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U-Slot Notch Band Mimo Antenna to Reduce Polarization Diversity

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Abstract: In this study, we are presenting U slot notch band MIMO antenna with polarization diversity technique. Polarization diversity is achieved by placing two pairs of monopoles orthogonal to one another. We used octagonal shaped slot antenna and differential feeding mechanism. We inserted slots which are in the shape of arcs to reject the Wireless Local Area Network (WLAN) band. For effective rejection of required band we inserted U shaped slots in feeding lines of port 3 and 4. The same can be done on port 1 and 2 as a result the parameters related to port 1 and 2 will be effected but port 3 and port 4 parameters are effected in this because the insertion is on port 3 and 4. The proposed model is achieving differential reflection coefficient of >-10dB over the rejection from 5 and 6 GHz. Due to differential feeding mechanism low cross polarization and port to port isolation of higher than 40dB is obtained in working range of antenna. Though the antenna is designed over 3-11 GHz, this is well suited for 6-9 GHz.

Key words: Ultra Wideband (UWB), polarization diversity, MIMO antenna, band rejection antenna, India

INTRODUCTION

A microstrip patch antenna is the widely used device in the modern communication systems. It consists of patch which is radiating on one side of substrate which is dielectric. It having ground plane on another side. The patch shape is varied according to the application. Generally patch is made of conducting material such as copper, gold, etc., patch and feed lines are placed on a substrate with a help of photo etching. The basic principle of micro strip patch antenna radiation is because of the fringing fields between the patch edge and the ground plane for better efficiency and better radiation the substrate having low dielectric constant is required (Lu and Lee, 2010; Chen and Ku, 2008; Madhav *et al*., 2016; Bhavani *et al*., 2015). But, such configuration will increase the antenna size. Hence, trade of between the antenna size and antenna performance have to be maintained.

We used micro strip line feeding mechanism. Here we are allowed to connect a strip which is of conducting to directly to the edge of micro strip patch. The width of the strip should be small compared to the size of patch. The main advantage of this kind of strip we can etch the feed on the same substrate to achieve planar structure. Without using any additional matching elements we can match the impedance of the feed line to the patch with the help of inside cut in the patch. The disadvantage of this kind of feeding is, as the thickness of the substrate is increased surface waves and spurious feed radiations also increases, which reduce the desired bandwidth (Lakshmi *et al*., 2015a, b; Ramakrishna *et al*., 2015; Babu *et al*., 2015; Sunder *et al*., 2015).

Ultra Wideband (UWB) communications demand is day to day increasing as it is providing information to more users with larger data rates. UWB is a remote innovation is created to exchange data at larger rates over short separations at extremely low power densities and region of colossal current profile with various potential applications in distinct fields. To start with the data transfer capacity of UWB frame works, as characterized by the Federal Communications Commission (FCC) is >20% of an inside recurrence are >1.5 GHz. Plainly the transfer speed is much more prominent than the transmission capacity utilized by any present innovation for correspondence. UWB is carrier less communication (Srinivas *et al*., 2015; Ramkiran *et al*., 2014).

The MIMO transmitter and receiver antennas introduce signalling degrees of freedom that were not present in SISO technology by using MIMO technology we achieve higher data rates. The main advantage of MIMO technology is to mitigate multipath fading caused by reflection, refraction, scattering etc. Both diversity and multiplexing are possible with MIMO a better quality of signal SNR is obtained by using multiple antennas at the receiving antennas (Kaiser *et al*., 2009; Sadasivarao and Madhav, 2014; Madhav *et al*., 2014, 2015a-c). In MIMO we transfer different versions of input signal depending up on the diversity technique we used. In time diversity input signal is transmitted at different intervals of time. In polarization diversity the transmitted signals need to have different polarizations. In this paper we used polarization diversity (Lakshmikanth *et al*., 2015; Ramkiran *et al*., 2015;

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Lakshmi *et al*., 2015; Ren *et al*., 2014.). Due to this we can avoid physical rotation of antenna to detect the particular polarization signals. As we are transmitting both polarized signals the receiver tracks its corresponding signals.

MATERIALS AND METHODS

Antenna design and geometry: We can consider this differential polarization antenna as two port differential network or single ended four port network. Here we denoted port 1 and 2 as differential port 1, 3 and 4 as differential port 2. The reflection coefficients of differential port 1 and differential port 2 can be calculated as:

$$S_{dd11} = S_{11}\text{-}S_{12}$$
$$S_{dd22} = S_{33}\text{-}S_{34}$$

Where, S_{ij} (I, j = 1, 2, 3, 4) are single-ended S-parameters when the designed antenna is considered as a single-ended four port network.

By considering fabrication errors S_{11} may not be equal to S_{22} and S_{33} may not be equal to $S_{44.}$ To get higher degree of accuracy differential reflection coefficients are modified as:

$$S_{dd11} = (S_{11}\text{-}S_{12}\text{-}S_{21}+S_{22})/2;\ S_{dd22} = (S_{33}\text{-}S_{34}\text{-}S_{43}+S_{44})/2$$
$$S_{dd12} = (S_{13}\text{-}S_{14}\text{-}S_{23}+S_{24})/2;\ S_{dd21} = (S_{31}\text{-}S_{41}\text{-}S_{32}+S_{42})/2$$

The design process of basic antenna is showed in Fig. 1. We have used FR-4 epoxy substrate to design all the antennas. FR-4 epoxy substrate is having relative dielectric constant value of 4.4, loss tangent value of 0.02 and thickness is 0.8 mm. Firstly, single-ended slot antenna is developed and denoted as Ant. 1 in Fig. 1, next its opposite pair is designed to form differential driving mechanism and is denoted as Ant. 2 in Fig. 1. Then, to obtain polarization diversity another differential pair added to Ant. 2 to form Ant. 3. At last, Ant. 4 is developed by inserting quarter wave length arc slots in the patches to reject the required WLAN band. Figure 2 shows the geometry of basic model and feed line after inserting U-shaped slot.

We have employed irregular octagonal ground plane to improve impedance matching especially at lower ultra wide band frequencies. The parameters of proposed antenna are calculated using High Frequency Structure Simulator (HFSS Version 15) and the optimal dimensions of the antenna are shown in the Table 1.

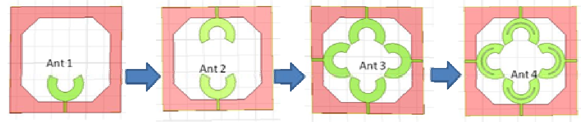

Fig. 1: Iterations of the MIMO antenna

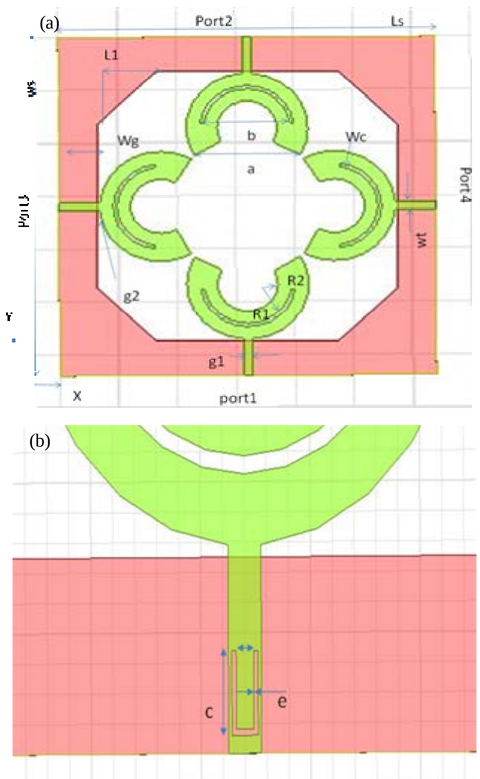

Fig. 2: a) Geometry of MIMO antenna; b) U-shaped slot on feed line

Table 1: Antenna dimensions in mm (except a and b which are in degrees)

Parameters	Values
WS	64.0
Ls	64.0
Wg	6.5
L1	10.0
Wf	1.5
g1	0.2
g2	0.4
R1	10.0
R2	5.0
a	240.0
b	188.0
c	2.6
d	1.0
e	0.2

RESULTS AND DISCUSSION

The designed models on FR4 substrate are simulated using finite element method based electromagnetic tool

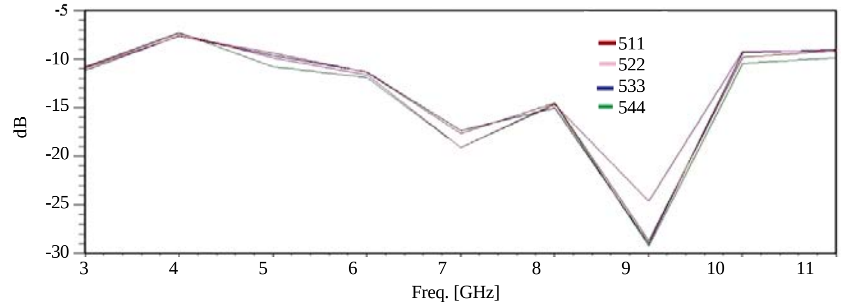

Fig. 3: Reflection coefficient of MIMO antenna

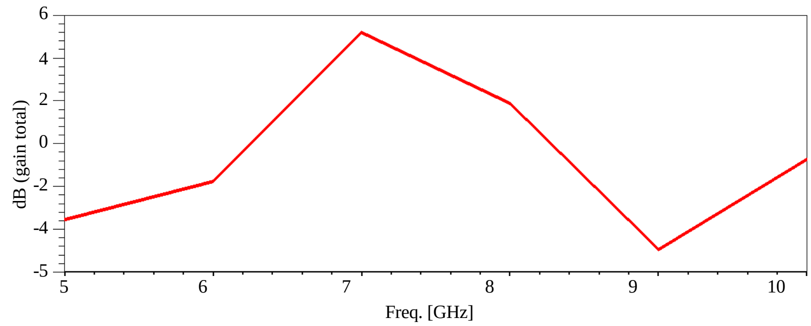

Fig. 4: Frequency vs. gain

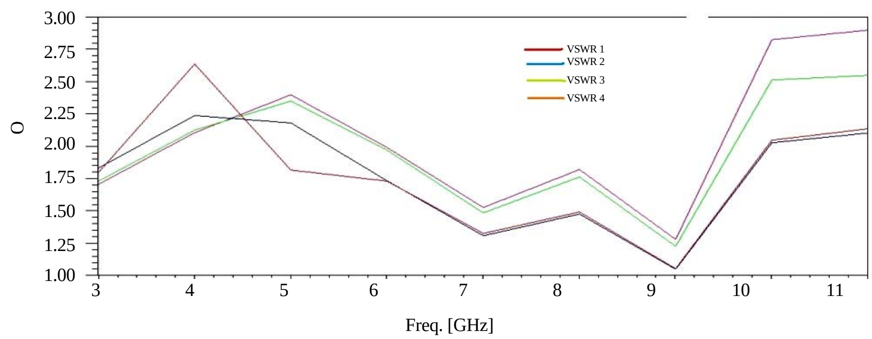

Fig. 5: The VSWR vs. frequency

HFSS. Initially, to find out the pass bands and notch bands the reflection coefficient curve is constructed and presented in Fig. 3. The $S_{xx\ (x=1,\ 2,\ 3,\ 4)}$ curve shown in Fig. 3 gives the clear picture regarding operating bands and the corresponding designed notch bands. It is observed that from the frequencies 4-6 GHz the reflection coefficients are >-10 dB. Both basic model and U-shaped slot inserted model reflection coefficients are giving the same notching but in the proposed model the reflection coefficients corresponding to ports in which we have inserted slots (port 3 and 4) are giving better rejection than the basic model.

A Peak realized gain of 5.25 dB is observed at 7.2 GHz. Both basic model and proposed model are giving almost similar gain performance. Figure 4 showing the gain vs frequency of the proposed antenna model.

In basic model at all four ports VSWR of <2.4:1 is observed. In proposed model at ports 3 and 4 VSWR of 2.5:1-3:1 is observed as when we inserted U-shaped slots in the feed lines of those ports. At port 1 and 2 VSWR performance which is similar to basic model is observed. Figure 5 showing the VSWR performance of the proposed antenna model.

At pass band the antenna is showing an average impedance of around 36 Ω and at notch band impedance of around 29 Ω is observed. Figure 6 showing the impedance performance of the notch band MIMO antenna.

The radiation characteristics of any antenna can be described completely with their radiation pattern curve in E plane and H plane. Figure 7 showing the radiation pattern of basic antenna and proposed antenna in E and H plane at 4 GHz. It is been observed that an omni directional pattern is observed in H-plane where as a dumbbell shape radiation pattern is observed in E-plane.

Figure 8 showing the surface current distribution of the antenna model at 6.5 GHz. At higher band the

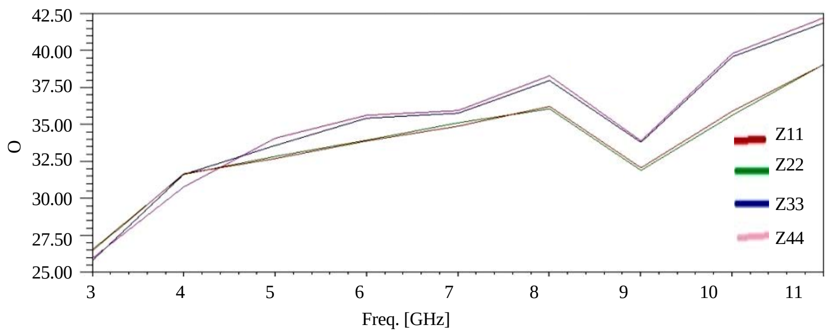

Fig. 6: Impedance vs frequency

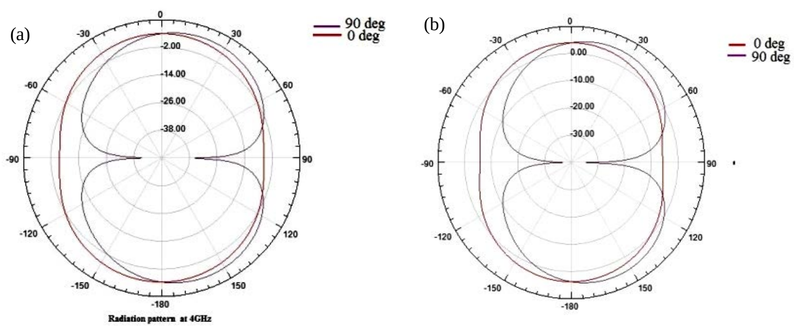

Fig. 7: Radiation pattern of Basic MIMO and Notch band MIMO at 4 GHz

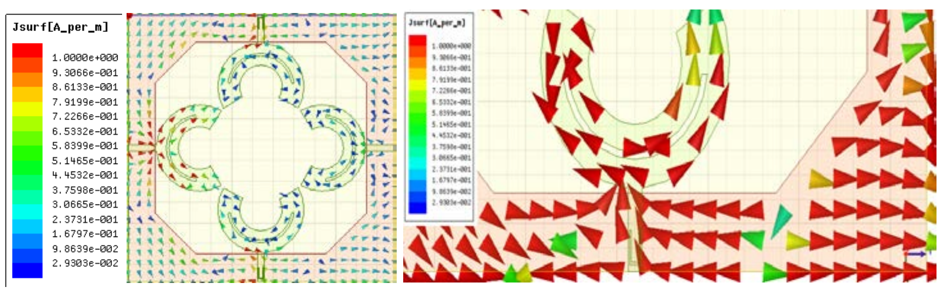

Fig. 8: Current distribution on overall surface and at notch point

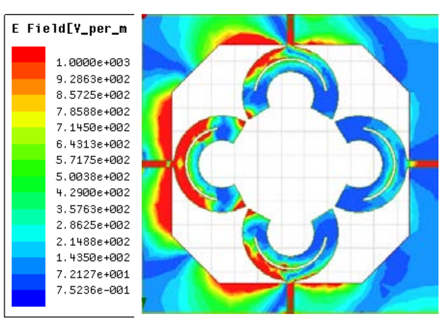

Fig. 9: The E-Field at 6.5 Ghz

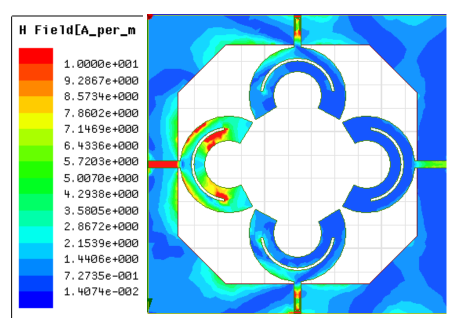

Fig. 10: The H-Field at 6.5 Ghz

radiating patch is giving more intensity with directive radiation whereas at lower frequency range of operation most of the current distribution is because of the feed line and the plane nearer to the patch. In figure it is showing that at notch band the radiation is very low. Figure 9 and 10 shows the E-Field and H-Field plots of the proposed MIMO notch antenna at 6.5 GHz.

Figure 11 shows the fabricated antenna prototype on FR4 substrate with thickness 1.6 mm. The front view with

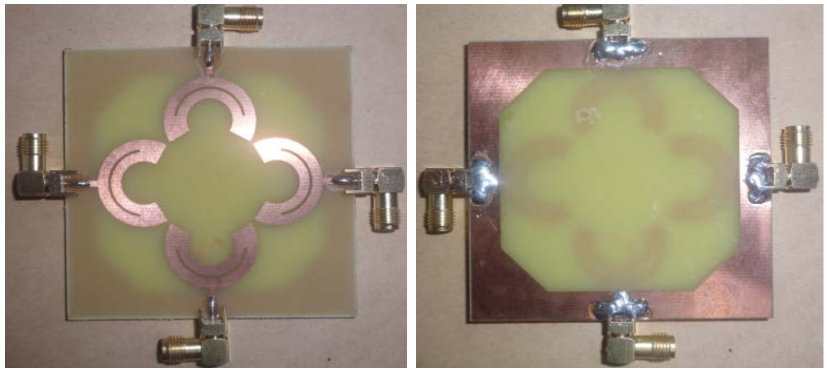

Fig. 11: Prototyped MIMO Antenna Front View and Back View

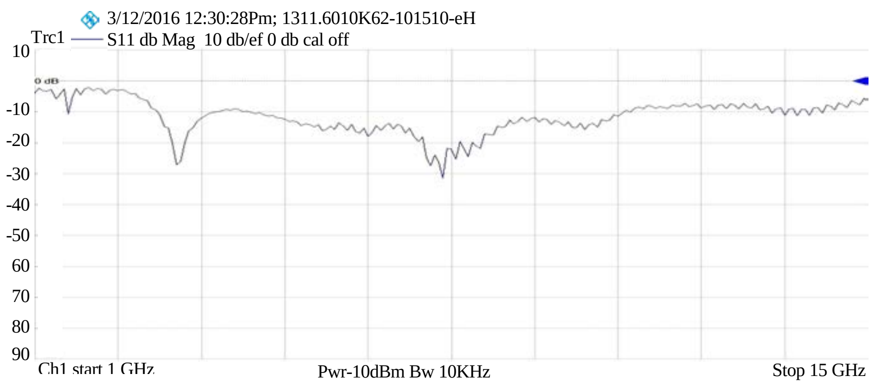

Fig. 12: Measured S11 on ZNB 20 VNA

MIMO configuration and defected ground structure on back side can be observed from the prototyped antenna images. Gold coated SMA connector is used in the model to connect RF cable for real time measurements. Figure 12 shows the reflection coefficient of the proposed antenna on ZNB 20 vector network analyzer. An impedance bandwidth of 65% can be observed from the measured results curve.

CONCLUSION

A compact MIMO notch band antenna is designed with defected ground structure in this work. U-shaped monopole is modified with slot on the feed line and all the iterations are analyzed with respect to reflection coefficient, gain and radiation patterns. The modified structure of MIMO with U-slot on the feedline is tested for notching characteristics and linear polarization. The proposed optimized antenna model is fabricated on FR4 substrate and tested for reliability on ZNB 20 vector network analyzer. Measured reflection coefficient is showing 4 GHz bandwidth and impedance bandwidth of 65%. The measured results are in very good agreement with simulated results taken from HFSS.

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