SPEED AND ACCURACY FOR NEAR-FIELD SCANNING MEASUREMENTS

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ABSTRACT

Rapid data acquisition is crucial in making comprehensive near-field scanning tests of electronically-steered phased array antennas. Multiplexed data sets can now be acquired very rapidly with high speed automatic data acquisition. To obtain high speed without giving up accuracy in probe position a feature termed subinterval triggering has been devised. To obtain simultaneously reliable thermal drift or tie scan data a feature termed block tie scans has been devised. This paper describes these two features that yield speed and accuracy in planar near-field scanning measurements.

INTRODUCTION

The conventional procedure for near-field scanning antenna measurements is to obtain the far field by first measuring the near field over a close-in surface then computing the far field with a transform algorithm based upon a transmission equation and the free space solutions of the Maxwell equations. The key to making near-field measurement an acceptable alternative to direct far-field or plane-wave illumination is the ability to make the measurements rapidly and accurately. This is especially a challenge for the case of electronically-steered phased array antennas because of the large quantity of pattern data required. The solution to this challenge is to employ beam-multiplexing in the data acquisition process. In this paper we show how beam multiplexing has been realized in the Scientific-Atlanta Model 2095, which has been expanded to include capability for planar near-field measurements.

PHASED ARRAY TESTING

A schematic of an electronically steered phased array antenna is shown in Figure 1. The antenna consists of a set of radiating elements connected to several ports through a digital/microwave network termed a beam steering controller (BSC). Phased arrays often have thousands of elements and typically a few ports. There are tens or hundreds of beam states for which a pattern test might be made; often at perhaps ten different frequencies.

One thinks then of the phased array antenna having many different patterns—one for each combination of port, frequency and beam state for which the antenna might be operated.

Whether on a far-field range, a compact range or a near-field range, testing multistate phased array antennas can be handled by the Model 2095 automatic system by the approach to testing known as multiplexing. One makes use of the high speed of switching of the typical phased array antenna to measure all states of interest in a single physical scan by rapidly switching among all the test states as the scan occurs. At each coordinate position where pattern data is to be recorded a sequence of measurements is taken where each member of the sequence corresponds to a unique combination of range polarization test antenna port, test antenna beam state and frequency. An example of such a sequence is shown in Figure 2, where a repetitive sequence of frequency changes and beam state changes is illustrated.

Beam state and frequency changes and range polarization changes are controlled through the 2095 system software in a feature called the Test State Control (TSC) list. The user lists in order the sequence of combinations through which the antenna test is to be stepped at each coordinate record increment. The antenna state or BSC control signal is designated by a series of hexadecimal letters each pair of which corresponds to a set of eight digital lines. The complete list is set up once, when the antenna is first integrated with the test controller; then designation of individual entries from the list for a particular test is a simple matter of selection.

The key to making beam/frequency multiplexing work is speed. The system requires a high speed receiver such as the Scientific-Atlanta Model 1795, a high speed signal source such as the Model 2180 that works with it and a computer that can acquire data and control the test sequence in a very time-efficient way. The 2095 employs a special high speed data acquisition coprocesser (DAC) which is peripheral to the 486 CPU to implement instrument control.

The DAC employs a special parallel data channel from the receiver to acquire data at 200 microseconds per data point; the IEEE-488 bus is used for control of the receiver state in the 2095 system.

The sample interval at which an individual near-field or far-field pattern is to be measured is called the sample record increment. In planar near-field scanning this would usually be just less than one-half a wavelength. In systems in the past for multiplexed data sets, where perhaps five or ten frequencies were to be measured, the sequence of frequency changes would be triggered by the automatic system recognizing that a coordinate position corresponding to a desired sample record increment had been passed. This caused the frequency to be changed and the receiver to make a fresh measurement as rapidly as the hardware would permit the multiplexing process to proceed.

In the 2095 planar near-field system, a feature called subinterval triggering has been employed to obtain the closest registration possible between the desired equally spaced coordinate grid and the true positions where data are recorded. The feature of subinterval triggering permits the major sample record increment to be subdivided into many tens of subintervals for beam/frequency multiplexing and the equal increments maintained for all members of the multiplexed family of patterns. Fresh triggers insure the accuracy of position data. See Figure 2. Speed is the key to accuracy, by minimizing time delay or latency in the data acquisition.

EXAMPLE OF MODEL 2095 SYSTEM TIMING FOR PLANAR NEAR-FIELD SCANNING

Suppose that one has a phased array antenna to be tested that is characterized as follows:

Number of Range Polarizations	2
Number of Frequencies	5
Number of Ports (1 Azimuth, 2 Difference)	3
Number of Beam States	10
Total Number of Patterns	300

Suppose further that the antenna is to be tested with planar near-field scanning whose raster is described below:

Linear Travel	in Y-Axis	±90 inches
	in X-Axis	±45 inches
Record Increment	in Y-Axis	0.50 inch
	in X-Axis	1.00 inch
Total Number of Coordinate Grid Points		32,851

Simple mindedly, at a receiver speed of 5000 measurements per second the total test time required is approximately 33 minutes. A more sophisticated consideration shown below demonstrates a more accurate estimate of approximately 75 minutes. See Tables I and II. Thus just over an hour is needed to collect the data for 300 individual combinations of range polarization, antenna port, beam state and frequency. Clearly system measurement speed is crucial to malting the near-field scanning process practical.

BEAM MULTIPLEXING AND TIE SCANS

The practice of planar near-field scanning dates from an era where hardware instability was a key element of concern in making reliable and repeatable measurements. Even today although signal sources and receivers are quite acceptably stable because of the advances of indirect synthesis, a simple item like an RF signal cable if run over long distances through a thermally varying environment cannot be trusted not to change. The use of tie scans has become standardized to overcome apparent thermally related system drift.

There is a difficulty with tie scans which is illustrated in Figure 3. The vertical lines of Figure 3 indicate the lines of travel, along the y-axis, of the probe, with the major record increments shown and the subinterval record increments shown. Note that even though the direction of the adjacent scans are opposite, the subintervals are properly advanced or delayed in relation to the proper record increment by the software control to maintain an equally spaced grid. The tie scans are made following the raster scan in the horizontal direction. Necessarily the subintervals are offset from the major record increment horizontally, along the line of travel of the tie scan. Notice that the offset between the raster scan data and the tie scan data becomes significant when multiplexing many simultaneous patterns. The use of conventional tie scans is logically inconsistent for high order multiplexed data.

To overcome this difficulty a scheme that incorporates both the concept of tie scans and the concept of return-to-point monitoring has been implemented. See Figure 4. The scheme, called block tie-scan, works by breaking large data acquisition rasters into blocks of scans and then uses a selected point within the block to monitor thermal drift over time. The data acquisition proceeds one block at a time under automatic control. The selected local point is monitored before the block is scanned and after the scan of the block is finished. The time clock of the computer is read and recorded with the data from the local point that is monitored for drift. While the scan data are being measured one can infer the time at which the data point is recorded by knowing when the scan begins and when it ends. A correction factor is applied to the recorded data based upon the observed change in the initial point data, with linear drift versus time assumed. Once all the successive blocks have been acquired, a tie scan is made that connects all the local initial points monitored again at closely spaced points in time. However, rather than using continuous motion, this block tie scan stops the probe, just as it was stopped during the initial point measurement, to measure all the multiplexed test states. The offset problem is thus avoided because there is no motion of the probe antenna either during the measurements of the local initial points or during measurement of the block tie scan data.

OTHER CORRECTION FEATURES

Once data is acquired, the process of near-field to far-field transform takes place on each member pattern of the multiplexed data set, but not before correction of the near-field for recognizable errors. The list of pre-transform corrections in the 2095 PNF system is

(1) Receiver Non-Linearity
(2) Probe Position Errors
(3) Cable Path Variation
(4) Thermal Drift Errors
(5) Polarization Data Channel Imbalance
(6) Impedance Mismatch
(7) Range Insertion Loss Normalization.

Item (4)—Block Tie Scan Correction for Thermal Drift Error was described above. Correction for cable path variation by the three-cable method is described in another paper. (Ref. 3) Probe position error correction is performed by adjusting the phase of the recorded data knowing the local direction of propagation **k** and the local position error **Δr** from an error map table. This process is known as **k**-correction. (Ref. 2)

Correction of the far-field and the plane wave spectrum for the directivity pattern of the probe is performed in the process of the transform. The effect of the probe's pattern is removed by a simple calculation at each sampled point of the far field; to do this, the software architecture provides for storing calibration pattern data on the probe horn. An analogous process permits the effect of the element pattern upon the far field of phased arrays to be removed before the aperture field is computed. This has the effect of providing the aperture distribution of array element excitations.

Correction for probe-to-antenna standing waves is performed by averaging of the plane-wave spectrum files. This has the advantage of permitting probe correction to be done only once—on the composite file. Averaging is also used in the gain insertion loss measurement.

SUMMARY

Planar near-field measurements of multiplexed data sets for phased array evaluation require both speed and accuracy to be found acceptable and competitive with other forms of measurement. Speed is enabled by the hardware of the 2095/PNF system. Accuracy is enabled by the provisions for correction afforded by the architecture of the 2095/PNF system. The block tie scan with return to point scheme and the three cable correction scheme have been implemented for the first time with the 2095/PNF system. Speed and accuracy are integral features of 2095 Planar Near-Field System.

REFERENCES

1. Measurement system performance considerations for planar near-field scanning applications. J. H. Pape and O. M. Caldwell, 1991, AMTA Symposium Digest, p. 5-25.

2. Planar Near-Field Measurements, A. C. Newell Short Course Lecture Notes pp. 24, 25. 1985.

3. Principle of the three-cable method for compensation of cable variations. D. W. Hess, 1992 AMTA Symposium Digest.

Table I
Detailed Test Time Estimate—
Time for One Record Increment

Suppose that the following additional facts are known about the test problem

Time to Change Frequency (100 MHz step at 40 Ghz/sec plus phase-lock time)	3.0 msec
Time to Change Beam States (limited by beam steering controller)	0.5 msec
Time to Change Range Polarization or Ports (overlaid with receiver timing)	----
Maximum Speed of Y-Axis Positioner	6.0 IPS
Maximum Speed of X-Axis Positioner	3.0 IPS

Then the time to measure one record increment sequence at 200 microseconds per receiver channel is given by the following consideration

Time to Measure 3 Ports at 2 Polarizations	1.2 msec
Time to Change Beam States	.5 msec
Subtotal	1.7 msec

Time to Measure 10 Beams	17.0 msec
Time to Change Frequency	3.0 msec
Subtotal	20.0 msec
Time to Measure 5 Frequencies	100.0 msec

This assumes no averaging of data by the receiver.

Since the Y-Axis positioner can cover one record increment of 0.5 inch in 83 msec, the scan axis will be able to run fast enough.

Table II
Detailed Test Time Estimate
Time for Raster Scan

The time to make a complete raster motion of pattern measurement is given by the following computation

Time to Complete Measurement Corresponding to One Record Increment	100.0 msec
Time to Reset Signal Source to First Frequency and Beam State to Beginning Condition	13.0 msec
Margin for Positioner Speed Variation	2.0 msec
Subtotal	115.0 msec
Time to Measure at 361 Record Increments in Y-Axis	41.5 sec
Time to Reset the X-Axis to the Next Step Value	7.5 sec
Subtotal	49.0 sec
Total Time for 91 X-Axis Step Values	75 minutes

NOTE: The Y-Axis will be running at 4.34 inches per second.

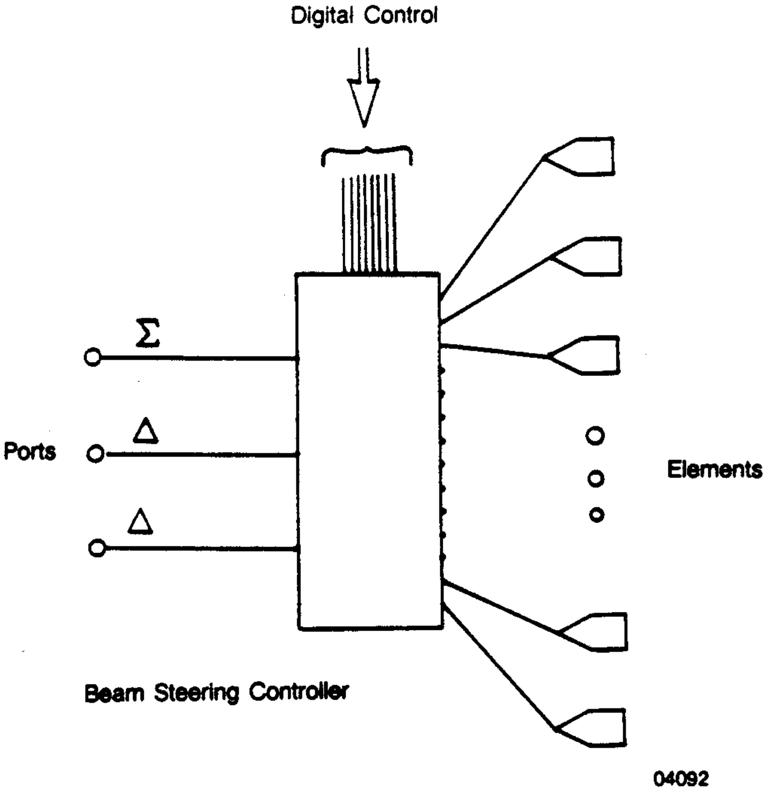

Figure 1. Schematic -
Electronically Controlled Phased Array

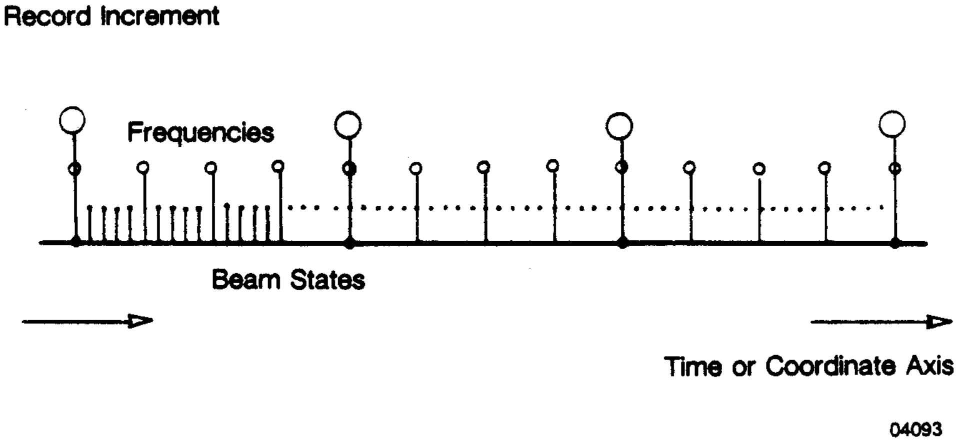

Figure 2. Schematic -
Measurement Sequence of Subinterval Triggers

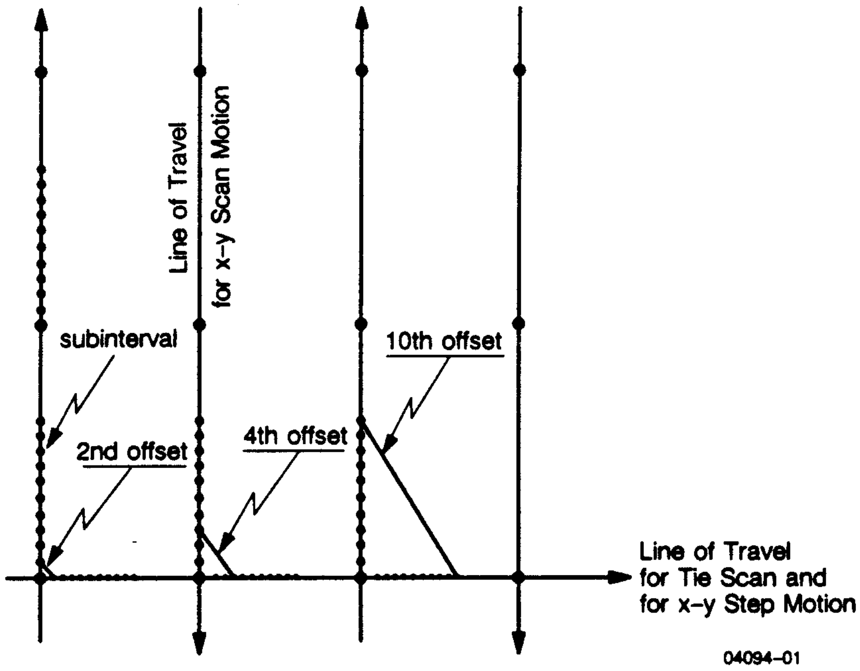

Figure 3. Spatial Offsets Between Locations for Corresponding x-y Grid Points and Tie Scan Grid Points

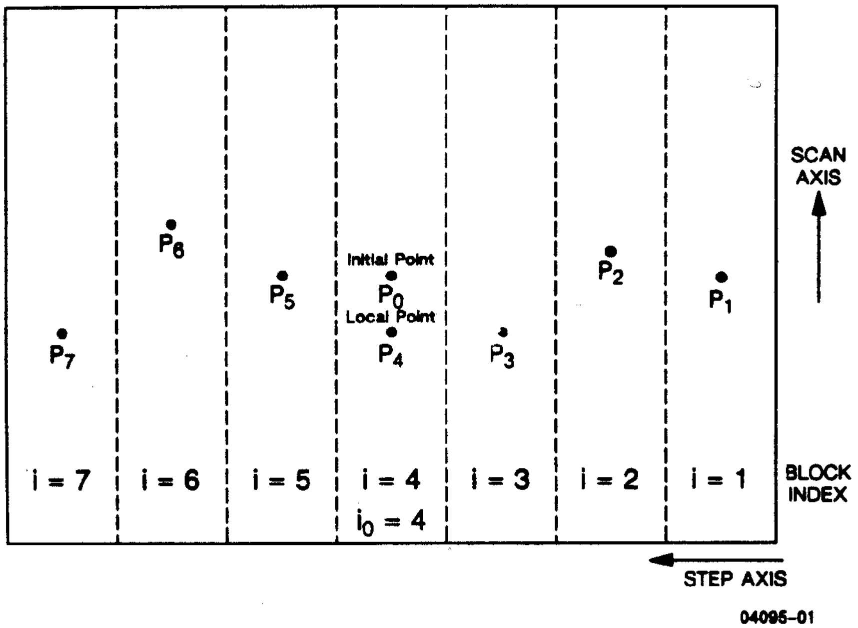

Figure 4. Data File Example with Seven Tie Scan Blocks and Seven Local Points