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Beam Probability Metric for 5G OTA Testing in Multi-Probe Anechoic Chamber Setups

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***Abstract*—Over-the-air (OTA) testing for 5G antenna systems has become a strong need because conducted testing is no longer applicable. New OTA testing metrics are required to evaluate new performance of 5G antenna systems. This paper investigates the recently proposed metric, e.g. beam probability for 5G OTA testing in multi-probe anechoic chamber (MPAC) OTA setups.**

***Index Terms*—5G OTA testing, MPAC, adaptive antenna, beam probability.**

I. INTRODUCTION

Massive MIMO and millimeter-wave (mmWave) technologies have been utilized in 5G communications [1]. Since the radio channel is highly sparse and dynamic, the adaptive beamforming operation with beam selection process has become a key feature of 5G antenna systems. However, this feature introduces new challenges to the performance testing of 5G antenna systems.

Among three OTA testing methodologies, multi-probe anechoic chamber (MPAC) test system is more suitable for OTA testing of 5G antenna systems [2]. A new metric of beam probability is developed for 5G antenna systems testing because of the beam management and beam scheduling in 5G new radio [3]. In this metric, the beam selection performance of 5G antenna systems is evaluated.

It is still interesting to investigate how to quantify the emulation accuracy in terms of beam probability under target channel and emulated channel. In this paper, the beam probability metric is investigated in MPAC OTA setups. 3D channel models are selected because they are more suitable for 5G research.

II. METHOD

The prefaded signal synthesis (PFS) technique is adopted in MPAC OTA setups to transmit fading signals to device under test (DUT) by OTA probes with appropriate power weights allocated. With noise neglected, the signals received at the DUT array elements are as follows [4]

$$\boldsymbol{x}[n] = \mathbf{F}\boldsymbol{s}[n] \tag{1}$$

where $\boldsymbol{x}[n] \in \mathbb{C}^{M\times 1}$ and $\boldsymbol{s}[n] \in \mathbb{C}^{K\times 1}$ are vectors containing M received signals and K transmitted OTA signals at the nth snapshot, respectively. $\mathbf{F} \in \mathbb{C}^{M\times K}$ is a transfer matrix from K OTA probes to M DUT elements.

The beam power from the space angle Ω using Bartlett beamforming at the nth snapshot is

$$P(\Omega)[n] = \left|\boldsymbol{a}^H(\Omega)\boldsymbol{x}[n]\right|^2 \tag{2}$$

where $\boldsymbol{a}(\Omega) \in \mathbb{C}^{M\times 1}$ is the steering vector. $\{\cdot\}^H$ denotes the Hermitian operator.

The bth beam with the highest power at the nth snapshot is

$$P[n] = \max_b P(\Omega_b)[n] \tag{3}$$

where Ω_b denotes space angle of bth beam direction.

Then the probability of detecting the maximum power in the bth beam is

$$p(\Omega_b) = \frac{n_b}{N} \tag{4}$$

where n_b is the time for bth beam satisfying (3) over N snapshots.

The beam peak distance D_p and the beam statistical distance D_s are the barycenter offset and the similarity percentile respectively between the reference and the OTA beam probability distributions [5]

$$D_p = \left\| \sum_{b=1}^{B} \Omega_b p_r(\Omega_b) - \Omega_b p_o(\Omega_b) \right\| \tag{5}$$

$$D_s = \frac{1}{2}\sum_{b=1}^{B} |p_r(\Omega_b) - p_o(\Omega_b)| \tag{6}$$

where $p_r(\Omega_b)$ and $p_o(\Omega_b)$ are probabilities of the bth predefined beam in the reference and the OTA cases, respectively. B is the number of predefined beams.

III. SIMULATION RESULTS

A 3D sectored MPAC OTA setup emulating 3D channel models [5] is shown in Fig. 1. A 3D single cluster channel model with azimuth angle spread of departure (ASD) 5° and zenith angle spread of departure (ZSD) 3° [6] is selected as an example. Both the azimuth angle of departure (AoD) and the zenith angle of departure (ZoD) are 0°. The probe panel covers 60° from -30° to $+30^\circ$ in azimuth and 30° from -15° to $+15^\circ$ in elevation. The angular spacing is 5°. Five OTA probes are active from the probe panel as an example. The power angular spectrum (PAS) of the single cluster channel model and the active probes are shown in Fig. 2.

DUT is an 8×8 planar array with half-wavelength spacing. The beamforming power pattern of adaptive DUT using

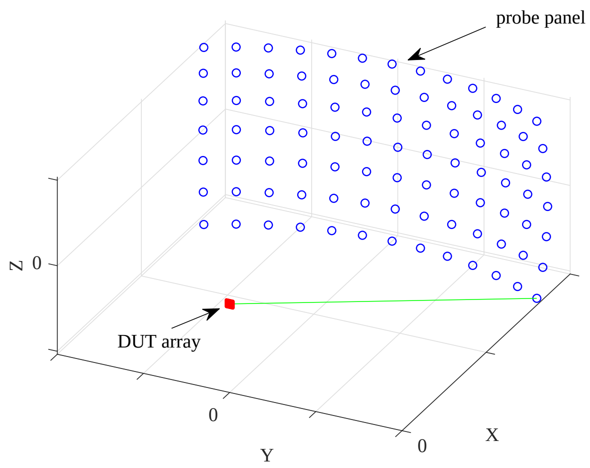

Fig. 1. 3D sectored probe configuration in MPAC OTA setup.

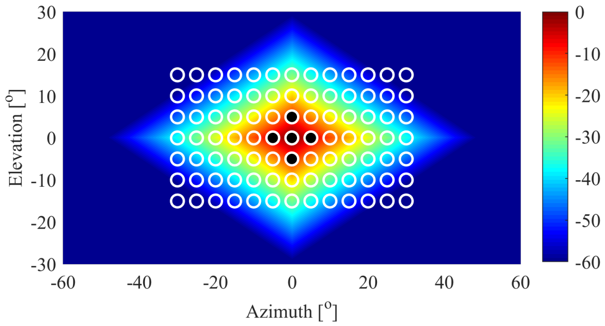

Fig. 2. PAS of single cluster channel model and active OTA probes.

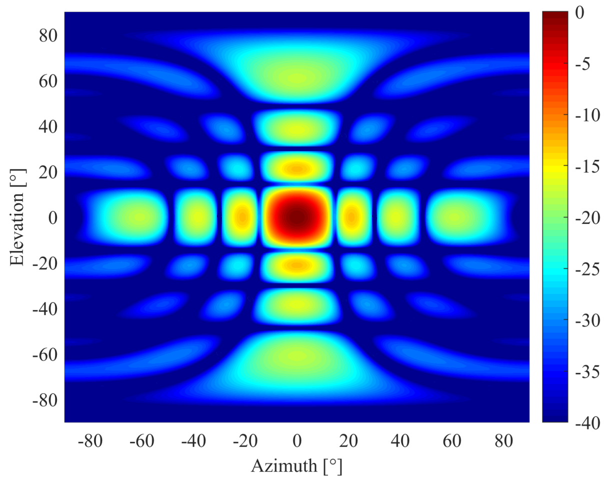

Fig. 3. DUT Beamforming power pattern.

Bartlett beamforming in azimuth of 0° and elevation of 0° is shown in Fig. 3 as an example.

It is assumed that the predefined main beams of DUT array are targeted to $B = 91$ directions, i.e. 7 in elevation and 13 in azimuth. The beam probability distributions under the reference and the OTA channel models are presented in Fig. 4. The beam peak distance and the beam statistical distance are 0.18° and 0.07, respectively.

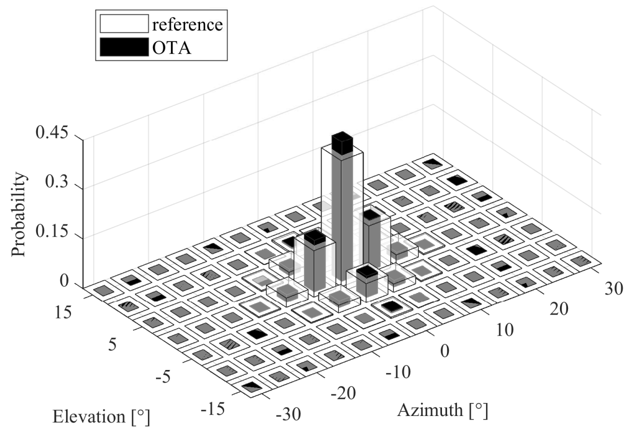

Fig. 4. Predefined beam directions and their probabilities under the single cluster channel model in the reference and the OTA cases.

IV. Conclusion

A beam probability metric for 5G OTA testing is presented in this paper. This metric is adopted to evaluate the beam selection performance of 5G antenna systems. The emulation accuracy is quantified by the beam peak distance and the beam statistical distance. Good emulation accuracy is achieved with given probe number and locations for 3D single cluster channel model as an example. For 3D multi-cluster channel models, the corresponding probe number and locations will be required.

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