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Short Communication

# Development of Multiband Antenna for Wireless Communication

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Multibeam antenna systems operating in the millimeter-wave frequency ranges have garnered a lot of research attention due to the challenging system requirements for fifth-generation (5G) wireless communications and the acute spectrum scarcity at traditional cellular frequencies. In order to support a high data transmission rate, an improved signal-to-interference-plus-noise ratio, an increased spectral and energy efficiency, and versatile beam shaping, they represent the key antenna technology. As such, they hold great promise for acting as the essential framework for enabling beamforming and massive multiple-input multiple-output (MIMO), which are key components of the 5G network. The multibeam antenna technologies currently in use are reviewed in this paper, including passive multibeam antennas (MBAs) based on quasi-optical components and beamforming circuits, multibeam phased-array antennas made possible by various phase-shifting techniques, and digital MBAs with various system architectures. In particular, their operational, design, and implementation concepts are examined together with a number of instructive application cases. The applicability of these MBAs for upcoming 5G massive MIMO wireless systems and the problems involved are then examined.

The vast quantity of spectrum that is accessible in the millimeter-wave (mmWave) bands represents substantial prospects for 5G enhanced mobile broadband (eMBB) applications. In order to increase the signal-to-noise ratio (SNR) at the receiver due to the substantial propagation loss of electromagnetic waves in mmWave bands, high-gain antenna systems with directed beams are often used (Rx). However, focusing all energy towards the primary propagation channel via directed communication reduces the variety provided by the multipath and poses a genuine danger of communication disruption in the case of impediments (human or vehicle) in the direction the beam is pointed. In mmWaves, a situation like this is referred to as a human (or vehicle) blocking phenomena. The directed beam has to be physically or electrically guided in order to preserve the communication connection while it is moving. In mechanical beam steering, the antenna is manually rotated to face the desired direction. This method works well since the antenna gain is kept constant and the steering range is flexible, but it can only be used in conditions where propagation is static or changes very slowly. In order to provide quick beam aiming, electronic steering (or beamforming) antennas are suggested. However, in mmWave bands, the feed network and electrical restrictions are complicated and expensive. In order to improve the system's directivity, a high number of antennas are also necessary.

The multibeam antenna (MBA) technique attracted a lot of interest owing to several advantages including low profile (small height and breadth), light weight, cost-effective, and simple to produce in order to address these problems of both electrical and mechanical beam steering. MBAs often refer to an antenna system that can produce a number of independent, contemporaneous directed beams that have a high gain and can span a certain angular range. In order to implement an MBA system, a number of common methods have been used. One strategy is to install many feed antennas in front of a reflect array at various locations (RA). Another method is to utilise the incident waves from the feed antennas to light one side of a lens or transmit array (TA), and then use the other side to concentrate the beams in the appropriate directions. MBA design may also be accomplished utilising beamforming circuits like Butler matrix, which can be merged with an array of antennas onto a single substrate. This is in contrast to RA and TA approaches based on optic principle.

Whatever the design decision, the MBA may be seen as a viable middle ground for managing user mobility, particularly the phenomena of blockage in the mmWave setting. At first glance, a big beam may be utilised to simply absorb energy from the other multipath components when the primary path is blocked by an obstruction; however, in this scenario, a significant portion of transmitted power is wasted, and the cell coverage is inefficient. This problem may be resolved by creating an MBA system that concurrently points in a few well selected directions. If one route is blocked, others are kept open thanks to an effective power distribution scheme. The following additions are made to a generic model that is presented in this study for the modelling of the MBA system. In fact, the suggested model is appropriate for estimating performance in an MBA's design and hardware implementation. For mmWave systems, it is more adaptable, comprehensive, and realistic than the antenna models recommended by standards and others  for which gain decrease for a certain scan range is acceptable. The 5G physical layer simulation chain is then built using this model, which includes human blocking and multipath propagation channels. To demonstrate the benefits of the MBA, simulations are conducted.

These frequency band areas are necessary to satisfy anticipated needs due to the size and volume of wireless communication data traffic that have increased dramatically in recent years. In order to attain more bandwidth than conventional frequency bands, 5G and later 6G mobile networks operate in high-frequency zones. This allows for high-capacity wireless transmission of multi-gigabit-per-second (Gbps) data rates. As a consequence, millimetre wave bands have attracted a lot of interest in research on 5G and 6G mobile networks. Despite having a huge bandwidth, mm-wave technology has basic technical challenges in signal transmission due to its short wavelengths, including obstruction sensitivity, substantial route losses, and directivity. The physical size of antenna arrays based on these bands is somewhat small from a technology standpoint. As a result, a reliable communication connection between users and base stations may be established and maintained using massive Multiple Input Multiple Output (MIMO) with beamforming technology.

Because it greatly boosts data speed and connection range in wireless communications without needing extra capacity or transmitting power, MIMO technology has received a lot of coverage. Because beamforming gain is used to build networks with an appropriate signal-to-noise ratio (SNR) to expand the communication range and mitigate route losses, MIMO solutions for mm-wave frequencies are essential.

According to data obtained using the Angle-of-Arrival (AoA) approach, beamforming technology often uses an antenna array to conduct spatial filtering in order to catch or radiate a signal in certain directions throughout its aperture. Due to this, both base and mobile stations may be greatly enhanced by prioritising transmit and/or receive gain above omnidirectional transmission or reception. As a result, by boosting reception power in desired signal directions while reducing radiated power in undesirable directions, antenna gain may be regulated and enhanced to compensate for penetration losses and excessive path in millimetre-wave bands. This is made feasible by a certain physical configuration of a phased antenna array and an electronic beam guiding approach. According to a literature analysis and background information, J. C. Bose is the first scientist to have created and characterised mm-wave research by employing a horn antenna to study the 60 GHz band across a distance of 23 metres and with Line-of-Sight (LOS) signal transmission circumstances. Following J. C. Bose's experiments, about 50 years of mmWave technology development were conducted in government and academic laboratories. The mass manufacture of mmWave devices began in the 1980s with the development of mmWave integrated circuits. Japan started researching 60 GHz communication in the late 1990s, and as a result, a point-to-point base station user with a speed of 156 Mbps was developed utilising a Monolithic Microwave Integrated Circuit (MMIC). As a consequence, the mmWave frequency band's actual revolution era began in the 1990s.

Numerous studies have examined and addressed high-bandwidth communication lines that may provide multiple Gigabits per second (Gbps) for 5G mobile devices since the FCC's notice of inquiry. Two-dimensional (2D) microwave beam steering in reflect array antennas was presented using a novel method known as MAcro-Electro-Mechanical Systems (MMS). Without the use of any integrated phase shifters or solid-state electronics within the antenna aperture, the beam steering was accomplished via collective control over large-scale mechanical motions of the ground plane in the technique that was given. A large number of electromechanical actuators were utilised to rotate a flat ground plane supporting the reflecting components in order to scan a direct beam. It has been shown to be capable of being implemented using quick electromechanical devices. Therefore, it is regarded as a noteworthy accomplishment as it performs 2D beam steering with a huge element while overcoming the complexity of the earlier techniques by controlling each unit cell independently. The provided antenna is unable to fulfil the minimal criteria for beam steering due to excessive sidelobe levels and beamwidth expansion, which remain major obstacles to this technique.

In proposal for a digital beamformer receiver (DBR) that consists of a signal generator and a tapered slot antenna array is made in order to accurately control the beam and provide a fine beamforming technology for the 5G communication network. Eight components make up the antenna array, while the signal generator is made up of a PLL and a DSS (direct digital synthesiser) (phase lock loop). By adjusting and rotating the main lobe's radiation pattern in a variety of orientations, including 0, 15, and 30 degrees, the beamforming performance was assessed. However, the actual beamformer only produces one beam and guides it in 1D. For a 5G mobile network, a hybrid beamforming approach based on a large MIMO rectangular antenna array has been suggested. We have modelled and simulated four planar antenna arrays with various numbers of array elements. When the radiation pattern was evaluated with and without Chebyshev tapering, it was shown that the latter might increase main lobe gain while simultaneously decreasing sidelobe levels. In order to enhance beamforming in the uplink of a cell-free network, a centralised and distributed method based on deep reinforcement learning (DRL) was developed. The created system was contrasted with two popular linear beamforming schemes: simplified symmetric conjugate techniques and minimum mean square estimation (MMSE). It has been discovered that the suggested plan performs better than the designs that were compared.

In order to characterise mm-waves with specific interest bands, such as 28 GHz, 38 GHz, 60 GHz, and E-band (71-76 GHz and 81-86 GHz), which will be utilised by 5G and eventually 6G mobile cellular communications, the majority of antenna design research is now concentrated on these bands. In order to achieve this, this study suggests a design for a 60 GHz compact-size circular patch for 5G mobile cellular applications, with an acquired bandwidth of 4 GHz at a return loss threshold of 10 dB. The modelling and design of two distinct phased array geometries is intended to improve the reception of 5G base stations. Projection Noise Correlation Matrix (PNCM), a brand-new, effective beamforming technique, is introduced in order to provide antenna array components with the weights required to produce numerous beams at the base station receiving end. The PNCM method's theoretical idea and operating principle are explained and developed. The benefit of the PNCM technique is that the signal and interference correlation matrices do not need to be computed, which reduces execution time and power consumption. The PNCM technique and the two antenna array configurations that make up the beamforming scheme are tested and employed to provide numerous active beams that enhance the reception for the intended consumers. Software such as MATLAB and CST are used to test the design. In order to demonstrate the efficiency of the PNCM method, it is contrasted with a number of well-known beamforming approaches using numerical examples and a thorough Monte Carlo simulation. The development of 5G communication technologies that use mm-wave frequencies will open up new possibilities for multimedia services and applications. Several technical issues related to antennas must be resolved in order for this to happen. The major goals of current mm-wave antenna array research are the attainment of high-gain characteristics and agile beamforming with wide-scan capabilities. This study provides a current review of antenna array technology for mm-wave wireless communications. The examination of the most cutting-edge antenna array approaches for point-to-point and point-to-multipoint radio connections at specified frequencies is given special attention.