Next Generation Antenna: Large scale antenna for Mobile Communication

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Abstract: Cellular Communication technology is stepping towards the 6G and particularly in the context of antennas, 6G will demand a revolution, since they are going to be designed for short wavelength (mm-waves), which easily fit in handsets. There are many practical challenges of 6G requirement, millimeter waves suffer from high attenuation due to rain, to overcome all these challenges as well as free space attenuation, high efficiency, all space coverage antenna; researching configurable, large scale array antenna and radio frequency technology, breaking through the multiband and high integrated radio frequency circuit, including low power consumption, low noise and non-linearity. The crucial challenges include the theory and implementation method of high integration RF circuit optimization design, different antenna types have been exploited for 6G networks.

For device-to-device communication, we have demonstrated that is possible to reach multi-Gbps throughput using spatial multiplexing and a simple RF architecture. a new spectrum at 140 GHz that may play a major role for 6G wireless communication. Terahertz wave has high frequency and wide bandwidth which can meet the requirements of spectrum bandwidth for wireless broadband transmission also terahertz waves are having strong penetration. Terahertz wave is easily absorbed by moisture in the air, which is more suitable for high speed, short distance wireless communication. The constraints include physical barriers to sub-THz wave propagation, which can be blocked or strongly attenuated by walls, trees or even windows. Even in a clear propagation path, high-gain antennas are required

Multi antenna technology, especially very large-scale antenna technology is one of the key technologies to improve the spectrum efficiency of wireless mobile communication system. The large-scale antenna system aims to offer an increased number of antenna module and alters the way in which signals are sent to device by arranging and tuning them in different ways

The more antenna modules that are deployed, the higher the concentration of beams and therefore the lower the beam that each antenna needs to send information. In order to obtain large scale antenna gain, channel status information (CSI) is needed at both transmitter and receiver.

Keywords: The fifth-generation mobile communication, large-scale distributed antenna systems, spectral efficiency, channel state information acquisition, resource allocation.

1. Large Scale Antenna System

The main aim of early mobile systems was to achieve a large coverage area by using a single, high-powered transmitter with an antenna mounted on a tall tower. While this approach achieved very good coverage, it was impossible to reuse same frequencies throughout the system. Any attempts to achieve frequency reuse. The improvement of antenna system performance will inevitably lead to improvement of the overall performance of wireless communication systems result interference. The cellular concept was a major breakthrough in solving the problem of spectral congestion and user capacity. It offered very high capacity in a limited allocation without any major technological changes. [1,3]

In recent years, mobile data traffic has been increasing exponentially. At the same time, as the energy consumption of information and communication technology becomes large, it is very urgent to reduce the energy consumption of mobile communication systems. To meet the future demand for huge traffic volume of wireless data service, the research on sixth generation mobile communication system has been undertaken. [2,3]

Comparison between 4G, 5G and 6G
Android Authority takes a closer look at 4G, 5G and 6G wireless realms as they exist today and show where the worlds intersect and where they have clear distinctions. It’s is also important to define 4G, 5G and 6G because the wireless tribe is an industry in a hurry when it comes to the generation. [5,7,11]

4G is synonymous with Long Term Evolution (LTE) technology, there are two key technologies that enable LTE to achieve higher data throughput than predecessor 3G networks: MIMO and OFDM. Orthogonal frequency division multiplex (OFDM) is a transmission technique that uses a large number of closely-spaced carriers that are modulated with low data rates. It's a spectral efficiency scheme that enables high data rates and permits multiple users to share a common channel. Multiple-input multiple-output (MIMO) technique further improves data throughput and spectral efficiency by using multiple antennas at the transmitter and receiver. It uses complex digital signal processing to set up multiple data streams on the same channel. The early LTE networks support 2×2 MIMO in both the downlink and uplink. [8,9]

The LTE standard uses both forms of duplex operations: Frequency division duplex (FDD) and time division duplex (TDD). 5G is an end-to-end ecosystem to enable a fully mobile and connected society. It empowers value creation toward customers and partners, through existing and emerging use cases delivered with consistent experience and enabled by sustainable business models. [10,12]

Essentially, LTE-A is the foundation of the 5G radio access network (RAN) below 6 GHz while the frequencies from 6 GHz to 100 GHz will explore new technologies in parallel. Take MIMO, for instance, where 5G raises the bar to Massive MIMO technology, a large array of radiating elements that extends the antenna matrix to a new level—16×16 to 256×256 MIMO—and takes a leap of faith in wireless network speed and coverage. [4,9]

The early blueprint of 5G pilot networks mostly comprises of beamforming technology and small cell base stations. The companies like Ericsson, Nokia and Samsung have launched pilot projects using these two technology building blocks and so far results have been encouraging. [5,12]

How 4G and 5G differs while working

1. First and foremost, while the LTE-based 4G networks are going through a rapid deployment, 5G networks mostly comprise of research papers and pilot projects. The wireless industry is broadly targeting 2020 for the widespread deployment of 5G networks. [3,11]
2. Wireless networks till 4G mostly focused on the availability of raw bandwidth, while 5G is aiming on providing pervasive connectivity to lay grounds for fast and resilient access to the Internet users, whether they are on a top of a skyscraper or down under a subway station. Although LTE standard is incorporating a variant called machine type communications (MTC) for the IoT traffic, 5G technologies are being designed from grounds up to support MTC-like devices. [4,17]
3. The 5G networks are not going to be a monolithic network entity and will be built around a combination of technologies: 2G, 3G, LTE, LTE-A, Wi-Fi, M2M, etc. In other words, 5G will be designed to support a variety of applications such as the IoT, connected wearables, augmented reality and immersive gaming.
   Unlike its 4G counterpart, 5G network will offer the ability to handle a plethora of connected devices and a myriad of traffic types. For example, 5G will provide ultra-high-speed links for HD video streaming as well as low-data-rate speeds for sensor networks. [13,15]
4. The 5G networks will pioneer new architectures like cloud RAN and virtual RAN to facilitate a more centralized network establishment and make the best use of server farms through localized data centers at the network edges. [9]
5. Finally, 5G will spearhead the use of cognitive radio techniques to allow the infrastructure to automatically decide about the type of channel to be offered, differentiate between mobile and fixed objects, and adapt to conditions at a given time. In other words, 5G networks will be able to serve the industrial Internet and Facebook apps at the same time. [16,20]

In simple words, 6G is widely believed to be smarter, faster and more efficient than 5G. It promises mobile data speeds 100 times faster than 5G network currently available in limited countries. With speeds of up to 100 times of 100 gigabits per second, 6G is set to be as much as 100 times faster than 5G.

Features	**5G Technology**	**6G Technology**
Frequency Bands	✓ Sub 6 GHz, ✓ mmwave for fixed access	✓ Sub 6 GHz, ✓ mmwave for mobile access exploration of THz bands (above 140 GHz), ✓ Non-RF bands (e.g. optical, VLC) etc.
Data rate	✓ Downlink Data Rate - 20 Gbps, ✓ Uplink Data Rate - 10 Gbps)	✓ 1 Tbps
Latency	✓ 5 ms (Radio : 1 msec)	✓ < 1 ms (Radio : 0.1 msec)

Architecture	✓ Dense sub 6 GHz smaller BSs with umbrella macro BSs ✓ Mmwave small cells of about 100 meters (for fixed access)	✓ Cell free smart surfaces at high frequencies ✓ Temporary hotspots served by drone mounted BSs or tethered Balloons. ✓ Trials of tiny THz cells (under progress)
Application types	✓ eMBB (Enhanced Mobile Broadband) ✓ URLLC (Ultra Reliable Low Latency Communications) ✓ mMTC (Massive Machine Type Communications)	✓ MBRLLC ✓ mURLLC ✓ HCS ✓ MPS
Device types	✓ Smartphones ✓ Sensors ✓ Drones	✓ Sensors and DLT devices ✓ CRAS ✓ XR and BCI equipment ✓ Smart implants
Spectral and energy efficiency gain	✓ 10 x in bps/Hz/m2	✓ 1000 x in bps/Hz/m3
Traffic Capacity	✓ 10 Mbps/m2	✓ 1 to 10 Gbps/m2
Reliability	✓ 10-5	✓ 10-9
Localization precision	✓ 10 cm on 2D	✓ 1 cm on 3D
User experience	✓ 50 Mbps 2D everywhere	✓ 10 Gbps 3D everywhere

Table-1 Showing the comparison between 5G and 6G Technology

2. 6G Concept and Technology

6G is being developed using a host of technologies like Artificial intelligence (AI), Extended Reality (XR), Automation, robotics and many others, working in conjunction with artificial intelligence (AI), the computational infrastructure of 6G will be able to autonomously determine the best location for computing to occur; this includes decision about data storage, processing and sharing. Further high bit rate, high reliability, low latency, green communication, network availability, localization, communication convergence, intelligent networks, high spectral efficiency, high energy efficiency, control, and sensing. [21,22]

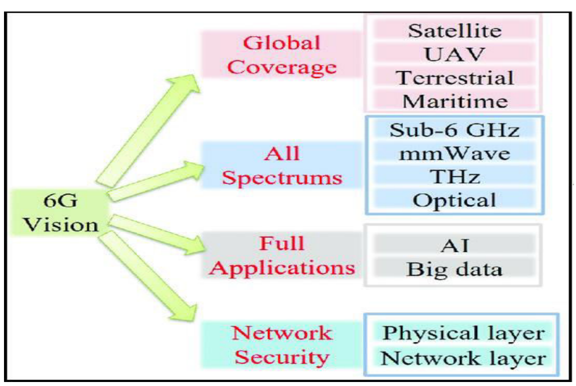


Figure-1 Features of 6G Technology

The rapid development of AI technology has provided possibilities for overcome the challenges to fully enable the future 6G network.so the building of 6G network based on AI technology will be an evitable choice and one of the inherent features of 6G network so called “intelligent connectivity.

Intelligent connectivity will meet two requirements at the same time:

- ✓ All the related connected device in the network itself are intelligent.
- ✓ The complex and huge network itself needs intelligent management.

Information exchange demand are becoming more and more complex with the expansion of human production and living space, Previous generation cellular network aimed at people centered communication needs, evolution of 6G, the object of communication has expanded from human centered communication to the simultaneous communication of things. So, the future wireless communication networks need to take in to account both the deep coverage requirement of people and objects. [21,22]

1) The deep expansion of the connecting object activity space.
2) Deeper perceptual interaction.
3) Deep data mining in the physical network world.
4) In depth nerve interaction.

AR/VR (virtual and Augmented Reality) is considered to be one of the most important requirements of future cellular network, the media interaction will be mainly planar multimedia, high fidelity AR/VR interaction, wireless holographic communication and display can also be carried out at anytime and anywhere .to achieve all these we will face many challenges and this can be summarized as Holographic connectivity.

A vast world will become more and more accessible, three- dimensional coverage and connection to all types of terrain and space, which means deep connectivity emphasizes the depth of the connected objects, while ubiquitous connectivity emphasizes the breadth of the distributed area of the connected objects. [6]

3. Terahertz Communication

Terahertz radiation is typically understood to be electromagnetic radiation in the frequency range from roughly 0.1 THz to 10 THz, corresponding to wavelengths from 3 mm down to 30 µm. Such frequencies are higher than those of radio waves and microwaves, but lower than those of infrared light. The energy of terahertz waves is too low to knock the electrons from atoms, i.e. they do not have the potential to ionize materials, and therefore won't damage living tissue. This makes them very attractive for medical uses, but also for security application, such as scanning airline passengers. [23]

Increasing the carrier frequencies from millimeter wave to THz is a potential solution to guarantee the transmission rate and channel capacity. Due to the large transmission loss of Low-THz wave in free space, it is particularly urgent to design high-gain antennas to compensate the additional path loss, and to overcome the power limitation of Low-THz source. Recently, with the continuous updating and progress of additive manufacturing (AM) and 3D printing (3DP) technology, antennas with complicated structures. [16]

Terahertz radiation is strongly absorbed by the gases of the atmosphere, and in air attenuated to zero within a few meters, so it is not usable for terrestrial radio communication.it can penetrate thin layers of Materials but is blocked by thicker objects.

Terahertz 6G Communication

The THz spectrum is sandwiched between the mm wave and the far infrared bands and has for long, been the least investigated electromagnetic spectrum. The THz band offers much higher transmission bandwidth compared to the mm wave band and more favorable propagation settings compared to the IR band. [19]

THz transmission incur very high propagation losses, which significantly limit the communication distances. Hence, while in aerial, satellite, and vehicular network, THz frequencies can provide low latency communication, the propagation losses can hinder the gains.

Because of its unique characteristics, terahertz communication has many advantages over microwave and wireless optical communication, which determines that terahertz wave has broad application prospects in highspeed short distance broadband wireless communication, broadband wireless secure access, space communication and so on. [13]

- ✓ Terahertz wave is easily absorbed by moisture in the air when it propagates in the air, which is more suitable for high speed, short distance wireless communication
- ✓ Narrower beam, better directivity, stronger anti jamming ability, and can achieve secure communication within 2-5 km
- ✓ Terahertz wave has high frequency and wide bandwidth, which can meet the requirement of spectrum bandwidth for wireless broadband transmission.
- ✓ Space communication, in outer space, terahertz wave has relatively transparent atmospheric windows. it can transmit without loss and achieve long distance communication with very low power.

- ✓ The terahertz band has short wavelength and is suitable for Massive MIMO with more antenna arrays, literature review show that the beam configuration and spatial multiplexing gain provided by Masssive MIMO can overcome the rain and atmospheric degradation of terahertz propagation.
- ✓ Terahertz wave has low photon energy, about10-3ev, only 1/40 of visible light. it can be used as an information carrier to achieve high energy efficiency.
- ✓ Terahertz wave can penetrate the material with a small attenuation, which is suitable for the communication.

4. Evolution and Innovation of antenna system for 6G

The 6G mobile communication system has become an important area with both academic and industrial concerns. 6G will achieve higher access rate, wider communication range with better energy and spectrum efficiency, lower access delay. Faced with the challenge of 6G requirement, large scale antenna technology needs to study and break through the following problems solving the problems of theory and technology realization in the field of cross-band, high efficiency all space coverage antenna ;researching configurable, large scale array antenna and radio frequency technology, breaking through the multiband and high integrated radio frequency circuit, including low power consumption ,high efficiency, low noise and non-linearity. [23,24]

In addition, in order to obtain large scale antenna gain, channel status information (CSI) is needed at both transmitter and receiver, assuming TDD duplex mode, the upstream link pilot sequences from different cells interfere with each other. These problems are very challenging for very large antennas. The number of arrays are more also the number of channels to be estimated will be very large. In Massive MIMO system, transmitters and receivers are equipped with large scale antenna arrays. Terahertz signal arrival consists of a small number of path clusters, and each cluster has only a small angle expansion. [19,21,24]

There are several important factors in the development of antenna and RF system.

- ✓ The internet of space, which is one of the possible evolution directions of 6G, also needs a variety of antenna system that work in Ka and other bands to achieve wider coverage at all time and locations.
- ✓ FSS technique, meta-material, features that are difficult to obtain naturally will enable antennas to be much smaller, more immune to interferences, and much better in performances.
- ✓ For considering antenna performance in the presence of different channel characteristics in different scenarios and applications, antennas with a new configuration are employed.
- ✓ The improvement of antenna system performance will inevitably lead to improvement of the overall performance of wireless communication systems.

5. Terahertz band has irreplaceable advantages for mobile communication

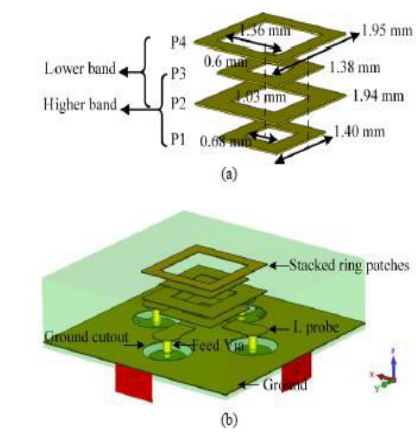
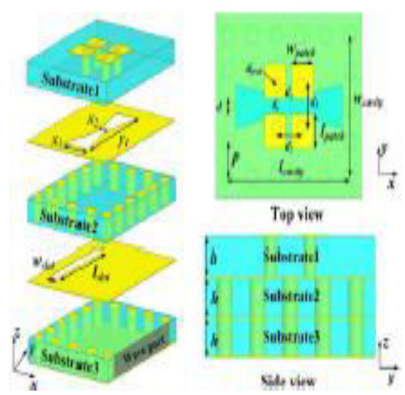
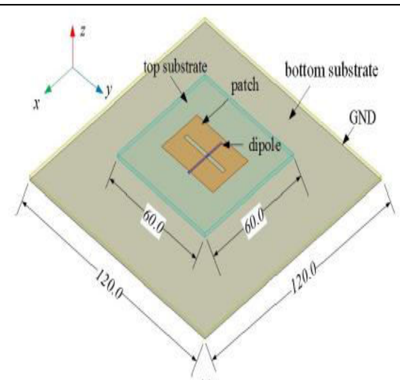
Coverage and directional communication: Terahertz have larger free space fading than low-frequency band. Terahertz propagation characteristics and huge antenna array means that Terahertz communication is highly directional. [16]

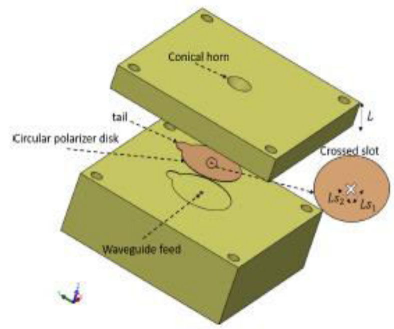
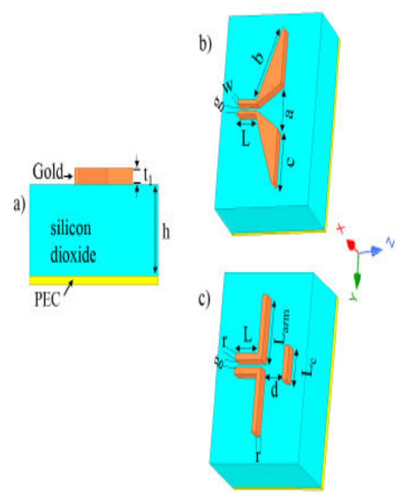
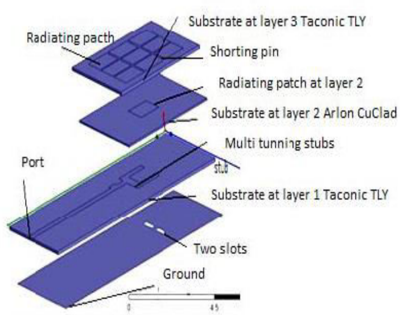
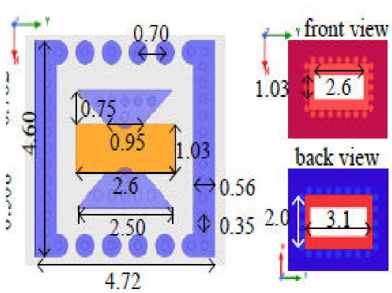
Large scale fading characteristics: Terahertz signal is very sensitive to shadows and has a great influence on coverage, the effect of rainfall fading on terahertz communication is very small. [9]

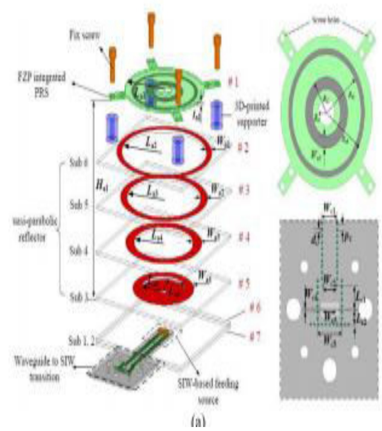
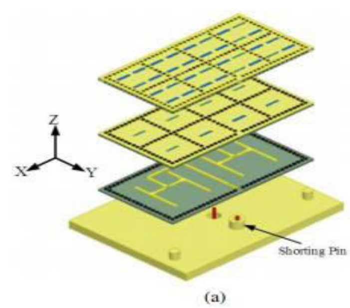
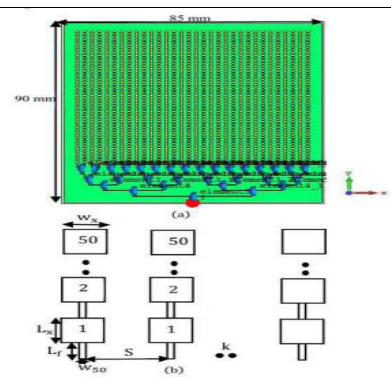
Fast channel fluctuation and intermittent connection: Terahertz system mainly consists of microcells with small coverage and high spatial orientation, it means that path fading, service beam and cell correlation will change rapidly. Also, the coherence time of terahertz band is very small and Doppler spread is large. From the system point of view, it means that the connection of terahertz communication system will be highly intermittent, and a fast adaptive mechanism is needed to overcome this fast-changing intermittent connection problem. [24,25]

Processing power consumption: A major challenge in utilizing very large antennas is the power consumption of broadband terahertz system (A/D) conversion. Power consumption is generally linear with sampling rate, and exponential with sampling number per bit. Large bandwidth and huge antennas in terahertz band need high resolution quantization. [22]

6. Literature Review

A Differential Dual-band Dual-polarized Antenna for 5G mm Wave Communication System	2020 IEEE		Inner length is an additional parameter offered by the ring geometry to control its resonant frequency, impedance and bandwidth. For resonance, the outer length remains between quarter to half-effective wavelength for an antenna array, spacing between the element plays a fundamental role in its far-field performance, particularly gain and grating lobe free scan range. The differential feed has an added advantage in the form of enhancement in radiation performance. The out of phase current on the two probes, cancel their effect on the radiation pattern.
A Review of Broadband Low-Cost and High-Gain Low-Terahertz Antennas for Wireless Communications Applications	IEEE Access April 1, 2020.		The proposed unit cell is composed of a pair of wideband magneto-electric dipoles, together with a substrate-integrated waveguide (SIW) aperture-coupling transmission structure for independent phase adjustability. This element provides a full 360◦ phase coverage and realizes nearly parallel phase response in a wide frequency range. A 40 × 32 array is fabricated by LTCC technology. The measured peak gain of the TA prototype is 33.45 dBi at 150 GHz with the aperture efficiency of 44.03%, and the measured 3-dB gain bandwidth is 124–158 GHz (24.29%)
A Compact Shared-Aperture Hybrid-Mode Antenna for Sub-6G Communication	2019 IEEE		The slot acts as an inductive load for the size reduction. Also, the slotting in the center of the patch may help to suppress the cross polarization level. The slot mode has a large magnitude and it determines the radiation at 4.0 GHz. Apparently, the dipole mode arises at 5.0 GHz and it influences the radiation. The slotted rectangular patch is used to enhance the impedance bandwidth through sequentially exciting multiple resonances in the interested band

Sub-THz Circularly Polarized Horn Antenna Using Wire Electrical Discharge Machining for 6G Wireless Communications	IEEE Access July 6, 2020		The conical horn element is a smooth walled conical horn antenna which is easier to manufacture at high frequencies (i.e. 300 GHz) compared to a corrugated walled which becomes complicated in terms of manufacturing process. The aperture ''ao'' and throat ''ai'' radii of the conical horn plays a very important role in the performance of the antenna such as directivity
Plasmonic Nanoantennas for 6G Intra/Inter-Chip Optical-Wireless Communications	IEEE 2020		The nano-antennas separated by a distance of 1 μm. We must remark here the high electric-field amplitudes at the gold nanorod-tips in Fig. 3, which are due to the excitation of localized surface plasmon resonances. These strongly confined and enhanced optical fields amplify the received signal and then re-radiates it to the neighboring dipole nanoantenna, which in turns excite the fundamental mode of the plasmonic transmission line for communication with an optical nanocircuit. This ability of plasmonic nanorods to capture, enhance, and redirect light make the plantenna design an ideal candidate to work as an optical receiver nanolink
A New Gridded Parasitic Patch Stacked Microstrip Antenna for Enhanced Wide Bandwidth in 60 GHz Band	IEEE 2017		Layer 1 at the bottom is use for feeding microstrip line electromagnetically coupled to the patch and two slots under it. At layer 2 in the middle serve as radiating element with rectangular patch shape for gain the radiating electro-magnetically to the nine gridded patches at the top layer 3. At the layer 3, there are nine patches to reach the maximal bandwidth
A 60 GHz PCB Wideband Antenna-in-Package for 5G/6G Applications	IEEE Antennas and Wireless Propagatio n Letters		As compared with C1 I , the choking current C2 I , the common-mode current on the EW and also co-polarized, has more effect on the radiation, and is much more crucial. To suppress C2 I , a structure composed of the EW, CW, and ground is introduced, the cross section of which is shown in Fig. 2c, also the region A in Fig. 2a. In the structure, one end of the EW and CW is short circuited by the ground with the other end open circuited.

A millimeter-wave Fabry–Pérot cavity antenna using fresnel zone plate integrated PRS,’’	IEEE Trans. Antennas Propag., vol. 68, no. 1, pp. 564–568, Jan. 2020		This work introduces a new structure of PRS to realize gain enhancement. It is the first attempt to apply a fresnel zone plate (FZP) to a single-layer PRS this antenna uses a substrate-integrated quasi-curve reflector and a FZP integrated PRS to form a FPC. With the quasi-curve reflector, multiple resonate modes are excited, providing a wide 3-dB gain bandwidth. This antenna is processed by low-cost and mature PCB technology. The antenna illustrates 17.8% impedance bandwidth from 54 to 64.5 GHz, and the 3-dB gain bandwidth is about 13.3 % (56-64 GHz). The measured peak gain is 21.0 dBi at broadside direction.
A Miniaturized Design of Shared-aperture Antenna with High Aperture Reuse Ratio for 5G Applications	2019 Photonics and Electromagnetics Research Symposium		The SIW cavity-backed slot array has a multilayer structure, which increases the metal thickness of the shorted patch antenna Due to the fringing field at the radiation edge of the folded patch antenna, an additional extended length ΔL will appear to change the resonant frequency The cross polarization of the shorted patch is relatively high due to the magnetic current along the non-radiating side cannot be counteracted after folding the patch antenna. However, the cross polarization can be counteracted by arrays.
High Gain Terahertz Microstrip Array Antenna for Future Generation Cellular Communication	September 05,2020 IEEE EXPLORE		The width of each radiant element (Wx)should be smaller than a half wavelength to reduce SLL and grating lobes. in hybrid feed, a wider BW can be obtained.

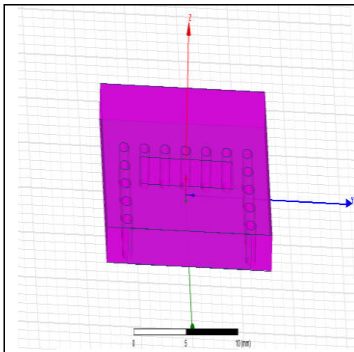


Figure-2a Feeding structure of the proposed antenna

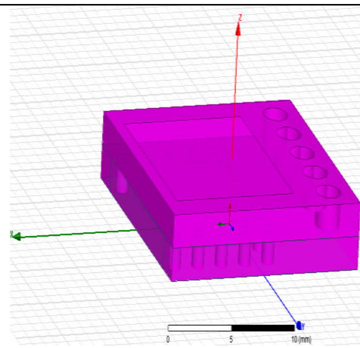


Figure- 2b Two layer of the proposed Antenna

Antenna Parameter	Dimension
Substrate length (l)	16 mm
Substrate width (w)	16 mm
Substrate FR4 (permittivity)	$\varepsilon_r = 4.4$
Upper layer radius via (a)	9.8mm
Inner layer radius via (b)	5mm
Radius of via (R_{via})	1mm
Slot length (ssx)	15 degree
Slot width (ssy)	1mm

Antenna Geometry

Proposed antenna is consisting of two-layer FR4 substrate along with ridge waveguide to provide good gain. The lower layer of the proposed antenna is the feeding structure, and the upper layer of FR4 consists of superstrate along with metallic via to enhance the gain and to maintain the directivity of antenna. Figure 1. Shows the configuration of the proposed antenna which includes the overall three-dimensional view of the proposed antenna. The dielectric constant of the material is 4.4 and surface area size of l x w and height h1 are 16 mm x 16 mm and 1.6 mm respectively. The radius of a metallic vias (via) and pitch (p) are refined in such a manner that it offers minimal leakage of power. SIW aperture coupled feeding is applied to improve the transmission efficiency and achieve a stable radiation pattern. The other end of the microstrip line is connected to the SMA connector.

Antenna has the advantages of low profile, lightweight, conformability to planar or curved surfaces, and easy integration with planar circuits. An astonishing problem arising in the MSA is the appearance of surface waves that generally decrease the antenna efficiency.

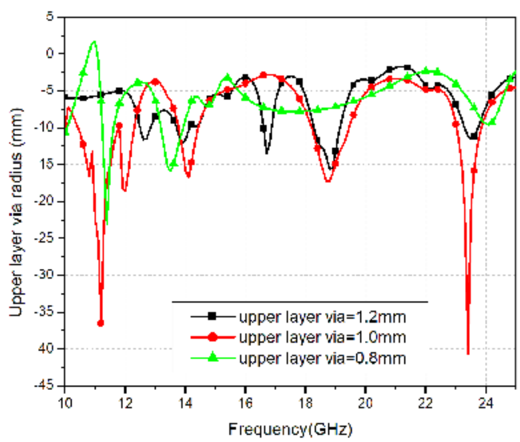


Figure 3: Variation of return loss with frequency for different radius of upper layer via

Effect of radius of upper layer via

Slot between the SIW at lower layer acts as a feeding element element and variation of return loss with resonant frequency for the different value of upper layer via from 0.8mm - 1.2mm exhibit in Figure 3. The radius of upper layer via effects the impedance matching. The upper layer via along with slot of dimension ssx*ssy enhances the gain of the proposed antenna.

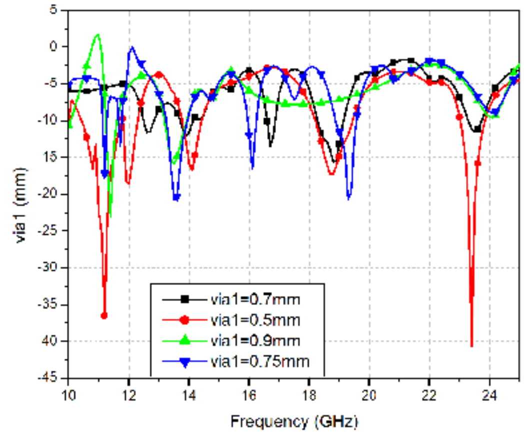


Figure 4: Variation of return loss with frequency for different radius of lower layer via

Effect of radius of lower layer via

Slot between the SIW at Upper layer acts as a superstrate and variation of return loss with resonant frequency for the different value of lower layer via1 from 0.5mm – 0.9mm exhibit in Figure 4. The radius of lower layer via effects the impedance matching as well as the directional pattern of an antenna. The lower layer via along with slot effects the return loss of the antenna.

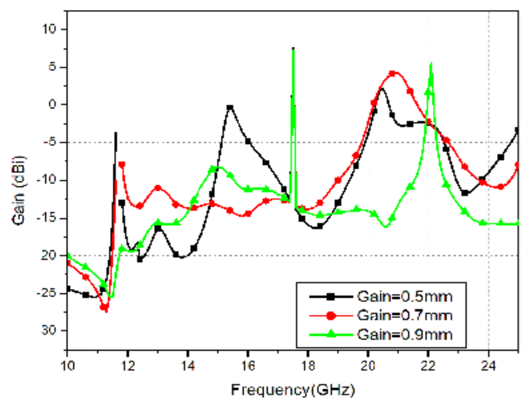


Figure 5: Variation of Gain with frequency at different radius of lower layer via.

Effect of dimensions of upper layer slot

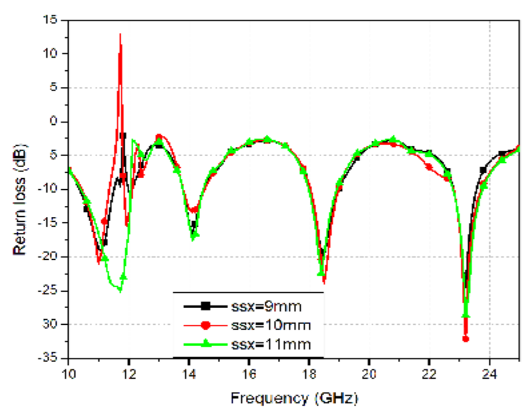


Figure6: Variation of return loss with frequency for different length of superstrate slot

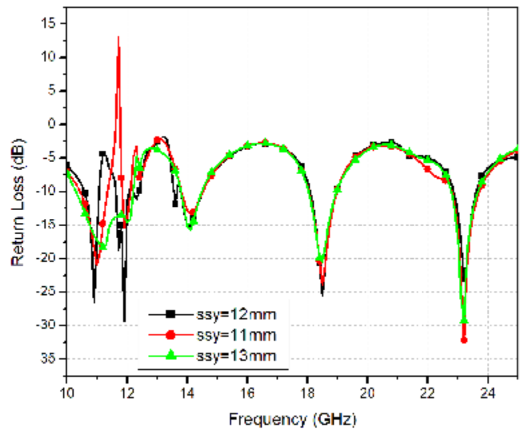


Figure 7: Variation of return loss with frequency for different length of superstrate width

The effect of dimensions of slot at the upper layer, effects the gain, radiation efficiency and front to back ratio of an antenna. Figure 6 and Figure 7shows the variation in ssx and ssy varies the gain of an antenna. Radiation efficiency of an antenna without upper layer 66% and front to back ratio 94.1and along with upper layer the radiation efficiency enhances to 75% but FBR reduces to 34.6

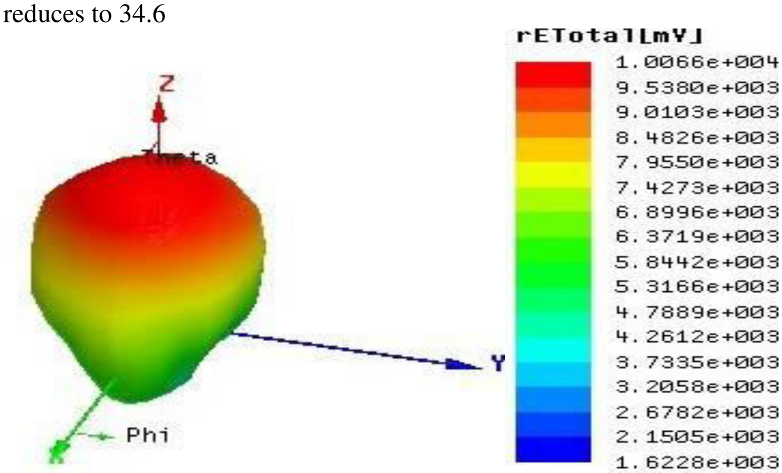
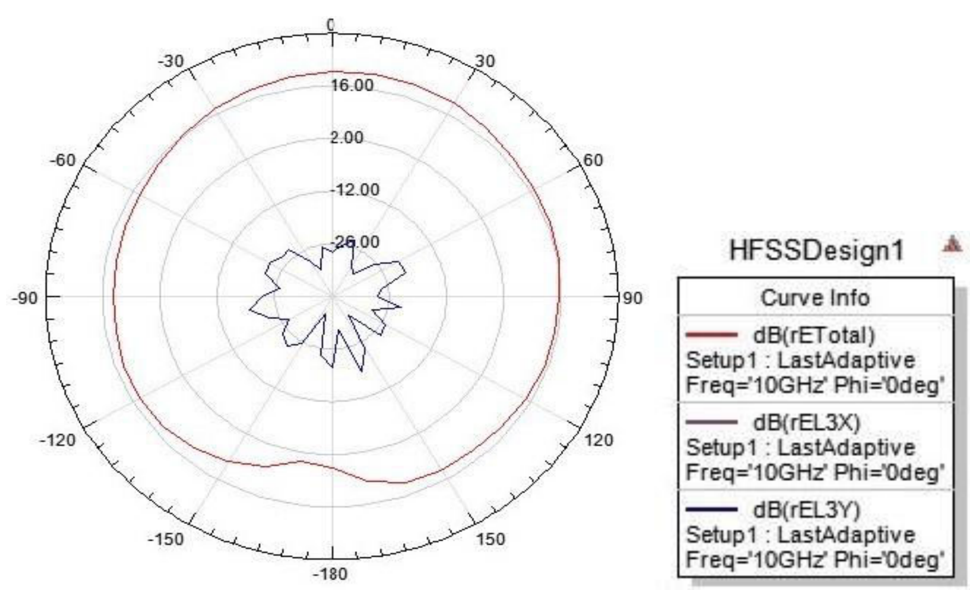


Figure 8: 3D Polar plot of Proposed antenna



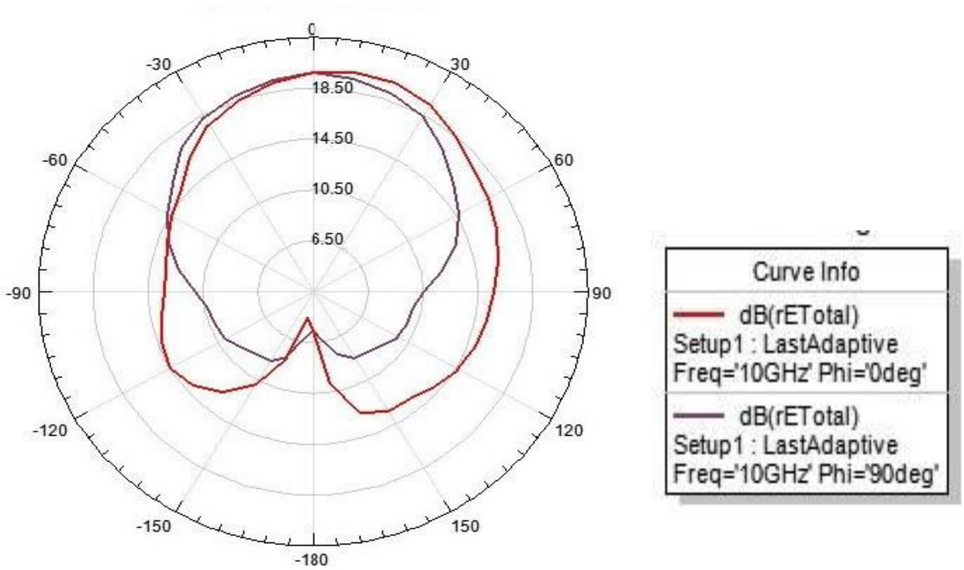


Figure 9: a) YZ-plane radiation pattern at resonance frequency at 15GHz
b) XZ- plane radiation pattern at resonance frequency at 15 GHz

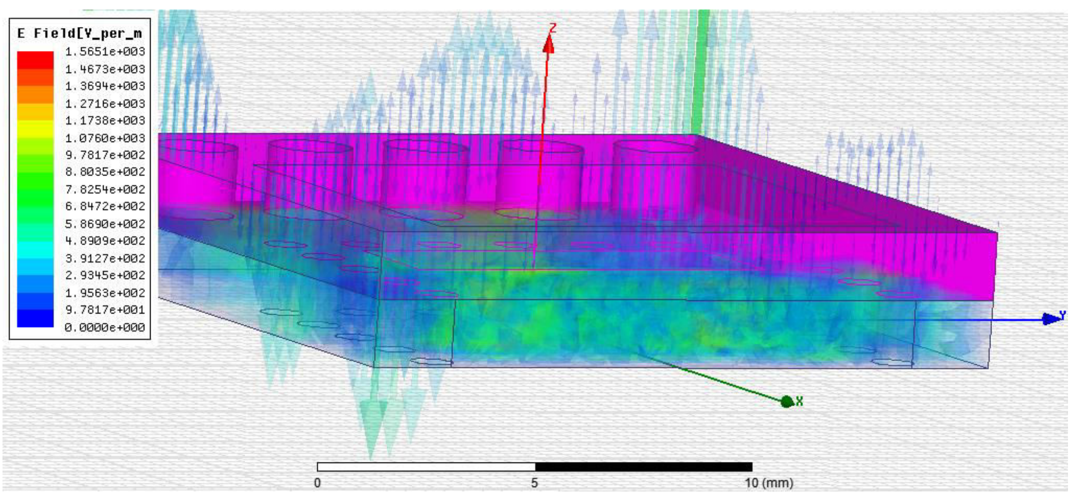


Figure 10: Surface Electric field distribution of proposed antenna (Double Layer)

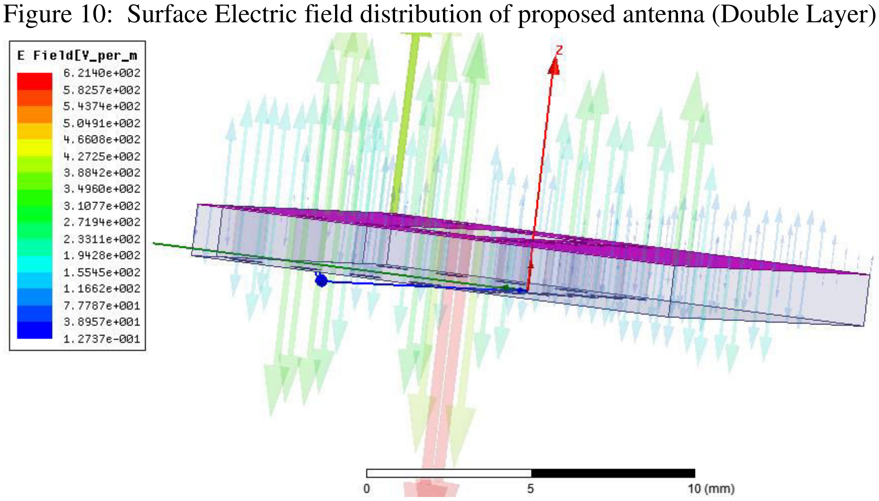


Figure 11: Surface Electric field distribution of proposed antenna (Single Layer)

Result and Discussion

The measured S11 of the proposed antenna offers 23.25 return loss shown in Fig. 11. The surface current flows along the top metal plane of the SIW of both the layer, and on the sides, it can flow vertically along the metalized surface of the cylinders, perturbed by the gaps (if the gaps are small). For this reason, the electromagnetic field confined inside the SIW and there is no radiation leakage. The electric field is normal to the broad wall and its amplitude does not vary in the vertical direction. The radiation efficiency of an antenna is 75%. The gain at the resonance frequency is more than 5dBi. also, the front to back ratio is 34dB.

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