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Wearable Tri-Band Antenna for Mm-Wave

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Abstract:- In this research, we introduce a compact wearable patch antenna designed for smartwatches. The antenna operates in millimeter wave frequency bands, making it suitable for wireless communication applications. In this study, a coplanar waveguide (CPW) technology is used to maintain a small size. The suggested antenna is inked upon an RT Duroid 5880 flexible Roger substrate, which has a standard 0.25mm thickness. The antenna is 4 x 3 x 0.25 mm overall. The recommended antenna's overall radiation efficiency is more than 85% and has gain values of 5.3dB, 7.57dB, and 9dB for 28GHz, 38GHz, and 60GHz frequencies, respectively. Because of this, the suggested tri-band antenna is therefore perfect for various application.

Keywords: *5G application, millimeter wave, triband.*

1. Introduction

Wearable technology is rapidly expanding globally as a result of the evolution of current electronic systems, and it is regarded as one of the technologies with the greatest prospects. Over time, embedded systems are becoming larger in size as a result of the integration of several modules into a single framework, which increases the system's capacity, robustness, and reliability. To meet future expectations, it is necessary to build technologies that are more efficient, low power, and small. This idea can be applied to the creation of smart cities, smart healthcare systems, and military applications. An antenna that is flexible or wearable is a crucial part of every wearable electronic system. The antenna which are wearable is an ever-expanding system of diverse items that facilitates a multitude of io devices, sensors as well as actuators through the use of multiple wireless technologies and communication protocols. It also helps to increase the effectiveness of smart watch application operation and the device's internet connection. A unique millimetre antenna was suggested for internet of things (IoT) applications including smart watches. The suggested antenna, which operates in the millimetre frequency bands was further examined in terms of its performance with boundary conditions. The antenna displayed an omnidirectional pattern that is appropriate for use with wearing smart watches. A ground plane, slots, and a split-ring resonator provide the proposed antenna. A hand model was not used to analyze the antenna prototype. For forthcoming 5G applications, a wideband antenna with a frequency range of 23 GHz to 50 GHz was demonstrated. The antenna's overall dimensions were 15 x 8 x 0.254 mm^3, and it is utilized for Internet of Things wrist watch applications. The antenna's gain ranges from 7dB to 10dB. To enhance the bandwidth connected to ground, the parasitic element technique was employed and impedance matching was accomplished using an inductive shorting plate. This study presents the design of a triband small millimetre wave antenna which is printed upon a flexible Roger substrate with a thickness of 0.25mm. With an overall volume of $4\times3\times0.25mm^3$, the suggested antenna has a peak-gain of 5.3dB, 7.57dB, and 9dB at 23 GHz, 36 GHz, and 50 GHz, respectively.

2. Literature Survey

An overview of current research findings in the study into the design of wearable tri-band antennas for millimeter-wave 5G applications is given in this review of the literature. This section defines a number of antenna designs.A compact uniplanar tri-band antenna for wearable smart watches. A uniplanar tri-band antenna for smart watch applications is presented. Implemented on a FR4 substrate and occupying $38x38x0.8mm^3$, the antenna supports Bluetooth, Wi-Fi 2.4/5.8 GHz and WiMAX 3.8 GHz bands. The antenna is composed of an edge tapered, bent monopole element with a capacitively couple inverted L shorting strip supporting the tri-band operation in 3:1

VSWR standard and exhibiting positive gain in all bands. The specific absorption rate of the antenna is well within the acceptable limits specified by FCC.[1]

Compact Liquid Crystal Polymer Based Triband Flexible Antenna For WLAN/ WiMAX/5G Applications. A new compact coplanar waveguide (CPW)-fed liquid crystal polymer (LCP) based tri-band antenna is presented and fabricated for Wireless Local Area Network (WLAN), Worldwide Interoperability for Microwave Access (WiMAX) and 5th-Generation (5G) systems. The antenna combines two strips with the main radiation rectangular patch and coplanar waveguide ground. The proposed antenna is printed on LCP substrate with a thickness of 0.1 mm and has a small overall dimension of 20mm×32mm×0.1mm. To analyze the characteristics, the antenna is designed and fabricated, and then the performance of the antenna is measured and tested. The measurement results show that the proposed antenna has three operating bandwidths, including 2.38-2.79 GHz, 3.27-4.05 GHz, and 4.80-8.44 GHz. To test the flexibility of the antenna, the antenna is simulated and measured in bent configurations for radii of 10 mm and 50 mm. In addition, the antenna is attached to different parts of the human body to test the integration effect in wearable equipment.[2]

An Independently Tunable Tri-Band Antenna Design for Concurrent Multiband Single Chain Radio Receivers. In this paper, a novel tunable tri-band antenna is presented for concurrent, multiband, and single chain radio receivers. The antenna is manufactured on a 50 × 100 mm FR4 printed circuit board, and is able to provide three concurrent, independently tunable operating bands covering a frequency range from 600 MHz to 2.7 GHz. The antenna performance is investigated for both numerical and experimental methods when using, first, varactor diodes and, second, digitally tunable capacitors (DTCs) to tune frequencies, which shows that the antenna gain can be improved by up to 2.6 dBi using DTCs. A hardware-in-the-loop test-bed provides a system level evaluation of the proposed antenna in a direct RF digitized, concurrent, and tri-band radio receiver. By measuring the receiver's error vector magnitude, we demonstrate sufficient isolation between concurrent bands achieving 30 MHz of aggregated bandwidth as well as strong resilience to adjacent blockers next to each band.[3]

A Miniaturized MIMO Antenna With Dual-Band for 5G Smartphone Application. In this paper, a dual-band multiple-input and multiple-output (MIMO) antenna with ceramic substrate is designed for the miniaturized application in 5G smartphone. The proposed method of miniaturization is different from the traditional ceramic loading technique. It is a new method which not only associated with the path extending technique but also combined with the parasitic sub method so that a 68% size miniaturization is achieved. The antenna prototype is fabricated to demonstrate the proposed method. The simulated and measured results indicate that the MIMO antenna has an excellent performance in the frequency band of 3.4 – 3.93 GHz & 4.5 – 5.3 GHz (reflection coefficients < −6 dB) where its isolations are over 10 dB, envelope correlation coefficients (ECCs) are lower than 0.23 and efficiencies are higher than 50%. At last, the on-body effects of the proposed design are analyzed to guarantee the robustness in practical application.[4]

Small New Wearable Metamaterials Antennas for IOT, Medical and 5G Applications. Efficient small antennas are crucial in the development of wearable wireless communications and medical systems. Low efficiency is the major disadvantage of small antennas. Meta materials technology and active components are used to improve the efficiency of small antennas. Moreover, the dynamic range and the efficiency of communication system may be improved by using active wearable antennas. Amplifiers may be connected to the wearable antenna feed line to increase the system dynamic range. Novel wideband passive and active efficient wearable metamaterial antennas for IOT, BAN and 5G applications are presented in this paper. The gain and directivity of antennas with Split-ring resonators, SRR, is higher by 2.5dB than the antennas without SRR. The resonant frequency of the antennas with SRR is lower by 4% to 11% than the antennas without SRR. The resonant frequency of the antenna with SRR on human body is shifted by 3% to 5%. Active small wearable antennas may be used in receiving or transmitting communication systems. For example, the active metamaterial antenna gain is 13+3dB for frequencies from 0.1GHz to 0.8GHz. The active antenna Noise Figure is 0.5+0.3dB for frequencies from 0.1GHz to 0.8GHz.[5]

Miniature Patch and Slot Microstrip Arrays for IoT and ISM Band Applications. In this paper we present the design and fabrication of a two-antenna array to resonate at 5.8 GHz, a frequency that satisfies a host of applications, especially those associated with the ISM band, but including IoT applications. The design incorporates several techniques to improve figures of merit and reduce its size. The array presents a measured bandwidth of 617 MHz (from 5.503 to 6.120 GHz, or 10.63% about the central frequency) when built on a thin substrate, and of 455 MHz (from 5.517 to 5.972 GHz; 7.84%) when fabricated using a thicker one. The simulated gains were of 6.89 dBi and 7.63 dBi, whereas the measured ones were 6.7 dBi and 7.2 dBi, respectively. Size reduction is better than 30% and the simulated efficiencies are higher than 90%.[7]

Evaluation of the Frequency Bandwidth and Gain Properties of Antennas: Characteristics of Circularly Polarized Microstrip Antennas. Frequency bandwidth, gain, and dimensions are some of the most important characteristics of antennas. A comparison of the most important characteristics of circularly polarized microstrip antennas (CP MSAs) [1]-[33], using traditional methods, is accomplished in this article. The CP MSAs were chosen for the study because MSAs have been the most dynamically developing field of antennas over the last few decades [34], [35] and the CP is the more complex type of polarization than linear polarization (LP). The disadvantages of traditional methods of comparison, in which the antennas are practically compared according to only one characteristic, are indicated. Several criteria, simultaneously taking into account the effect of the frequency bandwidth, gain, and antenna dimensions, are proposed. These criteria can be used for a more complete evaluation of antenna characteristics.[8]

There is a distinct research gap because no thorough investigation has been done to date on the miniaturisation of antenna size with multi-band performance. We created a miniaturised antenna with triple band performance in order to maximise efficiency and achieve the size and power requirements for 5G millimeter-wave technology. Thus, our created antenna presents a bright future for 5G millimeter-wave applications.

3. Antenna Geometry and Design

Here, we use HFSS Software to design antenna. The suggested antenna's design makes use of coplanar waveguide (CPW) technology to provide a large bandwidth and a small antenna size. A low-profile mm-wave tri-band antenna with operating frequencies of 23 GHz, 36 GHz, and 50 GHz is presented in the proposed design. The radiation patch has truncated sides and two internal slots. The shortened sides contribute to resonance at 23 GHz, and the lower U- shaped slot is specifically designed for functioning at 50 GHz. The higher inverse U-shaped slot is also intended to support 38 GHz resonance. The reduction of the antenna's back radiation enhances the performance of the suggested system. The physical layers examine the suggested system using regular relative permittivity. Fig 1. Displays the graph that illustrates the reflection coefficient of the tri-band antenna as a function of frequency. One of the two frequency bands that is produced by the suggested antenna design's integration of the U-shaped addition sufficiently covers the necessary frequency range for 5G communication systems. The application of the stub loading technique broadens the impedance bandwidth while simultaneously enhancing impedance matching at the targeted frequency. The resonant frequencies are then enhanced and fine-tuned using specific band spectrums.

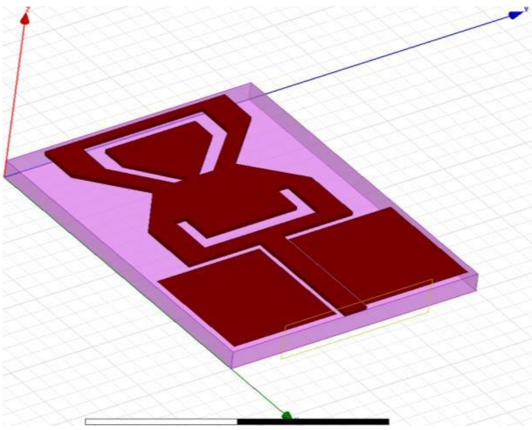

Fig 3. Proposed antenna design

4. Theory and Calculation

Rogers R/Duroid5880, which has a loss tangent of 0.12 and relative permittivity of 2.2, is used to mimic the antenna design. The material is 0.25 mm thick and was supplied by Rogers. Because of its low dielectric constant and low dielectric loss, using copper on the substrate's upper side having of λ/2 as its effective length is beneficial for high-frequency broadband applications. This material has isotropic qualities and a low absorption of moisture. The radiator now features U- and C-slots in place of the centrally deleted piece of the rectangular monopole antenna. In the shortened side, top inverted C-slot, and bottom U-slot, the resonance is detected at 23 GHz, 36 GHz, and 50 GHz, respectively. HFSS software is used to simulate the antenna design. To get the best radiation characteristics, the antenna design procedure involves fine-tuning a number of antenna parameters.

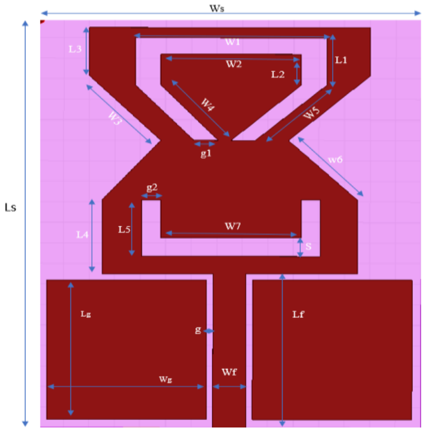

Fig 4.1 Antenna's Geometry

Parameters	Values(mm)	Parameters	Values(mm)
Ls	4.0	Ws	3.0
Lg	1.35	Wg	1.24
Lf	1.4	Wf	0.26
L1	0.58	W1	1.5
L2	0.5	W2	1.0
L3	0.51	W3	1.1
L4	0.71	W4	0.64
L5	0.59	W5	0.65
g1	0.19	W6	0.68
g2	0.15	W7	1.1
g	0.03	Hs	0.25
S		2.4	

Table 4.A Antenna Measurements

5. Results and Discussion

5.1 S11 Parameter

An examination of bending along the x and y direction is necessary for validating the S11 of the tri-band antenna. The flexible Roger RT5880 substrate makes up these axes. For reference, a graph showing the antenna's reflection coefficient as a function of frequency is shown in Fig 5.1. A cylindrical form with 30mm, 60mm and 90mm diameters is used in simulation to verify the antenna's bending analysis. The results show that even in bending situations at these designated diameters, the antenna performs consistently and steadily.

5.2 Surface Current Distribution

Functionality in the 60 GHz frequency range is enabled by the lower U-shaped slot, and the 38 GHz frequency band is generated by the upper C-slot in Fig 5.2

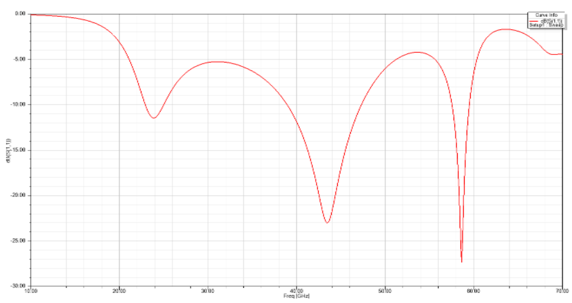

Fig 5.1. Reflection Coefficient(dB)

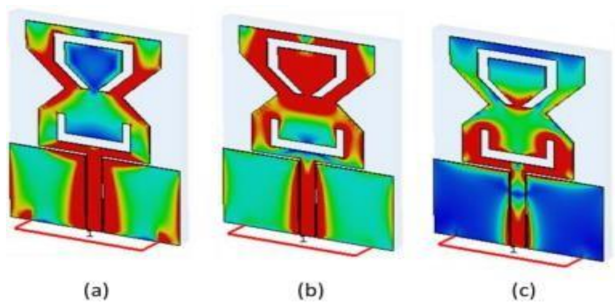

Fig 5.2 Surface current distribution a)23GHz, b)36GHz, c)50GHz

5.3.Radiation Pattern

Fig 5.3 displays the recommended antenna's radiation pattern at different resonance frequencies. The radiation patterns show an elliptical pattern in the E- plane and an omnidirectional pattern in the H-plane for both the 23 GHz and 36 GHz situations. A significant agreement has been seen between the measured and simulated results in the 23 GHz – 36 GHz frequency range. The 40 GHz measurement limit, however, restricts the 50 GHz frequency to a broadsided pattern along the E-plane and an omnidirectional pattern along the H-plane.

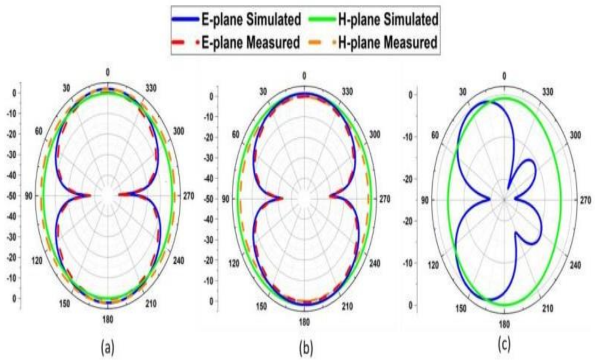

Fig 5.3 Radiation Pattern a)23GHz b)36GHz c)50GHz

Sl.NO	Frequency (GHz)	Size (mm^3)	Substrate's Material	Efficiency	Gain
1	28, 38	4.7×3.0×0.6	DENIM	53.58, 73.92	1.40, 4.41
2	38, 60	34.5×20.0×0.050	ULTRALAM	69.21, 73.71	2.18, 4.3
3	22.9-50	14.50×8.0×0.250	----------	------	7.4-10.0
4	26	22.5×18.0×0.350	Polyester Textile	61.0	8.64
6	28	7.0×7.0×0.80	FR-4	82.0	6.58
7 [This work]	28 GHz, 38 GHz, and 60 GHz	4.0mm × 3.0mm × 0.250mm	ROGER RT 5880	<85%	5.28dB, 7.46dB, 9.0dB

TABLE 5.A

The suggested antenna and recently published literary studies are contrasted in Table 5.A. The antenna on this piece is smaller than on the majority of the others, which sets it apart. For this reason, even though the antennas in [1–4] are tri-band compact, their bandwidth is constrained and their strength is low. Large antennas with dual-band capability, constrained bandwidth, high antenna gain, improved radiation efficiency, and a simple, compact design have been reported by researchers[5–7].

6. Conclusion

The flawless operation of an ultra- compact millimeter-wave tri-band antenna in the 28 GHz, 38 GHz, and 60 GHz frequency bands is presented. The antenna is made out of a flexible Roger 5880 substrate printed with a CPW fed radiating patch. The design's total dimensions are 4 x 3 x 0.25 mm^3. Gains of 5.3 dB, 7.57 dB, and 9 dB are demonstrated by the suggested antenna at 23 GHz, 36 GHz, and 50 GHz, respectively. Furthermore, the total radiation efficiency is higher than 85%. The suggested tri-band antenna hence shows to be a good fit for wearable technology integration. Additionally, a comparison between the suggested antenna and existing research indicates that the suggested design is an excellent choice for a future communication system

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