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Compact MIMO Antenna with High Isolation for Wireless Applications

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ABSTRACT: In this paper, a simple two element compact tri-band multiple-input-multiple-output (MIMO) antenna for GSM900, GSM1900 and WiMAX applications is proposed. Each monopole of two-elements MIMO antenna is a three arm radiator symmetrically spaced 0.077λ_o apart where λ_o is the free space wavelength at the lowest operating frequency of the lowest band. The antenna occupying an area of 58 mm × 68 mm (0.154λ_o × 0.181λ_o) offers triple band operation over 0.8-1 GHz, 1.8-2.1 GHz and 3.3-4.69 GHz which corresponds to 22%, 15.4% and 34.8% impedance bandwidth respectively. Isolation greater than 22 dB is achieved by introducing three stubs between the two monopoles and integrating these stubs to the ground plane. The proposed antenna exhibits stable gain and radiation patterns. Envelope correlation coeffcient (ECC), diversity gain (DG) and mean effective gain (MEG) of the antenna measured over the operating bands adhere to the MIMO criteria.

Keywords: Compact antenna, high isolation, MIMO, monopole antenna, triband, multiple-input-multiple-output.

I. INTRODUCTION

In today's era of almost continuous connectivity, wireless devices are ubiquitous. As the RF electronics technology for these wireless devices continues to shrink in size, there is an analogous demand for the design of a compact antenna. Moreover, the necessity for high data rate and user multimedia experiences has pushed the limits in available bandwidth and power transmission. Multiple-Input-Multiple-Output(MIMO) technology is one of the feasible solutions that overcome the data rate limit experienced by Single-Input-Single-Output systems. MIMO technology requires multiple antenna elements at transmitter and receiver to achieve a linear increase in the data rate with an increase in the number of antennas which leads to increase in the size.

In addition to deal with the challenge of designing a compact MIMO antenna, it must also meet the requirement of operating over multiple frequency bands. Further, the design of compact, multiband MIMO antenna is more challenging if one of the bands lie below 1GHz [1] because, due to larger wavelength, the field and radiation pattern couple strongly with adjacent elements and as a result, mutual coupling increases and the performance of antenna degrades. Various isolation enhancing techniques [2] viz. defected ground structures[3], neutralizationlines [4], metamaterials [5], parasitic elements [6],have been reported in the literature.

Printed multiband MIMO antenna systems covering atleast one band of operation below 1 GHz [1-7], and compact in size are few in literature. Moreover, achieving in-band isolation in these antennas is a demanding task. Two-elements printed multiband MIMO antenna on 80mm × 84mm substrate area is designed to resonate at GSM 900, DCS 1800, LTE-E 2300 and LTE-D 2600 [8]. Isolation > 30dB is achieved by using neutralizing lines and defects in the ground plane. Another two-elements triple band MIMO antenna on 65 mm × 100 mm is proposed for GSM900/1800 and LTE2600 [9] services with mutual coupling < -16 dB. Two Meander-line type Inverted-L (MLIL) radiators and two physical decoupling devices are incorporated to improve isolation. A dual-band (0.75 GHz/2.5 GHz) MIMO antenna using stacked dipoles placed orthogonally to each other is proposed in [10]. Isolation of about 20 dB is achieved using polarization diversity technique. A meandered microstrip loop multiband antenna is designed in [7] to operate over 4G LTE (699–798 MHz) band, UMTS (DCS/PCS) bands (1.7–2.0 GHz), WiMAX bands (2.3 and 3.5 GHz), and WLAN bands (2.4 and 5 GHz). The antenna dimensions are 150 × 150 mm^2.

Multiband antennas are designed to operate above 1GHz bands in [11, 12]. A dual- band CPW fed MIMO antenna on 42 mm×62 mm substrate for Bluetooth, WLAN and WiMAX applications with isolation > 15 dB is presented in [11]. A triple band MIMO antenna is designed by loading the square loop antenna with CRLH unit cell [13]. Isolation more than 15 dB is obtained by implementing an open ended I-shaped slot in the ground plane. Diversity based stub loaded meander line antenna [14] is designed to operate over 1.95-2.5 GHz, 3.153.85 GHz and 4.95-6.6 GHz bands. Isolation more than 17 dB is achieved using split ring resonators (SRRs). A tri-band MIMO antenna [15] based on composite right/left handed transmission line (CRLH-TL) for the fifth generation (5G) mobile handsets is designed to cover 1.525/3.45/4.9 GHz bands. An ohm-shaped metal line is employed between the two triband (2.4/5.8 GHz WLAN and 3.5 GHz WiMAX bands) monopoles to obtain a mutual coupling < -18dB

[16]. A tri-arm triband monopole antenna is designed to operate over 2.1-2.7 GHz, 3.3-3.7 GHz and 4.9- 5.35 GHz bands with isolation > 20dB over the three bands [12].

Two elements compact tri-band monopole MIMO antenna with high isolation for wireless applications is proposed in this article. Each monopole radiator comprises of three arms. The longest, middle and smallest arm resonate over GSM900 band, GSM1900 band and Wi-Max band respectively. Three ground stubs are integrated in between the two antenna elements. The stub near to the excited monopole increases the effective surface current path length and therefore, along with the longest arm, determines the lowest resonating frequency while the other stubs and the spacing between them act as a band stop filter to provide isolation more than 22 dB. The proposed MIMO antenna has merits like design simplicity and compactness as compared to other similar state of art antennas reported in the literature.

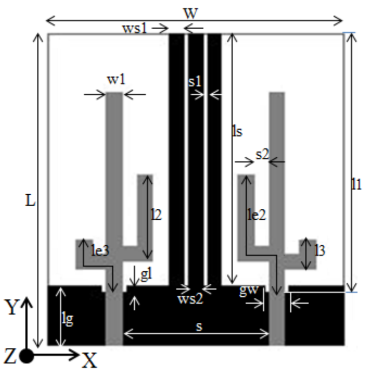
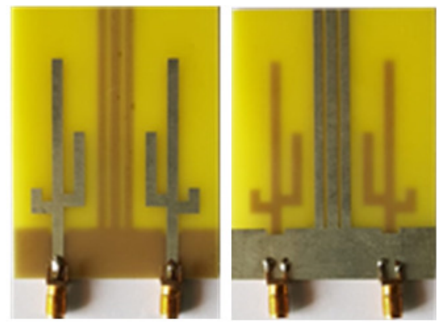


Fig. 1. The proposed tri-band MIMO antenna



(a) (b)

Fig. 2. The fabricated MIMO antenna system: (a) Top view and (b) Bottom view

II. ANTENNA DESIGN THEORY AND CONFIGURATION

A. Design Theory

A multiband monopole antenna can be designed using multiple branches. The resonant frequency offered by a branch depends on the effective current path length. The longest arm of the monopole antenna resonates at lowest frequency, while the shortest arm resonates at highest frequency. Moreover, the width of the band is controlled by the width of the branch. Hence, the three arms of the monopole element independently control the three bands. Based on this principle, a two element triband MIMO antenna on 1.6 mm FR4 substrate (dielectric constant (εr) = 4.4 and loss tangent (tan δ) = 0.02) is designed as shown in Fig.1. The MIMO antenna structure is simulated and analyzed using High Frequency Structure Simulator (HFSS). The optimized dimensions are recorded in Table.1. The antenna is fabricated on a 58 × 68 mm^2 substrate and is shown in Fig.1b.

B. Antenna Configuration Evolution

The antenna evolution stages and the simulated S-parameters of each stage are shown in Fig. 2 and 3, respectively. In Antenna 1 to accommodate the second element the ground plane dimensions are increased and to isolate the antenna elements a ground stub is protruded between the two monopoles. In a monopole antenna, ground plane dimensions affect the resonant frequency and impedance of antenna. Therefore in Antenna 1, ground stub dimensions, ground plane width and length, and monopole dimensions are optimized. Antenna 1 comprising of two 3 × 43.5 mm^2 rectangular monopoles separated by a distance of 29mm (0.07λ_o) which operates in the 0.78 – 0.9 GHz band. The ground stub length of 55mm (about 20% more than the monopole length [13]) provides isolation of 15 dB. Another branch is added in Antenna 2, so that it resonates over another 2.02-2.16 GHz band. The isolation > 19.4 dB is obtained in this band but it degrades the isolation to 12.6 dB in the lower band. Three branches in Antenna 3 offer three operating bands viz., 0.75-0.94 GHz, 2.01-2.18 GHz and 3.46-5.0 GHz with respective isolation of 12.8 dB, 19.7 dB and 33.6 dB. However, addition of these branches affect the impedance of the antenna structure and impedance matching of antenna degraded over the lower and middle bands. To improve the isolation further, two more ground stubs are added to the present ground stub on the either side at a spacing of 1mm resulting in Antenna 4 structure. The stub near to element 1 electromagnetically couples with the longer and middle arms of the monopole and thus improves impedance matching over the lower and middle bands. The stub increases the effective surface current path length and thus decreases the dimensions of antenna. The resonating frequency of the lowest band can be calculated using (1).

$$f_{r1} = \frac{c}{4(l_g + 0.5(s - w_{s2} - w_{s1}) - s_1 + l_s)} \quad (1)$$

The other two ground stubs provide decoupling path and also the stubs and the spacing between them act as band stop filter. As a result, these stubs do not allow the surface current due to surface waves to couple to the other element as indicated by the surface current distribution shown in Fig.4a, b c. These stubs also act as reflectors to near fields, improving isolation over the desired operating bands. Isolation is improved by 5.2 dB and 2.3 dB in the lower and the middle band respectively. Isolation > 22 dB is achieved over all the three bands. In Antenna 5, two rectangular slots are introduced in the ground plane below the feed line. The slot dimensions are optimized to 5mm × 1.5mm.

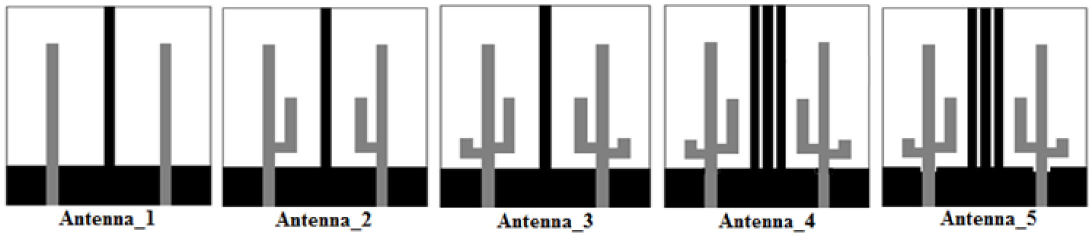


Fig. 3. Evolution stages of proposed tri-band MIMO antenna.

Table 1: Dimensions of the proposed antenna.

Parameter	**L**	**W**	**l_1**	**l_2**	**l_3**	**l_{e2}**	**l_{e3}**	**w_1**	**l_s**
Value (mm)	68	58	56.5	18.5	6.3	31.5	17.5	3	55
Parameter	**ws1**	**ws2**	**s**	**s1**	**s2**	**lg**	**gl**	**gw**	--
Value (mm)	2.5	3	29	1	3	13	1.5	5	--

These slots behave as LC filter. It affects mainly the impedance bandwidth and isolation of the higher band form 3.3-4.69 GHz. The isolation in the lower, middle and the higher bands are more than 22.6 dB, 20 dB and 34.2 dB respectively. Thus, isolation more than 20 dB in the bands below 1 GHz is achieved, which is a challenging task as stated in [1] Bandwidth and Isolation of each stage involved in the evolution of triband MIMO antenna is listed in Table 2.

III. EXPERIMENTAL RESULTS ANDDISCUSSIONS

A. Simulated and Measured S–Parameters

The proposed antenna is fabricated and its S-parameters are measured using Agilent 9916A vector network analyzer. The |S12| measurement is carried out by exciting one port and match terminating the other port Fig. 5 displays the simulated and measured S-parameters of the MIMO antenna. The results are in close agreement with each other. |S11| < -10dB and |S12| < -22 dB are obtained for the desired operating bands viz. 0.8-1 GHz, 1.8-2.1 GHz and 3.3-4.69 GHz.

B. Diversity Characteristics

The measured radiation patterns for φ = 0◦ (X-Z) and φ = 90◦ (Y-Z) planes at 0.9 GHz, 1.9 GHz and 4 GHz are shown in Fig. 5. The radiation patterns are measured in the X-Z plane and the Y-Z plane, with port 1 or port 2 excited and the other port matched terminated. The radiation patterns are stable and are mirror images of each other deciphering antenna diversity. Table 3 gives a comparison of the proposed MIMO antenna with reported multi-band antenna design.

Table 2: Summary of evolution stages of the proposed triband MIMO antenna.

Antenna stages	**Antenna 1**	**Antenna 2**	**Antenna 3**	**Antenna 4**	**Antenna 5**
BW (GHz)	0.78-0.90	0.750.93/2.0 22.16	0.750.94/2.01 2.18/3.465.0	0.771.07/1.872. 1/3.394.8	0.8-1/1.872.1/3.33 4.67
I_{min}	15	12.6/19.4	12.8/19.7/ 33.6	18.6/22/ 33.8	22.6/22.2/ 34.2

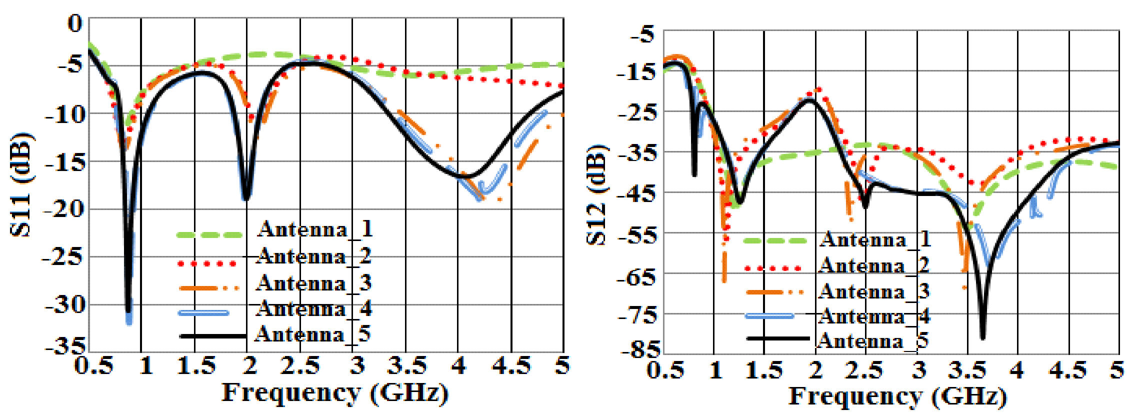
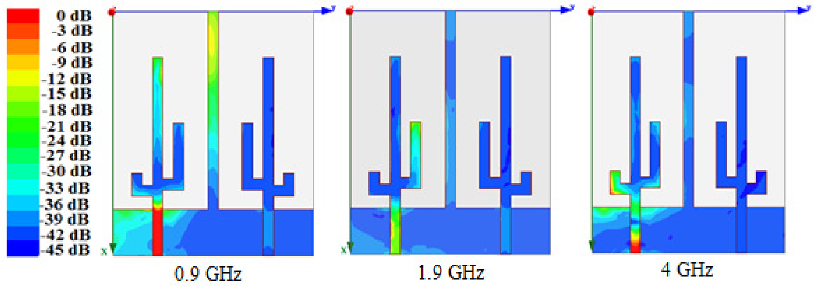
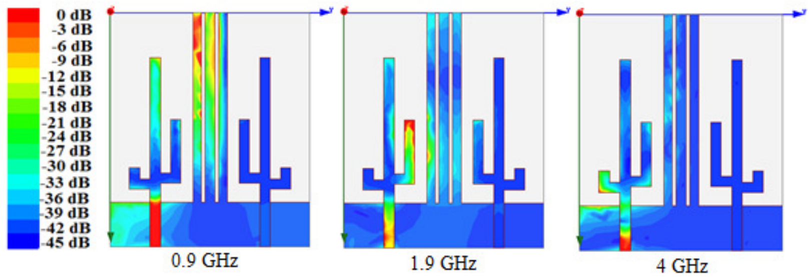


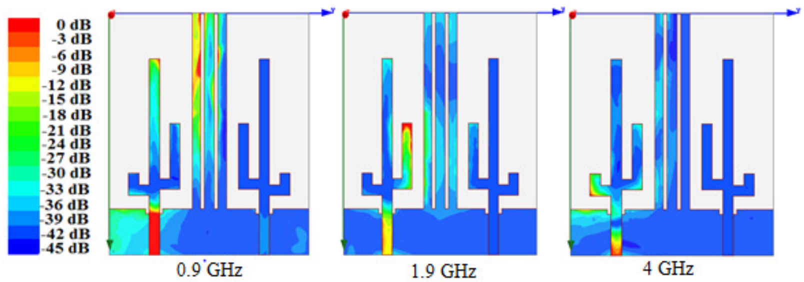
Fig. 4. S11 and S12 of different stages in the evolution of tri-band MIMO antenna.



(a) Antenna_3



(b) Antenna_4



(c) Antenna_5

Fig. 5. Surface current distribution for resonating frequencies (a) Antenna_3 (b) Antenna_4 and (c) Antenna_5

Table 3: Comparison of the proposed MIMO antenna with reported multi-band antenna design.

Ref.	**Approach**	**Antenna Size (mm^2)**	**BW (GHz)**	**Electrical Size ($\lambda_o \times \lambda_o$)**	**I_{min} (dB)**
[7]	NL + Ground slits	80×84	0.89-0.96/1.71-1.88/2.32-2.37/2.57-2.63	0.23×0.25	30
[8]	Decoupling circuits	65 × 100	0.88-0.92/1.78-1.81/2.45-2.62	0.19×0.29	16
[9]	PD	80 × 80	0.69-0.81/2.12-2.84	0.18×0.18	30
[11]	PD	42×62	2.38–2.52/3.19–6.44	0.33×0.49	15
[12]	DGS	45 × 25	2.37-2.64/3.39-3.58/4.86-6.98	0.36×0.2	15
[13]	SRR	40 × 40	1.95-2.5/3.15-3.85/4.95-6.6	0.26×0.26	22
[14]	NR	75×150	1.49-1.713.3-3.6/4.8-5	0.37×0.74	>10
[15]	Ω-shaped line	30×50	2.3–2.6/3.2–4.1/5.6–6.1	0.23×0.38	31
[16]	Ground stub	38×37	2.1-2.7/3.3-3.7/4.9-5.35	0.26×0.25	20
P.W.	Split Ground Stub	58×68	0.8-1/1.8-2.1/3.3-4.69	0.15× 0.18	22

BW: Bandwidth, I_{min}: Minimum Isolation, NL: Neutralization Line, PD: Polarization Diversity, NR: Not Reported, DGS: Defected Ground Structure, SRR: Split Ring Resonator, P.W: Proposed Work.

IV. CONCLUSION

A two element triband MIMO antenna with high isolation is presented. The multibranched monopoles symmetrically placed 0.077λ_o apart, over the design simplicity. The three ground stubs integrated to the ground plane between the two elements not only decreases the size of antenna but also improves the isolation. S11 <-10 dB and S12 < -22 dB is obtained over the three bands that over GSM900, GSM1800 and WiMax services. Descent agreement is achieved between the simulation and the measured results of developed prototype. Furthermore, the ECC, MEG and Diversity Gain are within the allowable limits that certify the MIMO suitability of the proposed antenna.

REFERENCES

[1]. M. S. Sharawi (2014). "Printed multi-band MIMO antenna systems: Techniques and Isolation mechanisms", *Proc. 8th Eur. Conf. Antennas Propag. (EuCAP)*, pp.779-783.
[2]. L. Malviya, R. K. Panigrahi, and M. V. Kartikeyan (2017). "MIMO antennas with diversity and mutual coupling reduction techniques: a review*," International Journal of Microwave and Wireless Technologies*, pp.1–18.
[3]. P. S. Rao, K. J. Babu and A. M. Prasad (2017). "*Compact multi-band MIMO antenna with improved isolation," Progress In Electromagnetics Research M*, vol. *62*, pp. 199-210.
[4]. A. Diallo, C. Luxey, P. L. Thuc, R. Staraj and G. Kossiavas (2006). "Study and reduction of mutual coupling between two mobile phone PIFAs operating in the DCS1800 and UMTS bands," *IEEE Trans. Antennas &Propag.*, vol. 54.
[5]. M. S. Sharawi, A. B. Numan and D.N. Aloi (2013). "Isolation *Improvement* in a Dual-Element MIMO Antenna System using Capacitively Loaded Loops," *Progress In Electromagnetics Research*, vol. *134*, pp. 247–266.
[6]. A. C. K. Mak, C. R. Rowell, and R. D. Murch (2008). "Isolation enhancement between two closely packed antennas," *IEEE Trans. Antennas Propag.*, *56*(11), pp. 3411–3419.
[7]. Y. Yang, Q. Chu and C. Mao (2016). "Multiband MIMO antenna for GSM, DCS and LTE Indoor Applications," *IEEE Antennas Wireless Propag. Lett.*, vol. *15,* pp. 1573-1576.
[8]. J. S. Sun, H. S. Fang, P. Y. Lin and C. S. Chuang (2015). "Triple band MIMO antenna for mobile wireless applications," *IEEE Antennas Wireless Propag. Lett.*, vol. *15,* pp. 500-503.
[9]. M. Han and J. Choi (2011). "Multiband MIMO antenna using orthogonally polarized dipole elements for mobile communications," *Microwave and Optical Technology Lett.*, *53*(9), pp. 2043-2048.
[10]. S. C. Fernandez and S. K. Sharma (2013). "Multiband printed meandered loop antennas with MIMO implementations for wireless routers," *IEEE Antennas Wireless Propag. Lett.*, *12,* pp. 96-99.
[11]. I. Desde, G. Bozdag and Alp Kustepeli (2016) "Multi-band CPW fed MIMO antenna for Bluetooth, WLAN and WIMAX applications," *Microwave and Optical Technology Lett.*, *58*(9), pp. 2182-2186.
[12]. S. Nandi, A. Mohan (2017). "CRLH Unit Cell loaded Tri-band compact MIMO antenna for WLAN/WiMAX applications," *IEEE Antennas Wireless Propag. Lett.*, *16,* pp. 1816-1819.
[13]. A. Ramachandran, S. Mathew, V. Rajan and V. Kesavanath (2016). "A compact triband quad element MIMO antenna using SRR Ring for high isolation," *IEEE Antennas Wireless Propag. Lett.*, vol. *16*, pp. 1409-1412.
[14]. C. Huang, Y. C. Jiao, Z. B. Weng (2018). "Novel compact CRLH-TL-based tri-band MIMO antenna elementfor the 5G mobile handsets," *Microwave and Optical Technology Lett.*, *60*(10), pp. 2559-2564.
[15]. C. M. Luo, J. S. Hong, M. Min (2017). " A decoupling method between two tri-band antennas for WLAN/WiMAX applications," *IEICE Electronics Express, 14*(11), pp. 1-6.
[16]. A. Chaudhari and R. K. Gupta (2018). "A simple triband MIMO antenna using a single ground stub" *ProgressIn Electromagnetics Research C, 86,* pp. 191-201.

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