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Compact MIMO Antenna for UWB Application

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ABSTRACT: In this paper, a compact multiple-input-multiple-output (MIMO) antenna for ultra-wideband (UWB)and GSM applications is proposed. The antenna features two identical monopoles placed 0.08$\lambda_0$distance apart and inhabits70 mm × 60 mm board range. Each monopoleelement comprises of a rectangular arm and two semicircular rings which independently control0.85GHz -1.1GHz and 2.5GHz - 14.5GHz bands respectively. Isolation of more than22 dB is achieved by integrating three stubs in the ground plane. The structure exhibits stable gain and radiation patterns. Various performance metrics including envelope correlation coefficient (ECC), diversity gain (DG), total active reflection coefficient (TARC) and mean effective gain (MEG) are evaluated which observe the MIMO standards. The proposed structure has a nearly constant group delay over the operating bands.

Keywords: Ultra-Wideband (UWB), compact antenna, GSM band, high isolation, MIMO antenna.

I. INTRODUCTION

Ultra-wideband (UWB) systems offer large bandwidth that facilitates a wide range of wireless applications. In February 2002, the Federal Communication Commission (FCC) allocated a frequency band for UWB systems between 3.1 GHz to 10.6 GHz with maximum mean Equivalent Isotropic Radiated Power (EIRP) of -41.3 dBm/MHz. The prospective of UWB technology is enormous due to its remarkable advantages such as the capability of providing high speed data rates at short transmission distances with low power dissipation. This has drawn the attention of researchers towards the UWB antenna design [1-5]. The real challenge in designing the UWB antenna lies in attaining the impedance matching and radiation stability over the wide operating bandwidth. Furthermore, in the light of recent developments in the telecommunication field, Multiple-input-multiple-output (MIMO)technology has captivated the market. MIMO technology comes with several advantages like increased channel capacity, high data rate, better link reliability, exploitation of multipath fading etc.[6-10] present antenna structures offering integration of UWB and MIMO technology. In [6], a compact planar monopole MIMO antenna covering the UWB range is presented. The structure offers isolation of about 25 dB over the operating frequency band by employing bent microstrip lines and thus disturbing the current distribution. MIMO antenna with un-identical elements, a rectangular monopole and a tapered slot element, is proposed in [7] which offer (3.1 GHz-10.6 GHz) 7.5 GHz bandwidth and an isolation of about 18 dB. Two element semi ring MIMO antenna operating over 1.85 GHz – 10.6 GHz is presented in [8]. Fork shaped structure employed in between the elements on the ground plane provide about 10 dB isolation over the operating band. Modified elliptical shaped elements are used as radiators in UWB MIMO antenna in [9]. Variable length tilted SRR like structure has been used to obtain an isolation of 22 dB over 3.1 to 10.6 GHz. [10] realizes a compact wideband MIMO antenna comprising of modified P shaped elements. The impedance bandwidth achieved is over 2.5 GHz to 12 GHz while triangular slots and meshed metal strip are claimed to be responsible for 20 dB isolation. Furthermore, need of the hour is to design a compact antenna functioning on several available wireless standards simultaneously. This administers the design of a compact integrated UWB antenna that facilitates operation on multi wireless radiation bands including the UWB range. [11-13] have been reported to focus the integration of the UWB band and Bluetooth band while [14] presents UWB antenna assimilated with GSM/WCDMA/WLAN bands. Although, these antennas offer UWB integrated with other service bands, but the structures lack the MIMO technology.

Amalgamation of MIMO technology and UWB antenna unified with available service bands would prove a major contribution to the antenna community. On the contrary, the challenges in the design of such antennas are more. One of them being the size constraint imposed on the antenna because of the compact size of the application device in which the antenna needs to be mounted. This leads to reduced inter-element spacing in MIMO structures that is accountable for pronounced mutual coupling in between the antenna elements, thus degrading the diversity performance. Though there are numerous techniques reported in the literature to mitigate mutual coupling, reduction of the same over a wide bandwidth maintaining S11< -10 dB is a challenging task. Also, achieving in-band isolation in a MIMO antenna, responsive to UWB range integrated with low frequency service bands (GSM) is particularly difficult because when the integrated band lies below 1 GHz frequency, the performance of antenna degrades significantly. Due to larger wavelength for frequencies below 1 GHz, the fields and radiation pattern couple strongly with adjacent elements [15], depriving antenna from desired performance. So, careful employment of mutual coupling reduction technique in such structures is a requisite.

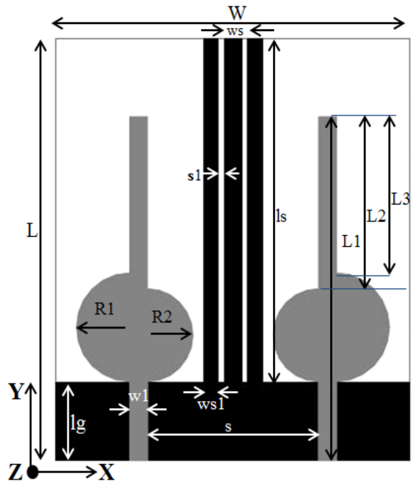


Fig. 1. The proposed MIMO antenna geometry.

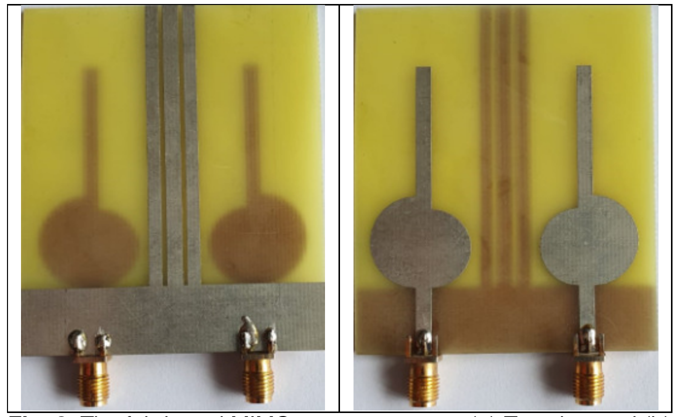


Fig. 2. The fabricated MIMO antenna system: (a) Top view and (b) Bottom view.

Table 1: Optimized dimensions of the proposed antenna.

Parameter	L	W	L1	L2	L3	R1	R2	s1	ls	ws1	w1	lg	s
Value (mm)	70	60	57	28.5	25.9	9	7.7	1	57	2.5	3	13	29

In this paper, a high isolation compact inverted comma shaped UWB MIMO antenna integrated with GSM 900 band is proposed. Each monopole element comprises of a rectangular arm and semicircular rings which independently control 0.85GHz -1.1GHz and 2.5GHz - 14.5GHz bands respectively. The isolation technique comprises of three stubs originating from the ground plane, realizing an isolation of 22 dB and 28 dB over the 10 dB impedance bandwidths of 1.250GHz (850MHz - 1.1GHz) and 11.5 GHz (2.5GHz - 14GHz)correspondingly. The proposed MIMO antenna is small in size and simple to design and offers isolation > 22 dB for GSM and UWB applications.

III. DESIGN THEORY AND ANTENNA GEOMETRY

A. Antenna Geometry

A dual band monopole MIMO antenna is designed for GSM 900 and UWB applications, on a low-cost FR-4 substrate of 1.6 mm thickness with dielectric constant (ε_r) of 4.4 and loss tangent (tan δ) of 0.02.The physical area occupied by the proposed antenna is 70 mm × 60 mm which corresponds to $0.19\lambda_0 \times 0.17\lambda_0$electrical area, where $\lambda_0$is the free space wavelength corresponding to lowest operating frequency. In order to obtain the MIMO gain, the antenna elements must be atleast separated by a distance of $0.5\lambda_0$. The edge to edge spacing between the monopole elements is 29 mm which corresponds to $0.08\lambda_0$ electrical spacing. Each monopole antenna printed on one side of the substrate consist of a longer arm controlling the GSM 900 band and two semicircles of unequal radii on the either sides of the arm offering the ultra-wideband. The semicircle with larger radius offers the lower band while the semicircular patch with smaller radius provide the higher band within the UWB. The mechanism for isolation is printed on the other side of the substrate which consist of three stubs originating from the ground plane, maintaining symmetry of the strucutre as well. The geometry of the proposed MIMO antenna is shown in Fig. 1 while the detailed antenna dimensions are listed in Table. 1. The prototype of the proposed system is realized using the photolithography technology to substantiate the simulated results. The top and the bottom view of the fabricated MIMO antenna are shown in Fig. 2. The antenna is evolved in four stages as displayed in Fig. 3. The lowest frequency f_L(corresponding to VSWR=2) of ANT_4 is determined using (1) [16].Here, f_L is in GHz while R_1 and L are in mm.

$$f_L(GHz) = \frac{75}{\pi R_1 + L} \qquad (1)$$

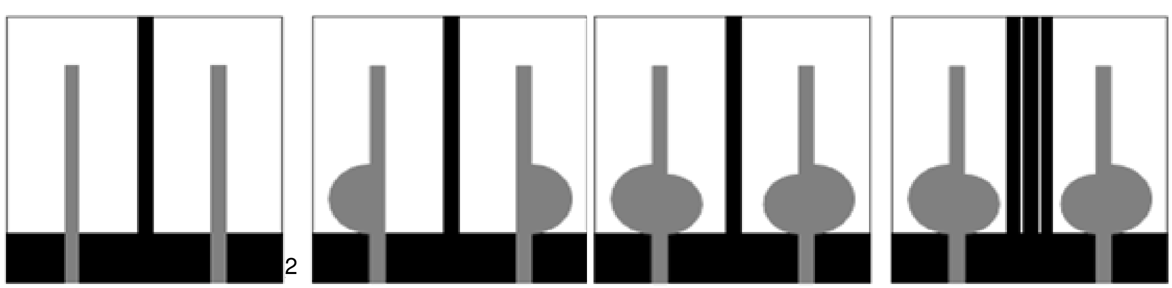


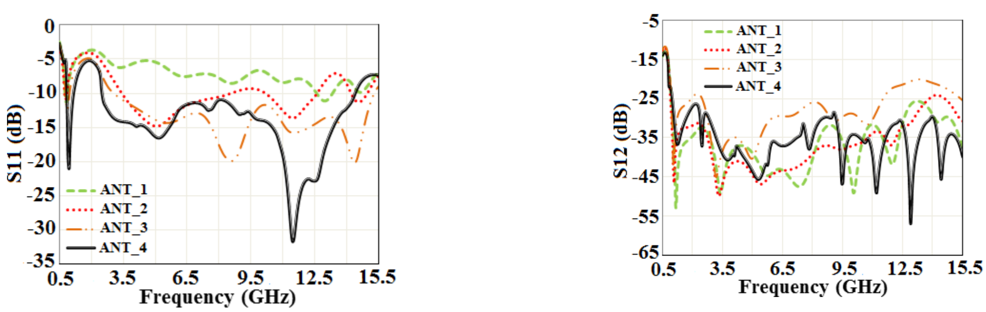
Fig. 3. Evolution stages of proposed tri-band MIMO antenna.

The behavior of S-parameters in every stage of the antenna evolution areshown in Fig. 4. The antenna in its preliminary stage (ANT_1) comprises of two rectangular monopoles that offer 760 MHz – 870 MHz. Stub is extended from the ground plane that isolates the radiators by an amount of 14.5 dB. ANT_2 offer two operating bands, viz., 750 MHz – 850 MHz and 3.4 GHz – 8.5 GHz. The resonance in the higher band is obtained due to the semicircular patch (SC1) of radius 9 mm, which is connected to the rectangular arm in ANT_1. The isolation mechanism in ANT_2 is same as that of ANT_1 not affecting the lower band isolation but provides high isolation of about 37 dB in the higher band. ANT_3 evolves when another semicircular patch (SC2) of radius 7.7 mm is connected to the other side of the rectangular monopole. It is observed that the ANT_3, along with the opearating band (790 MHz – 970 MHz), it also offers a wideband response from 3.05 GHz – 15.2 GHz. This is due to the fact the SC1 and SC2 resonate very close to each other and hence electromagnetically couple to provide a wideband response. The isolation offered by ANT_3 is 14.5 dB and 20 dB in the lower and the higher band respectively which needs further improvement for high diversity performance. ANT_4 focuses on isolation improvement where two additional ground stubs are connected to the either sides of the already existing stub at a spacing of about 1mm. Addition of two more stubs affects the impedance of antenna. S11 improves over lower and upper UWB frequencies. The other two ground stubs provide aditional decoupling path and also the stubs and the spacing between them act as band stop filter. As a result, these stubs decrease the surface current due to surface waves to couple to the other element as indicated by the vector surface current distribution as shown in Fig. 5(b). These stubs also act as reflectors to near fields, improving isolation over the desired operating bands. This antenna offers isolation of about 22dB and 28 dB over the GSM and UWB respectively. Since the isolation is 14.5 dB and 20 dB in the lower and the higher band in ANT_3 and > 20 dB in ANT_4, when multiple stubsare used; scalar current distibution for ANT_3 and vector current distribution for ANT_4 is shown in Fig. 5.

B. Parametric Study

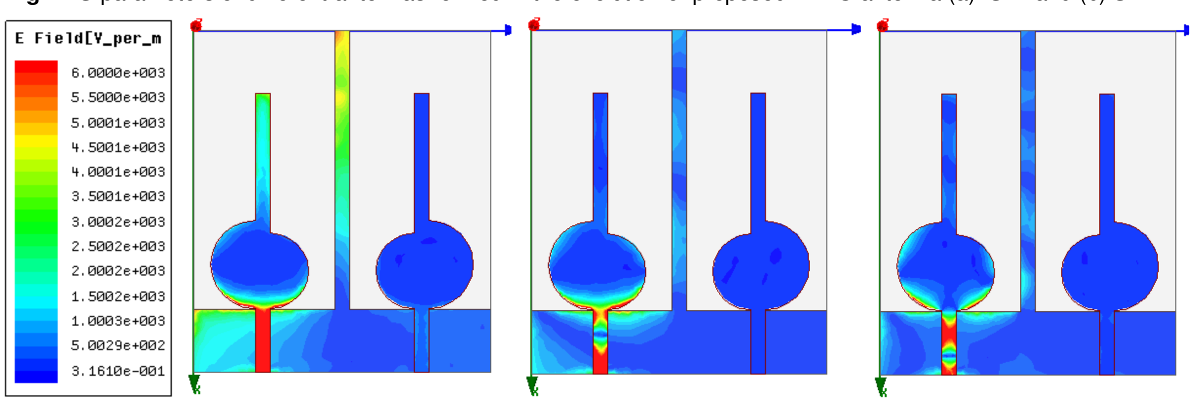
To support the design theory, parametric studies based on the radii of the semicircles is carried out. Stub parameters viz., spacing (s1) between the center stub and the end stubs and width (ws1) of the smaller stubs are varied too.

(a) Radii variation of semicircles (R1 and R2). The two semicircular discs monopole should couple electromagnetically to provide UWB. When the larger disc radius is much larger than the smaller disc radius 7.7 mm, there is not much coupling between the two disc monopoles, as a result, S11 < -10 dB is not obtained over the entire UWB, but two distinct bands in UWB are observed as shown in Fig.6(a). As the radius of larger disc is decreased, S11 improves due to improvement in electromagnetic coupling between the two disc and optimum coupling is obtained when the radius of larger disc is 9 mm. When the radius of larger disc is further decreased, S11 degrades again due to weaker electromagnetic coupling. There is negligible effect on S12 as it is mainly governed by three ground stubs as shown in Fig. 6(b). Similar resultsare obtained when the radius of smaller disc is varied while keeping the radius of larger disc as 9mm as shown in Fig. 6(c) and (d). Fig. 6(a) and (c) show that the larger circle controls the lower band of the UWB while the higher band of the UWB is controlledby the smaller semicircle.



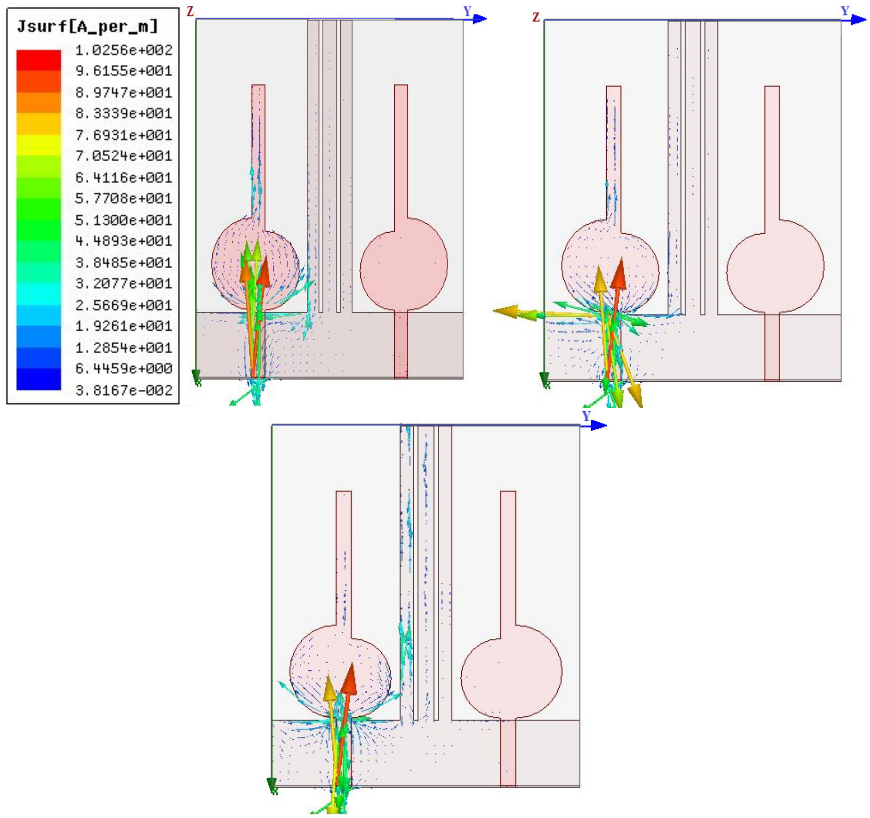
(a) (b)

Fig. 4. S-parameters of different antennas formed in the evolution of proposed MIMO antenna (a) S11 and (b) S12.



1 GHz 3.5 GHz 8.5 GHz

(a) ANT_3



1 GHz 3.5 GHz 8.5 GHz

(b) ANT_4

Fig. 5. (a) Surface current distribution for different ground stub length and (b) Vector Surface current distribution for different frequencies.

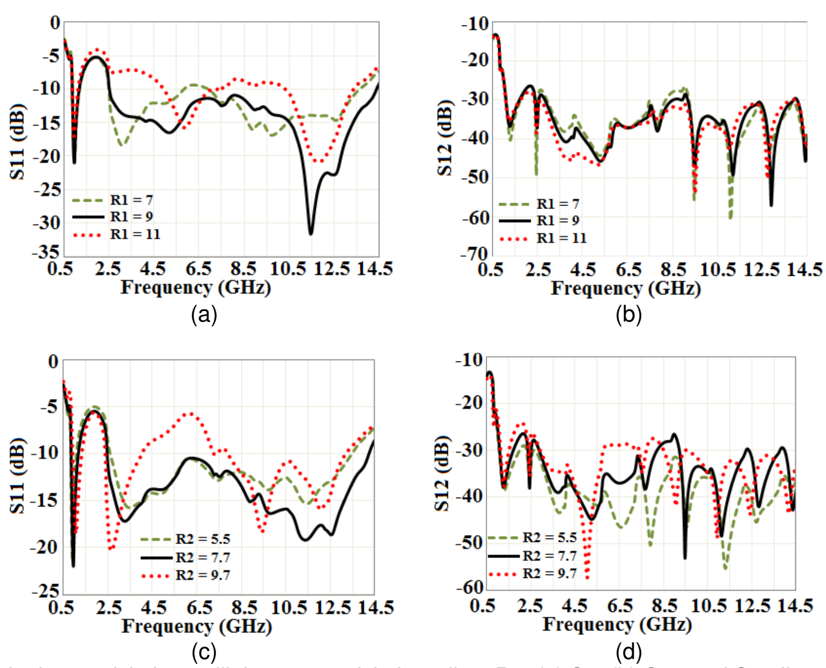


Fig. 6. Variation in the semicircles radii, Larger semicircle radius, R1: (a) S11(b) S12 and Smaller semicircle radius, R2: (c) S11(d) S12

III. CONCLUSION

A compact dual element monopole MIMO antenna offering GSM service band (0.85GHz - 1.1GHz) and UWB (2.5GHz -14.5GHz) arbitrated by |S11| < -10 dB is implemented on a low cost PCB substrate. High isolation of about 22 dB over the operating bands is obtained using unequal length stubs. The proposed low profile antenna with an electrical size of 0.19λo ×0.17λo offers impedance bandwidth of 22.8% and 141% over the dual operating bands.

REFERENCES

[1]. C. C. Chong, F. Watanabe and H. Inamura (2006). “Potential of UWB Technology for the next generation wireless communications,” *IEEE Ninth International Symposium on spread spectrum techniques and applications*, pp. 422-429.

[2]. P. Gao, P. Wang, Z. Xu, X. Wei, L. Jin and Z. Tian, “Development of compact Ultra Wideband antennas,” *Forum for Electromagnetic Research Methods and Application Technologies*.

[3]. A. T. Mobashsher and M. T. Islam, (2013). “Design, Investigation and Measurement of a compact Ultra Wideband antenna for portable applications,” *Measurement Science Review, 13*(4), pp. 169-176.

[4]. H. Qin and Y. F. Liu (2014). “Compact UWB MIMO antenna with ACS-fed structure,” *Progress In Electromagnetics Research C, 50*, pp. 29-37.

[5]. B. S. Femina and S. K. Mishra (2016). “Compact WLAN band-notched printed Ultrawideband MIMO antenna with polarization diversity,” *Progress In Electromagnetics Research C,* vol. *61,* pp. 149-159.

[6]. H. Babashah, H. R. Hassani and S. M. A. Nezhad (2019). “ A compact UWB printed monopole MIMO antenna with mutual coupling reduction,” *Progress in Electromagnetics Research C*, vol. *91,* pp. 55-67.

[7]. Y. Wu, K. Ding, B. Zhang, J. Li, D. Wu and K. Wang (2018). “Design of a compact UWB MIMO antenna without decoupling structure,” *International Journal of Antennas and Propagation*, pp. 1-8.

[8]. S. K. Dhar, M. S. Sharawi (2015). “A UWB semi ring MIMO antenna with isolation enhancement,” *Microwave and Optical Technology Lett., 57*(8), pp. 1941-1946.

[9]. S. Kharche, G. S. Reddy, R. K. Gupta and J. Mukherjee (2017). “ Mutual coupling reduction by using tilted variable length SRR like structurein UWB MIMO antennas,” *IEEE AP-S*.

[10]. P. C. Nirmal, A. Nandgaonkar, S. Nalbalwar, R. K. Gupta (2018). “ Compact wideband MIMO antenna for 4G, Wi-MAX, WLAN and UWB applications,” *International Journal of Electronics and Communications*

[11]. A. Kohirkar, V. Jadhav, and R. K. Gupta (2016). “Dual-band compact monopole antenna for Bluetooth, LTE, WLAN and Ultra-wideband Applications,” *Proceedings of the Asia-Pacific Microwave Conference*.

[12]. S. K. Mishra, R. K. Gupta, A. Vaidya, and J. Mukherjee (2011). “A compact dual-band fork shaped monopole antenna for Bluetooth and UWB applications,” *IEEE Antennas Wireless Propag. Lett. 10,* pp. 627-630.

[13]. G. Li, H. Zhai, T. Li, X. Ma, and C. Liang (2013). “Design of a compact UWB antenna integrated with GSM/WCDMA/WLAN bands,” *Progress In Electromagnetics Research*, vol. *136*, pp. 409–419.

[14]. L. Xiong, and P. Gao (2012). “Dual-band planar monopole antenna for Bluetooth and UWB applications with WiMax and WLAN band-notched,” *Progress In Electromagnetics Research Letters*, vol. *28*, pp. 183-194.

[15]. M. S. Sharawi (2014). “Printed multi-band MIMO antenna systems: Techniques and Isolation mechanisms”, *Proc. 8th Eur. Conf. Antennas Propag. (EuCAP)*, pp.779-783.

[16]. K. P. Ray (2008). “Design aspects of printed monopole antennas for ultra-wide band applications,” International Journal of Antennas and Propagation., vol. 2008, pp. 1-8.

[17]. S. Ghosh, T. N. Tran and T. L. Ngoc (2013). “Minaturized four-element diversity PIFA,” *IEEE Antennas Wireless Propag. Lett.*, vol. *12*, pp. 396-400

[18]. S. Kharche, G. S. Reddy, B. Mukherjee, R. K. Gupta and J. Mukherjee (2014). “MIMO antenna for Bluetooth, Wi-Fi, Wi-Max and UWB applications,” *Progress In Electromagnetics Research C,* vol. *52*, pp. 53-62.

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