Mutual Coupling Reduction among Closely Spaced Linear Array Reconfugrable Microstrip Antenna

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Abstract: The fifith-generation 5G multiple-input multiple-output (MIMO) microstrip antenna with isolation enhancement that is tiny and based on a bandpass metamaterial (BPM) is presented in this paper. The expectation of higher data rates drove the development of 5G mobile communication networks. The performance of a two-element microstrip antenna array with and without bandpass metamaterial, as a mutual coupling reduction tool, is introduced. The antenna consists of two parts, with its radiators positioned to report the opposite direction. The array antenna's overall dimensions are small, measuring 40 × 72 × 1.6 mm³. The proposed isolated two-element antenna array produces bandwidth and mutual coupling are 16GHz at -53.83dB, respectively, while the rectangular microstrip patch antenna array produces these values at 12.03GHz at -14.69dB. When compared to the double microstrip parallel antenna, the double microstrip opposite antenna with BPM is superior in terms of mutual coupling. The increasing demand for faster data speeds in the rapidly changing field of mobile communication technologies is met by the presented creative antenna.

Keywords: HFSS, 5G, Mutual Coupling, Reconfugrable Microstrip Antenna.

1. Introduction

Ever since the first Generation "1G" phone was introduced in the early 1980s, allowing users to make and receive phone calls, mobile communication systems have gone through several evolutionary stages [1, 2]. This development mainly depends on increasing data transfer speeds, which can be as high as 100 Mbit/s for fourth-generation systems and possibly as high as 1 Gbit/s. By achieving speeds of up to 10 Gbps and latency of less than 1 ms, the fifth-generation systems hope to cut down on energy usage [3]. Fifth-generation (5G) antennas work in the 28 GHz and 38 GHz bands, while fourth-generation (4G) antennas use the 0.5–3 GHz frequency range [4-6]. By utilizing the millimeter wavelength spectrum, this new cellular technology can access wireless broadband, use multiple antennas for transmission and reception, and reduce mutual coupling between antennas, among other benefits [7]. High gain and directed radiation patterns are essential for antennas operating in the millimeter-wave spectrum [8]. Antennas for mobile phones need to be small, light, have a low Specific Absorption Rate (SAR), and work with other radio frequency (RF) components [9-11]. As a result, antenna design becomes more difficult when the millimeter-wave spectrum is adopted because it naturally reduces the electrical length of the antenna. Additionally, this makes it possible to improve gain in the millimeter-wave band by using array antennas, which reduces excessive path loss [12-14]. Furthermore, as shown by the numerous works that propose dual-band antennas for mobile phones using a variety of techniques, dual-band antenna solutions are preferred for 5G applications.

The article's main goal is to design, simulation and manuipulate a patch array antenna specifically for 5G mobile phone transmission while, using bandpass metamaterial to reduced mutual coupling between colsely spaced antenna elements. The proposed antenna should have a wide bandwidth, a simple geometry, a characteristic radiation pattern beam, and high gain. The suggested isolated microstrip array antenna approaches reduce mutual coupling and increase antenna gain. In comparison to 2.23 dB and -14.69 dB obtained by the traditiona rectangular patch Microstrip antenna RMPA array, the suggested isolated microstrip antenna array is delivering a greater gain of (phi = 0) at 7.81 dB and a mutual coupling of -53.83 dB.

2. Antenna Geometry

2.1. The Single Element Antenna

The aim of this section is to design an antenna specifically for next-generation mobile communication on mobile phones, with a higher gain and a more concentrated radiation pattern. Since the millimeter-wave frequency is designated for future 5G systems, antennas operating in this range need to be small. Figure 1 shows the antenna's dimensions and geometry in detail. The antenna is built on a Epoxy-FR4 substrate with the following specifications: permittivity $\varepsilon_r = 4.4$, loss tangent tanδ = 0.025, and thickness h = 1.6 mm. The ground plane of the antenna is 36 × 14.5 mm^2. The antenna's critical parameter values are illustrated in the Table 1, which are necessary to attain different operating bands.

Table 1: Dimension of the sigle antenna element.

Parameter	dimension	Parameter	dimension
W_1	2.8mm	L_1	7.5mm
W_2	18.4mm	L_2	6mm
W_f	3mm	L_f	16mm

Ansys® Electronics High Frequency Structure Simulator HFSS Ver 2023 R2 was used for the antenna's design, simulation and optimization, guaranteeing exacting attention to detail in the creation of an antenna with a high gain and a directed radiation pattern that would meet the changing needs of next-generation mobile phones.

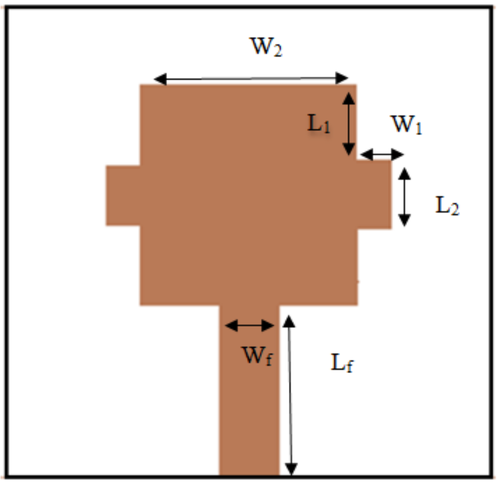

Figure.1: The geometry of the proposed RMPA single-element antenna.

The reflection coefficient for the single element of the 5G antenna is shown in Figure 2. The operating bands of the antenna are obtained the band ($S_{11} <$ −26.87 dB) from 2.50 to 13.03 GHz with a width of 10.53 GHz. The bands obtained cover millimeter-wave frequency bands for future mobile cellular devices.

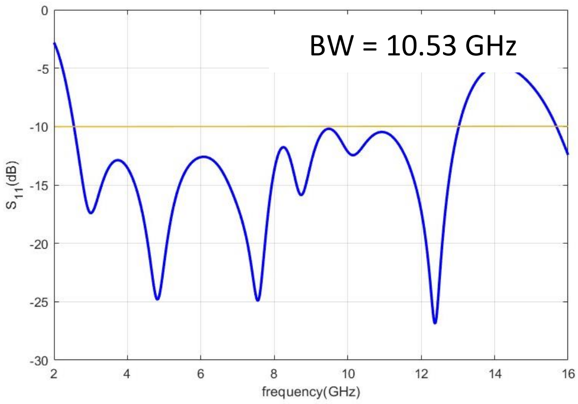

Figure .2: Simulated reflection coefficients for the proposed antenna.

2.2. The Antenna Array Geometry

. We describe The two-element MIMO antenna with an opposite orientation is presented in this section. (RMPA) were used as the starting point for the construction of the 1 x 2 antenna plannar array. The RMPA size is 40 × 72 × 1.6 mm^3. A readily available flame resistant Epoxy-RF4 substrate with a thickness of h and dielectric constant (ε_r) of 4.4 has been employed. The resonant patch's surface current distribution may be changed to produce the mono-band behavior. As shown in Figure 3, this is achieved by reconfugrable edges. The 1 x 2 RMPA array's patch elements are separated by 12 mm. Provides a summary of the fundamental design parameters for the 1 x 2 mono-band RMPA array, are summarized in Table 2. It is evident from Figure 4 that the coupling is stronger when the two antenna elements are closer to each other meanwhile, the performance of the antenna system could seriously deteriorate, which is why the decoupling structure to reduce the interference.

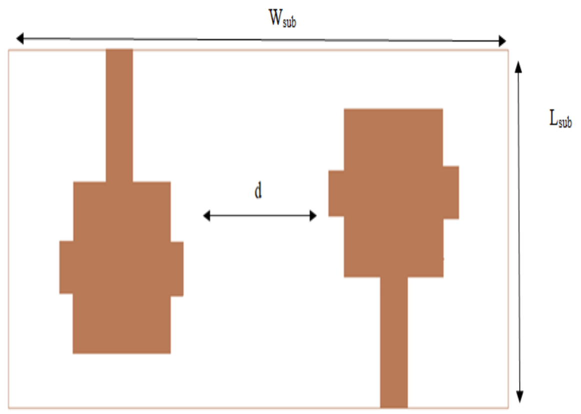

Figure.3: Top view of 1×2 plannar array antenna.

Figure.(4) shows the simulated result of the modified 1x2 report the opposite direction array antenna this plot displays S_{11}, reflection coefficient, amd S_{12}, the coupling coefficient, as a function of the operating. RMPA array is resonating at 2.36 GHz. The reflection coefficient obtained at the resonant frequency is equal to -50.00 dB. The bandwidth of RMPA array is very large. The graph depicts that the value of mutual coupling at the fundamental resonant frequency of 2.36 GHz is equal to -14.69 dB. This value of mutual coupling is very high as it is greater than -20 dB. Additionally, from Figure.4 we also see that the graphs of reflection coefficient and mutual coupling are overlapping at the fundamental resonant frequency of 2.36 GHz. This means there is huge amount of interference between the two antenna elements 1and 2 of RMPA array. This implies the transmission and reception of electromagnetic signals between the two antenna elements is not proper and better.

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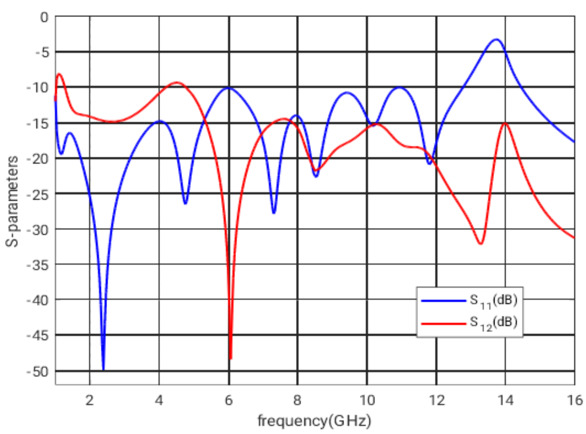


Figure.4: Simulated S-parameters of the two-element microstrip patch array antenna.

3. BandPass Metamaterial (BPM)

The problem of the coupling, in all frequencies wherever the distance between the elements is extremely small, and this causes a robust coupling, and thus the traditional methods of reducing coupling would not bring the desired goal in these all frequencies and therefore we have got provided a more professional and novel techniques to solve this drawback. The main objective here is to build a decoupling structure that has a strong band rejection characteristic, and this we can implement through using Ansys® Electronics HFSS Ver 2023 R2 . The proposed structure, as shown in Figure 5, It consists of a group of rectangles, each with a height of W_R= 2 mm and lengths L_{R1} = 4 and L_{R2} = 3 mm, while the spacing between them is S=1 mm. Bandpass metamaterial (BPM) structures are structures which can stop or assist propagation of electromagnetic waves. These structures are responsible for the formation of stop bands. These structures also eliminate the surface waves which emanate from the substrate.

2.3. The proposed isolated two- element MIMO antenna

The solution to this coupling problem is to make the antenna's mutual impedance (both real and imaginary parts) at antenna resonance equals to zero. This state can be reached by increasing antenna isolation. The band-pass filtering system structure has been implemented between the microstrip patches on the surface to improve antenna isolation, as shown in Figure.6. Here our concern is to achieve good band rejection characteristics by inserting the BPM in the proposed MIMO antenna. The BPM filtering structures are introduced between the patches on the surface to investigate the mutual coupling suppression attributes.

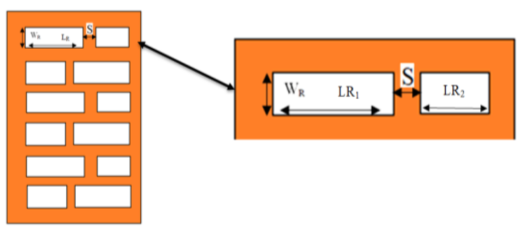


Figure.5: The layout of the designed BandPass Metamaterial structures.

Table 2. Dimensions of the Designed Antenna.

parameter	Value(mm)	Parameter	Value(mm)
W_{sub}	72	L_{R2}	**3**
L_{sub}	40	W_R	2
h	1.6	s	1
d	12	L_{R1}	4

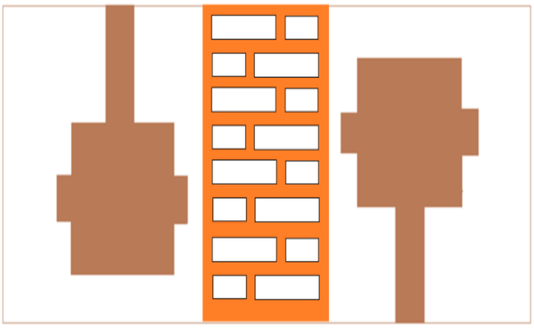


Figure.6: Layouts for the 1 × 2 MIMO RMP antenna array with metamaterial structures.

Figure.7 displays of two MIMO antenna patches with inserting BPM between them. A reduction from - 53.84 dB in the mutual coupling between the antennas is observed at the desired frequency.

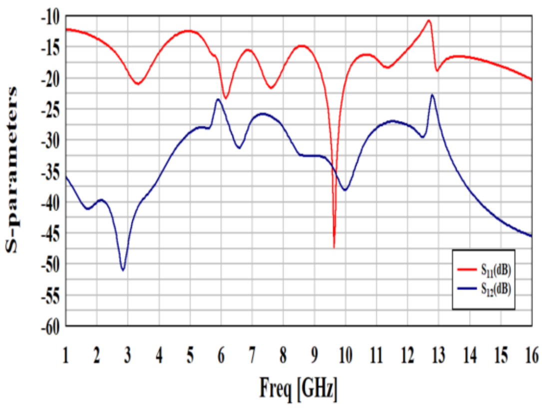


Figure.7: Simulated S-parameters of the two-element microstrip patch plannar Array antenna with metamaterial structures.

A comparison of the mutual coupling between two MIMO antenna patches with and without the addition of BPM between patches is shown in Figure 8. Resonant frequencies for the suggested isolated microstrip antenna array are 3.27, 6.11, 7.56, 9.61, and 12.91 GHz, in that order. These resonant frequencies have bandwidths of 16.00GHz, in that order. In comparison to an RMPA array without the addition of BPM, the isolated microstrip antenna array Produces a very high bandwidth and also has a very low multual coupling - 53.83 dB at the resonant frequency of 2.84 GHz compared to proposed microstrip antenna array without BPM, Additionally, the suggested isolation microstrip antenna array are no more overlapping at the resonant frequency of 2.84 GHz.

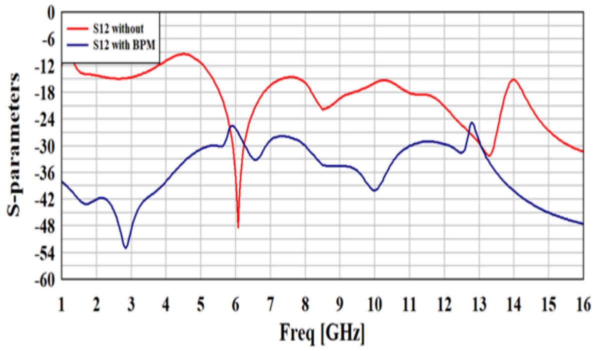
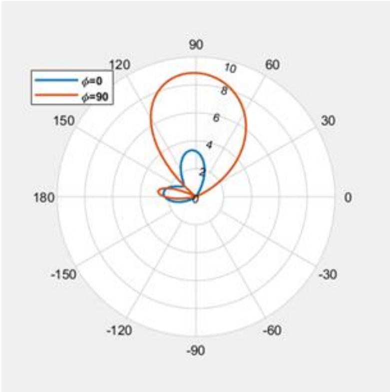


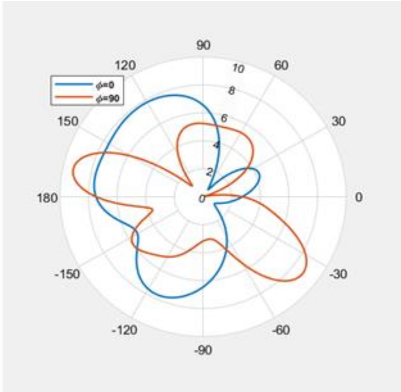
Figure.8: Comparison of the mutual coupling S_{12} of two MIMO antenna patches with and without inserting BPM between patches.

4. The Radiation Pattern

The radiation pattern is a graph that gives information regarding the distribution of electromagnetic energy. The radaition patterns of RMPA without BPM and proposed microstrip isolated antenna array are plotted in Figure.9. The forward power radiated by the antennas is measured at the angle (Phi = 0) and backward power at (Phi = 90) at the same frequency . The RMPA without BPM is producing forward and backward powers equal to 2.23 and 7.95 dB respectively. The forward and backward powers radiated by the proposed isolated microstrip antenna array are 7.81 and 9.27 dB respectively. the proposed isolated microstrip antenna array is a better radiator compared to the RMPA without BPM array because the forward power radiated is more compared to its opponent.



(a)



(b)

Figure.9: Comparison The radiation pattern of the of two MIMO antenna Patches, (a) with BPM between patches and (b) without BPM between patches.

5- Conclusion

In this paper the plannar array of 1x2 antenna element is demonostrated for 5G application, to improve the antenna performances such as band width and the gain for the traditional rectangular patch Microstrip antenna. The reconfugrable patch and ground plane are presented to enhanceing the band width the led to increased band width rather that the traditional RPMS. To enhanced directivity and gain the 1x2 array simulate and design, to remove the rffect of mutual coupling between colsely spaced elements the BPM are presented the result shows the S_{12} is clearly differnet when comparing to cases with and without inserting BPM between the two elements, the lead to size reduction of the orveral design. The array may be used in the wide wireless applications such as ISM band, WiFi, WiMax, and UWB.

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