Multi-Beam Antennas for Massive MIMO System with Vertical Spatial Filtering Technique

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***Abstract*—To alleviate the RF-complexity of massive multiple-input multiple-output (MIMO) system, in this paper, we first introduce a new technique named vertical spatial filtering (VSF). Based on the proposed technique, the reduced system with only a small amount of radio frequency chains has the performance comparable to the complete system. Then, three antenna arrays are presented as good candidates for massive MIMO system with the VSF technique. With simplified feeding network or phase compensation in free space, dual beams with single-polarization, eight beams with single-polarization and ten beams with dual-polarization are achieved by the antenna arrays, respectively.**

Keywords—Massive MIMO; RF complexity; Multi-beam

I. INTRODUCTION

Recently, the fifth generation (5G) wireless communication system have been popularly studied. One of the promising key technology in 5G is the massive multiple-input multiple-output (MIMO) [1]. However, the technique of massive MIMO requires hundreds of antennas at base stations. In traditional technique, the complexity and the cost will dramatically increase when the number of BS antennas grows, because each antenna needs to connect to one specific radio frequency (RF) chain [2]. In this paper, a new technique named vertical spatial filtering (VSF) [3] is introduced to alleviate the RF-complexity of massive MIMO system, and three antenna arrays are presented as candidates for massive MIMO system with the VSF technique.

II. VERTICAL SPATIAL FILTERING TECHNIQUE

The VSF technique [3] is applied in the macro-urban area cellular networks, high speed train system and so on. In the place mentioned above, the power angular spectrum within a 120° sector derived from 3rd Generation Partnership Project three-dimensional channel model is shown in Fig. 1. It is found that the signal power is constrained in a small area in elevation domain, and 99% of signal power is restricted in the elevation angle between 75° and 121°. In the VSF technique, the redundant beams are discarded and only desired beams in elevation domain are preserved. By selecting part of vertical beams in elevation domain, large amount of RF chains might be saved, however, the system performance could still be maintained. Moreover, with the VSF technique, the reduced system can save RF chains in vertical dimension of two-dimension (2D) array. Beam forming can be simply realized by passive networks. The total power fed to the aperture is divided into several RF chains in the horizontal dimension, which avoids high power amplifiers and expensive RF components.

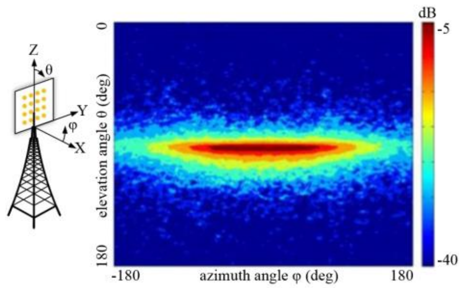

Fig. 1. Simulated power angular spectrum at BS array in NLOS environment with 10000 UTs. Sector angle is 120◦ in azimuth domain. The result is normalized by maximum value.

III. LINEAR MULTI-BEAM ANTENNAS

Based on the requirements of massive MIMO system with the VSF technique [3], a 2D antenna array should be formed by multiple linear multi-beam antenna arrays. In horizontal dimension, the 2D antenna array can be treated as a phased array. In vertical dimension, the 2D antenna array should generate multiple beams with fixed directions, wide coverage angle and stable gain to reduce the number of RF chains. To satisfy the requirement, three linear multi-beam antenna arrays are presented in [4]-[6].

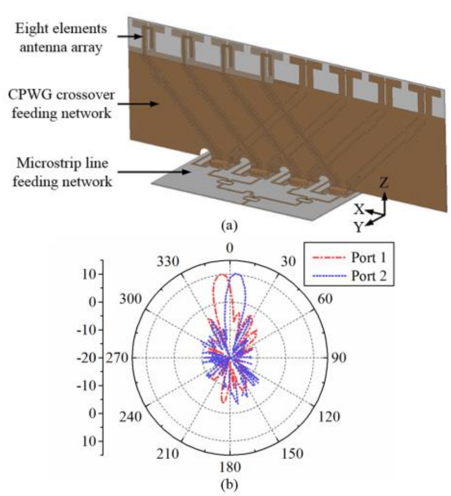

Fig. 2. (a) Geometry of the 1 ×8 antenna array with microstrip-line feeding network and CPWG crossover feeding network. (b) E-plane (xoz-plane) radiation patterns of the two ports at 5.8 GHz.

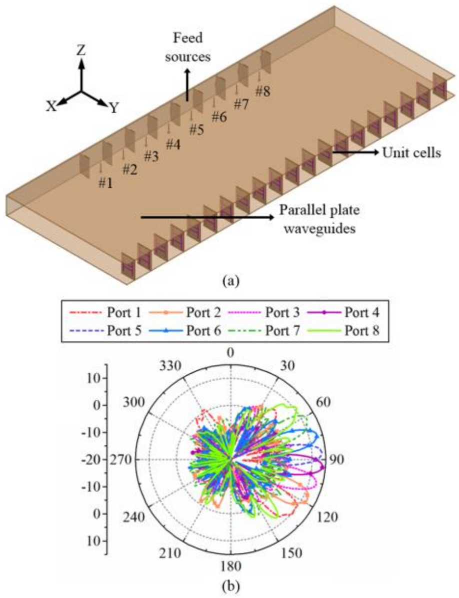

Fig. 3. (a) Geometry of the linear single-polarized multi-beam transmitarray. (b) H-plane (xoy-plane) radiation patterns of the eight ports at 5.8 GHz.

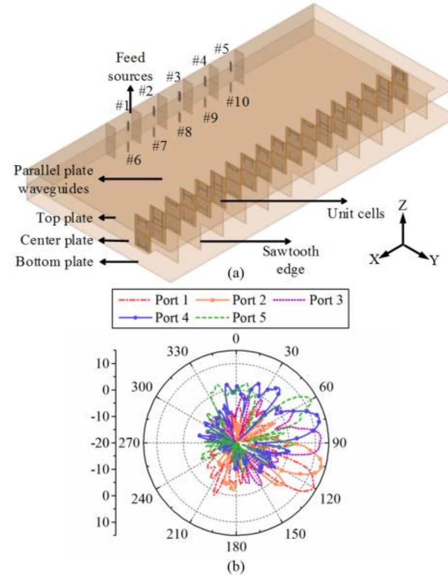

Fig. 4. (a) Geometry of the linear dual-polarized multi-beam transmitarray. (b) H-plane (xoy-plane) radiation patterns of the ports from #1 to #5 at 5.8 GHz.

A dual-beam eight-element antenna array is proposed in [4], as shown in Fig. 2(a). The feeding network is composed of a microstrip-line feeding network with four 90° hybrids and a coplanar waveguide with ground feeding network with compact crossover structures. As shown in Fig. 2(b), at 5.8 GHz, the antenna array achieves two beams pointing to ±7°. Compared to a conventional 8 × 8 Butler matrix that uses twelve 90° hybrids, the proposed antenna array has only four 90° hybrids and compact crossover structures, which is important for massive MIMO system in reducing the cost of RF chains.

To further simplify the structure of multi-beam antenna arrays, a linear single-polarized multi-beam transmitarray is exhibited in [5], as shown in Fig. 3(a). The proposed antenna array is with a simple structure consisting of a parallel plate waveguide (PPW), eight feed probes and twenty phase-shifted elements. The compensation phase distribution is designed based on sliding aperture technique. This technique refers to the customization of each beam by part of the aperture, resulting in a good performance of low scan loss over a wide angular range for the antenna array. At 5.8 GHz, the measured radiation pattern of H-plane is shown in Fig. 3(b). Eight beams cover the ±42° azimuth area and the beam intersection level better than -4 dB.

To achieve the performance of ±45° dual polarization and the ability of forming a 2D array, a linear dual-polarized multi-beam transmitarray is presented in [6], as shown in Fig. 4(a). The antenna consists of two PPWs, ten feed sources and thirty-six unit cells. Each PPW has a height of 0.34 wavelength at center frequency of 5.8 GHz, and has five feed sources and eighteen unit cells. On the center plate, saw-tooth edge is adopted to transform the vertical polarization in the top and bottom PPWs to ±45° linear polarization, respectively. Comparing to the antenna array in [5], the height of phase-shifted unit cell has been decreased, which makes it feasible to realize dual polarization while keeping the thickness of array under 0.68 wavelength. In each parallel plate waveguide, the five beams with same polarization cover a wide azimuthal range between ±30°. At 5.8 GHz, the measured H-plane radiation pattern of the five ports on top PPW is shown in Fig. 4(b).

IV. Conclusion

In this paper, the principle and advantages of the VSF technique is introduced briefly, and three linear antenna arrays based on the requirement of massive MIMO system with VSF technique are presented. The VSF technique and the antenna arrays provide a new choice for the massive MIMO system to reduce the RF complexity while keeping good performance.

Acknowledgement

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