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A survey on design and analysis of MIMO antenna array for 5G application

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***Abstract*---**This paper is a Survey on Design and Analysis of MIMO Antenna Array for 5G Application. 5G is evolving as a technology that will employ both low and high frequencies. The Indian government has taken steps to make the 5G vision a reality. The impact of 5G in India on exponential data usage increase was examined. It goes over the 5G specifications that must be met in order to create a 5G system. Mobile network capabilities are rapidly expanding, driven by new requirements such as latency, traffic volumes, data speeds, and the need for consistent connectivity. Advanced antenna systems (AAS) provide cutting-edge beam shaping and MIMO techniques, which are useful for enhancing end-user experience, capacity, and coverage.

***Keywords*---**SAR, TARC, ECC, diversity gain (DG), link reliability, MIMO.

Introduction

Antenna is also called an aerial, an antenna is a conductor that can transmit, send and receive signals such as microwave, radio or satellite signals. A high gain antenna increases signal strength, where a low-gain antenna receives or transmits over a wide angle. In case of wireless communication systems, antennas play a prominent role as they convert the electronic signals into electromagnetic waves efficiently. Antennas are essential components of all radio equipment, and are used in radio broadcasting, broadcast television, two-way radio, communications receivers, radar, cell phones, Satellite communications and other devices.

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Enabling Technology for 5G

5G Smart Antenna Motivation

On 31st Dec. 2019, Telecom Minister, Ravi Shankar Prasad announce permission for testing of 5G spectrum in India on trials to all operators. The recent progress in carrier aggregation (CA), licensed assisted access (LAA), massive MIMO (MaMi), beam forming techniques, cooperative spectrum sensing (CSS), compressive sensing (CS), machine learning, etc., has provided inspiring and promising approaches to address 5G and beyond challenges. However, at the user equipment (UE) end, limited design budget and hardware resources bring along a series of challenging implementation issues when delivering multi-standard and multi-functional wireless communications.

Table 1
Comparison of design targets between 4G and 5G

Technology	5G	4G
Peak Data Rate (Gbits/s)	20	1
User data rate (Mbps)	100	10
Spectrum Effeciency	3x	1x
Mobility (km/h)	500	350
Latency (ms)	1	10
Connection density (devices/km^2)	10^6	10^5
Network energy effenciency	100	1
Area trafic capacity (Mbit/s/m^2)	10	0.1

Key Enablers

A paradigm shift in the technology that drive networks is taking place to enable diverse services with varying requirements. To fuel the next generation of mobile networks, new ways are being developed. To provide the optimal combination of latency, throughput, and cost effectiveness for many potential application, mobile network operations are being broken up, distributed, and virtualized.

Spectrum

- New bands (3.5 GHz, milimeter wave)
- Large bandwidth to support high data rates
- Efficient use of spectrum through spectrum sharing technique-Licensed Share Access (LSA)
- Use of unlicensed band for offloading the traffic

Network

- Network designification through small cells
- New front haul, mid haul, back haul solutions
- Massive MIMO antenna (beam forming)

- Distributed network
- Edge computing to support low latency application
- Cloud and user plane sepration
- Softwarization
  -Network Function Virtualization (NFV)
  -Software Defined Networking (SDN)
- Network slicing (Network as a service) to support application specific QoS
- Real time machine learning/Artificial intelligence

Furthermore, high frequency bands have far more bandwidth than bands below 1GHz, making it possible to provide much wider channels and faster speeds. The usage of spectrum in three separate frequency ranges (below 1 GHz, 1-6 GHz, and over 6 GHz) supports a variety of use cases with various requirements. Licensed spectrum sharing is an example of a spectrum sharing strategy. LSA (Local Shared Access) increases spectrum use. In addition, combining unlicensed and licenced spectrum increases access network capacity and improves the wireless experience for customers.

MIMO Solution for 5G

Advanced antenna systems (AAS) have become a feasible alternative for large-scale deployments in present 4G and future 5G mobile networks thanks to recent technological advancements. It improves network performance in both the uplink and downlink directions. MIMO refers to the ability to send several data streams over the same time and frequency resource, each of which can be beam shaped. The capacity to focus radio energy over a radio channel toward a specific receiver is known as beam shaping. Constructive addition of the matching signals at the UE receiver can be performed by altering the phase and amplitude of the transmitted signals, which increases the received signal strength and hence the end-user throughput. Because of the additional degrees of freedom given by the larger number of radio chains, often known as Massive MIMO, applying AAS features to an AAS radio results in significant performance benefits. Large frequencies are necessary for providing high data rates in 5G, but their propagation is difficult. The deployment of improved antennas is critical in combating the difficult propagation circumstances at these frequencies.

Literature Review

- Hsiang Nerng Chen et al. [1] have presented Circularly polarized (CP), MIMO, dielectric resonator antenna (DRA) with electromagnetic band-gap (EBG) structure etched onto the ground plane of the MSTL. Specifications of antenna are 3.3 to 3.8 GHz in the Republic of Korea, bandwidths of 18.5% (3.34 to 4.02 GHz) verified with the diversity analysis of ECC, DG, and CCL. The Dielectric Substrate used for fabrication is FR-4. The Software and Hardware used is HFSS, N5224A PNA Network Analyzer, anechoic chamber and application of antenna is in 5G wireless, MIMO applications.
- Jia-Nan Sun et al. [2] have presented Dual-polarized magneto-electric dipole antenna. It consists of four fishtail-shaped patches horizontally placed and four vertically placed patches shorted to the ground. Specifications of antenna are 3.05 to 4.42 GHz, covering the entire N77(3.3 GHz-4.2

GHz)/N78(3.3 GHz-3.8 GHz) band, achives relative bandwidth of 62% ranging from 2.18 to 4.11 GHz with isolation over 28 dB. The Software and Hardware used is HFSS, Agilent N9918A and anechoic chamber and Application of antenna is sub-6GHz 5G wireless communications.

- Botao Feng et al. [3] have presented Dual polarized magneto-electric dipole antenna with dual wide beamwidths, Dual-layer U-shaped electric dipoles are cooperated along with 3D MIMO. Specifications of antenna are 3.5 GHz and 4.9 GHz, impedance bandwidth of 22.6% with the stable gain of 6.9 dBi. The Dielectric Substrate used for fabrication is Copper patch of 0.3-mm thick with a dielectric constant of 1 and a loss tangent of 0. The Software used is Ansoft HFSS and Application of antenna is 5G microcell applications.
- Bao-Jian Wen et al. [4] have presented Wideband resonance-based reflector (RBR) is proposed for front-to-back ratio (FBR) bandwidth enhancing antenna with a low profile. The bow-tie antenna consists two symmetric teardrop-shaped patches. Specifications of antenna are 3.48 to 6.12 GHz (55.00%), Impedance bandwidth of the -10 dB and maximum FBR is up to 20.4 dB. The Dielectric Substrate used for fabrication is F4B (metamaterial). The Software and Hardware used is Vector network analyzer (AV3656B), FBR and gain were measured by the NSI2000 system in an anechoic chamber and Application of antenna is 5G system applications.
- Guiping Jin et al. [5] have presented Four PIN diode (BAR64-02V) switches arranged on the two substrates, differentially fed frequency reconfigurable antenna. Specifications of antenna are Two states operating at 2.45- and 3.50-GHz, impedance bandwidth from 2.37 to 2.67 GHz (11.9%) and from 3.39 to 3.62 GHz(6.6%) for -10 dB. The Dielectric Substrate used for fabrication is FR4. The Software and Hardware used is Ansys HFSS and Application of antenna is WLAN (2.45 GHz) and sub-6-GHz 5G (3.50 GHz) applications.
- Yasin Kabiri et al. [6] have presented 4 element, IFA, MIMO antenna, Specifications of antenna are 2.11 GHz with bandwidth set to 100 MHz. The Dielectric Substrate used for fabrication is FR4 and Application of antenna is massive MIMO antenna for the 5G system.
- Syeda I. Naqvi et al. [7] have presented Defected Ground Structure (DGS), consists of rectangular shaped patch with trimmed corners and edges along with double bowtie slots at the centre of the patch. Specifications of antenna are 27.3-28.6 GHz, with 1.3 GHz bandwidth. The Dielectric Substrate used for fabrication is 0.508 mm thick Rogers RT/Duroid 5880 substrate has relative permittivity = 2.2, and a dielectric loss tangent= 0.0009. The Software and Hardware used is CST, MWS, Rohde & Schwarz ZVA 40 Vector Network, ORBIT/FR, anechoic chamber Analyzer and Application of antenna is 4G LTE or 5G wireless communication applications.
- Joni Kurvinen et al. [8] have presented Conventional 1x4 Vivaldi antenna design with microstrip to slot-line transition is used in a linear four-element array enclosed inside a plastic. Specifications of antenna are 25–30 GHz, supports beamsteering angles of at least ±25 deg , peak gain of 7 dBi. The Dielectric Substrate used for fabrication is 0.101-mm thick Rogers RO4350B substrate (r = 3.48, tan = 0.0037). The Software and Hardware used is CST Microwave Studio, vector network analyzer and far-field

measurements, NSI2000 planar nearfield scanner equipped with WR-28 measurement probe and Application of antenna is 4G LTE and 5G wireless communication applications.

- Muhammad Kamran Ishfaq et al. [9] have presented four-element compact phased Planar Inverted-E Antenna (PIEA) array, Peak gain is 8.36 dBi, -19 dB in the operational bandwidth from 5.7 to 6.4 GHz, max. scanning angle of 70 deg. Specifications of antenna are Peak gain is 8.36 dBi, -19 dB in the operational bandwidth from 5.7 to 6.4 GHz, max. scanning angle of 70 deg. The Software and Hardware used is CST Microwave Studio (v. 2016) and Application of antenna is 5G communication applications.
- Mohamad Mantash et al. [10] have presented 2x2 Yagi Uda antenna, circularly polarized electromagnetic band-gap (EBG) antenna array backed by an artificial magnetic conductor (AMC) with beam-switching capability. Specifications of antenna are 26 to 32-GHz, a gain of 11.9 dBi, and an axial ratio bandwidth of 10% from 28 to 31 GHz. The Dielectric Substrate used for fabrication is Rogers RO3006 substrate permittivity of 6.15 and thickness of 0.254 mm. The Software and Hardware used is Anritsu M54647A 70 GHz vector network analyzer, anechoic chamber and Application of antenna is 5G communication applications.
- Yixin Li et al. [11] have presented 12-port dual-band massive MIMO antenna array using, inverted pi -shaped antenna (IA), longer inverted L-shaped open slot antenna (LA) and shorter inverted L-shaped open slot antenna (SA) are disposed at edges of the system circuit board. 3400 3800 MHz (LTE bands 42/43) and 5150 5925 MHz (LTE band 46) for future 5G mobile handsets. Specifications of antenna are 3400-3800 MHz (LTE bands 42/43) and 5150 5925 MHz (LTE band 46) for future 5G mobile handsets. The Dielectric Substrate used for fabrication is FR4 dielectric substrate and Application of antenna is 5G multiband MIMO applications.
- Manoj Stanley et al. [12] have presented Four sub-arrays of 12 patch antenna elements each providing 90o in the elevation plane have been integrated into the mobile phone chassis for providing 360o coverage. 24-28 GHz, bandwidth of 7.3 GHz. Specifications of antenna are 24-28 GHz, bandwidth of 7.3 GHz. The Dielectric Substrate used for fabrication is Rogers RT5880. The Software and Hardware used is CADFEKO, VNA and Application of antenna is 5G smartphone applications.
- Haiwen Liu et al. [13] have presented1x8 E-plane, a miniaturized gain-enhanced antipodal Vivaldi antenna (AVA) with gradual corrugated edges (GCEs) and triangular metal directors (MDs), gain at lower frequencies has been improved by GCEs at each radiate arm. Two triangular MDs are added to improve the gain at higher frequencies without the need of extra circuit size. 24.75 to 27.5 GHz. Specifications of antenna are Impedance bandwidth of 24.75 to 27.5 GHz. The Dielectric Substrate used for fabrication is Rogers RT 5880. The Software and Hardware used is Electromagnetic (EM) simulator, Altair FEKO 7.0 and Application of antenna is 5G communication applications.
- Muftah Asaadi et al. [14] have presented Frequency selective surface (FSS) superstrate layer is proposed for gain and bandwidth enhancement of low profile, linearly polarized square dense dielectric patch antennas. 28 GHz. Specifications of antenna are Antenna acquire a measured gain of about 17.78 dBi at 28 GHz with a 9% bandwidth and radiation effeciency of 90%.

The Dielectric Substrate used for fabrication is For DD patch Rogers RT/duroid 6002 (r= 2.94 and tanD= 0.0009), bottom substrate is a Rogers RT 3010 (r=10.2 and tanD= 0.0023), thickness (h1 = h2= 0.787 mm). The Software and Hardware used is CST and Application of antenna is Millimeter-wave wireless communications.
- Nosherwan Shoaib et al. [15] have presented 8x8 H-shaped MIMO antennas. 25.2 GHz with a 6-dB percentage bandwidth of 15.6% with gain above 7.2 dB with a maximum value of 8.732 dB. Specifications of antenna are 25.2 GHz with a 6-dB percentage bandwidth of 15.6% with gain above 7.2 dB with a maximum value of 8.732 dB. The Dielectric Substrate used for fabrication is Rogers RT-5880. The Software and Hardware used is CST and Application of antenna is compact 5G devices.
- Waleed El-Halwagy et al. [16] have presented Via-fence surrounds the dipole structure connected to a parallel-strip line (PS). Specifications of antenna are 28 GHz. The Dielectric Substrate used for fabrication is Rogers RO5880 substrate (with dielectric constant 2.2 and loss tangent 0.0009). The Software and Hardware used is ZVA67 Rohde&Shwarz, NSI 2000 near field anechoic chamber, ANSYS HFSS, VNA and Application of antenna is 5G wireless devices transceivers.
- Nor Hidayu Shahadan et al. [17] have presented An array consist of three elements dielectric resonators (DRs). The beam can be steered by adjusting the value CA and CB at port 2 and port 3, respectively. Specifications of antenna are Steer from -32 deg to +32 deg at 15 GHz. The Dielectric Substrate used for fabrication is Duroid 5880 dielectric substrate with a permittivity of 2.2, thickness of 0.254 mm and a loss tangent of 0.001. The Software and Hardware used is ANSYS HFSS and Application is 5G IoT applications.

Reviewed articles are selected from latest pear reviewed IEEE conference or journal. The literature review of selected 50 paper out of 108 paper is summarized in Table 2.

Research Gap from Research Variable

All the articles reviewed are observed carefully for research variable to be satisfied and proposed research variables are presented in Table 2 to find research gap.

Table 2
Research Variable for 5G MIMO Antenna

Sr. No.	Research Variable	Paper	Sr. No.	Research Variable	Paper
1	Bandwidth	30	17	User Proximity Analysis	1
2	Beam Steering	7	18	Vertical Polarization	8
3	Beam width	3	19	VSWR	1
4	Channel Capacity (CC)	8	20	Single sub-6GHz Frequency Band	19
5	Compact Size	15	21	Multiple sub-6GHz Frequency Band	18

6	Data Rate	1	22	Single sub-28GHz Frequency Band	15
7	Frequency Reconfigurable	2	23	Multiple sub-28GHz Frequency Band	1
8	Gain	22	24	Single sub-60GHz Frequency Band	0
9	Horizontal Polarization	7	25	Multiple sub-60GHz Frequency Band	0
10	Isolation	21	26	Envelope Correlation Coefficient	21
11	Link Reliability	1	27	Diversity Gain (DG)	6
12	Low Profile	10	28	Channel Capacity Loss (CCL)	3
13	Radiation Efficiency	23	29	Mean Efficient gain (MEG)	4
14	SAR Analysis	6	30	Front to Back Ratio (FBR)	5
15	Signal-to-Noise Ratio	1	31	Beam switching	5
16	Total active reflection coefficient (TARC)	3			

About 31 research variable are selected from literature review of 50 selected article. Graphical representation of all the research variable verses number of article is as shown in figure 1. All the research variable are observed carefully and cutoff of 7 is selected. Below which all the research variable are selected as objective of proposed research.

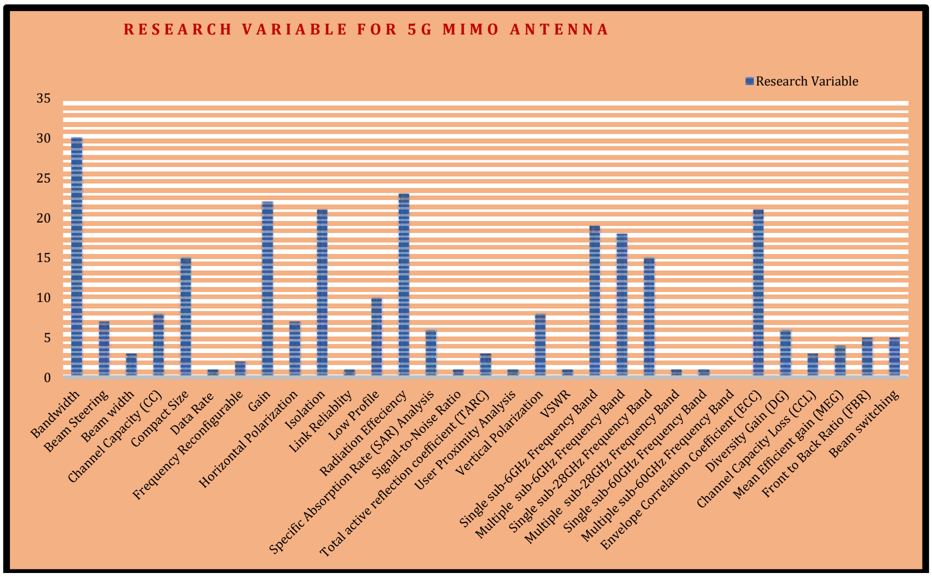

Figure 1: Research Variable for 5G Antenna

Research Gap

About 12 research variables are below cutoff line and they are as follow:

- To design Beam Steering, Frequency Reconfigurable, sub-28GHz Frequency Band antenna for 5G application.
- To Keep Channel Capacity, Data Rate high.
- To perform analysis of Specific Absorption Rate (SAR), Total active reflection coefficient (TARC), Envelope Correlation Coefficient (ECC) and Diversity Gain (DG).
- To test the antenna performances in terms of:
  – Link Reliability
  – Mean Efficient gain (MEG)
  – Front to Back Ratio (FBR)

Proposed Objectives

Proposed objective of proposed research is listed below:

- To design and develop massive MIMO antenna array for future 5G application.
- To enhance Gain, Bandwidth, Isolation, Radiation Efficiency for multipath propagation in 5G MIMO systems.
- To perform Diversity analysis using the S-parameters method.
- To test the antenna performances in terms of:
  – Mean Efficient gain (MEG) to evaluate the correlation and the polarization diversity.
  – Front to Back Ratio (FBR) bandwidth for unidirectional pattern.
- To test developed antenna by experimentation using Vector Network Analyser (VNA) and an anechoic chamber.

Proposed Methodology

A methodology for proposed research is proposed as below:

- Design and test conformal antenna using CST Simulation Software
- Fabrication of Conformal antenna
- Testing of antenna by experimentation using Vector Network Analyser (VNA) and an anechoic chamber.
- Comparative Study

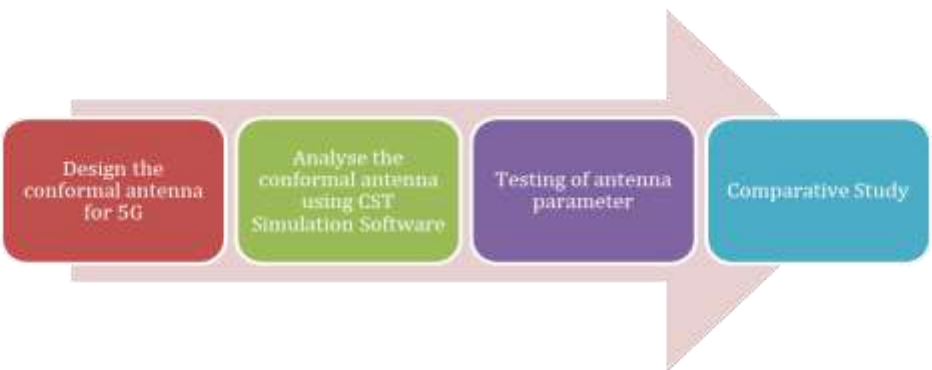

Figure 2: Work Flow

Summary and Discussion

A 5G High Level Forum (5G HLF) was set up by the Government in September 2017 to articulate the vision for 5G in India and to recommend policy initiatives & action plans to realize this vision. Mobile network capabilities are evolving quickly, continuously pushed by new requirements relating to latency, traffic volumes, data rates and need for reliable connectivity. AAS enables state of the art beam forming and MIMO techniques that are powerful tools for improving end-user experience, capacity and coverage. It significantly enhances network performance in both uplink and downlink.

Conclusion

In this research, we can investigate recent 5G technologies focused on design and analysis of MIMO antenna array for 5G application to measure Gain, Bandwidth, Isolation, Radiation Efficiency for multipath propagation in future 5G MIMO systems. The performance of diversity analysis using the S-parameters method can carried out to find correlation. The antenna performances in terms of Mean Efficient gain (MEG) can be investigate to evaluate the correlation and the polarization diversity. Similarly Front to Back Ratio (FBR) bandwidth can be calculated for unidirectional pattern.

References

Bao-Jian Wen1, Lin Peng, Xiao-Feng Li, Kun-Shan Mo, Xing Jiang, & Si-Min Li (2019). A Low-Profile and Wideband Unidirectional Antenna Using Bandwidth Enhanced Resonance-Based Reflector for Fifth Generation Systems Applications, IEEE Access, (vol. 7). pp. 27352-27361.

Botao Feng, Can Zhu, Jui-Ching Cheng, Chow-Yen-Desmond Sim, & Xinyuan Wen (2019). A Dual-Wideband Dual-Polarized Magneto-Electric Dipole Antenna with Dual Wide Beamwidths for 5G MIMO Microcell Applications, IEEE Access, (vol. 7). pp. 43346-43355.

Guiping Jin, Chuhong Deng, Ju Yang, Yechun Xu & Shaowei Liao (2019). A New Differentially-Fed Frequency Reconfigurable Antenna for WLAN and Sub-6GHz 5G Applications, IEEE Access, (vol. 7). pp. 56539-56546.

Haiwen Liu, Wenjuan Yang, Anxue Zhang, Shuangshuang Zhu, Zhengbiao Wang, & Taotao Huang (2018). A Miniaturized Gain-Enhanced Antipodal Vivaldi Antenna and Its Array for 5G Communication Applications, IEEE Access, (vol. 6). pp. 76282-76288.

Hsiang Nerng Chen, Jeong-Moon Song, & Jung-Dong Park (2019). A Compact Circularly Polarized MIMO Dielectric Resonator Antenna Over Electromagnetic Band-Gap Surface for 5G Applications, IEEE Access, (vol 7). pp. 140889-140898.

Jia-Nan Sun, Jia-Lin Li, & Lei Xia. (2019). A Dual-Polarized Magneto-Electric Dipole Antenna for Application to N77/N78 Band, IEEE Access, (vol. 7). pp. 161708-161715.

Joni Kurvinen, Henri Kähkönen, Anu Lehtovuori, Juha Ala-Laurinaho & Ville Viikari (2019). Co-Designed mm-Wave and LTE Handset Antennas, IEEE Transactions on Antennas and Propagation, (vol. 67). pp. 1545-1553.

Manoj Stanley, Yi Huang, Hanyang Wang, Hai Zhou, Ahmed Alieldin & Sumin Joseph (2018). A Capacitive Coupled Patch Antenna Array with High Gain and Wide Coverage for 5G Smartphone Applications, IEEE Access, (vol. 6). pp. 41942-41954.

Mohamad Mantash & Tayeb A. Denidni (2019). CP Antenna Array with Switching-Beam Capability Using Electromagnetic Periodic Structures for 5G Applications, IEEE Access, (vol. 7). pp. 26192-26199.

Muftah Asaadi, Islam Afifi & Abdel-Razik Sebak (2018). High Gain and Wideband High Dense Dielectric Patch Antenna Using FSS Superstrate for Millimeter-Wave Applications, IEEE Access, (vol. 6). pp. 38243-38250.

Muhammad Kamran Ishfaq, Tharek Abd Rahman, Mohamed Himdi, Hassan Tariq Chattha, Yasir Saleem, Bilal A. Khawaja & Farhan Masud (2019). Compact Four-Element Phased Antenna Array for 5G Applications, IEEE Access, (vol. 7). pp. 161103-161111.

Nor Hidayu Shahadan, Mohd Haizal Jamaluddin, Muhammad Ramlee Kamarudin, Yoshihide Yamada, Mohsen Khalily, Muzammil Jusoh & Samsul Haimi Dahlan (2017). Steerable Higher Order Mode Dielectric Resonator Antenna with Parasitic Elements for 5G Applications, IEEE Access, (vol. 5). pp. 22234-22243.

Nosherwan Shoaib, Sultan Shoaib, Riqza Y. Khattak, Imran Shoaib, Xiaodong Chen & Aqib Perwaiz (2018). MIMO Antennas for Smart 5G Devices, IEEE Access, (vol. 6). pp.77014-77021.

Syeda I. Naqvi, Aqeel H. Naqvi, Farzana Arshad, Muhammad A. Riaz, Muhammad A. Azam, Mansoor S. Khan, Yasar Amin, Jonathan Loo & Hannu Tenhunen (2019). An Integrated Antenna System for 4G and Millimeter-Wave 5G Future Handheld Devices, IEEE Access, (vol. 7). pp. 116555-116566.

Waleed El-Halwagy, Rashid Mirzavand, Jordan Melzer, Masum Hossain & Pedram Mousavi (2018). Investigation of Wideband Substrate-Integrated Vertically-Polarized Electric Dipole Antenna and Arrays for mm-Wave 5G Mobile Devices, IEEE Access, (vol. 6). pp. 2145-2157.

Yasin Kabiri, Alejandro L. Borja, James R. Kelly & Pei Xiao (2019). A Technique for MIMO Antenna Design with Flexible Element Number and Pattern Diversity, IEEE Access, (vol. 7). pp. 86157-86167.

Yixin Li, Chow-Yen-Desmond Sim, Yong Luo & Guangli Yang (2018). 12 -Port 5G Massive MIMO Antenna Array in Sub-6GHz Mobile Handset for LTE Bands 42/43/46 Applications, IEEE Access, (vol. 6). pp. 344-354.