Accurate Gain Measurements for Large Antennas using Modified Gain-Transfer Method

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***Abstract*—The classic gain-transfer method assumes a uniform plane wave incident over the apertures of the gain-transfer standard (typically a standard-gain horn) as well as the antenna under test. Variations in the incident field over the quiet zone of an antenna test range can produce large errors in the estimated gain of the antenna under test. These errors can be significant, especially when there is a large difference in aperture dimensions between the antenna under test and the standard-gain horn. In this paper a modified gain-transfer method is described to reduce errors in gain measurements when antennas, significantly larger than the standard-gain horn are measured in a test range using the gain-transfer method. The aperture of the antenna under test is usually much larger than that of the standard-gain horn and therefore these antennas will typically be exposed to different variations in the incident field. Measured results are presented to illustrate accurate gain measurements for antennas significantly larger than the standard-gain horn.**

***Index Terms*—Antennas, aperture antennas, gain measurements.**

I. Introduction

THE widely used gain-transfer method employs a standard-gain horn antenna (SGH) with a priori known gain values as transfer standard to measure the gain of an antenna under test (AUT). The received power when the antenna is illuminated with an incident field is compared to the power received by the SGH antenna when illuminated by the same incident field. The gain of the AUT is given by [1], [2]

$$G_{\mathrm{AUT}} = G_{\mathrm{SGH}} P_{\mathrm{AUT}} / P_{\mathrm{SGH}} \ , \qquad (1)$$

where G_{SGH} is the a priori known gain of the SGH, P_{AUT} is the power received into a load matched to the AUT, and P_{SGH} is the power received into a load matched to the SGH.

Accurate gain measurements require that both antennas are ideally illuminated by a uniform plane wave. This implies that the measurement should be performed in a region free from reflections and unwanted signals that can interfere with the desired incident plane wave. In practice, this condition can only be approximated to a certain extent, and consequently, field variations within the quiet zone of an antenna test range usually result in some errors during gain measurements [3], [4]. Errors in gain measurements due to differences in field variations illuminating the AUT and SGH are more evident with larger antennas where the SGH typically has a much smaller aperture compared to the AUT. The two antennas are thus exposed to different incident field distributions across their apertures, violating the assumption on which (1) is based.

In this paper a modified gain-transfer method is described and the improved performance in gain measurements for large antennas is illustrated. The modified method employs multiple reference measurement positions with the SGH over the same aperture extend as the AUT. Measured results are presented to illustrate the improvement in accuracy of gain measurements for antennas much larger than the SGH antenna. The measured results are compared with gain values obtained on a far-field range using the three-antenna method [1].

II. Modified Gain-Transfer Method

The aperture of an AUT can be much larger than that of the SGH, thus in general the two antennas will be illuminated with an incident field with different field variations over the apertures of the two antennas. In order to reduce these different variations in incident field over the apertures of the AUT and SGH it was proposed that the reference measurement of the SGH be repeated at different positions comprising the incident field illuminating the aperture of the AUT [5]. Figure 1 illustrates the modified reference measurement of the SGH in a compact antenna test range (CATR) for a typical high-gain cellular base-station antenna (AUT). The conventional gain-transfer method performs one reference measurement with the SGH in the center of the test zone (black rectangle), while the proposed modified method performs additional reference measurements over the whole aperture (transparent rectangles) of the AUT.

Equation (1) is modified to represent a more accurate estimate of the average power density incident on the aperture of the AUT, as follows:

$$G_{\mathrm{AUT}} = G_{\mathrm{SGH}} P_{\mathrm{AUT}} \Bigg/ \left(\frac{1}{N} \sum_{n=1}^{N} P_{\mathrm{SGH},\, n} \right), \qquad (2)$$

where $P_{\mathrm{SGH},\, n}$ is the power received into a matched load by the SGH at position n of N total measurement positions.

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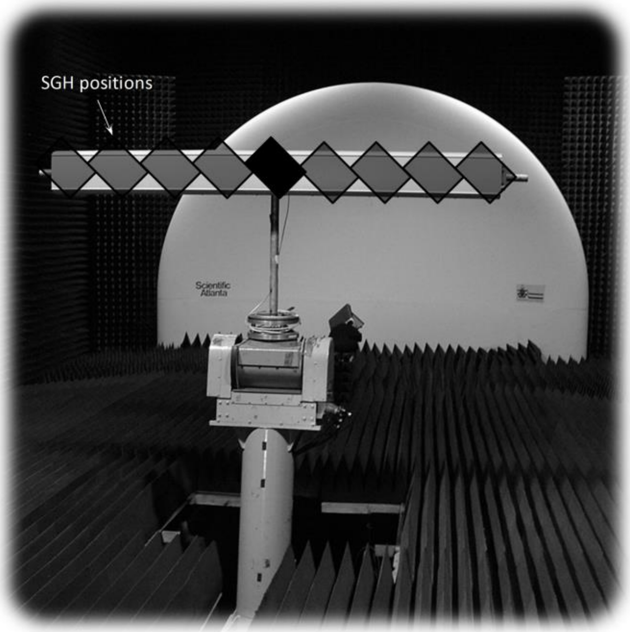

Fig. 1. The modified reference measurement of the SGH in a CATR for a typical high-gain cellular base-station antenna as AUT. The black rectangle represents the position of the SGH for conventional gain-transfer method and the transparent rectangles are additional reference measurements over the whole aperture of the AUT for the modified method.

III. Measured Results

The modified gain-transfer method was validated with measurements performed in the CATR at the University of Pretoria on a large (2.57 m long) cellular base-station antenna. The AUT operated over the 790 – 960 MHz frequency band and was dual-polarised (±45°). The long AUT was somewhat larger than the quiet zone in the CATR. A double-ridged horn was used as gain-transfer standard antenna (Manufacturer: SAAB; Model: P/N 470531-00000; Operating frequency: 0.7 to 8 GHz; Aperture dimensions (mm): 280 × 214). This allows for a sufficient number of measurement positions along the length of the AUT.

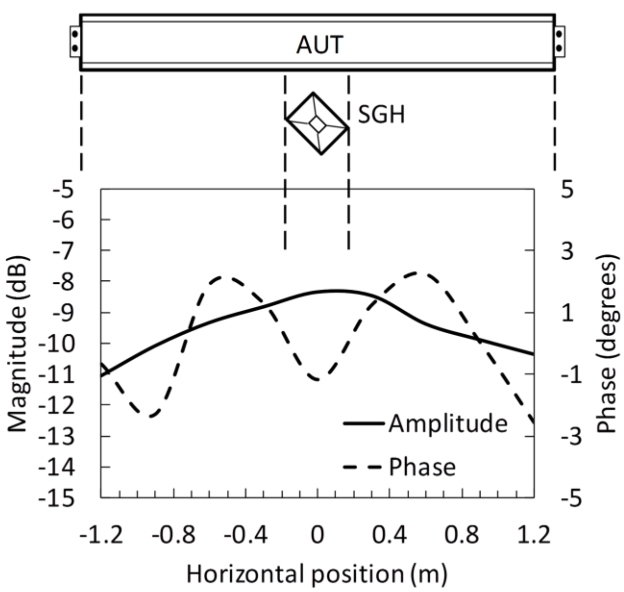

Fig. 2. The incident field distribution in the quiet zone of the CATR, measured at 900 MHz.

The actual incident field distribution (magnitude and phase) in the quiet zone of the CATR was measured using a linear scanner at 900 MHz and is shown in Fig. 2. The relative sizes of the AUT and SGH are also shown to illustrate the difference in field variations illuminating their apertures, respectively. The phase variation over the aperture of the AUT is less than ±3°, with an amplitude variation of approximately ±1.5 dB. In comparison the amplitude variation over the aperture of the SGH is less than ±0.15 dB. The requirement of an identical incident field illuminating the SGH and the AUT for the conventional gain-transfer method is seriously violated. Applying the conventional gain-transfer method, with one reference measurement of the SGH at the center of the quiet zone, would result in large measurement errors for this AUT. This expected result is confirmed in Fig. 3, with the measured gain for both polarizations of the AUT approximately 1 dB below the actual gain values of the base-station antenna.

In order to obtain accurate gain values for the AUT (indicated in Fig. 3), for comparison purposes, the gain of the cellular base-station antenna was measured using the three-antenna method on a far-field range at the National Antenna Test Range just north of Pretoria, South Africa. All measurements were corrected for impedance mismatches in order to reflect the absolute gain values of the antennas.

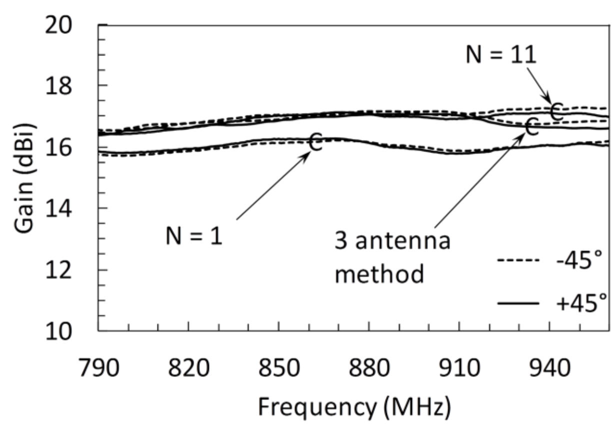

Fig. 3. The measured gain values (±45°) of a large AUT using the three-antenna method on a far-field range, the conventional gain-transfer method using one reference measurement of the SGH and the modified gain-transfer method with 11 reference measurement of the SGH over the aperture of the AUT.

The measured gain for the AUT employing the modified gain-transfer method with a total of 11 reference measurements of the SGH over the area covering the aperture of the AUT is also shown in Fig. 3. There is a significant improvement in accuracy achieved with the modified gain-transfer method compared to the conventional gain-transfer method. Except for the high part of the frequency band, the gain values closely agree with that obtained on the far-field range with the three-antenna method.

As a quantitative measure of accuracy, consider the RMS error (over frequency) between the gain values measured using the three-antenna method and the conventional gain-transfer method; and modified gain-transfer method, respectively. The RMS error improves from approximately 0.85 dB for the conventional gain-transfer method to less than 0.25 dB for the modified gain-transfer method.

IV. Conclusions

A modified gain-transfer method is presented and the improved performance in gain measurements for large antennas is illustrated, for an incident field with different distributions over the apertures of the SGH and the AUT. The modified method employs multiple reference measurement positions with the SGH over the same aperture extend as the AUT. The measured results for the modified gain-transfer method are compared with gain values obtained for the AUT on a far-field range using the three-antenna method.

The proposed method allows for accurate gain measurements of large antennas, even if there is a significant difference in field variation over the aperture of the SGH and the AUT. Although the method was only demonstrated for a long antenna, in principle the method would yield improved gain measurement performance for antennas with large apertures in both horizontal and vertical directions if additional reference measurements with the SGH are also performed in the vertical direction – covering the whole aperture of the AUT.

References

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