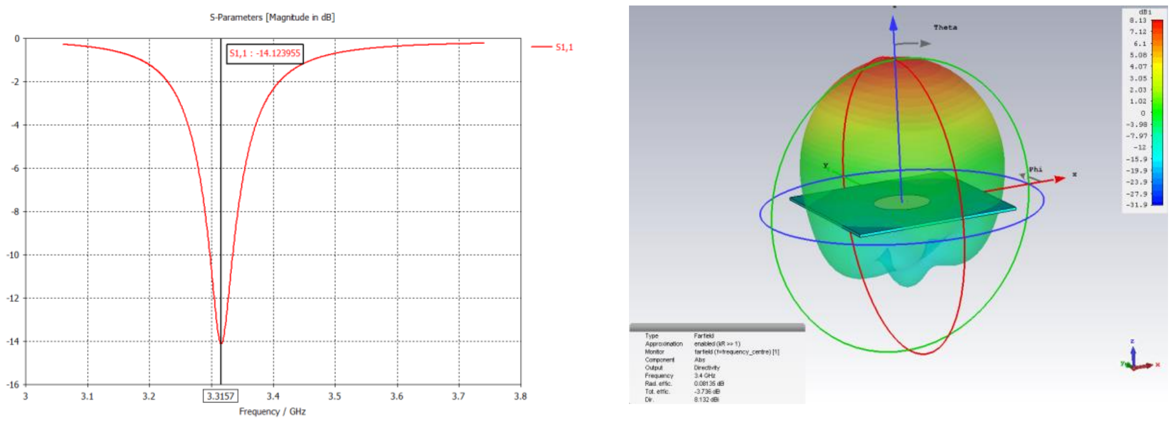

Fig 2: Reflection coefficient and Radiation pattern of the circular patch antenna.

TABLE III: The results of the simulation

Frequency (GHz)	3.3157
Directivity(dBi)	8.132
Gain (IEEE) (dB)	8.213
Realized Gain (dB)	4.396
S11(dB)	-14.12
VSWR	1.489
Radiation Efficiency(dB)	0.081
Total Efficiency(dB)	-3.76
Bandwidth	37.8MHz

III. CONCLUSION

A circular patch with coaxial line feed was designed for 3.3GHz for UWB range using CST MW studio suite applicable for biomedical applications. Return losses of this antenna is -14.12 dB and VSWR is 1.489. The antenna characteristics and radiation pattern are applicable for many wireless applications. This paper examined a compact circular microstrip antenna for use within UWB range. Results are tabulated in TABLE II. Overall findings suggested that a microstrip antenna of this design may have true merit in medical applications and future studies are warranted. Work is in progress to address the specific absorption rate, temperature induced within the surrounding tissues, and experimental characterization of the antenna in different operating environments.

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