



Design Methods of MIMO Antenna for 5G New Radio Applications in Mobile Terminals-A Review

Hatte J.S.¹ and Rupali B. Patil²

¹Research Scholar, Department of Electronics and Telecommunication Engineering, G.H. Rasoni College of Engineering and Management, Wagholi, Pune (Maharashtra), India.

²Assistant Professor, Department of Electronics and Telecommunication Engineering, G.H. Rasoni College of Engineering and Management, Wagholi, Pune (Maharashtra), India.

(Corresponding author: Hatte J. S.)

(Received 10 March 2020, Revised 06 May 2020, Accepted 08 May 2020)

(Published by Research Trend, Website: www.researchtrend.net)

ABSTRACT: The fifth generation (5G) communication technology is the subject undergoing intense study for the world's leading telecommunication companies. Antenna miniaturization designs made it possible to resonate them at higher frequencies, thus enabling the multiple (with large number of antennas) antenna system to obtain data rate larger than that is in 4G technology. 5G Wireless system that promises higher data rate 1000 × current 4G technology, round trip latency of about 1ms, an order of magnitude faster than 4G, 3 × more spectral efficient than LTE.

Objective of the study is to highlight on the recent advancements in design of MIMO antenna for 5G applications. With this goal the paper has tried to carry out diligent review under the influence of MIMO 5G application antennas in various aspects such as size, gain, efficiency, isolation, order of MIMO and substrate etc. Also MIMO design with folded monopole, Inverted F, loop antenna, edge fed bended monopole, self decoupled, self isolated, etc. are studied. Improvement in the antenna isolation techniques are studied using different methods such as neutralization line, multimode decoupling techniques, orthogonal mode pair, self isolated antenna element method.

Keywords: MIMO (multiple input multiple output), 5G(5th generation), 4G(4th generation), ECC (Envelope Correlation Coefficient), Channel Capacity, Isolation.

I. INTRODUCTION

Apart from overcoming the few drawbacks of 4G LTE, 5G system offers the capacity to develop in the future for industry as well as users. There are two possible ways in which the 5G technologies can emerge, one way is using the pre-existing technologies and then allowing the higher data rates, higher density of network, small cells, and large coverage and reduced latency time. Other way is to go for the totally new technology for radio access, with particular aim for higher data rates, lower latency, and use of millimeter waves to increase bandwidth [1]. Thus 5G will be a fundamental change in approach that gives higher carrier frequency with exponentially large bandwidth, increased densities of devices, more number of antennas, large number of base stations, also it will be compatible with LTE and Wi-Fi so that high rate of coverage is obtained and users' experience is smooth. The network should be flexible in all terms and spectrum has to be cleverly supervised and made better, also the system has to be cost effective. To achieve higher data rates (1) Utmost off loading and densification, (2) Bandwidth improvement and (3) Increase in spectral efficiency is required. This increase in spectral efficiency can be obtained through MIMO technology [2].

The new air interface is developed which enables all the services of 5G. This interface obviously provides noteworthy advantages when it is compared with the present 4G system. This air interface of 5G is designed to serve: (1) Improved broadband mobile

communication, (2) Lower latency communication and (3) Large machine to machine type communication [3].

Workable technologies in 5G are local IMT (International Mobile telecommunications) small cells, MIMO design, design for saving energy and design for flexible usage of the spectrum. To improve the performance of system in terms of coverage, data rates and capacity, MIMO is one of the most essential technology [4]

It has been practically proved that a high data rate can be obtained by using antenna system which contains comparatively more number of antennas that is multiple input multiple output system. MIMO means spatial multiplexing in which the multiple data streams are transmitted using same frequency resource and time resource. Beam forming is used for data stream transmission. In MIMO the concept of receiving data (with reduced power) on many streams rather than a full power data stream is employed. Also in the MIMO system, mutual interference between the streams is reduced. The main advantage of the MIMO system is the increase in the channel capacity [5].

II. ANTENNA STRUCTURE FOR WIDE BANDWIDTH

A multiple input multiple output system of antenna is proposed with some distinctive arrangements of the coupling section. The proposed system consists an array of elements and is designed to cover the N77/N78/N79 band. The distinctive arrangements of loop antenna in which coupling sections are placed at top, two sides and central providing the three different modes as 0.5λ , 1.0λ and 0.75λ (which is new and not obtained by traditional loop antenna) is described [6].

These three different modes provide the wide band which can cover 3.3-5.0 GHz band. The proposed antenna system is designed from the conventional loop antenna by just fragmenting into three coupling sections. These coupling sections also exclude the need of tuning stubs. The proposed antenna system gives the isolation of 14.7 dB to 15.3 dB. Envelope Correlation Coefficient observed is below 0.1 and Channel capacity is in the range of 31.6 to 39.2 bps/Hz and better efficiency upto 60% is obtained. The system design is as given in figure 1 [6]. Among the 8 antennas 4 each are placed perpendicularly on the lateral sides of the mobile handset substrate.

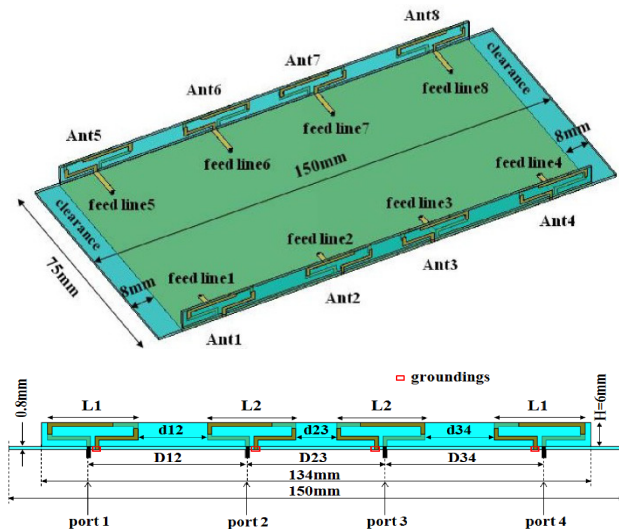


Fig. 1 (a) Three dimensional view and side view of 8-antenna system [6].

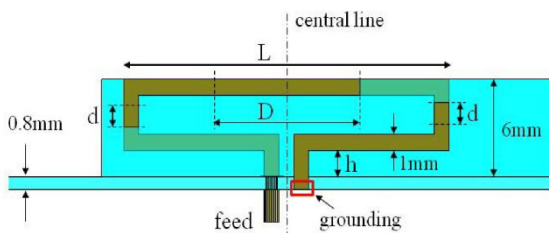


Fig. 1 (b) Enlarged side view [6].

Some area is reserved for back compatibility i.e for 4G and other antennas. The system substrate is made up of FR4 having dielectric constant of 4.4 and loss tangent of 0.02. Microstrip line of 50Ω is used to feed each antenna. D denotes the top overlap portion and d denotes the side overlaps, whereas L denotes the length of loop antenna. h denotes the substrate and element gap. These values of D, L, d, h are optimized to get the three modes. It has been demonstrated that modes frequency is decreased if the length L is increased. Improvement in efficiency is observed from 36% to 65% if length is increased from 21-22 mm in the working band of 3.5 GHz. Also by varying the parameter D mode resonant frequency can be varied and height h affects the impedance matching [6].

A dual-band structure of antenna array made up of eight slot antennas which are L-shaped is proposed for mobile terminals in 5G applications [7]. The principle of

operation depends upon stepped impedance resonators (SIRs). It has been shown that regulation of impedance ratio gives required resonance in both bands. Here the microstrip feed lines are used and by regulating the position of these feed lines better match of impedance is obtained. Return loss of higher than 10 dB, isolation between antenna elements of more than 11dB, total efficiency which is greater than 51% in LTE band 42 and 46, ECC which is less than 0.1 and 36.9 bps/Hz of channel capacity has been demonstrated. The geometrical dimensions and structure of the 8 × 8 proposed MIMO system for dual-band is given in Fig. 2 [7]. FR4 having dielectric constant of 4.4 and dielectric loss tangent of 0.025 is used. A50 Ω microstrip fed line with one end shorted to develop an inductance and other end connected to SMA connector is printed on the substrate at its top side. The produced inductance aids to obtain the good impedance matching. The multiband characteristic of antenna is obtained by varying electrical length ratio and impedance ratio of the Stepped Impedance Resonator. At 3.5 MHz choosing 1.0 as electrical length ratio and selecting 5.5 MHz as first harmonic, the calculation has shown the impedance ratio approximately of 1.6. Characteristic impedances of 40 Ω and 64 Ω for slot lines, are used to get the desired result [7].

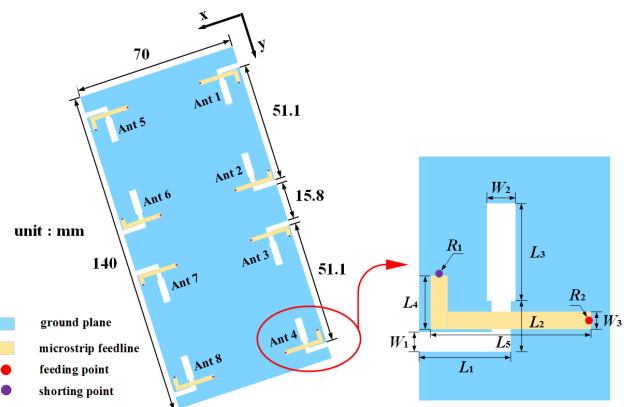


Fig. 2. Geometrical dimensions and structure of the 8 × 8 proposed system [7].

A very wise technique of obtaining the high isolation alongwith the dual-band, just by allocating one common grounding branch for the units of antenna that are adjoining has been proposed [8]. The proposed system of 4 antenna is not only self decoupled but also compact and hence finds application in 5G for mobile handsets. Each pair among the four antenna system are mounted perpendicular to the lateral sides of plane. The proposed MIMO system is designed in such a way that it can operate in 3.4-3.6 GHz and in 4.8-5.0 GHz bands and provides isolation of -17.5 dB and -20dB for the low band and the high band respectively along with envelop correlation coefficient of 0.14 and 0.12 in low and high band respectively. CC is within 31.6 to 39.2 bps/Hz. Fig. 3 [8] gives the dimensions and construction for the proposed antenna design applicable for mobile terminal. FR4 with $\epsilon_r = 4.3$ and $\tan \delta = 0.02$ has been used for the substrate. Antenna system consists of two elements which are similar.

One radiating branch is present in each element to develop the 3.5GHz band which is U shaped, inverted and large, one more radiating branch for 4.9GHz band which is also U shaped, inverted but small and an I-shaped structure as a feeding strip. One common grounding branch is shared by these two elements of the antenna. This grounding is also coupled to both the adjoining radiating structures. The vertical and horizontal trace are of fixed widths.

The trace, radiating branch and feeding branch have coupling gaps within them which are also fixed at some value. SMA connectors of 50Ω are used as fed for the antenna elements. The top part L_f of feeding element is coupled with the U shaped element (large) to induce 3.5GHz band. And the lower part L_t of feeding element is coupled with U shaped element (small) which will generate 4.9GHz band [8].

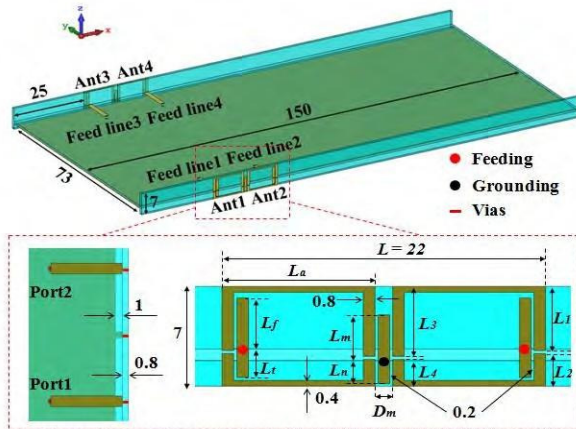


Fig. 3. Dimensions and construction of MIMO system with 4-antennas [8].

The proposed antenna system have a compact structure consisting of two 1×8 linear arrays for 24.75-27.5 GHz band and a 8-antenna array for sub-6GHz which is dual band and covers both 3.3-3.6 GHz and 4.8-5.0GHz. In Fig. 4 [9] the perspective and lateral view of suggested antennas is mentioned. Along the two long sides of the plane, all the antenna elements are symmetrically located. The FR4 substrate with dielectric constant of 4.3 and dielectric loss tangent of 0.02 is used for printing the eight antenna units which are placed perpendicular to the ground plane of the system. Clearance area has been reserved for other antennas and 4G LTE used nowadays in mobile terminals. Fig. 5(a) [9] shows the antenna unit used for sub-6GHz which is made up of a U-shaped and a Z-shaped monopole elements, printed on the different sides of the substrate separately. Fig. 5(b) shows the variant of dipole antenna and consists of two right triangles, this arm structure helps in increasing the bandwidth of the antenna system. There are 8 antenna elements in the mm-wave each separated by a distance of about 0.47λ at 26GHz. It has been demonstrated that the system of antenna elements for sub 6GHz band can cover two bands which are 3.3-3.6 GHz and 4.8-5.0GHz respectively and give the isolations greater than 12dB, 50% of total efficiencies in both bands and ECC values less than 0.05. The calculated channel capacities of 35bps/Hz, in both the 3.5 and 4.9GHz bands. Also total

efficiency nearly of 90% is obtained for 1×8 Linear Array for Millimeter-Wave System. Isolation of 30dB is observed [9].

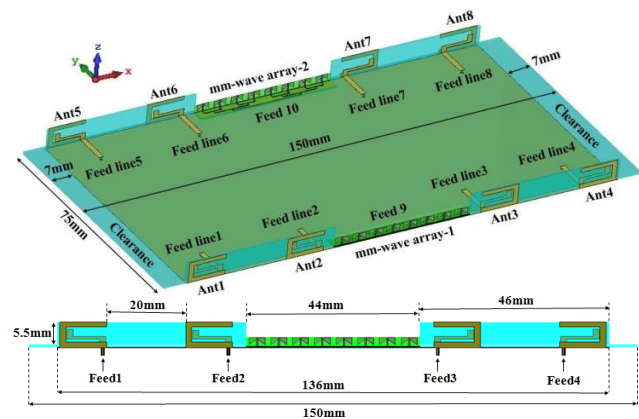


Fig. 4 (a) Proposed antenna system (b) side view [9].

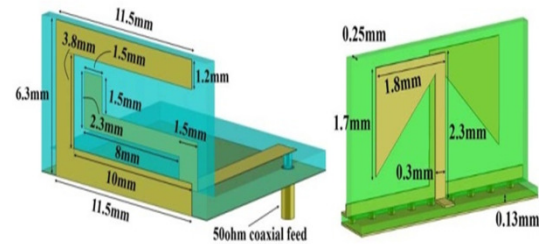


Fig. 5 (a) sub 6GHz antenna (b) mm-wave antenna [9].

Two separate antenna system of 4 elements each is proposed which finds application in smart phones. One group of multi antenna system is designed to operate below 6 GHz bands and the other group is to operate at 28GHz for 5G applications. In the presented work the modified version of mono-pole antenna is used. In this work, L shape MIMO antenna system consisting of 4 elements for 4G and 4 slot antenna based MIMO system for 5G on the same substrate, as shown in Fig. 6 [10], is implemented. The design has some unique features such as compact size, integration of all elements on single substrate and dual band.

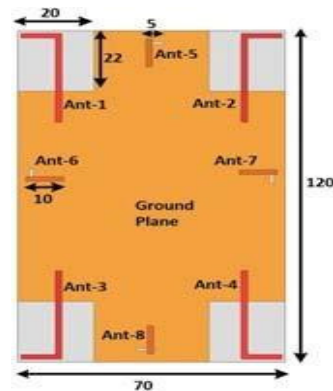


Fig. 6. Proposed antenna geometry [10].

The FR4 substrate with dielectric constant of 4.5 and loss tangent of 0.02 is used to design the system. Vertical L shaped monopole antenna is used as a

resonating element. The entire length of the antenna is around 0.25λ at 2 GHz. The slot antenna whose size is 0.5λ at 28 GHz is designed for 5G, 28 GHz application. The 4 slot antennas use microstrip feed lines and are etched in the ground plane. Four slot based 5G antennas (Ant-5 to Ant-8) are integrated between 4 monopole based 4G antennas (Ant-1 to Ant-4) which makes this structure suitable for 4G and 5G applications. For Antenna 1 to Antenna 4 the total gain observed is 5dBi at 2.1GHz and that for Antenna 5 to Antenna 8 is 10dBi at 28 GHz. For all the antennas the total efficiency was found to be more than 92% [10].

MIMO antenna system of 10 elements is proposed for 5G applications in 3.3-3.6 GHz band. Among the suggested MIMO system four are slots and six are monopoles with coupled feed. Monopole elements and slot elements with different radiating modes are arranged along the mobile sides alternately. The simulation results of the fabricated antenna gives the isolations much higher than 11 dB, the efficiencies in the range of 50-76%, ECC lower than 0.15 and calculated CC about 48-51bps/Hz [11].

The presented antenna geometry is shown in Fig. 7 [11]. The substrate used is FR4 having dielectric constant of 4.4 and dielectric loss tangent of 0.024 to print the antenna. Among the two types of elements the monopoles of length which is 0.4λ at 3.45 GHz are fed by the feeding line of 50Ω . It has been demonstrated that the resonance in the required band of 3.3-3.6 GHz can be obtained by length and width adjustment of the monopole element along with impedance matching. Similarly length and width adjustment of slot gives better match of impedance along with resonance at 3.45GHz band. Isolation of more than 11dB, channel capacity of 48-51bps/Hz and efficiency about 50-76% have been reported for the design [11].

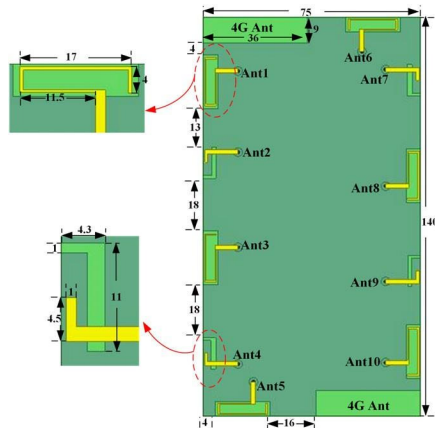


Fig. 7. Geometry of the 10 element antenna system [11].

A MIMO antenna system is proposed for the mobile communication and WLAN communication. Here compact decoupled paired inverted-F/loop antennas are used which covers 3.5/5.8 GHz (3400–3600/5725–5875 MHz). The channel capacities for the given system are about 37bps/Hz in 3.5GHz band and 42 bps/Hz in the 5.8 GHz band, which is quite higher than 2x2 MIMO

system of present fourth-generation (4G) (about 10bps/Hz or less).

The key design technique of this proposed system is that the occupied length of the system is reduced because decoupling frame is not required and spacing between antenna elements is also not required [12].

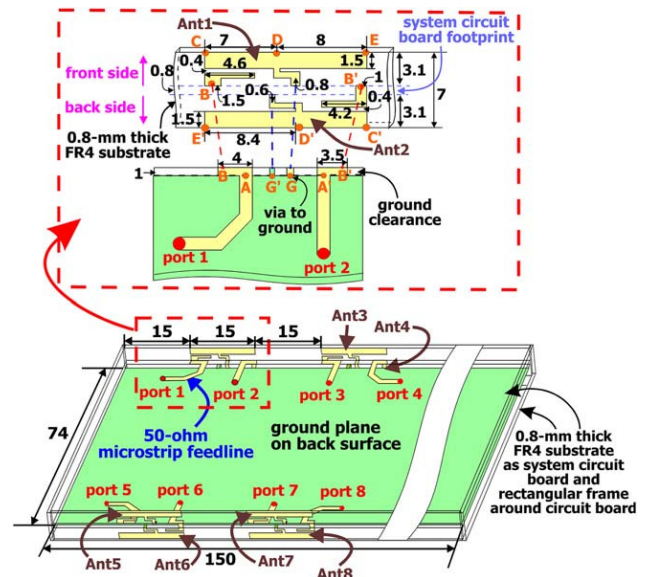


Fig. 8. Structure of 8 antennas formed by inverted F and loop antennas [12].

As given in Fig. 8 achieve good matching of impedance similar structures with some dimensional variations are used for elements of one block. In 3.5GHz band the proposed antenna operates as coupled loop with a coupling gap of 0.4mm, this excites capacitively the loop antenna to produce its $\lambda/4$ resonant mode. In the band of 5.8-GHz the proposed antenna operates as an inverted-F, in which the coupling gap is not present. Thus the coupling gap functions like coupling feed in a band of 3.5GHz and in 5.8GHz it acts like a direct feed because of its capacitive reactance which is smaller in 5.8GHz band and larger in 3.5GHz [12].

III. VARIOUS ISOLATION TECHNIQUES ALONG WITH THE MIMO STRUCTURE

The proposed antenna system is made up of C shaped which is coupled fed along with monopole slot of L shape. This antenna system of 8 elements demonstrated here is for 2.6GHz band. These elements are orthogonally polarized which reduces the coupling between them. The length of the monopole slot is about $1/4\lambda$ at 2.4GHz and its one open end is bent back to increase the isolation between the neighboring units. The feed line which is L shaped is used to couple fed the monopole slot. And it has been demonstrated that regulating length of feed line gives better impedance matching and less than 10dB of return loss can be obtained. Also this system of antenna elements can cover the total band of 2.6 GHz. The C-shaped elements in array are placed perpendicular to the substrate in the middle section which will save space and will allow easy desegregation with handset frames.

The dimensions of the antenna structure is given in Fig. 9 [13].

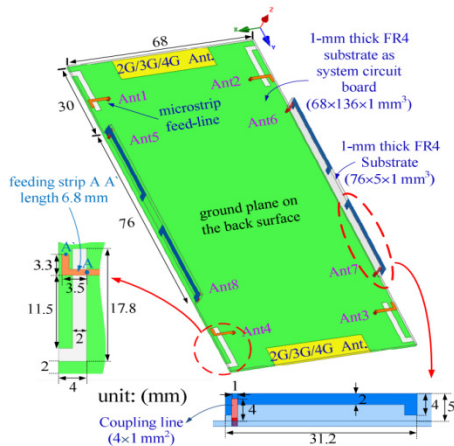


Fig. 9. Dimensions of the L-shaped and C-shaped structure [13].

The proposed design is for 5G future applications and compatible with present 4G application. Different antenna arrays are used for 4G which is meant to cover 2.3-2.5GHz and GSM. For 4G 2×2 MIMO system is used, here the decoupling technique is used by providing extended ground surface. 50 Ω mini coaxial line is used as feeding strip, shorting strip which is bended is implemented and an inductor of 6.8nH is embedded in the structure. Thus this will give effects of decoupling in the upper band and in the lower bands the impedance matching is improved. The lower band isolation is improved by a neutralisation line between the two structures of antennas provided for 4G. It is observed that resonance of higher order can be obtained by the shorting strip. Due to this neutralization line an improvement in isolation is observed which is nearly 3dB more than that of the design which is implemented without neutralisation line. Antennas from 3 to 10 are meant for 5G application i.e. 8×8 array has been implemented along the lateral sides of the system. Each element of this array is a bending monopole fed with 50 Ω microstrip. The resonant mode of the lower band is obtained by tuning the extended stub of monopole element at the open end. The monopole dimensions are selected in such a way that it covers the 3.5GHz band. It has been demonstrated that the isolation of more than 10dB is obtained and efficiency in the range of 56% to 70 % is obtained. The structure used and dimensions are as shown in Fig. 10 [14].

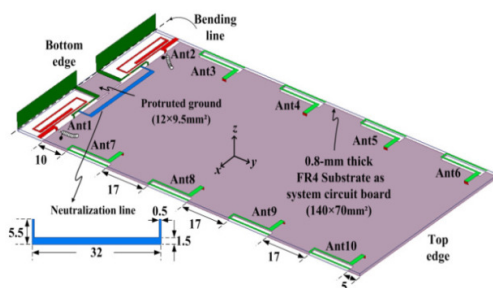


Fig. 10. Details of the proposed antenna structure [14].

A MIMO system consisting of 8 components is proposed which finds application in 5G band of 3300-4200MHz and 4800-5000MHz. Here the two antenna structure consisting of 4 elements each are fabricated along the lateral sides of the hand set. Each element consists of monopoles with two branches used for dual band operation and a T-shaped stub for decoupling structure on both sides between antenna 2 and 3, between antenna 6 and antenna 7. The decoupling structure not only improves the isolation but also gives very good impedance matching between the array elements which returns help in obtaining the widebands. The geometry and dimensions of the given system are shown if Fig. 11 [15]. The proposed system gives the performance with the efficiency of >53.8%, ECC which is <0.12 and channel capacities which is approximately 39.5 bps/Hz [15].

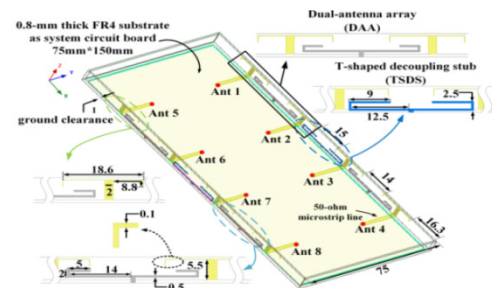


Fig. 11. Detailed dimensions and geometry of the antenna system [15].

Antenna structure with 4 elements is proposed for 4G applications, 5G applications and also for GPS without any decoupling system, this task is obtained by main antenna and sub antenna. 698-960 MHz band and GPS band is covered by two elements of antenna while the band of 1710-2690 MHz and 3400-3600 MHz is covered by four elements of antenna. The working band isolations are bigger than 10dB. Efficiency observed is in the range of 40% to 73.2%. ECC observed are less than 0.35 and 0.15 at lower band and at higher band respectively [16].

The proposed antenna structure is self decoupled and consists of two elements fabricated on the lateral edge of the system. Each element of the structure are mounted at nearly 0.014λ distance between them. They share one common branch for grounding. This system can operate in 3.4-3.6 GHz band and give the better isolation of -17dB. The geometry along with the dimensions is shown in Fig. 12 [17]. Here the shape of the branch used for feeding is an I type and that used for radiating is of U type. The width, gaps between radiating elements, vertical lengths are selected in such a way that it can cover the 3.5GHz band. Hence it has been proposed that this system finds application in 5G communication. In the desired band the total efficiency of antenna is greater than 58%, isolation more than -17dB, value of ECC less than 0.1 and channel capacity between 16-19bps/Hz [17].

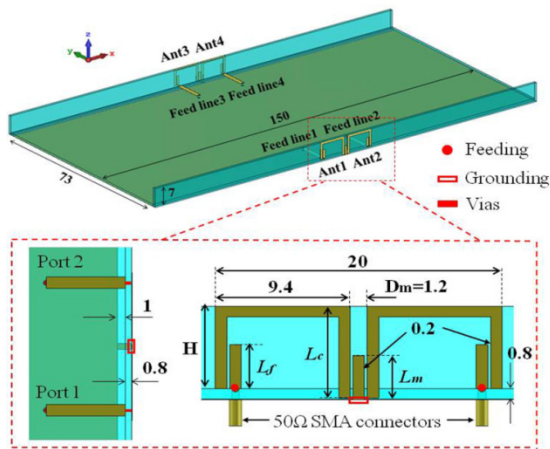


Fig. 12. 4-antenna system with detailed dimensions [17].

The antenna system for mobile terminals is proposed which is self isolated. Here the system consists of 4 elements on each side and each element construction is as in Fig. 13 [18]. It consists of T patterned structure as feed element and two similar L patterned structure for radiating. It has been demonstrated that isolation of better than 20 dB is obtained for 4-antenna MIMO system without any techniques of decoupling. ECC values less than 0.003 in the 3.5GHz band and CC above 35bps/Hz with efficiency above 60% have been demonstrated. Total length of the element is 0.5λ at resonant frequency. The dimensions of the L structure are fixed and that of the T structure are varied to obtain the desired resonance and impedance matching [18].

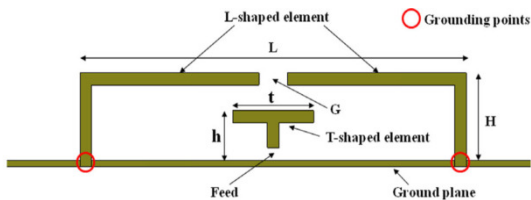


Fig. 13. Antenna element structure [18].

It is very intelligently demonstrated that by just adding two vertical stubs into an antenna element proposed in [18] which itself is self isolated, isolation can be improved to greater extent and also the efficiency of antenna elements can be increased.

Table 1: Comparison of various Designs.

Ref. No.	Bandwidth(in GHz)	Isolation (in dB)	Efficiency (in %)	ECC(Envelope Correlation Coefficient)	CC(Channel Capacity) (in bps/Hz)	Order of MIMO and type of antenna	Technology
[6]	3.3-5.0	14.7-15.3	55(lower band) 60(Higher Band)	<0.1	31.6-39.2	8 × 8 & coupled loop.	New Mode of 0.75λ is demonstrated to provide wide-band.
[7]	3.4-3.6 & 5.150-5.925	>11	>51(lower band) >62(higher band)	<0.1	36.9	8 × 8 Slot Antenna of L-Shape	Regulation of impedance ratio and electrical length gives multiband characteristics

Thus it has been shown that above results can be obtained without any decoupling techniques or without by any isolation elements. Thus this system of antenna reduces size, finds application in mobile phone for 5G. As shown in Fig. 14 [19], it can be seen that 30% reduction in length can be achieved while maintaining the efficiency greater than 60% in the band of 3.5 MHz. Thus it can be said that there are two approaches one [18] and the other in this paper which can achieve both better isolation and best efficiency without the use of any techniques for decoupling. The ECC values observed were lower than 0.0125 in desired 3.5GHz band, which is advantageous for 5G application. Due to the above MIMO system calculated channel capacity (CC) is better than 34bps/Hz in the required band[19].

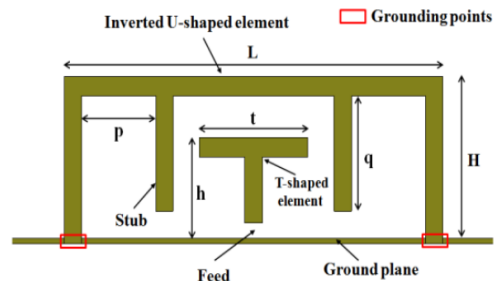


Fig. 14. Structure of antenna element (self isolated) [19].

The MIMO antenna system is proposed for 5G applications, both 4×4 and 8×8 system have been demonstrated. The elements are arranged intelligently to get orthogonal mode which will reduce the mutual coupling between these closely spaced pairs. Each pair consists of two antenna structure one is monopole that is bended and the other is dipole fed at the edge. Also this system does not use any decoupling structure. The proposed antenna system gives the isolation greater than 20dB for 4×4 MIMO system and greater than 17dB for 8×8 system. Efficiencies in the range of 51.7% to 84.5% and from 49% to 72.9%, Envelope correlation coefficients (ECCs) less than 0.06 and 0.07 for the 4×4 and 8×8 MIMO system respectively have been proved [20].

4×4 antenna system is demonstrated which can cover the N-77 band of 3.3-4, 2GHz. It is a self isolated system that gives good isolation which is greater than 17.9Db [21].

[8]	3.4-3.6 & 4.8-5.0	17.5(lower band) 20(higher band)		<0.14(lower band) <0.12(higher band)	31.6-39.2	4 × 4 U-shaped Inverted and I shaped	Top part and lower part of feeding element are coupled with U shaped to get the required band
[9]	24.75-27.5, 3.3-3.6 & 4.8-5.0	>12(lower band) >30(higher band)	50(lower band) ≈90(higher band)	<0.05	35	1 × 8 & 8 × 8 Monopole of Z shaped and U shaped for sub 6GHz. Dipole Variant with Z Arm for mm wave	Right triangle structure is used to get mm wave band.
[10]	28 & below 6	>6(below 6 GHz) >35(for 28GHz)	>92			4 × 4 for lower and higher band each. Monopole of L-Shape and slot type	Dimensional Variation to obtain the dual band
[11]	3.3-3.6	>11	50-76	<0.15	48-51	10 × 10 6 Monopole and 4 slot type	Length and width adjustment of antenna elements gives required resonance
[12]	3.4-3.6 & 5.725-5.875	>11	50	-	37(lower band) 42(higher band)	8 × 8 Coupled loop in 3.5 GHz band and inverted F in 5.8GHz	Variation in coupling gap gives smaller capacitive reactance in 5.8GHz and larger in 3.5GHz
[13]	2.4	>18		<0.15	38-40	8 × 8, 4 C shaped and 4 Monopole slot of L shape	Length of Monopole gives required band resonance. Isolation is increased by bending one open end of monopole
[14]	2.3-2.4 & 3.4-3.6	>10	56 -70	<0.4(lower band) <0.2(higher band)		10 × 10, 2 × 2 bending monopole for 4G and 8 × 8 for 5G.	Decoupling technique is used in upper band and In lower band Isolation is improved by neutralization line.
[15]	3.3-4.2 & 4.8-5.0		>53.8(lower band) >79.1(higher band)	<0.1(lower band) <0.12(higher band)	35.5-39.5(lower band) 38.2-40(higher band)	8 × 8 Monopoles with T shaped decoupling structure	Improvement in isolation by T shaped structure.
[16]	698-960,GPS & 1.710-2.690, 3.4-3.6	>10	40 – 73.2	<0.15		4 × 4 Inverted L shape	Mirror technique is used for isolation
[17]	3.4-3.6	>17		<0.1	16-19	4 × 4 U type(inverted) and I type	Self decoupled structure and share one common grounding branch
[18]	3.5	>20	60	<0.003	35	4 × 4 L pattern structure and T pattern structure	Self isolated antenna structure
[19]	3.5	>19.6	60	<0.0125	34	8 × 8 U –pattern structure (inverted) & T pattern structure	Self isolated antenna structure

IV. CONCLUSION

The new mode of 0.75λ to provide wideband is demonstrated [6]. Varying the parameters of antenna

gives variation in resonant frequency and improvement in efficiency has been proved [6].

It is observed that typical design methods such as Monopole, Inverted F, loop antenna, etc. structures are used to realize multi-band operations.

Techniques such as Stepped Impedance Resonator are implemented for obtaining dual resonance and regulation of impedance ratio gives required resonance [7].

High isolation can be obtained by allocating common branch for grounding [8]. Right triangle structure in the arm of antenna increases bandwidth [9]. L shaped element for 4G and slot antenna for 5G on the same substrate has been demonstrated in [10]. It has been proved that length and width adjustment of slot gives better match of impedance [11]. Self isolated antenna structures are demonstrated [16, 18]. Also improvement in isolation is demonstrated in [19]. Comparison of various designs is given in table above.

V. FUTURE SCOPE

This study aids for those who are involved in scheming different antenna structure for increasing bandwidth, improving efficiency along with multiband operations. Table provided also aids in giving varied structure study.

Conflict of Interest. No.

REFERENCES

- [1]. Dewar, C., & Warren, D. (2014). Understanding 5G: Perspectives on future technological advancements in mobile. *GSMA Intelligence*, 1-26.
- [2]. Andrews, J. G., Buzzi, S., Choi, W., Hanly, S. V., Lozano, A., Soong, A. C., & Zhang, J. C. (2014). What will 5G be?. *IEEE Journal on selected areas in communications*, 32(6), 1065-1082.
- [3]. Brown, G. (2016). Exploring 5G new radio: use cases, capabilities & timeline. *Qualcomm White Paper*, 1-12
- [4]. Chen, S., & Zhao, J. (2014). The requirements, challenges, and technologies for 5G of terrestrial mobile telecommunication. *IEEE communications magazine*, 52(5), 36-43.
- [5]. Ericson White Paper GFMC :18:000530, (2018). Advanced antenna systems for 5G networks.
- [6]. Zhao, A., & Ren, Z. (2019). Wideband MIMO antenna systems based on coupled-loop antenna for 5G N77/N78/N79 applications in mobile terminals. *IEEE Access*, 7, 93761-93771.
- [7]. Li, J., Zhang, X., Wang, Z., Chen, X., Chen, J., Li, Y., & Zhang, A. (2019). Dual-band eight-antenna array design for MIMO applications in 5G mobile terminals. *IEEE Access*, 7, 71636-71644.
- [8]. Ren, Z., & Zhao, A. (2019). Dual-band MIMO antenna with compact self-decoupled antenna pairs for 5G mobile applications. *IEEE Access*, 7, 82288-82296.
- [9]. Ren, Z., Wu, S., & Zhao, A. (2018). Coexist design of sub-6GHz and millimeter-wave antennas for 5G mobile terminals. In *2018 International Symposium on Antennas and Propagation (ISAP)*, 1-2.
- [10]. Khan, M. N., Gillani, S. O., Jamil, M., & Iftikhar, T. (2018). Multi Antenna Systems for 5G Mobile Phones. *International Journal of Electrical and Information Engineering*, 12(4), 299-306.
- [11]. Deng, J. Y., Yao, J., Sun, D. Q., & Guo, L. X. (2018). Ten-element MIMO antenna for 5G terminals. *Microwave and Optical Technology Letters*, 60(12), 3045-3049.
- [12]. Wong, K. L., Lin, B. W., & Li, B. W. Y. (2017). Dual-band dual inverted-F/loop antennas as a compact decoupled building block for forming eight 3.5/5.8-GHz MIMO antennas in the future smartphone. *Microwave and Optical Technology Letters*, 59(11), 2715-2721.
- [13]. Li, M. Y., Ban, Y. L., Xu, Z. Q., Wu, G., Kang, K., & Yu, Z. F. (2016). Eight-port orthogonally dual-polarized antenna array for 5G smartphone applications. *IEEE Transactions on Antennas and Propagation*, 64(9), 3820-3830.
- [14]. Ban, Y. L., Li, C., Wu, G., & Wong, K. L. (2016). 4G/5G multiple antennas for future multi-mode smartphone applications. *IEEE access*, 4, 2981-2988
- [15]. Cui, L., Guo, J., & Liu, Y. (2019). An 8-element dual-band MIMO antenna with decoupling stub for 5G smartphone applications. *IEEE Antennas and Wireless Propagation Letters*, 18(10), 2095-2099.
- [16]. Huang, D., Du, Z., & Wang, Y. (2019). A Quad-Antenna System for 4G/5G/GPS Metal Frame Mobile Phones. *IEEE Antennas and Wireless Propagation Letters*, 18(8), 1586-1590.
- [17]. Ren, Z., Zhao, A., & Wu, S. (2019). MIMO antenna with compact decoupled antenna pairs for 5G mobile terminals. *IEEE Antennas and Wireless Propagation Letters*, 18(7), 1367-1371.
- [18]. Zhao, A., & Ren, Z. (2019). Multiple-input and multiple-output antenna system with self-isolated antenna element for fifth-generation mobile terminals. *Microwave and Optical Technology Letters*, 61(1), 20-27.
- [19]. Zhao, A., & Ren, Z. (2018). Size reduction of self-isolated MIMO antenna system for 5G mobile phone applications. *IEEE Antennas and Wireless Propagation Letters*, 18(1), 152-156.
- [20]. Sun, L., Feng, H., Li, Y., & Zhang, Z. (2018). Compact 5G MIMO mobile phone antennas with tightly arranged orthogonal-mode pairs. *IEEE Transactions on Antennas and Propagation*, 66(11), 6364-6369.
- [21]. Zhao, A., & Ren, Z. (2019). 5G MIMO Antenna System for Mobile Terminals. In *2019 IEEE International Symposium on Antennas and Propagation and USNC-URSI Radio Science Meeting*, 427-428.

How to cite this article: Hatte J. S. and Patil, R. B. (2020). Design Methods of MIMO Antenna for 5G New Radio Applications in Mobile Terminals-A Review. *International Journal on Emerging Technologies*, 11(3): 738-745.