Performance evaluation of near-field plane wave generated by a reflectarray for 5G testing

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***Abstract*—In this work a reflectarray is proposed to be used as a plane wave generator (PWG). The reflectarray works at 28 GHz and produces a plane wave in the Fresnel region of the antenna in order to obtain a compact structure. The generated wave front must satisfy tight requirement both in amplitude and phase in order to be considered as an uniform plane wave. The designed reflectarray based on a three-parallel-dipole cell has been manufactured. The prototype is measured in a planar range facility to evaluate the performances of the plane wave generated. The antenna satisfies the tight requirements and shows low ripple both in phase and amplitude and, therefore, promising results are obtained.**

***Keywords*—Plane wave generator, PWG, reflectarray, measurement system, compact antenna test range.**

I. Introduction

The rise of the interest on the applications at (sub)millimeter frequencies has led to new technological requirements, particularly the development of efficient 5G communications at 28, 39 or 60 GHz [1,2], satellites communications at Ka-band [3] or automotive radars at 70 GHz [4]. Therefore, antenna measurement systems need to evolve in order to satisfy these new requirements, where CATR systems are a potential candidate. These systems are generally based on a parabolic reflector that transform a spherical wave front into a plane one. This plane wave is generated in the near-field region of the reflector and is used to measure the radiation pattern of the device under test (DUT) [5], but the plane wave cannot be considered uniform because of the illumination taper produced by the feed.

In this work, a reflectarray antenna is designed to generate the required uniform plane wave in an area to measure antennas, replacing the traditional parabolic reflector. In this case, a small reflectarray of $17.61\lambda \times 17.61\lambda$ elements is proposed to generate the plane wave at a distance of 46.6λ or 500 mm at 28 GHz. This antenna provides a quiet compact structure that can be potentially used in the measurement of 5G devices. The desired plane wave satisfies tight requirement in both amplitude and phase within an area of radius 100 mm. The proposed reflectarray is manufactured and measured in a planar range facility to evaluate the generated plane wave.

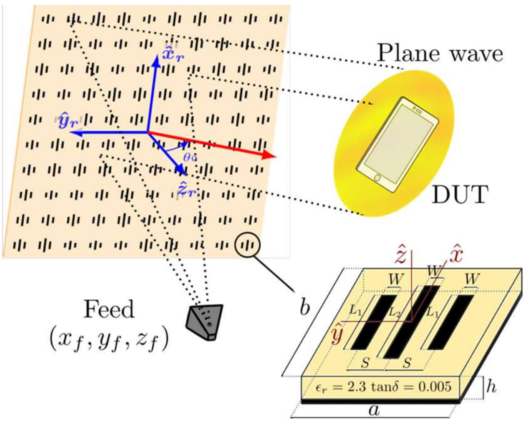

Fig. 1. Scheme of a plane wave generator (PWG) based on a reflectarray to measure the DUT.

II. Reflectarray and Quiet Zone characteristics

A. Antenna optics

A squared reflectarray made up of 44×44 elements, distributed in a regular grid of periodicity 4.29×4.29 mm^2 $(a \times b)$, is proposed to demonstrate its use as a PWG at 28 GHz. The reflectarray is fed in an offset configuration and the phase center of the feed is placed at $(x_f, y_f, z_f) = (-79.3, 0, 200)$ mm taking the center of the reflectarray as the origin of the coordinate system (see Fig. 1). The feed is a pyramidal standard gain horn of 15 dBi that generates an illumination taper of -15.80 dB at the edge of the reflectarray.

The reflectarray is designed using cells based on a set of three parallel dipoles oriented to the polarization axes as Fig. 1 depicts. The dipoles width is $W = 0.5$ mm and the separation among the three dipoles is $S = 1.43$ mm. The length of the lateral dipoles (L_1) depends on the central dipoles and is defined as $L_1 = 0.7L_2$. The variation of the length L_2 allows to adjust the phase-shift of the cell, obtaining a phase-shift larger than 360° [6]. The dipoles are printed on a single layer of Diclad 880 substrate ($h = 0.762$ mm, $\epsilon_r = 2.3, \tan\delta = 0.005$). The reflectarray is tilted an angle $20°$ around the y_r-axis, resulting on an equivalent aperture (D) of

$$D = D_x \times D_y = 188.7\cos\gamma \times 188.7 = 177.3 \times 188.7\ \text{mm}^2 \quad (1)$$

B. *Quiet Zone specifications*

The plane wave is generated on a perpendicular plane to the propagating direction, particularly at 500 mm (46.66λ) from the center of the reflectarray. This configuration provides an ultra-compact structure considering that the far-field region starts at 12.52 m (1170λ). The typical tight specifications of 1 dB and $10°$ for this applications are imposed on an area of diameter 100 mm (9.33λ), more than the 50% of the antenna aperture width in both x- and y-axis.

III. Experimental validation

The proposed reflectarray has been manufactured and measured in the planar acquisition range at the University of Oviedo. The antenna is oriented to generate a plane wave parallel to the probe aperture, an open-ended Ka-band waveguide, and the plane $z = 500$ mm is measured. The co-polarization component of the electrical field, both amplitude and phase, is obtained and shown in Fig. 2. Most of the amplitude ripple is nearly close to 1 dB in the whole area and a maximum peak-to-peak ripple of 1.8 dB. The ripple compliance within 1 dB is close to the 70% in the measured area while a 93% of this area is within 1.5 dB of ripple. Furthermore, the phase of the generated plane wave obtains a very flat phase. The maximum deviation measuring the peak-to-peak ripple is 18°, nonetheless the phase distribution along most of the area is within a maximum deviation of 10°-12°. It may be highlighted the smoothness of the main cuts ($x = 0$ and $y = 0$), both amplitude and phase. These cuts represent the larger dimension of the requirement area and show satisfactory results. Particularly, the cut $x = 0$ since it is not affected by the non-symmetry of the feed.

IV. Conclusion

A reflectarray antenna is analyzed to generate a plane wave to measure the radiation pattern of the antenna. The reflectarray generates the plane wave in an area close to the antenna providing a compact structure. Particularly, the proposed reflectarray is made of 44×44 elements based on three parallel printed dipoles cells at 28 GHz. The plane wave satisfies the tight ripple requirements close to 1 dB in amplitude and $10°$ in phase. The reflectarray is manufactured and evaluated in a planar range facility, where the plane wave is measured. The measurement shows a nearly uniform plane wave at a distance equivalent to 46.6λ, which is suitable to be used for the test of 5G devices at millimeter waves.

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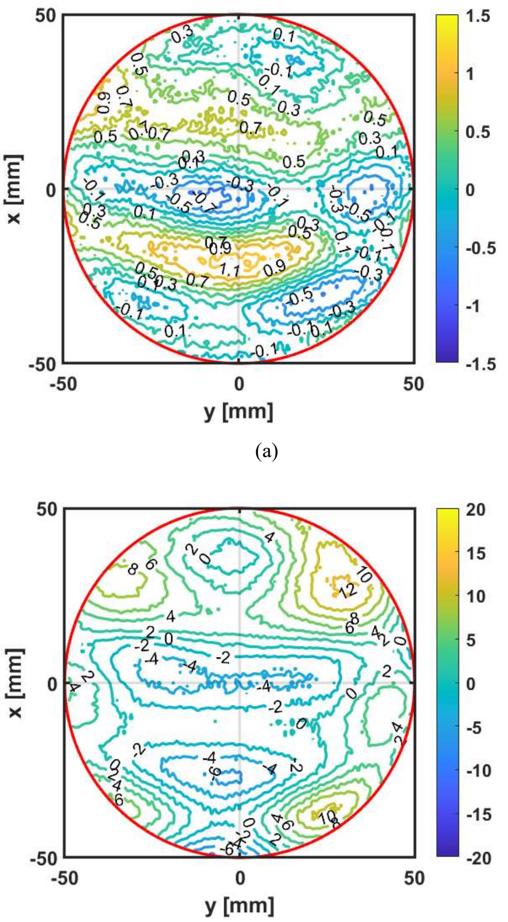

(a)

(b)

Fig. 2. Plane wave generated by the proposed reflectarray at $z = 500$ mm and measured in the planar facility range at 28 GHz (a) Normalized amplitude (b) Phase.

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