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A Review on 5G Antenna: Challenges and Parameter Enhancement Techniques

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ABSTRACT- The need for a high-speed mobile network has increased due to the COVID19 pandemic.5G is the newest and most sophisticated technology designed to handle the demands of the internet. The 5G network ensures connection security and simplifies mobile device connectivity to wireless devices. This paper explains every parameter related to 5G technology that has been covered in various papers. It addresses some of the difficulties that 5G technology faces. The development of Vivaldi, conformal, MIMO antennas satisfies the requirements of the 5G mobile network and presents opportunities to overcome obstacles. In the paper, MIMO antenna is discussed along with various techniques for enhancing its parameters, such as appropriate substrate selection, antenna element placement, and mutual coupling reduction. Different techniques like isolation, DGS, slot, metamaterial, neutralizing line, and frequency reconfigurations are explained under mutual coupling reduction techniques. A comparative analysis of various antenna feeding techniques is presented in the paper. The article provides details on how various parameters are affected by parameter enhancement techniques.

Keywords: Multiple Input Multiple Output (MIMO), Defected Ground Structure (DGS), neutralization line, Slot, Mutual Coupling, Substrate.

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1. INTRODUCTION

In 1979 Japan identified that mobile communication is one of the efficient modes of communication. It was suffered from interference, reliability issues. The mobile network was evolved from 2G to 3G. 3G provide features of video call, playing online games, sharing files, watching TV. For 3G network downloading and uploading video time was high. 4G network overcome drawback of 3G network. Long term evolution (LTE) technology is used for 4G to deliver speed of network between 10Mbps to 1Gbps [1]n paper [2,3] information of evolution of mobile network with technology used is given.

Table1: Evolution of mobile network

1G	2G	2.5G	3G	3.5G	4G	5G
TDMA	CDMA, TDMA with data rate of 14.4Kbps, It uses GSM technology	It used CDMA2000 technique and general packet radio services (GPRS)with data rate of 384Kbps	It used CDMA technique with GSM service	More demand to high-speed uplink and down link Data rate of 2Mbps	100Mbps data rate used long term evolution (LTE) technique. It supports video conferencing, gaming etc	10Gbps data rate, low latency, and greater reliability. It supports IOT enable devices and smart vehicles, High Bandwidth, energy efficient

4G network have some drawbacks which are listed as follows.

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1.1 Slow Data Speeds
Improvement in data transmission speed was expected from 3G network to 5G network. Speed Comparison for 3G, 4G and 5G network is as shown in *figure 1* and 5G network can provide 10GB/s data transmission rate.

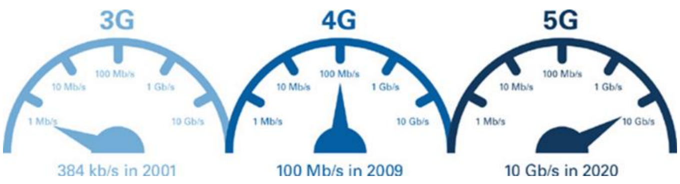

Figure1: Speed comparison of 3G,4G,5G Network

1.2 Having No Connection in the 4G Mode
Network issue was often observed in case of 4G network[4]. Then a unique strategy was brought about to make it work in a phased manner outdoor as well as indoor. It is by installing both 4G Volte and 4G L900 [5].

1. Having Weak or Poor Signals on Smartphones: Switching from 4G-to-4G LTE option in a better way to improve signal quality[4], [6]
2. Drop in The Connection Level: When you can see frequent call drops on your phone, you should configure the network settings on your phone in a better way. iPhone users can easily choose Reset Network Settings for the configuration [4]
3. When No Network Is there on The Second SIM: Paper [7] discussed about dual SIM phones, people usually find this problem that 4G VoLTE is not supported in the second sim slot.
4. Understanding 5G technology and MIMO fundamentals:

Mm wave signal have shorter wavelength which is useful to reduce size of device so that more no of antenna can be fit in small area. There is one more frequency band called as midband. It ranges from 2.5GHz,3.5GHz,3.7GHz to 4.2GHz band. It is 5 times wider compare to lower frequency band FR1.It has more data transfer capacity to transport large amount of data[20]. increasing FR1 range need to be extended up to 7 GHz whereas FR2 range up to 52.6 GHz and more[8,9]

Table 2: Frequency bands[10]

FR1 &FR2 frequency ranges for 5G NR [7, 9]	
Frequency range Designation	Frequency Range (GHz)
FR1	Below 7 GHz
FR2	24.25 Hz to 52.6 GHz

Vivaldi antennas work in a broad range of millimeter frequency ranges for both transmission and reception of signals. In radar systems, especially ground-penetrating radars where a wide frequency range is required to attain the required resolution, Vivaldi antennas are frequently employed. Various methods for enhancing the Vivaldi antenna's performance are presented in this paper [10], along with their respective application areas. A novel Antipodal Vivaldi Antenna is presented in the paper[11 ,12]. The conventional exponential tapered slot is replaced with a linear tapered slot (LTS) loaded with metal vias to facilitate miniaturization and simpler fabrication. As a result, when compared to conventional Vivaldi antennas for 5G millimeter-wave applications, it can successfully eliminate energy loss and suppress sidelobe, enhancing the antenna's gain and directivity without requiring a modification to the antenna's original size. In paper [12], a 5G MIMO conformal antenna design is presented. The frequency is 35 GHz, and a cylinder serves as the conformal carrier. Paper [1] concentrates on 6G benefits, challenges and how to improve performance of 5G network.

Printed graphene antenna at a single element that satisfies the 5G requirement is described in Paper [11]. Using a higher conductivity can help to improve the graphene antenna. To preserve conductivity and dielectric stability, graphene ink or the selection of graphene ink must not require a curing procedure**.** With the global deployment of 5G, capabilities of today's mobile network are dramatically increasing. Expectations of users are also increasing[13]. The new inventions in 5G are making empowering technology with mm frequency waves, beam-forming device centric architecture and massive Multiple Input Multiple Output[10]. Here mm wave for mobile, beam-forming, and low latency is considered which improves parameters of mobile devices and network. Microstrip line was used for higher frequency range but for millimeter frequency ranges microstrip antenna cannot transfer information so fin line and slot line were used for different frequency ranges [9]. One of the efficient technologies to meet 5G wireless network requirements is MIMO antenna, it can provide high throughput and signal to noise ratio.

In paper the author has conducted a thorough survey on the application of the millimeter-wave band for cellular applications, taking into account the majority of recent publications and research contributions in this area. The ability of Millimeter wave Communications to support a significant increase in capacity over an LTE network has made them a promising candidate for 5G mobile networks. The author of paper [5] have researched the millimeter-wave band as a potential 5G communication bandwidth. This band's difficulties have been noted and discussed. This survey also explored using millimeter-wave(mm-wave) in 5G for backhaul, indoor, and outdoor applications. It also covered the use of massive MIMO to enable dependable 5G services.

a novel and distinctive two-port MIMO antenna structure that resembles an L-shaped, vertically oriented Yagi-Uda ladder antenna is recommended in[6].In [15] wrenched shape patch with addition to etched circular slots on the ground plane, the proposed design includes a partial ground structure. The antenna that is being presented is unique in that it can function at four different frequency bands: 16 GHz, 25.5 GHz, 28 GHz, and 32 GHz. Paper[16] describes that with lower SAR values obtained for the proposed antenna design, the proposed communication applications involving human body parts (human palm and head).

The structure of the paper is as follows: *Section 2* flowchart explaining design steps of MIMO antenna. *Section 3* challenges of 5G technology and performance enhancement techniques with classification of antenna *Section 4* performance enhancement technique based on substrate selection *Section 5* performance enhancement technique using proper substrate selection. *Section 6* performance enhancement using Mutual coupling reduction techniques. *Section 7* performance enhancement using different feeding techniques. Lastly conclusion and future scope.

2. FLOW CHART OF MIMO ANTENNA DESIGN [4 ,5]

The flowchart in *figure 1* depicts the MIMO antenna design procedures. It is necessary to choose the appropriate substrate and antenna design based on a review of the literature. Utilizing an antenna simulation tool, simulate the antenna design. Examine the results; if the desired result is obtained, build the antenna, and use a network analyzer to test it. Anechoic chamber is to be used for the checking of radiation patterns.

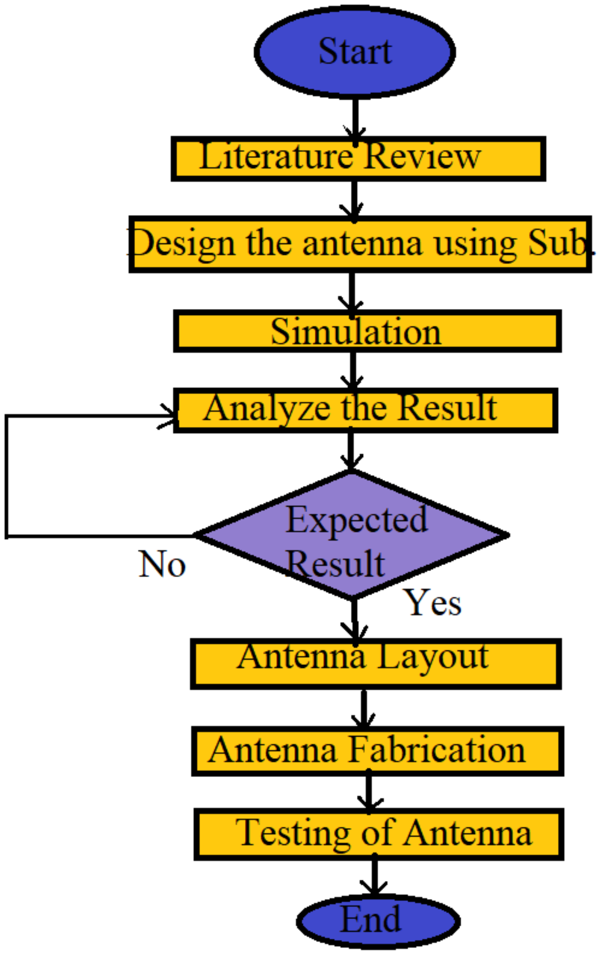

Figure 2: Flowchart of MIMO antenna design

3. CHALLENGES OF 5G [17]

1. Buying frequency band up to 300GHz is very costly.
2. Traffic capacity should be 10Mbps/sq. meter in hotspot area.
3. Low latency
4. *Area coverage*: As high frequency waves have a shorter wavelength; they can't travel a long distance. More no of base stations are require in smaller area to give reliable connection to each user which increases cost and complexity of network.
5. 5G system development is costly.
6. *Device support*: Current phone does not support 5G. Developing new cheaper phone would be very challenging for manufacturer.
7. *Security and Privacy*: Key agreement systems and authentication are used in 5G.
8. *Cybercrime*: need strict cyber law.

Paper [18], [19] provides information to meet 5G challenges and discuss about future 6G mobile network. 5G technology can be used to provide services such as smart cities, smart buildings, healthcare instruments, and vehicle-to-vehicle communication. Major societal transformations are possible because of 5G technology in the fields of industry, education, and other sectors where security, reliability, quality of services, and efficiency are critical. Smart antennas with minimal path loss, low latency, large capacity, and wide bandwidth are required to meet 5G needs. To meet 5G standards, this paper examines a variety of antennas, including microstrip patch antennas and their many configurations, as well as design features such as efficiency, compactness, and isolation. For 5G technology, this article offered various antenna designs and performance enhancing techniques. This paper proposed different antenna designs and their performance enhancement techniques for 5G technology. Proposed paper tried to review their work, comparison of results and future scope[20]. The Envelop correlation coefficient, Directive gain, Channel capacity loss, Total active reflection coefficient, transmission coefficient, and peak data rate should all be provided for the 5G antenna [21,22]. The expected standard values for above parameters are as mentioned below *table 3*.

Table 3: 5G antenna specifications.

Sr. No	Parameters	Value
1	Envelop Correlation coefficient (ECC)	<0.5[23]
2	Directive Gain	>9.95dB [29]
3	Channel capacity loss (CLL)	=0.04bits/sec/Hz [30]
4	Total active reflection coefficient (TARC)	<0dB [15]
5	Transmission coefficient	<-2dB [29]
6	Peak data rate	=20Gbps [30]
7	Latency	=1 millisecond [25]

Scientist have anticipated that new wireless system will be enables n no of different radio access networks. Low latency feature of 5G will enable downloading and uploading of high-quality video in real life. In this paper we have tried to enlist different performance enhancement techniques of recent antenna.

5G antenna are basically classified as single input single output (SISO)and multiple input multiple output (MIMO). SISO and MIMO antenna are divided into wideband and multiband

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antenna [2,19]. Classification of 5G antenna is as shown in *figure 3*.

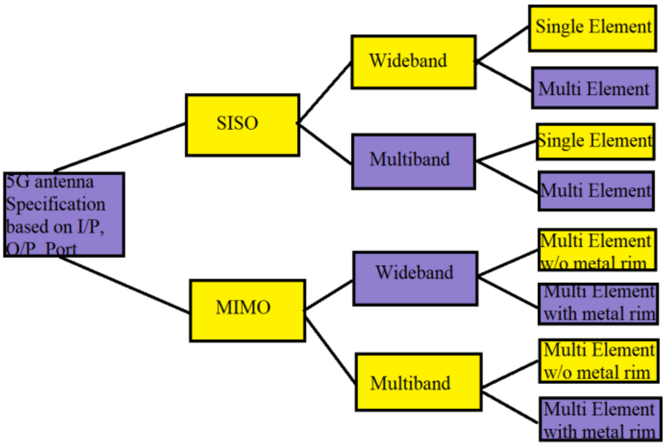

Figure 3: Classification of 5G antenna based on Input output port.

4. PERFORMANCE ENHANCEMENT TECHNIQUES.

Following is the list of different approaches to improve performance of MIMO antenna.

(1) substrate selection (2) corrugations also (3) Array of elements (4) dielectric lens (5) Technique for reducing mutual coupling are the different approaches for improving performance of antenna. The various performance enhancing techniques is shown in *figure 4*.

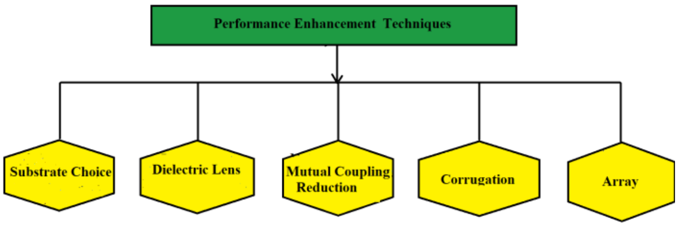

Figure 4: Performance Enhancement techniques.

4.1 Substrate Choice

The thickness of the substrate, the loss tangent, and the dielectric constant all help to improve antenna performance such as gain, size, efficiency, bandwidth, and return loss [9,27].

4.2 Corrugation

It is the process of removing a metal portion from the radiator's edge. It improves bandwidth and front-to-back ratio while lowering input impedance [2,19]

4.3 Array of elements

The gain of an antenna can be increased by employing an array or several elements, which increases the antenna's bandwidth and efficiency. It has drawbacks, such as difficulty in designing the feeding network and increasing antenna size[2,9].

4.4 Dielectric Lens

It transmits radiation in one direction, allowing the antenna's gain and directivity to be increased. Different substrate materials are utilized to make different shapes of dielectric antenna. However, the drawback of this antenna is that it increases the antenna's size[19].

4.5 Mutual coupling reduction technique

Performance of antenna can be improved by using mutual coupling reduction or decoupling techniques. It is also called as Isolation technique which has disadvantage of increasing complexity of design of antenna [2, 28,29].

4.6 Neutralization line

In this method electromagnetic waves are passed between antenna elements using lumped element or metallic slit. When connected between ground planes, this technique minimizes antenna area while improving bandwidth. When a point on the neutralization line moves, the impedance changes, affecting the effective bandwidth [28], [29].

4.7 Decoupling Network

By adding discrete components or transmission lines to this type of network, cross admittance is changed to a fully imaginary value. As the plane decoupling network serves as a resonator, mutual coupling is reduced. For dummy load coupled resonators and multielement techniques, it adds pattern diversity. By adding discrete components or transmission lines to this form of network, admittance is changed to an illusory value. More than 140 research papers have been published so far [27]

4.8 Electromagnetic Bandgap (EBG) Structure

It is made up of metallic and dielectric structure with periodic arrangement. It is used as a channel for relocation of electromagnetic wave [27].

4.9 Dielectric resonator

It provides high radiation efficiency, high isolation with high gain, and low loss. Rectangular, Cylindrical, Hemispherical are the most commonly available shapes of dielectric resonator [2,28].

4.10 Defected ground structure

In this type of antenna slots or defects are etched in the middle of the two antennae. The microstrip antenna is etched with one or more defects on the ground plane. The defects can be periodic or non-periodic, and they are employed to offer high bandwidth, minimum mutual coupling, and high efficiency[29, 27].

4.11 Metamaterial

Two or more materials with minimal mutual coupling and compact size can give high gain and bandwidth. Material containing EM characteristics such as single negative, double negative, isotropic, photonic, nonlinear are some of the combinations of materials [28,29].

Negative permittivity and permeability of metamaterial helps in miniaturization with increasing gain of antenna.

4.12 Slot or parasitic element

To reduce mutual coupling between different antenna element additional coupling path is used. This method reduces size of antenna also simple to design but selecting location of slot is difficult [19].

4.13 Complementary split ring resonator (CSRR)

It is a repetitive structure made up of capacitive gap shunt strip. It enhances efficiency by maintaining a compact size also improves diversity gain, isolation. Two concentric ring structures with slots on opposite sides are used here [30].

4.14 Frequency Reconfigurable

It uses MEMS switches, P-I-N, varactor diode and switching approaches to boost the envelop correlation coefficient. Low mutual coupling, great diversity gain, and efficiency can all be achieved using a reconfigurable antenna configuration [31,32]. From the above enhancement reduction technique mutual reduction technique is used in most of research. If Isolation of antenna port is increased, it can help to solve mutual coupling reduction problem. To improve isolation of antenna various studies have been performed such as tree like parasitic structure, Electromagnetic band gap structure (EBG), Defected ground structure (DGS). The detail explanation of each performance enhancement technique is given bellow.

4.15. Polarization

Paper[33] explains apart from above different parameters polarization is also one of important parameter to be consider for enhancement of antenna gain, bandwidth etc. Polarization gives idea about how the electric field and magnetic field vibrates. When n no of EM signal is transmitted and received with some angle then there is a diversity in signal transmission and reception. The signal can be orthogonally transmitted or received the concept is called as polarization diversity. To improve performance of antenna this concept is used. compared to a single omnidirectional radiator, a combination of two or more antennas with distinct radiation pattern selection across a broad angle space can yield a higher gain.

Antenna gain must be strong to avoid severe pathloss. To boost gain, polarization and pattern diversity techniques can be applied for MIMO employing a multilayer PCB structure. [33] proposes a structure that operates between 34 and 38 GHz. The structure has a bandwidth of 21%, isolation of 17dB, and 5dBi gain. It also has dual polarization, pattern polarization, and end fire and broadside pattern diversity. The ECC parameter is used to assess uncorrelated channels. ECC and mutual coupling between two antennas or any two ports can be determined using S parameters. The lower the ECC value, the less the correlation between antenna elements is 0.5. Pattern diversity [21,34,35] can be used to achieve this.

MIMO antenna structure in [33]proposed pattern and polarization diversity antenna as 5G system expects high gain with negligible path loss. To achieve high bandwidth with more isolation multi-layered PCB structure is proposed at frequency 34 to 38GHz.Proposed structure of MIMO antenna provides pattern diversity with end fire pattern and broadside pattern and dual polarization.

To improve antenna performance, various polarization techniques are utilized. Circular polarization is one of the most often utilized polarization techniques. Circular polarization boosts antenna bandwidth and gain[33] . MIMO antenna can be fabricated using multilayer PCB [34]

In [33] Dual polarized beam switching technique was proposed which was found to be effective Phased array structure for mm frequency.

4.16 Orthogonal Placements of Elements

Orthogonal antenna patch location helps to improve antenna parameters. Antenna patch positioning is also important for improving antenna performance. The use of orthogonal element placement improves gain, ECC efficiency, and MEG[34 ,36]. The detail of performance enhancement techniques is explain below.

5. SUBSTRATE SELECTION

It is important to select proper substrate which can give better performance of antenna. properties of dielectric substrate can be considered in selection of substrate. Paper [16] gives comparative study to understand dielectric properties of different substrate. The example of antenna in [36] is a 2× 2 MIMO antenna with a size of 11.2 ×15.25 mm^2. The MIMO antennas are printed on substrate materials. such as FR-4, Roger RT Duroid 5880, and RO3003. *Figure 5* shows a comparison of reflection coefficients for various substrate materials. Comparatively Substrate RT5880 have better reflection coefficient. Each substrate has a permittivity and loss tangent value that is unique to it. A substrate with a lower relative permittivity and a low loss tangent must be chosen to improve gain and reduce power loss[37]. The *table 4* lists the many substrates that have been used to print MIMO antennas.

Table 4: List of Substrate with permeability and loss tangent.

Reference no	Name of substrate	Relative permittivity	Loss tangent(tanδ)
[19,37]	Roger RT 5880	2.2	0.0009
[39]	Melinex	2.9	0.06
[5]	Rogers R03003	3	0.004
[33]	Rogers R04350B	3.48	0.0037
[3]	FR-4	4.4	0.02
[40]	Rogers 4003c	3.38	0.0027

Height of substrate(thickness) also plays important role in the performance of antenna. It has been studied that increasing height of substrate improves bandwidth[22]. In [24] Substrate Teflon of Dielectric constant 2 and loss tangent 0.0007 is used. The author[41] mentioned that Substrate thickness varies from 0.127mm to o.78 mm which shows increase in radiation efficiency from 81 to 92.8%for thickness 0.127mm to 0. 381mm.

For 2 port network antenna correlation between the antenna gets affected by mutual coupling which makes antenna pattern orthogonal to each other. The correlation between communication channels is describe by correlation coefficient. Power envelops and signal are the 3 types of correlation. It is equivalent to envelop correlation. In the process of correlation third signal is produce by signal correlation of two signals. The squared correlation coefficient is known as the envelope correlation coefficient. (ECC). Mutual coupling affects scattering parameters of antenna and ECC, higher the value of ECC higher is the correlation and mutual coupling so ECC value should be lower for MIMO antenna. In a multiple-antenna system, the effect of one antenna on the performance of the other is defined by the ECC. In other words, it measures the impact that a single member has on the overall system performance of other members. If there are two antennas, one is transmitting and other is receiving the energy, then the correlation between them is given by scattering parameters S_{11}, S_{12}, S_{21}, S_{22}.Equation1can be used to calculate ECC.

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

Diversity gain is one of the most important factors to consider when analyzing MIMO antenna performance. The better the isolation between the antennae, the higher the diversity gain value. It can be calculated using the antenna signal correlation coefficient. Diversity gain can be calculated using *equation 2*.

$$G_{DG} = 10 \times \sqrt{1 - |Pe|2} \quad (2)$$

6. MUTUAL COUPLING REDUCTION TECHNIQUES

Mutual Coupling between two elements of antenna can be reduce by using mutual coupling reduction techniques such as Frequency Reconfigurable, Dielectric Resonator, Complementary Split Ring Resonator, Slotted elements, Electromagnetic Bandgap Structure, Defected Ground Structure, Decoupling network, Metamaterial. *Figure 5* shows different mutual coupling reduction techniques.

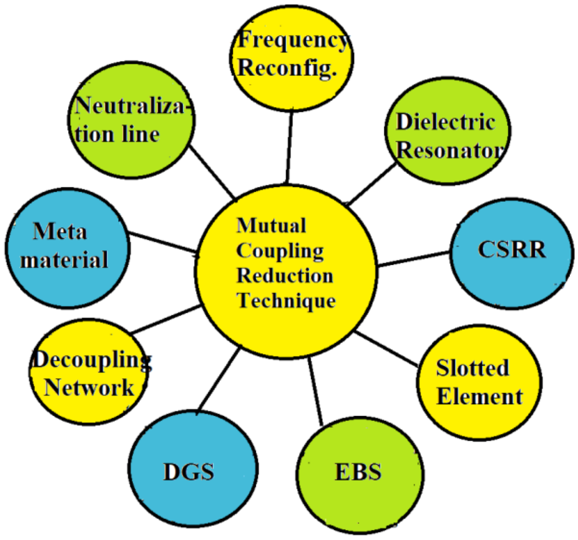

Figure 5: Types of Mutual coupling Reduction Techniques

Mutual coupling causes due to energy absorption by another close by antenna when just one antenna is in use. It is undesirable as the energy radiated is capture by unwanted antenna. It reduces antenna efficiency and performance of antenna in both transmission and reception mode. Mutual coupling affects the antenna's radiation pattern and mutual impedance.The *equation 3* can be used for mutual coupling calculation of ith and jth antenna elements with *dij* distance between them and for N no of element mutual coupling can be calculated using *equation 4*.

$$MC_{ij} = \exp\left(-\frac{2dij}{\lambda}(\alpha + j\pi)\right), i \neq j \quad (3)$$

$$MCij = 1 - \frac{1}{N}\sum_i \sum_{i \neq j} MCij \quad (4)$$

Mutual coupling between antennas is determined by the array configuration and element excitation in practice. It's commonly calculated in dB using the S parameter between the ith and jth elements, with isolation of -20 log $_{10}$(| Sij|). Summary of different types of mutual coupling reduction techniques and their benefits are listed below *table 5*.

Table 5: Mutual Coupling Reduction techniques at different frequencies

Ref. no	Frequency	Size	technique	Remarks
1.	28GHz,38GHz	9.2 × 18 mm^2	The metamaterial is positioned between the two radiating elements in a deliberate manner.	increased bandwidth in the designed lower band (24–28.8 GHz) of 3.8–4.8 GHz. Improves isolation.
13	28 GHz ,40GHz	7.5× 19.8 mm^2	a parasitic element was precisely placed between two patch elements on the substrate.	Improves bandwidth to 2.83GHz and 4.29GHz at 28 and 40GHz respectively. Gain is 79 dBi and 6.97dBi with 92% efficiency.

40	28GHz ,38GHz	30×15 mm^2	One of the antennas is printed on the upper layer while the other is located on it's back of the sub	Reduce mutual coupling, Improved gain.
25	24 to 30 GHz	12.8× 7.5 mm^2	Antenna is design with DGS and coplanar waveguide feed.	Improves directivity and gain of antenna.
20	26.1 GHz to 30 GHz 25.5–29.6 GHz	30 ×35mm2	Performance of antenna is improved by defected Ground Structure (DGS) with circular, rectangular, zigzag shaped	Reduced Mutual couplings.BW is 4.1GHz, gain is 8.3 dB with ECC < 0.01 dB
37	27 GHz,39GHz	26 × 11 mm^2	In this paper hexagonal patch with rectangular slot is proposed.	Isolation is increased by more than 30dB, gain is 5 and 5.7 dBi, efficiency is 99.5 and 98.6 at 27 and 39 GHz
5	2.008 to 7.309 GHz	54.82 × 96.09 mm^2	In this paper set of 3 partially extended ground arms are used to reduce mutual coupling.	isolation is12.6 dBi for freq.2.07.31GHz, Gain=3.997 dBi at 5.05 GHz,ECC is from 7.13 to 8.21.
34	n77, n79 3.3–4.2 GHz and 4.4–5 GHz	10 × 5 mm^2	In this paper 4 port MIMO antenna with L shaped patch antenna are printed at 4 corners	Mutual coupling is less than -18.8 dB
28	15GHz	12.2 × 11.8 mm^2	Mutual coupling is improved by DGS which improves other parameters.	Mutual coupling reduces to -4.66dB. Impedance bandwidth is 48.64%, gain is 8.41 dBi and efficiency is 72.98%
41	2.5GHz to 8 GHz	60×60 mm^2	Minkowski patch antenna is presented with rectangular slots at the end of patch which resulted in minimum mutual coupling,	With addition of slot, it increases bandwidth of reduces size and mutual coupling of antenna.
42	3.1 to 17.3GHz	75.19×75.19 mm^2	Four orthogonal and back-to-back triangular monopole elements are presented in this paper. The neutralization ring is made up of two parts: a rectangular ring and a straight strip line.	Mutual coupling reduced from -5.5 dB to -8.5 dB and less than 0.1E[48]CC
44	2.24 to 5.90GHz	37 ×56 × mm ^{2}	by modified feedline and Y shaped back plane stub loaded partial rectangular ground plane can be used to excite two spider shaped radiating patches	The proposed structure results in isolation more than 10dB
45	28,33,38GHz	40 ×40 mm^2	Elements are placed orthogonally	Isolation is increased by 20dB
31	2.7 to 4.94 GHz	-	4 ×4 MIMO elements are interconnected to ground plane. Elements are inverted L shaped monopole antenna	Mutual coupling is reduced upto -16dB

Mutual coupling between two antennas can be reduced by proper isolation between the antennas. For MIMO antenna spacing between elements is 0.41λ isolation achieved is 1.15×10^{-7} and directive gain is 10dB [31]. The detail information of mutual reduction techniques is given below.

6.1. Defected Ground Structure (DGS)

As shown in the table above, there are numerous enhancing techniques. Defected ground structure is one of the most successful enhancing techniques. Paper[39 ,29] depict that DGS can improve the characteristics of MIMO antennas. DGS helps

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in the formation of bandgap structural characteristics as well as the suppression of higher harmonics and mutual coupling. DGS[43] improves antenna gain and bandwidth, as well as the antenna's quality factor. It also helps in the prevention of cross polarization, which improves the radiation pattern. DGS can take any form. The antenna size is compact due to a defective ground structure. DGS can take the shape of an H, T, Z, U, V, spiral, or dumbbell. Defective ground structure disrupts current distribution and ground plane. The etching of the ground influences the effective capacitance and inductance of the microstrip line. Line resistance, capacitance, and inductance are all affected by a defective ground structure. The inductance and capacitance of the microstrip line are changed by etching into the ground plane under the microstrip line. Slot can be added to DGS. Addition slot with DGS helps to improve bandwidth[22, 27, 44]. Split ring slot can be added as DGS to change current distribution of ground[45]. Following table shows effect of addition of DGS to antenna structure.

Table 6: Effect of addition of DGS to antenna structure

Ref.	Frequency	Band width	Gain	Efficiency	Radiated power	isolation	ECC
50	28GHz 38GHz		7.8,6			30,28	0.0001
48	28GHz	0.5	9.638	-	-	3	<0.01
24	28GHz	-	8.35dB	-	659.5 mW	-	-
39	1.5Ghz 2.2GHz 28Ghz	-	6.01dBi 7.35dBi 6.62dBi	-	-	-	-
22	25.1 to 37.5 Ghz 36GHz	-	5dBi 10dBi	>80%	-	-	-
46	5.29–6.12 GHz 26–29.5 GHz	630MHz	5.13 and 9.53 dB	Efficiency is 71% and 68% at 5.9 and 28GHz	-	-	at 5.9GHz is ≤0.05 and at 28GHz ECC is 0.005
49	25.5–29.6 GHz	4.1 GHz	8.3 at 27.5 & to 8.1 at 28.5 GHz	79 and 82 % at 27.5 GHz and 28.5 GHz	-	-	< 0.01
51	28 to 38 GHz	23 to 40GHz	9.8 to 10.5dB	>70%	-	-	<0.5dB
54	2.4 GHz 5.2GHz	-[46]	1.202 3.478	-	-	-27.125 -39.513	-

6.2. Slot addition to antenna structure

Many slot designs were proposed to enhance parameters of antenna. Slotted multiple E shaped patch is proposed at freq. of 34.1 to 38.9GHz with BW of 13% Directivity of 5.7 and 6.5 dBi with HPBW = 100^0 [42] Following *table 7* shows comparative analysis of different parameters when slot is added to a patch antenna.

Table 7: Effect of addition of slot to antenna structure

Ref	Frequency (GHz)	Size	Band width (GHz)	Gain (dBi)	Efficiency	Isolation (dB)	ECC
40	28GHz,38GHz	30×15 mm2	-	5.7 6.9	- -	-32.3 -36.7	<0.0001
48	28GHz,38GHz	20×20 mm2	-	9.5 11.7	83 95	24 25	0.0001
5	2.0-7.31	54.82x96.09 mm2	4.99	5.06	56.0%-91.57%,	12.6	7.13 to to 8.21 $\times 10^{-2}$
19	26.8 to 29.6	30 × 35 mm2	4.1	8.3	79% at27.5 GHz and82%at 28.5GHz	-	0.01
32	1.9, 2.4, 3.5, 5.2, and7.6	21 × 21 mm2	0.3	6, 4, 1.5, 1, 1.25	-	-	-
36	27.7 to 28.1 36.92 to39.5	50 × 35	0.3 2.38	13.3 10.09	-	-	<0.01

23	36.5	13× 15.6 mm2	4.8	6.5	-	-	-
25	28,38,45,60	9.7 × 13.3 mm2	1.81,1.09,2.05 and 4.75	3.26, 3.28, 3.34 4.51	-	-	<0.005
55	28	6 x 18mm2	4.07%	5.94	-	-	0.0098
51	28	30×60 mm2	1.7	-	-	-	<0.3
48	60	2.9 ×3.5 mm2	30	8.82	-	-	-
52	15.09	12.2 × 11.8mm2	1.55	5.63	72.98%	-	-
53	15.2 to 62	11.2 × 15.2mm2	46.8	>13.5	-	-	-
54	28	30×30 mm2	-	6.1	92	<- 29	<0.16
50	28.26 45.61	6×18mm2	4.07% 3.22%	7.674.94	-	-	0.0026 0.0191

6.3. Reconfigurable antenna

The demand for wireless applications is increasing as the number of wireless fields grows. Traditional antennas are unable to match the demands of wireless communication systems. Paper [48]explains that reconfigurable antenna has been built to satisfy the demands. It can change its properties as needed. It can make use of frequency reconfigurability, in which the ON and OFF states of the diode can be used to create an open and short circuit between radiating patches. PIN diode, Varicap diode, and Micro electromechanical systems are used in a variety of reconfigurable antennas (MEMS). Antenna can be used for two frequency bands. Table 8 shows different parameters of reconfigurable antenna at 2.4GHz and 28GHz frequency.

Using a PIN, Varactor diode can be used for several reconfigurable antennas. The advantages and disadvantages of different switching component can be understood from *figure 6*.

Table 8: Reconfigurable antenna parameters at 2.4 GHz and 28 GHz[48]

Reflection coefficient (dB)	-22.39	-22.15
The Bandwidth	32.5 MHz	2.57Ghz
Directivity (dBi)	4.34dBi	8.57
VSWR	1.16	1.16

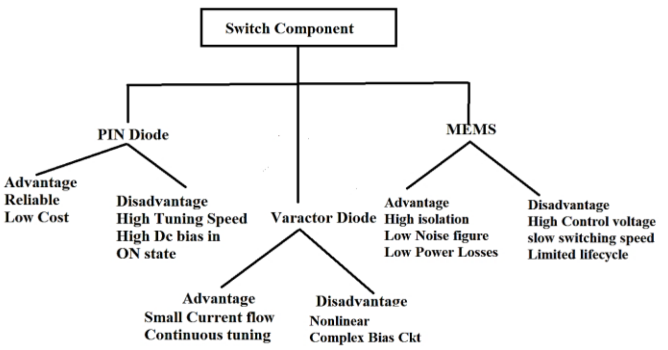

Figure 6: Different Reconfiguration antenna components

6.4. Metamaterial antenna

Pentagon-shaped monopole metamaterial antenna that offers excellent isolation and dual band response. A fascinating family of synthetic materials with unique qualities do not present in natural materials are called metamaterials. These can be used above or between the antenna elements to improve the separation without enlarging or complicating the MIMO system. [49].To address the needs of modern wireless communication technologies, a multiband antenna configuration is proposed in[50]. The use of metamaterial in antenna systems increases the number of frequencies that can be used. A quad band antenna configuration with two metamaterial unit cells at the ground structure is proposed. The proposed metamaterial structure employs a split ring, gapless ring, and two capacitance-loaded strips to provide good impedance matching, steady radiation properties, antenna designed with a trapezoidal slot in the radiating patch and a rectangular slot in the ground plane to obtain the desired outcome such as high gain. At 2.8 and 5.9 GHz, this dual band antenna construction is designed. Pentagon-shaped monopole metamaterial antenna that offers excellent isolation and dual band response is described in[10]. A fascinating family of synthetic materials with unique qualities which are not present in natural materials are called metamaterials. A material with negative permeability and permittivity is known as a metamaterial; it is also known as an artificial medium with a negative index of refraction. Snell's Law was used to determine negative refraction. A metamaterial is referred to as "zero-index material" if its permittivity and permeability are close to zero[51].

These can be used above or between the antenna elements to improve the separation without enlarging or complicating the MIMO system [10,52,53].

7. ANTENNA FEEDING TECHNIQUES

Paper [34,58] illustrate that different feeding approaches can be utilized to increase the performance of MIMO antennas over a wide range of frequencies. Aperture feed, coaxial feed, proximity feed, and electromagnetic coupling feeding are all examples of inset feeding. Antenna gain is improved by using an inset feed. Radiation from the feeding line or patch junction causes radiation reduction. The feeding technique has the advantage of being substrate independent. The aperture feedline has excellent polarization and a wide bandwidth. Paper [51,58] describes that the patch is fed by coaxial cable with the outer conductor connected to the ground plane and the inner conductor making direct contact with the patch through the dielectric material in the coaxial feeding technique. Even though the probe is in direct touch with the antenna, impedance matching is difficult to achieve with this method due to the thick substrate. When it comes to proximity feed, Feed is placed between two substrates. This feeding enhances bandwidth, efficiency, but it comes with the drawbacks of multilayer construction and poor polarization.

In [2]paper CPW fed MIMO antenna is proposed with graphene material. Graphene ink has a sheet resistivity between 0.003 W.cm and 0.008 W.cm with a thickness near 100 nm.

Table 10 gives comparative analysis of different feeding techniques based on parameters such as bandwidth, S11, directivity, beam width, VSWR.

As per the above literature review, there is a need for improvement in bandwidth, isolation, and antenna gain. To meet 5G antenna specifications for mobile communication, a small antenna size is necessary.

Table 9: Comparative study of feeding techniques [43,53]

Parameter	Inset feed	Coaxial feed	Proximity feed	Aperture Feed	Electromagnetic Coupling feed
Bandwidth	0.04252	0.042144	0.07	0.1441	3400-3660
S11(dB)	-16.11	-19.993	-18.176	-37.871	-18
Directivity	7.082	5.4	5.6	6.468	-
Beam width	92.4	104.3	101.7	84.9	-
VSWR	1.2944	1.4123	1.2815	1.0757	-

8. CONCLUSION

This article provides a thorough examination of several 5G antennas, as well as a comparison and analysis of their performance enhancing approaches. The specifications for 5G communication are also detailed. The historical development of wireless communication is reviewed, along with a summary of its five generations. According to the study, millimeter wave antennas hold a lot of potential for future 6G applications. It has been found that orthogonal antenna location, correct substrate selection, polarization diversity, and mutual coupling reduction approaches such as defective ground structure, addition of slot, metamaterial, reconfigurable structure, and EBG structure can improve MIMO antenna performance. Microstrip line feed technique enhances bandwidth. Targets for gain, efficiency, bandwidth, data rate, and ECC can all be met with the help of these performance-enhancement technique.

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