A Compact Textile MIMO Antenna with Modified DGS for ISM Band Applications

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***Abstract*—A miniature cloth mimo antenna is introduced in this work. The design of the antenna makes use of jeans material. Two mirror-image rectangular antenna pieces are part of the proposed structure. An imperfect layout is produced by perforating the base structure. The design with its total size is 65 × 150 × 1.5 mm³. With a resonant range of 2.40 to 2.485 GHz and an isolation of approximately 26 dB, this structure is excellent for use in medical, scientific, and industrial settings. The radiation parameters and diversity performance that were tested are considered adequate for use as a mimo antenna.**

Keywords— Textile antenna, MIMO, ISM band, DGs, Jeans, Wearable applications

I. INTRODUCTION

Antennas for wearable wireless devices that are small, flexible, and capable of high data rates are in great demand [1]. Modern small wireless gadgets are increasingly using textile substrate materials to create flexible electronics that can be worn. Wearable textile antennas need to work well in a wide range of situations that happen when a person moves. Wearable antennas made of textile substrates are simple to integrate into smart body worn substances and flexible textile electrical systems [2]. It incorporates wireless communication, sensing, and location capabilities that enable adaptable integration within clothing [3].

The use of a multiple-input multiple-output (MIMO) antenna on textile substrates enhances the quality of signal transmission and adds durability, thus circumventing these limitations. Because of the dynamic nature of the human body, wearable MIMO antennas must be biocompatible, pliable, isolated, and provide strong radiation performance [4].

Wearable textile MIMO antenna structures have a dearth of literature that takes into account the needs of ref. [5-11]. As a whole, the MIMO antenna is influenced by the different isolation enhancement strategies used for radiating elements in these works. Additionally, these patch antennas have a complex structure, limited bandwidth, and low efficiency. As a result, designing a simple wearable textile MIMO antenna with strong radiation performance, excellent isolation, and small size is challenging. Different methods can be considered to achieve very high port isolation. In this paper, we have used the DGS technique for better isolation.

This paper proposes a small wearable textile MIMO antenna. The proposed design consists of a ground structure flaw and two indistinguishable microstrip radiating patch components. The properties of the jeans fabric used are ϵ_r=1.6 with tan δ=0.02, and a thickness of 1.5 mm. It offers near about 0.1 GHz bandwidth and a resonant band at 2.45 GHz. Between two ports, a notable 26 dB of isolation is attained.

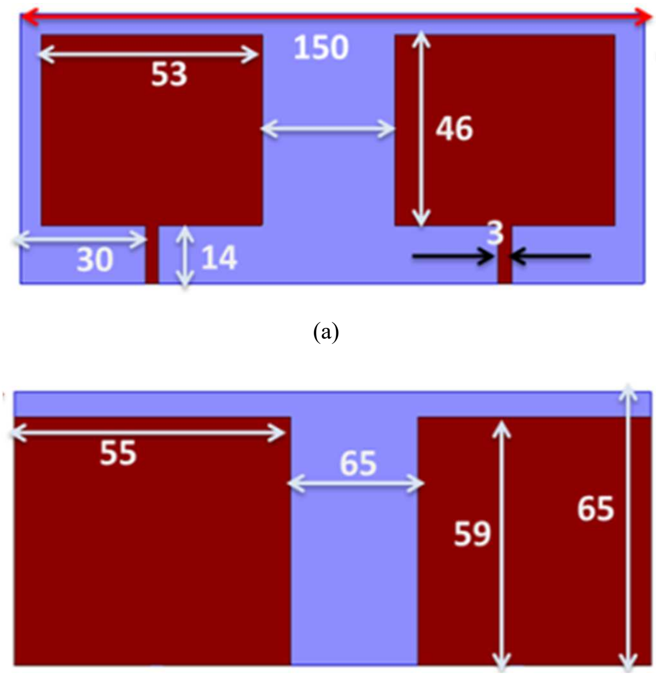

Fig.1. The suggested MIMO antenna arrangement (a) Front and (b) Back-views (All dimensions are in mm)

Ansys Electronics Desktop software is used for the simulation and analysis. Good optimization is done to obtain the better results. The suggested design is appropriate for high data rate wearable devices because of its properties, which include flexibility, good bandwidth, better size, and significant isolation. It is found very suitable as a flexible antenna to use with the clothing materials and turned into a wearable MIMO radiator.

II. STRATEGY OF TEXTILE MIMO ANTENNA

Fig.1 depicts the suggested MIMO antenna's design configuration. As seen in Fig. 1(a), there are two micro-strip components in the patch. As seen in Fig. 1(b), the ground layer is made up of the partially ground structure with a central incision.

A. Outcomes of the Antenna

Figure 2 displays the MIMO antenna's simulated transmission and reflection characteristics. With a bandwidth exceeding 0.1 GHz, the two antenna elements resonate at 2.45 GHz. This operational band was found to be between 2.40 and 2.485 GHz. The actual level of isolation concerning the dualistic ports beats 26 dB.

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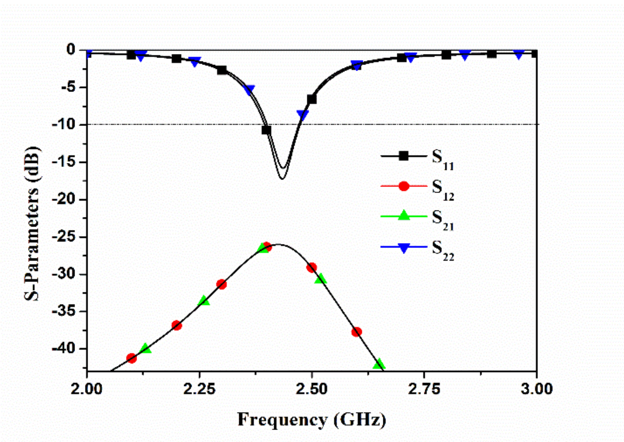


Fig.2.Simulatedreflection and transmission properties (S_{11}&S_{22})

Fig. 3 shows the two-element antenna's current distributions at 2.4 GHz. The left sided antenna element is considered as the first antenna to which excitation is applied. The figure and element colors make it very evident that there is very little signal coupling between the leftward and right sides of the element. It guarantees an extremely high level of port-to-port isolation. In addition, the distribution of surface currents provides insight into the reflection performance. It is also discovered to be highly dependable. Defection in the ground plane contributes the low amount of current scatterings. If surface current scattering is less, it will mean fewer reflections. The found current scatterings satisfy the MIMO criteria.

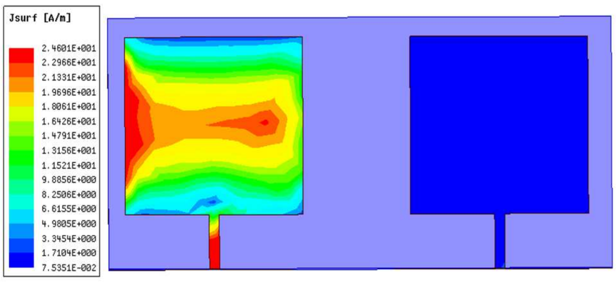


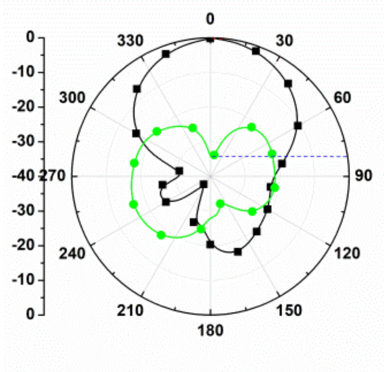
Fig.3.Simulatedsurfacecurrentdistributionforthe antenna of excitations at 2.4 GHz

Fig. 4 displays the two-port radiating antenna's E and H-plane radioactivity orientations. In both the E and H planes, the x-polarization is extremely low in comparison to the co-polarization.

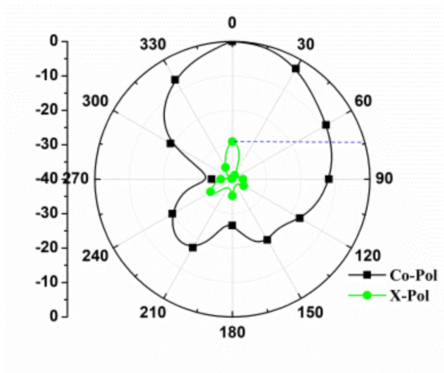
B. MIMO Characteristics

Analysis of the correlation between antenna elements is necessary for determining their separation. One way to quantify this association is by looking at the ECC. A little numeral, typically below 0.49, indicates strong isolation, whereas a high value indicates poor isolation. ECC and DG are used to assess the MIMO antenna diversity performances. A low ECC is necessary for improved performance. Equation 1 [12] describes how the scattering factors are used to determine it. On the operational bandwidth, the ECC value of the planned MIMO antenna is 0.02. The suggested textile MIMO antenna design's simulated ECC curves are displayed in Fig. 5.

$$ECC = \frac{|S_{aa}^{*}S_{ab} + S_{ba}^{*}S_{bb}|^{2}}{(1-|S_{aa}|^{2}-|S_{ba}|^{2})(1-|S_{bb}|^{2}-|S_{ab}|^{2})} \qquad (1)$$



(a)



(b)

Fig.4.Simulatedradiation patterns of the antenna, a) E and (b) H-plane at 2.4 GHz

Another crucial MIMO metric for characterizing multiplexing performance is the diversity gain (DG). Equation 2 [13] defines the relationship between ECC and DG. It is quite important to observe the high DG value of 10 dB. The investigated all the outcomes found here are very reliable to establish the design as a good MIMO structure. It is illustrated in Fig. 5.

$$DG = 10\sqrt{1-(ECC)^{2}} \qquad (2)$$

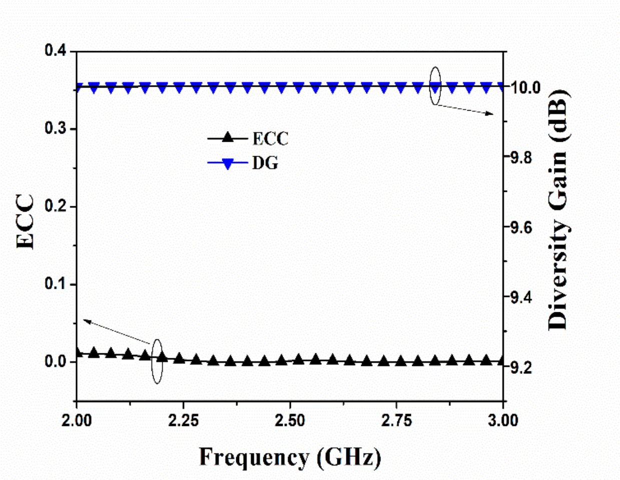


Fig.5.Variations of ECC and DG values

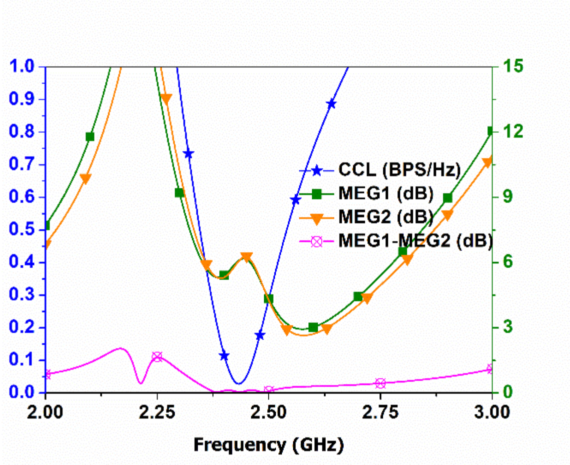


Fig.6.Variation of MEG and CCL.

TABLE 1. Comparison with 2-port MIMO Literature

S. No	Substrate	Size(L×W×h)mm³	f_0(GHz)	Efficiency (%)	Gain(dB)	Isolation(dB)
[5]	Felt	42×32.5×1	5.2	NR	5.7	18
[6]	felt	42×34.5×1	5.25	NR	5.7	18
[7]	jeans	55×35×1.5	5.8	NR	6.9	26
[8]	felt	37×76×1	5.8	90	4.33	29.26
[9]	Felt	38.1×38.1×2	2.4	27	2.79	12
[10]	Jeans	40×70×1	5.92	NR	4.4	53
[11]	RT duroid5880	28×25×0.5	2.45	40	0.5	30
Proposed work	Jeans	55×65.×1.5	2.45	88	3	26

Another important consideration when assessing the MIMO structure is mean effective gain. The constructed antenna is assessed using the computed value of MEG from Equations in ref. [14] to determine whether it can operate in a multi-path fading scenario.

From the Fig. 6 a reliable performance parameter of MEG value is seen. According to the article [14], this figure also shows the antenna's channel capacity loss (CCL). A very little CCL value (<0.24 bits/sec/Hz) suggests a negligible amount of signal loss while being sent. Table 1 shows a comparison between the current literature on ISM bands and the put forwarded MIMO antenna. The advocated antenna has good radiation and isolation performance in a small package, which is crucial for modern wearable technology.

III. CONCLUSION

For use in wearable devices, this article deals with the planning and designing of a small but very effective cloth MIMO antenna. This antenna is of 65 × 150 × 1.5 mm³. It has a significance frequency of 2.45 GHz and a bandwidth of 0.1 GHz. We achieve an impressive 26 dB of isolation. With DG near to 10 dB, and ECC to 0.02, MIMO performance is significantly improved. Good radiation performance of the design has been achieved. A textile MIMO antenna is thus a worthwhile option for future wearable devices operating in the ISM band.

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