Research Article

Investigation of compact dual port octagonal MIMO antenna with triple band rejection capabilities with good isolation

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Abstract:

This papers focuses to investigate a 35mm*60mm*1.6mm novel dual port MIMO antenna with triple notch rejection capabilities that exhibits good isolation performances. An Octagonal radiating patch is incorporated with defected ground structure and relevant slots in the radiator. Two slots and DGS contribute for the rejection capabilities of potential interference bands like WIMAX,WILAN, and X band in the ultra-wide band region of the designed antenna. Further to improve its performance, the antenna is modified as dual port MIMO which experiences mutual coupling. A strip line is introduced above the radiating patches in the substrate to obstruct the surface waves and to reduce the mutual coupling between the radiating elements. Crucial parameters like mutual coupling and the diversity gain are analyzed and are found to be promising. The proposed variant's impedance bandwidth spans from 1.5 GHz to 9.05 GHz.

Index terms: Triple notch, Isolation, MIMO, ultra wide band

I. INTRODUCTION

In yesteryears compact antennas received acute interest; while nowadays the researchers focus on various methods of creating wide bandwidth, since various applications at various frequencies have to be addressed by a single radiating element which occupies less space., FCC has provided unlicensed frequency band from 3.1GHz to 10.6 GHz for the ultra-wideband technology [1]. While designing such antennas, some of the pre-existing frequency bands endure some problems to the system such as WIMAX, WLAN , C-band and X-band, etc in the previous ultra-wideband region. So to junk those bands in the past decade field, experts introduced multiple techniques. Initially traditional filters were
used , but nowadays by introducing feed disturbance [2] slots[3-4], spiral slots[5]**,** split-ring resonators[6] ,U-slots[7], meander line slots[8,9], metamaterial[10-12], capacitive loaded [13], parasitic slits[14] , parasitic strips[15] , spur lines [16], are used along with the radiating element to improve its performance.. More recently literatures report single band[17], dual band notch[18] multiple notch characteristics[19-22]. The main challenging task is to achieve the notches without altering the performance of the radiating element. The performance factors include data rate, signal to noise ratio and multipath fading. Fading is due to reflection and refraction from the surfaces. The multiple input multiple antenna which comprises of multiple identical elements placed near such designs ultimately it suffers due to mutual coupling effects. This is due to their close placements. In order to achieve better isolation between radiating elements, various techniques were deployed such as introducing slots on the ground [23-25], decoupling structures[26],electronic band gap references[27],neutralization line[28-29] ,Metamaterial[30] were properly added in such designs.

By reviewing all the aforementioned literatures, in this communication, a novel minimized triple notched compact MIMO antenna is designed by us. This communication is organized into three parts; Part 1 deals with design of a ultra-wide band antenna, Part 2 presents suppression of the three bands interfering bands Part 3 encompasses the design of MIMO with reduced mutual coupling

II. Proposed structure

Present section discusses about design strategy of the proposed antenna, dual port MIMO antenna is shown in the Fig 1. An ultra-wide band antenna with triple band rejection SISO element which is the base element for the MIMO antenna this is shown in the Fig.2, the radiating patches are mounted over a FR4 substrate with a dielectric constant of 4.4 and a loss tangent of 0.02 with a substrate thickness of 1.6mm.

Radiating patch is designed to be an octagonal shape and DGS is deployed over it. Identical radiators antenna are fed with a Microstrip line with a characteristic impedance of 50 ohm

The optimal parameters of the proposed antenna are tabulated in the Table 1 and the complete evolution of the proposed antenna from SISO to MIMO is shown in the figure 3. The final proposed MIMO antenna with a size of 60mm*65mm.The entire antenna design is drawn and simulated by means of FEM based software. Simulated results of the final radiating element are shown in the figure, simulated reflection co efficient and VSWR of the proposed structure are depicted in the figures 4-5.

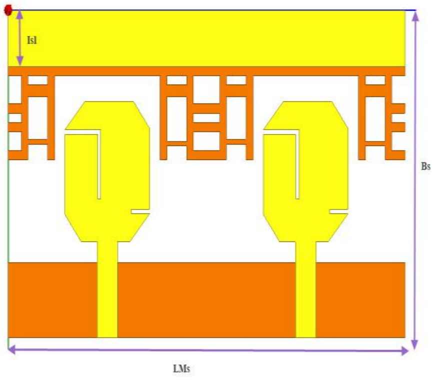

Fig.1 schematic layout of the proposed MIMO antenna structure

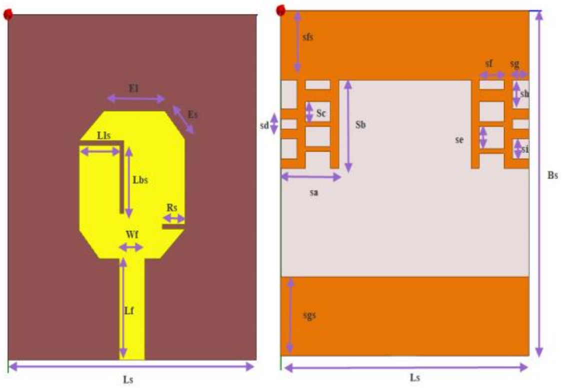

Fig.2 schematic layout of the SISO

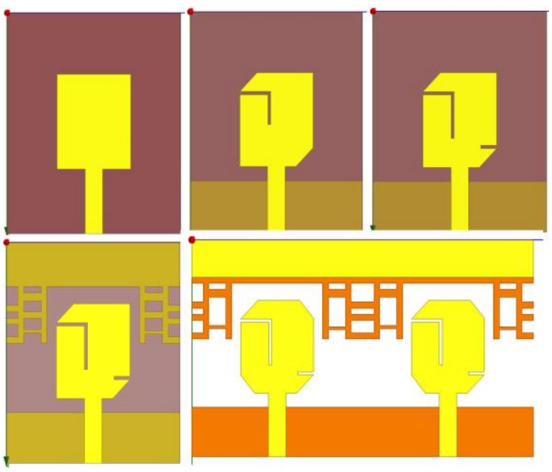

Fig.3 evolution of antenna structure

S.No	Parameter	Size (mm)
1.	Length of the substrate (Ls)	30
2.	Breadth of the substrate (Bs)	35
3.	Width of the feed line (Wf)	3.05
4.	Length of the feed line (Lf)	10.25

5.	Length of the rectangular slot (Rs)	2.75
6.	Length of l slot (Lls)	5.375
7.	Width of the l slot (Lbs)	7.45
8.	ground Slot dimension (sa)	7
9.	ground Slot dimension (sb)	9
10.	ground Slot dimension (sc)	2
11.	ground Slot dimension (sd)	1
12.	ground Slot dimension (se)	2.75
13.	ground Slot dimension (sf)	2
14	ground Slot dimension (sg)	2
15.	ground Slot dimension (sh)	3
16	ground Slot dimension (Si)	2
17.	partial ground optimal size (Sfs)	7
18	Strip size in the DGS (sgs)	8
19	Length of the upper side of the radiator (Ei)	7.31
20	Chamfering edge distance (Es)	2.43
21	Isolation strip length (ISl)	6
22	Length of the MIMO (LMs)	60
23	Height of the substrate (h)	1.6

Table 1 Antenna parameters

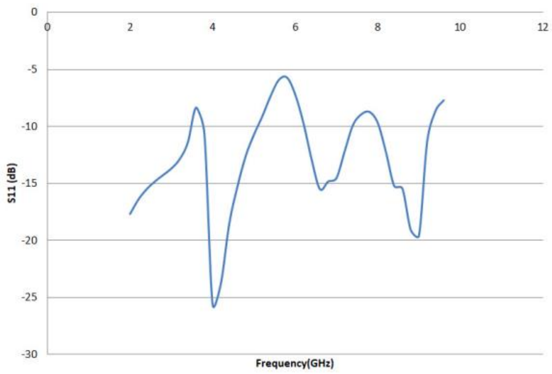

Fig.4. Scattering parameter of the proposed variant

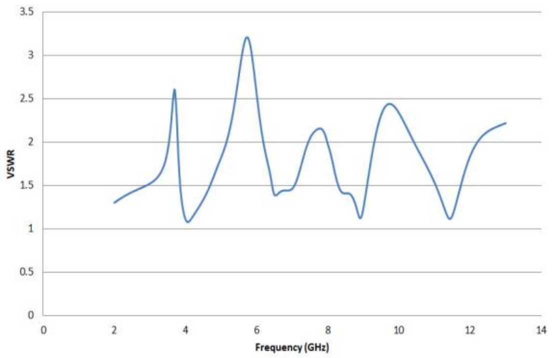

Fig.5 VSWR of the proposed variant

III. Design strategy

In order to design triple band notched MIMO antenna, the designing process is divided into three parts ,foremost step is to design a ultra wide band antenna and further to create triple notch characteristic and finally MIMO antenna with good isolation.in preceding section SISO and MIMO are also designed and analyzed

Design of SISO Antenna

Ultra-wide band antenna design strategy

Initially a rectangular patch antenna is designed to resonate at 9.05 GHz since it provides the narrow band characteristics and to size reduce and to enhance the bandwidth wider the ground of the antenna is created as partial ground which results in the widening of band width the scattering parameter of initial step is shown in the Fig 6 and the impedance bandwidth offered by the resonator is from 2.95 GHz to 9.05 GHz.

Study of triple band rejection characteristics

To inherit the triple band notch characteristics a novel defected ground structure is adopted in this work and also in the radiating patch the a l shaped slot and rectangular slot is introduced all together these slots constitutes for the triple notch behavior in the proposed antenna Triple notch behaviors scattering parameter is shown in the Fig 7 Defected ground in this structure which is comprised of a rectangular strip with multiple rectangular slots ,Defected ground structure utilized in this antenna facilitate to create notch in the radiation performance of the antenna by establish a high slow wave effect which offers rejection of the band which is interfering in the existing ultra wide band range ,actually the symmetrical slots added in the ground plane controls the effective capacitance and effective inductance preventing the interference of the frequency band in the antenna performance. .the simulated results of the antenna is depicted in the figure 6 from the figure we could find three interfering bands were removed their frequencies are as follows which works for the application like WIMAX, WLAN,X Band., 3.5 GHz-3.9 GHz, 4.9 GHz – 6.1GHz 6.8 GHz-8.35GHz.but a decremented bandwidth occurred in order to increase that edges are chamfered which increases the band width.

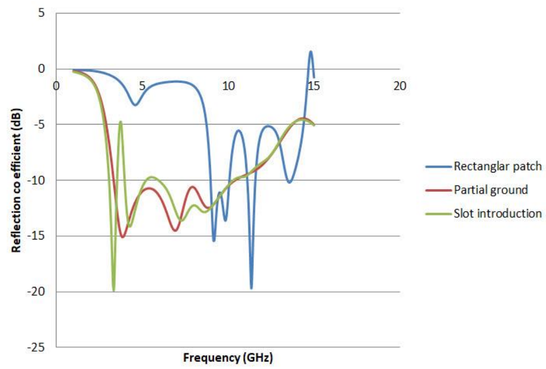

Fig.6 Reflection co efficient of the Band notched antenna

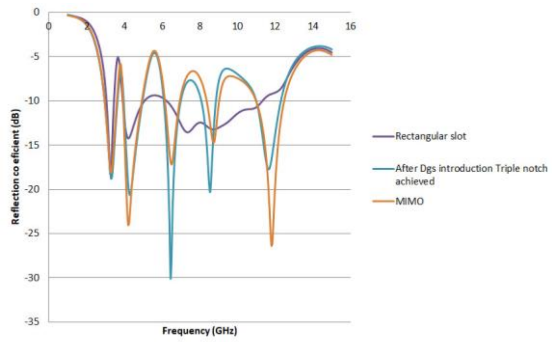

Fig 7Triple band notch of triple band notched antenna

Design of MIMO antenna

By holding the idea of miniaturized MIMO antenna in mind the two identical antennas were kept adjacent to each other but while keeping two identical elements adjacent it experiences a degradation in signal which is the main drawback due to mutual coupling between the elements and excitation of surface waves. To reduce that surface radiation need to be attempted. Fig 7 shows the results of the antenna without any decoupling element in it.

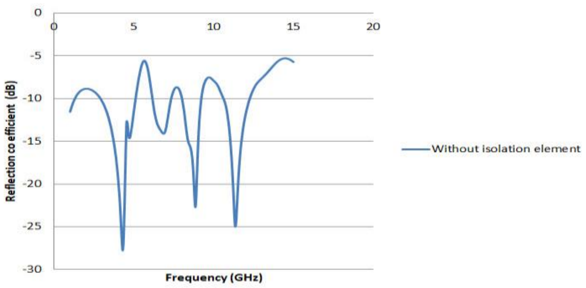

Fig.7 without decoupling element reflection co efficient

Effect of conducting strip over the substrate

To mitigate the mutual coupling between the radiating between patches and significantly enhances the isolation. we introduce a strip above the radiating elements and the size of the strip is parametrically analyzed at a certain point of the strip size the mutual coupling is found to be reduced and also it exhibited a bandwidth increase meantime there is a slight degradation in the notch band is exhibited but that is within allowable limits.

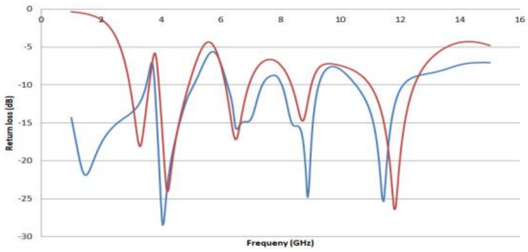

Fig.9 Reflection co efficient with isolation element

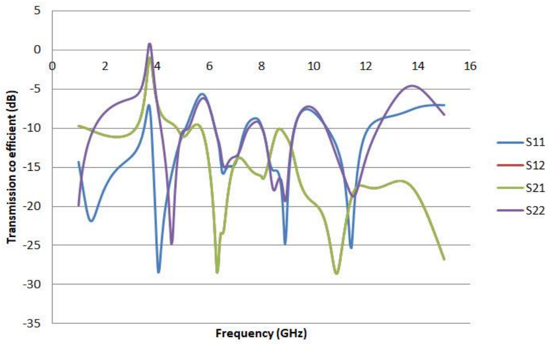

Fig..10 All reflection co efficient of the proposed structure

Thee simulated results shown in the Fig. 9 and also transmission coefficients S12 and S13 are analyzed isolation is achieved around 10 dB which is clearly seen in in the Fig.10

IV. Results and discussion

Prototype Measurement and discussion

Both single element and multiple element antenna is realized using the FR4 substrate over which the patch is implemented using usual photolithographic technique. To ensure the validity of simulated results, the fabricated antenna is tested with N9971A vector network analyzer. Fig 11 shows the photograph of the fabricated antennas front and back sides for measuring the MIMO antenna. One port is terminated with impedance of 50 ohm and exited another one. The measured results are depicted in Fig 11. It exists a slight difference in the measured result comparing simulated one which raised owing to the insertion loss in the connector fabrication errors copper losses. For both the case of single element and dual element antenna the bandwidth is increased in the higher end comparing to the simulated ones, for the simulated single element antenna it exhibits a bandwidth from 2.95GHz to 9.05GHz while measuring the bandwidth is achieved from 3.4GHzto 10.2GHz , and for the MIMO element bandwidth is exhibited from 1 GHz to 9.25 GHz and measured one is from 3.37 to 10.4GHz in both cases the lower end frequency is shifted

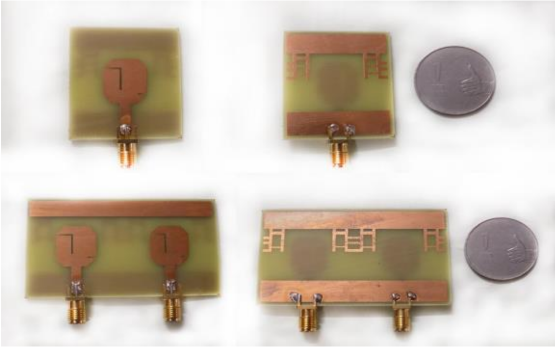

Fig.11 Fabricated antenna structures

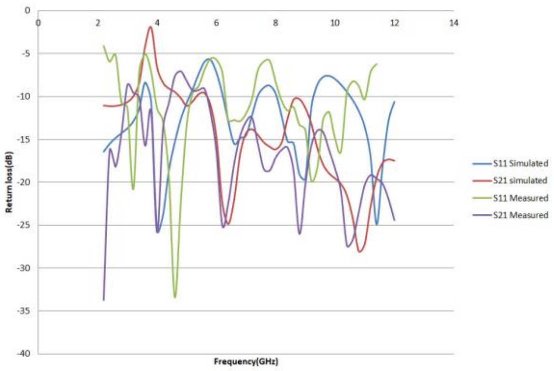

Fig.12 Return loss s11 and s21 measured and simulated of the proposed antenna

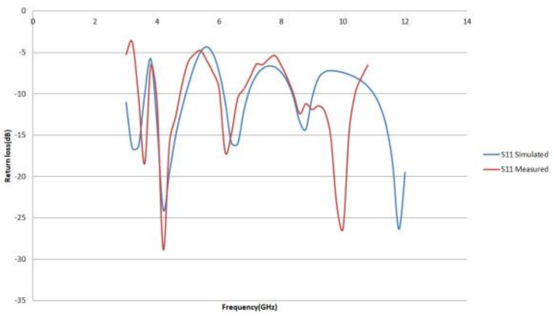

Fig 13 single element measured and simulated return loss comparison

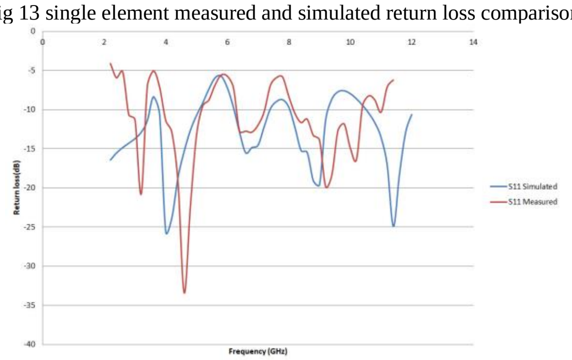

Fig 14 MIMO antenna measured and simulated return loss comparison

Surface current density

This section provides further more insights like radiating mechanism of the proposed antenna. It is mainly analyzed by looking into the surface current circulation flow of the antenna. In general, a surface current concentrates on the antennas part which is most influencing in the radiation and also coupling effect between the dual port radiating element. Here Surface current density is analyzed for both the single element antenna and also for dual port MIMO antenna in order to explain the effect of notch and the coupling effects and isolation from the figures 15-24.

It clearly shows that EM waves were suppressed to be surface current between the radiating elements. Fig 15 reveals that surface current is perturbed by the slots and it is concentrated near to l slot since there is impedance match creation with a notch frequency of 3 GHz .

Therefore attenuation at the notch frequency is achieved. Fig 16 depicts the surface current circulation at the notch center frequency 5.6GHz. Here the current is accumulated near the radiating edges, start of the L-slot over the rectangular slots and also at the edge of the feed also at the DGs structure so the DGS inductive effective notch is completely achieved. Fig 17 shows the current distribution for the third desired notch that is the X band center frequency 7.6 GHz; the current is accumulated at the lower side of the radiating patch and feed line which constitute for the notch behavior.

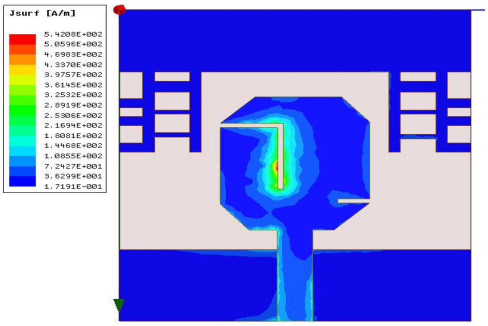

Fig.15 Surface current circulation for notch characteristics at 3 GHz

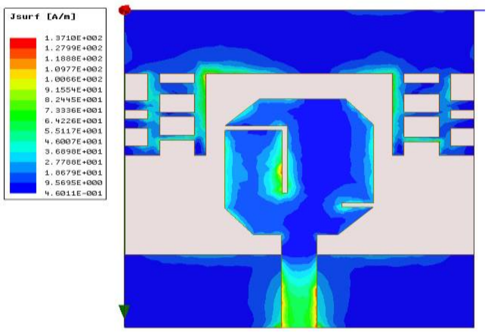

Fig.16 Surface current circulation for notch characteristics at 5.6 GHz

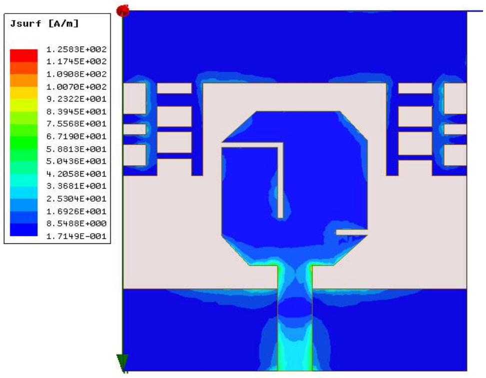

Fig17 Surface current circulation for notch characteristics at 7.6 GHz

Fig 18-20 illustrates the current distribution behavior of the single element with resonant peak 3.2GHz,4.2GHz,6.45GHz,.

The current is more concentrated near the l slot feed and underneath the feed that is in the ground portion where as for the 6.45GHz peak the current is gathered near the lower edge of feed and slightly in the DGS slot structure areas.

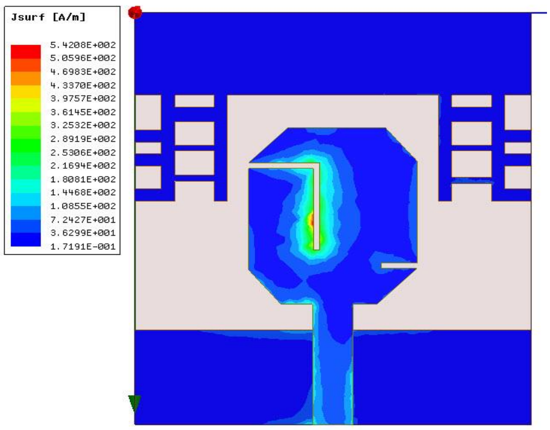

Fig.18 Surface current circulation for notch characteristics 3.2GHz

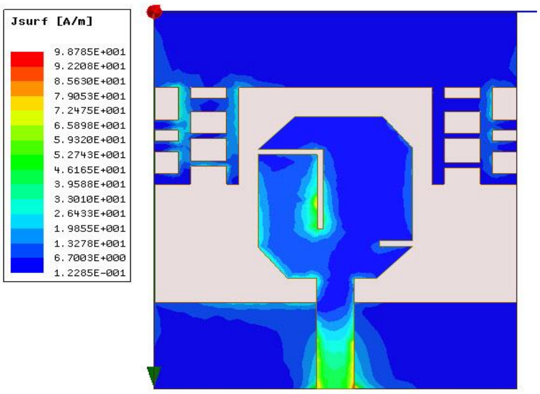

Fig.19Ssurface current circulation for notch characteristics 4.2GHz

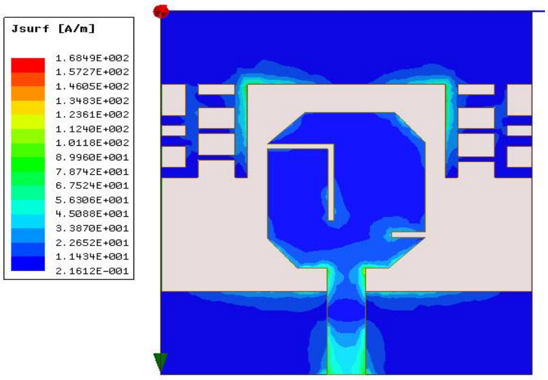

Fig.20 Surface current circulation for notch characteristics 6.45GHz

While moving to the MIMO part, the current distribution with and without isolation element are analyzed. When there is no isolation element, coupling between the elements are found to exist; Which is shown in Fig 21. After introducing a strip at a frequency of 6.55GHz, the current is more accumulated in the strip region and there is little evidence of mutual coupling. This is evident from the Fig 23. For the resonant frequency 8.9GHz slight coupling is visible in between the patches is clearly seen in Fig 24 The conductor plays a vital role in reduction of mutual coupling. While At a lower frequency the current is found in the primary radiators over the feed and edges of the radiating side and also some current distribution is found in the secondary radiator which is shown in Fig 23 and Fig 24.

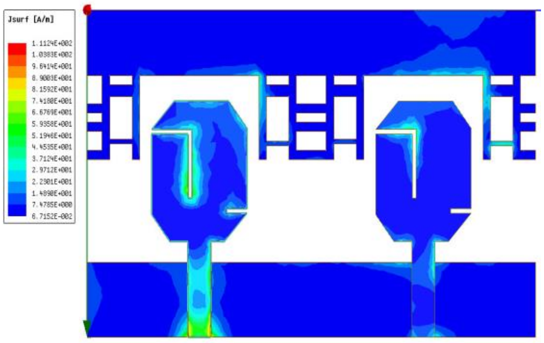

Fig.21 Ssurface current circulation MIMO without isolation element

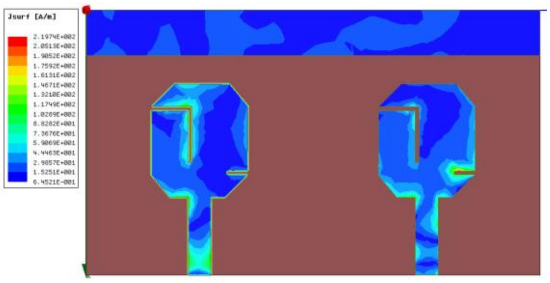

Fig.22 Surface current circulation Proposed MIMO at 4.3 GHz

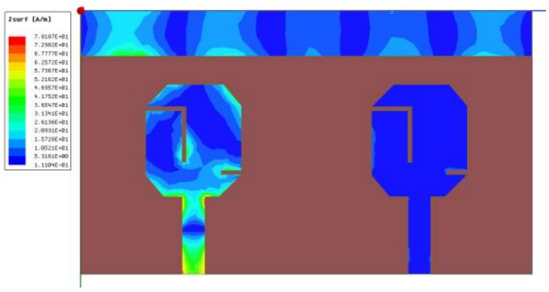

Fig.23 .Surface current circulation proposed MIMO at 6.55 GHz

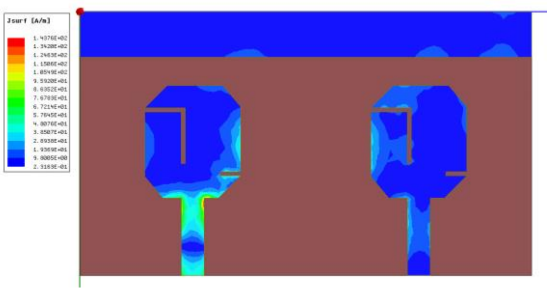

Fig.24. Surface current circulation proposed MIMO at 8.9 GHz

Radiation characteristics

Radiation characteristics are presented with the principle planes E Plane (YZ plane) and H plane (XZ plane) at the resonating peaks both figures below display for both the proposed SISO antennas and also the MIMO antennas. The radiation pattern at their resonant peaks. From the figures it is clearly understood that the performance of the antenna is well reported. In the images red marker shows the E plane and blue marker shows the H plane E and H plane patterns are observed Having Omni directional pattern through the region E plane H Plane nearly a bi directional pattern through the region and it is stable over the region. From the Fig. 25-31.

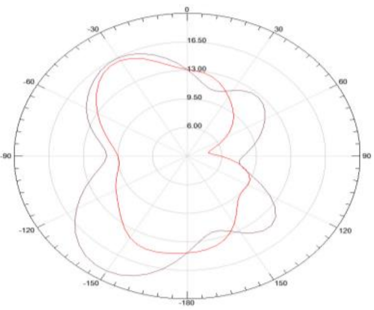

Fig..25 Simulated Radiation pattern of the proposed SISO structure at E plane and h plane at 3.25GHz

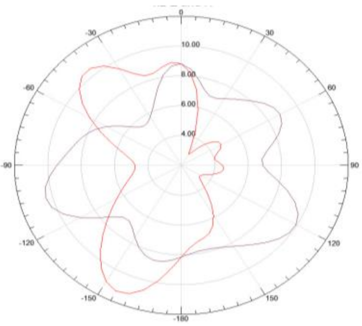

Fig..26 Simulated Radiation pattern of the proposed SISO structure at E plane and h plane at 4.2GHz

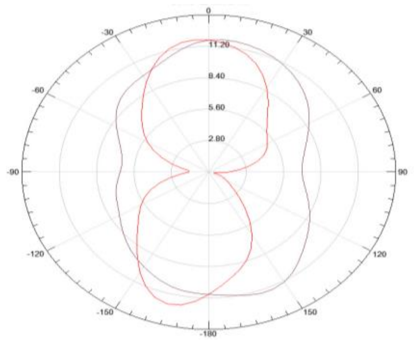

Fig..27 Simulated Radiation pattern of the proposed SISO structure at E plane and h plane at 6.45GHz

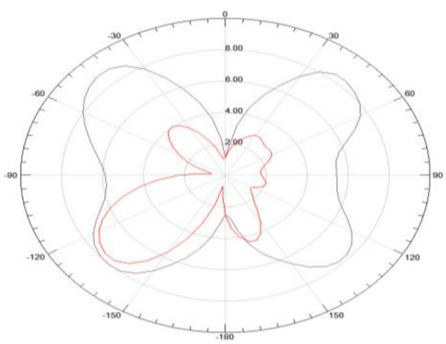

Fig .28 Simulated Radiation pattern of the proposed SISO structure at E plane and h plane at 8.75 GHz

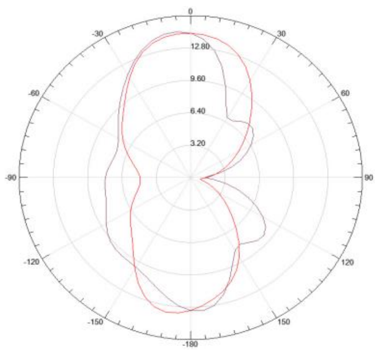

Fig.29 . Simulated Radiation pattern of the proposed MIMO structure at E plane and h plane at 6.55 GHz

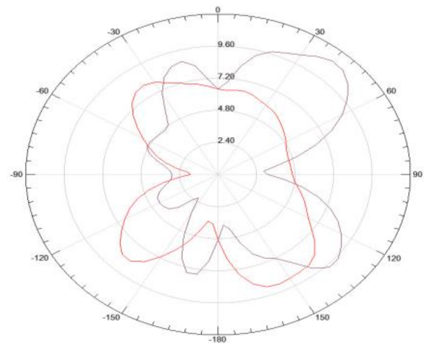

Fig.30 .Simulated Radiation pattern of the proposed MIMO structure at E plane and h plane at 8.9 GHz

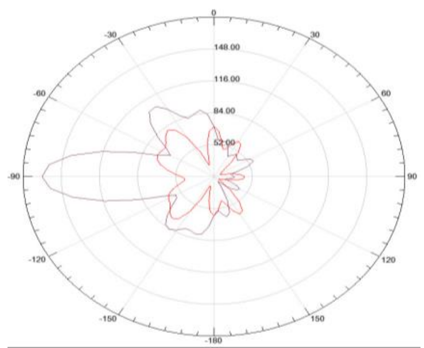

Fig..31 Simulated Radiation pattern of the proposed MIMO structure at E plane and H plane at 4.05 GHz

MIMO Diversity performance

This section elucidates about the various crucial parameters like ECC, TARC, Group delay for the proposed MIMO element.

ECC envelope correlation co efficient

ECC is foremost indispensable parameter while analyzing MIMO antenna, which exhibit how radiating elements are. In the proposed design the conducting strip is adopted over the radiating patches to achieve better isolation and good correlation. In general, ECC is calculated by means of radiation parameters and also by using the reflection co efficient among these two method scattering parameter based method is usually used equation related it is expressed in the equation 1 since radiation based is tedious comparing the reflection coefficient based method , practical limit of the ECC should be under 0.5 ideally value should be zero , Noteworthy decrease in the ECC is shown in this model .is depicted in the Fig 32

$\rho_e = |S_{11}{*}s_{12}+s_{21}{*}s_{22}|^2 \div (1-|s_{11}|^2 - |s_{21}|^2)(1-|s_{11}|^2 - |s_{12}|^2)$ ----1

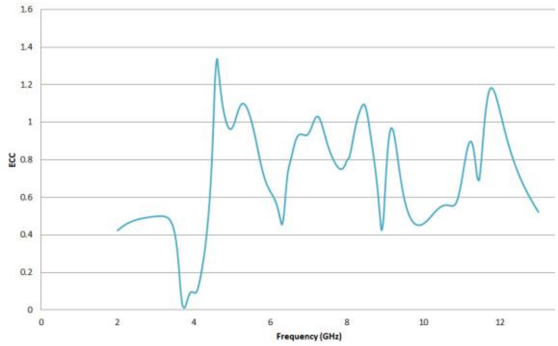

Fig.32 .ECC of the designed antenna

Group delay

Group delay is another valid factor which pin point signal dispersion ,the error occurred due to multiple reflection between the radiators s, usually identical radiators placed face to face excitement , the group delay is observed Fig 33 demonstrates the simulated group delay of the proposed antenna .

Group Delay = $-\Delta \Upsilon / \Delta \xi$ -----3

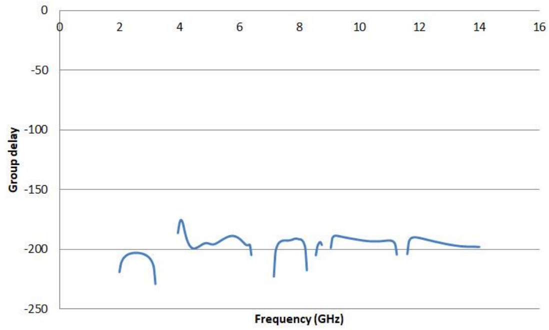

Fig.33 Group delay of the proposed antenna

TARC

Another definitive parameter to anticipate the functioning of the MIMO antenna is TARC. Which is measured by means of the reflection co efficient of the antenna which is under the -10 dB over the operating band depicted in Fig 34.

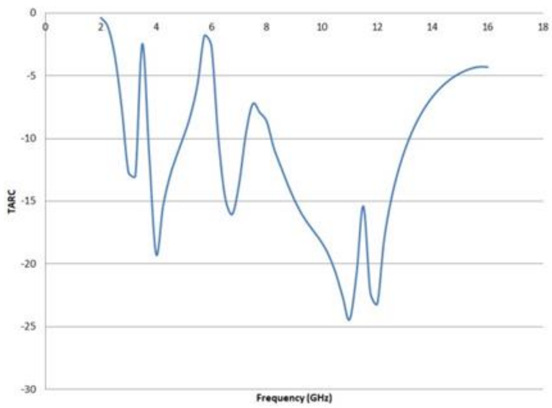

Fig.34 TARC of the antenna

Gain

Gain is plotted as a function of frequency and we could see a spurt and the proposed model gives the peak gain of 42dB which is depicted in the Fig. 35 and a stable gain is observed over the notch less region.

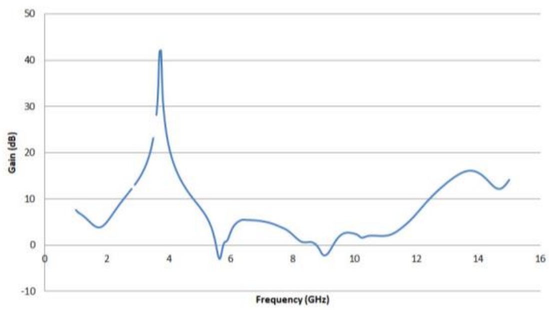

Fig.35 Gain of the antenna

V. Conclusion

Thus a compact dual port tri notched MIMO antenna is reported , Antennas are found to be reduced mutual coupling effects and an increased impedance bandwidth. Proposed model exhibits ultra wide band width from 2.95GHz to 9.05 GHz. It demonstrate a high gain with a peak gain of 42 dB and stable radiation patterns. The antenna essential parameters like ECC, Diversity gain , group delay are found to be very promising. The antenna is very compact. Hence proposed antenna is the best candidate for the UWB applications with potential interference removal. Further antenna could be moved to four port antenna and also enhance the isolation by reducing its mutual coupling; The simulated and measured results of the proposed antenna are in good agreement with each other.

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