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A Quad Element Textile Material Based Printed MIMO Antenna for Wearable Application

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Abstract: In this manuscript, 4-port textile material-based peddle-shaped MIMO antenna is introduced. The presented antenna is electrically small (58 mm × 79 mm), made on textile/felt material of dielectric value is 1.34 and a thickness of 1 mm. To minimize mutual coupling among the elements, a combination of H-and Π -formed design is implanted in the ground layer to decrease the surface current among the elements. The total dimension of the 4-elements MIMO design is only 58 × 79 × 1 mm^3. The advantages of the designed MIMO antenna can be observed in the term of simple in structure for isolation improvement as well as simple in geometry. Using these contemplations, a compact textile-based 4-elements MIMO antenna is planned and analyzed to work in the range of from 2.34 GHz to 6 GHz application. The isolation among the ports is below than -20 dB across the entire frequency range and also MIMO performances are analyzed and studied. Experimental authentication of the proposed structure MIMO is also provided and it can be used in wideband application.

Keywords: multi-in multi-out (MIMO); ECC; TARC; isolation; wearable

1. Introduction

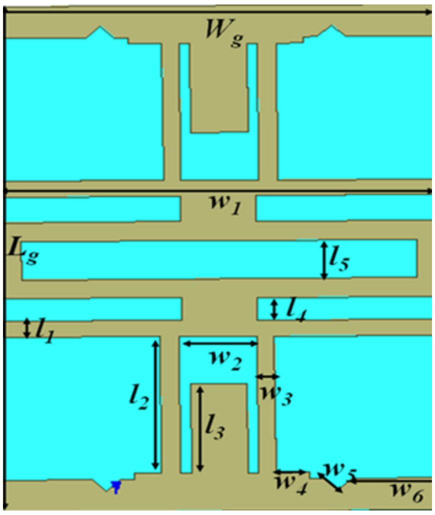
The quick improvement of portable innovation toward the 5G-innovation requests wideband, ultrawideband (UWB) and multiband application-based antenna apparatuses are generally helpful to serve remote updates and to diminish the structure by and large device size, intricacy, and assembling costs. The wideband based antennas have pulled in research towards as a result of various highlights, for example, high information rate, low force prerequisite, numerous channel network at an at once as capacity to serve great pictures[1-7]. Wideband antenna can be utilized in business applications and for this application, begun analyst toward development of UWB based reception apparatuses for wideband applications, for example, wearable gadgets, IoT and intellectual radio[8-11]. At long last, a solitary wideband radio antenna has its particular constraints in dealing with multi-channel correspondence for a wide range application[12-16]. In[17-18], Wearable antennas are now used for researching medical problems, sports, military applications, etc. It attracts the attention of researchers around the world for such interesting applications. Printed antennas are a critical component. In[19-23], a number of publications discuss distinct wearable MIMO antennas that are designed for use in MIMO and wireless applications, with the goal of reducing element-to-element coupling. A wearable device with a dual-polarized design has been introduced. The existing manuscript is used subsurface radiation exhibiting polarisation diversity activity. It covers isolation is above 17 dB and an S_{11} B.W. of 144 MHz. Despite the fact that previous research has focused on MIMO antennas with linear polarisation properties for use in wearable devices, [19]. In[22], a MIMO designed structure with dual-band capabilities is described. Circular-shaped high-impedance surface supported MIMO antenna has been presented in[23]. Many MIMO antennas with low mutual coupling have been designed and presented for wireless applications in various current literatures. While, no one wearable 4-element textile material-based MIMO antenna is presented for wireless application. So, MIMO antenna structure that gives wide working range, high gain and secure RD as well as high data rate. A 4-element textile material-based antenna is developed and analyzed.

In this work, a peddle-shaped MIMO antenna based of microstrip-fed single-layer compact textile material is introduced. The intended design shows the isolation among the port element is less than -20 dB and operating band is ranging from 2.4 GHz to 5.8 GHz. The exceptional feature of this presented design is that the simple structure is used for reducing the mutual coupling. In addition, ECC and TARC are measured and it compare with simulated outcomes.

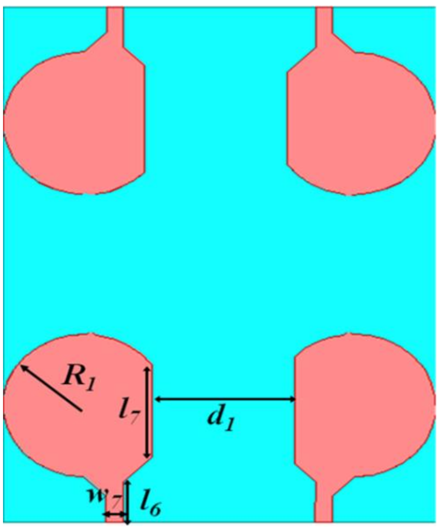
2. Antenna concept and design

2.1 4-Element MIMO antenna geometry

The design parameters are as given: L_g = 79 mm, W_g = 58 mm, W_1 = 57.5 mm, W_2 = 10.25 mm, d_1 = 19 mm W_3 = 2.5 mm, W_4 = 4.3 mm W_5 = 2.55 mm, W_6 =12 mm, W_7 = 2.3 mm, l_1 = 2.5 mm, l_2 = 21.5 mm, l_3 = 14 mm, l_4 = 4 mm, l_5 = 6.25 mm, l_7 = 14.2 mm and R_1 = 11.5 mm. Structure of the designed textile based 4-element MIMO antenna is shown in Fig. 1.



(a)



(b)

Fig. 1: 4-element proposed textile MIMO antenna (a) back portion (b) front portion.

2.2 MIMO antenna design and configuration

Textile MIMO antennas for wearable applications are described in detail in this segment. A combination of triangular with semi-circle shape and two compact monopole radiator and to build a MIMO combination, 22 × 22 mm^2 squares are arranged in the opposite position and run through the CST software for simulation.. The complete dimension of the planned antenna is only 79×58×1 mm^3 and a textile substrate of 1 mm thickness is used. The substrate possesses a loss tangent of 0.002 and a dielectric constant of 1.34. In the first step, two identical peddles-shaped monopole type antenna is using 50-ohm microstrip lines, all antennas are fed from a common ground plane and positioned in mirror configurations. Mutual coupling occurs between antennas printed on the same substrate due to surface wave coupling and current flowing on the shared ground plane, Poor impedance bandwidth and isolation between radiators result as a result of this. In this proposed design, a combination of H- and Π -shaped strip are introduced in such a technique that the isolation between port elements of designed MIMO geometry is improved strangely. Fig. 1(a) shows the insulating structure, which is completed of an H-and Π-geometry with couple triangular structure placed into the bottom layer; Fig. 2 shows the outcomes of these slots. Nonetheless, there is still a connection between the four components' bases. This improves the MIMO antenna's suitability for use in handheld electronics. The geometric distortion in the ground plane, which is formed like an H, Π, and triangle, functions as a stop-band filter. To suggest an arrangement among the antenna parts that improves isolation, these methods employ the overall shape of these triangular faulty ground structures.

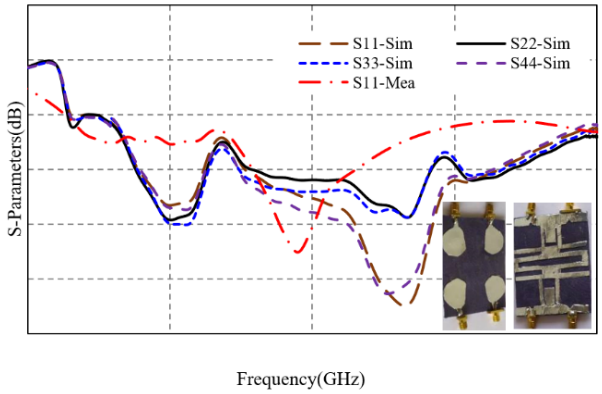


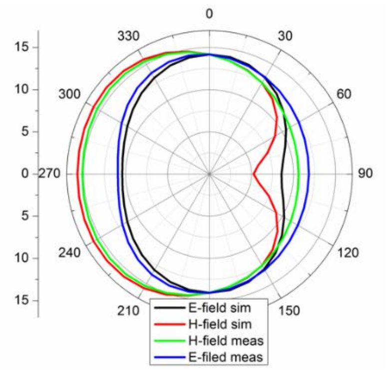
Fig. 2: Simulated and measured S-values.

3. Results discussion and analysis

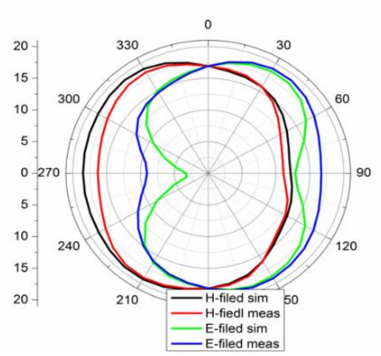
3.1 S-Parameters

To verify accuracy of the peddles-shaped textile-based MIMO antenna simulation outcomes, the antenna is fabricated and tested. The computed and verified S-characteristics exhibit good accuracy as shown in Fig. 2. The measured BW for the intended antenna is 3.6 GHz (from 2.3 GHz to 5.9 GHz) and the isolation among the port 1, port 2, port 3 and port 4 is 20 dB higher in most frequency bands as shown in Fig. 3. The small variation between measured and simulation result is due to manufacture and welding tolerances, lead damage, and SMA connector things.

3.2 Radiation performance



(a) E and H filed at 2.5 GHz



(b) E and H filed at 5.0 GHz

Fig. 3: Measured and simulated radiation fields.

In this part, we'll look at how well the radiation performance of designed 4-element peddle-shaped textile antenna is analyzed. Figure 4 illustrates the gain radiation shape at 2.5 GHz and 5.0 GHz. Simulated and measured values are approximately identical. The measured and simulated graphs towards the broadside are excited by Port 1 and remaining ports are matched with 50 ohms. When Port 1 is enabled, all other terminals are connected with a value of 50-Ω and operate in a manner consistent with good value. In the same way, if Port 2 is enabled and all other ports are matched with 50-Ω.

3.3 MIMO parameter analysis

To endorse the diversity analysis of the presented peddle-shaped MIMO design and this requires analyzing different It is crucial to use MIMO performance metrics like ECC and TARC and it should be ECC < 0.5, TARC < 0 dB[24, 25].

3.3.1 ECC

In MIMO structure, ECC is a key parameter that explains how one antenna is separated from one another. If one antenna's element is horizontally polarized, the other must be vertically polarized. In this situation, ECC is zero between them. Thus, in an ideal scenario, ECC would be zero, but in a real setting, an acceptable number for an uncorrelated condition is less than 0.5[24], which means that the antenna elements can be more diverse. The following relation has been used to compute the ECC in equation (1)[24].

$$\rho_a = |\rho_{mn}|^2 = \frac{|S_{mm}{}^{*}S_{mn} + S_{nm}{}^{*}S_{nn}|}{(1-|S_{mm}|^2 - |S_{mn}|^2)(1-|S_{nn}|^2 - |S_{mn}|^2)\rho_{rad,m}\rho_{rad,n}} \quad (1)$$

where, $\rho_{rad,m}$ and $\rho_{rad,n}$ are the radiation efficiency of mth and nth antenna element respectively.

The planned MIMO design has an ECC of less than 0.02 and Fig. 5 shows a comparison of the ECC that has been measured and that has been simulated.

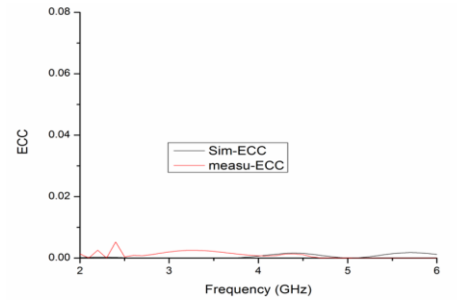


Fig. 4: Experimental and computational estimates of ECC.

3.3.2 TRAC

In a multi-port antenna system, when a MIMO system's antennas work concurrently. In this case between antenna element affects one another and the complete analysis of the MIMO system will influence in relations of impedance BW, isolation, and efficiency. As a result, relying solely on the S-parameter values will not be sufficient to reveal the MIMO system's true performance. Therefore, a TARC is investigated and described as the "square root of the ratio of total incident and reflected power" of the overall MIMO antenna system[25]. To determine the TARC for the designed antenna system, use the following equation (2)

$$\Gamma_a^T = \sqrt{\sum_{i=1}^{N}|b_i|^2 / \sum_{i=1}^{N}|a_i|^2} \quad (2)$$

where the "incident" and "reflected" signals from each port are denoted by a_i and b_i, respectively. Figure 6 shows TARC is lower than -10 dB in both modelling and measurement results. Figure 7 illustrates the proposed antenna's simulated and practical peak gain, which is 2.9 dB at 5.4 GHz.

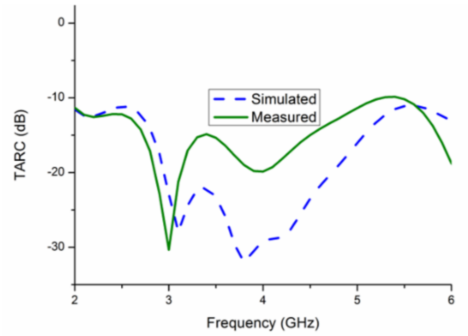


Fig. 5: Measured and simulated values of TARC

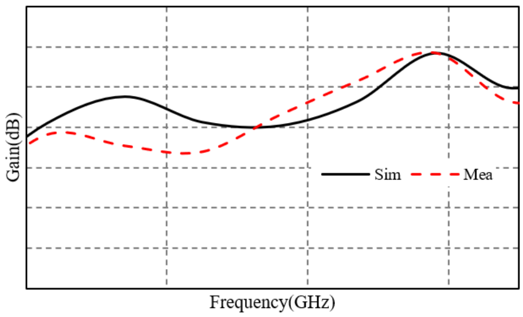


Fig. 6: Measured and simulated gain of proposed MIMO antenna.

4. Conclusion

A quad element peddle-shaped printed MIMO antenna with H-and Π - formed in the ground plane for wearable application is presented and examined in this article. The overall size of the 2-port MIMO antenna is 58 × 79 × 1 mm^3. The advantages of the designed structure observed in the term of simple in structure for isolation improvement as well as simple in geometry. Using these contemplations, a compact textile-based two elements MIMO antenna is intended and analyzed to function in the range of from 2.34 GHz to 6 GHz application. The results are equally encouraging, with a TARC value greater than -10 dB and an ECC value lower than 0.02. Subsequently, the presented design is a lot of suitable for wearable and different frequency band applications.

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