C-Shaped triple band MIMO antenna for GSM, Wi-Fi & Satellite applications

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Abstract— **A Compact MIMO antenna was proposed in this article. The designed antenna is compact in size with dimensions of 20 x 34 x 1.6 mm^3.The patch antenna consists of two C- shaped elements facing each other and a hexagonal ring with a strip line which is placed in between the two C-shaped patch antenna elements. This model has a partial ground with mounted structures of inverted C-shaped strips, slots and a ring. In this model FR-4 material is used as substrate with permittivity (ε) = 4.4 and a loss tangent (δ) = 0.02. the proposed antenna is working under three bands, where the bands are under go condition of S_11≤ -10dB, those bands are 1.74GHz - 1.87GHz, 2.45GHz-4.15GHz and 9.62GHz – 11.13GHz with their respective bandwidth's of 0.13GHz, 1.70GHz and 1.51GHz. The antenna can work in the bands of GSM, CDMA, Wi-Fi, Wi-Max, Maritime navigation, Aeronautical navigation(Ground), Radio location and fixed satellite services.**

Index Terms— **MIMO antenna, high isolation, WiFi, GSM**

I INTRODUCTION

Now a day's wireless communication is at its higher pace where attraction towards this research area has been increased linearly. wireless communications require high data rates, High channel capacity, compact size and high isolation too. A dual band MIMO antenna is designed with a transmission line which is acting as a neutralizing part also called as neutralizing decoupling transmission line [1]. A design of dual band MIMO antenna with high port isolation, where high isolation is achieved from the T-shaped patch mounted on the top of the patch along with DGS on the ground [2]. A dual ISM band MIMO antenna with two sickle shaped radiating patch, DGS and microstrip feed line where they created a good isolation [3]. A dual band MIMO antenna with two C-shaped monopole antenna elements and a decoupling structure is used to obtain high isolation in the acquired bands [4]. A multi band printed MIMO monopole antenna with CPW feed, to increase its bandwidth performance U-inverted slots and meander line slots are employed [5].A dual band printed diversity antenna is deployed to combat multi path fading and increase isolation, it is printed on a PCB board and a methodology of design was proposed [6]. A dual band MIMO antenna is made using the complementary split ring resonator where the CSRR is placed on the ground to achieve high isolation [7].A dual band MIMO antenna with high isolation is proposed where the high isolation is due to the two transmission lines mounted on the top of substrate and with DGS [8].A dual band slot MIMO antenna is proposed, where there is a high isolation between two antenna elements is achieved by employing decoupling slot structures [9]. A dual band MIMO antenna was made with a common radiating element where the antenna is CPW fed, where an irregular ground plane is employed to achieve its performance [10]. A triple band notch MIMO antenna is proposed where it is employed with Defected ground compact electromagnetic band gap to achieve band notches, which is more compact compared to conventional EBG structure [11]. A dual band MIMO antenna is proposed with a multi-port, where in the proposed antenna it has four ports in total. The antenna is made on a printed circuit board having a good isolation [12] consists of both inverted f decoupling element and a meandering resonating branch for higher isolation [13]. A compact triple band MIMO antenna with CRLH (composite right/left hand) unit cell which is used to achieve triple band as well as quasi omnidirectional radiation [14]. A planar triple band MIMO antenna is proposed which consists of three individual meander inverted-L radiators, here it is fed with proximity coupling feed, with decoupling devices which is T-shaped slot and meandering microstrip -line resonator [15]. A coupled fed triple band MIMO antenna is proposed, where two antenna elements are oriented diagonally opposite to each other, the antenna elements are PIFA's with a spiral silt (parallel resonant) in the ground [16].A triple band MIMO antenna is proposed which consists of folded monopoles, a stepped slot and an ellipse slot is etched to reduce the mutual coupling between the monopoles [17]. A compact multi band MIMO antenna is having enhancement in isolation is proposed, even though the separation between antennas is small, the mutual coupling is low [18]. A compact MIMO antenna with a inverted U-shaped slot having triple band with good isolation [19].In this paper, A Three-band MIMO antenna is proposed. The basic antenna has gone through two more iterations to reach its final proposed antenna. The antenna works in the few of the UWB bands, the antenna is compact in size, the small strip line in the ground etched can create a band in the few bands mentioned, the antenna can work for GSM, Maritime , Aeronautical navigation(Ground), Radio location and fixed satellite services.

II. DESIGN AND GEOMETRY

The proposed antenna consists of the inverted C-shaped radiating patch which are placed opposite to each other. The antenna fabricated on the a FR4 substrate material with dimension of 20 x 34 x 1.6 mm^3 and having the dielectric constant of 4.4. The both antennas are separated by the circular ring and stub attached to stub to separate the antennas. To close the inverted C-shaped antenna same inverted C-shaped line are connected to radiating patch. The partial ground structure is taken on the ground structure and rectangular slot is made on the partial ground below the rectangular slot a line slot is made with the dimensions of 23 x 0.3 mm. The slotted portion on the ground structure is attached with stubs on the ground structure to partial ground. The u-shaped slots are made on the feed lines of the proposed antenna which helps in the performance of the antenna.

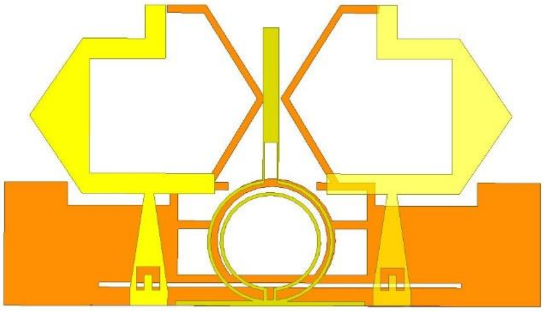

Fig 1 Proposed Antenna

Iterations

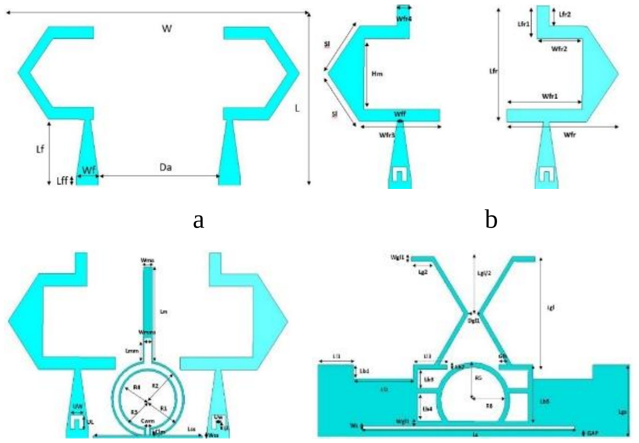

Fig 2 iterations c d

The basic antenna has gone through different iterations where there is a total of three iterations, one with c-shaped patch and conical feed. In second iteration a strip-line is placed at the bottom side and top of the C-shaped patch, inverted U-shaped slots are made on the feed line and converting it into 90 degrees phase shifted U-shaped patch. In third iteration a double ring with a strip attached at the top with some slots etched on them both. The ground is common for all the three iterations where the partial ground has multiple etches and c-shaped thin strip is mounted on the partial ground on top which is united. A long strip line is removed from the ground. The Dimensions of the Antenna is given below table 1

+

Lmm	Lm	Wms	Wmms	Clm	Cwm	R1	R2	R3	R4	UL	Ul	UW	Uw	Lss	Wss
2.67	9.88	1	0.8	0.75	0.4	4	3.8	3.2	3.0	1.5	1	1.5	0.5	12	0.3

Lfr	Lfr1	Lfr2	Wfr	Wfr1	Wfr2	Wfr3	Wfr4	SL	Hm	Ll1	Ll2	Lb1
12.22	3.5	2.2	11.75	7.95	4.8m	8.4	1.3	5	7.43	4	6.5	1.5

Ws	Ls	Ll3	Lb2	Lgl	Lgs	Lb3	Lb4	Lb5	Wgl1	Lg2	Dgl1	Gfs	Gap	R5	R6
0.3	23	3.7	0.5	12	8	2	3	6	0.5	2.3	1	0.9	1.2	4	3.5

L	W	Lf	Lff	Wf	Wff	Da
20	34	7.25	1	2.4	0.6	13

Table 1

III RESULTS

3.1 Reflection coefficients

From fig 2(a), for the first iteration model, two C-shaped antenna elements are placed in such way that facing each other, these C-shaped elements are mounted on top of the conical feedline, the partial ground with slots and a ring is placed on the ground combined to it, with inverted C-shaped strip mounted on top of the partial ground. where the first iteration achieved bands from 2.60 - 3.86GHz, 4.70 – 10.53GHz, under the condition $S_{11} \leq$ -10 dB, bands achieved by the 1st iteration are shown in the fig 3.From fig 2(b), For the Second iteration model, 2 strips are added to the C-shaped patch where the C shape in converted into an inverted U-shaped patch with added strips beside and top of it.

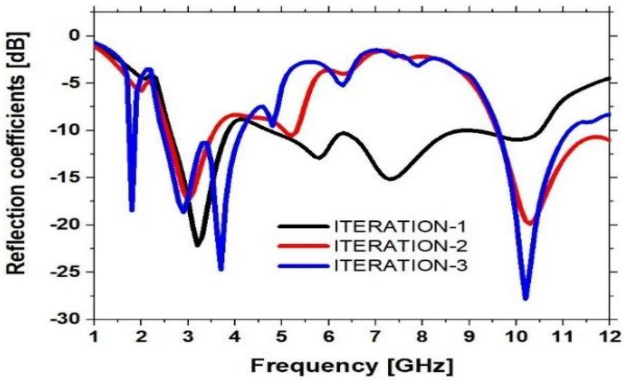

Fig 3 Reflection Coefficients of all iterations

From fig 2(d), the partial ground with slots and a ring is placed on the ground combined to it, with inverted C-shaped strip mounted on top of the partial ground. where the Second iteration achieved bands from 2.55 – 3.57GHz, 5.05 – 5.31GHz and 9.59 – 12GHz under the condition $S_{11} \leq$ -10dBwhich is shown in Fig 3. From fig 2(c), For the final iteration model, in addition to 2nd iteration a double ring structure with slots are added in the middle of the 2nd iteration model, from fig 2(d), the partial ground is with slots and a ring is placed on the ground combined to it, with inverted C-shaped strip mounted on top of the partial ground. where the final iteration achieved bands from 1.74 - 1.87GHz, 2.45-4.15GHz and 9.62 – 11.13GHz under the condition $S_{11} \leq$ -10dB. The iterations have lot many bands in common, the main variation wanted is to get a large notch in between the UWB region. So, by comparing all the reflection coefficient values of the iterations the final modal is selected as an antenna model.The s-parameters of the final iterated antenna which is the final model is represented in the form of graph in the fig 4.where the S-parameters consists of four values, those are s_{11}, s_{12}, s_{21} and s_{22} of the final antenna. There are totally four because of 2 ports as it is a MIMO antenna of number two.

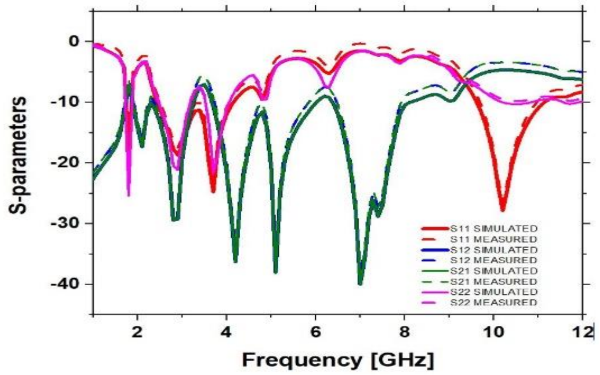

Fig 4 S-Parameters of the Final Antenna

3.2 Parametric analysis

Parametric analysis is done on the final antenna by varying the thickness of the substrate from 0.8mm to 1.6mm by taking a step size of 0.2mm. the values of the reflection coefficients is shown in the fig 5, the reflection coefficients vary with the variation in the substrate thickness. From the fig.5(a) S_{11} and S_{21} of the antenna are noted in the plot. When the thickness of the substrate is fixed to 1 mm the antenna shows better resonance performance at the resonating frequency. Similarly, the S_{21} of the antenna are noted and the isolation values are less than the -10dB at the resonating frequencies.

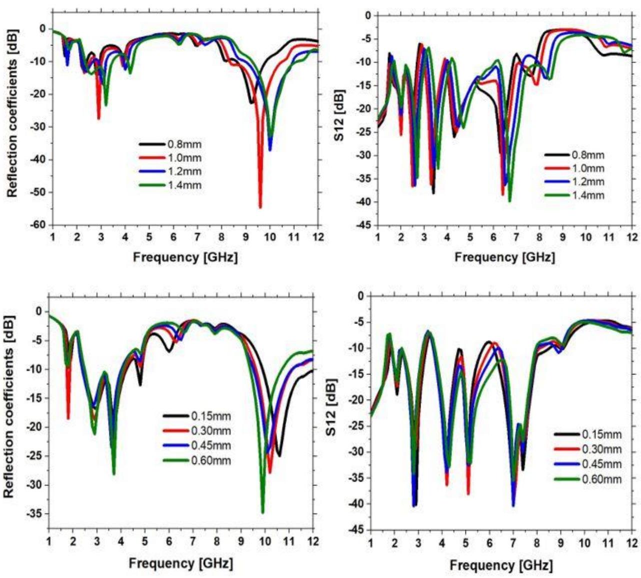

Fig 5 Reflection Coefficient of the Final Antenna

3.3 Current Distributions.

The current Distributions are the pictorial representation of current distributions over the antenna patch and ground where the antenna is MIMO type so one port is excited at first and then other. The port excited orderly. The current distribution plots are represented in the below fig 6. At the frequency is 1.8 GHz currents are traveling in the feed line and slotted line on the ground structure. The maximum currents are distributed on the feed line of the first feed line and patch of the antenna this is because only first port of the antenna is excited. For the frequency is 3.7 GHz the currents are distributed on the feed line and the circular ring attached to as isolation line between the elements. Similarly, the currents are also distributed in the ground structure of the slotted line back of the ground structure.

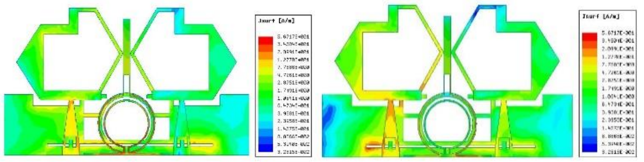

Fig 6 Current Distribution at (1)1.8GHz and (2) 3.7GHz

3.4 Radiation patterns

The radiation of antenna is represented in the form of graphs where the radiation plots presented are XY-plane and YZ-plane. The antenna's radiation pattern at 1.8GHz and 3.7GHz, where both the measured and simulated are presented in that graph. Most of the radiation pattern are dipole structure at the 1.8 GHz which are observed in the XY-Plane and YZ-plane. Similarly, the radiation pattern is distributed along the direction of -60 to -120 at 3.7 GHz. And the radiation patterns are semi omnidirectional in the both planes of XY-Plane and YZ-plane.

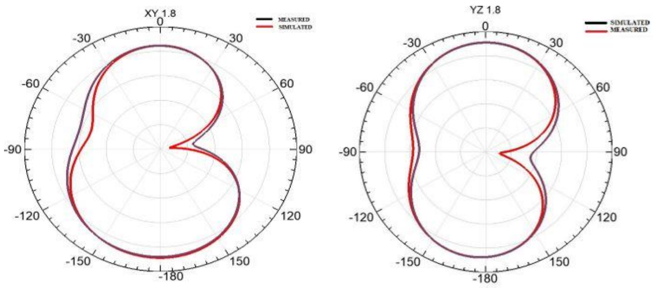

Fig 8 Radiation pattern at 1.8 GHz

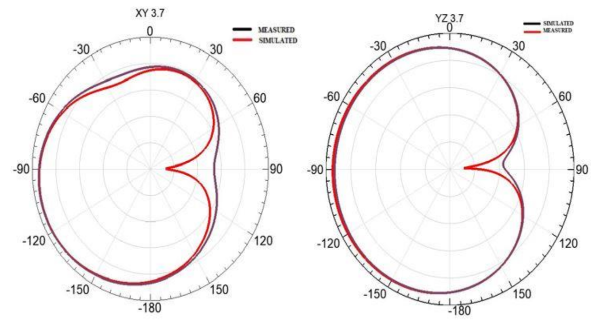

Fig 9 b) Radiation pattern at 3.7 GHz

3.5 Envelope Correlation Coefficient

The multipath indoor propagation can be determined with the help of ECC. The two MIMO antennas are independent in nature. The value of ECC should be less than or equal to 0.3 for a MIMO antenna. Proposed antenna is a MIMO antenna the value of ECC for this antenna is less than or equal to 0.05 for operating bands of the final antenna. Assuming the antenna is lossless, ECC can be calculated by using its s-parameters.

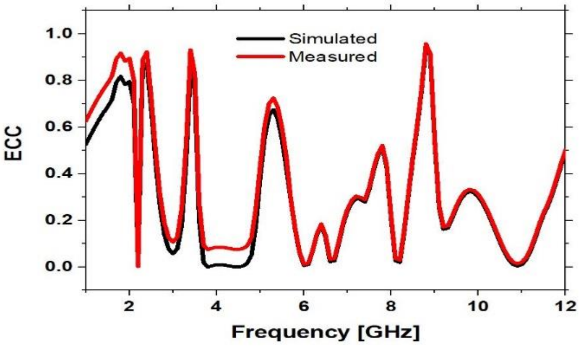

Fig 10 ECC of Final Antenna

The ECC can be calculated by using below formula

$$\rho = \frac{|s_{11} * s_{12} + s_{21} * s_{22}|^2}{(1-(|s_{11}|^2+|s_{21}|^2))(1-(|s_{22}|^2+|s_{12}|^2))}$$

3.6 Fabricated antenna

The Fig.11 presents the fabricated model of the proposed antenna model in top and bottom ground structure. To antenna fabricated on the FR4 material and size of the antenna is compared with coin placed on the side of the antenna. Table 2 presents the comparison of the previous literature of the work. The proposed antenna provides the best results compared to previous in some of the aspects.

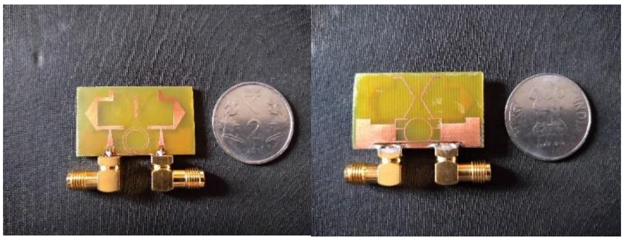

Fig 11 Fabricated Antenna front and back

Comparison of previous literature

REFERENCE	Dimensions	Operating Frequency	Bands	Isolation	ECC
[1]	80 x 40 x 1.6	2.4-2.6 5.2-6	Dual	15	0.01
[3]	90 x 40 x 1.6	2.1-2.7 5.1-6.1	Dual	15	0.0023
[5]	42 x 62 x 1.6	2.38-2.52	Dual	10	0.02
[7]	70 x 90 x 0.8	2.4/5.2	Dual	33	0.016
[9]	70 x 40 x 0.8	2.4/5.8	Dual	20	0.01
[12]	40 x 20 x 1.6	2.4-2.5 4.9-5.75	Dual	15	-
[13]	52 x 75 x 1.6	2.4-2.48 5.15-	Dual	15	0.03
Proposed	20 x 34 x 1.6	1.7-1.87 2.45-	Triple	10	<0.05

Table 2

CONCLUSION

A triple band MIMO antenna has been designed, where the antenna is compact with the measurements 20 x 34 x 1.6 mm^3, FR-4 is used as substrate material. The MIMO analysis has been done, where the ECC and diversity gain values are simulated. Coming to ECC the values are less than 0.05 in the operating bands and diversity gain is greater than 0.03 for the operating frequency band. This antenna can be used in different applications like GSM, Maritime navigation, Aeronautical navigation(Ground), Radio location and fixed satellite services. The antenna provides the good isolation between the elements of the antenna and provides the considerable gain at the operating frequency of the antenna.

REFERENCES

[1]. Huang, J. H., W. J. Chang, and C. F. Jou, "Dual-band MIMO antenna with high isolation application by using neutralizing line," *Progress In Electromagnetics Research* Letters, Vol. 48, 15–19, 2014.

[2]. Qin, H. and Y. Liu, "Compact dual-band MIMO antenna with high port isolation for WLAN applications," *Progress in Electromagnetics* Research C, Vol. 49, 97–104, 2014.

[3]. Roshan, R. and R. K. Singh, "Dual ISM band MIMO antenna for Wi-Fi and WiMAX application*," International Conference on Signal Propagation and Computer Technology* (ICSPCT), 209–213,2014.

[4]. Liu, Y., L. Yang, Y. Liu, J. Ren, J. Wang, and X. Li, "Dual-band planar MIMO antenna for WLAN application," Microwave Opt. Technol. Lett., Vol. 57, No. 10, 2257–2262, Oct. 2015.

[5]. Desde, I., G. Bozdag, and A. Kustepeli, "Multi-band CPW-fed MIMO antenna for Bluetooth WLAN and WiMAX applications," Microw Opt. Tech. Lett., Vol. 58, No. 9, 2182–2186, 2016.

[6]. Ding, Y., Z. Du, K. Gong, and Z. Feng, "A novel dual-band printed diversity antenna for mobile terminals," IEEE Transactions on Antennas and Propagation, Vol. 55, No. 7, 2088–2096, 2007.

[7].Yang, D. G., D. O. Kim, and C.-Y. Kim, "Design of dual-band MIMO monopole antenna with high isolation using slotted CSSRR for WLAN," Microw. Opt. Technol. Lett., Vol. 56, 2252–2257, 2014.

[8]. Cui, S., Y. Liu, W. Jiang, and S. X. Gong, "Compact dual-band monopole antennas with high port isolation," Electron. Lett., Vol. 47, No. 10, 579–580, May 12, 2011.

[9]. Jiang, W., L. Yang, B. Wang, and S. Gong, "A high isolation dual-band MIMO antenna for WLAN application," 2017International Symposium on Antennas and Propagation (ISAP), Oct. 30–Nov. 2,2017.

[10]. Zhao, N. and W.-P. Tian, "CPW-fed dual-band MIMO antenna with common radiating element, "Progress In Electromagnetics Research Letters, Vol. 62, 71–75, 2016.

[11]. Jaglan, N., S. D. Gupta, B. K. Kanaujia, S. Srivastava, and E. Thakur, "Triple band notched DGCEBG structure based

UWB MIMO/diversity antenna," Progress In Electromagnetics Research C, Vol. 80, 21–37, 2018.

[12]. Soltani, S., P. Lotfi, and R. D. Murch, "A dual-band multi-port MIMO slot antenna for WLAN applications," IEEE Antennas Wireless Propag. Lett., Vol. 16, 529–532, 2017.

[13]. Deng, J. Y., J. Y. Li, L. Zhao, and L. X. Guo, "A dual-band inverted-F MIMO antenna with enhanced isolation for WLAN," IEEE Antennas Wireless Propag. Lett., Vol. 16, 2270–2273, 2017.

[14]. Nandi, S. and A. Mohan, "CRLH unit cell loaded tri-band compact MIMO antenna for WLAN/WiMAX applications," IEEE Antennas Wireless Propag. Lett., Vol. 16, 1816–1819, 2017.

[15]. Sun, J. S., H. S. Fang, P. Y. Lin, and C. S. Chuang, "Triple-band MIMO antenna for mobile wireless applications," IEEE Antennas Wireless Propag. Lett., Vol. 15, 500–503, 2016.

[16]. Zhu, J., B. Feng, L. Deng, B. Peng, and S. Li, "Coupled-fed tri-band MIMO mobile antenna for WWAN and LTE applications," Microwave and Optical Technology Lett., Vol. 59, No. 2, 463–468, 2017.

[17]. Fang, Q., D. Mi, and Y.-Z. Yin, "A tri-band MIMO antenna for WLAN/WiMAX application," Progress in Electromagnetics Research Letters, Vol. 55, 75–80, 2015.

[18]. Srinivasa Rao, S., K. J. Babu, and A. M. Prasad, "Compact multi-band MIMO antenna with improved isolation," Progress In Electromagnetics Research M, Vol. 62, 199–210, 2017.

[19]. Alex, Lisha, and Sreekumari Amma. "Compact Inverted U-Shaped Slot Triple Band MIMO Antenna for WLAN and WiMAX Applications." 2018 Second International Conference on Inventive Communication and Computational Technologies (ICICCT). IEEE, 2018.