IMPROVING ANTENNA TEST RANGE PRODUCTIVITY

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ABSTRACT

This paper presents the productivity improvements that are possible in complex antenna measurements using state of the art instrumentation. The productivity improvement is calculated for a hypothetical antenna, and from this productivity improvement manufacturing cost reductions and payback times are derived.

Keywords: Productivity, Antenna Measurements, Cost Reductions

1.0 INTRODUCTION

The antennas used in modern communications, weapons and radar systems are becoming increasingly more complex and thus more difficult and costly to test. Electronic beam scanning, electronic beam forming, active apertures and other modern antenna design techniques, while dramatically increasing an antenna's performance, are also requiring more and more testing to verify the antenna's performance in the design, production and maintenance phases of its lifecycle. These increased test times add to both the development and production cost of the antenna and cause costly bottlenecks and schedule delays at the antenna range. Companies are faced with a choice of either finding ways to test their antennas more efficiently or being forced into the construction of more antenna ranges. This paper describes a method of using modern instrumentation to increase the efficiency of an antenna range, thus compressing development times, reducing production costs and helping to alleviate schedule bottlenecks without building new antenna ranges.

2.0 A SAMPLE PROBLEM

To establish a baseline, a hypothetical antenna test requirement is defined. Assume an electronically scanned airborne radar antenna operating at X band. The antenna has a sum and two difference outputs. The test requirements are to characterize the performance of its three outputs at 10 beam positions at three frequencies 100 MHz apart. Each beam must be sampled at 0.2 degree increments over a 60 degree by 60 degree sector. A data sample will consist of phase and amplitude as a function of beam position, frequency and output. The total number of data samples required is 8,100,000.

3.0 THE CLASSICAL SOLUTION

The classical solution to this measurement problem would be to mount the antenna on an azimuth over elevation positioner and to make individual scans in azimuth at a fixed frequency, a fixed beam position and with the receiver connected to a single output. A diagram of this test configuration is shown in Figure 1.

This solution requires that 27,000 azimuth scans of the positioner be made. Assuming a 1 RPM positioner, a 60 degree scan takes 10 seconds. If one retraces to the starting angle, each scan requires a total of 20 seconds. Assume that one measures all outputs at all frequencies at all beam positions prior to repositioning elevation. Thus at a given elevation angle one would measure 90 scans. If each scan takes 20 seconds, these 90 scans can be measured in 30 minutes. If one now allows 12 seconds to reposition the elevation axis, repositioning for 300 elevation angles requires 60 minutes. If it takes 30 minutes to measure the required scans at each elevation angle and one must measure at 300 elevation angles, the total test time is 151 hours. Of course this neglects set-up and tear-down time and coffee breaks, so in the real world the test time might be somewhat longer.

4.0 THE PROPOSED SOLUTION

In order the reduce the measurement time, it is proposed to measure all of the required parameters with the positioner making only a single traverse of the sector to be measured. To accomplish this one must configure the measurement such that beam positions, frequencies and outputs can be selected quickly enough that individual data points can be measured without stopping the scan of the positioner. A block diagram of a possible configuration is shown in figure 2.

This configuration requires the use of instrumentation with state of the art performance in frequency agility and data rates. Synthesized signal sources are available that can change frequencies in less than 5 microseconds. Receivers such as the Scientific-Atlanta Model 1795 are available that can select one of several inputs and measure its phase and amplitude in 200 microseconds. Beam steering computers can be built with comparable speeds, and for the purpose of this example assume that beam positions can be selected in less than 1 millisecond. The measurement scenario using such equipment might be as follows:

Function	Time Allowed
Select Frequency #1	5 microseconds
Select & Measure Output #1	200 microseconds
Select & Measure Output #2	200 microseconds
Select & Measure Output #3	200 microseconds
Subtotal	605 microseconds
Repeat for 2 more frequencies	1210 microseconds
Subtotal 3 freqs, 3 outputs	1815 microseconds
Select Beam #2	1000 microseconds
Subtotal 1 Beam, 3 freqs, 3 outputs	2815 microseconds
Total for 10 beams, 3 freqs, 3 outputs	28150 microseconds

In order to sample the antenna pattern at 0.2 degree increments, the positioner must run slow enough that there are 28.15 milliseconds between sample points. At 1 RPM there are actually 33.33 milliseconds between .2 degree sample points. Thus there are still 5.18 milliseconds to spare before it is time to start the next measurement cycle.

Since it is possible to run the positioner at its full speed, the measurement time is simply the time it takes to move the positioner through the required 60 by 60 degree sector. At 20 seconds per scan and 12 seconds to position the elevation axis, this requires 32 seconds per scan times 300 scans, or 9600 seconds. This equates to 2.67 hours.

5.0 PRODUCTIVITY IMPROVEMENT

In the classical method, it took 151 hours to measure the hypothetical antenna. By optimizing the test equipment and measurement scenario, this time was reduced to 2.67 hours, a productivity improvement of 148.33 hours. Assuming that the tests require 2 technicians making $15 an hour and that their direct labor is burdened with an overhead of 200%, the labor savings on this one antenna amounts to $13,350.

Perhaps as important as the manufacturing cost savings is the improvement in throughput on the antenna range. A production rate of 50 units a year of the hypothetical antenna would have required operating the range three shifts a day, six days a week with no allowance available for downtime due to weather or equipment maintenance. When one considers mounting and dismounting, other tests (such as boresighting), and any time for electrical or mechanical alignment, the hypothetical antenna would have bottlenecked several antenna ranges.

6.0 PAYBACK

In order to calculate the payback on the investment for modern test equipment, one must make some assumptions on the cost the test equipment. One would need an automatic measurement system with a fast receiver and fast synthesized signal source. Based on current test equipment costs, assume a $600,000 cost for such a system. For the purpose of this example, assume that the beam steering computer would be needed in any test setup and that its cost does not need to be included in the payback calculations. Since the calculated labor savings on each antenna amounted to $13,350, the investment of $600,000 will have been paid back after testing 45 antennas.

7.0 FURTHER IMPROVEMENTS

This paper has only considered the productivity improvements possible in acquiring the measured data. Another consideration is the amount of time required to analyze the data for specification compliance and plotting the data for test reports. Here too there is a classical method of pattern analysis which consists of a clear plastic overlay. The hypothetical test problem would have resulted in 27,000 amplitude patterns and another 27,000 phase patterns. Considering only the amplitude patterns and allowing 1 minute for a technician to analyze the pattern for specification compliance, it will take 27,000 minutes or 450 hours to analyze these patterns. Now suppose that the system computer is programmed to do this as the data is acquired. This 450 hours could be reduced to the time required for the actual data acquisition, thus saving the entire 450 hours. At the $15 per hour labor rate and the 200% overhead burden, this results in another $20,250 savings per antenna. Including this saving into the payback calculation reduces the number of antennas that must be tested to achieve a payback of the original $600,000 investment in new test equipment to 18 antennas.

8.0 CONCLUSIONS

It has been shown that it is possible to take a fairly complex and difficult antenna measurement problem and with the use of modern test equipment, measure all of the required parameters with one traverse of the mechanical positioner. What is more, this mechanical positioner was able to run at its full rated speed during the traverse. Thus the measurement time was limited by the maximum speed of the mechanical positioner. It was shown that this resulted in significant cost savings over a simpler and slower test method, and that the investment payback could be from the savings in labor cost in testing only 45 antennas. It was also shown that automatic data analysis could further reduce the test time to the point where a payback of the original investment could be achieved in measuring only 18 antennas.

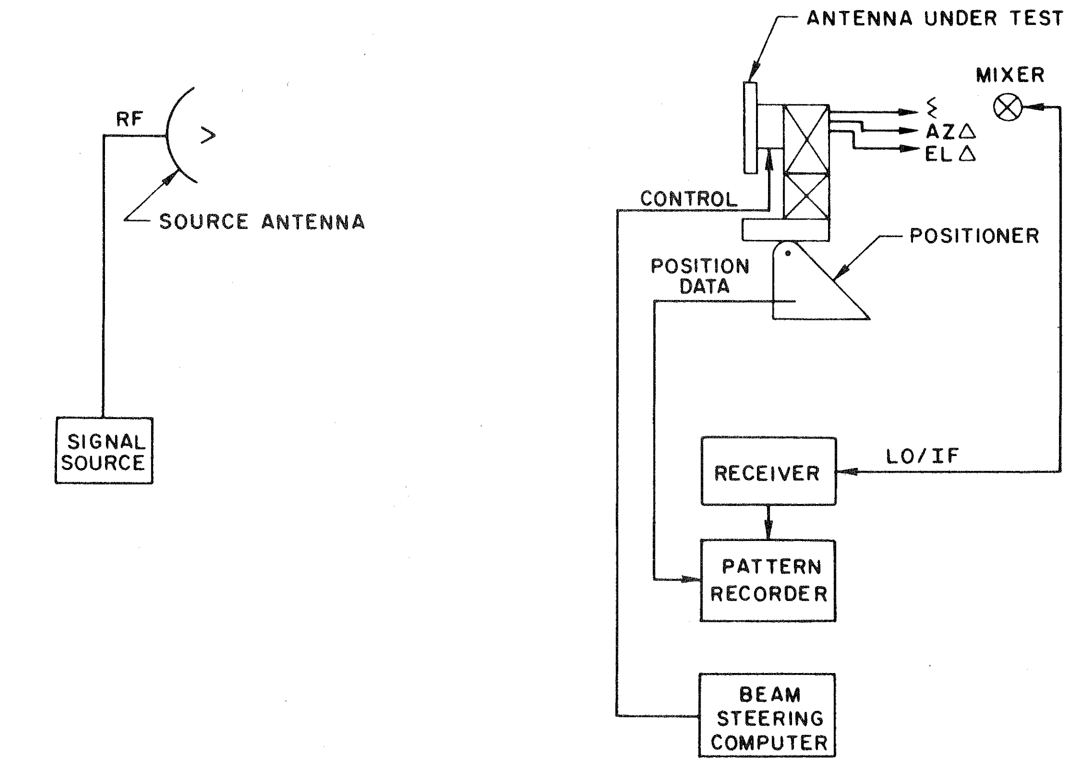

Figure 1

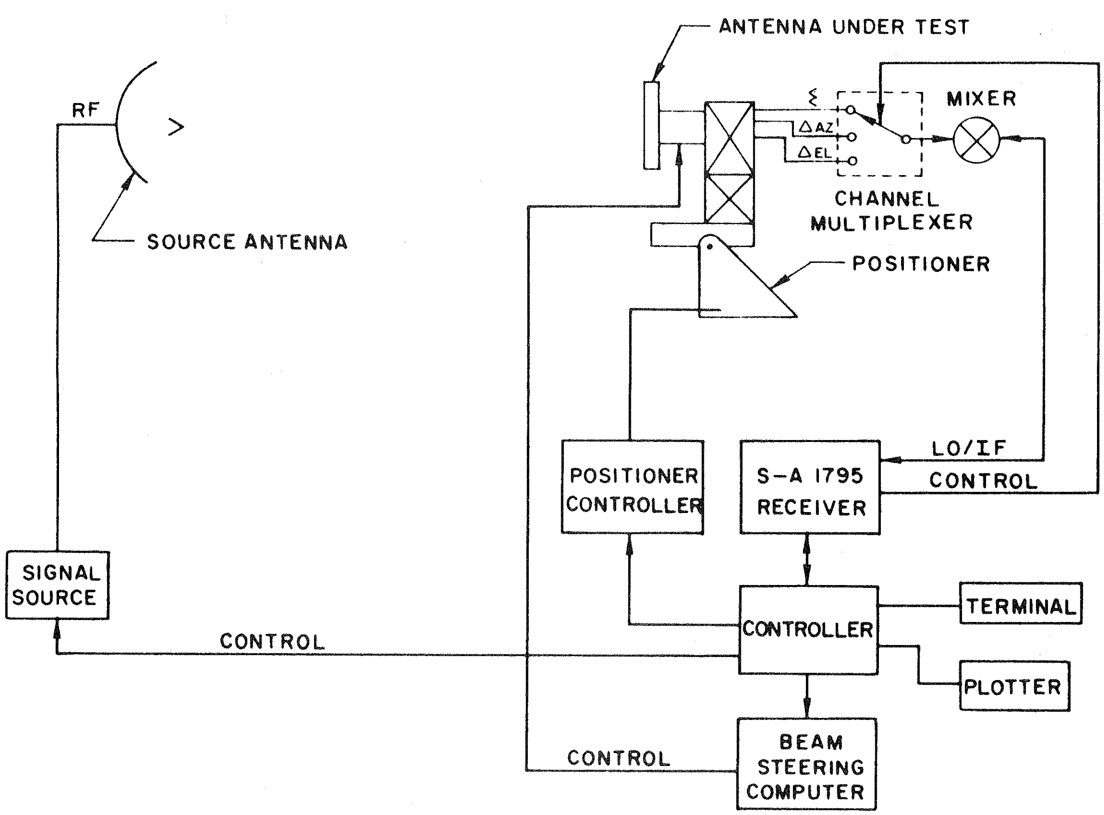

Figure 2

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