Research on 5G Millimeter Wave Phased Array Antenna for Broadband Communication

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Abstract. A highly integrated millimeter wave communication active phased array antenna has been developed to meet the demand of a new generation of 5G millimeter wave communication. It has a high gain for compensation of millimeter wave transmission loss. It can generate multi-beams for multi-user by beamforming to multiplex time-frequency resources with a interference suppression between multiple users. The highly integrated millimeter wave communication active phased array antenna has a wide scanning range, a high emission EIRP value, a good cross-polarization characteristics, a high-speed real-time beam control, and a good interactive performance of the host computer software. It has a system verification to meet the need for a new generation of 5G millimeter wave broadband communications. 5G millimeter wave phased array antenna test result for brandband communication shows that data transmision rate is more than 2.8 Gbps with a spectrum width of 800 MHz and a modulation of 64 QAM. At the same time, highly integrated millimeter wave communication active phased array antenna can be applied to satellite communications and tactical mobile hotspots, etc.

Keywords: phased array antenna, phased array, antenna array, millimeter wave communication

1 Introduction

The traditional active phased array antenna is usually realized by tile and brick structure transciever module based on Multi Chip Module technology[1,2]. This causes a complicated process, a high cost and a big size of the traditional active phased array antenna. It is difficult to meet the demand of mass production of future 5G millimeter wave communication base stations.

With the development of new generation of 5G mobile communication technology, a lot of research has been conducted on the millimeter-wave phased array antenna technology that may be applied to communication and detection. It is foreseeable that in the next 3 to 5 years, more and more technological breakthroughs will appear in millimeter wave devices, packaging, integration and even system architecture design. Low-cost and other aspects relying on the civil technology, the millimeter wave phased array technology that meets the needs of future military applications will also show a rapid and even leapfrog development [3]

5G communication requires high data transmission rate. But it is difficult to find continuous broadband frequency band below 6 GHz, and it is difficult to greatly improve spectrum utilization efficiency by simply relying on coding technology. While millimeter wave frequency

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band can provide continuous large bandwidth, which can meet the requirement of high data transmission rate of 5G communication. Therefore, it is necessary to conduct research on millimeter wave antenna technology in order to realize millimeter wave broadband communication.

The transmission loss of the millimeter wave signal in the atmosphere is larger than that of the low-band microwave signal. The millimeter wave active phased array antenna technology brings a higher gain based on the multi-antenna beamforming technology, which can compensate the large transmission loss of the millimeter wave. In addition, the millimeter-wave active phased array antenna technology realizes multi-user multiplexed time-frequency resources by time-division multi-beam or simultaneous multi-beam. It can suppress interference between multiple users through beamforming, which improves the capacity and frequency effectiveness of the 5G communication system. Therefore, millimeter wave active phased array antenna technology has become one of the key technologies of 5G communication.

2 Highly integrated millimeter wave phased array antenna technology

The research on millimeter-wave phased array antenna technology will inevitably need to combine specific requirements such as military early warning detection, wireless communication, and multi-functional integration, and keep up with the latest advances in millimeter-wave frontier technology in the industrial world. The possible technical approaches in the field of phased array causes military electronic equipment to achieve a leapfrog in performance, and the cost will continue to fall. This not only meets the objective needs of equipment development, but also provides a good reference for the subsequent application of millimeter wave technology to the low-band microwave band application [3].

The prototype of the 5G millimeter wave phased array antenna developed is shown in Figure 1. A multifunctional antenna board is used to integrate the antenna unit, feed network, power network and wave control network. The multifunctional transceiver chip is used to integrate the transceiver channel to simplify the phase array antenna topology. It reduces the thickness of the phased array antenna, which can meet the requirements of thin, light and modular [4,5,6].

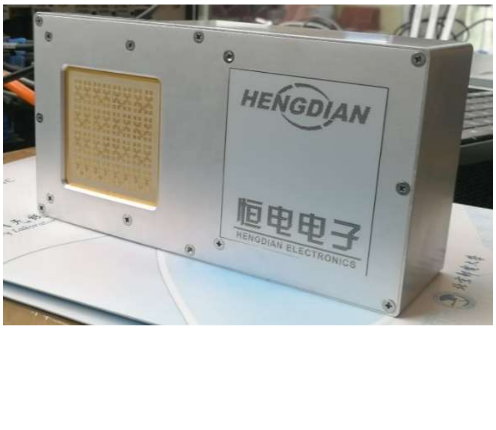


Fig. 1. 5G millimeter wave phase array antenna photo.

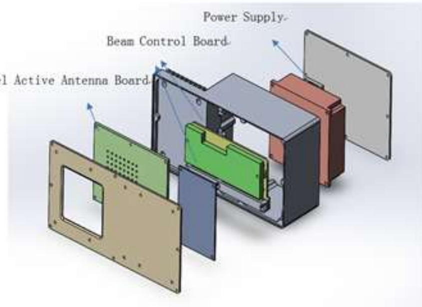


Fig. 2. 5G millimeter wave phase array antenna structure

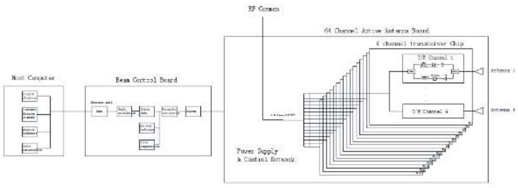


Fig. 3. 5G millimeter wave phase array antenna working principle diagram

5G millimeter wave phased array antenna structure schematic diagram refers to Figure 2. It is composed of multi-function antenna board, multi-function transceiver chip, wave control board, power module and host computer control program.

When the millimeter-wave active phased array antenna operates in the transmitting state, the transmission switch state, the numerically controlled phase shifter and the numerically controlled attenuator control code of the transceiver channe are set to complete the power allocation according to the azimuth, elevation angle and other information from the terminal. After phase, attenuation setting and power amplification, signal is sent to the antenna front to realize the space power synthesis, so that the radiation direction of the phased array antenna is directed to the target direction.

When the millimeter wave active phased array antenna operates in the receiving state, parameters such as the switch state, the numerically controlled phase shifter and the numerically controlled attenuator control code are set according to the azimuth angle and elevation angle information returned by the terminal. At the same time, the received high-frequency signals are amplified and phase-shifted and attenuated by the respective receiver channels after passing through the antenna array. And the received high-frequency signals enter the receiving feed network. They form the sum signal, the azimuth difference signal and the elevation difference signal. And they output to the receiver for related signal processing .

2.1 Millimeter wave phased array broadband array antenna technology

In order to achieve a thin and light structure, the millimeter wave phased array antenna uses a form of magnetoelectric dipole antenna. The array antenna is divided into three layers as a whole, which is fed by a slot through a strip line. The structure of the antenna cell is shown in

Figure 4. The antenna cell size is 4*4 mm. The simulation antenna gain is more than 6.4 dB between the frequency range of 26-31GHz as Figuer 5 shows. Figure 6 shows that 3dB beamwidth of the antenna is about 90 degrees.

The standing wave characteristic of the antenna is shown in Fig. 7 and S11 of antenna is maintained below -18 dB.

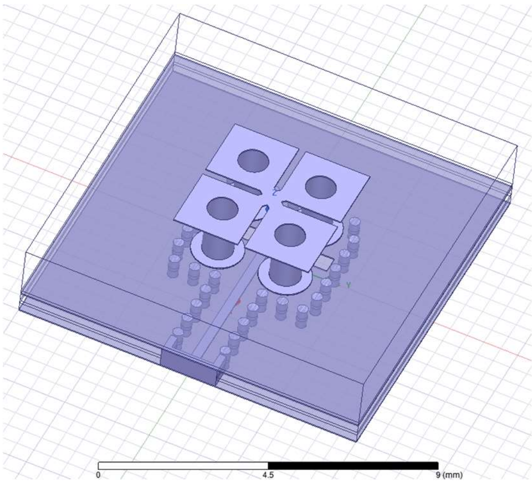


Fig. 4. Antenna cell structure

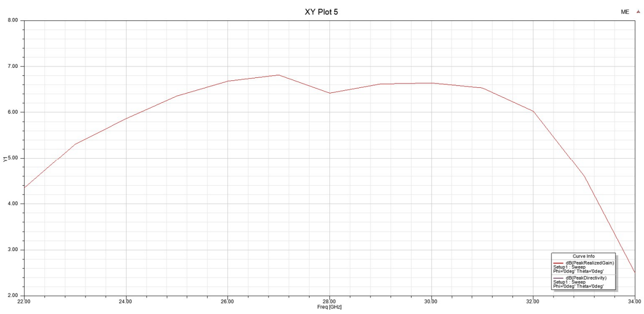


Fig. 5. Gain of antenna cell

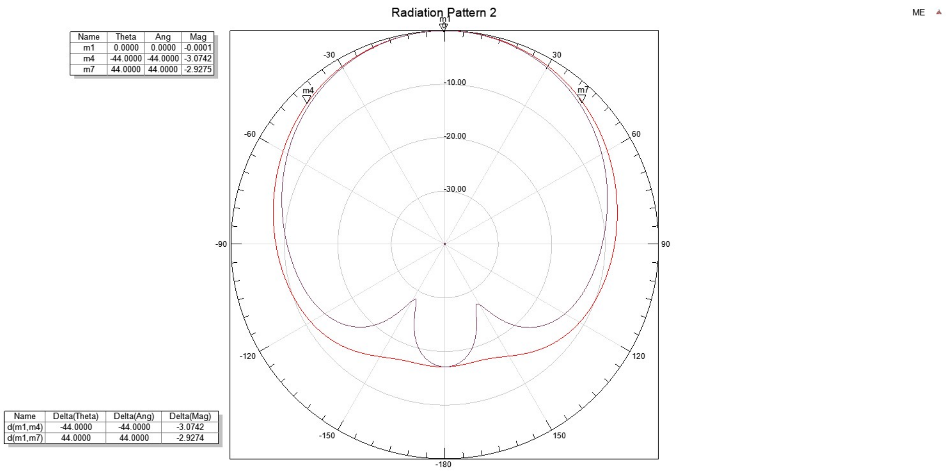


Fig. 6. Radiation pattern of antenna cell

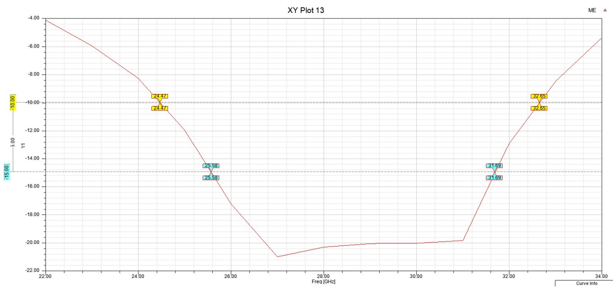


Fig. 7. Antenna cell standing wave

2.2 Millimeter wave phased array antenna wave control technology

The beam control system controls the phase shifter of the transceiver channel according to the control instruction of the terminal. And it performs the beam scanning and pointing function of the phased array antenna. At the same time, it controls the transmission and reception state of the multi-function chip of the transceiver channel according to the control instruction from the terminal. The phased array working mode is switched. In order to ensure the stable and reliable operation of the system, the beam control system also controls the power modulation driver.

The beam control board performs the timing control of the beam controller and the calculation of the wave control digital code based on FPGA. FPGA has the characteristics of fast speed and high flexibility. In order to improve the response speed of the beam control system, the main function of the beam control is realized in the FPGA.

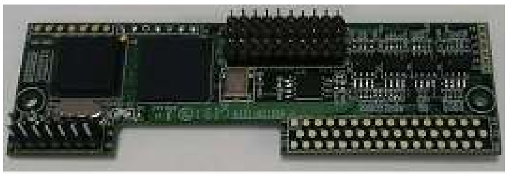


Fig.8. Beam control board photo

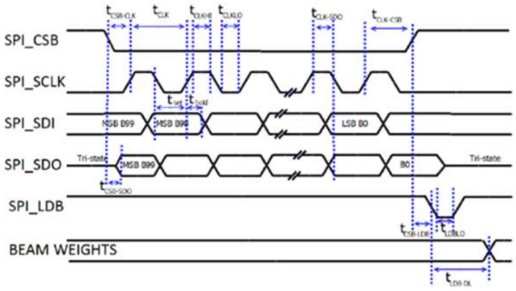


Fig.9. Beam control timing diagram

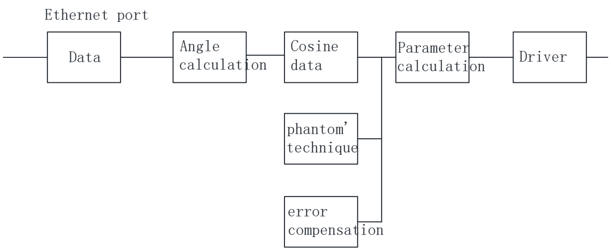


Fig.10. Block diagram of wave control code calculation principle

2.3 Host computer control software for millimeter wave phased array antenna

The host computer control software is responsible for setting the beam scanning azimuth and elevation angles, setting the transmitting state and receiving state, and monitoring the phase shift code and pattern.

The communication between the host computer and the beam control board is completed through Ethernet, SPI interface or serial port RS-232. The host computer for beam control test based on VC6.0 is used to control and observe the results of the beam control system. Its operation interface is shown in the figure 11. Its functions include interface communication, angle data transmission, transmission status control and monitoring, line phase shift base code, and column-wise shift base code monitoring.

Fig.11. Host computer program control interface

3 Test and verification of millimeter wave phased array antenna

Scanning pattern test results of tiled millimeter-wave phased array antennas are shown in Figure 12 [7].

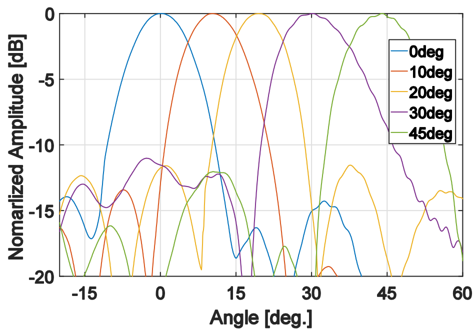


Fig.12. Antenna scanning pattern

The normalized emission scan pattern of the millimeter-wave phased array antenna has good pattern characteristics in the range of ± 45 degrees. And the side lobe level is lower than -12dB.

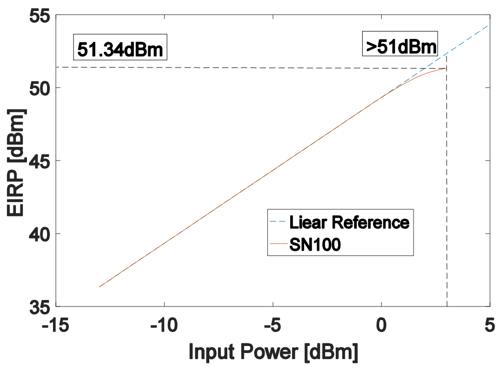


Fig.13. Transmmion EIRP test result

Figure 13 shows the equivalent isotropically radiated power (EIRP) test results of a tiled millimeter-wave phased array antenna at 28 GHz. The EIRP value is greater than 51 dBm.

Figure 14 shows the cross polarization test results of the tile millimeter wave phased array antenna in the range of ± 45 degrees. The cross polarization isolation is better than -30 dB in the range of ± 45 degrees.

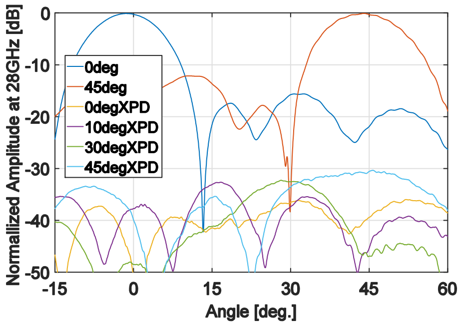
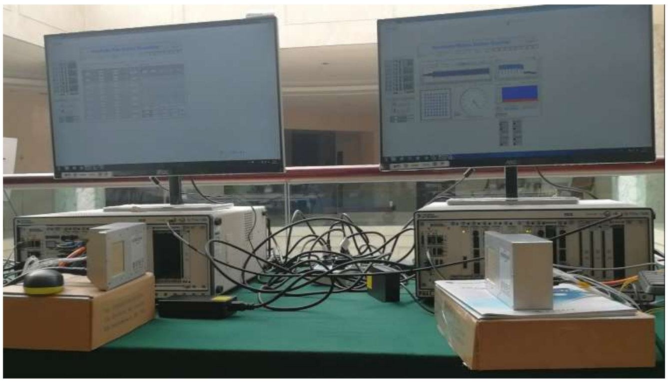
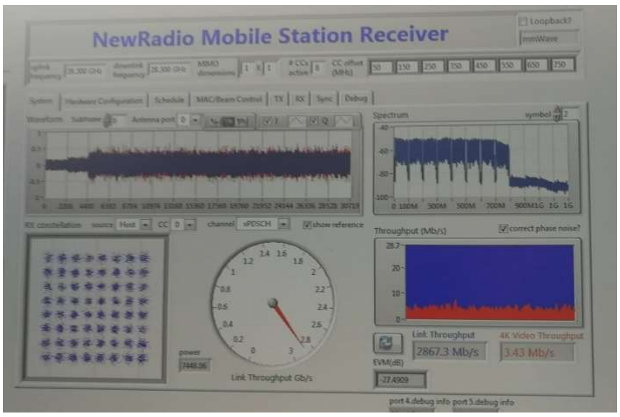


Fig.14. cross polarization isolation test result



(a)



(b)

Fig. 15. 5G Millimeter wave phased array antenna test for brandband communication

Figure 15 shows the 5G millimeter wave phased array antenna test results for brandband communication. Data transmision rate is more than 2.8 Gbps with a spectrum width of 800 MHz and a modulation of 64 QAM.

Conclusions

A highly integrated millimeter-wave communication active phased array antenna has been developed for the needs of next-generation 5G millimeter-wave communication. It has a high gain to compensate for millimeter-wave transmission loss. It forms a multi-beam to realize multi-user multiplexing of time-frequency resources. And it uses beamforming to suppress multi-user Interference. Highly integrated millimeter-wave communication active phased array antenna has a wide scanning range, a high transmit EIRP value, a good cross-polarization characteristics, a high-speed real-time beam control performance, and a good computer software for human-computer interaction. It meets the needs of the new generation of 5G millimeter wave broadband communications. 5G millimeter wave phased array antenna test result for brandband communication shows that data transmision rate is more than 2.8 Gbps with a spectrum width of 800 MHz and a modulation of 64 QAM. At the same time, highly integrated millimeter wave communication active phased array antenna can be applied to satellite communications and tactical mobile hotspots, etc.

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