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NEW RESULTS OF ANTENNA-CALIBRATION IN A SINGLE-ANTENNA SET-UP

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Abstract: Results of a method are presented to measure the gain factor of a single passive antenna without the need of any reference antenna(s). A set-up for insertion loss measurement and only the antenna itself in front of a totally reflecting surface is required simulating a second identical antenna speeding up calibration procedures considerably. Since altogether only the antenna to be calibrated and a complex network analyser is needed one can expect among other things much smaller measurement uncertainty, directly traceable results, as well as much shorter time and lower cost in routine calibrations in broad frequency bands.
Keywords: Antenna, gain, calibration

1 INTRODUCTION

The conventional “2-antennas-method“ [1] determines the gain factor of an antenna from the insertion loss of a 2-port free-space transmission system. Such an arrangement requires at least one pair of identical antennas facing each other. For determining the gain of an unknown customer's antenna, the laboratory must have another one of the same type and verify the identity of the gain factors of both in a separate measurement. Other alternatives are even more complicated, e.g. the 3-antenna method, or the calibration against a standard gain antenna, where the gain factor of the latter has to be known beforehand, e.g. from a previous calibration. The 2-antennas method also seems to be a kind of chicken-and-egg problem. What is needed therefore is an antenna calibration method with only the device to be calibrated itself. For passive antennas that would be the so-called one-antenna method.

2 CALIBRATION METHOD

Exploiting the symmetry of the 2-antennas set-up it may be cut into half by placing the one antenna to be calibrated in front of a perfectly reflecting surface (Fig. 1). Only this antenna is needed to evaluate its gain factor thus considerably decreasing the measurement uncertainty because even residual gain differences between the two “equal“ antennas no longer exist. The length of the set-up is reduced by half, thus saving a lot of space and at least one extra antenna.
Additionally, all rf-powers involved (transmitted and received) can be determined only from difference (relative) measurements, e.g. using a bidirectional coupler. Therefore it would be advisable to define the antenna gain factor such that it directly relates to the voltage or power amplitudes of the forward and the received waves at the antenna connector. This ratio can easily be measured by a complex network analyser as the input s-parameter s_{11} of the simulated transmission system.

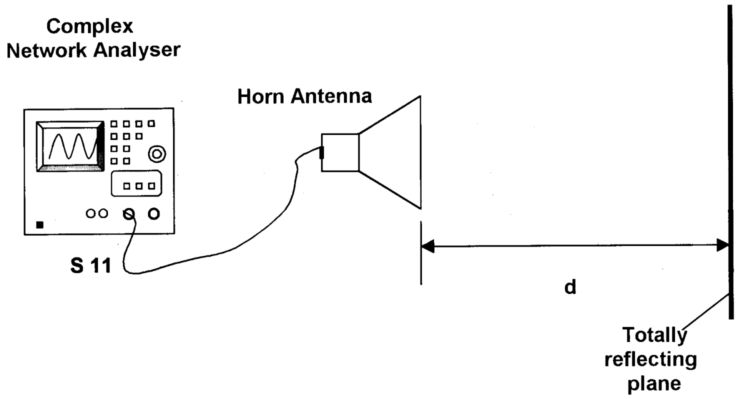

Figure 1. Set-up of One- Antenna-Method

Practical execution of the measurement would now be a 3-step procedure:

At first, the set-up itself must be calibrated by a measurement with the reflector removed and the antenna directed towards an as perfectly non-reflecting surface as possible (e.g. the sky), and the residual response would be stored as s_{11null}, i.e. as the „baseline“ of crosstalk in the measurement system caused by unavoidable noise.

In a second measurement with the reflector in place the signal from the *a priori* identical image of the antenna behind the plane would be included, resulting in s_{11meas}.

Thirdly, assuming a stable set-up, the transmission coefficient of the path „antenna-reflector-antenna“ could now easily be seperated by vectorially subtracting the results from those of the first step, resulting in the complex difference of s-parameters needed for the antenna gain factor calculation

$$s_{11} = s_{11meas} - s_{11null} \qquad (1)$$

3 ANTENNA GAIN FACTOR BY COMPLEX S-PARAMETER MEASUREMENT

The theory of this method was described before by E.M. Purcell, but Pippard et al. [2] found out that power gain measurements of aerials were seriously hampered by reflected energy e.g. from the aperture of the antenna. And they only got correct results for certain frequencies in a fixed set-up in front of the reflector or for certain distances with any frequency. The reason for that is that they had measured with scalar equipment. In this case (1) holds only for those frequency - distance combinations where transmitted and received wave vectors are in phase at the point of measurement in the antenna such that they are superimposing algebraically.

With the conventional 2-antennas method leading to the H.T. Friis formula [1], the product of the two antenna gain factors G_T^* and G_R^* (which should be equal) from the ratio of transmitted and received powers P_T and P_R is

$$\frac{P_R}{P_T} = D_S . G_T^* . G_R^* = \left[\frac{l}{4 . p . r} \right]^2 . G_T^* . G_R^* \qquad (2)$$

where r : antennas (aperture) separation
: wave-length
D_s : path-loss

This equation can only be solved for the gain factors G_T^* or G_R^* seperately, if they are equal, which is intrinsically the case with the one-antenna method.

For this method, we have to obtain the input reflection parameter s_{11} of the set-up (Fig. 1) resulting in a simplified Friis formula from (2):

$$G = |S_{11}| . \frac{8 . p . d}{l} = |S_{11}| . \frac{8 . p . d . f}{C_0} \qquad (3)$$

where d : separation between antenna (aperture) and reflector, r = 2d

Testing the method complex measurements have been carried out at frequencies of 1.1 GHz through 1.7 GHz and up to 18 GHz. We have been using different stainless steel plates as not so perfect finite reflectors in distances from 1.00 m through 2.00 m to include analysis of distance dependancy of gain factors.

4 RESULTS

Measurement results for the antenna gain factor vs. frequency according to (3) show oscillations of about ± 0.5 dB only even at lower frequencies of about 1.5 GHz in (Fig. 2). Here, a reflector of constant dimensions is worse a simulation of an infinite totally reflecting plane than at the upper frequency end because of longer wavelengths. For higher frequencies, depending of course on the directivity of the antenna, oscillations of antenna gain factors are much smaller (approx. ± 0.2 dB). E.g. the averaged frequency response of the gain factor at around 2.45 GHz has been compared to measurements using manufacturer's typical antenna data and theoretical calculations and were found to have no larger deviations than 0.25 dB.

Those oscillations in the results of the antenna gain factors give hints of residual crosstalk that has not yet been compensated for. Such effects are caused by deviations from theory (which would be a free space situation with an infinite reflecting plane surface) in the real world calibration set-up in an anechoic chamber. Here, we would have additional reflections from the ground, other objects in the chamber, edges of the finite reflector, or the antenna aperture itself etc.

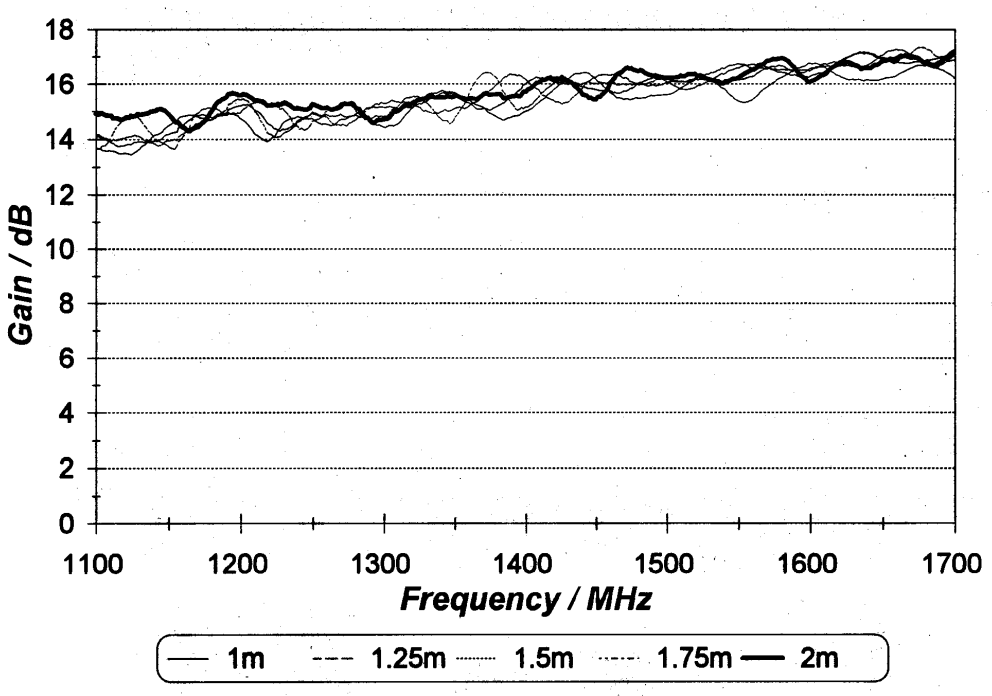

Figure 2. Distance Dependent Antenna Gainfactor of Horn 1.1 GHz - 1.7 GHz

5 CONCLUSIONS AND OUTLOOK

The measurement procedure of an antenna calibration in a single-antenna set-up enhances the fast and precise evaluation of antenna gain factors of preferably directional passive antennas without any second or third reference antenna that could complement or replace conventional multi-antennas methods. There are only reduced hardware requirements and because of shorter time needed for the very simple calibration procedure much lower cost can be expected. Further experiments should study in-deapth the influences of all disturbant reflections in a real world environment, so as to improve even further the residual measurement uncertainty of this method. Questions remaining to be answered would deal with the minimum size of the reflector still simulating an infinite plane relative to the directivity of the antenna, roughness height and width of the reflector vs frequency, the optimal distance range of the reflector, minimum distance for the antenna gain factors to settle down to steady-state far-field factors etc.

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