Survey: 5G for future aerial communications

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Using previous research work, we conducted a survey on the current state of 5G technology towards its future in network communications.

Abstract
The increase in research under 5G network technology in industries, universities, and private sectors has clearly indicated the need for high and powerful antennas to meet the needs of high-speed communication as well as the internet of things [1]. Researchers have clearly stated the positive and negative effects of 5G technology in the future, and the 5G aerial communication mechanism has hampered several consequences in our daily lives[2]. 2022-January-04: The aviation industry threatened AT&T and Verizon companies to remove all 5G antennas in airports, stating that wireless carriers' 5G radios using C-band spectrum will interfere with aircraft altimeters, which are used to measure altitude. 5G antennas could cause interference due to the narrow gap between the frequencies of 5G and radio altimeters, which will result in airplanes missing the main runway[3]. This has caused a rise in questions about 5G aerial technology for future communication. In this survey, we will look at the kinds of antennas suggested by other researchers and the impact of antennas on UAVs, mobile phones, and the Internet of Things (IoT), as well as how some of the problems will be solved for the future of 5G aerial networks to provide secure network communication.

Index Terms: antenna (aerial), SISO, MIMO, mMIMO, mWave, Full-Duplex Communication, C-band.

1. Introduction
Since 2021, 5G technology has grown in popularity, and because it is open to everyone in terms of development, significant progress has been made. 1G-LTE, like all other network communications, had flaws. 5G has its own set of flaws [2]. The most common is that the distance coverage is very low in comparison to 4G, and it is highly affected by obstacles of all kinds, including wind and massive vibration, which has an impact on frequency. Some countries have banned 5G, claiming that it will cause cancer, which is false. Because of collisions with airplane altimeters, it is also prohibited in airports. All of these issues have numerous solutions, ranging from selecting the type of antenna to use in various situations and locations.Many researchers have detailed the solutions that can be implemented, paving the way for 5G's future communication life. In terms of network speed and data packets transferred per second, 5G has a significant advantage[5 , 8].

2. MIMO & Massive MIMO
MIMO is an abbreviation for Multiple Input - Multiple Output, and a MIMO system consists of at least two antennas for reception and two for transmission, if not more. A MIMO capable base station can receive data from multiple sources and transmit it to multiple users. Massive MIMO is a MIMO system extension in which the number of antennas in the array exceeds 64. A system like this has the advantage of being able to serve more clients at the same time. 12 antennas are typically used in 5G base stations: 8 for transmission and 4 for reception[4 , 5].

3. Full-duplex communication
This communication method allows simultaneous broadcast and receipt of information on the same frequency using the same antenna. This is accomplished by utilizing silicon transistors, which disrupt the reciprocity of the antenna and allow it to send and receive data at the same frequency without clashing[5 , 7]. When an antenna transmits and receives at the same time, the broadcast wave is picked up as an echo by the transmitting antenna and added to the received signal, conveying information. This echo is more powerful than the wave received and sent by the antenna. For the system to function correctly, the echo must be suppressed. Therefore, echo-canceling technology is used. This technique records the broadcast signal and subsequently

subtracts it from the received signal, leaving only the received data. Communication was usually accomplished using two methods in prior generations of cellular devices. The first was to use the antenna as a transmitter or receiver, switching back and forth in a half-duplex mode. The second most frequent method was full duplex, which used two distinct frequencies for transmission and receiving. The full duplex approach used in 5G has the benefit of just requiring a single carrier frequency, requiring half the spectrum resources of older full-duplex methods. In addition, the resources are used continuously as opposed to half-duplex mode, resulting in a higher performing system[2, 9 , 10 , 12].

4. Sub6 – mmWave

The terms Sub6 and mmWave refer to frequencies between 24 and 300 GHz, respectively. The Sub6 frequency band is used by most wireless technologies, resulting in collision signals in the crowded spectrum, resulting in poor performance of systems that rely on frequency resources, as seen in [2-4], where Wi-Fi and LTE signals coexist on the same frequency range. To address this issue, the 5G standard recommends using the mmWave spectrum, which is primarily used for satellite communications and radar systems and is less congested than the Sub6 bands. For 5G communications, Sub6 and mmWave frequencies are being proposed. For Sub6 communications, for example, mmWave frequencies are potentially viable candidates for providing 5G services[11].

5. Circular/smartphones polarization

When an electromagnetic wave travels through space in one direction, its associated electric field vector creates a form in the plane perpendicular to the propagation direction, which is known as the polarization. Because of the periodic characteristics of the moving wave, the aforementioned form is an ellipse. If the ellipse is drawn clockwise from the observer's perspective, the wave is right-handed polarized; otherwise, it is left-handed polarized. The wave exhibits circular polarization when the length of both ellipse axes is equal. When the polarization is neither circular nor linear, it is elliptical. When the ratio is infinite, the polarization is linear; when it is equal to one, the polarization is circular; and when the ratio is between one and infinite, the polarization is elliptical [13, 14]. In a basic 5G connection between an antenna and a mobile device aerial, if the base station's antenna has linear vertical polarization, the antenna in the user's device must be orientated in the same way, else the wave will not be correctly received and communication will be impossible or degraded. Circular polarization is essential for communication to be feasible regardless of the device's orientation.Because wave reflections simply modify the direction of the polarization without adding or removing the reflected waves, circular polarization reduces propagation losses[19].

6. Antenna Arrays

A single patch antenna has low network gain, a base station's coverage area will be limited if it pretends to provide service with only one antenna. To solve this problem, an array of antennas can be used.An array's antennas can be positioned at a predetermined distance from each other to form a linear, planar, or volumetric array. Each antenna in a linear array is positioned in a line, but each element in a planar array can be found in the same plane, commonly in the shape of an EAI. A complete survey 7 grid for the design of 5G-oriented patch antennas [6 , 13]. Each antenna in a volumetric array is positioned in 3D space.If the antenna array is linear, altering the relative phase between components results in directional steering of the radiated beam along a linear axis created by the antennas. Depending on the area of service, a planar array or a linear array may be required for 5G applications.For an array to be beamforming capable, each of its elements must be independently provided with a phase-changing signal. The gain is greater than that of a single antenna when the elements are linked by a fixed feeding network, but electronic steering of the emitted beam is not possible. [13 , 21] show this type of array. The array illustrated in [5] can only beamform in the vertical direction because all of the horizontal pieces are connected by a fixed feeding network. When constructing an array of several antennas, two variables must be considered: the number of antennas and the distance between them. That is, while constructing a planar array, the horizontal distance between successive antennas is always the same, as is the vertical distance between consecutive antennas on a vertical axis. To reduce coupling between antennas, they should be spaced apart by at least half the wavelength of the radiated wave. If the antennas are too far apart, undesired diffraction lobes form. Given the mutual coupling and diffraction lobes, a spacing between consecutive antennas is advised[22].

7. Communication Scenarios

Furthermore, when compared to the local search method, the proposed DNN-based method can achieve significant complexity reduction. More specifically, when the number of IRS elements is 16, the complexity of the exhaustive search, the local search method, and the DNN-based method increases. In general, the complexity of the offline phase is not considered here. Furthermore, as the number of reflecting elements increases, the computational complexity of both the local search method and the exhaustive search method increases significantly, whereas the proposed DNN-based method varies slowly[19 20].

8. 5G introduction Sensors

The research focuses on the role of satellites in 5G networks, emphasizing that enhanced mobile broadband, for which user data rates and spectrum efficiency are critical, and massive Machine Type Communications are common scenarios in which the satellite serves as backhaul to connect separate parts of the same 5G network including antennas[22 , 26]. In the case of massive Machine Type Communications, the ability to support a large number of connections, distributed over time and frequency, each exchanging a few data packets, is critical. The research shows that in some scenarios, terrestrial infrastructure may be insufficient to guarantee 5G Key Performance Indicators, such as providing ubiquitous coverage or in the case of infrastructure unavailability, necessitating the use of aerospace solutions to increase both the resilience and the availability of the network, thereby improving the Quality of Experience perceived by users. When considering the joint use of satellites, UAVs, and ground nodes, the different roles and equipment envisaged for IoT devices in 5G scenarios are analyzed, proposing UAVs to act as 5G User Equipment, as base stations (5G-gNBs), or as transparent relay nodes[13 16 , 19].

9. UAV’s

The beamforming gain of M-MIMO, on the other hand, is critically dependent on the availability and accuracy of channel state information (CSI) at ground BSs, whereas cellular-connected UAVs present new challenges. First, due to their strong LoS channels, UAVs can cause severe pilot contamination to a large number of ground BSs, which cannot be resolved by existing pilot decontamination techniques designed solely for terrestrial users. Second, the high mobility of UAVs in 3D space makes efficient beam tracking a more difficult task for them than for terrestrial users, and it can incur excessive pilot overhead [23]. To address inter-cell air-ground interference and improve network throughput, a more ambitious approach known as cell-free M-MIMO, which combines ideas from distributed/network MIMO and coordinated multipoint transmission, was recently proposed, in which massive antennas distributed across a large geographical area are linked with a central processing unit. Because of the LoS-dominant air-ground channels, such a user-centric architecture allows for greater degrees of freedom to exploit the macro diversity provided by the many distributed BSs. However, key issues that must be addressed include efficient centralized and distributed power control; low-complexity fronthaul and backhaul provisioning; and network scalability with regard to UAV swarms[23]. MmWave communication, like M-MIMO, requires the use of a large number of antennas, and the channel coherence time is shortened due to the high UAV mobility and shorter wavelength signals. Furthermore, due to the passive reflection mechanism of IRS, it requires a relatively larger aperture than M-MIMO and mmWave-based active arrays and imposes new challenges on the related passive IRS channel estimation, which requires larger installation space in practice and may result in higher computational complexity[6].

10. Antenna on UAV sensing and sensing for UAV

In addition to communications, the ability to enable effective and efficient sensing is required to realize the ambition of integrating UAVs into 5G and beyond networks. Commercial unmanned aerial vehicles (UAVs) are already outfitted with a plethora of sensors of various sorts, such as an inertial measurement unit (IMU), accelerometers, tilt sensors, and current sensors. Such integrated sensors provide critical real-time information for assuring safe UAV operation, such as estimating the UAVs location and orientation, preserving the direction and flight route, and managing power consumption. However, for future wireless networks, when large-scale deployment of UAVs will be seamlessly linked into terrestrial communication systems, depending just on those on-board embedded sensors may be insufficient. To achieve high sensing performance in terms of reaction time, sensing range, coverage, reliability, accuracy, and efficiency, a combination of both UAV embedded sensing and infrastructure-based sensing is required. Sensing technologies are used in the former example to assist safe UAV flying as well as low-altitude airspace monitoring and traffic management. In the UAV sensing paradigm, specialized UAVs are sent as aerial flying platforms to offer sensing assistance from the sky[20 , 23, 27.

11. IRS-assisted SWIPT system

The first assignment tried to maximize the EUs' weighted sum-power while achieving the stated SINR targets at the IUs, while the second sought to maximize the IUs' weighted sum-rate while satisfying the EH criteria at the EUs. In both cases, the transmit precoder at the AP and the reflection-coefficient matrix at the IRS were jointly optimized. Interestingly, removing specific energy beams from the SDR reformulations of both optimization problems resulted in no loss of optimality[20]. Based on these discoveries, efficient suboptimal solutions to the resulting issues were proposed. When compared to the benchmark scheme using a passive IRS, numerical results revealed that the recommended designs with an active IRS may significantly enhance the performance of both the EUs and the IUs. There were also helpful insights on the ideal deployment of an active IRS, which helped in the practical design and execution[24].

12. 5G Security

The 5G threat environment is dynamically based on sophisticated attacks such as flame and stuxnet malware. The feature that can safeguard data transmission from disclosure to unauthorized entities and from passive assaults (i. e., eavesdropping) is one of the fundamental security criteria in the 5G security model. Given the 4G-LTE and 5G designs, any user-plane data must be kept private and secure from unwanted users [11]. The integrity of 5G New Radio (NR) traffic is safeguarded in the same way that 4G traffic is. Only the Non-Access Stratum (NAS) and Access Stratum (AS) of 4G LTE provide integrity protection (AS). This is crucial since 4G does not enable user plane integrity protection. This new capability is beneficial for tiny data exchanges, especially for IoT devices with limited bandwidth. Furthermore, the 5G authentication technique 5G-AKA employs integrity-protected communication[7 , 14].

13. Network Slicing related Security Issues

The primary goal of network slicing is to segment physical network resources in order to appropriately group distinct traffic, isolate them from other tenants, and customize network resources at a macro level. Logical slicing is the process of dividing a single common physical network into many virtual, full E2E networks. It isolates these virtual networks from one another in terms of access, transit, devices, and core networks[4]. These slices are assigned to various sorts of services and situations. During division, the goal is to personalize and optimize each network in terms of resources, QoS, and security. The main advantage of NS is that it enables MNOs to split their networks and network resources to suit a wide range of customers and traffic classes. For example, NS may be used to support several 5G traffic classes, such as massive Machine Type Communication (mMTC), improved Mobile Broadband (eMBB), and Ultra Reliable Low Latency Communication (URLLC) over the same physical network infrastructure. For example, mMTC is associated with enabling connectivity for a large number of IoT devices, some of which may have extremely poor throughput. However, because this traffic class is focused on carrying very high bandwidth information and services, it has the opposite features. In this case, a single physical network is separated into numerous virtual networks that may support a variety of RANs. Network slicing is expected to play a significant role in 5G since it may increase flexibility, infrastructure operation, and resource allocation. The security of NS is critical for the effective implementation of network slicing[13]. An appropriate mechanism is necessary for the communication between functions, slices, and interfaces to enable secure functioning within expected parameters as well as operator security needs.Attackers can interrupt communication between slices if the communication route between them is not secure. Within an operator network, neither a host (physical) nor a network slice manager can be regarded as impersonal if the network slice manager creates or destroys network slices dynamically and maps and loads them to access the physical host platform. Both the network slice manager and the physical host must identify each other through authentication for safe and secure communication. An impersonation attack on a network slice instance has ramifications for all of its services. As a result, authentication is also required for network slice instances [14]. Because of the demand for or the given task it must accomplish, or because of varied latency requirements, each slice has distinct protocols and network services with varying security levels. However, this must not compromise the security of another slice. Capping resources and, optionally, ring fencing resources ensure maximum and minimum suggested resource levels. Ring-fencing network resources allows security protocols to function even when resources are depleted [28]. In the event of a cryptographic information leak, the security of the sharing hardware device may be jeopardized. Such deployments must maintain a minimum degree of security. The user's use of numerous services with distinct slices at the same time necessitates effective sealing between slices. For greater protection, the proposed security mechanism should exist not only in the UE but also in the network [22,29].

14. 5G power consumption

In order to enhance network interference control, presented an improved ZF-based transmission that incorporates ONB-and-PCA in the DL and SIC in the UL. The GEE maximization criteria were used to explore resource allocation for RIS-assisted multiuser MIMO uplink communication systems. In the transmission design, the transmit covariance matrices of the UTs and the phase shifts of the RIS reflector were simultaneously optimized, subject to a transmit power limitation at each UT. Then, using a fixed RIS phase shift matrix, we used Dinkelbach's technique to address the power allocation problem. In order to optimize the RIS phase shift matrix, we proposed an analogous MSE minimization issue, which was solved using both the BCD approach and the MM methodology[12]. The presented technique is effective in both GEE and SE maximization, as evidenced by numerical results. Furthermore, as compared to some standard baseline methods, RIS-assisted systems can achieve large GEE performance enhancements. When scalability in the uplink of cell-free massive MIMO systems is taken into account, structured massive access gives a new option to deliver greater SE to more users. The suggested scalable initial access method, User-Group, and IB-KM pilot assignment schemes in our framework greatly alleviated the bottleneck of structured enormous access, i.e., pilot contamination induced by pilot sharing. Finally, the suggested scalable fractional power control provides a trade-off between user fairness and average SE. In this research, we present a realistic approach for structured massive access in cell-free massive MIMO systems. Although we focus on SE performance while taking user density and fairness into consideration, the approach is easily generalized to analyze other critical issues like energy efficiency, hardware impairment, and restricted fronthaul capacity. This research suggested a novel IRS-assisted UAV OFDMA communication system and investigated its combined trajectory, IRS scheduling, and resource allocation design to maximize the system sum-rate[24]. The resource allocation and IRS scheduling mechanisms, as well as the trajectory of the UAV, were designed using an alternating optimization approach. Extensive simulations were run to illustrate the system sum-rate enhancement that might be achieved by implementing an IRS in a UAV OFDMA communication system. Our findings show that the IRS's substantial beamforming gain and the UAVs high maneuverability are both critical for improving communication performance; the size of the IRS has a significant impact on the trajectory of the UAV in exploiting the degrees of freedom of the system to improve the achievable rate of all users[26].

15. Massive Machine-Type Communications

The use of long-range radio (LoRa) and cellular networks in the IoE has been proposed to provide mass access. Traditional communication networks, on the other hand, are designed and utilized for human-to-human (H2H) communications, serving a relatively limited number of users in comparison to the enormous number of devices in the (IoRa)[11]. Unlike traditional communication networks [4], which prioritize downlink performance for a small number of users, MTC places a far larger demand on system resources in the uplink because of the huge uplink connection. The recorded photos are sent to a ground BS on a regular basis for additional data analysis. Due to the simplicity of the architecture, allocating dedicated radio resources to MTD orthogonally has been recommended in the literature in this context. However, because the number of MTDs is huge in MTC, orthogonal multiple access (OMA) would soon deplete precious radio resources and produce extremely lengthy delays[28-30].

16. Conclusion

This investigation provides a thorough examination of the future communications of 5G antennas in terms of performance strategies, security stages, and applications in everyday usage. while detailing the obstacles that are likely to stymie the expansion of 5G aerial communication and specific remedies to each challenge The ideal answer is to understand the precise type of antenna needed for a given activity, such as SISO, MIMO, mMIMO, mWAVE, and Full-Duplex Communication. This eliminates the need for frequency convergence, latency, and security concerns. Full-duplex antennas are preferred for airplanes, while MIMO antennas are preferred for cell phones and radio stations, with mMIMO being more effective. Many airports employ mMIMO, which is a bad idea because it causes frequency interference between 5G C-band and altimeters.5G antenna security makes them more secure than earlier communication networks. The key issue that remains is distance coverage, which is being investigated by a number of researchers. This survey is extremely beneficial to 5G antenna manufacturers, researchers, and consumers since it allows them to discover that the biggest issue that develops is due to inappropriate antenna usage. A well-chosen antenna for each task yields spectacular results from 5G network technology.

References

1. Pant, M. and Malviya, L., 2022. Design, developments, and applications of 5G antennas: a review. International Journal of Microwave and Wireless Technologies, pp.1-27.

2. Zhang, P., Yang, X., Chen, J. and Huang, Y., 2019. A survey of testing for 5G: Solutions, opportunities, and challenges. China Communications, 16(1), pp.69-85.

3.https://www.law.com/dailybusinessreview/2022/01/04/att-and-verizon-delay-5g-after-airlines-threaten-to-sue/

4. Nahar, T. and Rawat, S., 2022. Survey of various bandwidth enhancement techniques used for 5G antennas. International Journal of Microwave and Wireless Technologies, 14(2), pp.204-224.

5. Pan, Cunhua, et al. "Intelligent reflecting surface aided MIMO broadcasting for simultaneous wireless information and power transfer." IEEE Journal on Selected Areas in Communications 38.8 (2020): 1719-1734.

6. Ikram, M., Sultan, K., Lateef, M.F. and Alqadami, A.S., 2022. A Road towards 6G Communication—A Review of 5G Antennas, Arrays, and Wearable Devices. Electronics, 11(1), p.169.

7. Irram, F., Ali, M., Naeem, M. and Mumtaz, S., 2022. Physical layer security for beyond 5G/6G networks: Emerging technologies and future directions. Journal of Network and Computer Applications, p.103431.

8. Du, H., Zhang, J., Cheng, J. and Ai, B., 2021. Millimeter wave communications with reconfigurable intelligent surfaces: Performance analysis and optimization. IEEE Transactions on Communications, 69(4), pp.2752-2768.

9. Chen, S., Zhang, J., Björnson, E., Zhang, J. and Ai, B., 2020. Structured massive access for scalable cell-free massive MIMO systems. IEEE Journal on Selected Areas in Communications, 39(4), pp.1086-1100.

10. You, L., Xiong, J., Huang, Y., Ng, D.W.K., Pan, C., Wang, W. and Gao, X., 2021. Reconfigurable intelligent surfaces-assisted multiuser MIMO uplink transmission with partial CSI. IEEE Transactions on Wireless Communications, 20(9), pp.5613-5627.

11. Uwaechia, A.N. and Mahyuddin, N.M., 2020. A comprehensive survey on millimeter wave communications for fifth-generation wireless networks: Feasibility and challenges. IEEE Access, 8, pp.62367-62414.

12. Nguyen, H.V., Nguyen, V.D., Dobre, O.A., Sharma, S.K., Chatzinotas, S., Ottersten, B. and Shin, O.S., 2020. On the spectral and energy efficiencies of full-duplex cell-free massive MIMO. IEEE Journal on Selected Areas in Communications, 38(8), pp.1698-1718.

13. Dicandia, F.A., Fonseca, N.J., Bacco, M., Mugnaini, S. and Genovesi, S., 2022. Space-Air-Ground Integrated 6G Wireless Communication Networks: A Review of Antenna Technologies and Application Scenarios. Sensors, 22(9), p.3136.

14. Yu, Xianghao, et al. "Robust and secure wireless communications via intelligent reflecting surfaces." IEEE Journal on Selected Areas in Communications 38.11 (2020): 2637-2652.

15. Wu, Q. and Zhang, R., 2020. Joint active and passive beamforming optimization for intelligent reflecting surface assisted SWIPT under QoS constraints. IEEE Journal on Selected Areas in Communications, 38(8), pp.1735-1748.

16. Ai, B., Molisch, A.F., Rupp, M. and Zhong, Z.D., 2020. 5G key technologies for smart railways. Proceedings of the IEEE, 108(6), pp.856-893.

17. Xu, D., Yu, X., Sun, Y., Ng, D.W.K. and Schober, R., 2020. Resource allocation for IRS-assisted full-duplex cognitive radio systems. IEEE Transactions on Communications, 68(12), pp.7376-7394.

18. Liu, X., Liu, Y., Chen, Y. and Poor, H.V., 2020. RIS enhanced massive non-orthogonal multiple access networks: Deployment and passive beamforming design. IEEE Journal on Selected Areas in Communications, 39(4), pp.1057-1071.

19. Sarieddeen, Hadi, Mohamed-Slim Alouini, and Tareq Y. Al-Naffouri. "An overview of signal processing techniques for terahertz communications." Proceedings of the IEEE (2021).

20. Wei, Z., Cai, Y., Sun, Z., Ng, D.W.K., Yuan, J., Zhou, M. and Sun, L., 2020. Sum-rate maximization for IRS-assisted UAV OFDMA communication systems. IEEE Transactions on Wireless Communications, 20(4), pp.2530-2550.

21. Hong, W., 2017. Solving the 5G mobile antenna puzzle: Assessing future directions for the 5G mobile antenna paradigm shift. IEEE microwave magazine, 18(7), pp.86-102.

22. Kumar, S., Dixit, A.S., Malekar, R.R., Raut, H.D. and Shevada, L.K., 2020. Fifth generation antennas: A comprehensive review of design and performance enhancement techniques. IEEE Access, 8, pp.163568-163593.

23. Wu, Q., Xu, J., Zeng, Y., Ng, D.W.K., Al-Dhahir, N., Schober, R. and Swindlehurst, A.L., 2021. A comprehensive overview on 5G-and-beyond networks

with UAVs: From communications to sensing and intelligence. IEEE Journal on Selected Areas in Communications.

24. You, L., Xiong, J., Ng, D.W.K., Yuen, C., Wang, W. and Gao, X., 2020. Energy efficiency and spectral efficiency tradeoff in RIS-aided multiuser MIMO uplink transmission. IEEE Transactions on Signal Processing, 69, pp.1407-1421.

25. Ma, X., Chen, Z., Chen, W., Li, Z., Chi, Y., Han, C. and Li, S., 2020. Joint channel estimation and data rate maximization for intelligent reflecting surface assisted terahertz MIMO communication systems. IEEE Access, 8, pp.99565-99581.

26. Hou, T., Liu, Y., Song, Z., Sun, X. and Chen, Y., 2020. MIMO-NOMA networks relying on reconfigurable intelligent surface: A signal cancellation-based design. IEEE Transactions on Communications, 68(11), pp.6932-6944.

27. Wu, Q., Xu, J., Zeng, Y., Ng, D.W.K., Al-Dhahir, N., Schober, R. and Swindlehurst, A.L., 2020. 5G-and-beyond networks with UAVs: From communications to sensing and intelligence. arXiv preprint arXiv:2010.09317.

28. Hong, W., Baek, K.H. and Ko, S., 2017. Millimeter-wave 5G antennas for smartphones: Overview and experimental demonstration. IEEE Transactions on Antennas and Propagation, 65(12), pp.6250-6261.

29. Gupta, P., Malviya, L. and Charhate, S.V., 2019. 5G multi-element/port antenna design for wireless applications: a review. International Journal of Microwave and Wireless Technologies, 11(9), pp.918-938.

30. Mahdi, M.N., Ahmad, A.R., Qassim, Q.S., Natiq, H., Subhi, M.A. and Mahmoud, M., 2021. From 5G to 6G technology: meets energy, internet-of-things and machine learning: a survey. Applied Sciences, 11(17), p.8117.