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A Quad-Band Ring shaped Wearable antenna for WBAN Applications

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Abstract— The article contemplates the proposal and analysis of ring-shaped quad-band antenna with a 1 by 3 power divider feeding network for wireless communication applications. The proposed antenna operates in four frequency bands 2.4 GHz, 2.93GHz, 3.3 GHz, and 4.4 GHz for Wi-Fi, WLAN, military navigation, and drone applications. The antenna is designed using a ring-shaped structure, which provides a compact size and easy integration with the wireless devices. The 1 by 2 power divider feeding network is used to excite the antenna, which helps to improve the antenna performance by providing a balanced feed. The simulated outcomes demonstrate that the suggested antenna with the Power splitter 1 by 2 serving network has the stable radiation pattern and a good gain performance across all the operating frequency bands. Therefore, the proposed ring-shaped quad-band antenna with a 1 by 3 power distributed serving network is the promising candidate for various wireless communication applications.

Keywords- HFSS Tool, Quad-Band, Wearable antenna, WBAN

I. INTRODUCTION

The proposal and improvement of a ring-shaped quad-band wearable antenna in Wireless applications using HFSS (High-Frequency Structure Simulator) involves using advanced simulation software to optimize the antenna design for maximum efficiency and radiation performance in the desired frequency bands. HFSS is a powerful electromagnetic simulation tool that allows engineers to design and simulate the performance of antenna structures with high accuracy. It can be used to simulate the performance of a ring-shaped quad-band wearable antenna and optimize its design parameters such as antenna dimensions and shape. The first step in the design and development process is to define the design parameters of the antenna, such as the frequency bands of interest, the dimensions of the ring, and the material to be used. These parameters are then input into the HFSS simulation software, which creates a 3D model of the antenna structure. The simulation software is then used to analyse the electromagnetic behaviour of the antenna structure, considering the material properties and geometry of the antenna. The simulation results are used to optimize the antenna design parameters, such as the size and shape of the ring, and the position of the feed point. After the optimization process, a physical prototype of the antenna is fabricated using flexible materials such as polymer or fabric. The antenna is then tested to verify its performance and ensure that it meets the design specifications.

The antenna is tested in a laboratory setting, and its performance is evaluated based on parameters such as its radiation pattern, impedance matching, and gain.Once the antenna design is finalized, it can be integrated into a wearable device for wireless applications. The ring-shaped quad-band wearable antenna can be used for various healthcare and medical monitoring applications, such as remote patient monitoring, vital signs monitoring, and health status tracking. In summary, proposal and improvement of ring-shaped quad-band wearable antenna in Wireless devices using HFSS involves using advanced simulation software to optimize the antenna design for maximum efficiency and radiation performance. This process is essential for the development of wearable devices for healthcare and medical monitoring applications. To design and optimize wearable antennas, electromagnetic simulation software such as HFSS or CST can be used. These tools allow engineers to simulate the antenna's performance and optimize its design parameters such as its dimensions, material, and shape to achieve desired performance characteristics.

Overall, wearable antennas play a crucial role in enabling wireless communication in a variety of wearable applications, and continued research and development in this area is essential for the advancement of wearable technology.

II. FELT MATERIAL

Felt is a type of textile material that is made from fibers that are matted, condensed, and pressed together without being woven. It is made by subjecting wool, fur, or other animal

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fibers to heat, moisture, and pressure, causing the fibers to interlock and form a dense, cohesive fabric. Felt has been used for thousands of years for a wide range of purposes, including clothing, blankets, hats, footwear, and even tents. Today, it is also used for industrial applications, such as gaskets, insulation, and soundproofing materials. Felt comes in a variety of grades and colors, depending on the type of fibers used and the manufacturing process. Some common types of felt include wool felt, synthetic felt, and blended felt (a mixture of natural and synthetic fibers). Felt can also be treated with various coatings or finishes to enhance its properties, such as water resistance or flame retardancy.

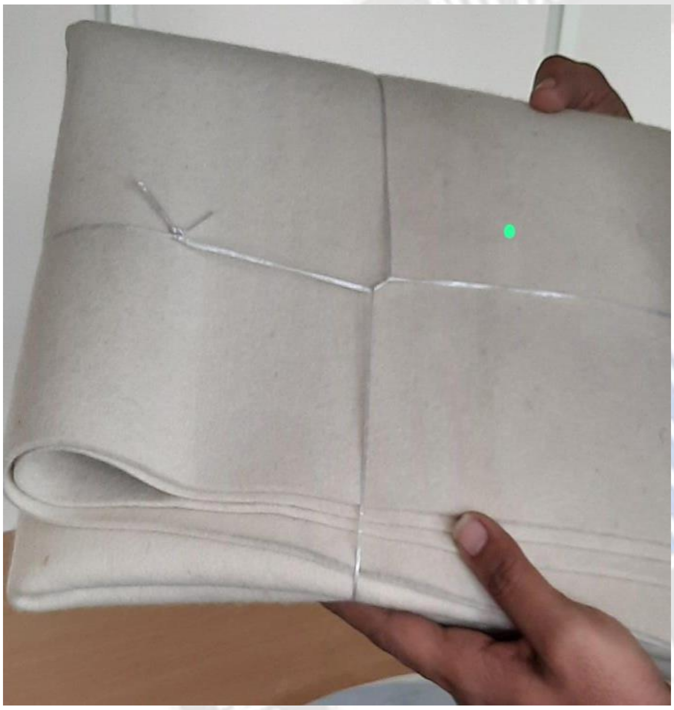

Fig 1: Felt Material

CHARACTERISTICS	PARAMETER
Base Material	Felt
Permittivity	1.45
Thickness	3mm
Width	3mm
Length	60mm

Table 1: Felt Material Characteristics

In [1] a tri-band off-body transmitter in WBAN connectivity has been designed consisting of three resonant frequency bands. However, the rigid FR4 base is unsuitable for applications involving wearable devices. In [2] another wearable antenna with three bands with malleable body is presented. This antenna design has a relatively low peak gain. The paper [3] also consists of three frequency bands with a substrate of jean textile; however, other factors like gain and efficiency are not mentioned in the paper. Flexible textile substrates like textile, leather, and jeans have a high loss tangent because of which antenna performance decreases. To overcome this in paper [4] on the wearable tri-band antenna with a less-loss tangent, Rogers' R04003 is offered with an elevated gain and productivity but with limited bandwidth. To overcome this problem on paper, [5] which is implemented with antenna which is constructed with a arrangement of rigid and cloth substrates and multiple band frequencies of 2.41 GHz, 2.9 GHz, and 3.45 GHz. The proposed antenna has two bare ring radiators, with interior and exterior rings printed on low-loss rigid substrate, with a gain of 4.2/6.6/5.0dB. But still, paper [5] operates only at three frequency bands; by implementing it to quad-band in this paper, we have designed the ring-shaped quad-band wearable antenna with higher gain and efficiency than the paper [5] by using the felt substrate for ground and TLY-5 as the patch with four frequency bands.

III. EVOLUTION OF ANTENNA DESIGN

A. Antenna -1

In the design of the wearable antenna, it is critical that antennas exhibit a high gain, high radiation efficiency, and a low return loss. To satisfy these requirements, In the existing paper they have designed a ring-shaped tri-band antenna structure with inner ring and outer ring, operating at three different resonant frequency bands.

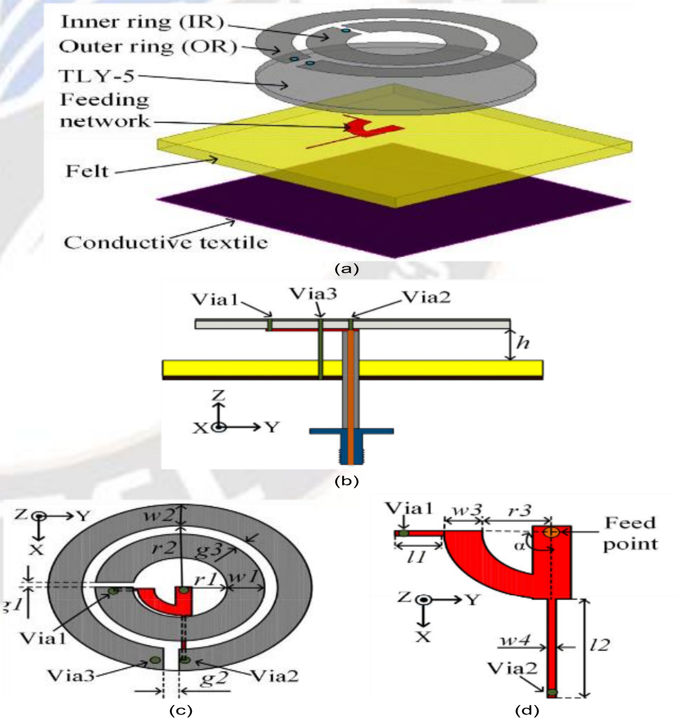

Figure2 Antenna 1: Configuration of antenna: (a) standpoint assessment, (b) lateral assessment, (c)Upper assessment, (d)Foot assessment

Figure 2 depicts the structure of a current wearable tri-band open-ring antenna for mobile communication. A TLY-5 base and a felt base make up the antenna construction. The lower substrate is the ground. A feeding network was designed and

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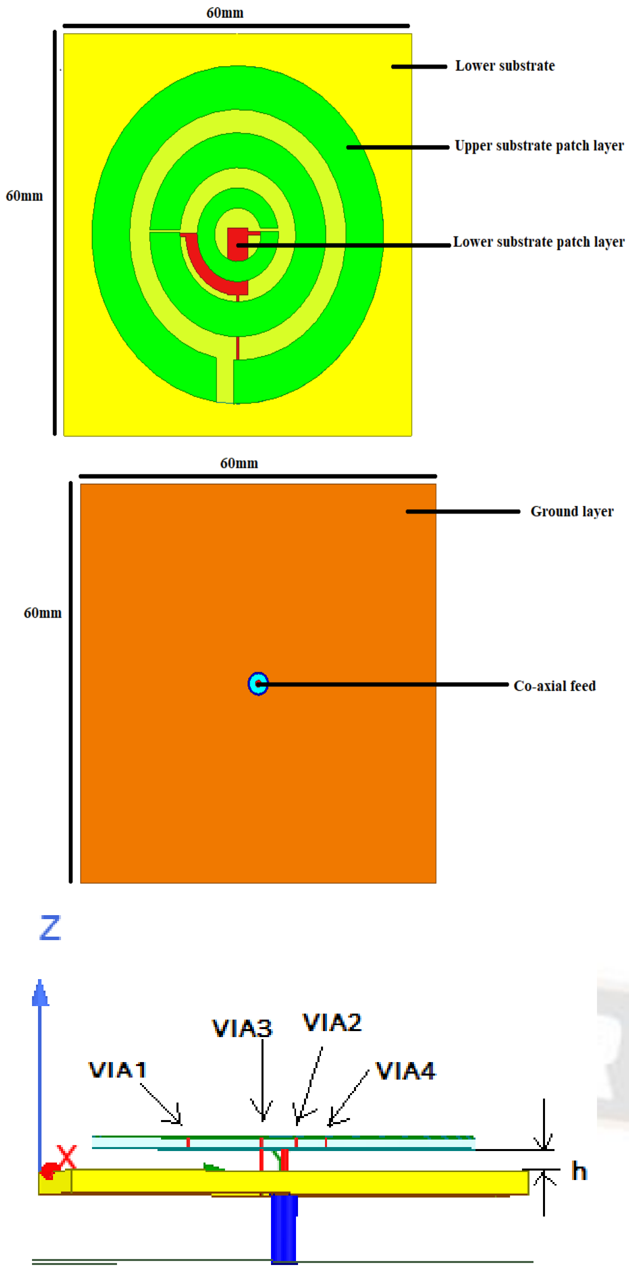
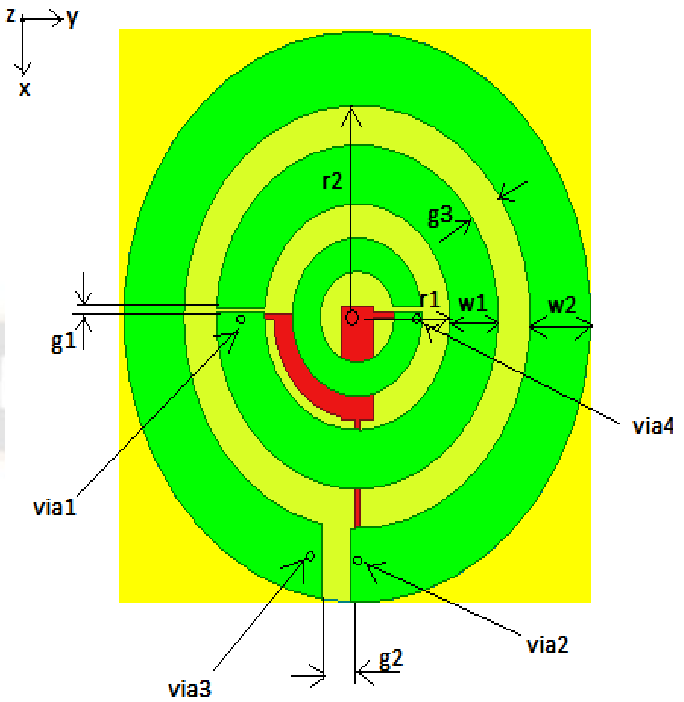
written on rear end of TLY-5 base. This feeding network was linked to inner and outer rings, denoted as via 1, via 2, and via3.

B. Antenna-2

In the existing wearable antenna can offer better bandwidth and isolation, while the ring-shaped quad-band wearable antenna design can offer a more compact size and simplicity in fabrication. And also, the tri-band wearable antenna only operates at three frequency bands whereas quad-band antenna operates at four frequency bands with higher gain and efficiency.



(a)



(b)

Figure3 Antenna 2: (a) top view, bottom view and side view, (b) geometry view of antenna

Figure 3 depicts the construction of the intended portable quad-band open-ring antenna for uses in wireless networks. A TLY-5 core and an artificial felt surface are used in the suggested antenna construction. The outer ring is known as the "OR," with a radius and width. In the inner ring, there was another ring connected to the feed. The lower substrate is the ground. A feeding network was designed and written on the rear end of TLY-5 surface.

IV. DESIGN EQUATIONS

An initial guess at the patch width:

$$W = \frac{c_o}{2f_r}\sqrt{\frac{2}{\epsilon_r+1}},\ c_o \text{ is speed of light} \qquad [1]$$

Find effective parameters:

$$\epsilon_{reff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2}\left[1+12\frac{h}{W}\right]^{-1/2}, W/h > 1 \qquad [2]$$

$$\frac{\Delta L}{h} = 0.412\frac{(\epsilon_{reff}+0.3)\left(\frac{W}{h}+0.264\right)}{(\epsilon_{reff}-0.258)\left(\frac{W}{h}+0.8\right)} \qquad [3]$$

Get patch length:

$$L = \frac{c_o}{2f_r\sqrt{\epsilon_{reff}}} - 2\Delta L \qquad [4]$$

Where fr is the frequency at which it operates of, Er and h are the constants for the dielectric and altitude of the base, W and L are the width and length of the antenna, and fo is the resonant frequency of the antenna. The constant of dielectric is identified by Eeff. Leff is the patch's effective length.

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The radiation covered the entire patch's breadth. We must determine the patch's width.

Lsub = 6h+L , Wsub =6h+L

Here Lsub ,Wsub are length and width of the base.

V. RESULTS

After designing the ring-shaped antenna 1 and antenna 2 simulated results are computed using high structure simulator. The both the antenna 1 and antenna 2 has obtained s11, gain and VSWR parameter. But the antenna 2 has obtained the greater results than the antenna 1.

Tri-band indicates the antenna 1 and quad-band indicates the antenna 2

Figure 4: simulation of s11 plot of antenna 1 and antenna 2

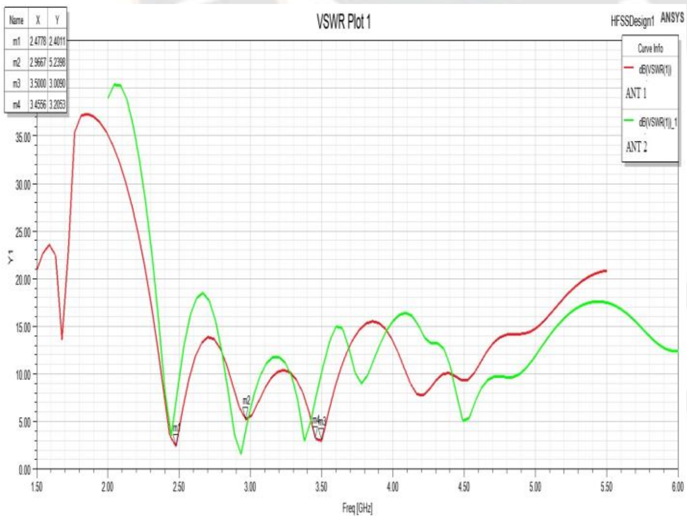

Figure5:simulation of VSWR plot of antenna1 and antenna 2

From the fig 4 the s11 should be obtained below -10dB. From fig 5 VSWR stands for "Voltage Standing Wave Ratio." It is a measure of how well the impedance of a transmission line (such as a coaxial cable) is matched to the impedance of the device it is connected (such as an antenna or a radio transmitter). A VSWR of 1:1 indicates a perfect match, meaning that all of the power sent down the line is absorbed by the device and none is reflected back if the value of the VSWR is equal to 1.0, there is no returned power and the voltage that exists has an even magnitude throughout the signal's transmission line. In real life, however, it is difficult to accomplish. As a result, the VSWR is always more than +1, and VSWR values are never greater than 3. Form fig 6 it represents the gain comparison of antenna 1 and the antenna 2 of the antenna at different frequency bands. As we can see that in the antenna 1 at the frequency bands of 2.41/2.93/3.5GHz has obtained a gain of 4.3/7.2/6.6dB. where the quad-band has obtained a higher gain than the tri-band with frequency bands of 2.44/2.93/3.3/4.4GHz has obtained a gain of 7.71/8.9/7.8/8.4dB.

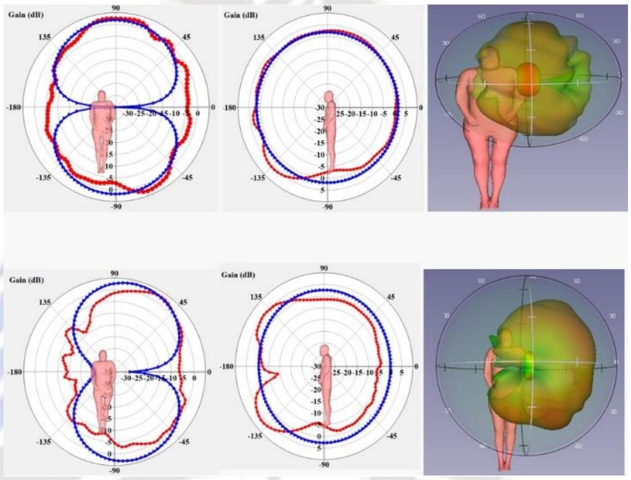

Figure 6: simulation of gain plot of antenna 1 and antenna 2

The radiation pattern of an antenna is a graphical representation of the directional properties of its radiated electromagnetic fields. It shows the relative strength of the electromagnetic field in different directions away from the antenna. The radiation pattern is usually represented in a three-dimensional space and is measured in units of power density or field strength. The radiation pattern of an antenna depends on its geometry, the frequency of the electromagnetic wave it radiates, and the electrical properties of the surrounding environment.

An antenna's performance is defined as a ratio of the electrical energy emitted by the antenna to the wattage provided to it. In other words, it is a measure of how effectively an antenna converts electrical energy into electromagnetic energy that propagates through space. Efficiency is an important parameter for antennas, as a low-efficiency antenna can result in a weak signal, interference, or loss of communication Considering the following frequency bands of tri-band of 2.41/2.93/3.5GHz obtained efficiency are 93/96/96 and frequency bands of quad-band of 2.44/2.93/3.3/4.4GHz obtained efficiency are 91/98/99/100.Hence, we obtained high effiency than traiband Antenna Figure2.

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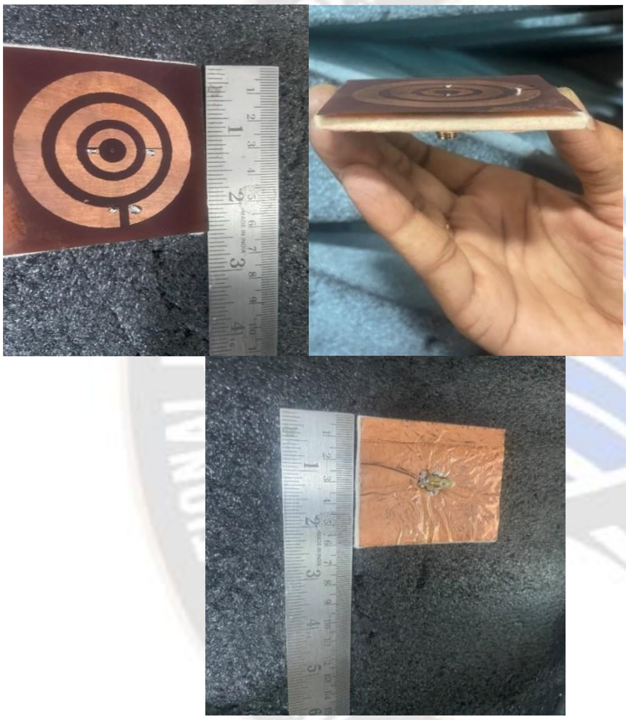
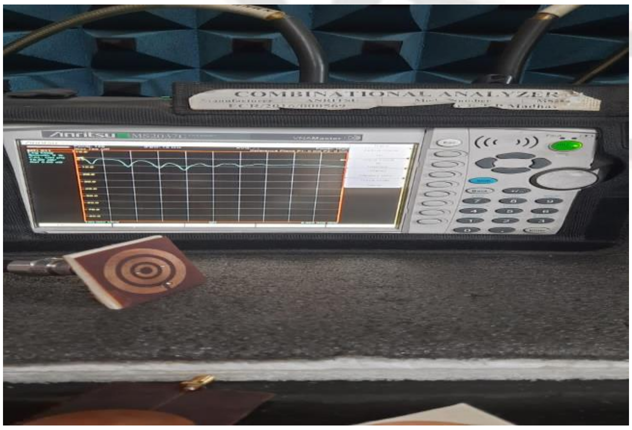
VI. FABRICATION OF ANTENNA

Once the design is finalized, the appropriate materials are selected for the antenna. In this project we have considered two substrates of Felt and Taconic TLY-5. The fabrication process involves cutting, bending, and shaping the materials create the desired antenna shape and size. This may be done using techniques such as milling, drilling, and molding. Once the individual antenna components are fabricated, they are assembled together to create the final antenna structure. Finally, the antenna is tested to ensure that it meets the desired performance specifications. This may involve measuring the antenna's radiation pattern, and gain, as well as testing it under various environmental conditions.



(a)



(b)

Figure 7 (a) front , side and bottom views of fabricated antenna 2 (b) measurement results of antenna 2

Table 2: A comparison with other wearable antenna applications

Reference	frequency	Overall size	Gain	Efficiency	substrate
[1]	3.5/5.5/9.1	.44x0.33x0.02	3.09/2.8/5.05	41/42/49	FR4
[2]	2.4/3.5/4.6	.67x0.67x0.02	1.1/0.9/2.1	71/68/76	Leather
[3]	3.9/6.5/12.2	0.3x0.3x0.01	48.5/N. A/N. A	N.A/N.A/N.A	Jeans
[4]	0.8/2.3/5.8	)5x0.05x0.0006	2.5/3.52/4.8	78/85/89	Rogers
[5]	2.41/2.93/3.5	0.5x0.5x0.06	4.2/6.6/5.0	79/83/82	TLY-5/felt
Proposed model	2.44/2.93/3.3/4.5	0.6x0.6x0.6	7.7/8.9/7.8/8.4	91/98/99/101	TLY-5/felt

VII. CONCLUSION

This work represents a wearable ring-shaped quad-band antenna for 2.44/2.93/3.3/4.5 GHz for Wi-Fi, WLANS, military navigation, drone applications correspondingly. The suggested antenna comprises of dual bodies: 1.rigid and 2. Textile.1 by 3 feeding network is written on Taconic TLY-5. In addition, a conducting textile on base is connected to the felt textile substrate. The quad band wearable antenna has an excellent gain, productivity, and s11 value.

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