INVESTIGATION OF SGH PERFORMANCE AND REPEATABILITY

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ABSTRACT

Standard Gain Horns (SGH) are utilized frequently either as measurements antenna or as reference antenna in antenna gain measurements by comparison or substitution method [1]. They also find use as source antennas in anechoic test chambers and for many other purposes such as fixed site antennas. The most widespread SGH geometry has a rectangular cross-section and is pyramidal with optimized geometry to achieve maximum gain [2, 3, 4]. When used as a precision gain reference in antenna measurements the SGH is often calibrated by a reference facility or another third party. When external or internal calibration means are not available the SGH peak gain is often determined directly from the reference tables of the NRL report [2]. The quality of the original work is such that even today the associated uncertainty on these peak gain values are generally accepted to be within +/-0.3dB [1]. In this paper the accuracy of the NRL gain tables are investigated by comparison with a full wave numerical method based on FDTD [7] and measurements in different antenna test ranges. Performance variation of the SATIMO Standard Gain Horns due to the manufacturing and measurement accuracy has been also investigated with conducted and radiated experiments.

Keywords: Uncertainties, Measurement, Errors, Evaluation, Standard Gain Horns.

INTRODUCTION

A commonly used gain references are SGH designed according to the indication in NRL report 4433 [2]. Due to weight, size and handling constraints these SGH are divided in five families with nominal mid-band gain increasing from 13.7dBi to 24.7dBi. Since the ohmic losses in the horns in most cases can be considered negligible if high quality materials are used [5] the gain is approximately equal to the directivity and can be estimated accurately using closed form formulas.

This gain estimate does not include losses due to matching and in the transition that has to be measured and taken into account separately to arrive at the SGH realized gain. In the original NRL report the peak gain uncertainty is estimated to +/-0.3dB for frequencies above 2.6GHz and +/-0.5dB below [2]. In this gain estimate the contributions from the diffraction from the aperture edge and the reflections due to the flare junction are not taken into account.

HORN DESIGN AND MANUFACTURING

The SATIMO Standard Gain Horns as shown in Figure 1 are manufactured to meet the requirements of NRL report 4433 [2] The horns are divided in five families with nominal mid-band gain increasing from 13.7dBi to 24.7dBi covering the frequency range [0.49-60] GHz.

Figure 1: SATIMO family of NRL compliant Standard Gain Horn.

The SGH design is based on an integral low loss coaxial to rectangular waveguide transition feeding a pyramidal horn. The SGH’s have been designed using commercial full-wave simulation tool [7] and optimized for minimum sensitivity to material and manufacturing variations.

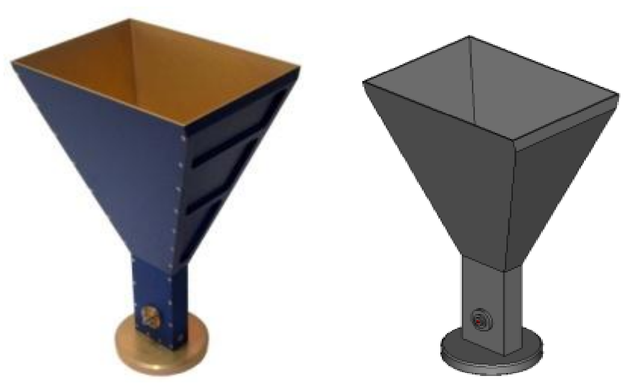

Figure 2: SGH395 Standard Gain Horn –real antenna and full-wave model.

MECHANICAL DESIGN

All SATIMO SGH's have been designed with high accuracy integral connector and standard interface specifically developed for fast and accurate antenna positioning.

Figure 3: SGH mechanical technology. Coupled plates at lower frequencies and coupled shells in the higher frequency range.

Due to the stringent electrical constraints of maintaining high accuracy/repeatability and mechanical constraints such as robustness, ease of handling, weight, size etc the SGH family is manufactured using two different mechanical technologies.

- Numerical machined coupled aluminum plates. The two lateral plates are thicker to allow precision coupling and further machined in order to reduce weight while maintaining high structural strength as shown in Figure 3 (Left).
- Two coupled shells with lateral screws as is shown in Figure 3 (Right). The coupling zone has been machined with a small dent to guarantee excellent coupling on the internal part of the horn as can be seen in Figure 4.

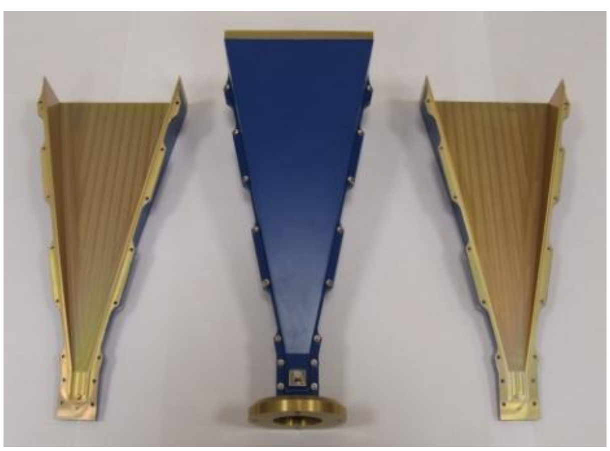

Figure 4: SGH1800 [18-26.5] GHz, mechanical technology - two coupled shells.

PERFORMANCE AND REPEATABILITY

The SGH performance parameters and repeatability has been investigated using measurements, numerical modeling and comparison with the closed form NRL prediction formulas [2]. In order to investigate the performance variations due to assembly, material and manufacturing tolerances repeated conducted and radiated measurements have been performed on several SGH's from different manufacturing lots. The SATIMO SGH395 with nominal frequency band [3.95-5.85] GHz has been selected for this study.

Boresight Gain Accuracy

The accuracy of the NRL gain tables is investigated. The NRL gain values do not include matching and ohmic losses in the transition. The contributions from the diffraction from the aperture edge and the reflections due to the flare junction are also not taken into account. The SGH395 horn has been modeled using full wave numerical method based on FDTD [7] and it has been measured in SG-64 Spherical near field test facility in Atlanta, US as shown in Figure 5.

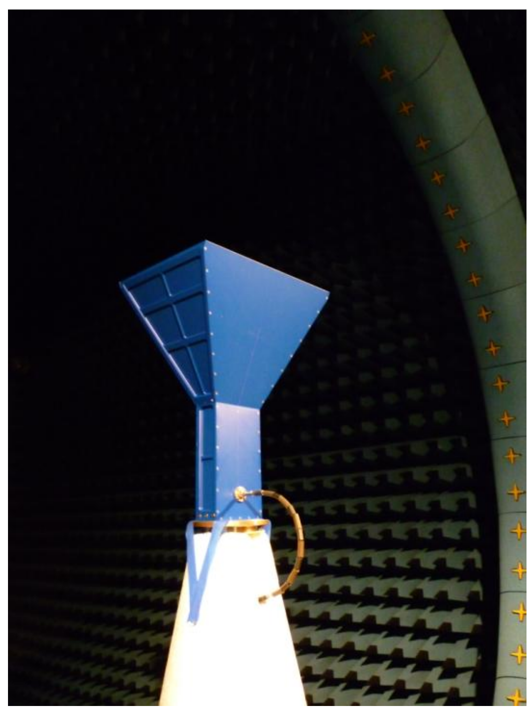

Figure 5: SGH in SG-64. Spherical near field test facility. Frequency range [0.4-6] GHz.

The boresight gain curves obtained from prediction formulas, numerical modeling and measurement have been compared in the frequency range [3.95-5.85] GHz. The results are shown in Fig. 6. Good agreement is observed with worst deviation within +/-0.25dB.

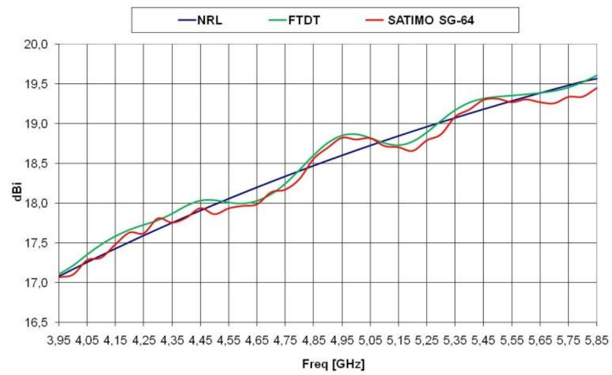

Figure 6: SGH395 Boresight gain curves obtained from prediction formulas (NRL), numerical modeling (FTDT) and measurements (SATIMO SG-64).

The NRL formulas do not take into account the performance contribution from the aperture edge diffraction and this difference is clearly visible in the comparison with the measured and numerical modeling data. However, all methods agree within the stipulated accuracies of the NRL formulas.

Performance Variation Study

The SGH performance parameter variation due to assembly, material and manufacturing tolerances has been investigated with conducted and radiated experiments. The SGH395 in the frequency range [3.95-5.85] GHz has been selected for measurements.

In both cases the measurements have been conducted on horns from different manufacturing lots. The parameters investigated are:

- Return loss
- Efficiency
- Gain

The gain and efficiency definition of this analysis is referred to as realized gain which is less than the IEEE definition [1] by the values of the antenna return loss.

The return loss of five (5) different SGH395 was measured in shielded 2.5 x 3.0 x 4.0 m anechoic chamber with VHP-8-NRL absorbers using an Agilent PNA N5230A Vector Network Analyzer calibrated with a Rosenberger calibration kit RPC-2.92. Figure 7 shows the return loss measurements of the different SGH395 in the operating frequency range. The RMS value of the deviation with respect to the mean values is 0.03dB.

The gain and efficiency of five (5) SGH395 were measured at 10MHz intervals in the StarLab spherical near field measurement facility [6] in Rome, Italy as shown in Figure 9. The gain of the antenna under test (AUT) is determined by the gain-transfer or substitution method in which the unknown power gain of the test antenna is compared to that of a gain-standard antenna. The gain standard used is a dual ridge horn calibrated in different facilities in the course of international facility comparison campaign [9].

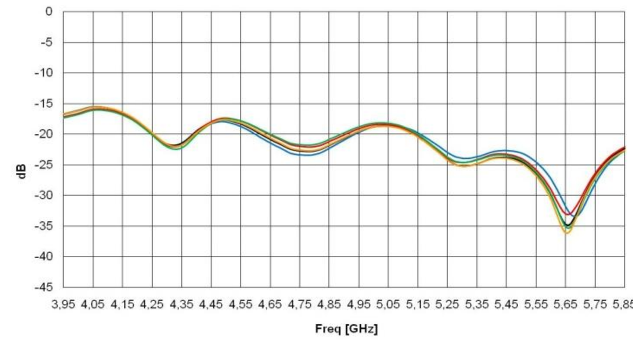

Figure 7: Measured return loss, five different SGH395

All SGH horns where measured during the same day one after another. No attempt was made to evaluate the system error in the repeated measurements (repeatability in alignment and mounting, cable movements, drift etc). This error has been quantified in an earlier study [8] to about 0.01dB with careful measurements.

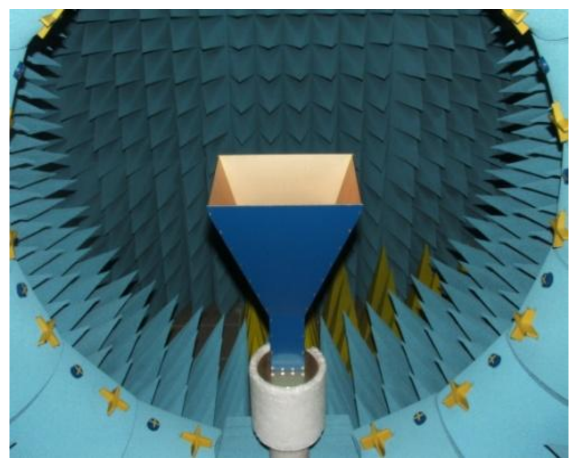

Figure 8: SGH395 during the measurements in the StarLab 0.8-18GHz, Spherical near field test facility.

The SGH395 efficiency variation of the 5 horns with respect to the calculated mean value is shown in Fig. 10. The "root mean square" (RMS) value determines the efficiency repeatability. This value is better than 0.01dB in the investigated frequency range.

The same approach was used to determine the variability of the boresight gain of the different SGH's. The RMS value of the measured variation with respect to the mean value is 0.03dB as shown in Figure 10.

The measured performance RMS variation between SGH395 of different manufacturing lots is summarized in Table 1.

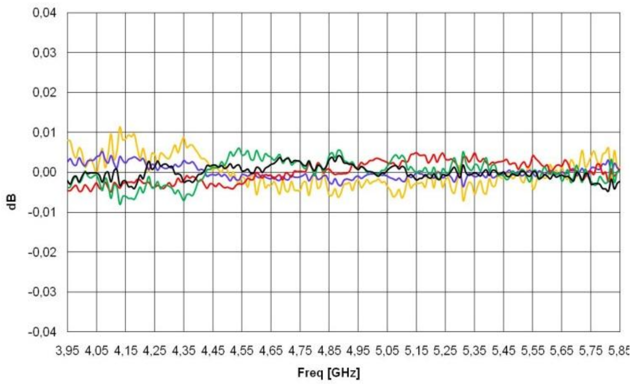

Figure 9: Deviations of measured efficiency with respect to the mean values for five different SGH395.

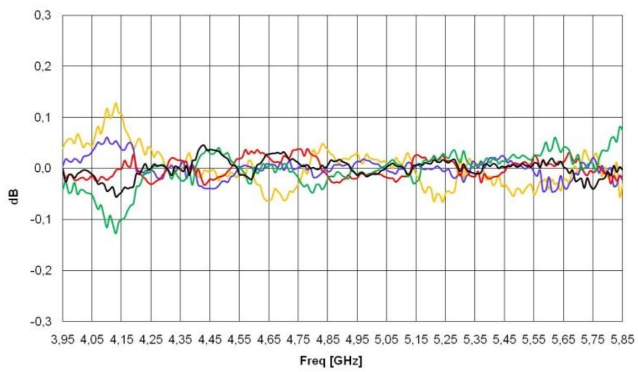

Figure 10: Deviations of measured boresight gain with respect to the mean values for five different SGH395.

Parameter	**Performance Variation (RMS)**
Gain	+/-0.03dB
Efficiency	+/-0.01dB
Return loss	+/-0.03dB

Table 1: Measured performance variation for SGH395

CONCLUSION

SGH performance parameters and repeatability has been investigated using measurements, numerical modeling and comparison with the closed form NRL prediction formulas [2]. In order to investigate the performance variations due to assembly, material and manufacturing tolerances repeated conducted and radiated measurements have been performed on several SGH's from different manufacturing lots. The SATIMO SGH395 with nominal frequency band [3.95-5.85] GHz has been selected for this study. The measurements have been performed in the SG-64 Spherical near field test facility in Atlanta, US and the SL18GHz facility in Rome, Italy.

Good agreement in terms of boresight gain has been observed between data from prediction formulas, numerical modeling and measurement. Worst deviation is within +/-0.25dB. The NRL formulas do not take into account the performance contribution from the aperture edge diffraction and this difference is clearly visible in the comparison with the measured and numerical modeling data. However, all methods agree within the stipulated accuracies of the NRL formulas.

The SGH performance parameter variation due to assembly, material and manufacturing tolerances show an excellent agreement between different horns from different manufacturing lots in terms of return loss, efficiency and gain. The return loss of five different SGH395 was measured in shielded anechoic chamber. The RMS value of the deviation with respect to the mean values is 0.03dB in the investigated frequency range. The gain and efficiency of five different SGH395 were measured at 10MHz intervals in the StarLab spherical near field measurement facility in Rome. The RMS value of the deviation with respect to the mean values is 0.03dB for the gain and better than 0.01dB for the efficiency.

The SATIMO Standard Gain Horns are commercially available in the [0.49-60] GHz frequency band

REFERENCES

[1] Standard Test Procedures for Antennas, IEEE Std.149-1979

[2] W. T. Slayton,"Design and calibration of microwave antenna gain standards" NRL report 443, Nov 9, 1954.

[3] C.A. Balanis, "Antenna theory", Wiley, 2nd Edition, 1997.

[4] T.S. Bird & A.W. Love, "Horn antennas", in J.L. Volakis, "Antenna Engineering Handbook", 4th Edition, McGraw-Hill, New York, 2007, Chapter 14.

[5] J. E. Hansen (ed.), Spherical Near-Field Antenna Measurements, Peter Peregrinus Ltd., on behalf of IEE, London, UK, 1988.

[6] P.O. Iversen, Ph. Garreau, K. Englund, E.Pasalic, O. Edvardsson, G. Engblom, "Real Time Spherical Near Field Antenna Test Range for Wireless Applications", AMTA, October 1999, Monterey Bay, California S.

[7] www.cst.com

[8] A. Giacomni, B. Bencivenga, L.Duchesne L. J. Foged. "Determination of high accuracy performance data for dipole reference antennas". AMTA Europe Symposium, Munich, May 1-4, 2006.

[9] L. J. Foged, A. Giacomini, L. Scialacqua, R. Morbidini, N. Isman "Comparative Investigation of SGH Performance Prediction Formulas, Measurements and Numerical Modelling", 4th European Conference on Antennas and Propagation, EuCAP 2010, Barcelona, Spain, April 2010.