COMPACT WEARABLE MIMO ANTENNA WITH IMPROVED PORT ISOLATION FOR ULTRA-WIDEBAND APPLICATIONS

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ABSTRACT

In this communication, a compact four-element ultra-wideband (UWB) wearable multiple-input multiple-output (MIMO) antenna with high port isolation is presented. The proposed structure is an '8' shaped stub is placed on the middle position of the antenna backside and connected to the partially suppressed ground structure to improve the port isolation characteristics.

The antenna covers the frequency range from 2.94 to 12.33GHz with port isolation of >26 dB over the entire UWB frequency range. The envelope correlation co-efficient is found to be <0.025 with a high diversity gain (DG>9.9) throughout the complete operating band. The channel capacity loss for proposed MIMO antenna is <0.13 bits/Hz.

INTRODUCTION

Nowadays, multiple-input multiple-output (MIMO) systems are widely engaged in the wireless communication area to expand the system capability and to overcome the degradation produced by the multipath fading. Ultra-wideband (UWB) technology is gradually becoming very significant because of offering high data at very low power level in the wide-spread frequency band. The problem of multipath fading existing in the UWB system is due to the diffraction and reflection between the interactive antennas. However, that may overcome by implementing MIMO technology [1,2].

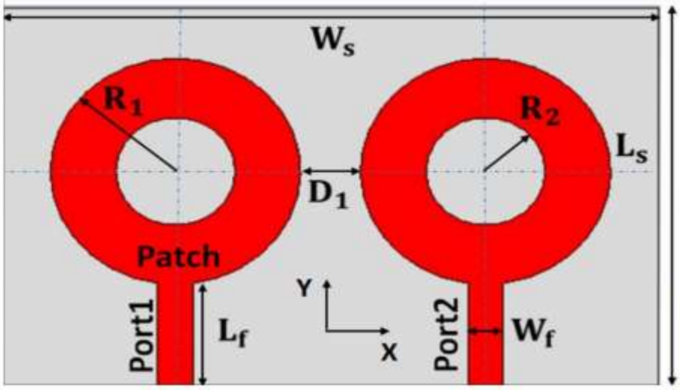
The high-performance compact antenna in a wearable device has a tremendous demand in the field of emergency rescue, health observing, medical care, telemedicine, physical training and satellite applications [3,4]. The emerging UWB technology promises low-cost, short-range with high-speed communication systems. Therefore, UWB technology may be an aspirant for wireless on-body networks with popular research in on-body transmission channels [5].

In this current article, an approach of mutual coupling reduction of a four-port MIMO antenna having four ring shaped antenna elements is presented. The prototype is simulated, analyzed and optimized using Ansys High-Frequency Structure Simulator (HFSS) [6].

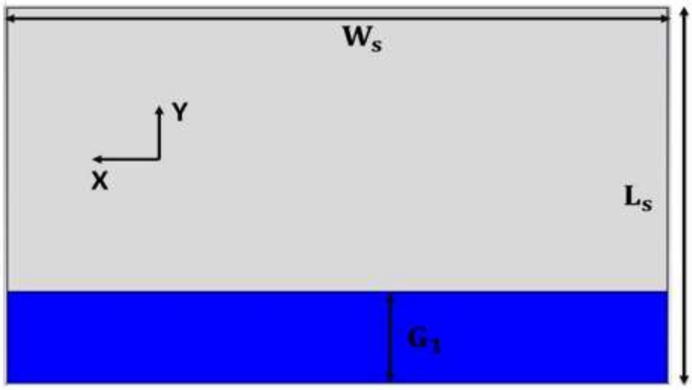
The whole design process of antenna that is explored in section 2 and the simulated and measurement results along with the antenna properties are discussed in section 3, followed by conclusion in section 4.

ANTENNA STRUCTURE AND DESIGN

The proposed UWB wearable MIMO antenna is shown in Figs 1a and b. the MIMO antenna consists of four ring-shaped patch elements on top of the substrate. the designed MIMO system is incorporated with an etched '8' shaped stubs connected to the GP to enhance the port isolation. The bottom layers of the MIMO antenna before integrating the stub and after adding the stub are shown in Figs 1b. the top view of the antenna demonstrates the two antenna elements along with their feed mechanism. The back view displays the GP where an adjusted structure is used in the proposed MIMO antenna. The principal objective of inserting the '8' shaped stub on the middle of the bottom layer is to achieve a higher level of mutual decoupling between the ports. The optimised dimensions of the proposed MIMO antenna are summarised in Table 1. 1



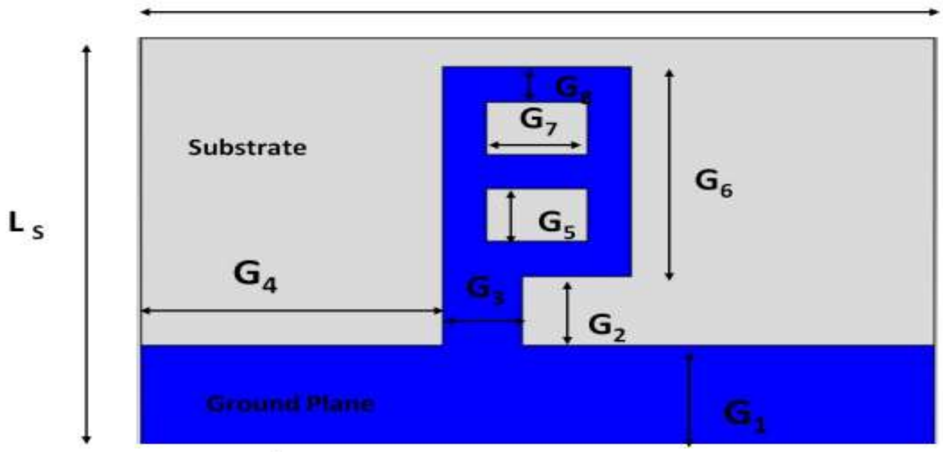
(a)TOP VIEW

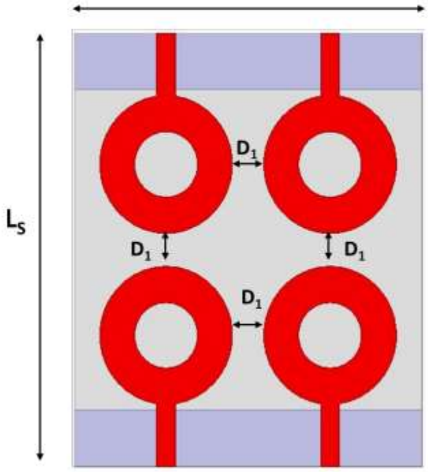


(b)BACK VIEW WITHOUT STUB

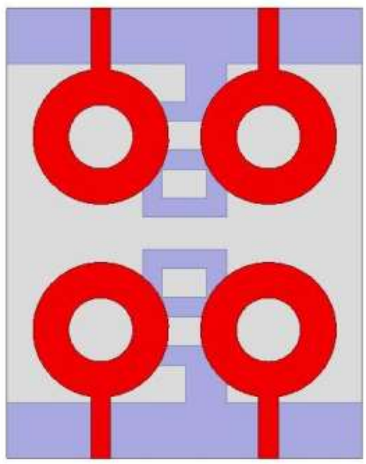
TABLE 1:-

BACK VIEW WITH STUB





1 FIG(a) Quad antenna without stub



1 FIG(b) Quad antenna with stub

Parameters	Dimensions(mm)	Parameters	Dimensions(mm)
LS	35	G1	8.6
WS	55	G2	5.9
R1	10.5	G3	5.5
R2	5	G4	21
D1	5	G5	4.5
Lf	9.6	G6	18
Wf	3	G7	7
W1	26	G8	3

RESULTS AND DISCUSSIONS

The proposed ring-shaped dual-element textile MIMO antenna is fabricated in-house using a piece of copper foil with a thickness of 0.07 mm. Ports are connected with 50 Ω SMA connectors for the excitation of the elements of the antenna. The antenna exposes the frequency spectra from 2 to 12.2 GHz (S11 ≤ −10 dB) during simulation. This MIMO antenna was also examined using the vector network analyser. The simulated and measured S-parameters are plotted and shown in Fig. 2a and 2b
The fabricated prototype covers the frequency range from 2.94 to 12.33 GHz (for S11 ≤ −10 dB) which provides a good agreement with the simulated results. However, when we investigate the MIMO characteristics, it indicates a very high mutual coupling between the ports. Therefore, some methodology is to be implemented into the present MIMO to achieve high port isolation along with acceptable divergence parameters like ECC, DG, CCL ans so on

Characterisation of ECC and DG: -

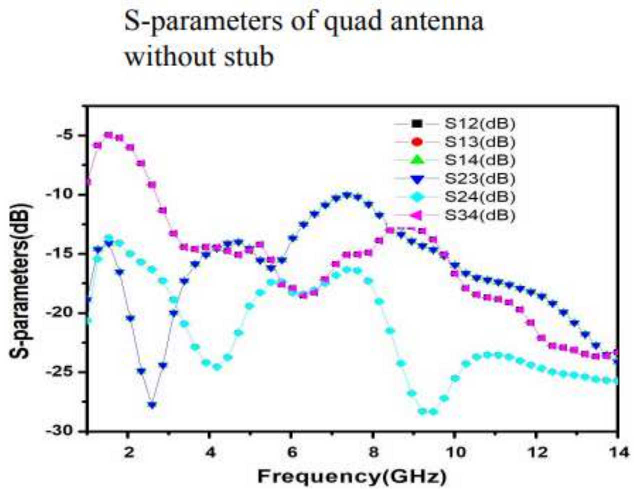


Fig 2a

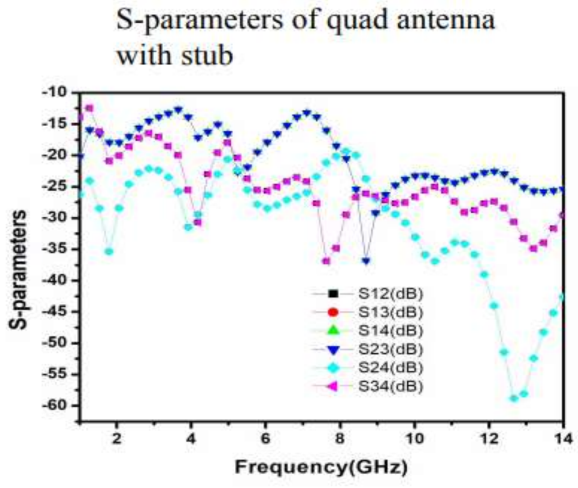
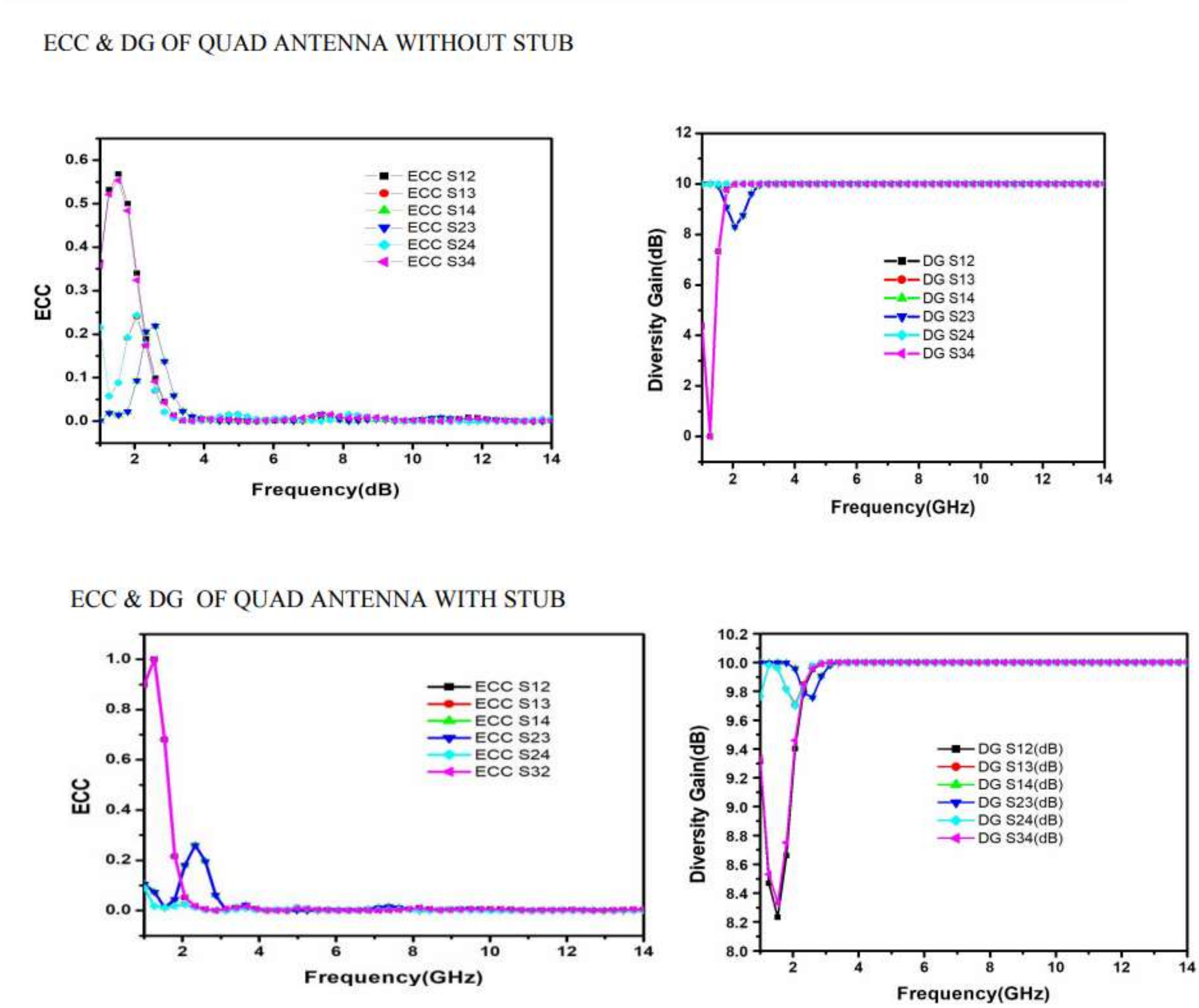


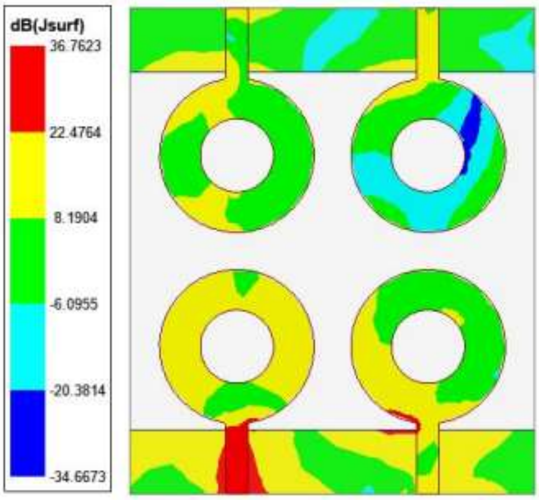
Fig 2b

The diversity and multiplexing is the principle functioning area of the MIMO antenna. Therefore diversity and multiplexing performances are important. To check the proficiency of the proposed MIMO antenna, the ECC is very low, preferably below 0.5, which specifies that the designed prototype can offer a good form of diversity. The effectiveness of diversity is determined in terms of DG. The DG of the proposed MIMO is shown below. It is noticed from the figure that the proposed MIMO antenna offers a very high DG (DG>9.9).

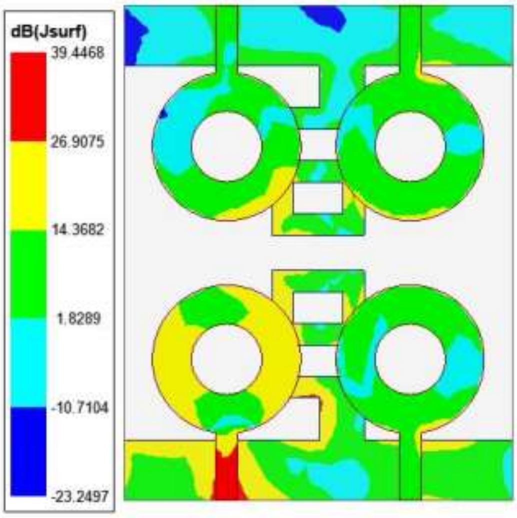


SURFACE CURRENT DISTRIBUTIONS:-

It is observed that the amount of current flowing (when '8' shaped stub is integrated and connected with the ground through a strip) from the input excitingport 1 to port 2 is very negligible or small and this leads to very low mutual coupling between two ring-shaped antenna elements. The proper insertion of the stub provides the stop band characteristics and reduces the current flowing towardsthe other port. This helps to couple the second radiator a lesser amount of current toachieve higher port isolation



Fig(a) ... t distributions of the quad antenna without stub at 5.24GHz



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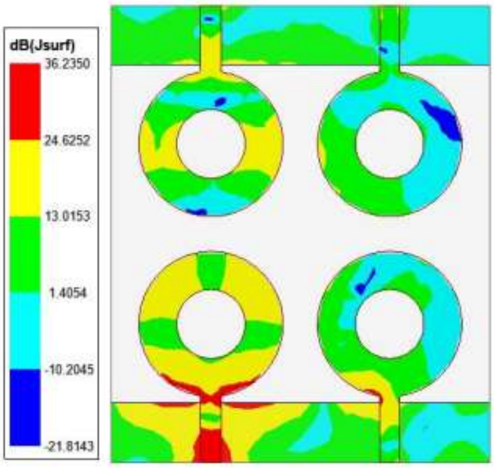
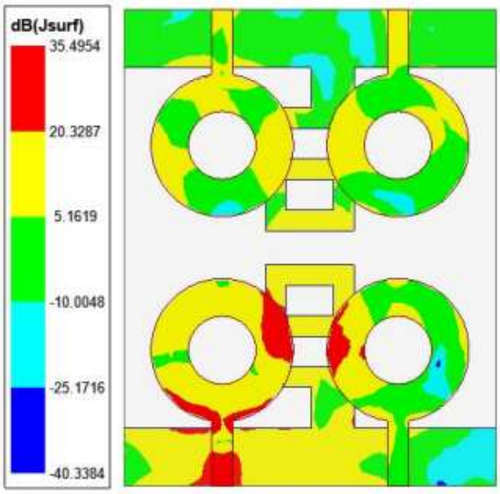


fig(a)C ... t distributions of the quad antenna without stub at 8.42GHz

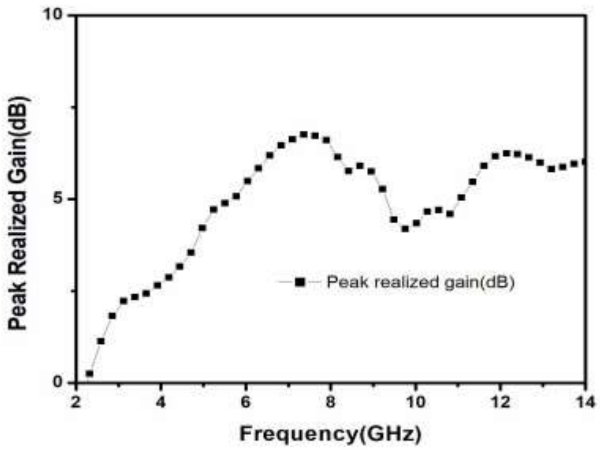


fig(a)(... t distributions of the quad antenna with stub at 8.42GHz

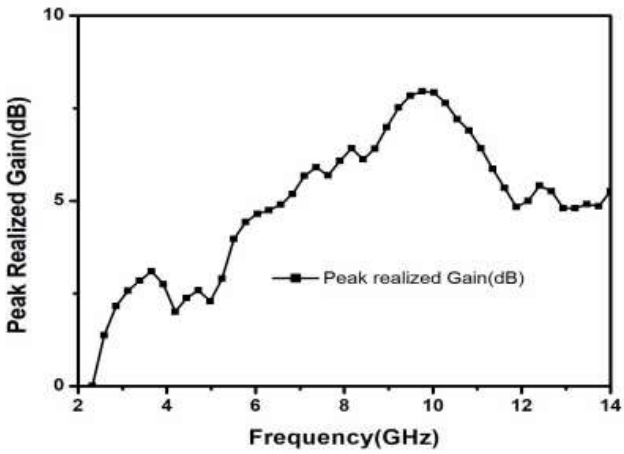
Peak Realized Gain:-

The realized gain is the gain calculated by taking into account the reflection losses at the input terminals of the antenna or the structure of the antenna. In other words it is the ratio of power radiated to the power input to the antenna . Gain doesn’t take into account the reflection losses at the antenna input. It is simply the ratio of power radiated to the power accepted by the antenna. Obviously realized gain will be less than the gain .

Peak realized gain of quad antenna without stub



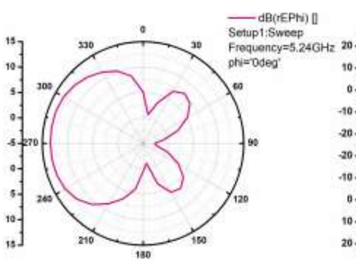
Peak realized gain of quad antenna with stub



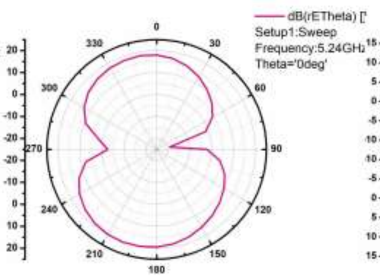
Radiation Patterns:-

The radiation pattern/antenna pattern is the graphical representation of the radiation properties of the antenna as a function of space. That is, the antenna's pattern describes how the antenna radiates energy out into space (or how it receives energy). It refers to the directional (angular) dependence of the strength of the radio waves from the antenna or other source. It is a polar diagram that indicates the magnitude of the response in any direction.

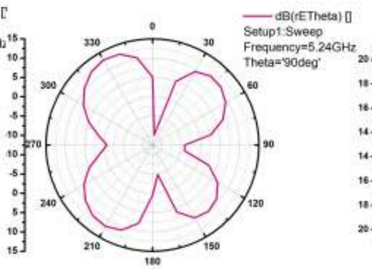
Radiation patterns without stub at 5.24GHz for quad elements



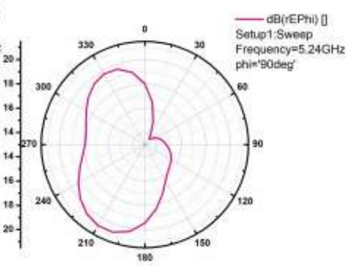
E-plane cross-polarisation at 5.24GHz



E-plane cross-polarisation at 5.24GHz

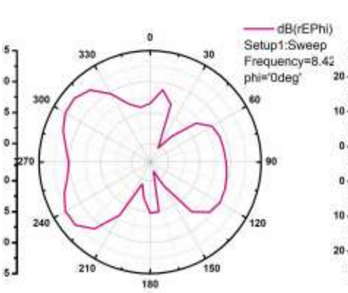


H-plane co-polarisation at 5.24GHz

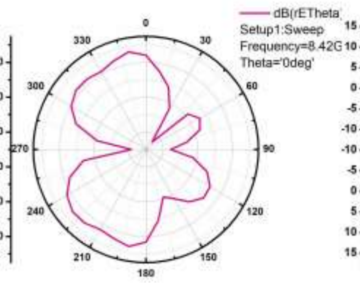


H-plane cross-polarisation a 5.24GHz

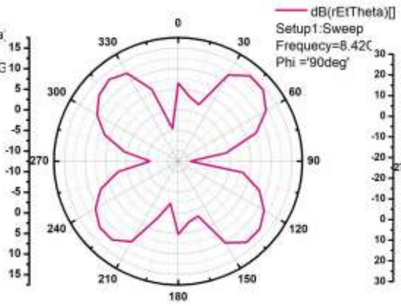
Radiation patterns without stub at 8.42GHz for quad elements



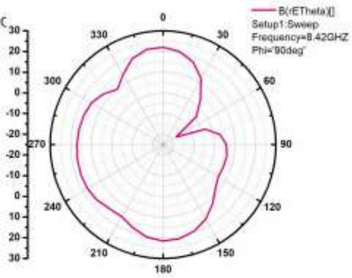
E-plane co-polarisation at 8.42GHz



E-plane cross-polarisation at 8.42GHz

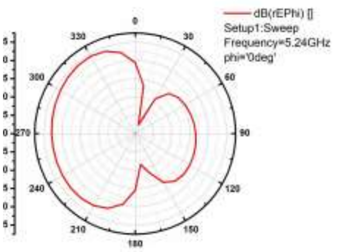


H-plane co-polarisation at 8.42GHz

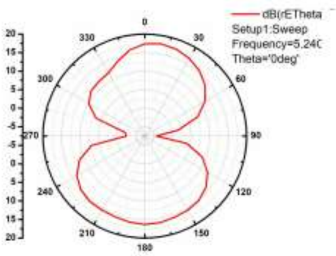


H-plane cross-polarisation at 8.42GHz

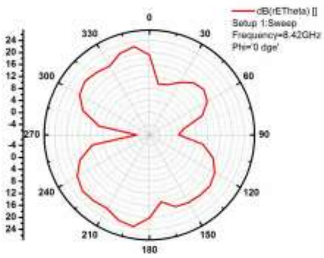
Radiation patterns with stub at 5.24GHz for quad elements



E-plane co-polarisation at 5.24GHz



E-plane cross-polarisation at 5.24GHz



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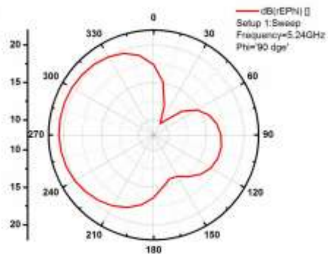
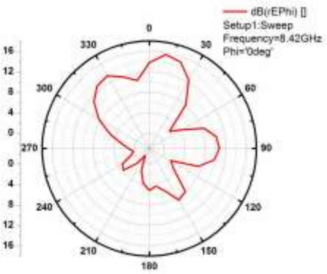
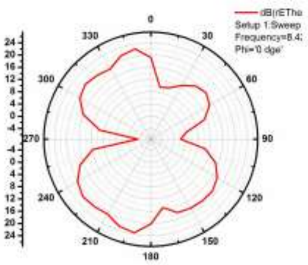


H-plane cross-polarisation at 5.24GHz

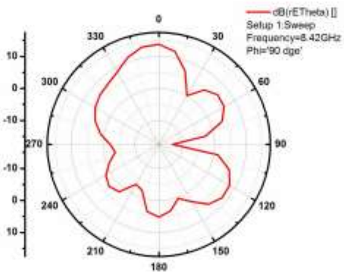
Radiation patterns with stub at 8.42GHz for quad elements



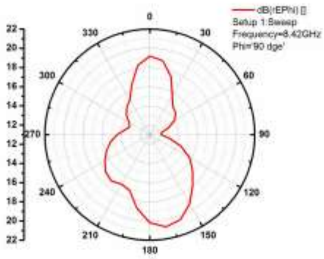
E-plane co-polarisation at 8.42GHz



E-plane cross-polarisation at 8.42GHz



E-plane co-polarisation at 8.42GHz

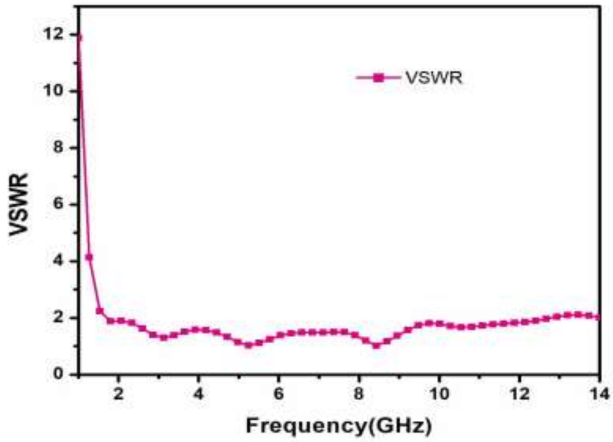


E-plane cross-polarisation at 8.42GHz

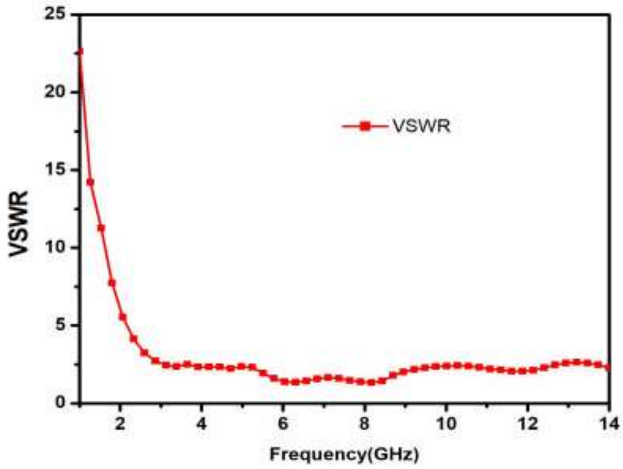
VOLTAGE STANDING WAVE RATIO: -

Voltage Standing Wave ratio (VSWR) is a measure of how efficiently the radio frequency power is transmitted from a power source through a transmission line into a load (for example from a power amplifier through a transmission line to an antenna). One of the most widely seen relationships or formulas for VSWR relates it to the reflection coefficient. The reflection coefficient, Γ is defined as the ratio of the reflected current or voltage vector to the forward current or voltage. VSWR = (1+Γ)/(1−Γ)

VSWR of quad antenna without stub



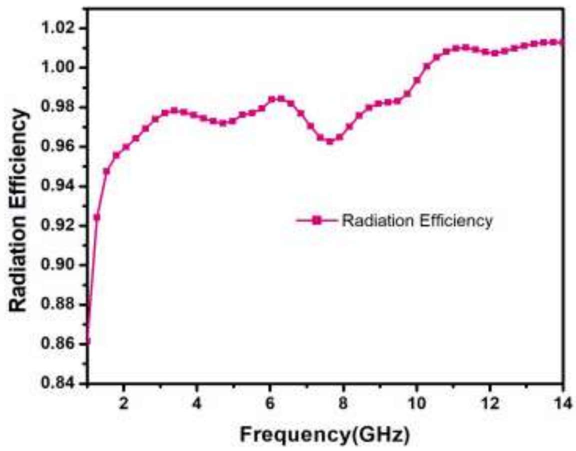
VSWR of quad antenna with stub



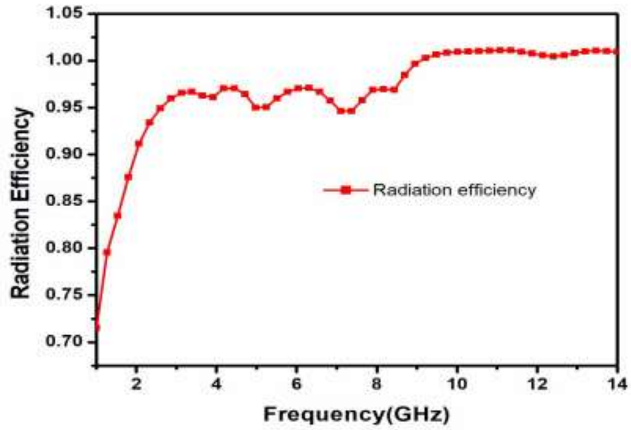
RADIATION EFFICIENCY: -

Radiation efficiency is another important parameter to describe how efficiently an antenna transmits and receives RF signals, which is defined as the ratio of the total power radiated by an antenna to the total input power received from the generator. An antenna with high radiation efficiency efficiently radiates the input power to free space. In the case of low radiation efficiency, the input power is mostly dissipated because of the internal losses such as metal conduction, dielectric and magnetic losses within the antenna. For ideal lossless antenna, the radiation efficiency is 1

Radiation efficiency without stub of quad antenna



Radiation efficiency of quad antenna with stub



CONCLUSION

A compact ring-shaped four-element textile MIMO antenna is investigated and discussed. Throughout the UWB band, the antenna provides very high port isolation due to the integration of an ‘8’ shaped stub in the GP of the antenna. The uniqueness of the work is that the wearable design offers very high port isolation of 26 dB through a wideband with the element spacing of only 0.052λ. The proposed antenna offers very low ECC (ECC9.9) over the entire UWB band. The present ring-shaped four-element textile MIMO antenna is suitable for ultra-wide band UWB(3.1GHz-10.6GHz) applications.

FUTURE SCOPE

Future scope of the work includes designing more compact antenna for the possible UWB applications. Various techniques can be used in order to achieve multiple band notch characteristics. Antennas for MIMO applications can be designed. Since, UWB enjoys a wide bandwidth and co-exists with other services, integration of these two technologies may be investigated for high-speed communication. Investigations can be made to realize compact ultra-wideband MIMO antennas having a very wide impedance bandwidth and high in-band isolation between radiators.

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