Antipodal Linearly Tapered Slot Antenna Array for Millimeter-wave Base Station in Massive MIMO Systems

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Abstract—**For massive MIMO systems, it is very challenging to have the large-scale antennas for a compact base station. This paper presents a 36 sub-sectors for a compact millimeter-wave base station. The antenna array for each sub-sector is comprised of 16 planar high-gain dielectric-loaded antipodal linearly tapered slot antenna (ALTSA) elements arranged in a 4×4 configuration. Down to 36 feed ports are required in a base station with 36×16 antennas. The realized gain of the antenna array is 25.6 dBi, and the half-power beam widths (HPBW) are 10.7° and 5.3° in H-plane and E-plane, respectively.**

I. INTRODUCTION

Recently, efforts have been made to utilize the millimeter waves in mobile communication with high capacity, due to the fact that for given aperture areas of transceiver antennas, shorter wavelengths can propagate longer compared to longer wavelengths as the transmission at higher frequencies becomes more directional [1].It is possible to pack hundreds or thousands of antennas into a small area due to the short wavelength. Based on the facts, investigations have suggested that massive antennas should be configured in the millimeter-wave mobile broadband (MMB) base stations to accomplish the massive MIMO framework. Providing significantly improved signal strength, spatial degree of freedom for spectral efficiency improvement and interference suppression, massive MIMO technology can provide tremendous communication capacity. It is obvious that the design and configuration of antenna array is the key in the massive MIMO system. Literature [2] proposed a 12×4 horn antenna array with an aperture area of about $6.4\lambda\times10.8\lambda$ for each MMB base station sector, which provides a net antenna plus beamforming gain of 26.28 dBi at the base station at boresight. However, the horn antenna often requires a large space to be embedded.

Although many promising benefits can be achieved using massive MIMO technology, there are still challenges, such as the hardware cost associated with the RF elements, the complexity of signal processing resulted from the large number of branch signals, the total energy consumption greatly increasing due to the use of large number of antennas [3]. Authors of paper [3] proposed a system design by integrating an EM lens with the large antenna array, which has the capability of focusing the power of any incident plane wave passing through the EM lens to a small focal area of the antenna array, depending on the angle of arrival of the wave. This method can substantially reduce the number of required RF chains at the receiver. In [4], a practical 2D active antenna array configuration for Full Dimension MIMO systems is presented. Fed with a single port, a patch antenna array with 1×4 elements is referred to as sub-array, which has a gain of about 11.7dBi. The MIMO array comprised of 8×4 such sub-arrays can provide an array gain of 15dB theoretically, and needs a total of 32 ports and occupies an area of $4\lambda\times8\lambda$.

This paper presents a demonstrative base station structure in Fig. 1, which has the benefits of massive MIMO system with a moderate number of RF chains. Each sub-sector has an HPBW of 10° in azimuth and can be steered in elevation. The focus of this paper is to design a high gain antenna array using millimeter-wave frequency at 38GHz with gain of at least 25dBi and half-power beam widths (HPBW) of 10° in azimuth.

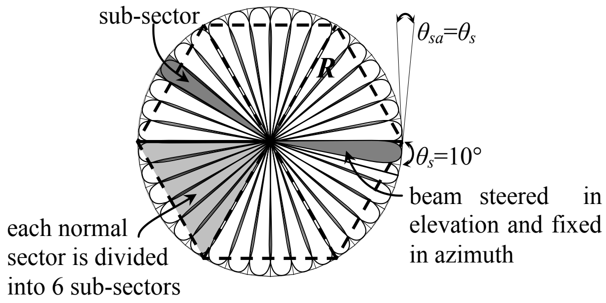

Fig. 1. Sub-sector desgin for massive MIMO base station.

II. DESIGN OF ANTENNA ARRAY

In order to meet the design requirement and simplify the fabrication technology, we choose the tapered slot antenna as the element of the antenna array due to its high gain and simple structure. According to the structure of antenna proposed in paper [5] , an antipodal linearly tapered slot antenna (ALTSA) operating on 38GHz band is modeled and simulated in the electromagnetic simulation software of CST Microwave Studio. Fig. 2(a) shows the structure of the dielectric-loaded ALTSA

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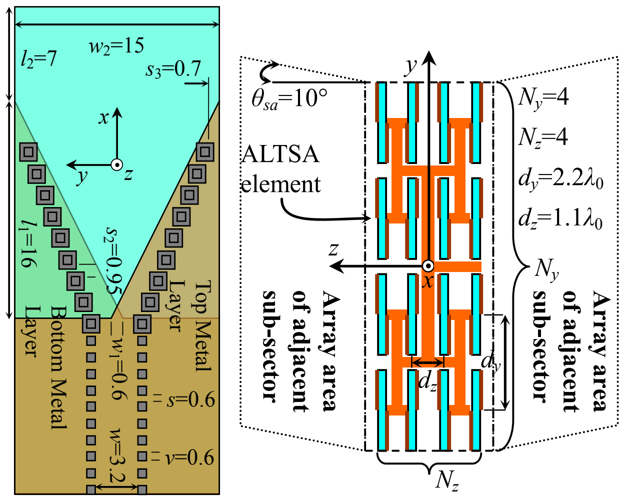
with horn shaped via designed on the substrate of Rogers RT6002 with relative permittivity constant of 2.94 and thickness of 1.016mm.

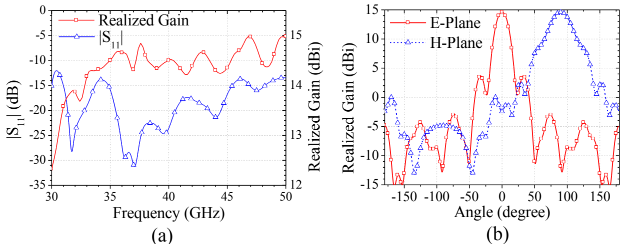


(a) (b)

Fig. 2. (a) Sturcture of the planar high-gain dielectric-loaded ALTSA with horn shaped via (all parameters are in mm), and (b) array configuration using 4×4 ALTSA elements mounted vertically to the backboard with feed network.

With the parameter optimization via extensive simulations, the ALTSA is tuned to operate at 35GHz to 45GHz, the port reflection coefficient is always less than -15dB and the realized gain is around 14.5dBi, as shown in Fig. 3(a); at 38GHz, the HPBWs are 22° and 38° in E-plane and H-plane respectively, as shown in Fig. 3(b).

The position relationship of the array for each sub-sector in the full MIMO array can be understood in Fig. 1 and Fig. 2(b). The array is comprised of 16 ALTSA elements arranged in a 4×4 configuration, in which ALTSA is mounted vertically to the backboard with an SIW feed network.



(a) (b)

Fig. 3. Simulated results of the ALTSA, (a) $|S_{11}|$ and realized gain, and (b) the radiation pattern at 38GHz.

Fig. 2(b) also gives a schematic feed network with only one feed port, which can deeply simplify the RF chains in the base station. If every four elements in the row (along z-axis) are fed by one port, there are four feed ports on the backboard; the narrow beam can be steered by ±5° in the elevation plane. All elements are interlaced across each other in the row to inverse the signal phase and increase the polarization purity of the whole array.

The simulation of the whole array and pattern multiplication are both applied. The simulated and calculated radiation patterns of the antenna array agree with each other well, as shown in Fig. 4. The design aim is realized with the specifications: realized gain is 25.6dBi, HPBWs are 10.7° and 5.3° in H-plane and E-plane respectively, side lobe level is suppressed at least 13.5dB in both H-plane and E-plane.

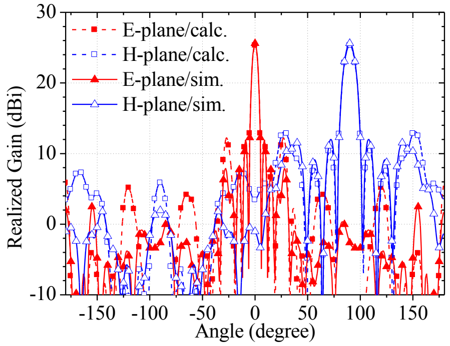


Fig. 4. Radiation pattern of the ALTSA array at 38GHz.

III. CONLUSION

It is a feasible scheme to use the ALTSA and the proposed array configuration for the millimeter-wave base station in massive MIMO system. For a base station with 36×16 antennas, the number of feed ports is 36×4 or down to 36, supporting by the high gain of the ALTSA array for each sub-sector. The proposed sub-sector design for massive MIMO system can further extend into hundreds, even thousands antenna elements in a compact size.

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