# A STANDALONE RF SYSTEM FOR SOLID-STATE PHASED ARRAY ANTENNA MEASUREMENTS

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## ABSTRACT

Lockheed Martin MS2 has a long history of utilizing antenna ranges for calibration, test and characterization of the phased array antennas. Each range contains an integrated RF receiver subsystem for performing antenna measurements, typically on the full array. For solid-state phased array testing, what is often needed, however, is a test station capable of performing complex S-parameter measurements on a subarray or subset of the full antenna system without incurring the expense of a test chamber. To address this requirement, Lockheed Martin, working with Nearfield Systems, has developed a portable standalone RF measurement system.

The standalone system consists of an Agilent PNA, automated transmit/receive unit (TRU) and a waveform generation (WFG) subsystem for interfacing to the phased array beam-steering computer.

This paper will discuss the capabilities of the Standalone RF System including the TRU and WFG subsystems. The TRU is used to tailor the RF signal by automated switching of amplifiers and programmable step attenuators for various test scenarios. The WFG is an automated pattern generator used to present many digital waveforms in arbitrary sequences to the phased array beam steering computer. The design features of the standalone RF system will be presented along with the COTS hardware utilized in assembling the station.

**Keywords:** phased array antenna, RF subsystem, automated test, waveform generator, beam-steering computer.

## 1.0 Introduction

Lockheed Martin MS2 has a long history of utilizing antenna ranges for calibration, test and characterization of the phased array antennas. As the performance features of phased array antennas advance, so too must the antenna ranges utilized to test them. One key component of antenna measurement ranges is an integrated RF stimulus & receiving subsystem for performing RF measurements, typically on the full array. For solid-state phased array testing, what is often needed, however, is a method to perform the above plus a capability to measure complex S-parameter measurements on a subarray or subset of the full antenna system without incurring the expense of a test chamber. To address this requirement, Lockheed Martin, working with Nearfield Systems, has developed a portable standalone RF measurement system.

## 2.0 Solid-State Antenna Measurement Application

The developments of solid-state phased array antennas have increased the performance requirements on antennas as sensors. Such applications may range from typical radar functionality to communications, target illumination, and countermeasures all packaged into one sensor. Coupled with the integration of typical off-antenna components into the modern solid-state antennas, the integrated package contains a wide range of stimulus and processing hardware.

Measurement requirements of these integrated phased array antennas places needs upon measurement systems once relegated to many test systems. Furthermore, the ability to provide stimulus and response to an antenna in a manufacturing test environment is advantageous. Thus with such a test system, an antenna test range with anechoic material is not required. Non-pattern antenna integration and testing could occur on the factory floor.

Active components within an antenna environment are susceptible to changing conditions such as temperature induced thermal drift, start-up transients and thus may create non-linear performance behaviors. To account for these factors, antenna designs include electrical calibration and alignment schemes to allow both factory and in field adjustments [1]. Secondary benefits of such designs allow the antenna to self-diagnose problems associated with malfunctioning hardware before the antenna is tested an antenna range.

From a manufacturing implementation viewpoint, test systems utilized for factory testing of solid-state antennas must be portable, flexible, and cost effective while providing commonality of test platforms. The antenna test system solution presented here meets such requirements.

## 3.0 Test System Solution

Lockheed Martin, working with Nearfield Systems, has developed a portable standalone RF measurement system (Figure 1). The test system is considered stand-alone in that it is capable of providing the required stimulus, antenna control, and response measurement capability is void of scanning mechanisms. It is portable in the fact that all components are contained in a single rolling equipment rack.

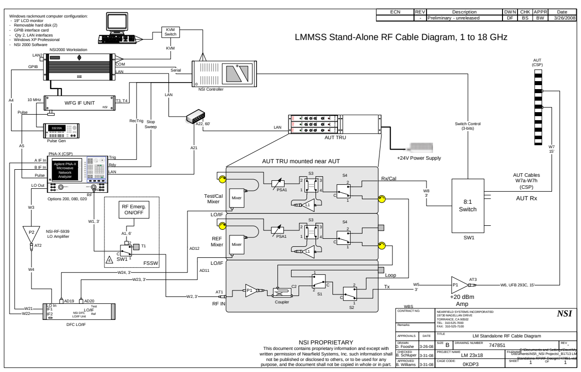


**Figure 1 Standalone System Diagram**

The brain of the standalone measurement system is the NSI2000 antenna measurement system for data acquisition. The NSI2000 software allows the efficient development of data acquisition scenarios in a scripting language which are transferable across other measurement systems.

The heart of the standalone measurement system is the receiver or network analyzer, in this case the Agilent PNA-X. The network analyzer serves as both an "S-parameter" meter and a pulsed measurement receiver. Application is not limited to just those two uses as capability now exists to perform spectrum analysis type measurements with a PNA.

The arms and legs of this system are the waveform generator (WFG).subsystem for stimulus and the RF switching subsystem (TRU) for signal conditioning and routing..

Finally, the system has a built-in self test capability to verify signal levels and operational readiness.

### 3.1 NSI 2000 Software

Control of the standalone system is performed by the NSI 2000 software. Using the NSI 2000 scripting capability, automated test scenarios may be developed to coordinate the control of the phase array for pulsed or CW measurements. The waveform generator (WFG) subsystem is controlled directly by the NSI 2000 software and allows the test operator to select and generate timing waveforms to control the phased array. The TRU subsystem may also be controlled directly by NSI 2000 scripts to configure the standalone system into the appropriate test mode. The test data may also be plotted or integrated with other applications to generate automated test reports.

### 3.2 Receiver

As mentioned above, the base receiver chosen for this application is the Agilent PNA-X. However, for dynamic range improvements in antenna ranges with potentially long cable lengths, an external mixer system, the NSI DFC LO/IF system, was integrated with the PNA. This implementation allows the PNA to be used as either antenna measurement receiver or as a standard network analyzer with little reconfiguration. The inherent benefit of this design is a measurement system with a high dynamic range, fast data acquisition, and broad frequency range. In this case, the base system is capable of but not limited to measurements from 1.0 GHz to 18.0 GHz.

### 3.3 Stimulus

The stand-alone test system is capable of providing all RF & control stimulus to the antenna under test (AUT). Specifically, the PNA provides the RF source for either a CW or Pulsed RF waveform to the AUT. However, a key requirement for solid-state antenna testing is that the RF stimulus must be coordinated with the AUT timing and control commands. These signals may be T/R gates, beam steers, operating modes, gain/attenuation states, and or measurement dwells.

A programmable multi-channel waveform generator (WFG) was developed and integrated with the NSI2000 software (Figure 2). The WFG and PNA are synchronized via a common 10 MHz clock source allowing precise control of timing signals. The WFG design allows the user to program specific scenarios and events via a convenient user interface. Furthermore, test scenarios can be saved and recalled for a variety of test applications. All measurements are thus managed through the NSI2000 software for integrated data acquisition.

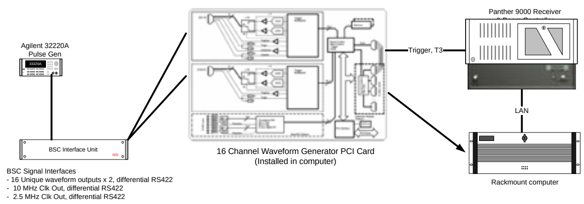


**Figure 2 Waveform Generator Subsystem**

## 3.4 Signal Conditioning and Routing

Pulling the standalone measurement system design together between the stimulus and receiving components is a Transmit/Receive switching and signal conditioning subsystem (TRU). See Figure 3. The combination of RF switches, amplifiers, and programmable attenuators allow the optimum signal distribution to the antenna under test. This design allows programmable & automatic signal switching between Transmit and Receive test configurations. Significant forethought was applied to component selection to optimize measurement system performance over various operating modes and from 1 to 18 GHz frequency band.

The TRU was developed specifically for the antenna range and includes the building blocks that are often used in the RF design of large ranges. The TRU is packaged in a 3U rack mount chassis for the standalone system, but is modular in construction allowing modules to be mounted directly on a scanner or positioner, if needed.

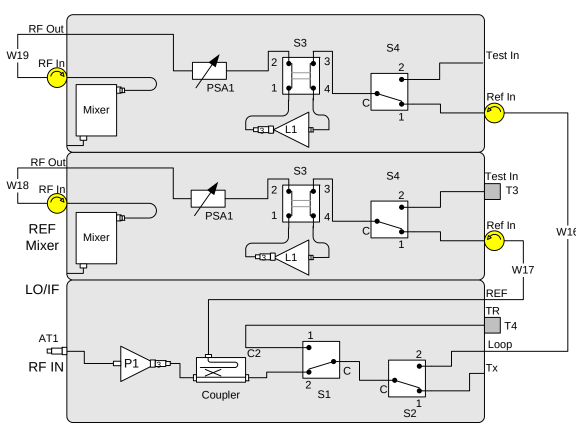


**Figure 3 Transmit Receive Unit (TRU)**

The TRU is a subset of the NSI Range Transition Manager (RTM) for automating antenna ranges [2]. The RTM provides a wide range of capability for automating large antenna ranges, but is oversized for smaller ranges. To address this problem, the TRU integrates the basic capabilities of the RTM into two module types while maintaining the LAN control scheme [3].

The TRU may be configured using two different module types; the base module and the mixer module. The base module contains elements from three of the RTM modules; the control module, Tx module and Cplr module. The mixer module contains elements from the mixer, PSA and Rx RTM modules. See Table 1.

**Table 1 – TRU Modules**

| Module Type | Description and Key Specs |
|---|---|
| BASE | Provides interface between host computer and mixer modules. Includes coupler, RF switching and amplifier, 33 dB, P1dB = +?? dBm. |
| MIXER | 0.5 to 18 GHz mixer, LO/IF is multiplexed. Includes programmable step attenuator, 0 to 70 dB in steps of 1 dB, RF switching and LNA, 33 dB, P1dB = +15 dBm. |

In a typical near-field range, as shown in Figure 4, two TRUs are used: one near the NF probe, possibly mounted on the probe carriage, and the other near the AUT.

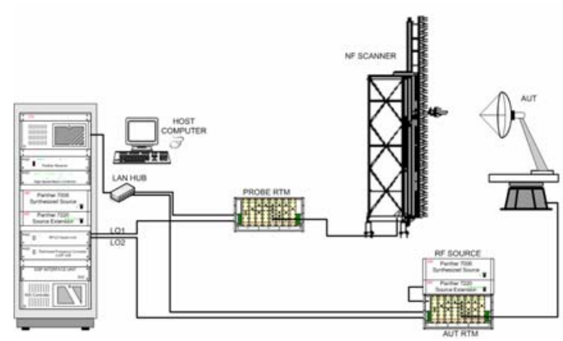


**Figure 4 TRUs Employed in Near-Field System**

For the standalone system, a single TRU is employed with a single base module and two mixer modules, as shown in Figure 5.

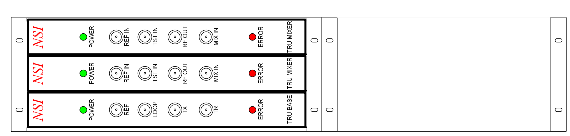

**Figure 5 TRU Package for Standalone System**

A graphical user interface, Figure 6, allows the settings of the switches and attenuators to be programmed and integrated into test scenarios.

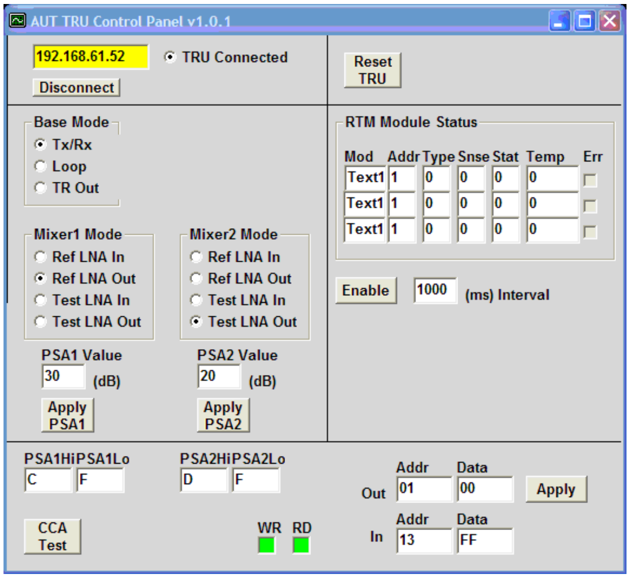


**Figure 6 TRU Graphical User Interface**

## 3.4 Built-In Test

One key feature of the standalone measurement system is a "loop-back" measurement path. The loop-back path is used to test the test system. With any measurement system, one of the first tasks encountered is the certification that the measurement system is ready to go and operating as needed. The loop-back RF path allows a signal to be routed from the source to the receiver bypassing the AUT. With RF switches, amplifiers, and attenuators in the loop-back path, each component can be exercised via software scenarios providing a health check or calibration of the measurement system. This feature provides the confidence, stability, and repeatability of the measurement system.

## 4.0 Test Results and Status

The standalone system has been built and tested with a phased array antenna to verify the interfaces and capabilites. Test results will be available at the AMTA conference.

## 5.0 Summary

A novel test system design and implementation has been presented for use in the measurement of solid-state antennas. This effort resulted in a turnkey measurement system with versatility needed for current and future test needs. The test system capability is expandable in either frequency range or measurement channels, and is comprised of COTS components. Furthermore, with additional investment, the system could be married with almost any type of antenna measurement scanner.

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