

HIGH-SPEED TESTING OF MICROWAVE ANTENNAS

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ABSTRACT

State-of-the-art microwave antennas often incorporate the ability to operate in many operating states and over wide frequency ranges. Adaptive arrays and electronically scanned antennas may have programmable beam shapes, configurations or scan positions resulting in several thousand operational states. In addition, these antennas may also require testing at many frequencies. To be properly characterized, these antennas may require testing in all these states. The amount of data required to characterize these antennas, coupled with the requirement to maximize antenna range throughput and minimize costs, puts ever increasing demands on the test equipment designed to perform these measurements.

This paper describes a new automated microwave measurement system utilizing a high speed measurement receiver and an 80386 PC based computer to rapidly test these new generation antennas. The recently introduced Scientific-Atlanta Model 2095 Microwave Measurement System incorporates a unique data acquisition coprocessor (DAC) for high speed test device control, instrument timing, frequency control, data buffering and transfer to the system controller. Antenna measurements on multi-beam and multi-port antennas can be made in a fraction of the time associated with other types of test systems.

The various timing parameters of the Model 2095 are described with special emphasis on how these independent and variable factors inter-relate to each other. A method is presented to calculate total test time, given the test requirement and timing for state changes of the AUT. Examples of typical test scenarios are presented as a further aid in understanding system timing.

1. INTRODUCTION

Modern communication, navigation and weapon systems are being designed to provide ever increasing levels of capability and flexibility. Added to this is the emphasis on smaller, lightweight systems which cost less than the systems they replace. "Cost less" in terms of not only the initial investment but also in terms of greater reliability and reduced maintenance costs. These requirements are challenging antenna designers to develop antenna systems that can be configured to perform multiple functions and perform each function more accurately and over wider bandwidths than the systems they replace.

Modern antenna designs incorporate phased array and "smart skin" technologies to provide electronic beam steering and beam configuration. These features allow the antenna to quickly change its operating characteristics based on externally applied control signals.

Characterizing the performance of these antennas can be as challenging as the design of the antenna itself. A typical antenna may consist of multiple input/output ports, and literally hundreds or even thousands of beam numbers, beam positions and/or beam configurations. In addition, since these antennas may change their operating characteristics with frequency, it is often necessary to test their performance at closely spaced frequencies. Conventional testing of these antennas will, many times, require the test engineer tasked with verifying performance of all operating states of the antenna to make a difficult choice. He must choose between a test program that will require an exorbitant period of time, if it can be practically accomplished at all, or to compromise the testing of the antenna by testing only a sub-set of its operating states. Either scenario can prove very costly; in terms of labor and facility costs in the first case; and in terms rework and lost time by not accurately not detecting design or production defects in the second case.

This paper describes the application of a new generation automated antenna measurement system to this measurement problem. The Scientific-Atlanta Model 2095 incorporates the recently introduced multi-channel Model 1795 Microwave Receiver, and the frequency agile Model 2180 Signal Source. It provides significant improvements in measurement speed over what can be achieved using other receivers, network analyzers and signal sources. A block diagram of the 2095 system is shown in figure 1.

2. A TYPICAL TEST PROBLEM

Let's assume a requirement to test the following antenna:

| | |
|------------------------|---|
| Antenna Type: | Active Phased Array |
| Ports: | 3 - Az Difference, El Difference, Sum |
| Number of Beam states: | 100 |
| Frequency : | 5 frequency steps over the 10.7-11.2 GHz Band; 100 MHz/step |
| Time to change beams: | 1.0 ms |
| Scan coverage: | +/- 90° Az; +/-30° El |
| Data Spacing : | +/- 0.5° Az; 1.0° El |

This antenna test will require 60 azimuthal scans with 1500 patterns recorded for each scan. This results in a total of 90,000 patterns to completely characterize the antennas performance.

3. THE MODEL 2095 TIMING FACTORS

To estimate the time required to perform the above test it is necessary to review the major timing parameters of any automatic measurement system in general and the 2095 in particular, and how these parameters relate to the overall test sequence. System timing can be broken into the following subsets:

1. Time required for the antenna to change beam states
2. Time required to change frequency
3. Time required to change antenna ports (receiver channels)
4. Receiver measurement period
5. Time for the Positioner readout to update
6. The time required for the computer to read the measured data and prepare to read the next data point, i.e., computer/software overhead.

1. Beam State Change Timing.

This parameter is made up of two parts; the actual time required for the antenna to change beam states and be ready to accept the next change commands, and, the time required for the 2095 system to issue the command to the beam steering computer and prepare to issue the next command.

The 2095 can be configured to control the AUT beam steering computer during the test. This allows optimization of the test timing by using the system computer to sequence the beam steering function into the other system timing parameters. The 2095 can issue commands to the AUT beam steering computer in 20 microseconds or less. Furthermore, this time actually occurs during the receivers processing period reducing the apparent beam steering command time to zero. Therefore the system timing is controlled by only the AUT beam switching time; in our example 1 millisecond. The beam control interface is shown in figure 2.

2. Frequency change timing

The 2095 utilizes Scientific-Atlanta's FAST-TRAK tuning system to accomplish rapid frequency stepping during the test processes. With FAST-TRAK tuning, the signal source is restricted to changing frequency at a slow rate which the receiver can accurately follow without losing phaselock. In this case the rate is 40 GHz per second or 25 microseconds per MHz. For frequency steps of 100 MHz or less the source can step frequency in 10 milliseconds. For frequency steps greater than 100 MHz the time to step frequency is .025 ms times the frequency step size in MHz plus 10 ms.

In our measurement example above there are four frequency change intervals. The total time required to step through all frequencies is 40 ms. In calculating total frequency time contribution during the test it is necessary to include the retrace time to slew the source back to the first frequency step (f1) in preparation for the next record increment. In our example this is 12.5 ms. The total time required during the test to change

frequency is therefore 52.5 ms per record increment. A block diagram of the signal source is shown in figure 3.

3. Time to change antenna ports

The 1795 Microwave Receiver can be configured with multi-channel multiplexers to provide measurement of multiple inputs. These multiplexers are under control of the receiver and are automatically configured by the receiver in accordance with how the receiver is set up by the system controller. The multiplexers provide rapid switching of inputs during the test sequence. Since the actual switching occurs during the receiver processing period, no measurement time penalty is incurred when measuring multiple inputs over that of a single input. Therefore in our example the time required to switch inputs is zero. The receiver subsystem is shown in figure 4.

4. Receiver measurement period

The 1795 Microwave Receiver has a fixed measurement period of 200 microseconds. Each measurement period results in one phasor measurement of one input signal, output as either phase and amplitude or I & Q data. The receiver can be configured to average data from multiple measurements to improve dynamic range and reduce noise levels. Averaging increases the measurement period by the number of samples selected. As an example, averaging 16 data samples, increases the total measurement period to 200 times 16, or 3200 usec. In our example we will assume a data samples of 1 (no averaging). The time required to measure the three antenna ports at each data point will be 3 times 200 or 600 usec.

5. Positioner readout update time

To achieve maximum accuracy from any measurement system it is important that the actual position of the AUT be known the instant the output from the antenna is measured. This requires that the position be measured at the same instant the receiver is measuring the AUT output. Further, it is important that the data which is read from the positioner be current; i.e. updated to coincide with the receiver data. An update time delay of even a few milliseconds can allow sufficient positioner motion to occur between the receiver and position measurement to result in significant pattern errors. The 1885 used in the position subsystem of the 2095 provides position data update in 400 nanoseconds which, for all practical purposes, eliminates this potential source of error. It is not necessary therefore to consider position update time in calculating total test time.

6. Computer/Software Overhead

A critical factor in the timing of an automated system is the time required for the computer to poll the measurement instruments, collect the measured data from the instruments, format the data and store it on the mass storage device, and prepare itself for the next data point. Many times this can be the slowest part of the system, particularly when attempting to incorporate the use of the IEEE bus for data transfer and instrument control.

The 2095 uses an exclusive Data Acquisition Coprocessor (DAC) in the system computer to enhance system performance. The DAC resides in the computer and provides parallel data interfaces to the measurement instruments. The DAC serves two primary functions: 1) to synchronize the triggering of the measurement instruments for maximum measurement efficiency, and 2) to collect the measured data from the instruments, format and buffer the data, then perform block transfer of the data to the computer for storage.

When a test is initiated by the system operator, the system controller programs the various instruments and the DAC. During the test, the DAC controls the acquisition process feeding data to the controller for storage. This frees the computer from the overhead tasks of the acquisition process itself leaving it free to perform multi-tasking operations during the data acquisition. For example, the operator may analyze and output data from previous acquisitions while he acquires data on the current test.

In addition to providing interface and control for the 2095 instrumentation, the DAC includes 96 additional bits of control and status that can be programmed by the user for control of external devices. In our example this would be the AUT's beam steering computer. In this way the 2095 can be programmed to incorporate these external devices directly into the test sequence.

The DAC also allows programming the sequence of measurements (or nesting) during the test. This allows those parameters that can be changed the fastest to be switched the most often and those parameters that change the slowest to be switched the least often. In our example, data is to be collected at 100 beam positions and at 5 frequencies. As described, beam states can be changed in 1 ms and frequency can be changed in 10 ms. It follows that the most efficient test scenario is to set frequency and measure all beam states before changing to the next frequency. If, however, beam state changes required 20 ms it would be more time efficient to measure all frequencies for a beam state, and then change beam state. The DAC allows the user complete control of this nesting capability insuring the most efficient test to be configured.

4. ESTIMATING THE ACQUISITION TIME

Refer to the timing diagram, figure 5, for the following discussion.

By applying the above data we can summarize the 2095 system timing as follows:

1. Beam State Change=1 ms
2. Frequency step time (ms) = $10 + (.025 \times \Delta f \text{ (Mhz)})$
3. Time to switch AUT ports = 0
4. Receiver measurement time (ms) = .2 (data averages = 1)
5. Position readout time = 0
6. Computer overhead = 0

From this summary the only items that significantly affect the acquisition time are beam state changes, frequency steps, and the receiver measurement period. The total acquisition time will therefore be the total of these three factors.

The most efficient nesting of the acquisition is to measure the three AUT ports for each beam state and all beam states at each frequency. Since all measurements take 200 microseconds we can calculate the acquisition time as follows:

| | |
|---------------------------------|-----------|
| Time to measure 3 ports | .6 ms |
| Add time to change beam state | + 1.0 ms |
| Total for one beam | 1.6 ms |
| Multiply by 100 beams | X 100 |
| Total for 100 beams | 160 ms |
| Add time to change frequency | + 10 ms |
| Total for one frequency | 170 ms |
| Multiply by 5 frequencies | X 5 |
| Total for 5 frequencies | 850 ms |
| Add time to slew back to f1 | + 13 ms |
| Total for one record increment | 863 ms |
| Multiply by 360 increments/scan | X 360 |
| Total time per scan | 311 sec |
| Multiply by the number of scans | X 60 |
| Total time for data acquisition | 5.2 hours |

This example assumes a positioner whose speed can be controlled to scan .58 degrees per second. Also, the time to move the positioner in elevation from one scan to the next must be added to the total test time. For example, if the positioner requires 15 seconds to move in elevation between each scan, a total of 60×15 , or 900 seconds (15 minutes) must be added to the 5.2 hours bringing the total to 5.4 hours.

In this example 90,000 patterns are recorded for the AUT during a single positioner raster scan.

5. SUMMARY AND CONCLUSION

The 2095 Microwave Measurement System represents the state-of-the-art in high-speed antenna measurements. The speed and accuracy of the system, its flexibility to adapt to many different test requirements, and its user friendly software make the 2095 the ideal measurement system for the production environment.

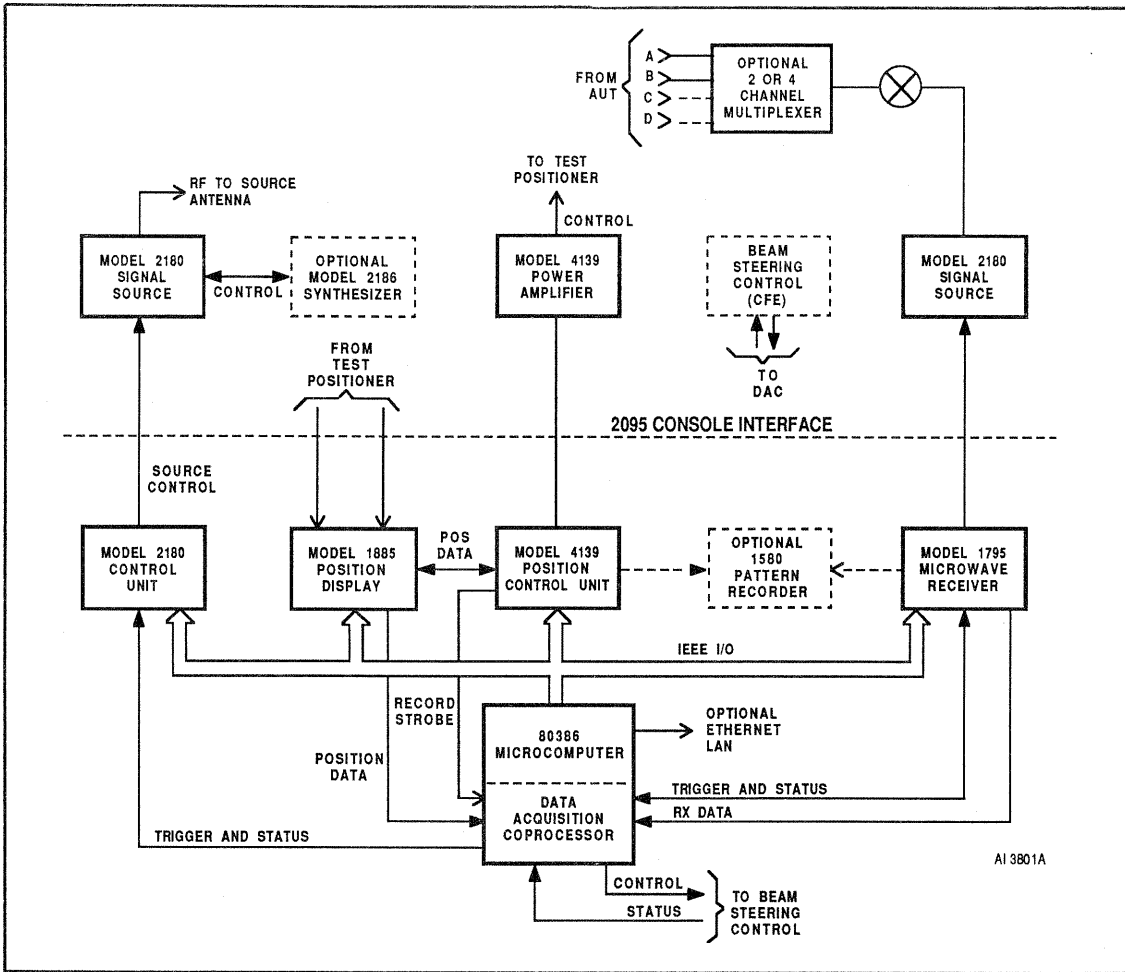


Figure 1.
Model 2095 System Block Diagram

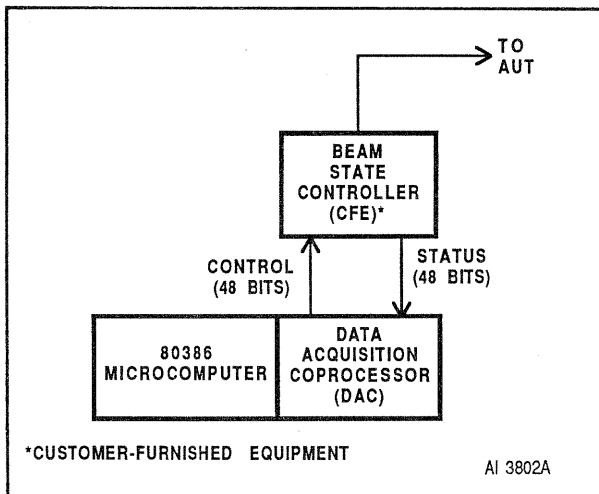


Figure 2.
Beam State Control Block Diagram

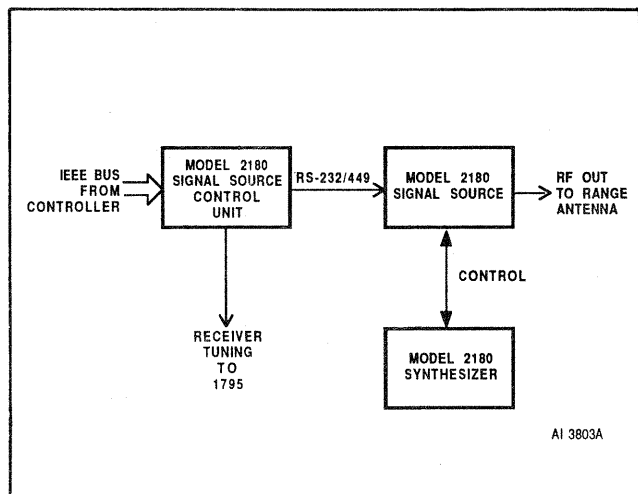
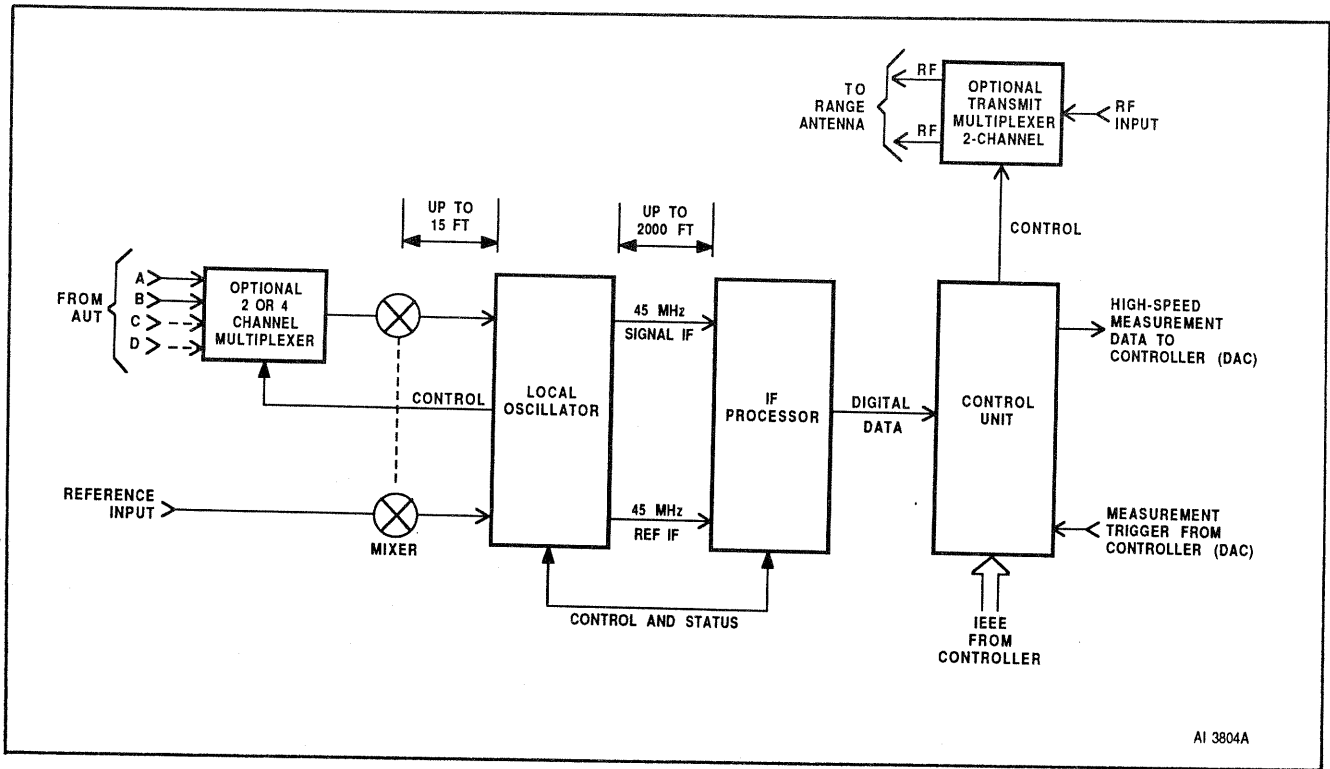
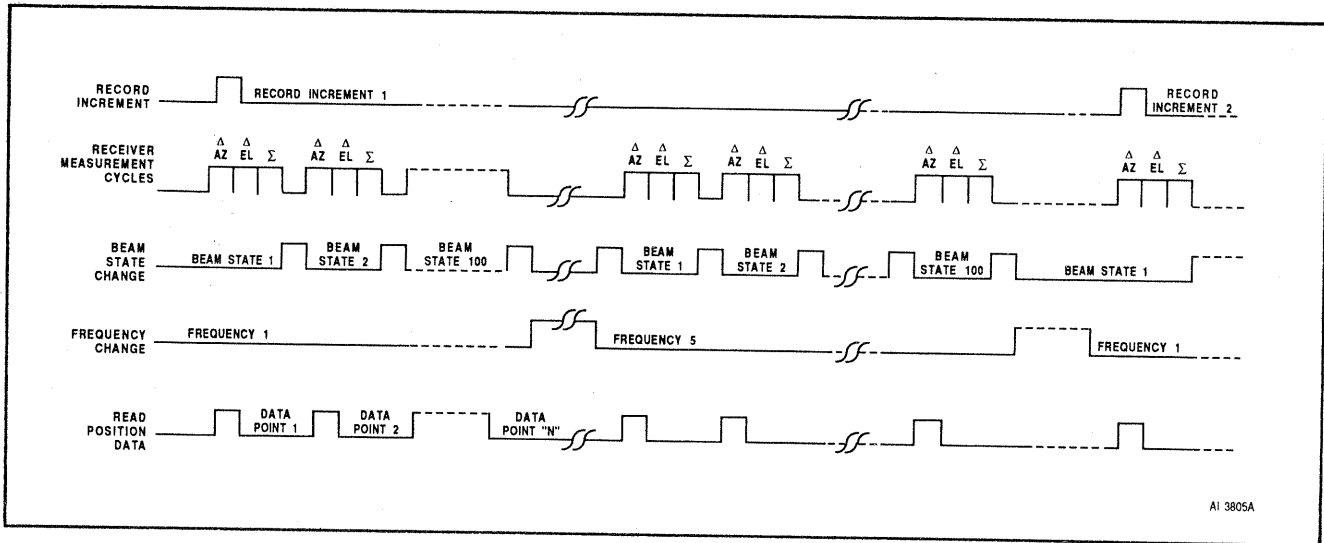


Figure 3.
Model 2180 Signal Source Block Diagram



AI 3804A

Figure 4.
Model 1795 Receiver Block Diagram



AI 3805A

Figure 5.
Model 2095 System Timing Diagram

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