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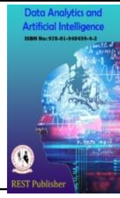

Design of Tri-Band Microstrip Array Antenna of Ultra-Wide Band for Medical Application

***[1] J. Joselin jeya sheela, [2]M. Logeshwaran, [2]M.G. Kumara vijay, [2]B. Jagadeeshwaran**
[1]Saveetha School of Engineering, Tamil Nadu, India.
[2]R.M.K Engineering College, R.S.M. Nagar, Kavaraipettai, Tiruvallur District, Tamil Nadu, India
*Corresponding author Email: joselinmoses@gmail.com

Abstract. Ultra-Wide Band (UWB) wireless communications, a developing technology, offers a significantly diverse approaches to wireless technologies than traditional narrow band systems, which generates significant research interest. Because of this, there are a lot of UWB applications that may be studied. Medicine is one of the applications that has a lot of potential. UWB is ideally suited for the medical industry thanks to a few special properties. Ultrawideband (UWB) radio waves are ideal for less intrusive medical applications due to their inherent properties. Medical equipment and wireless communication systems both rely heavily on antenna. Future and contemporary wireless technologies will place more demands on antenna design. This results in Ultra-wideband (UWB) from 3.1GHz to 10.6GHz, a high data rate wireless communication technology and medical equipment.An Ultra-Wide-Band (UWB) microstrip array antenna with a triple resonance frequency of 3.63 GHz, 3.86 GHz, and 5.5 GHz, has been developed to aid for medical application. The planned antenna features a copper patch and a 4x1 array configuration, etched on a FR-4 (lossy) substrate, with a dielectric constant of 4.4. (pure). CST Studio Suite simulates the intended antenna. The antenna parameters have been analysed in the terms of return loss, VSWR, gain, Directivity, and radiation pattern. Thus, the designed antenna has a satisfactory performance and, cam be implemented for bio-medical application.
Keywords: Medical applications, Ultra-wideband technology, biomedical communication, Ultra-wideband communication, Ultra-wideband antennas, medical diagnostic imaging, Microwave imaging, Patch antenna, Array antenna.

1. Introduction

Ultra-Wideband (UWB) technology has lately acquired favour for Short-range Wireless communications interface [1]. The IEEE 802.15.4a standard has approved UWB as one of the interfaces, for dependable Low-data rate transmission, in WPANs with precision range capabilities [2]. Due to its tremendously low extreme effective isotopically radiated power (EIRP) spectral density of 41.3dBm/MHz, UWB signals naturally exhibit noise-like behaviour. Due to their difficulty in being detected and resistance to jamming, they may do away with the necessity for intricate encryption techniques in small transceivers. These qualities have led to UWB's emergence as a Radio communication Interface option, for medical Wireless Body Area Networks-(WBANs) [3]. UWB signals also pose no danger to the security of patients and do not significantly interfere with other systems running nearby [4]. Impulse radio (IR) transceivers may be made smaller because of their straightforward design and extremely low power consumption [5].

Due to its very appealing characteristics, UWB is now used in a variety of application fields, including wireless communication, radar, and medical engineering [6]. A technology must meet numerous requirements and have the right qualities to be employed in the medical field. Nearly all of the conditions are met by the UWB approach, making it an excellent option for application in medicine. UWB exhibits certain special benefits that have long been admired in the field of mechanical engineering by employing low power ultra-short sub-nanosecond pulses. 1) The ability to pass past barriers due to UWB's high gain. The UWB may use this function to photograph interior human bodily organs for medical purposes. 2) Extremely high multipath resolving precision at the centimetre level thanks to UWB. Because UWB pulses are so brief, they offer excellent spatial and temporal resolution capabilities. UWB is useful for pathologic imaging since high resolution is necessary for medical imaging. 3) Low electromagnetic radiation caused by radio pulses with radio powers below -41.3 db. Hospitals may benefit greatly from the low radiation since it is safe for the human body and has no impact on the environment. 4) Low energy usage, allowing the use of long-lasting battery-operated devices [7].

UWB technology offers a wide range of potential uses in healthcare systems beyond from being utilised as a wireless communication interface [8]. For illustration, IR-UWB radar might be able to spot minute motions within the human body without causing any harm [9]. Utilizing the contrast in dielectric characteristics, UWB medical imaging is a promising method that offers numerous advantages in delivering Low-risk imaging of the interior organs, and tissues of the human body. Thus, for the detection, antennas have been employed in it. As a result, a UWB array antenna that resonates at three different frequencies of 3.63 GHz, 3.86 GHz and 5.5 GHz is created. The parameters are examined for use in medical applications, while the antenna is developed in "CST Studio Suite."

2. Antenna Design

Patch Antenna is a Singlelayer design, with four parts (patch, ground plane, substrate, and, feed). The ground plane is made of the same metal as the patch, which is a thin radiating metal strip, situated on one side of a non-conducting substrate. The metallic patch is often constructed of thin copper foil that has been nickel, tin, or another corrosion-resistant metal plated on it. There are many different designs for patches, but the rectangular and circular patch are the most common. A 4x1 configuration, microstrip patch array antenna is planned. Because the radiation from all the components adds up, the antenna array is chosen for this application because it produces a radiation beam with a high gain, great directivity, and higher performance with fewer losses. With 4.4 as the dielectric constant, the substrate is made of FR-4 (lossy), and the patch and ground layer are made of pure copper. The dielectric substrate's height is important for the Patch antenna because it should not be bulky and because increasing the substrate's height increases the volume of the fringing effects and reduces return loss. This antenna uses Microstrip 50 ohm as its feeding method. The design parameters are been calculated, according to the mentioned equations.

A. Width- (W)

$$W = \frac{c}{2f_o\sqrt{\frac{(\varepsilon_r + 1)}{2}}} \tag{1}$$

B. Effective dielectric Constant-(ε_{eff})

$$\varepsilon_{eff} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{W}\right]^{\frac{1}{2}} \tag{2}$$

C. Effective Length- (Leff)

$$L_{eff} = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} \tag{3}$$

D. Length Extension -(ΔL)

$$\Delta L = 0.412 \times h\,\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)} \tag{4}$$

E. Actual Length of Patch-(L)

$$L = L_{eff} - 2\Delta L \tag{5}$$

$$L = \frac{c}{2f_o\sqrt{\varepsilon_{eff}}} - 0.824h\left(\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W}{h} + 0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W}{h} + 0.8\right)}\right) \tag{6}$$

F. Length of Ground plane-(L_g)

$$L_g = 6h + L \tag{7}$$

G. Width of Ground plane -(W_g)

$$W_g = 6h + W \tag{8}$$

H. Width of Microstripline

$$w = \frac{7.48 \times h}{e^{\left(Z_0\frac{\sqrt{\varepsilon_r + 1.41}}{87}\right)}} - 1.25 \times t \tag{9}$$

3. Antenna Simulation Results

With the aid of the "CST Studio Suite" programme, the Antenna is Drawn. "CST Studio Suite is a powerful collection of 3D EM analysis tools for developing, analysing, and improving electromagnetic (EM) system and component performance. CST Studio Suite is essential for understanding how electromagnetic parts will behave when your devices are out in the real world, before you ever consider pricey, genuine prototyping." It can provide speedy convergence, with a probability of finding a local minimum and offers automatic optimization strategies for both locally and globally occurring issues (local). Alternately, you might conduct a global search, which requires more calculations but results in a detailed study. The parameters mentioned are crucial to study the designed antenna: “Return Loss, VSWR, Gain, Bandwidth, and Directivity” are all elements.

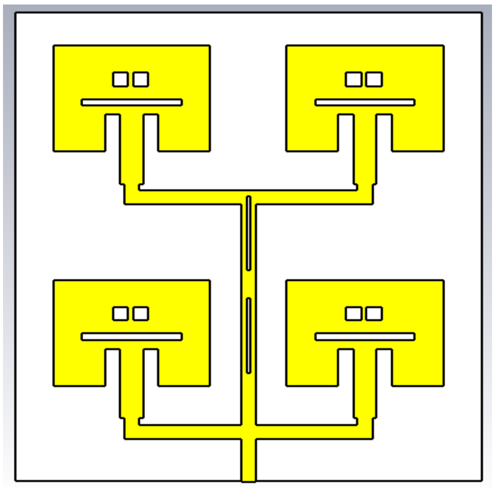

FIGURE 1. Antenna Design

4.

Return loss : Due to the discontinuities in the transmission line, nearly signal power at all times is reflected, or returned to the source, while a signal is broadcast via it. The connection to another transmission line, to a system, or connector might be the point of discontinuity. “Return loss” is the term for reflected power's measurement. The “return loss” (RL) is the ratio of incident power, to the reflected power (dB). There is less power reflected from the load, as indicated by a larger return loss. Typically, this is a desired result. More power is reflected back from the load, as shown by a smaller return loss. This often indicates that the load's impedances are out of phase.

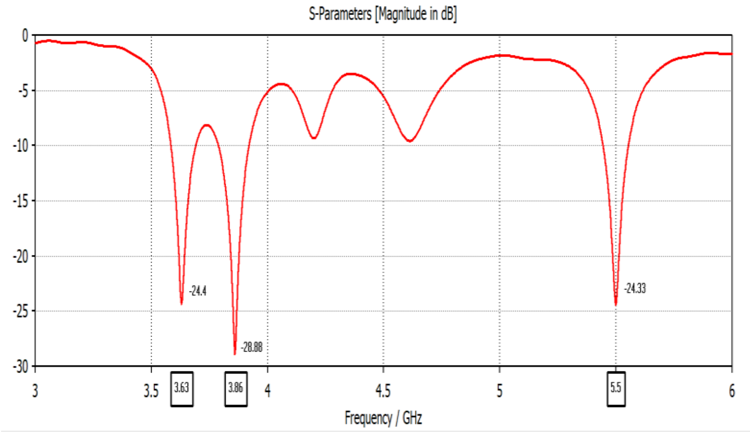

FIGURE 2: Return Loss

VSWR – (Voltage Standing Wave Ratio): The efficiency with which Radio-frequency power is transported fromPower source, over a transmission line, and into a load is gauged by the VSWR. When the VSWR is 1, the antenna system and the transmitter are matched, allowing the transmitter's energy to be delivered to the antenna as efficiently as possible.

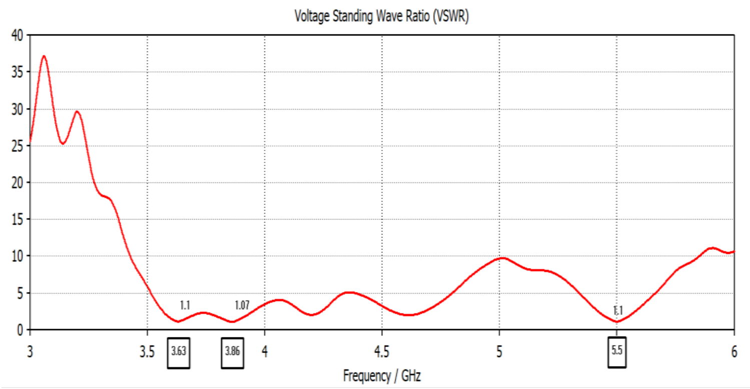

FIGURE 3. VSWR – Voltage Standing Wave Ratio

Bandwidth: The frequency range across which an antenna can function properly is mentioned to as its Bandwidth. The envisioned bandwidth is frequently one of the decisive factors, when choosing an antenna. The signal is spread across a number of frequencies when it is sent or received. This specific frequency band is reserved for a certain signal so that other signals won't interfere with it while it's being transmitted. It is possible to determine the antenna's bandwidth using the VSWR=2 reference level, the reflection coefficient of -10 dB, or the return loss of 10 dB.

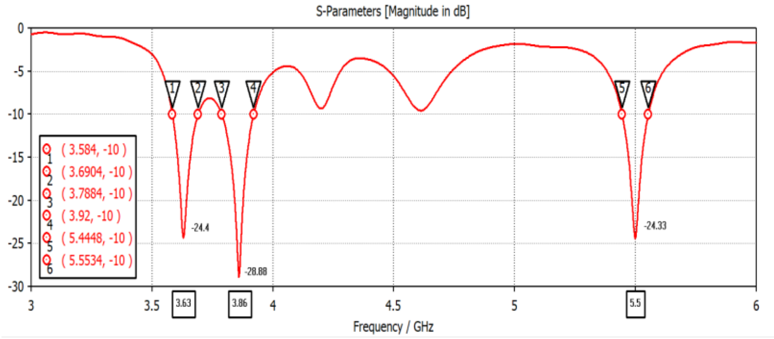

FIGURE 4. Bandwidth

Gain: The maximum radiation strength, produced by the antenna in contrast to a lossless isotropic radiator provided with the identical source of power is termed as antenna gain. The gain defines the strength of the signal, that it can broadcast or receive, in a certain direction. It is computed by comparing the observed power transmitted or received, in a specified direction, to the hypothetical power sent or received by an ideal antenna, in the same scenario.

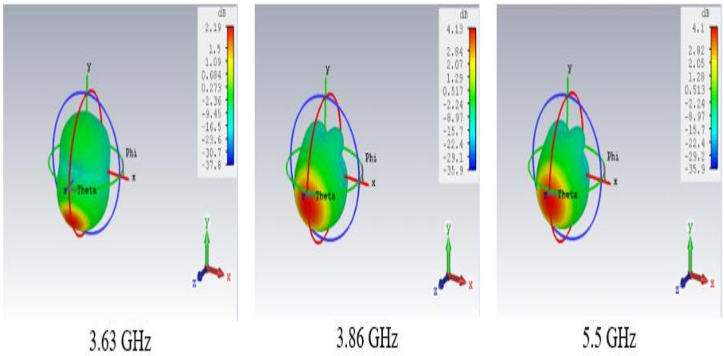

FIGURE 5. Gain

Directivity: The ratio of antenna's strength of radiation, from a specified direction, to its complete average radiation intensity is recognized as an antenna's directivity. By an efficiency factor called radiation efficiency, the directivity is larger than it's gain. Since several antennas, and optical system are built to emit Electromagnetic waves, in a single direction, or across a small angle, directivity is a crucial measurement. An antenna's directivity while receiving is the same as its directivity when sending according to the reciprocity principle.

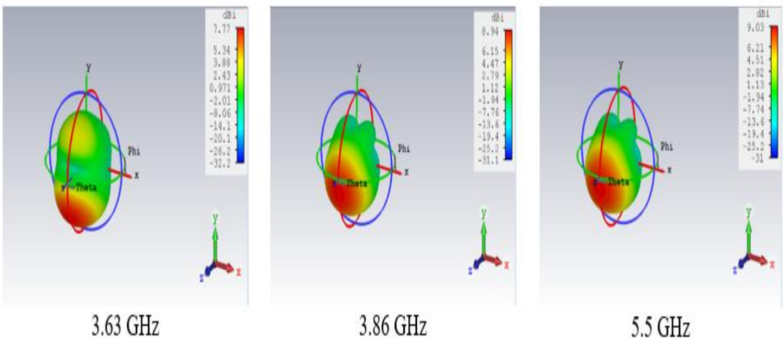

Figure 6: Directivity

Radiation Pattern: The term "radiation" is used to describe the emission or receipt of a wave front, at an antenna and to describe the intensity of the wave front. The outline used to depict an antenna's radiation, in any depiction is that antenna's radiation pattern. An antenna's function, and directivity may be easily understood, by observing its radiation pattern. Both near fields, and far field are affected by the power that is radiated by the antenna. The relationship between radiation, and Angular position, and Radial distance, from the antenna, can be exposed graphically. The mathematical representation of the antenna's radiation characteristics as a function of Spherical co-ordinates as E (θ, Ø), and H (θ, Ø).

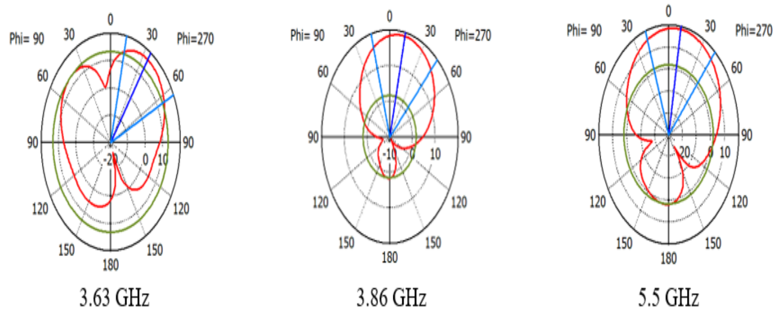

FIGURE 7. Radiation pattern (E-field)

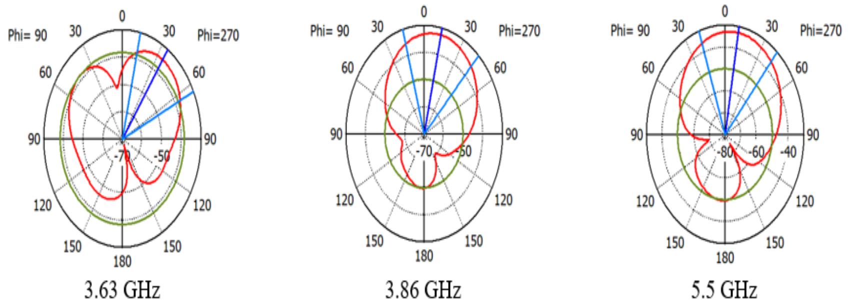

FIGURE 8. Radiation pattern (H-field)

TABLE 1. Antenna Simulation Results

Parameters	Values		
	Frequency		
	3.63 GHz	3.86 GHz	5.5 GHz
Return loss	-24.4 dB	-28.88	-24.31
VSWR	1.1	1.07	1.1
Bandwidth	106.4 MHz	131.6 MHz	108.6 MHz
Gain	2.19 dB	4.13 dB	4.1 dB
Directivity	7.7 dBi	8.94 dBi	9.03 dBi

5. Conclusion

One of the most popular wireless technologies is the UWB, which has several WBAN applications. In this essay, we addressed the value of UWB in the medical industry and touched on its special qualities that make it useful in medical settings. There are several possible uses for ultra-wideband technology in less intrusive medical procedures, monitoring and diagnosis. The UWB radar may be utilised in cutting-edge Non-invasive sensing, and due to its excellent progressive resolution, for identifying backscattered signals, in imaging methods. Other benefits of microstrip antennas are their compact size, light in weight, low-profile and ability to adapt to both planar, and non-planar surfaces. It just needs a little amount of the building, when mounting. They are easy and inexpensive to produce, by using current printed-circuit technology. In other words, UWB applications in medical imaging are a crucial component of UWB's medical applications. In the near future, more unique medical devices addressing various body areas will be created and developed. The medical imaging equipment employing UWB will grow in popularity and be favourably received by everybody as the RF wave interaction model with human tissue becomes fuller and more mature.

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