

A gain intercomparison between the NPL near-field scanner and extrapolation range

P A C McNair, D G Gentle and R J Rycroft

National Physical Laboratory, Teddington, Middlesex, TW11 0LW, UK.

Introduction

The recently introduced NPL planar near-field scanner [1] complements existing antenna measurement facilities at NPL. As part of the assessment of the capabilities of the facility, a gain intercomparison with the well established NPL extrapolation range [2] has been undertaken. A WG 16 pyramidal horn antenna with a nominal gain of 22 dB was chosen for the intercomparison as similar antennas had been measured on the extrapolation range and it was known that an uncertainty of ± 0.05 dB in the boresight gain could be achieved by this method.

Extrapolation Range Measurements

A description of the extrapolation range has been given in some detail before [2] and will not be repeated here, except to note that the measurement procedure was recently improved by the introduction of digital filtering [3]. This was introduced to remove the oscillations in the measurement data due to multiple reflections between the antennas before fitting the data, as these oscillations had proved difficult to fit accurately.

A Scientific Atlanta model 12-8.2 horn was calibrated for boresight gain from 8.0 GHz to 12.5 GHz in 50 MHz intervals, giving a total of 91 measurements. The measured gain was corrected for mismatches to obtain the true gain of the antenna. As a three antenna technique was used to calibrate the intercomparison standard, one of the other antennas used during the calibration could subsequently be employed as a probe for the near-field scanner measurements. Absolute gain measurements, in which the gain of the probe is not known *a priori*, are possible using the near-field scanner, but they do require three times the number of scans. By knowing the gain of the probe, only one set of scans is required from which the gain of the antenna under test (AUT) may be calculated.

A graph of the gain of the comparison antenna, as measured on the extrapolation range, is shown in figure 1. The uncertainty in the measured gain was ± 0.05 dB for a confidence probability of not less than 95%.

Near-Field Scanner Measurement

The standard gain horn was measured using a scan region of 0.559 m by 0.559 m, centred about the mechanical boresight of the horn. A step size of 8.73 mm in x and y was used which fulfils the $\lambda/2$ requirement of Nyquist where λ is the wavelength. A standard gain horn with a nominal gain of 10 dB was used for the probe antenna.

Near-Field Scanner Uncertainty Budget

A systematic approach to understanding the uncertainty budget for a near-field scanner measurement is required, given the large number and diverse nature of the possible sources of error (for example, scan-plane truncation, probe positioning errors and signal path errors). In

particular, some means of taking a readily measurable error and converting it into an error in the final far-field pattern obtained by the system is necessary. In addition, it is not sufficient to give a single figure for the measurement uncertainty since it depends on the pattern angle and field component of interest. Also, the measurement uncertainty depends on the characteristics of *both* the antenna range and the antenna under test, since the measured field involves a convolution of the fields due to the two antennas.

Rather than adopting 'rule of thumb' type approaches that have been used previously, NPL has developed a computer aided range simulation as a means of obtaining a comprehensive uncertainty budget for a near-field scanner measurement [4]. This approach mirrors the measurement of an antenna on a near-field scanner; the electromagnetic coupling between a probe antenna and the antenna under test being computed for each position of the probe antenna encountered in an actual measurement. The result is Fourier transformed and probe corrected to give the far-field pattern of the AUT. By comparing this far-field pattern with the true far-field pattern of the AUT (obtained by modelling), the performance of the near-field scanner measurement is assessed.

Truncation

The region over which the near-field of the antenna under test can be measured is limited by the finite size of the near-field scanner and the time available for the measurement. Consequently, a certain proportion of the field due to the antenna under test will not be measured. The effect of such truncation in the near-field scanner is determined by simulation of the measurement of the actual antenna under test using different scan sizes

Figure 2 shows the error in boresight gain that results purely from truncation for the measurement of the standard gain horn. Simulations are shown for two scan plane sizes; 65 by 65 points and 129 by 129 points. The larger scan size gives less truncation error - the largest error is 0.133 dB for the smaller of the scans and 0.033 dB for the larger of the scans.

Probe Position Error

Inaccuracies in the positioning of the probe in x , y , and z lead to errors in the far-field pattern that is obtained from the measured near-field. The positioning accuracy has been assessed using laser interferometry, indicating an accuracy of the order of 40 microns across the scan region. The effect of these errors on the far-field pattern is assessed by simulating a measurement of the standard gain horn with and without probe positioning errors. The maximum boresight error is found to be 0.004 dB.

Signal Path Errors

Any near-field scanner must provide a signal path between the probe antenna and the receiver that allows movement of the probe relative to the receiver, whilst maintaining proper phase coherence. The NPL near-field scanner employs a system of semi-rigid coaxial sections interconnected by rotary joints, a method that is superior to systems that employ a single cable interconnect. Signal path phase errors are of the order ± 0.23 degrees and magnitude errors are of the order ± 0.03 dB, in the region 8 - 12.5 GHz. Figure 3 shows the *difference* between far-field patterns obtained with and without signal path errors. Lighter regions indicate largest error. The maximum boresight error is 0.002 dB.

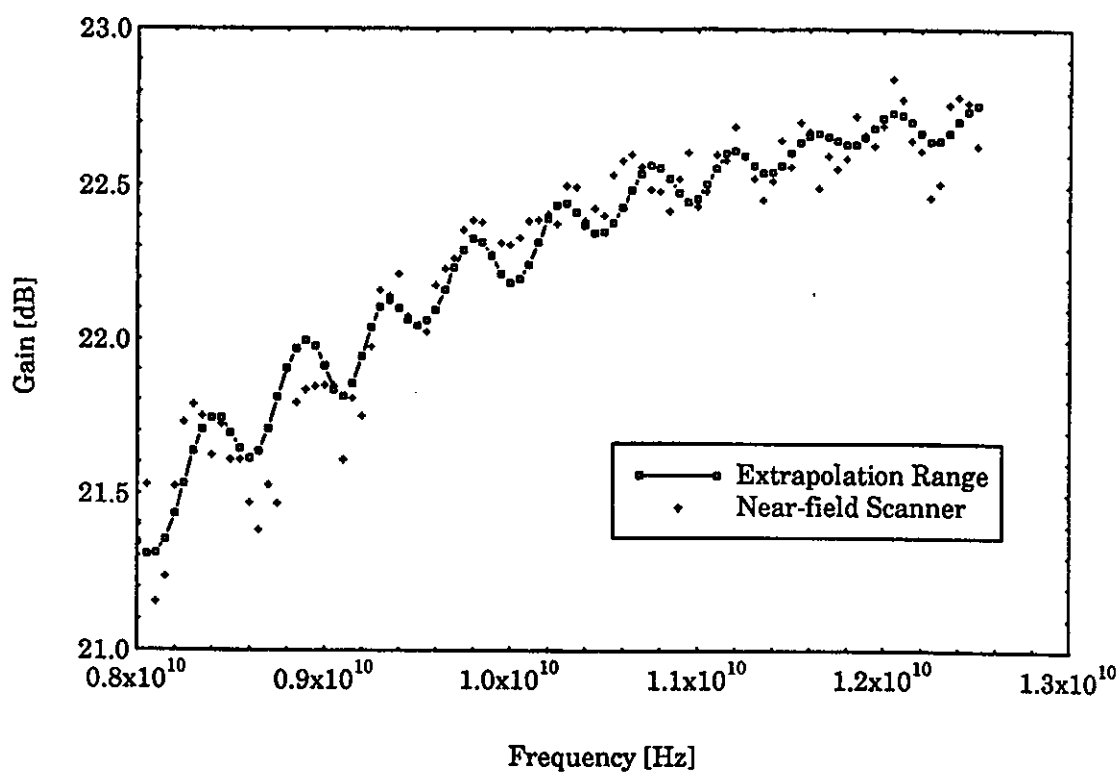


Figure 1 gain of the comparison antenna as measured using extrapolation range and near-field scanner

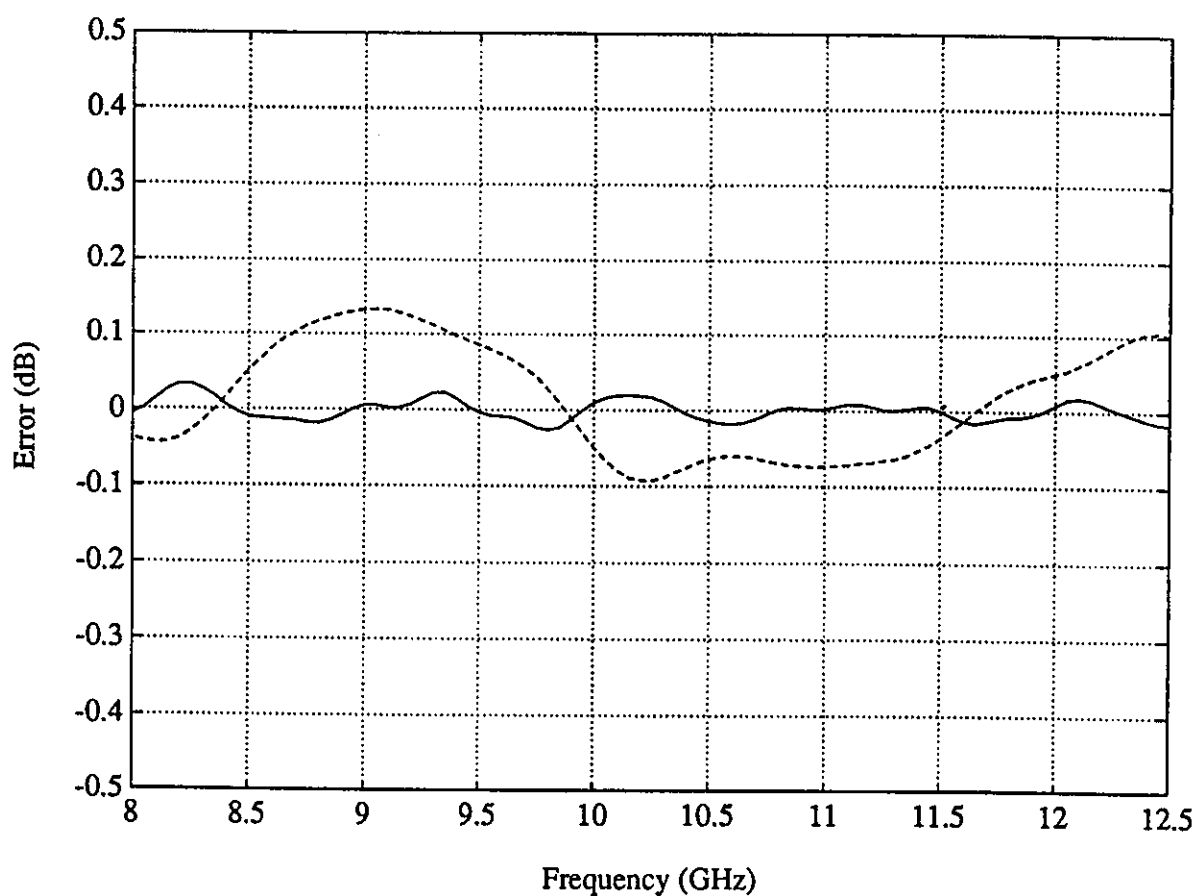


Figure 2 boresight gain error due to truncation (solid 129 by 129, dotted 65 by 65 points)

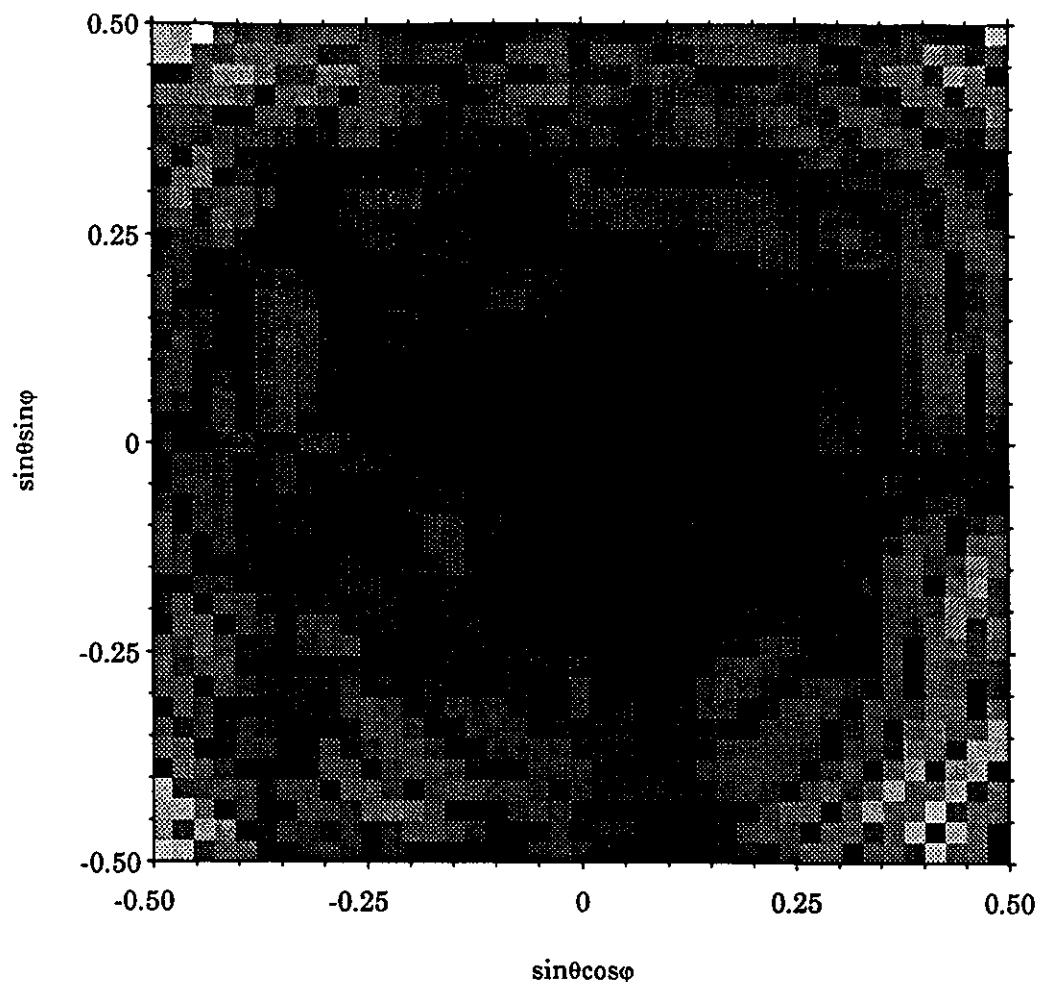


Figure 3 signal path errors give rise to errors in far field pattern

The table shows the uncertainty budget for the near-field scanner measurement of the standard gain horn. The uncertainties are for a confidence probability of not less than 95 %. The total uncertainty is ± 0.17 dB.

Item	Contribution (dB)
Truncation	0.133
Planarity and x, y Position	0.004
Signal Path	0.002
Probe Rotation	0.0
Probe Gain	0.05
Mismatch	0.05
Direct	0.044
Reflections	0.05
Total (rms)	0.17

References

- [1] J P Howes, 'The NPL Planar Near-Field Scanner, a New Antenna Measurement Facility', Sixth British Electromagnetic Measurements Conference, 2-4 November 1993, pp. 36-1 - 36-3.
- [2] D G Gentle, 'The measurement of the gain of microwave antennas at NPL', Fifth British Electromagnetic Measurements Conference, 11-14 November, pp. 29-1 - 29-4.
- [3] D G Gentle, 'The removal of the effects of multiple reflections in antenna extrapolation data by digital filtering', NPL Report DES 139, April 1995.
- [4] P A C McNair, 'Improved Microwave Antenna Measurements Using a Planar Near-Field Scanner', Microwave Engineering Europe, June/July 1995, pp. 33 - 39.