

Comparative Testing of Devices in a Spherical Near Field System and Plane Wave Generator

F. Scattone, D. Sekuljica, A. Giacomini, F. Saccardi,
A. Scannavini, L. J. Foged
MVG, Microwave Vision Italy SRL
Via dei Castelli Romani 59
00071, Pomezia, Italy
lars.foged@mvg-world.com

E. Kaverine, N. Gross, P. O Iversen
MVG, Microwave Vision
47 bd Saint Michel
75005 Paris, France
nicolas.gross@mvg-world.com

Abstract—The Plane Wave Generator (PWG) is an array of elements generating an approximately plane wave over a finite volume in the test area called Quiet Zone (QZ). The plane wave condition can be achieved in close proximity to the array with suitably optimized complex coefficients. The PWG thus achieve far-field testing conditions in a manner similar to the Compact Antenna Test Range (CATR) but with a reduced distance to the QZ [1-2]. As a complete system the PWG has the advantage of reduced physical size compared to the a CATR with equivalent testing capabilities, in particular at lower frequencies. In [3-4], the concept of a high performance, dual polarized PWG supporting up to 1:10 bandwidth was presented. A prototype of a dual polarized PWG has been designed, manufactured and tested in the 600MHz to 6GHz frequency range.

This paper presents the initial verification of the prototype PWG. The testing is performed using a representative analog beam forming network with narrow bandwidth. The QZ uniformity of the PWG is verified by spherical near-field measurements and back-propagation. The peak gain of a low directivity antenna is measured at different distances in the QZ and compared to reference measurements in a spherical near-field system. The aim of the comparison is to access the measurement accuracy of the PWG.

I. INTRODUCTION

A Plane Wave Generator (PWG) has several interesting advantages in comparison to other antenna testing systems. It shares with the Compact Antenna Test Range (CATR) the possibility to perform direct measurement of far-field performance in a controlled indoor environment [1-4]. Due to the similarity, the PWG measurement uncertainty contributions are similar to the CATR [1]. However, the direct illumination of the QZ by the feed as in CATR systems can be neglected. The PWG has the added advantage of having a physical size considerably smaller than the CATR, in particular for lower frequencies. The advantage of physical size affects the dimensions and associated cost of the anechoic chamber. This advantage is of importance for testing at sub-6GHz frequencies for Over-The-Air (OTA) testing of 4G and the upcoming 5G devices. The PWG concept is illustrated in Figure 1.

The PWG is a flexible system. It measures the complete spherical radiation patterns of the Antenna Under Test (AUT) by a simple mechanical rotation of the PWG or the AUT in 3D

space respectively. Another possibility is to use the array coefficients to steer the angle of arrival of the plane wave in the QZ. Such steering is however limited to small angles of incidence [5-6]. The size of the QZ sphere is a design parameter depending upon other constraints such as PWG dimension, number of radiating elements and the desired measurement distance between the PWG and AUT. The most natural way to generate the spherical QZ is by using a circular lattice array [7-10]. The array element is an important contributing factor to the achievable bandwidth of the PWG. The element must be physically small to fit the array lattice and radiate a nearly constant pattern in the usable bandwidth of the array.

A key parameter to consider the PWG a valid alternative to CATR is the achievable bandwidth. The PWG design goal is a wide band system, able to generate a uniform QZ for several octaves. A dual polarized PWG covering this 10:1 frequency range has been presented in [3,4] including design guidelines and justification. The synthesized QZ using ideal array coefficients of the measured PWG subarrays shows promising results. This was supported by emulation of different measurement scenarios by post-processing.

In this paper a narrow band beam forming network has been implemented at 3.5GHz and the full QZ performance measured my spherical near-field measurements and back propagation. The peak gain of a low directivity antenna is measured and compared to measurement in a spherical near-field system. This investigation is a first step in the process of accessing the measurement accuracy of PWG systems.

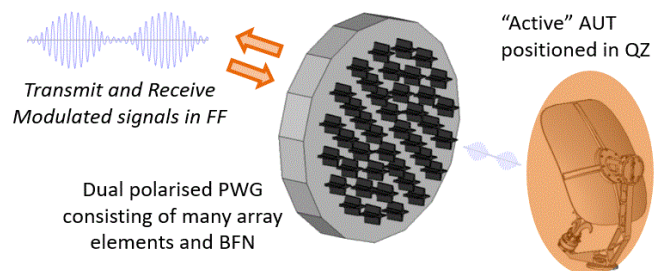


Figure 1. PWG prototype: An approximate plane wave is generated by suitably excited array elements.

II. QZ PERFORMANCE OF PWG WITH NARROW-BAND BEAM FORMING NETWORK

The PWG has been equipped with a narrow band Beam Forming Network (BFN) optimized for the desired excitation coefficients at 3.5GHz. Details of the optimization process is outlined in [3,4]. The field from sub-arrays of the PWG are determined by measurements and post-processing at points called stations in the QZ. This is achieved by taking advantages of the properties of the spherical wave expansion and the fact that the QZ is outside the minimum sphere surrounding the PWG [2]. The process of PWG optimization is to determine the optimum weights on the array elements, subject to the constraints of the BFN that minimize an objective function. An often adopted objective function is the maximum deviation, in amplitude and phase, between the synthesized field on the stations defining the QZ and the desired one.

The BFN consist of attenuators and phase shifters that operates over a narrow bandwidth. The QZ performance in terms of amplitude and phase deviation with respect to an approximate plane wave is determined by measurement of the full PWG in a spherical near-field system and back-propagation of the measured field to the QZ. Figure 2 shows the PWG testing in the SG-64 spherical near-field testing facility of MVG, Paris.



Figure 2. PWG during validation measurement in the spherical NF multi probe system SG-64 in Paris.

The down-range QZ amplitude and phase field distribution generated by the PWG @ 3.5GHz are shown in Figure 3 and Figure 4 respectively. The spherical QZ volume has diameter $d_{QZ} = 480$ mm and is centered in $C_{QZ} = 950$ mm distance from the PWG surface.

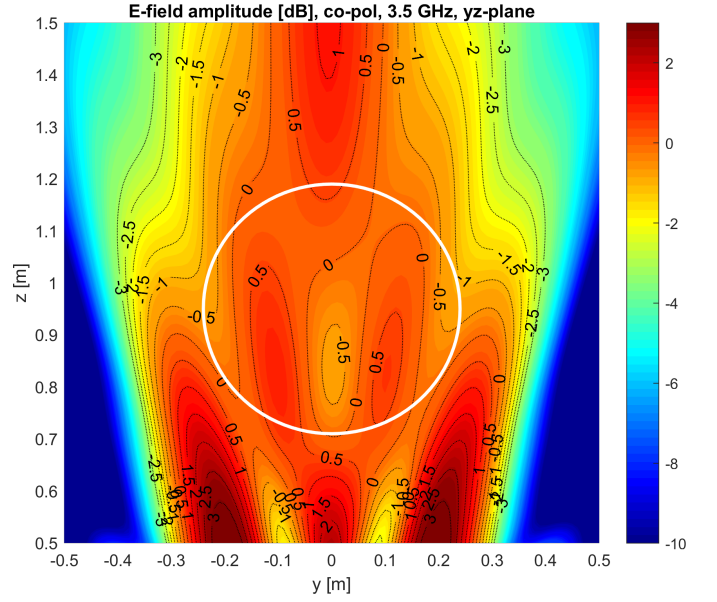


Figure 3. Measured E-field amplitude map of down-range QZ @ 3.5 GHz. The white ring indicates the QZ position of $C=950$ mm and dimension $d=480$ mm.

The measured QZ amplitude variation within the entire spherical region is lower than ± 0.7 dB. The Root Mean Square (RMS) of the amplitude variation is always lower than 0.4 dB. The worst-case phase variation has similar behavior, being lower than ± 8 deg within the QZ. Also in this case, the RMS is fairly low, with a maximum value of 5° . These values confirm the expected QZ deviations predicted from ideal excitation coefficients as reported in [3,4].

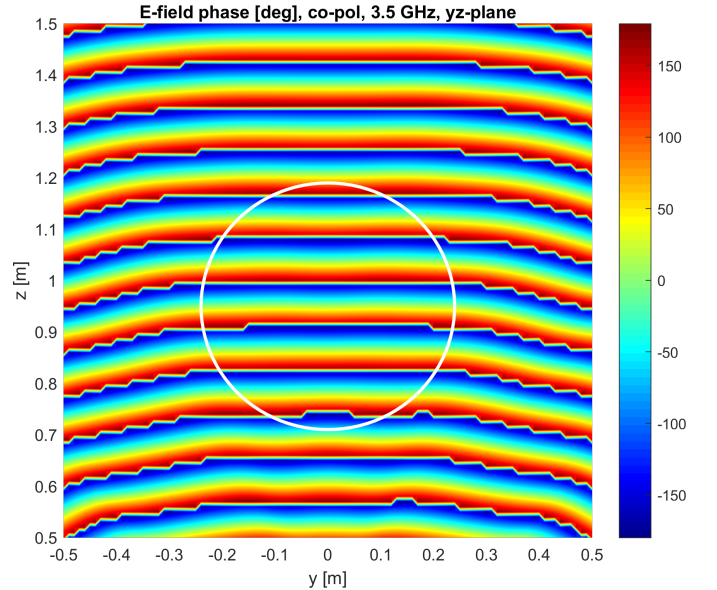


Figure 4. Measured E-field phase map of down-range QZ @ 3.5 GHz. The white ring indicates the QZ position of $C=950$ mm and dimension $d=480$ mm.

III. PRELIMINARY VALIDATION OF PWG BY MEASUREMENT OF PEAK GAIN OF A LOW DIRECTIVITY ANTENNA

In [3,4] the expected measurement accuracy was evaluated by simulation using the measured QZ performance and a known antenna. It was shown that the deviation from perfect plane wave condition in the QZ is sufficiently low to expect a good measurement accuracy. As a first step in the evaluation of measurement accuracy we decided to measure the on-axis gain of a low directivity antenna, the and compare with results from measurement in a standard spherical near field system. The test antenna is the single polarized, SH2000 dual ridge horn covering the 2-32GHz frequency range. As both systems use the gain-transfer or gain substitution technique [1,2] for gain determination the uncertainty on the reference antenna can be eliminated from the investigation by using the same reference antenna is both measurements. The test antenna is the single polarized, SH800 dual ridge horn covering the 0.8-12GHz frequency range.



Figure 5. Illustration of the on-axis gain measurements using the PWG prototype. The antenna and reference antenna are placed in different positions within the QZ.

The measurement setup for the on-axis gain measurement is shown in Figure 5. The cables of the analog BFN can be seen on the back of the PWG. The test and reference antenna are placed in the QZ of the PWG at approximately 950mm from the array aperture. Measurements consist in measuring the coupling S21 of the PWG and antenna in the QZ using a Network Analyzer (NA). The system and gain calibration are measurements with the SH800 dual ridge horn placed in the QZ. Measurement with the “unknown” test antenna, SH2000 dual ridge horn are performed at different distances around the center of the QZ. Reference measurements on both antennas are carried out in the SG-64 spherical near-field multi-probe facility of MVG, Paris as shown in Figure 2.

The preliminary results with the SH2000 test antenna in 3 positions in the PWG, QZ @ 3.5GHz are shown in Table I. The measured on-axis gain variation with respect to references measurements from the SG64 spherical near field multiprobe system is within 0.1dB. As the SH800 dual ridge horn was used as reference in both measurements, uncertainties due to the reference gain values are eliminated. Although these results are extremely encouraging, the final uncertainty quantified as difference between spherical near-field measurements and PWG are expected to be higher than the values for the limited experiment in this paper as reported in Table I.

TABLE I. MEASURED ON-AXIS GAIN OF SH2000 @ 3.5GHz

AUT	Reference Gain	Gain QZ +50mm	Gain QZ +0mm	Gain QZ -50mm
SH2000	5.05 dB	5.11 dB	5.12 dB	5.10 dB

IV. CONCLUSION

The concept of a high performance, dual polarized Plane Wave Generator (PWG) supporting up to 1:10 bandwidth has been presented by the design, manufacturing and testing of a prototype covering the 600MHz to 6GHz frequency range. In previous publications the expected measurement accuracy was evaluated by simulation using the measured QZ performance and a known antenna. It was shown that the deviation from perfect plane wave condition in the QZ is sufficiently low to expect a good measurement accuracy.

In this paper the possibility to measure low gain antennas using a PWG has been verified by experiment. The preliminary results with the test antenna place in different positions within the QZ show very encouraging results. Activities are on-going to investigate the achievable accuracies for such measurements.

REFERENCES

- [1] “IEEE Standard Test Procedures for Antennas,” ANSI/IEEE Std 149-1979.
- [2] J. E. Hansen (ed.), “Spherical Near-Field Antenna Measurements”, *Peter Peregrinus Ltd.*, London, United Kingdom, 1988
- [3] F. Scattone, D. Sekuljica, A. Giacomini, F. Saccardi, A. Scannavini, P. O Iversen, N. Gross, L. J. Foged “Plane Wave Generator for Direct Far-field Over-The-Air Testing of Devices”, AMTA 2018
- [4] F. Scattone, D. Sekuljica, A. Giacomini, F. Saccardi, A. Scannavini, N. Gross, E. Kaverine, P. O Iversen, , L. J. Foged “Design of Dual Polarised Wide Band Plane Wave Generator for Direct Far-Field Testing”, 13th European Conference on Antennas and Propagation EuCAP 2019, Krakow, Poland
- [5] A. Capozzoli, C. Curcio, G. D’Elia, A. De Simone, A. Liseno, “An optimized approach to plane wave synthesis”, Proc. of the *29th Annual Antenna Measurem. Tech. Ass. Symp.*, 2008.
- [6] A Capozzoli, C Curcio, G D’elia, A Liseno, G Ianniello, and P Vinetti, “Effective 2D generalised plane wave synthesizers: Experimental validation”, Proc. of the *30th Annual Antenna Measurem. Tech. Ass. Symp.*, 2009.
- [7] A. Buonanno, M. D’Urso, and G. Prisco, “Reducing Complexity in Indoor Array Testing,” *IEEE Transactions on Antennas and Propagation*, vol. 58, no. 8, pp. 2781-2784, Aug. 2010.
- [8] O. M. Bucci, M. D. Migliore, G. Panariello, and D. Pinchera, “Plane-Wave Generators: Design Guidelines, Achievable Performances and Effective Synthesis,” *IEEE Transactions on Antennas and Propagation*, vol. 61, no. 4, pp. 2005-2018, Apr. 2013.
- [9] O. M. Bucci, C. Gennarelli, and C. Savarese, “Fast and accurate near-field-far-field transformation by sampling interpolation of plane-polar measurements,” *IEEE Transactions on Antennas and Propagation*, vol. 39, no. 1, pp. 48-55, Jan. 1991.
- [10] O. M. Bucci, C. Gennarelli, and C. Savarese, “Representation of electromagnetic fields over arbitrary surfaces by a finite and nonredundant number of samples,” *IEEE Transactions on Antennas and Propagation*, vol. 46, no. 3, pp. 351-359, Mar. 1998.
- [11] P. E. Frandsen and S. B. Sørensen, “Formulations of the contoured beam array antenna minmax optimization problem”, *Proceedings of the 1994 Progress in Electromagnetics Research Symposium*, European Space Agency, Noordwijk, The Netherlands, Jul. 1994.