Original Article

Design And Evaluation Of Dual Band Eight Port MIMO Antenna For IOT Applications

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Abstract

A multiport MIMO antenna with Eight ports along with compact ring slots which provides good Isolation of high degree among four ports is proposed. This antenna is designed for multiband IOT applications which operate at frequency 2.4 GHz and 7.9 GHz. To have a better gain and isolation between ports, the antenna proposed was designed with two slots in the shape of a ring. HFSS EM software was used to simulate proposed MIMO antenna and few parameters are evaluated like radiation pattern, lower return loss, impedance view, gain, and VSWR, etc.

Keywords: FD-MIMO CR Slot Resonator FR4 Substrate Microstrip Line feed Internet of Things

1. INTRODUCTION

IoT is currently one of the most rapidly developing sectors in the realm of wireless communications. The current research topic being undertaken towards the evolution of Fifth Generation (5G) cellular systems and their applications is an FD-MIMO, or Full-Dimensional Multiple-Input-Multiple-Output, which is in plane array structure [1]. There will be an active antenna system (AAS) and a two-dimensional (2D) planar array structure in the FD-MIMO antenna system [2]. This configuration provides adaptive electronic three-dimensional (3D) beam formation in space by allowing a pack of so many antenna elements in the provided base station antenna. The spatial correlation of these planar array FD-MIMO systems with modest structure of large size elements will be dramatically increased [3]. To have an overall influence of antenna, the spatial correlation functions of the channels with each and every antenna element and with antenna ports in AAS are developed [4]. MIMO (Multiple-In, Multiple-Out) communication distributes the same data as numerous signals across multiple antennas at the same time while only using one channel [5].

Antenna diversity is a technique for improving the signal quality and strength of an RF link by using several antennas. Because MIMO radios receive and combine several streams of the same data, they can use bounced and reflected RF transmission to actually boost signal strength even without clear line-of-site[6]. This is especially effective in urban areas, where signal loss between single antennas with no clear line-of-sight is a big problem[7].

Overall throughput can be improved with MIMO configuration, allowing for higher-quality video or data to be sent over the network. Even BER (Bit Error Rate) and lost or dropped data packets can be reduced[8]. Various diversification strategies, such as time, frequency, and space, can also be used to reduce fading effects[9].

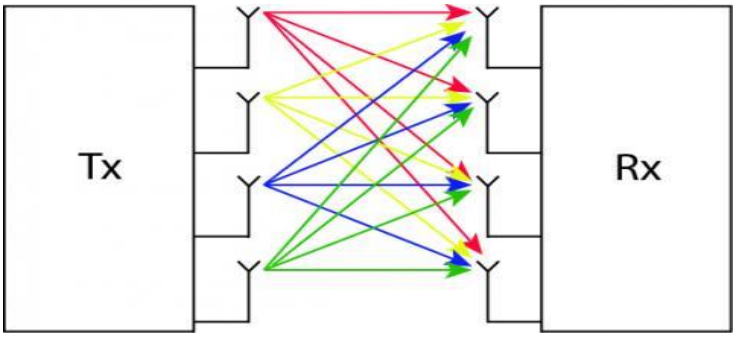


Figure.1: MIMO configuration in antenna system

The Internet of Things (IoT) is a network of physical objects or people referred to as "things" that are equipped with software, electronics, networks, and sensors to collect and exchange data. The purpose of the Internet of Things is to extend internet connectivity from traditional devices such as computers, smartphones, and tablets to relatively simple items such as toasters[10].

By improving parts of our lives, the Internet of Things makes nearly everything "smart"[11]. Sensors or devices are essential components for collecting real-time data from the environment[12]. Antennas built into devices are another crucial component that will allow all IoT devices to communicate and exchange data amongst themselves. The Fractal antennas and metamaterial antennas are also being finding their way to be used in 5G and IoT applications[13],[14].

In this study, an eight-port integrated MIMO antenna for IoT applications is described, with enhanced isolation and communication at a high data rate [15]. For microwave frequencies, this antenna design is outstanding in multiple-input-multiple-output (MIMO) antenna systems[16],[17],[18].

2. METHOD

The transparent picture of designed single element antenna can be seen in figure 2. In this antenna configuration, in the ground plane a circular ring (CR) slot is designed along with two microstrip-lines in rectangular at the other side of the slot resonator. In addition to that, two circular parasitic structured elements are used along with the CR slot resonator at the top side of antenna[19]. And this is designed with lower profile dimensions of WS × WS. The Antenna was designed with dielectric FR4 substrate with thickness of 1.6 mm. The relative permittivity value of Fr4 substrate is 4.4. Few designs use other substrates according to their requirements like improvement in gain, isolation, flexibility etc [20],[21]. The designed dimensions of proposed single-element MIM0 antenna is shown in Table 1. Also, the dimensions of the proposed MIMO array are also specified in table 2. All dimensions shown in table are in terms of millimeters.

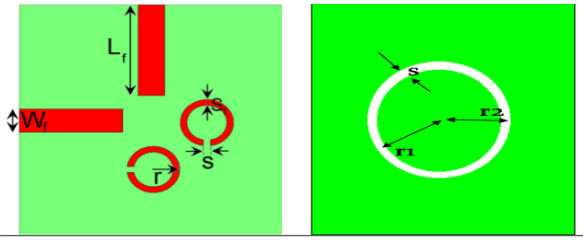


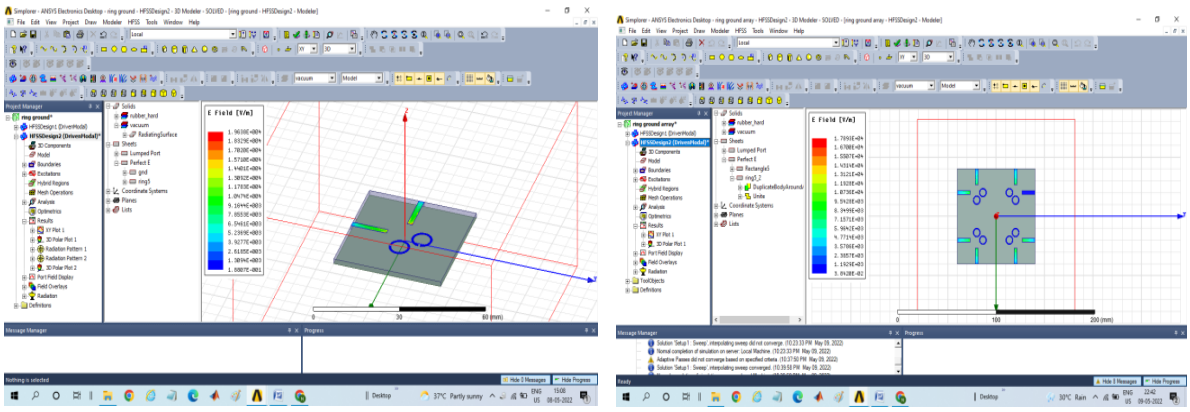
Figure.2: Front view and Back view of proposed antenna

The structure of designed Two element and Eight element MIMO antenna with 4X4 array configuration can be seen in figures 3(a) and 3(b). In this MIMO antenna configuration, the designed two element antenna is repeated in 2X2 array configuration. The area of the ground plane of eight element array antenna is four times that of the two element antenna. A circular ring (CR) slot along with two microstrip-lines in rectangular are used on the entire array elements[23].

The proposed MIMO array dimensions specified in table 2 are in millimeters.

Table 1: Dimensions of Single element Antenna

Parameter	**Value(mm)**
L	40
W	40
L_f	13.25
W_f	3
H	1.6
S	1.6
S_f	0.75
s	0.75
r	3
r1	6.25
r2	7



3(a) 3(b)

Figure 3: (a) The designed Two Element antenna in HFSS, (b) Two Element antenna in HFSS

Table 2: Dimensions of Eight elements MIMO Antenna

Parameter	**Value(mm)**
L	80
W	80
L_f	13.25
W_f	3
H	1.6
S	1.6
S_f	0.75

s	0.75
r	3
r1	6.25
r2	7

3. RESULTS AND DISCUSSION

3.1 Two Element Antenna

Return loss is an antenna parameter in terms of dB which gives the ratio of the power reflected (without being radiated) by an antenna to the power which is given as input to the antenna through transmission line[22]. The designed single element antenna had a return loss S(1,1) of -13.8371dB and –24.8547 dB at frequencies 2.4 GHz and 7.9 GHz. The obtained return loss is better than the minimum value of -10 dB as shown in figure 4(a).

The Antenna parameter VSWR defines how efficiently the power is radiated by an antenna at the desired frequency from a transmission line to a load[23]. For designed antenna, the VSWR values are 1.6703, 1.0949 at frequencies 2.4GHz and 7.9 GHz as shown in figure 4(b).

Another parameter Gain defines the amount of power transmitted in a direction in which the peak power is radiated to the power that is radiated by an isotropic source[24]. The designed single element antenna had a gain as shown in figure 5(a).

The pattern in which the power is radiated by the antenna in all the directions is defined as radiation pattern. After simulation, the radiation pattern obtained for the antenna is shown in figure 5(b).

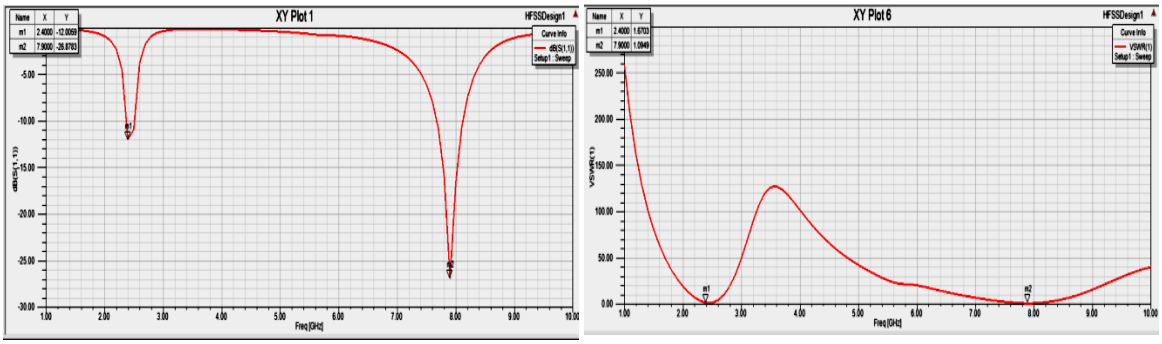


Figure.4: (a) Return Loss of Two Element antenna S(1,1), (b) VSWR of Two Element antenna

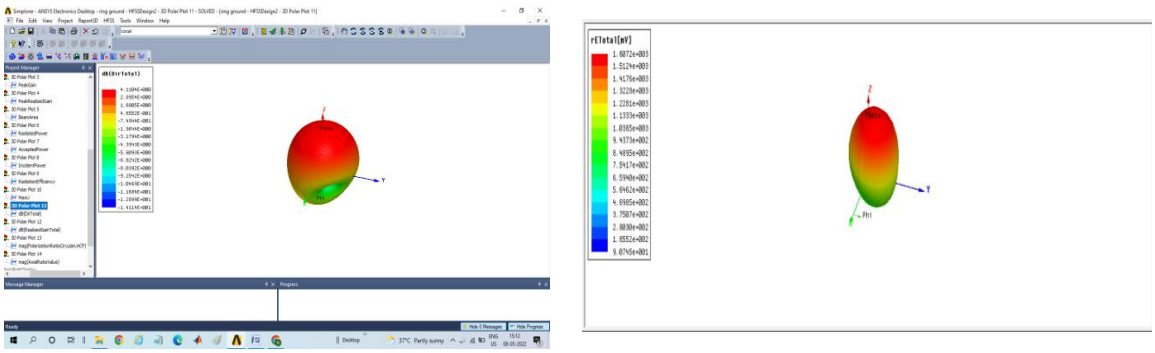


Figure 5: (a) The Gain of Two Element antenna, (b) Radiation pattern of Two Element antenna

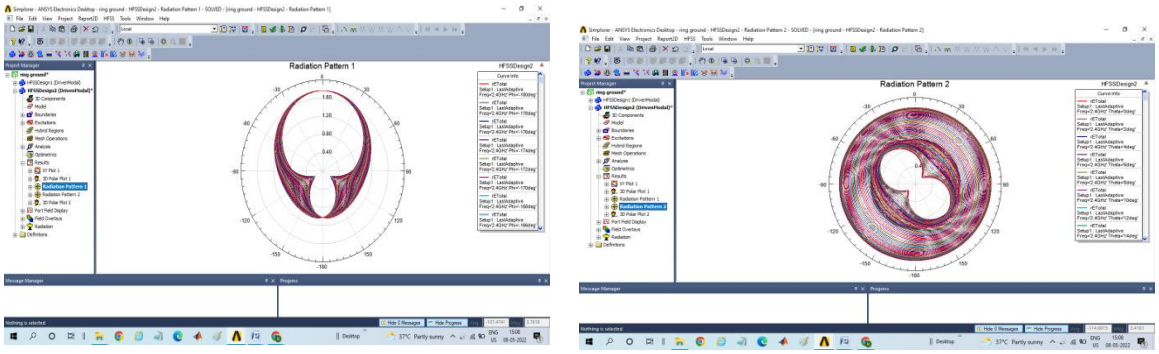


Figure 6: (a) E-Plane Radiation pattern and (b) H-Plane Radiation Radiation pattern of Two element Antenna

The radiation pattern of E-field on any plane that shows the maximum radiation in the direction from the antenna. After Simulation 2D E-plane Radiation Pattern is shown in figure 6(a). The radiation pattern of H-field on any plane that shows the maximum radiation in the direction from the antenna. After Simulation 2D E-plane Radiation Pattern is shown in figure 6(b).

3.2 Eight Element MIMO Antenna of 4X4 Array

In the design, FR4 substrate is used with microstrip line feeding technique. The designed single element antenna shown in figure 3(a) is used to design a MIMO antenna of 4X4 array is shown in figure 3(b). Various parameters are measured for the designed MIMO antenna array which is shown in corresponding figures.

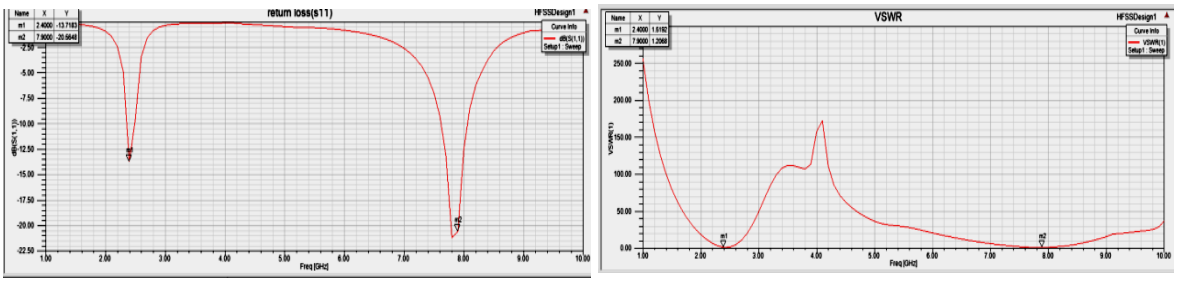


Figure 7: (a) Return Loss of Eight Element antenna S(1,1), (b) VSWR of Eight Element antenna

The designed MIMO antenna had a return loss of -13.7183, -20.5648 dB at frequencies 2.4GHz and 7.9GHz which is better than the minimum required return loss value of -10dB is shown in the figure 7(a) and the VSWR values are 1.5192, 1.2068 at frequencies 2.4 GHz , 7.9 GHz as shown in figure 7(b).

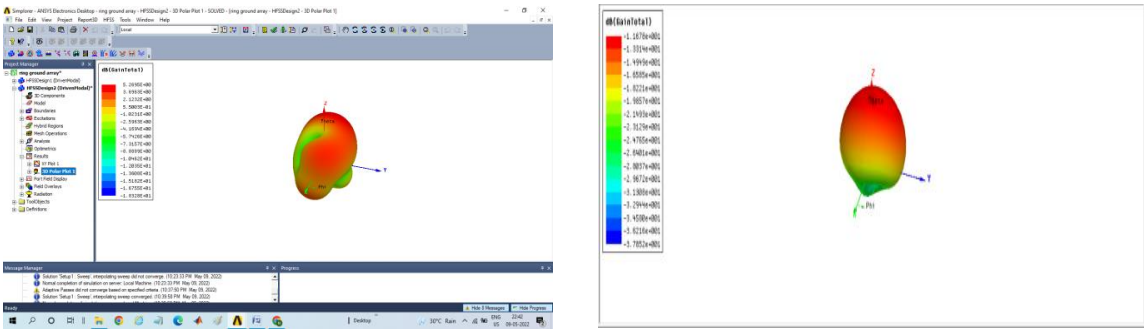


Figure 8: (a) The Gain of Eight Element antenna, (b) Radiation pattern of Eight Element antenna

For the designed MIMO antenna, the gain of the antenna is obtained as 5.2695 dB which is shown in figure 8(a). After simulation the obtained radiation pattern of simulated MIMO antenna is shown in figure 8(b). Also, The 2D E-plane and H-plane Radiation Patterns of the designed MIMO antenna are shown in figures 9(a) and 9(b).

Figure 9: (a) E-Plane Radiation pattern of Eight Element antenna, (b) H-Plane radiation Pattern

Isolation among the array elements of MIMO antenna is another important parameter to describe about the influence of one antenna element over the other with in the device [25]. For the better performance of the device, the Isolation or the Return loss between any pair of elements with in the device shoud be less than atleast -10 dB which is shown in Table.3, where x stands for 1,2,3,….. for input source.

The return loss values among all the eight elements (S=8) of the MIMO antenna are shown. It is observed that the Return loss between any pair of elements with in the device is less than the minimum required level. All the other parameters of the designed MIMO antenna are shown in table 4.

Table 3: Isolation among all the 8 ports of antenna

S Parameter	Isolation in dB at 2.4 GHz							
S_{X1}	-13.7	-42.8	-71.5	-54.7	-54.7	-51.2	-62.4	-74.6
S_{X2}	-42.8	-13.8	-55.0	-51.4	-71.8	-54.7	-73.7	-62.3
S_{X3}	-71.5	-55.0	-13.7	-42.8	-74.3	-62.5	-51.3	-54.7
S_{X4}	-54.7	-51.4	-42.8	-13.7	-62.4	-74.8	-54.8	-72.8
S_{X5}	-54.7	-71.8	-74.3	-62.4	-13.7	-42.8	-54.5	-51.1
S_{X6}	-51.2	-54.7	-62.5	-74.8	-42.8	-13.7	-74.3	-54.5
S_{X7}	-62.4	-73.7	-51.3	-54.8	-54.5	-74.3	-13.7	-42.8
S_{X8}	-74.6	-62.3	-54.7	-72.8	-51.1	-54.5	-42.8	-13.7

Table 4: Comparison of various other important parameters of Two Element and Eight Element Antennas

Parameter	Two Element Antenna	Eight Element Antenna
Maximum Radiation Intensity (Watts/Steradian)	4.1733m	5.0162m
Radiated Power (Watts/Steradian)	0.20189m	0.19132m
Radiation Efficiency	1.0211	1.0314
Gain (dB)	4.1104	5.2695

Incident Power (Watts)	2.0200	7.0700
Accepted Power (Watts)	0.1997m	0.18735m
Beam Area (Watts)	4.8860	3.8522
Axial Ratio	2.1057M	58.52k
Directivity (dB)	4.1104	5.1120

4. CONCLUSION

Primarily, a single element antenna with compact ring slot is simulated and designed and its parameters are shown. Also, using a single element antenna, a four port MIMO antenna is simulated. It had exhibited a high degree of isolation among all the four ports of designed MIMO antenna. It is to be primarily designed for IoT applications which operate at frequency 2.4 GHz. This MIMO antenna is designed with two slots in the form of a ring for better results. By using the circular ring as a defective ground surface we have improved the return loss and other parameters of antenna. The HFSS simulation software was used to design the proposed MIMO antenna. The measured parameters of MIMO antenna shows less return loss, better gain, better radiation pattern and good VSWR value. The proposed antenna had provided excellent isolation between multiple antenna elements. The antenna design shows good return loss which is less than -10dB. The designed MIMO antenna had achieved good VSWR and return loss values at 2.4GHz and 7.9GHz. So, the designed antenna is feasible for IoT applications at 2.4 GHz.

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