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A Survey on 5g Spectrum and Design of Microstrip Antennas for 5g Wireless Networks

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Abstract:- The demand for high data rate, good channel capacity and reliability has always been the main area of concern in the era of modern wireless communication systems. Present days mobile communication spectrum, below 3 GHz bands is faces more shortage and not able to serve people with more device connectivity and data speed. The 5th generation mobile technology standards have the guts to deliver high data rates, low-latency communications, and massive device connectivity. For the efficient distribution of the 5G systems and in order to support higher bandwidth need to design efficient antenna at sub 6 GHz and mm wave frequencies. This article presenting, different frequency bands allocated to 5G in the range of sub-6GHz and millimeter wave frequencies in various countries and the problems in utilization of 5G mm-wave spectrum are discussed along with solutions. Review focused in view of acquiring knowledge about the tips to achieve good radiation properties. Previous researchers introduced lot of antenna design techniques like employing dielectric lens, meta-material lens, parasitic elliptical patch, array topologies, creating slits, slots, and stubs etc., to improve gain and bandwidth of antenna. Though these kinds of techniques used in antenna design, there improvement in one antenna property is frequently accompanied by decline in its other property performances. Proposed work also gave the comparative studies on results of different micro strip antennas, designed using various techniques by previous researchers.

Keywords: *5G spectrum, MIMO, composite structures, mutual coupling, beam steering, reconfigurable.*

1. Introduction

A report of telecommunication (ITU) told that up to 2035, 13.2 trillion dollars is going to be created due to 5G technology and 22.3 million jobs going to be created on the base of OEMS (Original Equipment Manufacturers), Operators (Networking Area), Content Provider, App developers and Consumer.

In the future, the largest number of individuals supported by 4G mobile devices will receive a 10 Mbps data stream. Therefore, many researchers and Wi Fi providers have begun to develop the fifth generation of wireless communications [1]. For the rapid growth of wireless consumer products, it is urging to improve the communication quality by using 5G technology [2]. To the world, 5G offering excellent features than fourth generation technology, they are High data rates (1Gbps), Ultra low latency (1ms), High reliable communication, less battery usage, machine to machine communications and Driverless cars. This 5G technology could increase the accessibility of data on the Internet and utilize the spectrum more effectively.

Due to these excellent features the scope of 5G technologies is improving continuously. To implement a quality 5G network it is need to design a good antenna for transmission/reception of signals. To design 5G antennas with good specifications, the author of the article, investigated on challenges, problems and solutions on the design of antennas in order to fulfil the requirements of 5G technologies. The observations from literature is discussed in below sections and summarized in the Table I and Table II.

2. 5G Spectrum

Now, the spectrum used for 4G is less than 3GHz [7], which is in heavy traffic with already existing devices. Some of the ultimate challenges facing 5G are the continued rapid growth of network traffic [5]. End users' requirements continue to increase, making it difficult for the radio access network (RAN) to provide superior coverage, capacity [4] and end-user throughput. It needs wireless operative networks to progressively provide higher capacity more time. Because the current data usage is growing faster than the corresponding revenue, mobile network operators (MNOs) must develop RAN in a way that can reduce cost per bit and improve end-user performance. In order to meet these requirements, 5G antennas are suitable candidates. 5G New Radio can enable frequency bands in the range above 6 GHz [4].The frequency spectrum allocated for 5G is shown in Fig. 1.

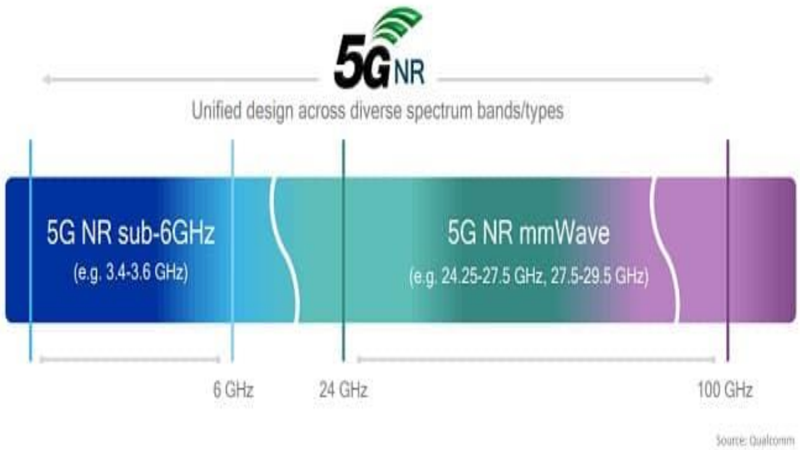

Fig. 1.5G Spectrum

For 5G, the use of spectrum in lower frequency bands i.e. below 6 GHz and higher frequency bands i.e. millimeter wave frequencies is being considered [4,9]. In japan, the frequency bands deployed for 5G in the range of sub-6GHz includes 3.3GHz-4.2GHz, 4.4GHz-4.9GHz. In UK, Europe and Germany 3.4GHz to 3.8GHz where as in china and India 3.3GHz to 3.6GHz is being deployed. The article [9] also shows the unlicensed frequency band in sub-6GHz range that is 5.15GHz-5.925GHz, in several research papers this band has been considered as a probable frequency band for 5G. Same for 5G, various countries being deployed mm-wave frequency bands 24.25GHz-27.5GHz, 26.5GHz-27.5GHz, 26GHz, 37GHz-37.6 GHz and 37.5GHz-42.5GHz. Among them, the 3.5GHz and the 26/28GHz frequency bands are regarded as pioneer bands. The frequencies higher than 60GHz that probably used for 5G are 53.3GHz-66.5GHz, 55.4GHz-66.6GHz, 56.6GHz-64.8GHz, 57.0GHz-64.0GHz and 57-65GHz [9].

In current days, the demand for high-speed cellular data and more spectrum have prompted the use of mm-wave carrier frequencies in future mobile networks [7]. To unify the consistency of millimeter wave frequencies on a global scale, the International Telecommunication Union (ITU) has released a recommended 24-86 GHz frequencies (24.25–27.5, 31.8–33.4, 37–40.5, and 40.5–42.5 GHz) [20] . As the signal frequency increases, atmospheric attenuation will affect the RF signal. The attenuation in free space is mainly caused by signals absorbed by atmospheric gases (such as O2 and H2O) [1, 3]. As shown in Fig. 2, the attenuation upsurges exponentially from 45 GHz to 60 GHz [1, 7]. In the 5G spectrum region of 26-43 GHz, at sea level, the average millimeter wave's atmospheric absorption in the atmosphere shows the lowermost attenuation and the higher frequency [1, 3]. In addition, the Federal Communications Commission (FCC) has given out an announcement of proposed rules for stretchy services in the 28, 37, 39, and 64-71 GHz frequency bands [1, 21]. Therefore, 5G services require spectrum in the 26, 28, and 43 GHz range.

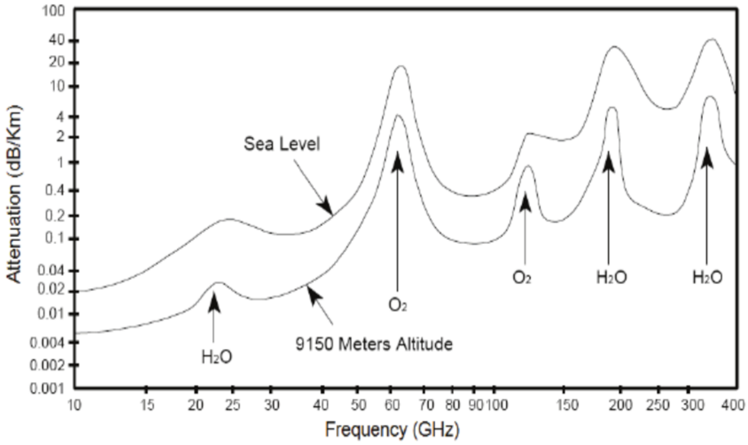

Fig. 2.Attenuation at different frequency bands

So, from above information, it is observed that for lower frequency bands (below 6 GHz), because of there are more interference environments, it is important to increase capacity. For higher frequency spectrum (millimeter frequency range), coverage improvement is very important, because of stimulating propagation and conditions of path loss. Multi-user beam forming allows many user beams to share time and frequency domain resources, it can maximizing the spectrum efficiency of 5G. This can be done by making precise beam-steer control on the antenna to defeat interference initiated by resource sharing [6].

3. Literature Survey

A. Design of ultra-wide tetra band phased array inverted T shaped patch antennas using DGS with beam-steering capabilities for 5G applications [13]

Here, 32×98×1mm^3 sized MIMO re-configurable antenna structure implemented with couple of elements. It can capable of switching among the frequencies 0.6, 1.8, 2.4, 3.5, and 5.5 GHz bands. The structure made with two semi-circular ring-shaped strip-lines and a rectangular slot on the top conducting layer of the substrate as shown in Fig. 3 front and a U-shaped slot, etched on the bottom side of the substrate as shown in Fig. 3 back. Achieved Frequency re-configurable properties with gain above 9.8dBi, Isolation greater than 15dB and envelop correlation coefficient greater than 0.04.

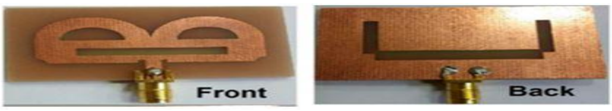

Fig. 3.Single element antenna structure

B. Employment of mixed mode in single-layer micro-strip antenna for ISM/WiMAX/WLAN/Sub 6 GHz 5G mobile communication [14]

Different slotted single layered multi-band (2.5, 3.5, 5.22, 5.8GHz) patch antenna structure as shown in Fig. 4 is presented here. For different slot modifications, the gain enhanced from 3.9GHz to 10.7GHz, efficiency increased from 67%-74% and isolation increased from 15 dB to 20 dB.

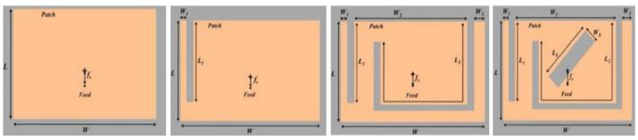

Fig. 4.Single layered patch antenna structure with different slots

C. High-directivity emissions with flexible beam numbers and beam directions using gradient refractive- index fractal meta-material [16]

In this paper High gain (around 15dB) and wide bandwidth in the range of 3GHz-7.5GHz are achieved by implementing 3D emission system as shown in Fig. 5 using gradient-refractive-index (GRIN) meta-materials. These meta-materials are arranged around the radiating antenna. Beam steering is studied by rotating the meta-material lenses with angles 0^0,30^0,45^0 and 60^0.

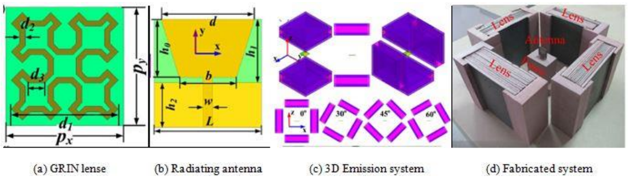

Fig. 5.High directive 3D emission system

D. Hilbert-shaped magnetic wave guided meta-materials for electromagnetic coupling reduction of micro-strip antenna array [19]

Hilbert shaped single negative meta-materials are embedded in MIMO antenna structure as shown in Fig. 6. The inclusion of meta-materials enhanced antenna miniaturization, current path on ground plane and reduced mutual coupling more than 9.7dB.

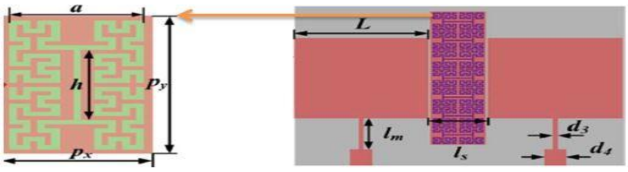

Fig. 6.Hilbert shaped complementary meta-material structure embedded MIMO antenna system

E. Design of ultra-wide tetra band phased array inverted T-shaped patch antennas using DGS with beam-steering capabilities for 5G applications [1]

In this paper in order to improve channel capacity an ultra-wide tetra (28, 43, 51, and 64 GHz) band defected ground structure employed 1X4 MIMO antenna system is designed with T-shaped slotted sectored radiating elements as shown in Fig. 8. This antenna system can capable of steer the beam in ±30^0 and achieved the gain 16.5dBi.

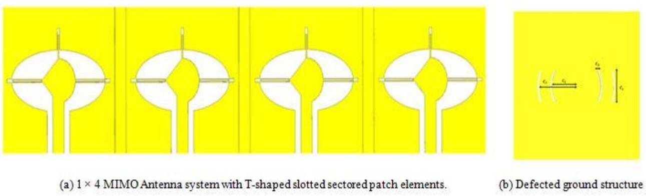

Fig. 7.1X4 MIMO antenna system

F. A Compact Gain-Enhanced Vivaldi Antenna Array with Suppressed Mutual Coupling for 5G mm Wave Application [2]

An eight element antipodal Vivaldi antenna arrays (AVA) as shown in Fig. 9 are implemented in this article in order to reduce mutual coupling. Addition of notches (AVR-CR) on the ground given isolation 37.3dB and extended bandwidth from 24.65–28.5 GHz to 24.55–28.5 GHz, and the gain is improved from 6.96–11.32dB.

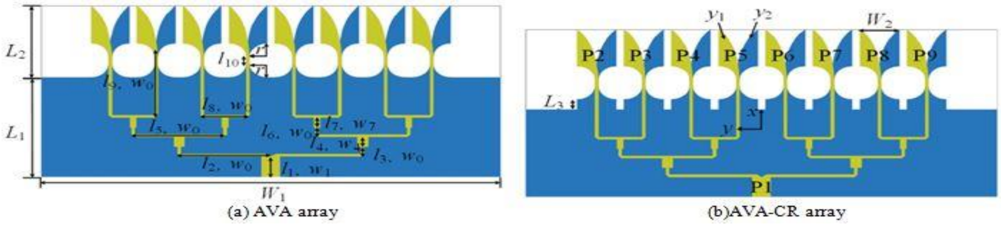

Fig. 8.Eight element antipodal Vivaldi antenna arrays

G. Millimeter-wave T-shaped MIMO antenna with defected ground structures for 5G cellular networks [3]

To fulfill the requirements (compactness, planar geometry, high bandwidth, and high gain performance) the DGS employed 1X4 MIMO antenna array as shown in Fig. 10 is designed using T-shaped radiating elements. Hear the antenna achieved band width from 25.1-37.5 GHz, Gain of 10.6dBi and efficiency greater than 80%.

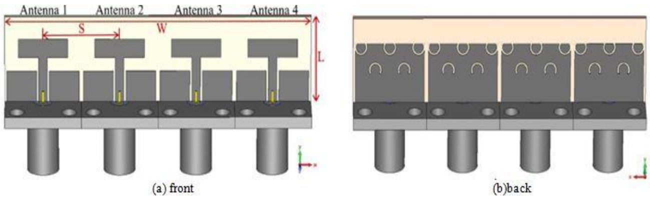

Fig. 9.T-shaped 1X4 MIMO antenna system

4. Existing Problems and Solutions in the design of 5G Microstrip Antenna below 6GHz and mm Wave Frequencies

From the literature survey, it is identified lot of problems that can degrade the performance micro strip antenna and also observed the solutions made by previous researchers to overcome the drawbacks. In this session illustrated problems and solutions occurred in micro strip antenna design, since the use of several design techniques to improve bandwidth, gain and antenna size reduction. Why because, though there is lot of techniques used to solve the problems in antenna design, there improvement in one antenna property is frequently accompanied by decline in its other property performances.

A. *For Bandwidth Enhancement*

So, due to continued rapid growth of network traffic 5G systems need the antennas capable of high channel capacity, the channel capacity increases with the enhancement of bandwidth. Previous researchers illustrated techniques for bandwidth enhancement like increasing substrate thickness [22], antenna structure with height reduction, usage of high permittivity dielectric resonators, electromagnetic band gap structures, split ring resonators [18], elliptical or hemi-spherical cuts on patch [12] and creating slots [28] in the ground plane (DGS). But increases of substrate thickness can degrade antenna efficiency, since more input power will be wasted, due to that insufficient power will be delivered by antenna [8]. Reduction of antenna structure height may also cause to lower radiation efficiency. Adding dielectric resonators with high permittivity to enhance the bandwidth is a poor choice, since the bandwidth is best for low dielectric substrates. In micro strip antenna without dielectric resonator, the amount of total available power from radiation is bounded along the surface of substrate. The article [8] suggested EBG and slot structures are better to improve the bandwidth, where as in [1] it is studied that, Mushroom-shaped electromagnetic band gap structures have been used in thin antennas that can be pattern-reconfigurable. The DGS has been used to improve the efficiency of antennas.

The paper [1], illustrated the significance of DGS and air-filled slots with beam steering capabilities over antenna structure. By using DGS, the antenna can achieve smaller component size, higher bandwidth, harmonic suppression, and higher-order undesired cross-polarization. DGS can cause disturbances, destroying the ground homogeneity and the continuity of surface current [1], this concept has also been demonstrated in [3]. The DGS symmetrical structure plays the role of resonant gaps. These gaps are directly added to both sides of the micro strip line, which can effectively connect the feeder line [1, 3]. DGS also changes the shielding current spreading of ground defects to promote controlled excitation and broadcast of EM energy through the substrate, so that changing the inductive and capacitive reaction of the transmission line [11]. This means that DGS can increase the effective capacitance of the antenna to produce multi-band antennas [1, 3], and can enhance the frequency band trapping capability of the antenna [3]. The required resonant frequency can be adjusted by electing the applicable geometric shape and placing it in the precise position of the premeditated antenna. In papers [2, 3], the authors said that MIMO and Vivaldi array type antenna could be suitable candidates for mm-Wave communication for its wide bandwidth.

TABLE I. OBSERVATIONS FROM ANTENNAS OPERATED AT BELOW 6GHZ FROM LITERATURE SURVEY

Ref. No	Used method to improve antenna performance	Resonated Frequency	Achievements
[13]	MIMO, re-configurable Structure semi-circular ring-shaped strip-lines rectangular and U-shaped slots	1.8GHz 2.4GHz 3.5GHz 5.5GHz	Gain: more than 9.8dB Isolation: more than 15dB Frequency re-configurable envelop correlation less than 0.04
[14]	Several slots in single-layer of Patch element	2.5GHz 3.5GHz 5.22GHz 5.8GHz	Gain:3.9- 10.7dB Efficiency: 67-74 % Isolation: 15dB-20dB
[16]	GRIN Meta-material lens	3-7.5GHz	Gain: around 15dB
[19]	Hilbert-shaped complementary SNG magnetic wave guided meta-material	3.5GHz	Isolation: more than 9.5dB
[24]	MIMO	2.4GHz 5.0GHz 13GHz	Gain:3.43dB Effeciency:66.54 % Directivity: 9.28dB
[25]	Monopole structure with textile substrate in order to reduce the size	2.45GHz	Return losses around -25dB, Used for body centric wireless communication

B. *For Gain Enhancement*

In this session, it is investigated several Gain Enhancement Techniques: adding negative capacitor/inductor, Partial Substrate Removal in Multiple-layer Dielectric Substrate [8], creating slots on patches [10, 14, 28], composite-resonator using meta-material resonators [16, 27], dielectric resonators [15], parasitic elliptical patches [17], and Array topologies: material distribution approach, cavity backing technique in which the shapes and connectivity are essential considerations in design [8]. Compared with traditional slot antennas, the gain and efficiency of slot (filled with air)-antennas have been suggestively enhanced, because current mostly flows through the slot edges [1]. From 27 to 28 GHz, the efficiency of the slot (filled with air)-antenna is 0.5 dB higher than that of the traditional slot antenna. In the sweep range of 0 to 50°, the gain exceeds 13 dB [1].

In [2, 3], it is discussed several gain enhancement techniques; employing dielectric lens, meta-material lens, and parasitic elliptical patch. These papers demonstrated that array techniques MIMO and Vivaldi are usually used to achieve high gains and to solve the inconsistency of side lobes and the mutual coupling of components in array design are also discussed. Due to the high side lobe and high coupling, bandwidth and antenna gain will be degraded.

Many researchers suggested that isolation achievement between the elements will overcome this problem. The isolation can achieve by inserting EBG, SRR, parasitic isolators and meta-material structures [19, 27] between antenna elements [2]. Though these techniques used to improve the isolation, it may cause to increase the geometry complexity. So, it is recommended to use defected ground structures and asymmetric coplanar strip walls to suppress the mutual coupling between MIMO antenna elements [2, 3].

C. *For antenna miniaturization*

Composite structures are very useful for high frequency applications and they can capable of reduction of antenna size also. Usage of Inductors or capacitors, composite meta-material resonators, Magneto-dielectric substrates and fractal geometries composed by self-similar structures are efficient techniques [8] for antenna miniaturization.

Table – 2 Observations From Antennas Operated At Mm-Wave Frequencies From Literature Survey

Ref. No	Used method to improve antenna performance	Resonated Frequency	Achievements
[1]	MIMO, DGS, Inverted T-shaped slotted stubs	28GHz 43GHz 51GHz 64GHz	Gain: 16.5dBi beam steer to ±30°.
[2]	Vivaldi antennas, multiple notches added on the ground	24.55 - 28.5GHz	Gain:6.96-11.32dBi Isolation:37.3 dB
[3]	MIMO, symmetrical split-ring slots as DGS,	25.1 - 37.5GHz	Gain:10.6dBi Effeciency: morethan 80%
[10]	CPW-fed T-shaped patch	26.84 - 29.46GHz	Gain:6.59dBi Effeciency:82.08%
[11]	Micro strip antenna with variations in slots	38GHz 60GHz	Gain:6.5,5.5dBi
[12]	Two electro magnetically coupled patches	28GHz 38GHz	Gain:1.27,1.83 dBi
[15]	MIMO, hemispherical cuts on patch	3.4 - 40GHz	Gain:8,15dB
[17]	Vivaldi opposite structure, with	2 - 32GHz	Gain:Morethan 10dBi
[23]	trimmed edges and trapezoidal dielectric lens	28GHz 38GHz	Gain:7.93,6.9dBi Effeciency: 99%
[26]	Antipodal Vivaldi antenna structure,	38GHz	Gain:23dBi, continuous beam steering, Beam tilting 30^0
[27]	parasitic elliptical patch	3.5 GHz 28 GHz 38 GHz	Compact, triband with 12.9%, 5.8%, and 2.4% bandwidths.

5. Conclusion

In this paper concerning to antenna performance few improved techniques are reviewed based on the previous work in micro strip antennas from past few years and also reviewed some research works in order to understanding the 5G spectrum and its applications. From the investigations it is observed that, for lower frequencies i.e. Below 6 GHz, there are more and more interference-constrained environments, so increasing capacity is essential. For mm-wave wave frequencies, coverage improvement is very important, because of stimulating propagation and conditions of path loss. In order to maximize the spectrum efficiency, interference is suppressed by implementing precise beam-steer control on the antenna, thereby realizing multi-user beam forming. It is also observed that the research have been going on improvement in radiation properties like gain, bandwidth and antenna efficiency. Why because these are the important considerations to develop more accurate and good quality antenna system, and it is not an easy for requirements of the user-defined stringent performance demanded by high frequency wireless applications. For this difficulty it is better to use arrays like MIMO, Vivaldi, etc. and composite structure with meta-materials, DGS and slots in the design. Further, based on their performance, comparison of various antenna designs in range of below 6GHz and mm-wave is done. It can be seen from the comparison that the antenna structures with MIMO, Vivaldi, DGS and Meta-materials maintain the better isolation, small size, beam tilting in different directions, reconfigurable capability with High efficiency and large channel capacity. This work will help to design a qualitative antenna in terms of bandwidth, gain and efficiency with good specifications for 5G wireless applications.

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