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Swastik Slotted Microstrip Patch Antenna For C Band Wireless Applications

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Abstract

Microstrip patch antennas are commonly used an- tennas for wireless application receivers. In this pro- posed work, a circular-shaped patch antenna is de- signed and simulated for tracking lives in C band ap- plications. An antenna has been designed and simu- lated for tracking purposes in C band applications using the Rogers RT-Duroid substrate. The antenna can achieve resonance at two different frequencies - 6.5 GHz and 8.7 GHz. With dimensions of 80*44 mm, it has been specifically designed for tracking lives. The maximum gain achieved by the antenna is 4.26 dB at 6.5 GHz and 4.93 dB at 8.7 GHz, making it suitable for tracking lives using the C band of the radio spectrum. The design process involved an ex- tensive literature survey on wearable microstrip an- tennas and wideband microstrip antennas that oper- ate in the C band spectrum. The antenna was modi- fied to obtain a wideband in the proposed radio spec- trum and was simulated using the ANSYS HFSS package.

Keywords **-**tracking, RT-Duroid, wearable, C band

Introduction

Wireless communication allows devices to transmit information wirelessly via radio frequency signals, eliminating the need for cables or wires. An- tennas play a crucial role in this process as they send and receive these signals through wireless media. An antenna can be described as wearable if it is spe- cifically made to function while being worn. In sev- eral kinds of industries, including healthcare, wire- less medicine, mobile communications, and military applications, wearable and textile antennas have grown in demand. These antennas are not like regular antennas in that they must be affixed to the body. Given that consumer electronics are using wearable antennas increasingly typically. To be ap- propriate for garment integration, these must be wearable, robust, and adaptable. Wearable antennas that are small and effective are made possible by de- velopments in miniaturization technology and mate- rials sciences.

Due to their small dimensions, lightweight- ness, and simplicity in integration, microstrip patch antennas are frequently utilized in wearable antenna design. They are appropriate for garments since they can be printed on flexible surfaces. Engineers may customize the size and shape of microstrip patch an- tennas to meet the form factor of wearable devices due to their compact size and versatility. This en- sures a dependable wireless connection without im- pacting the comfort or appearance of the device. In addition to offering a broader bandwidth, using thick substrates with lower dielectric constants will im- prove antenna efficiency.

This study discusses the design of a weara- ble C-band broadband microstrip patch antenna. The C band is used by a number of cordless phones, Wi- Fi devices, satellite communications broadcasts, ra- dar, and weather radar systems. Cellular corpora- tions utilize the C-band spectrum's radio frequencies to expand the 5G wireless networks' capacity and range. Previously, satellite TV providers made ex- tensive use of it. Large-scale 5G home internet and mobile phone operations at blazingly fast rates are made possible by a type of radio frequency known as C-band. Cell phone companies use electromag- netic radiation to deliver internet connectivity through cell phones. The part of the electromagnetic spectrum designated for satellite broadcasts in the 4GHz–8GHz frequency range is known as the C- band. The antenna was created on a Rogers duroid 5880 substrate with a dielectric constant of 2.2 and a substrate height of h=0.787mm. Rogers Duroid substrates are often used in designing wearable an- tennas due to their favorable characteristics. These substrates offer low dielectric loss, high thermal sta- bility, and excellent mechanical strength. The low dielectric loss ensures efficient signal transmission, while the thermal stability helps the antenna main- tain performance across various environmental con- ditions. The mechanical strength of Rogers Duroid makes it suitable for flexible and wearable applica- tions, allowing the antenna to conform to the shape of clothing or accessories without compromising its functionality. Wearable antenna design is influenced by several characteristics, including the worn de- vice's size, application, electrical performance, effi- ciency, and polarization effects. The antenna design incorporates the circular patch and defective ground plane to increase antenna gain and allow operation in the C band frequency spectrum.

Literature Survey

A novel kind of wearable antenna for communica- tion both on and off the body has been constructed by Yang and Xiongying. The antenna operates in two frequency bands: WiMAX (3.4-3.6 GHz) and the medical area of the body network (2.36-2.40 GHz). Because of its flexible construction, which in- cludes nylon conductive fabric and wool felt, it can adapt to the shape of the human body. The antenna's dimensions are 70 x 70 x 2 mm (0.56λ 0 * 0.56λ 0 * 0.016λ 0 at 2.38 GHz), and its radiation pattern, gain, and reflection coefficient have all been meas- ured. Even when the body shifts or changes shape, it continues to work well. Medical applications are a perfect fit for this antenna[1]. Ferrero et al. built a microstrip antenna having circular polarisation for use in spacecraft. The patches are on the same sub- strate and have twin orthogonal slots carved in their ground planes to aid in electromagnetic coupling. The prototype was created using an upper layer sub- strate that was 1.5 mm thick and a feed layer sub- strate that was 0.758 mm thick. Both layers were composed of the same dielectric material, which had a relative permittivity of 2.22. Based on simulation and measurement results, this tiny dual-band an- tenna meets Meteosat requirements for frequency bandwidth, circular polarisation bandwidth, and iso- lation between the two transmission bands[2].

Nathapat et al. developed a circularly polarized oc- tagonal-ring slot antenna array with four elements, arranged in a sequential rotation, and equipped with a feed network. The design, employing Characteris- tic Mode Analysis (CMA), aims for simplicity and a low-profile configuration, catering to S-band satel- lite applications. Through a combination of experi- ments, prototype construction, and simulations, the antenna array demonstrated a maximum gain of 7.8 dBic at 3.3 GHz. Notably, the antenna exhibited an impressive impedance bandwidth (IBW) of 91.6% (1.8 - 4 GHz) and an axial ratio bandwidth (ARBW) of 84.5% (1.97 - 4 GHz) centered around the mean frequency of 2.4 GHz[3]. Hao-Ran Zu et al. estab- lished a flexible, low-profile wearable circularly po- larised antenna that diminishes precise absorption rates using highly conductive graphene material. The antenna is lightweight, flexible, and rigid owing to its polydimethylsiloxane base and highly conduc- tive graphene layers. The wearable antenna operates at 5.8 GHz and has a profile of 0.05λ. It retains a reflection coefficient of under -10dB when utilized on the human body. Observed findings show that the axial-ratio (AR) bandwidth of 5.75–5.83 GHz for

AR< 3 dB has an actual gain that swings between

5.0 and 6.1 dBi. [4].

A performance examination of the Wearable An- tenna Array for WLAN-based applications was re- cently carried out by B.R. Sanjeeva Reddy et al. The design, analysis, and application of single--, pair-, and four-linearly arranged element antennas on wearable substrates are covered in the research they conduct. The study looks at how the wearable sub- strates, Jeans, and FR4, affect the models that are designed. The base antenna was a conventional square-shaped basic patch antenna measuring 20 by 20 mm. It was modified into a two-element type with a 34 mm inter-element separation between each element. Lastly, an analysis of the structure was con- ducted for a 4x1 linear array. The performance of the wearable antenna array, which has a high gain value of 13.09dBi and reflects at a frequency of 5.3GHz for WLAN applications, is a noteworthy success of this work.

Proposed Design

A circular patch configuration is simpler than other patch configurations because we only need to spec- ify one design parameter, the radius of the patch. The key factors for this technique are the dielectric constant, the operating frequency (f), and the sub- strate height (h). The following formula can be used to determine the patch's real size 'a'.

$a =$

F

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Our proposed design is a wearable broad-band cir- cular microstrip patch antenna `using a Roger Du- roid 5880 substrate with a dielectric constant of εr=2.3 and substrate height of h=0.787mm. The an- tenna operates at a frequency of 6.5GHz and has a radius of a=10mm, determined using equations and specified data. For this design, I have used an RT Duroid substrate with dimensions of 37mm×40mm. The feed has a depth of 27mm and a width of 2mm. Figure 1 illustrates a schematic diagram of a weara- ble circular patch antenna for wideband utilization.

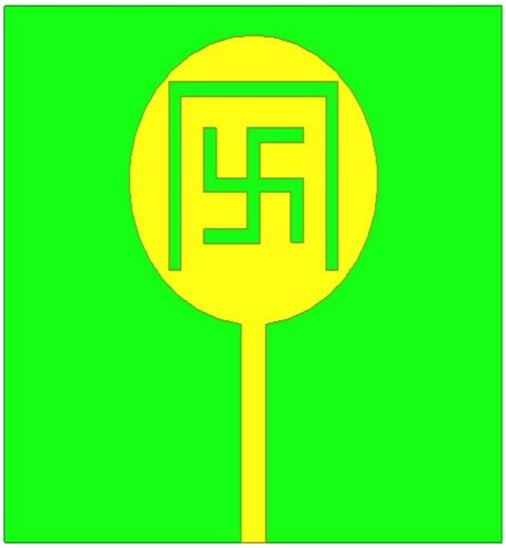

Fig 1: Intended antenna's Top View

$2h \quad \pi F \qquad 2h \qquad\qquad \pi F \qquad \frac{1}{}$

$[1+ \quad (ln\,(\quad)+1.7726]\{1+ \quad (ln\,(\quad)+1.7726\}2$

$\pi \varepsilon r F \quad 2h \qquad\qquad \pi \varepsilon r F \quad 2h$

$= \frac{8.791\, X\, 10^9}{}$

F

$f_r\sqrt{\varepsilon_r}$

Fig 2: Intended antenna's Bottom View RESULTS AND DISCUSSION

Using the ANSYS HFSS program, a circular mi- crostrip patch antenna architecture was designed and simulated. The antenna's performance was analyzed through several key parameters, including the reflec- tion coefficient, standing wave characteristics, di- rectivity, and gain. The investigation covered a fre- quency range spanning from 1 GHz to 10 GHz, providing a comprehensive study of the antenna's behavior across this frequency band. The graph il- lustrating the return loss of the proposed antenna is presented in Figure 3. The simulation results reveal that the antenna achieves resonance at two distinct frequencies within the C band of the radio spectrum, specifically at 6.5 GHz and 8.7 GHz, demonstrating return loss values of -31 dB and -28 dB, respec- tively. Furthermore, Figure 3's study indicates that the antenna has a wide bandwidth that covers the en- tire C band in the radio spectrum, from 5 GHz to 7 GHz. Partial ground plane refers to a configuration where the ground plane, typically a conducting sur- face beneath the antenna structure, is not continuous but rather exhibits breaks or irregularities. By strate- gically implementing a partial ground plane, the an- tenna can overcome limitations associated with nar- rower bandwidths, thereby achieving wideband characteristics. This is particularly advantageous in applications where a diverse range of frequencies within the specified radio spectrum needs to be cov- ered, ensuring the antenna’s versatility and effec- tiveness in various communication scenarios. This characteristic highlights the antenna’s capability to operate effectively across a wide range of frequen- cies within the specified spectrum.

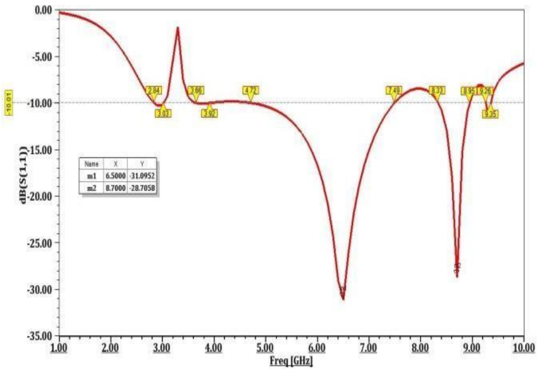

fig:7.1 Return loss (dB) versus frequency (GHz)

Figure 4 depicts the voltage standing wave ratio (VSWR) as a function of frequency. In practical ap- plications, a VSWR value below 3 is considered ac- ceptable. Notably, our proposed antenna design sur- passes this criterion by maintaining a VSWR below 2 across the entire span of the radio spectrum under consideration. Furthermore, an examination of the figure indicates that the proposed antenna achieves VSWR values approaching 1 at its resonance fre- quencies of 6.5 GHz and 8.7 GHz.+

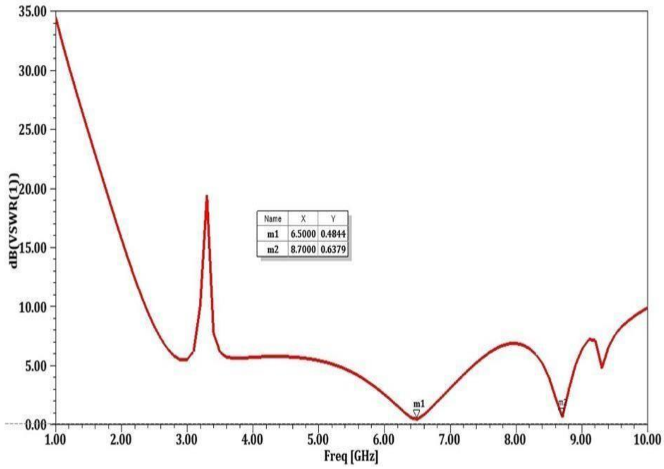

Fig 4: VSWR of the proposed antenna The VSWR is one of the key gauges for how suc- cessfully power is transmitted between the antenna and the transmission line. By reducing signal reflec- tions and exhibiting a better fit between the antenna and the transmission system, a lower VSWR implies better efficiency. The antenna design is effective in preserving a desired impedance match and ensuring

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optimal power transfer efficiency for practical appli- cations, as seen by the consistent VSWR below 2 across the radio spectrum. In addition, the antenna's accuracy and precision at these crucial places are further shown by the VSWR nearing 1 at resonant frequencies.

GAIN

A three-dimensional representation of the sug- gested antenna gain at 6.5 GHz is displayed in Fig- ure 5. The figure shows that at the resonance fre- quency, the recommended antenna achieves a note- worthy gain of 4.29 dB.

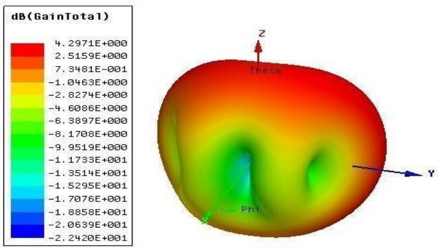

Fig:5 The gain of the antenna is 4.29dB at a fre- quency of 6.5GHz.

A three-dimensional representation of the suggested antenna gain at 8.7 GHz is given in Figure 6. The result suggests that at the resonance frequency, the suggested antenna achieves a notable gain of 4.93 dB.

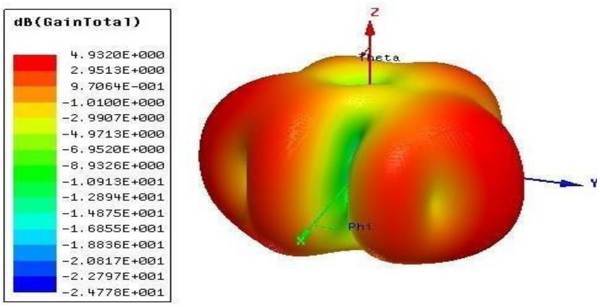

Fig 6:The antenna has a 4.93dB gain at an

8.7GHz frequency.

DIRECTIVITY

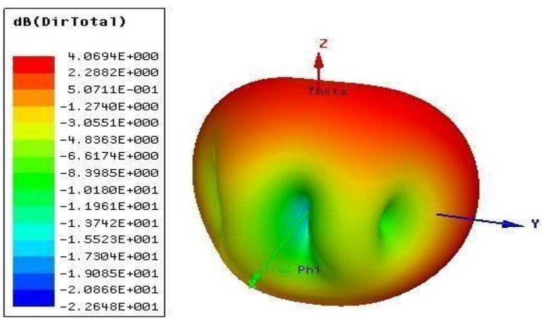

Fig 7: At a frequency of 6.5GHz, the directivity achieved was 4.06dBi.

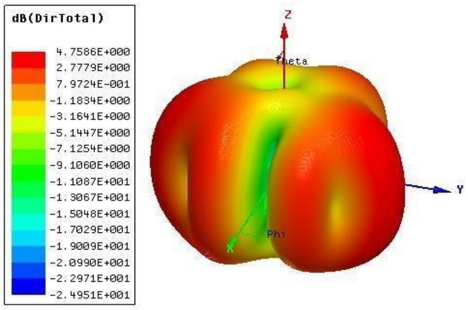

Fig 8: At a frequency of 8.7GHz, the directivity achieved is 4.75dBi.

From Fig. 7 and Fig. 8, it has been examined that the antenna has a directivity of 4.06dBi and 4.75dBi at resonance frequencies of 6.5Ghz and 8.7GHz.

Conclusion

In this study, a circular patch antenna with a swastik- shaped slit for C band applications was constructed and analysed using HFSS software. Two unique res- onance frequencies of 6.5 GHz and 8.7 GHz are dis- played by the antenna, with corresponding return losses of -31.09 dB and -28.70 dB. The antenna's im- pedance bandwidth is 2.77 GHz and 620 MHz for the resonant frequencies of 6.5 GHz and 8.7 GHz, respectively.The antenna exhibited gains of 4.29 dB and 4.93 dB at these frequencies, respectively. For the resonant frequency, the VSWR value is within the acceptable range of 1. For C band applications, especially those involving military applications, the antenna design is greatly effective.

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