A NEW GATED-CW RADAR IMPLEMENTATION

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Abstract

This paper describes the new ORBIT/FR *StingRay* Gated-CW radar implementation that provides both performance and speed improvements over those previously utilized and fielded in RCS measurement systems. The radar is implemented using one or multiple pulse modulators used to provide gating of the transmit and receive signals, in conjunction with the new class of Performance Network Analyzer recently introduced by Agilent Technologies. The radar features an order of magnitude improvement in speed over that previously offered using implementations with the Agilent 8510 or 8530 network analyzer/receiver. In addition, base sensitivity improvements are realized, and the radar is more flexible with user selection among many IF bandwidth settings now available. The physical profile of the radar is also improved, meaning that additional performance gains may be realized by creating a more efficient packaging scheme where the radar may be located closer to the radar antennas, either in a direct illumination configuration or in a compact range implementation. These factors, when considered in aggregate, result in the new ORBIT/FR *StingRay* Gated-CW radar offering that provides a higher performance-to-cost value trade-off than was previously available to the RCS measurement community.

Keywords

959 Spectrum,, Radar, Gated-CW, PNA, high speed

Introduction

Gated-CW radars have offered a high level of performance versus cost value trade-off to the RCS measurement community for a number of years[1]. These radars operate on the principle of using a pulsed transmit signal and gated receive path, in conjunction with an IF section of the receiver that is restricted in bandwidth such that it does not pass the entire received pulse spectrum of frequency components, but rather only the central component (thus the receiver is in effect “CW”). The gated-CW radar experiences additional losses termed “duty-cycle” losses, as these losses are proportional to the duty cycle of the transmitted waveform. This is in contrast to the “pulsed-IF” radar, where the IF section of the receiver utilizes a bandwidth capable of passing all the spectral components of the received pulse, and the baseband pulse is sampled at the peak. The gated-CW radars are very efficient for indoor use as the duty cycle losses may be easily compensated. Moreover, the gated-CW radar generally provides better accuracy and effective I/Q circularity, and is lower cost than an equivalent pulsed-IF radar.

Gated-CW radars have generally been implemented using vector network analyzers (VNAs) as the IF receivers[2]. The most commonly used VNA has been the HP8510/8530. This unit has been a reliable, high performance unit for a number of years. However, Agilent Technologies has recently introduced a new series of instruments, the Performance Network Analyzer (PNA) series, which are ideal for use in gated-CW radars. These units are Windows based instruments whose features provide several key enhancements to the implementation of gated-CW radars:

- An order of magnitude or better increase in data acquisition speed for multi-frequency measurements
- Improved sensitivity as well as flexibility in the selection of appropriate IF bandwidth
- The ability to easily remote the control of the instrument from the unit front panel, thus allowing the instrument to be located near the front end RF

instrumentation, resulting in additional performance improvements

The utility and performance of the ORBIT/FR *StingRay* gated-CW radar as implemented with the PNA is discussed herein.

StingRay Gated-CW Radar Configuration

The gated-CW radar typically comprises the following key elements:

- Pulse Modulator Assembly
- Pulse Modulator Timing Unit
- RF Synthesizer
- Remote Mixer System (if required)
- Receiver
- Data Acquisition System
- Positioning System
- Antenna System

In the case of a microwave band (e.g., 2-18 GHz) radar, a remote mixer system was often utilized to allow the point of RF to IF conversion to be placed in the anechoic chamber near the antennas, along with the pulse modulation functional hardware. In this manner, the VNA front panel could be located in the control room to allow for manual operation of the radar. The new *StingRay* gated-CW radar system utilizing the PNA now retains the full functionality of manual operation of the radar while allowing the unit to be located in the anechoic chamber next to the pulse modulator and antennas. Manual operation is achieved by locating a remote keyboard, mouse, and monitor in the control room. Thus, the remote mixers for the primary microwave band can be eliminated as RF cable lengths can be kept short. The resulting radar configuration is a simpler, higher performance, yet less costly alternative to gated-CW radar implementation. The elements of the *StingRay* system include:

- Pulse Modulator Assembly (FR8X05 Series)
- Pulse Modulator Timing Unit
- E8362B PNA Fundamental RF Source/Receiver
- 959 Spectrum Software Based Data Acquisition System
- Positioning System (optional ORBIT/FR pylon or conventional positioning system with foam column)
- Antenna System (monostatic or quasi-monostatic configuration using the FR 6400 series diagonal horns as the baseline antennas, or optional AL-22000 series compact range)

The baseline radar operates from 2-18 GHz, with options for 0.1-2 GHz. The system can also be upgraded with integrated higher frequency combination frequency converter/pulser modules for millimeter wave operation.

A block diagram of the basic *StingRay* gated-CW radar system is shown in Figure 1.

System Performance

The system performance is characterized by high sensitivity, high speed acquisition, and flexibility in setting up various measurement scenarios.

The sensitivity is derived from the use of a power amplifier inside the pulse modulator module, in conjunction with the excellent sensitivity of the PNA preceded by a low noise amplifier on the receive side. Limiting in the receive side chain as well as high isolation antennas such as the FR 6400 series of diagonal horns, used in conjunction with the pulse modulation capability of the radar, provides a highly clutter-free environment that effectively takes advantage of the available system sensitivity.

Data acquisition speed is greatly increased in the *StingRay* radar over that previously available by taking advantage of the order of magnitude improvement in frequency switching speed offered by the PNA synthesizer over the previous generation 8360 series synthesizer, as well as the improvement in sampling speed. With the wide range of IF bandwidth choices available in the PNA, the speed/sensitivity tradeoff can easily be optimized as the measurement scenario requires.

Benchmark test have shown that the radar is capable of stepped frequency sampling times on the order of 300-400 μs per point (depending on the band) for a wide IF bandwidth such as 10 KHz. The swept frequency sampling time is composed of two primary elements: (1) the basic sampling time, which to first order is approximated by the inverse of the IF bandwidth, and (2) the frequency switching and settling time.

The *StingRay* radar provides for flexibility in measurement execution in a number of ways. Some of the primary areas that provide for a user-friendly execution of the measurement include:

- Importation of specialized calibration target files
- Support for many common calibration targets using calculated theoretical RCS values
- Support of calibration and test targets measured at different separations from the radar
- Single or Multiple angle background subtraction
- Real time display of data vs. angle, frequency or time
- Full scattering matrix collection in a single scan
- Storage of data by sweep or by scan to optimize file access times
- Wide range of pulse width, delay, and PRF selection
- Sequence scripting for multiple step test and analysis execution
- Full flexibility in the calibration equation application

The import feature for calibration files allows ease in use of specialty calibration targets, such as the NIST squat cylinder series, commonly used now for range certification. These targets have the files of theoretical RCS values available when the target is purchased.

Access to the data generated by the radar may be accomplished using one of several methods, including export to ASCII, Microsoft Excel, Mathematica, or MATLAB. Alternatively, a file system API is available to call the binary data directly from C routines, or from other platforms using an easily constructed shell.

Sequence scripting allows the user to execute not only multiple 959 Spectrum acquisitions and DataPro RCS analyses, but also allows the user to execute any third party program that can be run from a command line, such as KNOWBELL or the new Pioneer analysis program.

One of the most attractive features of the *StingRay* radar is the use of the radar calibration equation. Each element of the calibration equation applied to the test target data can include:

- Reference target data
- Test target background
- Reference target background
- Test target pre-gate parameters
- Reference target pre-gate parameters
- Space Loss Correction
- Theoretical target parameters/data

can be selected from the current file, imported directly from another file, or alternatively can be "turned off" for the current calibration application.

The calibration equation as implemented in the 959 Spectrum is given as

$$\sigma = SL * Theo * (PG_{Test} *[TT - TB])/ (PG_{Ref} *[RT - RB])$$

where

σ = calibrated radar cross section
SL = space loss correction for cal /test target locations
Theo = absolute RCS value of cal target
PG = pre-gate settings for test or reference target as appropriate
TT = measured test target signal as function of frequency and angle
TB = measured test background signal as function of frequency and angle
RT = measured reference target signal as function of frequency
RB = measured reference background signal as function of frequency

StingRay Gated-CW Radar Specifications

Table 1 summarizes the primary specifications for the *StingRay* radar.

The radar features options for the following enhancements:

- Full polarization matrix switching or simultaneous measurements
- Band extensions down to 0.1 GHz or addition of millimeter wave bands
- Option H11 sensitivity enhancement to the PNA
- Pylon, string reel, or foam column based positioning system for target support
- Extra workstation for data analysis

- Specialty antenna set or addition of AL-22000 series compact range

Table 1 *StingRay* Specifications (2-18 GHz Version)

PARAMETER	SPECIFICATION
Frequency Range	2-18 GHz continuous (additional bands upon request)
Polarization	VV,HH,HV,VH depending on options
System Noise Figure	9 dB at Rx Port (7 dB with PNA Option H11)
Peak Transmit Power	+20 dBm (higher powers available upon request)
Pulse/Gate Width	0 to 10 µs in 1 ns steps
Pulse Repetition Frequency	0 to 20 MHz
Tx/Rx Gate Delay	0 to 10 µs in 1 ns steps
Data Acquisition Speed (10 KHz IF BW selected)	300-400 µs in step frequency mode typ., 120 µs in CW mode typ.
IF Bandwidth (selectable)	1 Hz to 40 KHz
Dynamic Range	90 dB typ.
Calibration Targets	Optional Squat Cylinders, Spheres, Trihedrals, Dihedrals, Flat Plates, and others
Pylons	500 lbs to 3 tons
Compact Range	AL-22000 series 1' x 1' QZ and up

Conclusions

A new gated-CW radar has been developed that takes advantage of the sensitivity enhancements and dramatic speed improvements available from the new Agilent Technologies Performance Network Analyzer (PNA). The system provides significant performance enhancements over that available with previous VNA based gated-CW radars, while at the same time providing a lower cost alternative to radar implementation. Numerous options and a very flexible functional interface in the 959 Spectrum allows for a highly tailored system for many user application scenarios.

References

1. B.W. Deats, "Performance Comparison – Gated-C.W. and Pulsed-I.F. Instrumentation Radars", AMTA 1989

2. L.R. Burgess and D.J. Markman, "Performance of Gated-CW and Antenna Measurement", AMTA, 1988

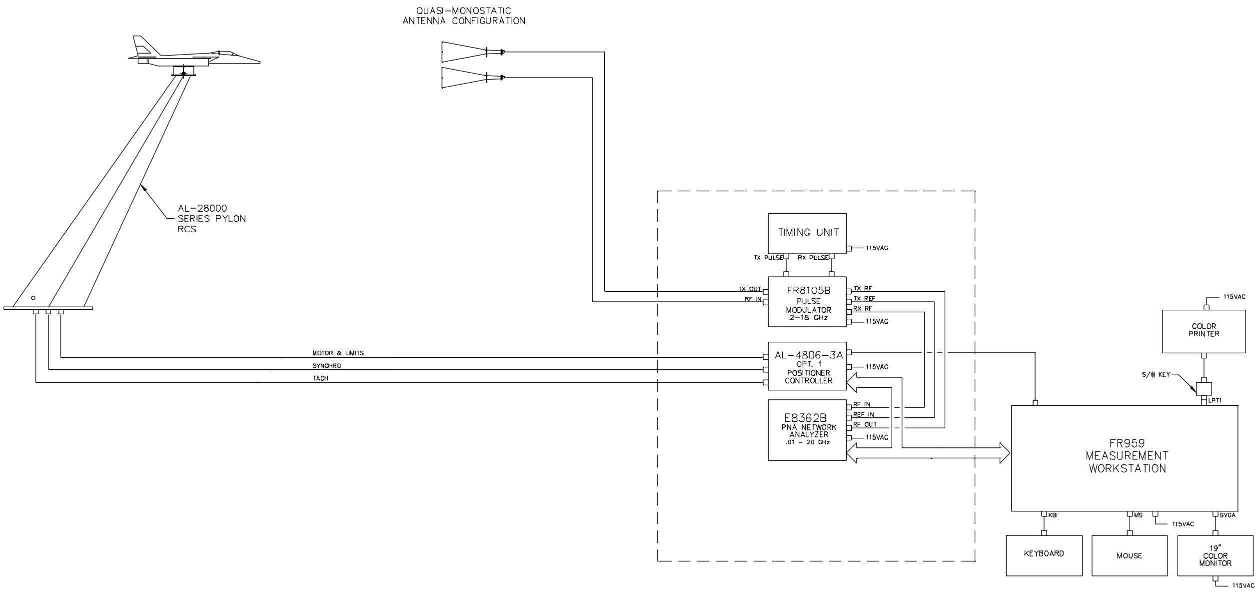

Figure 1 Block Diagram of High Speed *StingRay* Gated-CW Instrumentation Radar (2-18 GHz)