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Dual Port Frequency Tunable MIMO Dielectric Resonator Antenna for 5G Sub 6 GHz Application

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Abstract

In this article, a two-port Multiple Input Multiple Output (MIMO) Frequency Tunable (FT) Dielectric Resonator Antenna (DRA) for 5G Sub 6 GHz application is presented. FT is achieved through the PIN Diode switches. When all the PIN Diode is ON condition, the proposed antenna provides a dual-band characteristic. When all the Pin Diode is in OFF condition, the proposed antenna provides a wideband characteristic. The more than 18 dB isolation is obtained in the entire bands. The MIMO parameters are computed and confirmed to be within the allowed range. The proposed antenna has been constructed on a FR4 epoxy substrate. The simulated and measured findings are in good agreement. Hence the proposed MIMO antenna is suitable for 5G Sub 6 GHz application.

Keywords- MIMO, Frequency Tunable, Dielectric Resonator Antenna, Sub 6 GHz, Pin diode

1. Introduction

Frequency tunable (FT) antenna have grown in popularity due to their many advantages. These antennas are capable of automatically switching between radiation patterns, polarizations, and frequencies using a variety of techniques, thereby replacing many antennas [1]. Higher data transmission rates and greater channel capacities are becoming more and more necessary with the fast growth of wireless communications systems to accommodate as many users as possible within a coverage area and provide uninterrupted access to high-definition video streaming. However, fading becomes a major difficulty in a multipath environment because of nearby objects or obstacles making this problem even more important [2]. Therefore, the multiple-input multiple-output (MIMO) system was developed because it could handle faster data rates and larger capacities without requiring more channel bandwidth. All the specifications for the modern wireless communication system may be met by a MIMO antenna system [3-5]. Without using more radio spectrum or power, MIMO technology boosts system capacity and throughput of data by using many antennas on the transmitter and receiving sides. A compact design, excellent efficiency, and minimum mutual coupling across ports within the working frequency range are the criteria for the

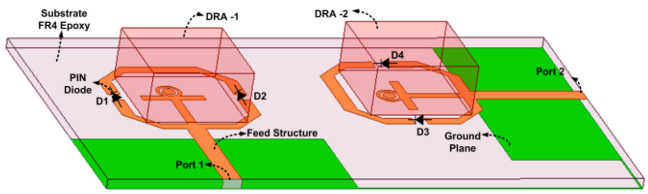

Figure 1. The proposed frequency tunable MIMO DRA

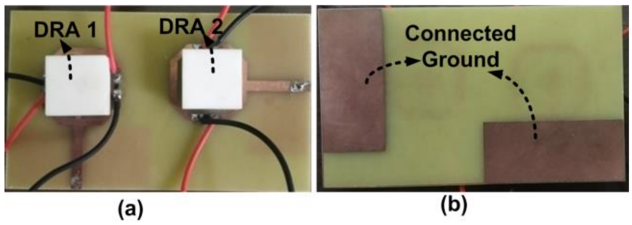

Figure 2. Fabricated dual port frequency tunable MIMO DRA

MIMO system. The Microstrip Patch Antennas (MPA) has been widely utilized for MIMO antenna methods, which enhance wireless communication. This is because the microstrip patch antenna is small and inexpensive. Nevertheless, the major conductor loss of the MPA results in an extremely low radiation efficiency. On the other hand, one attractive approach to offer a wide bandwidth and excellent radiation efficiency is to use a Dielectric Resonator Antenna (DRA). Coaxial feed probes, microstrip feed lines, co-planar waveguides, and aperture coupling are some of the other techniques that may be used to excite DRAs [6-10].

Limited research papers are available regarding DRA-based MIMO dual or triple bands operating in the lower frequency bands. In [11], cylinder DRA and annular ring together produce a two-port dual-band MIMO system. With this configuration, a strong isolation of more than 20 dB is provided for the frequency bands of 1.75 to 2.4 GHz and 3.5 to 5.5 GHz. In [12], In all frequency bands, a cylindrical DRA triple-band hybrid MIMO antenna may achieve isolation of more than 25 dB and give an impedance bandwidth of more than 20%. In [13], A MIMO DRA allows smartphone multi-band LTE MIMO operation and provides an impedance bandwidth of more than 24% in all frequency bands. In [14], By adjusting the permittivity values, a rectangular MIMO antenna was created that can function in the quad bands of 4.70–4.90 GHz, 3.79–4.04 GHz, 2.83–3.07 GHz, and 5.72–5.86 GHz. In [15], a dual-band MIMO DRA with permittivity values

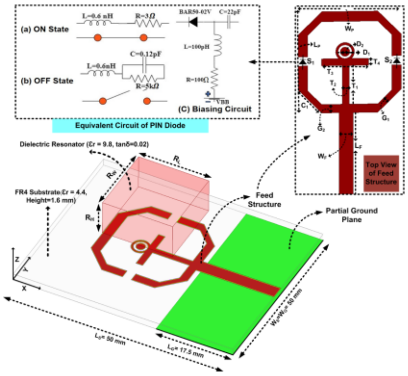

Figure3. Layout of single port FT antenna

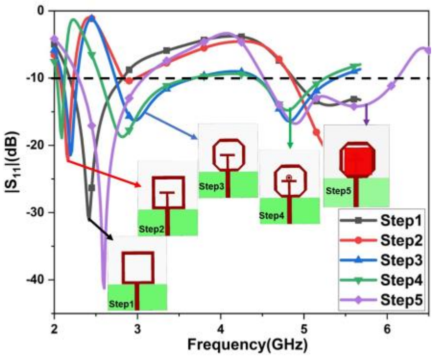

Figure 4. The effect of S_{11} due to various design steps

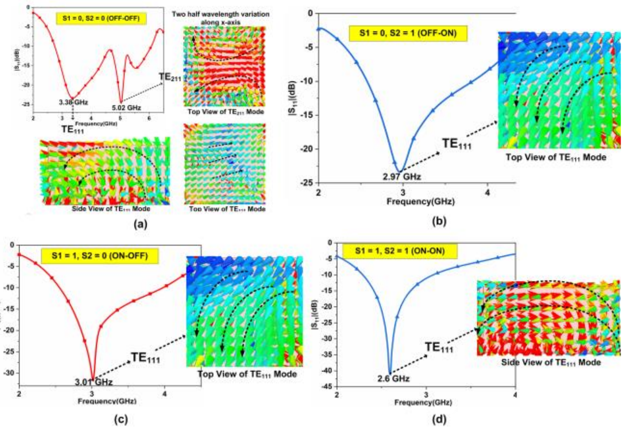

Figure 5. $TE_{111\delta}$ and $TE_{21\delta}$ in various configurations of single-port

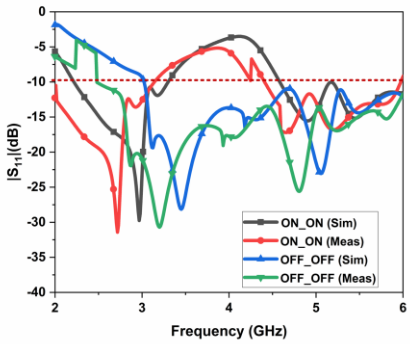

Figure 6. Measured and simulated S_{11} of the proposed MIMO antenna

of 10 and 30 that work at frequencies of 3.6 and 5.2 GHz, respectively. In [4], triple bands were created with a two-port MIMO DRA, although the impedance bandwidth percentage is low.

2. Antenna Configuration and Analysis

A. Single Port FT Antenna

The layout of the single port proposed antenna is shown in figure 3. It is designed on FR4 epoxy substrate (ϵ_r= 4.4). The size of the substrate is 50× 40 mm^2. The ground plane is below the substrate. The truncated rectangular with inner T-shaped is designed on above the substrate. The Rectangular Dielectric Resonator Antenna (RDRA) is the main antenna radiator. It is designed through Alumina (Al_2O_3) (ϵ_r= 9.8) $loss\ tangenet\ tan\delta = 0.0002$. The other dimensions of the single port antenna are given in Table I. The various design steps of the single port antenna are shown in Figure 4. $TE_{111\delta}$ and $TE_{21\delta}$ in various configurations of single-port antenna is shown in Figure 5.

Table I

Dimensions of the single port antenna

Parameters	Size (mm)	Parameters	Size (mm)
$W_S = W_G$	40	L_S	50
H_S	1.6	L_F	19
L_G	17.5	W_F	3
L_C	5	$L_P = W_P$	22
G_2	4	C_1	5
$T_1 = T_3$	10	$T_2 = T_4$	1.5
D_1	6	D_2	5
$R_L = R_W$	16	R_H	8

A. Mathematical Modelling

The single port antenna consists of two dielectric layers: FR4 epoxy and alumina (Al_2O_3). According to [4], The effective permittivity (ϵ_{reff}) and effective height (H_{eff}), are given by equation (1)-(2):

$$\mathrm{H}_{eff} = \mathrm{H} + \mathrm{H_S} \quad (1)$$

$$\epsilon_{reff} = \frac{H_{eff}}{\frac{H}{\epsilon_{r\,RDRA}} + \frac{H_S}{\epsilon_{rSub}}} \quad (2)$$

In [3], states that the resonance frequency of the fundamental $TE_{111}{}^{Z}$ is given by

$$k_z \tan\left(k_z \frac{d}{2}\right) = \sqrt{(\epsilon_{reff-1})k^2{}_0 - k^2{}_z} \quad (3)$$

Where, k_x, k_y, and k_z are wave numbers, they fulfil the subsequent formula.

$$k^2{}_x + k^2{}_y + k^2{}_z = (\epsilon_{reff})k^2{}_0 \quad (4)$$

Where, $k_x = \frac{\pi}{b}$ and $k_y = \frac{\pi}{b}$

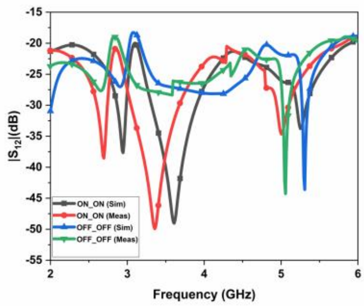

Figure 7. Measured and simulated S_{12} of the proposed MIMO antenna

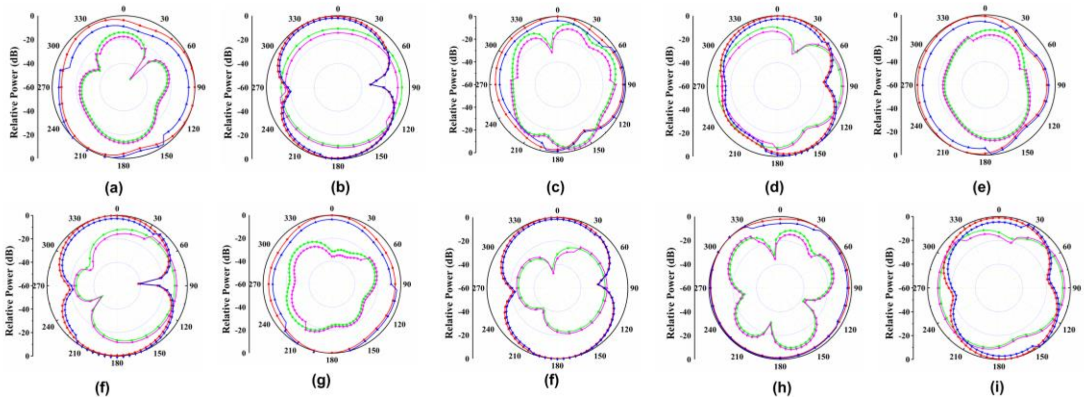

Figure 8. Radiation pattern in E-Plane at (a) 2.96, (c) 4.90, (e)3.12, (g) 3.45, (h) 4.18, and H-Plane at (b) 2.96, (d) (f)3.12, (h) 3.45, and (i) 4.18

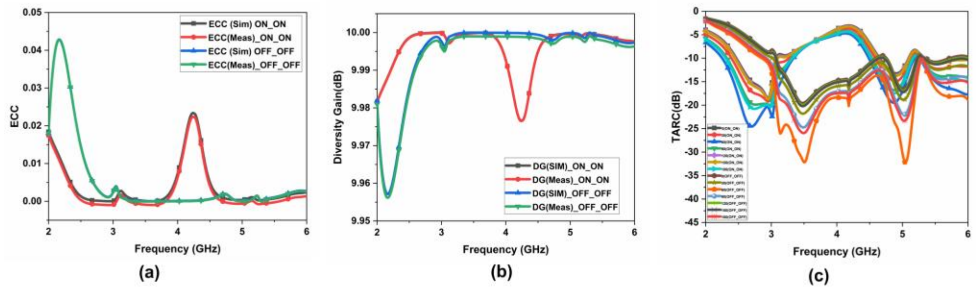

Figure 9. MIMO parameters (a) ECC, (b) DG, and (c) TARC

B. Dual Port Frequency Tunable RDRA

The dual port Frequency tunable RDRA is designed with the single port FT RDRA in a single substrate with a connected ground. The size of the substrate is 50 × 85 mm^2. The number of PIN Diodes is increased to four. The proposed antenna is fabricated to measure the simulated reflection coefficient S_{11} , isolation S_{12}, and radiation patterns in various configurations. The comparison between the measured and simulated results occurred due to fabrication errors of the substrate and DRA. The measured and simulated S_{11} in both ON and OFF configurations are shown in Figure 6. The measured and simulated S_{12} in both ON and OFF configurations are shown in Figure 7. When all the PIN Diode is in "ON" condition, the proposed antenna provides a dual band. In this case, it is used in WiMAX and WLAN applications. When all the PIN Diode is in "OFF" condition, it provides a wideband characteristic. In this case, it is suitable for cognitive radio applications. The more than 18 dB isolation is achieved by the proposed antenna. Figure 8 illustrates the radiation pattern at various frequencies in the H plane (θ=90) and E plane (φ=0). Table II lists the frequency range, bandwidth, and impedance bandwidth percentage for each arrangement.

C. MIMO Diversity Parameters

The Envelope Correlation Coefficient (ECC), Total Active Reflection Coefficient (TARC), Diversity Gain (DG), and are used for calculating the MIMO diversity parameters. The ECC values lie below < 0.05and it is shown in Figure 9 (a). The DG value is approximately 10 dB, and it is shown in Figure 9 (b). The TARC value is below < 0 and it is shown in Figure 9 (c).

Table II

Frequency Range (FR), Bandwidth (BW), and % of Impedance Bandwidth (IBW)

Configurations	FR (GHz)	BW (GHz)	% IBW
ON-ON Simulated	2.22- 3.29 4.58-6	1.07 1.42	39.6 26.8
Measured	2-3.13 4.4-5.8	1.13 1.4	44.8 27.4
OFF-OFF	3-6 2.48-5.8	3 3.32	66.6 80.2

Table III

Comparison of the proposed MIMO with other existing works

Ref.	No. of Port	Reconfigurable Antenna	ECC	Tuning Range
[11]	4	No	<0.5	No
[12]	2	No	<0.13	No
[13]	2	No	<0.1	No
[14]	2	No	<0.16	No
[15]	2	No	<0.16	No
[16]	2	No	<0.02	No
This work	2	Yes	<0.05	49.36

3. Conclusion

In this article, dual port frequency tunable DRA for 5G Sub 6 GHz application is presented. The proposed MIMO antenna is operating in various configurations. The TR of the proposed antenna is 49.36 %. The MIMO characteristics are determined to be within the limit. For 5G Sub 6 GHz applications, the recommended antenna is a good choice.

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