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Beam Shape Reconfigurability of Wide-Scan Focal Plane Array Antennas

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***Abstract*—In this contribution we investigate the flexibility of wide-scan focal plane array antennas at mmWave. Based on measurement data, it is shown that highly directive beams can be generated, as well as wide beams with increased transmission power which are useful in stormy conditions where the rain attenuates the signal and the antenna tower twists and sways due to the wind. In addition, it is shown that sum and difference beams can be generated which can be used for radar sensing applications. The directivity is between 31.4dBi and 37.2dBi depending on the beam type, with a relative transmission power between 10.5dB and 18.1dB, compared to the maximum transmission power of a single antenna element.**

I. Introduction

Wide-scan focal plane arrays (FPA's) have been proposed as a solution for the increased path loss and attenuation at mmWave frequencies. FPA's have several key benefits compared to phased arrays. This includes an increase in directivity due to the addition of the reflector, and a decrease of power consumption due to the decreased number of antenna elements that need to be active at a time. An example of a wide-scan reflector that can be used to generate multiple simultaneous beams is the parabolic toroid reflector. This reflector has been demonstrated for the use of remote sensing [1], mobile access [2] and point-to-multipoint communications [3]. This shows the wide range of applications that can be targeted with FPA antennas.

To show the flexibility of the system in more detail, we take the setup from [3], where an 8x8 analog beamforming array is placed in the focal plane of a parabolic toroid reflector with point-to-multipoint communication as the intended application. Here it was shown that the beam can be manipulated in order to compensate for twisting and swaying of the antenna tower by changing the excitation weights. In this contribution, two additional applications are shortly discussed and the associated beam shapes and weight distributions are given.

II. Model

The measurement setup used is shown in Fig. 1. The far-fields resulting from the excitation of each antenna element in the 8x8 array are measured at 25.9GHz. Based on this, a total resulting field can be calculated in Matlab by changing the excitation weights of each antenna element. We investigate three situations; 1) Maximum ratio transmission (MRT) beamforming. This is the same as conjugate beamforming, and this serves as the reference for the other two cases. MRT optimizes the power in the far-field in the intended direction

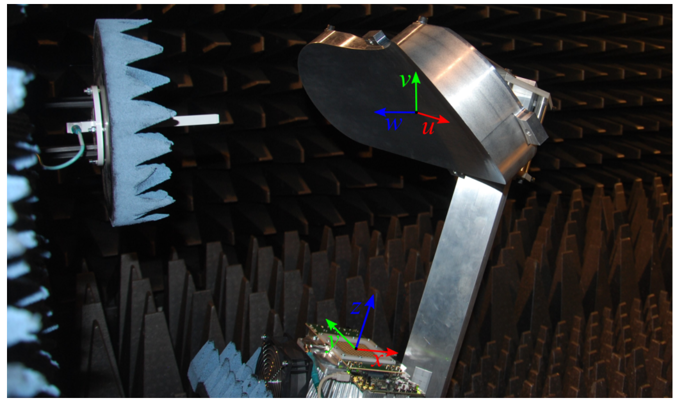

Figure 1: A picture of the wide-scan focal plane array system in the near-field measurement facility.

with respect to the transmitted power P_{Tx}. 2) All-on scenario, where antennas are turned on with the highest weight such that a wide beam is generated. This increases P_{Tx} at the cost of directivity. The effective isotropic radiated power (EIRP) is increased. It is useful to overcome stormy conditions, where the attenuation is increased due to rain, and simultaneously the link is impacted by twist and sway of the antenna tower. 3) To achieve monopulse radar operation, sum (Σ) and difference (Δ) beams need to be generated. As a proof of concept we show that a Δ-beam can be generated by using MRT to form two beams, towards $-0.8°$ and $0.8°$ in azimuth, and then exciting the array with the difference between the generated weights. The Σ-beam is not shown here for the sake of brevity.

III. Results

In Fig. 2 the resulting radiation patterns are shown for each of the three cases with the associated amplitude and phase settings. The settings are quantized to 8 bits, where 255 is the highest amplitude and phase setting. The estimated directivities based on the method described in [3] are given in Table I. The EIRP and P_{Tx} relative to the maximum transmission power of a single element are also given. These quantities are computed in the same way as in [3]. It can be seen that the EIRP is increased in the all-on condition. The Δ-beam also shows a high EIRP, also due to an increase in relative P_{Tx}.

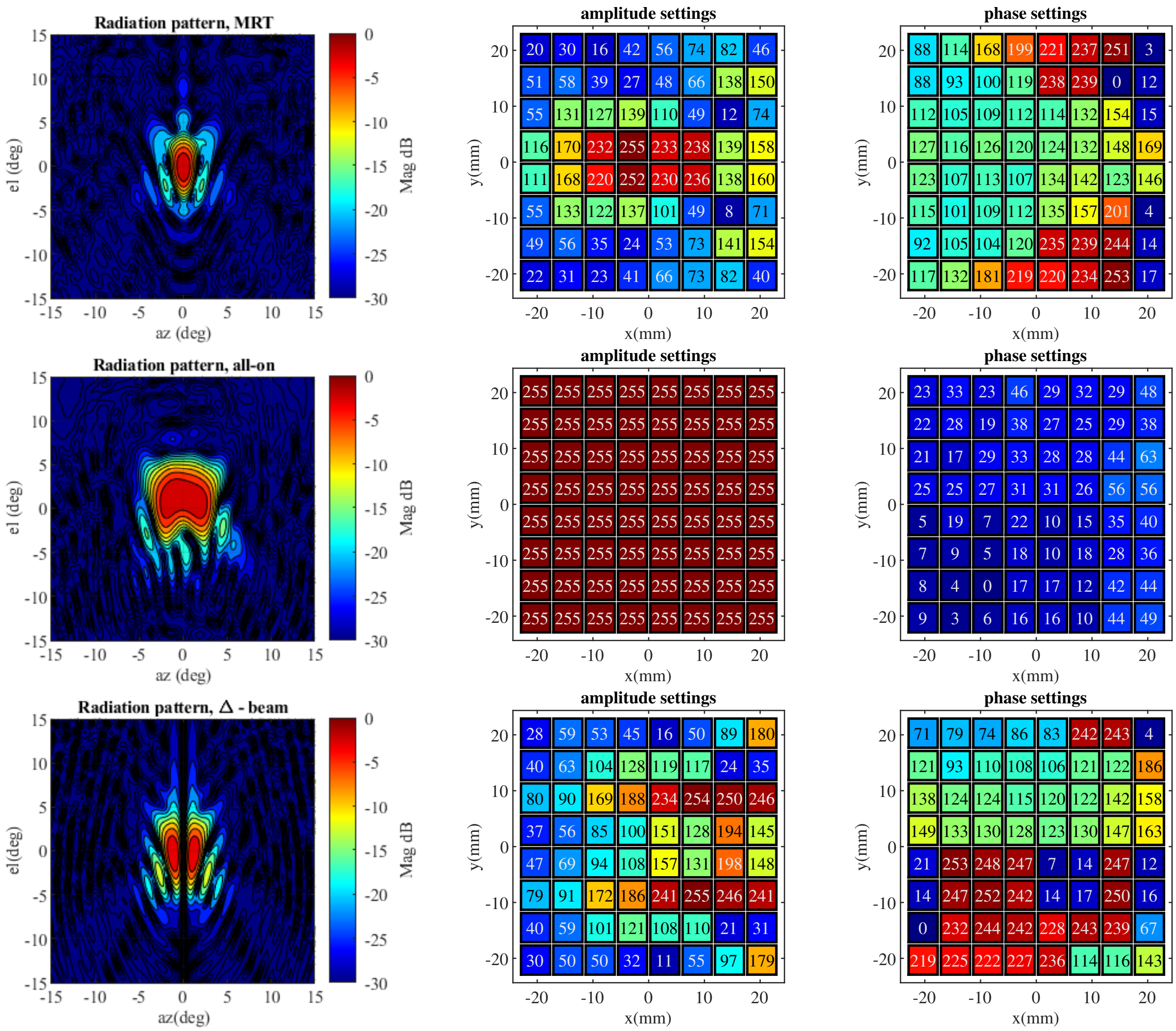

Figure 2: Beam shapes, gain, and phase settings of the considered scenarios. Upper row: MRT beam towards $(0°, 0°)$ in az and el. Middle row: all-on beam, where all antenna elements are turned on. Lower row: a Δ-beam, formed by exciting the array with the difference of the MRT weights that form a beam towards $\pm 0.8°$ in az.

Table I: Directivity, P_{Tx} and EIRP relative to the maximum power of a single element for the three cases.

	MRT	All-on	Δ-beam
Directivity (dBi)	37.2	31.4	34.7
Relative P_{Tx} (dB)	10.5	18.1	13.0
Relative EIRP (dB)	47.7	49.5	47.6

IV. Conclusion

In this contribution it is shown that wide-angle scanning FPA antennas exhibit a high degree of reconfigurability due to the ability to change the shape of the beams. We showed that the beam shape can be adjusted to be wider and with a higher transmission power which can be useful during stormy conditions in a point-to-multipoint setup. Furthermore we can also generate sum and difference beams that can be useful in the field of radar sensing.

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