E-band Point-to-Multipoint Antennas Based On Wide-Scan Focal Plane Arrays

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***Abstract*—An antenna-system concept is explored where a wide-scan focal plane array antenna is used for point-to-multipoint communications at E-band. As a preliminary study the directivity is investigated for a beam scanning to boresight for several array sizes and inter-element spacings and the azimuthal cuts are compared to the ETSI class-III radiation pattern envelope.**

I. Introduction

With mmWave-5G on the horizon, the required microwave backhaul and fronthaul capacity is expected to rise rapidly [1]. To achieve this capacity increase, we propose to use antenna systems at E-band with electronic beam steering, which facilitates multi-beam operation. Such antenna systems can be realized using phased arrays, but this is cost prohibitive as several hundreds of antennas are required to achieve a directivity that is high enough. Instead, we propose a novel point-to-multipoint antenna system that consists of a wide-angle scanning reflector with a number of beamforming arrays in the focal plane. Each individual array generates one independent beam pointing to a different site. In addition to this, the weights of each antenna element can be changed, combining the reconfigurability of a phased array and the high directivity of a reflector antenna [2].

In this paper this system is investigated in simulation at E-band. Only one array is considered, placed in the center of the focal plane, scanning towards boresight ($az = el = 0°$). The azimuthal cuts of the resulting radiation patterns are compared to the ETSI Class-III radiation pattern envelope (RPE) for different inter-element spacings and for different numbers of elements.

II. Model

The reflector that is used in this paper is based on the work presented in [3]. It is a parabolic toroid reflector with a scanning range of $\pm 30°$ in azimuth. For the feeding antennas we use balanced square patch antennas resonant at 80GHz. The isolated element pattern is obtained from a full-wave simulator, CST Microwave Studio. The resulting pattern is imported to GRASP where a square array of N-by-N elements with an inter-element spacing d is created as depicted in Fig. 1. From this the resulting radiation pattern can be calculated for each antenna separately. These patterns $\boldsymbol{E}_{\text{co}}$ and $\boldsymbol{E}_{\text{cross}} \in \mathbb{C}^{N_{\text{points}} \times N_t}$ are electric fields normalized to the free-space impedance, but not normalized to unity power. N_{t} is the total number of antennas equal to N^2 for square arrays. N_{points} is the number of points the electric fields are evaluated in.

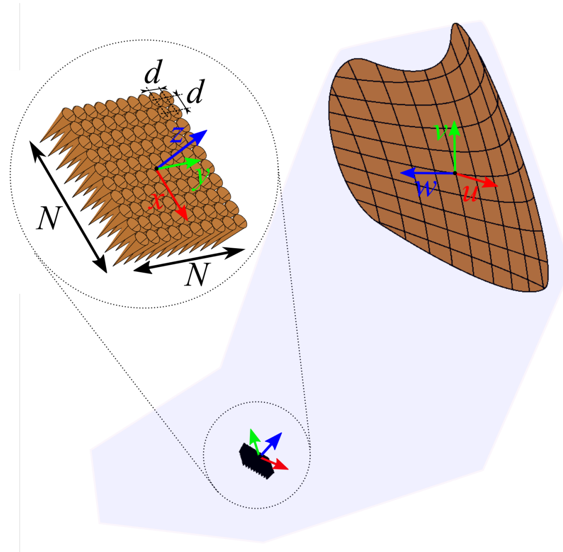

Figure 1. A depiction of the simulation setup in GRASP. Shown is the parabolic toroid reflecor illuminated by an array with $N = 10$ and $d = 1.0\lambda_0$.

The excitations of the antennas are found by applying maximum ratio transmission (MRT) beamforming on the simulated patterns, according to

$$\boldsymbol{w} = \boldsymbol{h}^{\dagger} \tag{1}$$

where $\boldsymbol{w} \in \mathbb{C}^{N_t \times 1}$ is the excitation vector and $\boldsymbol{h} \in \mathbb{C}^{1 \times N_{\text{t}}}$ is the channel vector. The dagger symbol † represents the hermitian transpose. The complex coefficients $h(n)$ that build $\boldsymbol{h}$ are found by evaluating the complex value of the co-polarized component of the electric field of antenna n in the scanning direction. We can then find the co- and cross-components of the directivity function $\boldsymbol{D}_{\text{co}}$ and $\boldsymbol{D}_{\text{cross}} \in \mathbb{C}^{N_{\text{points}} \times 1}$ using

$$\boldsymbol{D}_{\text{co}} = \frac{4\pi |\boldsymbol{E}_{\text{co}} \boldsymbol{w}|^2}{P_{\text{rad}}}, \boldsymbol{D}_{\text{cross}} = \frac{4\pi |\boldsymbol{E}_{\text{cross}} \boldsymbol{w}|^2}{P_{\text{rad}}} \tag{2}$$

where the total radiated power P_{rad} is computed by integrating the radiated power over a spherical grid that encloses the antenna array.

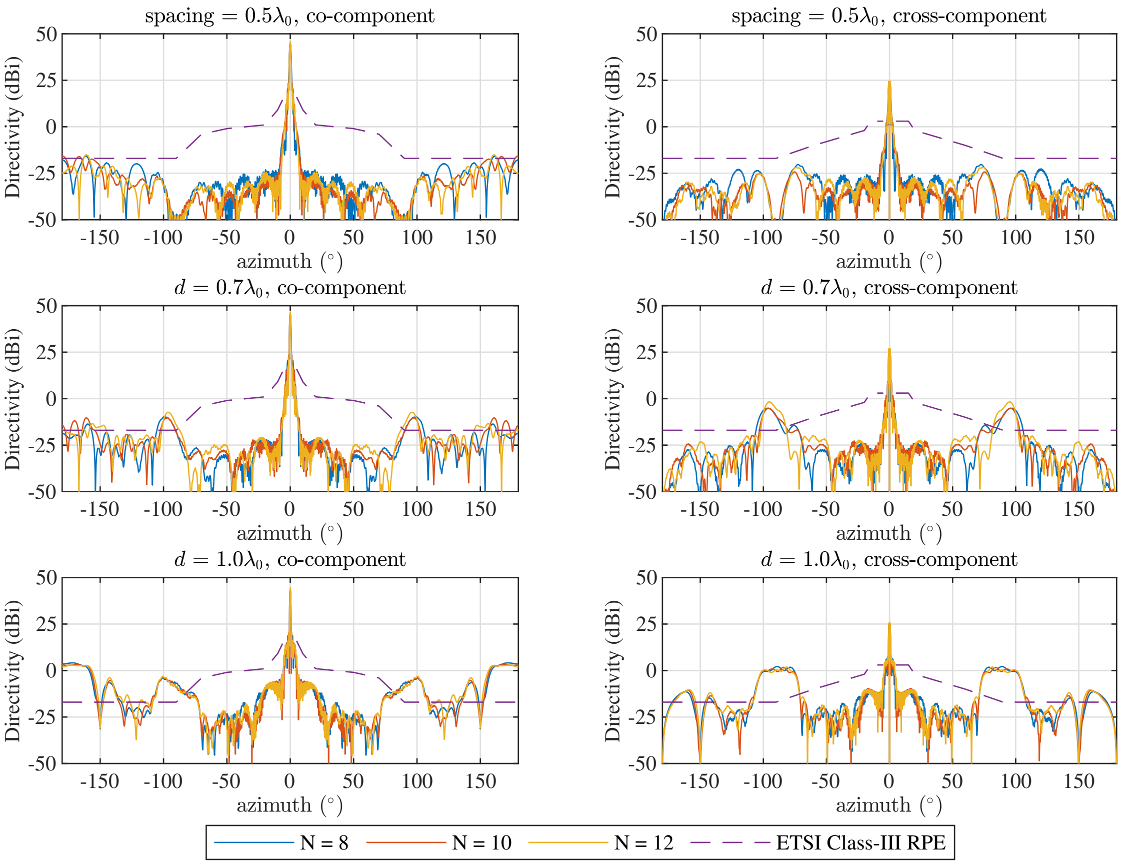

Figure 2. Azimuthal cuts of the directivity patterns of the focal plane array antenna with several array setups at 80GHz.

III. Results

The directivity function is calculated for arrays of 8-by-8, 10-by-10 and 12-by-12 elements and inter-element spacings $0.5\lambda_0$, $0.7\lambda_0$ and $1.0\lambda_0$. The calculated azimuthal cuts (uw-plane, see Fig. 1) are shown in Fig. 2. The directivity is the highest for the largest array (12-by-12) but depends on d. For $d = 0.5\lambda_0$ it is 45.7dBi, for $d = 0.7\lambda_0$ it is 46.6dBi, and for $d = 1.0\lambda_0$ it is 44.5dBi. This shows that $0.7\lambda_0$ is the best choice in terms of directivity. For the $0.7\lambda_0$ case the directivity of the 10-by-10 array is 0.4dB lower compared tot the 12-by-12 case and the directivity of the 8-by-8 array is 1dB lower compared to the 12-by-12 case.

Also shown in Fig. 2 is the ETSI Class-III RPE for E-band point-to-point antennas. From the figure we can see that the mask is not satisfied for any of the configurations because of back-radiation. This radiation that comes directly from the array without hitting the reflector. This can be solved by using absorbers surrounding the array itself, using more directive antenna elements or by using a different beamformer that minimizes this direct radiation.

IV. Conclusion and future work

An antenna concept was introduced where a wide-angle scanning reflector can be used to scan to multiple sites simultaneously by placing several antenna arrays in the focal plane. For a beam towards boresight, the azimuthal cuts of the radiation patterns are calculated for different array sizes and inter-element spacings. The directivity is the highest for an inter-element spacing of $0.7\lambda_0$. It is shown back radiation must be taken into account to avoid violating the ETSI Class-III radiation pattern envelope. In future work this concept will be further explored by investigating the performance of beams scanning in different directions, and by taking measurements with an experimental setup at K-band.

References

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