

HIGH SPEED, MULTI FREQUENCY MEASUREMENTS

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ABSTRACT

Precise and complete measurements of advanced electromagnetic systems demand dramatically higher data acquisition speeds than those commonly attainable. Specific challenges include requirements for wideband measurements with arbitrarily spaced frequency steps. These types of measurements are often encountered in characterizing EW/ECM systems, radars, communications systems, and in performing antenna and RCS measurements.

The Scientific-Atlanta Model 1795 Microwave Receiver offers capabilities directly applicable to solving measurement problems posed by highly frequency agile systems. These problems include:

- 1) timing constraints
- 2) data throughput
- 3) RF interfacing
- 4) maintaining high accuracy

A technique is discussed which shows the application of the Model 1795 Microwave Receiver in its high frequency agility mode of operation. Measurement examples are presented showing the advantages gained compared to previous methods and instrumentation configurations.

Key Words: Antenna measurements, RCS measurements, Frequency agility

1. Introduction

Productivity improvements on antenna and RCS ranges are important in maximizing the return on investments made on the equipment used in these facilities. Many emerging antenna and RCS performance specifications require multi-frequency measurements to be performed at speeds much higher than those commonly attainable. Factors which dictate this requirement center on the need for complete testing of broadband frequency agile systems, and possible post-processing of data. The simplest methods available for improving range productivity reduce the test time for each article under test. Many opportunities exist for reducing test times on a given device. However, the measurement scenarios which incorporate multiple test frequencies will benefit greatly from instrumentation and techniques where frequency agility is not a limiting factor in the measurement process.

Multi-frequency antenna pattern measurements have been common since the advent of computer controlled measurement systems in the early 1970's.

Systems have been primarily designed for automating the measurement process, which reduces operator intervention, and facilitates higher equipment utilization. Designing systems for radically improved productivity has been a secondary consideration until recently. The actual requirements for high speed multi-frequency measurements fall into two main categories; those simply requiring a massive amount of multi-frequency data, and those which require fast switching between a few frequencies in order to meet other measurement timing constraints such as closely spaced position record increments. Both types of application problems can be solved using the recently introduced Scientific-Atlanta Model 1795/1796 Receiver, a fast switching signal source, and proper computer controlled techniques.

2. Perspective

Swept techniques have long been a common practice for scalar transmission, reflection, and gain measurements. They provide a quick method for obtaining amplitude measurements of reasonable accuracy with virtually continuous frequency coverage.

However, the need for accurately characterizing the response of devices in both magnitude and phase has mandated the use of phasor measurement receivers or vector network analyzers for making complete measurements of devices across wide bandwidths. Accurate phase measurement requirements eliminate using traditional continuously swept frequency techniques. Therefore, techniques for rapid multi-frequency CW measurements are needed. Receivers with the ability to track and measure the response to rapidly changing inputs, and appropriate excitation sources are the keys to highly frequency agile measurement system designs.

A highly frequency agile measurement system should address the following major performance parameters:

- a) Broadband coverage
- b) Sufficient source power output for Device Under Test excitation
- c) Minimal source frequency switching time
- d) Simple computer interfacing
- e) Accurate receiver tracking of frequency steps
- f) Accurate receiver tracking of dynamic signals
- g) Minimum receiver measurement time
- h) Simple RF systems interfacing

These parameters involve interactive specifications. Compromises must be evaluated and solutions selected to meet the desired applications. However, the equipment configuration described below addresses all these characteristics in an optimal manner and provides major improvements over previously available instrumentation.

3. The Scientific-Atlanta Models 1795/1796

The Model 1795 Microwave Receiver is a micro-processor controlled, wide band, precision microwave measurement receiver providing complete phasor signal measurement capability. The basic receiver provides a single test channel and a reference channel. Optional RF input multiplexers allow multi channel operation. The Model 1795 is designed for operation over the 0.1 GHz to 140.0 GHz frequency range.

Receiver tuning is controlled using any one of four methods; manually, via the IEEE-488 bus, via the Scientific-Atlanta "FAST-TRAK" interface, or using the Measurement Control Buffer features.

The Model 1795 receiver consists of three main units; the Control Unit, the IF Processor, and the Local Oscillator Unit. The Control Unit provides the input/output functions, LO control and high speed digital signal processing. The front panel features a color display for presenting data, status, and control menus. The IF Processor provides analog signal processing functions for the signal and reference channels and A/D conversion. It is a separate rack mount housing intended to be located near the Control Unit. The Local Oscillator Unit is designed to be remotely located from the Control Unit and the IF Processor. The LO Unit provides downconversion to the first Intermediate Frequency and IF signal preamplification.

The Model 1796 is a separate rack mount unit for use in applications that require high frequency agility. It is designed to substitute the LO signal generation functions of the LO Unit with a high frequency agility synthesized oscillator. Receiver control and tuning when using the Model 1796 remains identical to that used when only the standard LO unit is present.

A special control feature of the Model 1795 is the Measurement Control Buffer (MCB). It provides a method for performing fast multiple parameter measurements. An internal look-up table in the receiver holds pre-programmed receiver parameters which are associated with an MCB index number. When the receiver is triggered, the parameters for that index value are used to make the measurement. The pointer to the table increases by 1 index number and loads the parameters for the next trigger event. In this fashion, key receiver control parameters can be changed "on the fly" without a command time penalty. The MCB has space for 512 entries and is loaded via the IEEE-488 Bus. Proper use of the MCB is an important aspect

of high speed multi-frequency measurements using the 1795/1796.

The Model 1795 Microwave Receiver linearly converts RF signals at the inputs to the signal channel and reference channel to digital format utilizing a double conversion approach. Signals at the inputs of both the signal channel mixer and reference channel mixer are converted to 45.000 MHz IF signals by mixing with either the fundamental or appropriate harmonic of the local oscillator. The local oscillator is phase-locked to the Reference channel input signal providing stable 45.000 MHz IF signals. The 45.000 MHz IF signals are converted to 100 kHz IF signals by mixing with a coherent 45.100 MHz reference signal furnished as a second local oscillator. This system provides a 100 kHz output signal which has a level proportional to the RF signal level at the input, and a phase directly related to the phase difference between the signal channel and reference channel RF inputs. These 100 kHz signals are processed by microprocessor based circuitry to yield the phasor (phase and amplitude or I and Q) components of the signal from the device under test.

As previously stated, the receiver typically uses a phase-locked local oscillator to perform the RF to 45 MHz conversion. However, when operating in the high frequency agility mode using the 1796, this characteristic is not required. Circuitry in the 1795 IF Processor can accommodate instantaneous frequency differences between the source frequency and the first Local Oscillator frequency of up to 1 MHz deviation from a 45 MHz IF while maintaining coherent measurement performance. This is accomplished by phase locking the receiver at the 100 kHz IF instead of the 45 MHz IF. This feature eliminates the need to separately phase lock the transmit source with the receiver local oscillator for coherent operation. Long range operation is simplified since high frequency synchronization clocks are not required between the transmit source and the 1796.

An important design feature of the 1795/1796 combination is incorporation of the signal settling time in the measurement cycle time. No time penalty or accuracy degradation is incurred in high speed operation. This is also true for high speed multi-frequency operation. Since all data is measured at a fixed 100 kHz IF, the signal processing circuitry resolves all input phasors identically, regardless of whether they result from amplitude, phase or frequency changes.

4. Model 1796 High Speed Local Oscillator

The Model 1796 High Speed Local Oscillator operates in conjunction with the standard Model 1795 Remote Local Oscillator to provide very high frequency agility measurements. The Model 1796 receives frequency commands directly from the Model 1795 Control Unit via a parallel programming interface in the standard Remote Local Oscillator. The output of the 1796 is an RF signal

which connects to the Model 1795 Remote Local Oscillator. No cabling changes to the mixers or to the Device Under Test are required when the 1796 is installed.

The Model 1796 High Speed Local Oscillator generates a 1.9 to 4.0 GHz signal used for the first frequency conversion of the RF input signals to the 45 MHz IF. Its fast switching time allows the LO frequency to be commanded, slewed, and settled within 30 microseconds after a trigger is received in the Model 1795 Control Unit (using the Measurement Control Buffer mode). This enables the receiver to operate at measurement intervals as short as 210 microseconds, equivalent to a rate of 4750 measurements per second, each at a different frequency. No restrictions are placed on the frequency differences programmed between measurements as long as the test frequency lies within the RF mixer bandwidth.

When using the Model 1796, the frequency agility of the Model 1795 Receiver is dramatically enhanced. Full utilization of this capability also requires the presence and proper control of a high speed transmit signal source capable of frequency changes at least as fast as those of the Model 1795/1796.

5. The Comstron FS-2000 Synthesized Signal Source

The Comstron Model FS-2000 is a synthesized signal source covering the frequency range of 10 MHz to 18 GHz with a frequency resolution of 1 Hz. The synthesizer is capable of making a frequency step from any one frequency to any other frequency in less than 1 microsecond. The output power is +10 dBm into a 50 Ohm impedance. It incorporates a 44 bit parallel BCD programming interface which facilitates high frequency agility operation. The synthesizer develops its output signal by a direct analog synthesis technique. A 10 MHz reference signal is multiplied to 100 MHz and is further multiplied and divided into five basic frequencies; 50, 100, 150, 200, and 800 MHz. These frequencies are applied to a series of decades where the final frequency output of the synthesizer is derived from successive addition, division, and multiplication.

6. High Speed Multi-Frequency Operation

A general system block diagram for high speed multi-frequency operation is shown in Figure 1. The system is based on the Scientific-Atlanta Model 1795/1796 Microwave Receiver and the Comstron FS-2000 Synthesized Source. A host computer/controller provides triggering and data handling for the Model 1795 Receiver and Model FS-2000 Synthesized Source. The receiver is interfaced to the computer via the IEEE-488 bus for setup commands, a general purpose 16 bit parallel interface for data transfer, and an 8 bit interface for triggering, handshaking and status. The FS-2000 is also interfaced to the computer via parallel interfaces. Three 16 bit words are required for the BCD frequency programming of the synthesizer. Therefore, the system computer will require a total of four 16 bit parallel ports, one 8 bit parallel port, and the IEEE-488 interface. The computer must have both the CPU and I/O speed capable of executing the required sequence of events at the desired rate up to the maximum receiver trigger rate allowed. Depending on the computer selected, this may be a severe constraint. Full speed operation may require the use of additional dedicated digital control hardware.

An example of the timing is shown in Figure 2. The computer issues triggers to the 1795 Receiver at period not less than 210 microseconds. In order to operate at this rate, the triggering and the data reading operations must be pipelined. The controller is free to issue the trigger for the next measurement interval prior to completion of the presently executing measurement by monitoring the "Not Ready for Trigger" status line and sending a trigger when the 1795 indicates that it is ready. This action ensures that the fastest possible trigger rate is achieved. Reading data from the previous measurements can be accommodated at the controller's discretion since the data is buffered by a 256 word FIFO on the 1795's 16 bit High Speed Parallel Port. The only constraint in reading the data is that the controller must not allow the FIFO to overflow, which would result in lost data. At the fastest triggering rate, the FIFO will completely fill in 13.44 milliseconds.

7. Application Examples

To illustrate the advantages gained by using the configuration previously described, two measurement scenarios are presented. Resulting measurement times are calculated for each scenario. No timing constraints for controller overhead and step axis positioning were factored into these examples. Tables show projected data acquisition performance for some typical single channel instrumentation configurations under receiver limited conditions. Total test times are calculated using the following equation:

$$\text{Time} = [T_s + T_m] * [N_f] * [N_i] * [N_s]$$

T_s = Frequency Switching and Settling Time
 T_m = Receiver Measurement Time
 N_f = Number of Frequencies per Record Increment
 N_i = Number of Record Increments per Scan
 N_s = Number of Scans per Test

Values used for the timing parameters are listed in Table 3.

Example #1

A wideband spiral antenna is to be tested over its forward hemisphere at record increment steps of 1 degree. Frequency coverage is 2 - 18 GHz and data is to be taken at 100 MHz increments.

The number of spherical coordinate system data points is $180 * 180 = 32,400$. Each coordinate system data point is to be measured at 161 frequencies. This corresponds to 5,216,400 separate measurements.

Table 1

Receiver Type	Source Type	Positioner Scan Speed	Total Test Time (Minutes)
S-A 1795/1796	FS-2000	4.93 RPM	18.26
HP 8510B (micro-stepped)	FS-2000	.690 RPM	130.4
S-A 1795	S-A 2180/2186	.092 RPM	973
S-A 1795/1796	S-A 2180/2186	.092 RPM	973
S-A 1783	S-A 2180/2186	.047 RPM	1912
HP 8510B (step and lock)	HP 8340	.033 RPM	2695

Example #2

An S band antenna is to be tested at 2.0, 3.0 and 4.0 GHz. The AUT will be raster scanned between ± 30 degrees of boresight in azimuth and elevation. A record increment spacing of .01 degree is desired with a step increment of .1 degree. The number of spherical coordinate system data points is $60/.01 * 60/.1 = 3,600,000$. Each coordinate system data point is to be measured at 3 frequencies. This corresponds to 10,800,000 separate measurements.

Table 2

Receiver Type	Source Type	Positioner Scan Speed	Total Test Time (Minutes)
S-A 1795/1796	FS-2000	1.57 RPM	37.8
HP 8510B (micro-stepped)	FS-2000	.055 RPM	1080
S-A 1795/1796	S-A 2180/2186	.030 RPM	2016
S-A 1795	S-A 2180/2186	.011 RPM	5400
HP 8510B (step and lock)	HP 8340	.011 RPM	5580
S-A 1783	S-A 2180/2186	.005 RPM	12,960

Table 3

<u>Parameter</u>	<u>Value</u>	<u>Configuration</u>
T _s	25 msec/GHz +5 msec (minimum retrigger interval = 11 msec)	S-A 1795 and S-A 2180/2186
T _s	56 msec/GHz +5 msec (minimum retrigger interval = 11 msec)	S-A 1783 and S-A 2180/2186
T _s	10-30 μsec	S-A 1795/1796 FS 2000
T _s	11 msec	S-A 1795/1796 S-A 2180/2186
T _s [1]	5 msec/GHz	HP 8510B FS 2000
T _s	30 msec	HP 8510B HP 8340
T _m	200 μsec	S-A 1795
T _m	11 msec	S-A 1783
T _m	1 msec	HP 8510B

8. Summary

A technique for performing high speed, multi-frequency phasor microwave measurements has been presented. A measurement configuration using the Scientific-Atlanta Model 1795 Microwave Receiver, the Model 1796 High Speed Local Oscillator, and the Comstron FS-2000 Synthesized source, shows excellent applicability for antenna, RCS, and component measurements. Multi-frequency data acquisition rates allow up to 4750 measurements per second to be achieved, each at an arbitrarily different frequency. A major advantage of the method shown is elimination of the requirement to phase lock the transmit source and the receiver local oscillator signal directly via a crystal controlled time base. This allows convenient range configuration over long distances while maintaining coherent measurements. Also, with pipelined digital control of the instruments, frequency switching times can be imbedded into the measurement cycle time of the receiver resulting in no apparent measurement speed penalty for frequency stepping.

9. References:

[1] R. Juels, "Speeding Up the HP 8510B for Antenna and RCS Measurements", Proceedings of Antenna Measurements Techniques Association, Atlanta, Ga., Sept. 12-16, 1988

FIGURE 1

Frequency Agile System Configuration using the Scientific-Atlanta 1795/1796 Receiver and the Comstron FS-2000 Synthesizer

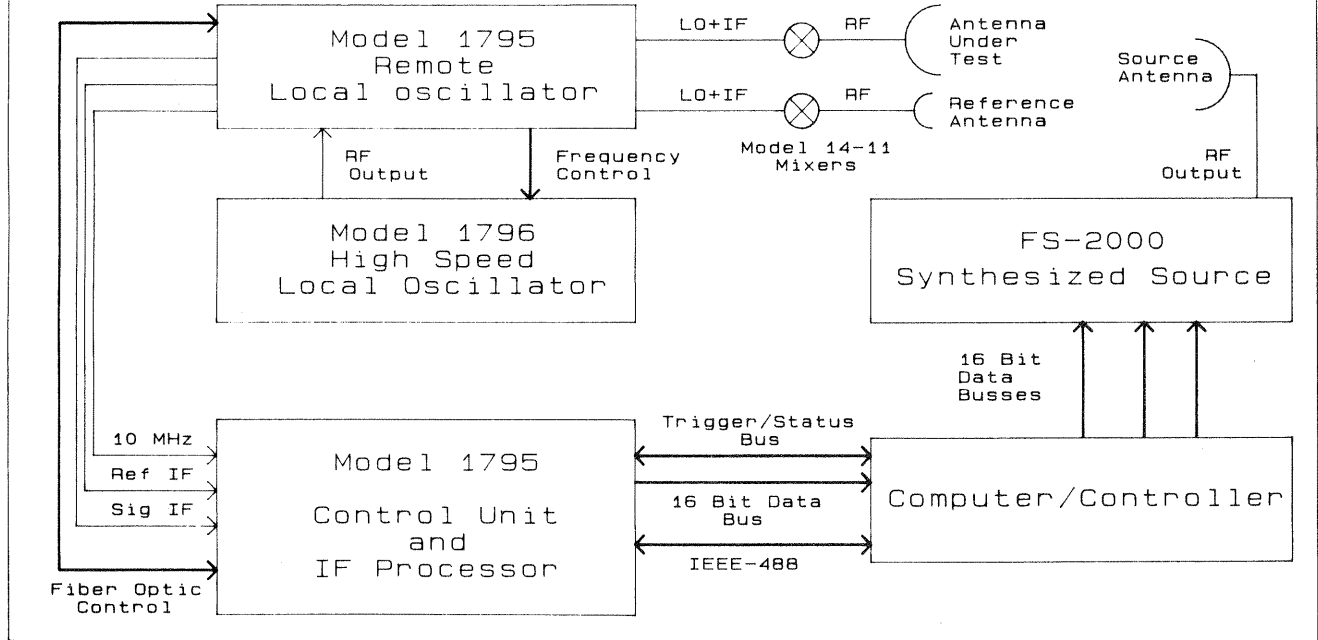


FIGURE 2

High Speed Multi-Frequency Timing using the Scientific-Atlanta 1795/1796 Receiver and the Comstron FS-2000 Synthesizer

