HOLOGRAM ACCURACY ESTIMATION

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ABSTRACT

Hologram measurements are becoming more and more popular as a reliable method for identifying bad elements and the tuning of active phased array antennas. Relying on holographic data to adjust phase shifters and attenuators in these antennas can give undesired results if the accuracy of the data is poor. Often measurements can be improved if the error sources can be isolated and quantified. This paper presents an approach to producing a hologram accuracy budget based on the NIST 18-term error budget created for near-field measurements. A set of hologram accuracy terms is identified and data is presented showing the typical hologram accuracy that can be expected from a near-field scanner.

INTRODUCTION

The accuracy of holographic measurements on a near-field range has been discussed in the past(1). A simple approach is presented in this paper which is based on the same method for estimating far-field errors from near-field measurements. This far-field error estimation method which is widely accepted in industry was put forth by Newell at NIST and includes 18-terms in its estimation(2).

For brevity I will call this method the NIST 18-term error budget. In the budget, 18-error terms are isolated through a series of measurements and simulation, and then RSS (Root-sum-squared) combined to form a composite error. The analysis is straight forward but the key is determining the proper tests and analysis to isolate each term. The purpose of the isolation being to minimize the cross-talk between terms and to identify which terms require additional testing or re-configuration in order to minimize their impact on measurement accuracy. The minimization of error term values is an interesting topic but will not be discussed in this paper.

What will be discussed in this paper is the use of the 18-term error budget as it relates to hologram measurement accuracy. Data will be presented on a sub-array designed by Boulder Microwave Technologies Inc.. Boulder Co., for a Direct Broadcast Satellite (DBS) TV-antenna. The 18-term budget shown in Table 1 is the result of the analysis.

Item	Description	Uncertainty (dB)	Uncertainty (deg)
1	Probe relative pattern	0.10	0.62
2	Probe polarization	0.00	0.00
3	Probe gain	0.00	0.00
4	Probe alignment	0.00	0.00
5	Normalization constant	0.00	0.00
6	Impedance mismatch	0.00	0.00
7	AUT alignment	0.00	0.00
8	Data point spacing (aliasing)	0.03	0.11
9	Measurement area truncation	0.02	0.08
10	Probe X-Y position	0.00	0.02
11	Probe Z-position	0.00	0.02
12	Mutual coupling	0.04	1.19
13	Receiver non-linearity	0.01	0.06
14	Systematic phase errors	0.01	0.06
15	Receiver dynamic range	0.01	0.06
16	Room scattering	0.17	1.90
17	Leakage	0.01	0.06
18	Random errors	0.07	0.49
	RSS Combination	0.22	2.38

Table 1 18-term Hologram Uncertainty Budget

The accuracy of the aperture's amplitude and phase distribution is important to optimizing antenna patterns and identifying errors in the antenna system. The calibration and adjustment of phase shifters and attenuators within the antenna system can be done directly on the near-field range. Since the accuracy to which the hardware can be adjusted, affects system parameters such as edge-of-coverage, gain and pattern isolation, a thorough knowledge of key hologram error terms is necessary prior to calibration or adjustment.

TEST CONFIGURATION

The antenna is shown in Figure 1. The antenna was measured on a 5x5 ft planar near-field range at Near-field Systems Inc. in Carson, Ca. The antenna is a uniformly illuminated planar array. A series of tests and analysis were performed on the antenna to determine the data in Table 1. Each applicable item was derived by transforming near-field data on the measurement plane to the far-field and then back to the aperture of the antenna.

During the testing and analysis of this antenna special attention was given to certain terms in the uncertainty budget: Data point spacing (item-8), Truncation (Item-9), Random amplitude and phase (Item-18), Mutual coupling (Item-12) and Room scattering (Item-16).

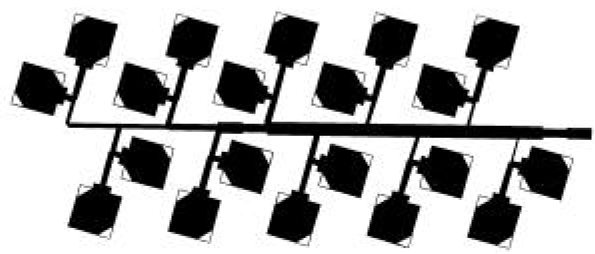

Figure 1 DBS Antenna Subarray

DATA PRESENTATION AND ANALYSIS

During testing a set of plots were made to show the uncertainty. The plots are the difference between a reference and a varied parameter. For example the Mutual coupling error plot was created by plotting the difference between a hologram produced by a scan taken with the probe position Z_0 and another taken at $Z_0 + \lambda/4$. An RMS error was computed by noting the difference in the plot at each element position. It is the RMS error values that are RSS combined in Table 1.

Data point spacing (Item-8),

In most cases data point spacing need not be set any smaller than 0.48 wavelengths, however tightly packed arrays can influence this value and so data at 0.48λ is compared to that of 0.24λ. This difference is shown in Figure 2.

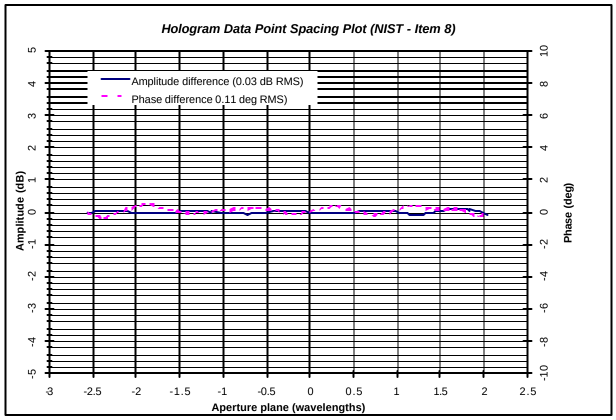

Figure 2 Data Point Spacing Error Plot

Truncation (Item-9)

In Figure 3, truncation effects were evaluated by comparing the hologram derived from a normal near-field data set to one with the outer ring zeroed-out. The difference is the expected error due to near-field truncation on the hologram.

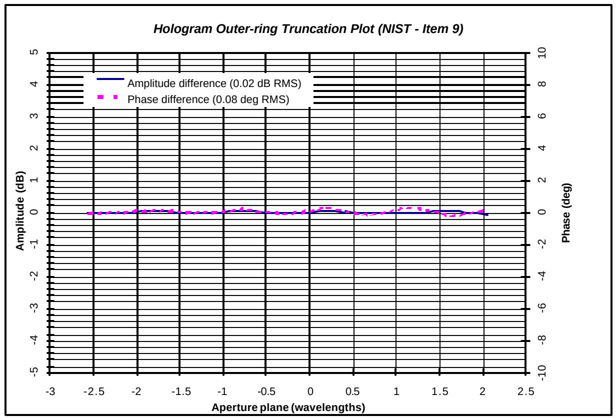

Figure 3 Outer-ring Truncation Error Plot

Random amplitude and phase errors (Item-18).

Random amplitude and phase errors were evaluated by making two scans under exactly the same conditions and comparing the results. The results are shown in Figure 4.

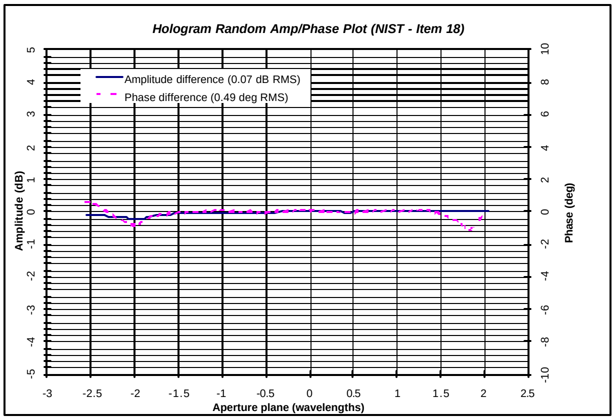

Figure 4 Random Amplitude and Phase Error Plot

Mutual coupling (Item-12)

In Figure 5, the plots show the effect of Mutual coupling evaluated by comparing two plots: one with the probe at a nominal position Z_0 and the other at $Z_0+\lambda/4$.

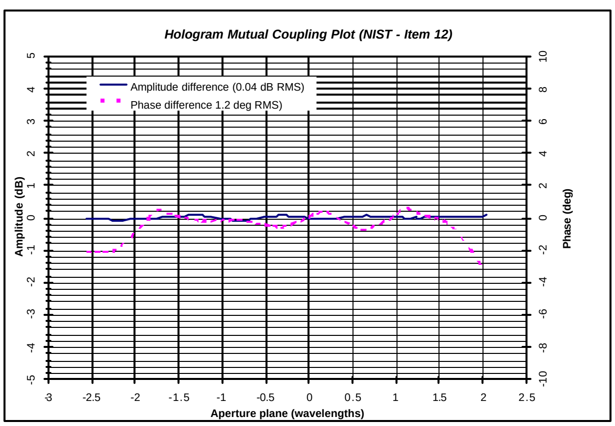

Figure 5 Mutual Coupling Error Plot

Room scattering (Item-16).

Room scattering effects shown in Figure 6 were evaluated in a similar way as Mutual coupling except that in this case both the probe and AUT move together. This keeps the multi-path between probe and AUT constant while evaluating scattering from other sources. Room scattering and Mutual coupling effects can be reduced if the scans are coherently processed[3]. This was not done in this case.

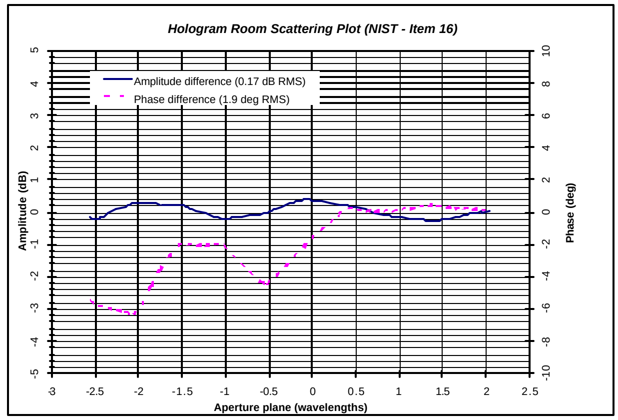

Figure 6 Room Scattering Error Plot

Other error terms

The effects of error terms: 2, 10, 11, 13, 14, 15 and 17 were evaluated through other tests and analysis and are shown in Table 1. Error terms 3-7 have no effect on relative hologram measurements and so are set to zero.

AUT error terms

Errors associated with the AUT can affect hologram accuracy. Often the designer would like to know the element excitation so that he can adjust attenuators or phase shifters within the AUT. This can be determined by applying element pattern correction prior to transforming to the hologram.

Element pattern

Element pattern correction theory is based on array theory which states that for arrays with similar elements, the array's pattern is the combination of the element pattern and the array factor (which includes element spacing and excitation). Since the element spacing is defined, the element excitation can be read directly from the hologram at the element locations. Knowledge of the element pattern is never exact. To the extent that the pattern of all elements is constant and known, the element pattern factor can be removed leaving only the array factor.

Element-to-element coupling

Another factor that can influence the resulting hologram is element-to-element coupling This term has a dramatic effect on the field distribution over the aperture by causing amplitude and phase ripples between elements. This term becomes significant if the antenna elements are tightly packed. Sometimes it is so severe that it can mask small variations in amplitude or phase errors in the array making it difficult to tune. Fortunately, if the number of elements is large and dummy elements are used at the edges, then the mutual coupling between elements will be equal over the entire array and can thus be considered as part of the element pattern.

Element pattern error and element-to-element coupling error can have a dramatic effect on the hologram. These error terms are not a part of this paper and are left for future discussion

CONCLUSION

A technique has been presented which uses the NIST 18-term far-field error budget from near-field measurements to determine hologram accuracy and resolution. The benefit of this technique is that the same error terms and budget, familiar to the near-field range operator, can be used to determine far-field and hologram accuracies. The data presented here shows that the technique is useful in predicting hologram accuracy and resolution.

ACKNOWLEDGMENTS

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I would also like to thank George Jankovic of Boulder Microwave Technologies, Inc. for the use of his antenna.

REFERENCES

1. Near-field Antenna Measurements, by Dan Slater, pp 253-256, Artech House, Norwood, Ma, 1991.
2. Error Analysis Techniques for Planar Near-field Measurements, by Allen C. Newell, IEEE Transactions on Antennas and Propagation, Vol 36, No.6, June 1988.
3. Error Suppression Techniques for Near-field Antenna Measurements, by G. Hindman and D. Slater, 1989 AMTA Symposium