Design and Analysis of Dual Band MIMO Antenna System for GPS and IoT Wireless Applications

R. Ramesh, Usha Kiran.K

Abstract*: *Ever since the birth of IoT (Internet of Things) into technology, there is a widespread bloom in geo-location applications. From satellite communication to wireless sensor network developments, there is a need for location identification. This demands a low power, interference free, efficient system for multi-purpose applications. This paper focuses on the design of a Dual Band Multiple Input Multiple Output (MIMO) Antenna System for Long Range (LoRa) band at 915 MHz and GPS (Global Positioning System) at 1.57 GHz. The return loss of -20 dB and-28 dB is obtained for the desired frequency. The main objection of the paper is isolation between the antennas for two different applications mentioned above. The isolation of -15 dB to -68 dB values is achieved between various port both in simulated and measured results for both the wireless applications.

Index Terms*: *Isolation, multiple-input multiple-output, radiation pattern, return loss.

I. INTRODUCTION

The onset of Internet of Things (IoT) technology has attracted the attention of numerous minds. There has been a vast development in the field because of the better connectivity it provided between humans and the environment. Science became very hand in hand after improvements in IoT technology. It is predicted that man power would be reduced and the whole universe would turn around the axis of science if IoT gets its hold in every application.

Many developments were noticed in Geo-location applications after the blooming of various wireless communication technologies like Global Positioning System (GPS), GNSS, Wi-Fi, etc. In today's world, it is very necessary to monitor people or an environment. Security of humans is at its risk as there is a heavy competition for survival due to the exploding populations, climatic change, and natural disturbances on the earth's surface. Applications like Wireless Sensor Network (WSN), hospitals, military, land and seanavigation demands the exact location of the target object. This brings the concept of IoT technology together with LoRa range (for low power consumption) as well as GPS monitoring in order to facilitate cheap, but, very efficient geo-location identification.

In this paper, they introduced how the antenna structure to be designed for the low profile devices first the measurements of the antenna structure has taken a vital role after that the analysis had done for the good return loss for internet of thing applications, the planar extension and thickness of the antenna are to desired in this section, as the dual-band operation of the Inverted F Antenna (IFA) on the printed circuit board. The advantage of using Ultra Narrow Band (UNB) antennas for IoT applications is discussed [1].

Antenna for best performance technology has been innovated for the Omni-directional antennas which are used by radio and mobile communication and GPS band location applications [2-3].The SEMTECH Corporation was the first to innovate the LoRa technology and in further recently the TATA communications had tied up for the internet of things as a client join for LoRa technology[4]. In this paper, the quality factor of a resonant, electrically small electric dipole is decreased to maximum by allowing the increasing the occupied spherical volume to the greatest extent possible [5-6].

Various isolation improvement techniques for MIMO, LAN card, and bus applications are presented and studied both numerically and experimentally in this paper. The proposed techniques can be easily implemented and could be effective to achieve high isolation among the antennas which is a compulsorily needed for MIMO terminals. This is to receive the signals with minimum possible mutual coupling. Various techniques like insertion of ground strip between antennas, cutting a ground slot, introducing a ground slot with open were introduced and analyzed here [7-8].The currently present isolation techniques to reduce the mutual coupling of the MIMO antennas while maintaining or improving the efficiency of the system. From among the possible techniques, creating a slot in ground plane was found to be compact, low cost and showed better results for good spatial diversity [9].

In the far outer space, revolving around the earth is a GPS constellation with 24 satellites. These satellites, launched by various nations have a database and act as transmitters of radio signals which are captured by GPS antenna receivers on earth surface and location is detected. The GPS L1 band of 1.57 GHz is commonly used worldwide and is also used in this paper. This is because it supports both Radio Navigation Satellite (RNSS)Service and Aviation Radio Navigation Service (ARNS)universally.

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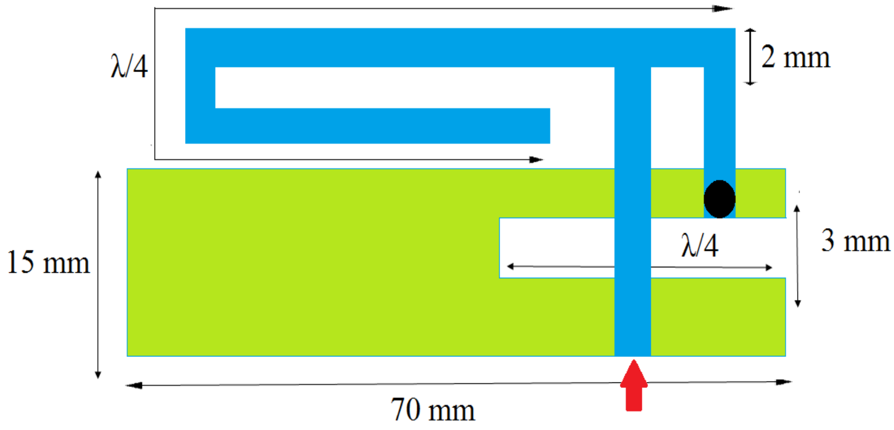

Fig. 1. Geometry of single IFA

The LoRa(RF) Radio Frequency technology, being integrated in cars, street lights, wearable devices and many more, is a long range, low power protocol developed by SEMTECH for low data rate application. It is a wise choice to build IoT networks worldwide. It finds in applications in telemetry because of its advantage over the existing cellular networks in its range of operation. Its key features includes low cost, enabling GPS tracking applications , providing high security, supporting high range, low power, and high capacity [10-11].

Multiple inputs, multiple outputs (MIMO) is an antenna technology for wireless communications in which multiple antennas are used at both the source.The antenna geometry is shown in Fig.1 and the dimension of the design is mentioned in Table I. The substrate used is FR-4 Epoxy. It is of width 1.6mm.FR-4 Epoxy is used because it is flame resistant and can be used in any situations for undisturbed location detection. In the design, the length of the F-arm determines the resonance at lower frequency (transmitter) and the destination (receiver). The antennas at each end of the communications circuit are combined to minimize errors and optimize data speed. MIMO is one of the several forms of smart antenna technology used in majority recently. This paper uses MIMO technology and analyses the antenna gain, diversity gain, correlation coefficient, return loss and isolation loss of the designed antennas.

The paper has two sections, one with the single Inverted F antenna for LoRa and GPS applications with simulated and measured results. In the second section 2 x 2 MIMO antennas are designed and simulated. The measured results shows the isolation between the various ports which is measured by the vector network analyzer.

II. DESIGN OF SINGLE IFA ANTENNA FOR GPS BAND AT LORA RANGE

First, by developing a Dual Band single IFA (Inverted F Antenna) for 915 MHz and 1.5 GHz and then replicating and reproducing it into MIMO system. The basic unit chosen is IFA because of its space efficiency and less complexity which enables us to develop any NxN MIMO system easily. For reviewrange of 915 MHz and the length and width of the ground slot is responsible for the resonance at higher frequency range at 1.57 GHz. The length of F arm is approximately λ/4. The actual length varies during optometric analysis. The arm is meandered here to reduce the space consumed. It could be folded or flipped too. The antenna is fed with a waveguide port.

TABLE I DIMENSION OF SINGLE IFA ANTENNA

Variable	Dimension (in mm)
L_s	70
W_s	15
L_g	λ/6 = 30
W_g	3
W_{IFA}	2
L_{IFA}	λ/4 = 80

III. DESIGN OF 2x2 MIMO ANTENNAS IN LORA BAND FOR GPS TRACKER

The 1x1 MIMO systems has been extended to 2x2 MIMO systems to be used as a GPS tracker. Thus, it is designed for receiving the data through GPS and sending/ receiving data via LoRa Range of 915 MHz.The design of the 2x2 MIMO is given in Fig. 3 and the dimensions of the design is mentioned in Table II.

TABLE II DIMENSIONS OF 2X2 MIMO

Variable	Dimension (mm)
L_{subs}	105
W_{subs}	110
L_{grnd}	90
W_{grnd}	82
L_{grnd_slot}	λ/6 = 32
L_{IFA}	λ/4 = 145
W_s	13
W_{grnd_slot1}	1.2
W_{grnd_slot2}	0.5

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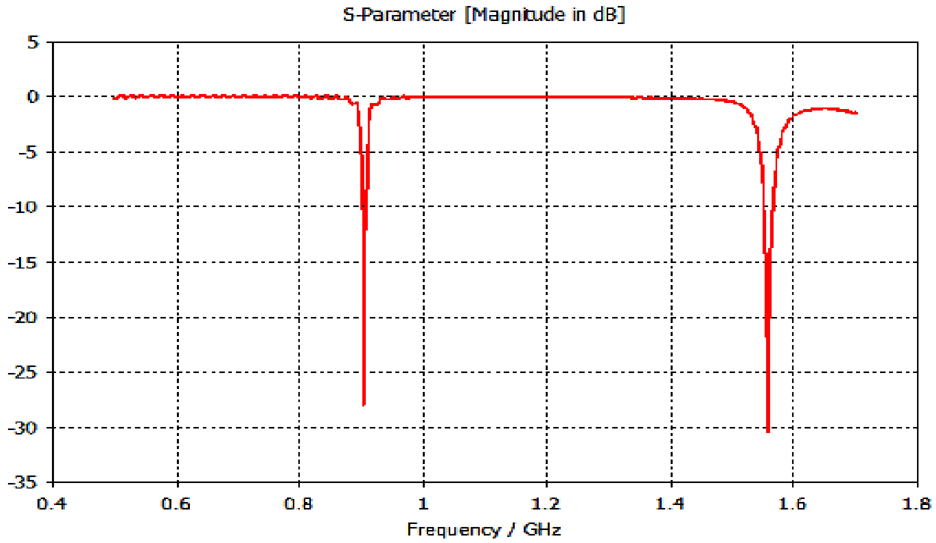

Fig.2. Return loss characteristics of simulated results of single IFA

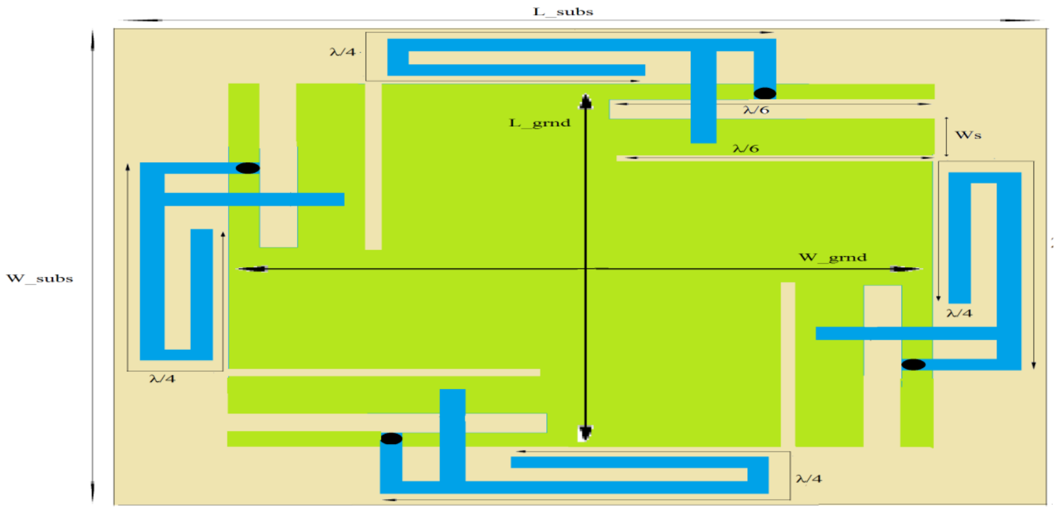

Fig.3. Design of 2x2 MIMO for GPS Tracker

IV. RESULTS AND DISCUSSION

The antenna geometry is shown in Fig. 3. The extra slit on ground plane helps to improve the isolation loss. The return loss is shown is Fig 4 and isolation loss of the proposed antenna with ground slot has been shown in Fig. 5. The return loss, being lesser than –15 dB, makes it more efficient. As we can see, since the isolation loss for 915 MHz is only -10 dB.

From Fig. 6, it is observed that the good return loss for 915MHZ is achieved. The measurements are performed using Vector network analyzer. Also the good desired isolation is obtained between s_{21}, s_{31}, s_{41} for 2x2 MIMO antennas as shown in Fig. 7,Fig. 8 and Fig. 9. All the results are measured using vector network analyzer. Fig. 10 (a) shows the top view of the fabricated 2x2 MIMO antenna and Fig. 10(b) shows the bottom view where the slots are made for isolation between the antennas.

The fabricated proposed antenna are shown in Fig.10.The Fig.10 (a) shows the top view of the MIMO antenna for desired applications and the Fig.10 (b) shows the bottom view that is the ground plane where the slots are provided to improve the isolation between the antennas.

The proposed antenna measured radiation pattern for both E-plane and H-plane are plotted in Fig. 11(a) and Fig. 11(b) for 1.5 GHz and 9.1 MHz for E-plane and H-plane are plotted. The left handed side plots shows the H-plane and the right hand side plot shows the E-plane polarization.

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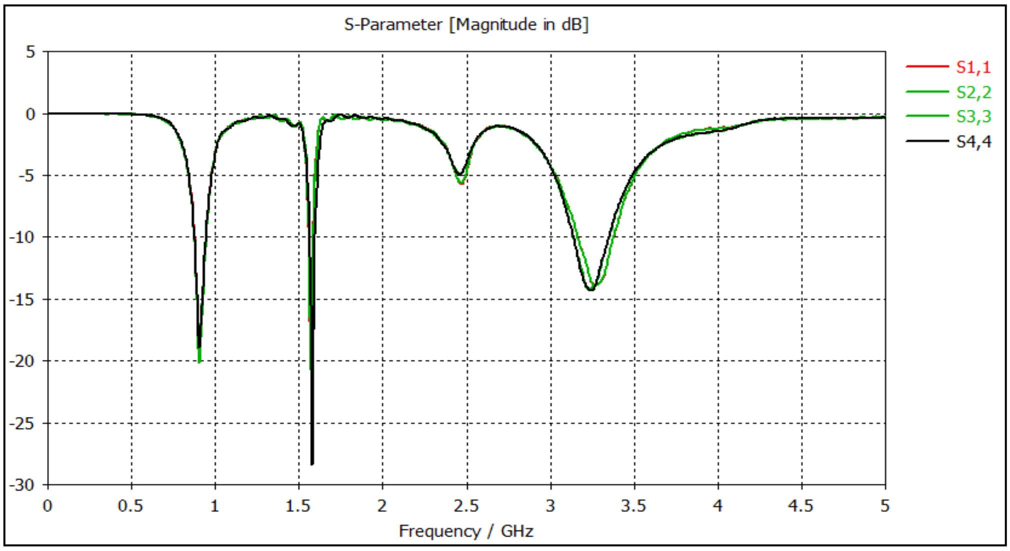

Fig.4. Return loss characteristics of simulated 2x2 MIMO antennas

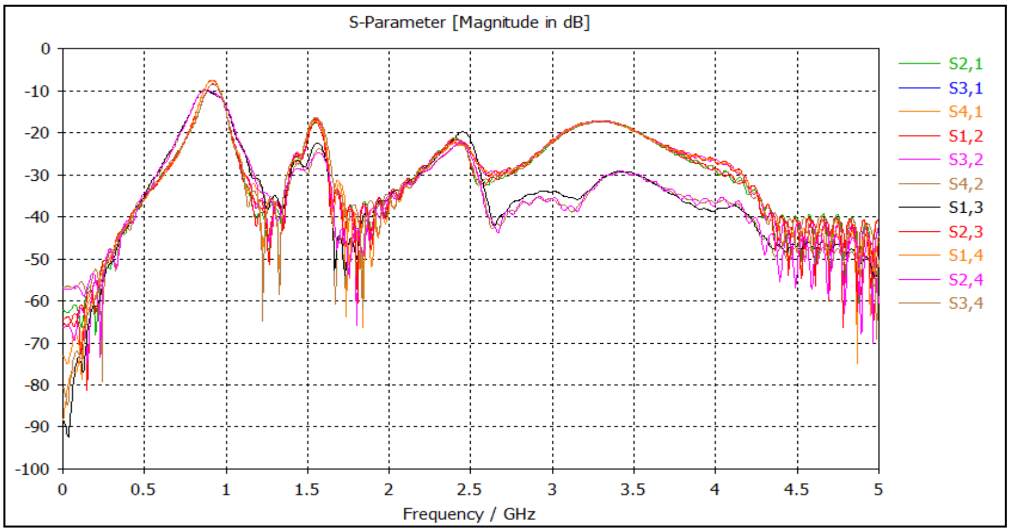

Fig.5. Isolation loss characteristics of proposed 4x4 MIMO antennas

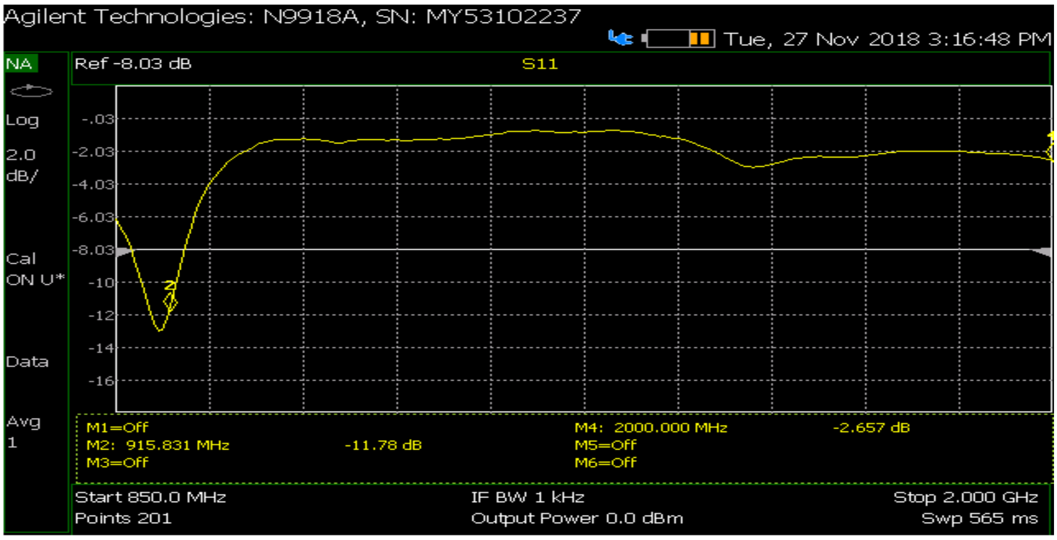

Fig.6. Measured return loss characteristics of 2x2 MIMO antennas

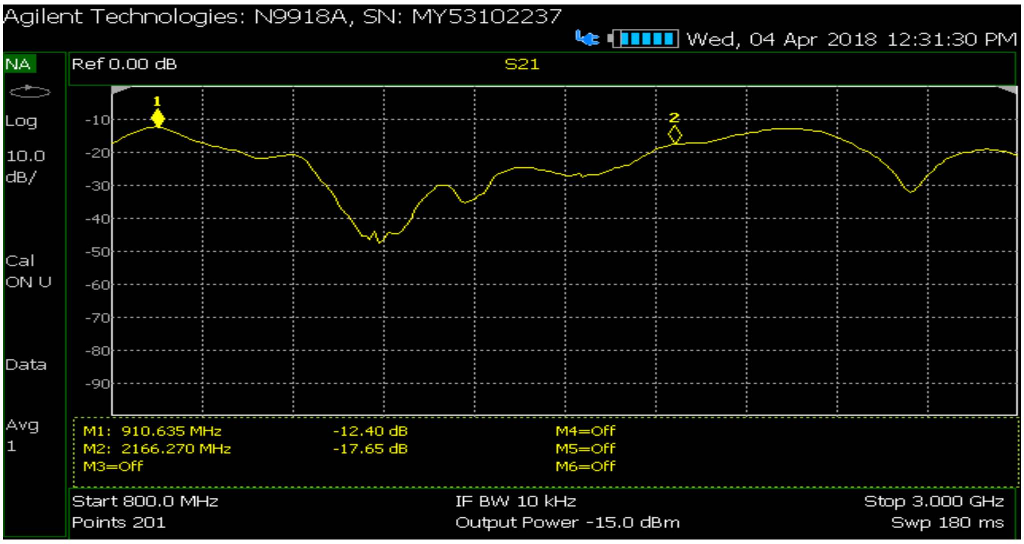

Fig.7.S_{21} Parameters of 2x2 MIMO antennas

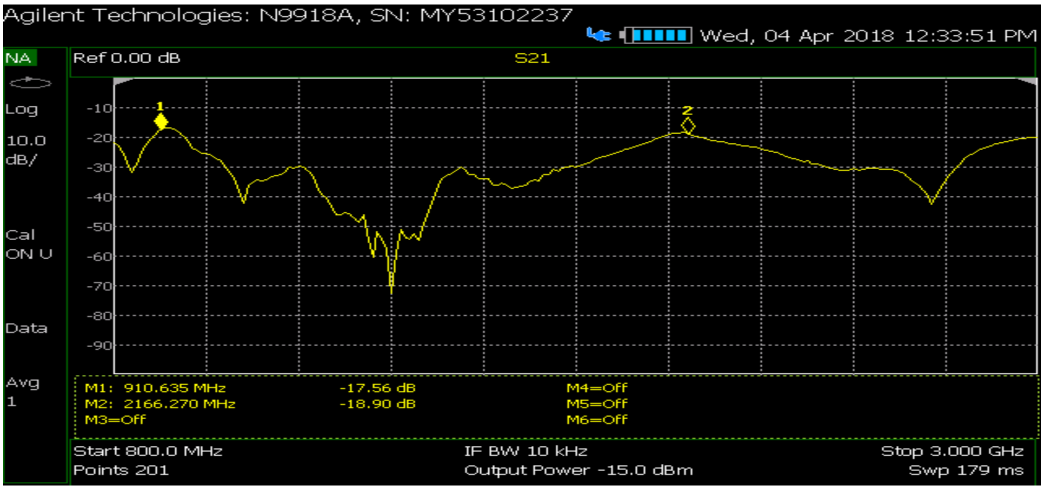

Fig.8 S_{31} Parameters of 2x2 MIMO antennas

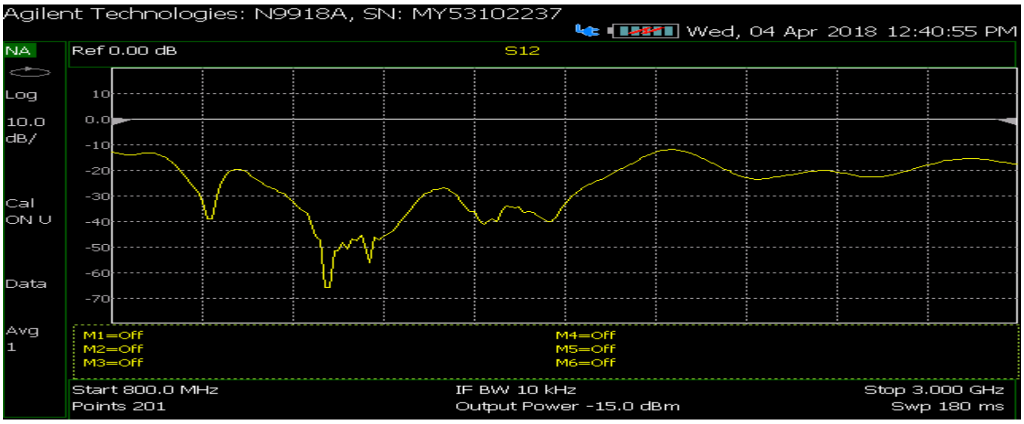

Fig.9 S_{41} Parameters of 2x2 MIMO antennas

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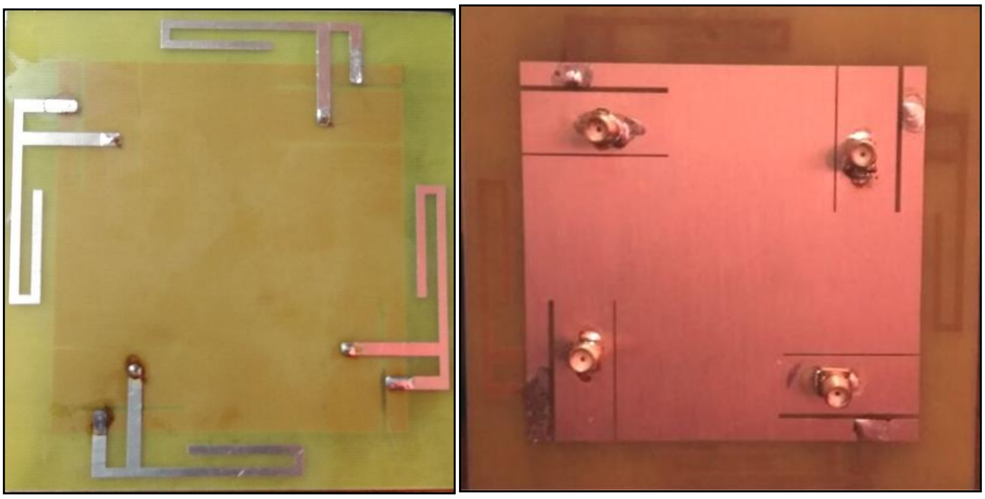

(a) (b)
Fig.10. Fabricated 2x2 MIMO antennas

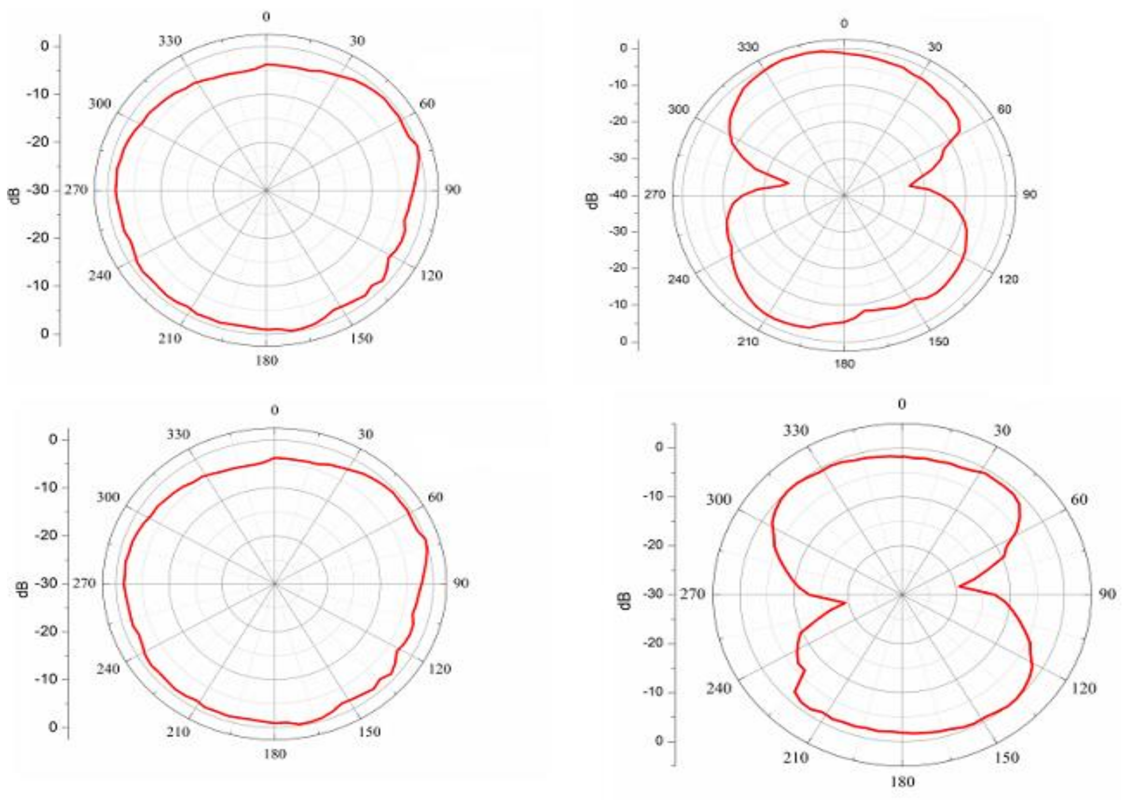

Fig. 11.Measured Radiation pattern of the proposed antenna at (i) 1.5 GHz and (ii) 9.1 MHz for E-plane and H-Plane

V. CONCLUSION

The MIMO antenna system for GPS tracker has been done for the use of dual-band frequencies at the GPS band 1.575 GHz and LoRa band 0.9 GHz. A good return loss of -20 dB and-28 dB is obtained for the desired frequency and good isolation losses of -40dB to -70 dB is achieved for the desired applications.. Environmental sensitivity can be the main issue in the design and application of GPS antennas. Thus, a sustainable and efficient antenna has been developed for GPS Tracker.

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