HIGH-SPEED, PULSED ANTENNA MEASUREMENTS USING THE MI TECHNOLOGIES MODEL 1795P

O. M. Caldwell

ABSTRACT

Characterizing antennas under pulsed RF conditions has focused attention on a class of measurement challenges not normally encountered in CW measurements. The primary problems often include high transmit power, thermal management of the AUT, and a close interaction between the antenna and its transmitting circuitry. This paper presents instrumentation techniques for pulsed RF antenna measurements using the 1795P Pulsed Microwave Receiver as an example of a commercially available solution applicable to both active and passive apertures. Emphasis is given to measurement speed, dynamic range, linearity, single pulse versus measurements, pulse width, pulse repetition frequency (PRF), frequency coverage, system integration and automation, and suitability of equipment for antenna range applications.

Keywords: antenna measurements; pulsed microwave measurements

1. INTRODUCTION

Characterizing antennas under pulsed RF conditions is becoming increasingly commonplace. Advanced radar systems and their enabling technologies such as monolithic microwave integrated circuits (MMICs) require testing methods to verify performance over a wide range of operating parameters. In addition to the pulse parameters, the major factors influencing pulsed RF testing include high transmit power levels, thermal management of the AUT and its supporting equipment in the test environment, and interfacing to a highly integrated antenna assembly with its associated transmitting and control curcuitry. Due to these issues, pulsed RF operation presents an additional set of test problems not often encountered in CW operation. As a result, instrumentation complexity increases and measurement system timing issues become critical.

An example of the problem is the MMIC based active aperture phased array typical of airborne radars. This antenna may cosist of up to 3,000 radiating elements producing a toatl output power exceeding 10 kW. Since beam forming is a direct funtion of each radiator’s amplitude and phase characteristic, accurate pattern testing must be performed at high power levels. The management of the radiation hazard requires well shielded chambers or extensive outdoor range facilities. Additionally, the typical 30% efficiencies of solid state power amplifiers will require removal of 30 kW of waste heat from the test chamber. The control of an antenna of this complexity requires extensive interfacing to a beam steering computer imposing additional constraints on the measurement process.

2. MEASUREMENT REQUIREMENTS

The basic pulsed antenna test parameters are identical to those encountered in CW measurements. Gain, sidelobe levels, pointing accuracy, beamwidth, null locations and depths, monopulse slopes, and polarization parameters are essential to fully characterizing an antenna. In addition to the traditional time invariant antenna performance parameters, some new time dependent parameters emerge when testing under pulsed conditions. These include transient effects such as beam formation and distortions as a function of time within a pulse or over an ensemble of pulses, power output (i.e. gain) as a function of time within a pulse or pulse burst, etc.

Compounding these measurements is the additional burden for multi-channel, multi-frequency, and multi-state measurements as a function of Pulse Repetition Frequency (PRF), Duty Factor (DF) and operating frequency. Due to the increasingly integrated nature of antennas with their transmitters, the measurement system must be responsive to external RF pulse generation and timing for both single and multiple pulse measurements. The traditional requirement that the measurement system control all aspects of the AUT's state during testing may no longer be possible or desirable.

In antennas where the radiating elements are essentially independent transmitters, testing may include circuit tests in addition to electromagnetic tests. System testing often requires characterization of pulse dynamics such as overshoot and ringing, droop, and phase drift. Characterization of these effects would ideally be accomplished using the same instrumentation as the antenna test. Therefore, instrumentation is needed with the following characteristics;

1. High measurement speed and precision
2. High selectivity
3. Wide detection bandwidth
4. Wide dynamic range with excellent linearity
5. Pulse width, PRF, and Duty Cycle agility
6. Integrated multi-channel measurements
7. Integrated pulse timing and range delay compensation

3. HISTORICAL SOLUTIONS

Historically, most pulsed antenna measurements have been performed either using broadband detection methods, traditional phase locked narrowband receivers or custom one-of-a-king recievers.Each method has limitations.

Broadband detectors such as those used in Pulse Power Meters are cost effective and have sufficient bandwidth to characterize short pulses. They do suffer from limited dynamic range (typically 40 dB) and no selective (useable response from 10 MHz to 18 + (GHz). Direct power detection also restricts the measurements to magnitude only. Without phase measurement, phased array antenna alignment is virtually impossible.

Phase locked narrowband superheterodyne receivers can provide some dynamic range recovery (PW and DF dependent) compared to broadband detectors and offer very high selectivity. Their major deficiency is their limited pulse measurement fidelity. Typical final IF bandwidths in the tens of kilohertz are common. This limited bandwidth restricts pulsed measurements to only an integrated ensemble of pulses over a relatively long (tens of milliseconds) period.

Custom receivers have been designed and built for special applications and can ensure optimum performance for a given set of parameters. As in any special design, high cost and limited flexibility for other applications are significant impediments to their use.

4. POTENTIAL SOLUTIONS

New instruments such as pulsed Vector Network Analyzers (VNA) and Instrumentation Radars offer high precision approaches to pulsed antenna testing. The pulsed VNAs have adequate measurement capabilities but are poorly suited for antenna range integration issues such as remote control and separation of the excitation and the AUT. Synchronization of triggering between the AUT and the receiver has also restricted their use. Short pulse Instrumentation Radars have adequate bandwidth, speed, triggering, and system integration features to characterize antennas under pulsed excitation. However, the expense of these systems has concentrated thier use almost exclusively to high performance RCS measurements.

5. MI TECHNOLOGIES MODEL 1795P

An instrumentation solution that addresses all the requirements listed in Section 2 is the 1795P Pulsed Microwave Receiver. The 1795P is an upgrade for the standard Model 1795 CW receiver introduced in 1989. Its architecture is identical to the standard 1795 as shown in Figure 1. The change made in the “P” version is the new Pulse IF Processor which is a direct replacement for the existing IF Processor. An additional High Speed Parallel Interface and, IEEE-488 interface on the new IF Processor facilitate complete system integration. Major features and specifications are listed in Tables 1-3. A simplified range application block diagram illustrating AUT receive testing is shown in Figure 2. The addition of a pulse modulator on the source for pulsed RF excitation and a pulse generator for generating the timing signals is all that is required. Multi-channel operation is obtained via the 1795P using the same internal controls and external interfaces of the standard 1795 Receiver.

6. SUMMARY

Pulsed RF antenna measurements for active and passive apertures present many measurement challenges. These include measurement speed, dynamic range, linearity, single pulse versus multiple pulse measurements, pulse duty factor, pulse repetition frequency, frequency coverage, system integration and automation, and suitability of equipment for antenna range applications. A simple system application and specification have been presented using the MI Technologies 1795P Pulsed Microwave Receiver as an example of a commercially available solution.

Table 1.
MI Technologies Model 1795P

Characteristic	Specification
Pulse Width	50 nanoseconds to CW
Pulse Repetition Frequency	0 to 1 MHz
Duty Factor	0 to 100%
Maximum Trigger Rate	10 kHz Master or Slave
Trigger Control	33 nsec resolution - up to 5 μsec delay
Multi-pulse Integration	Up to 2048 samples
IF Bandwidth	10 MHz
Linearity	.05 dB or 0.4° per 10 dB -input step
Data Types	I&Q or Amplitude and Phase
Data outputs	S-A HSPI or IEEE-488
Remote Capabilities	Remote Mixers and LO Multi-channel switching

Table 2.
Single Pulse
Dynamic Range (dB) (at S/N=1)

Pulse Width	0.1-4	4-8	8-12.4	12.4-18
100 nsec	54	51	50	44
500 nsw	60	57	56	50
1 μsec	63	60	59	53
10 μsec	73	70	69	63
50 μsec	79	76	75	69
100 μsec	82	79	78	72

Table 3.
Multiple Pulse (10 μsec)
Dynamic Range (dB) (at S/N=1)

Number of Pulses	0.1-4	4-8	8-12.4	12.4-18
1	73	70	69	63
4	79	76	75	69
16	85	81	80	75
64	91	87	86	81
256	97	93	92	87
1024	103	99	98	93

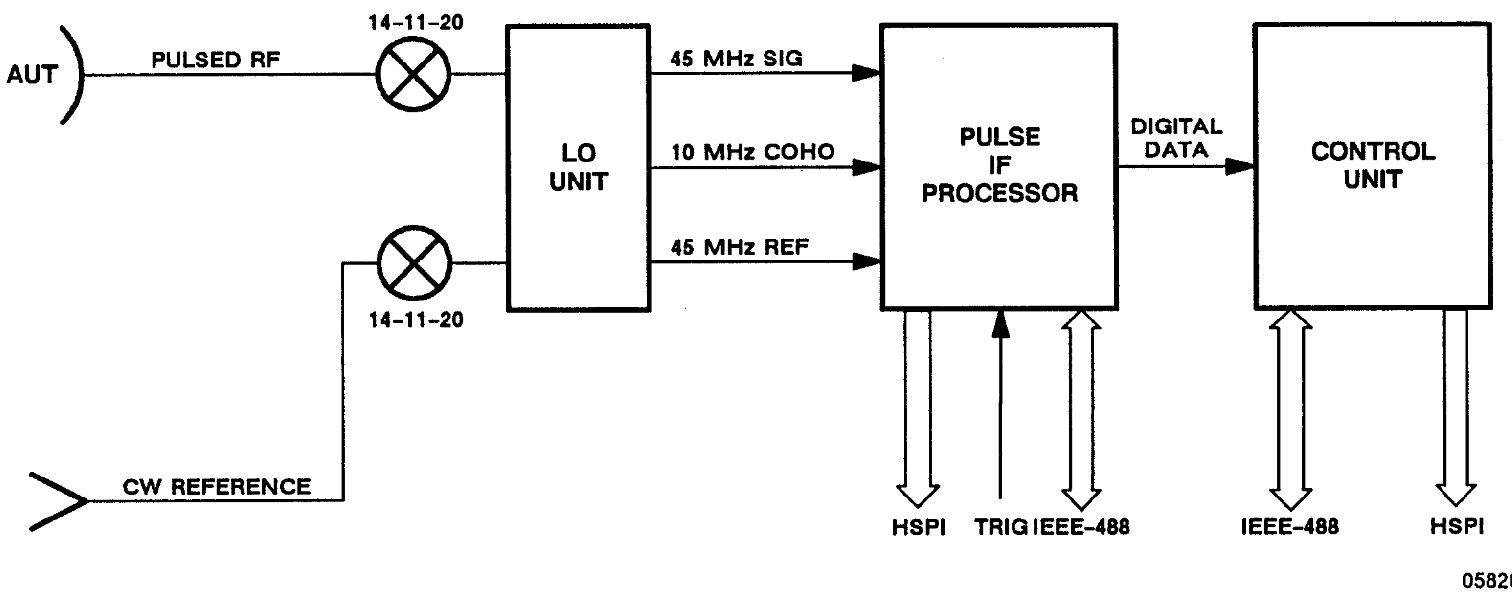

Figure 1. Model 1795P Pulsed Reciever

Figure 2. Pulse Measurement System Configuration