IMPROVING AUTOMATION FOR ANTENNA RANGES

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ABSTRACT

NSI has developed a novel technique for automating antenna range configurations. Although automation has shown to dramatically improve range productivity, most of today's antenna ranges are reconfigured manually. Today's automated ranges use electromechanical RF switches to control the RF signal path, which is contained primarily in a central rack, thereby limiting automation to ranges that are relatively small in size. Larger ranges, however, tend to locate many of the RF components such as mixers, couplers, amplifiers and multipliers remotely near the probe or AUT, sometimes 100 ft (30 m) or more from the rack, making the remote RF components more difficult to access and control. To address this problem, NSI has developed the Range Transition Manager (RTM) for automating large antenna ranges. The RTM uses modular packaging with a LAN interface and embedded processor to provide commonality and flexibility in automating various range sizes and types. The RTM family of modules provide a full range of automation capability for 0.5 to 18 GHz and higher frequencies.

This paper will describe the capabilities of the Range Transition Manager developed for a large near-field scanner and describe how the RTM improves overall range productivity.

Keywords: Antenna Range, Automation, Near-field, Far-field, LAN, Productivity

1.0 Introduction

The history of antenna testing since the advent of low cost computers in the 1970s has seen continued growth in automation and processing [1]. Computer control of instrumentation using the GPIB interface was a major step forward in standardizing automated test for antennas. More recently, high speed receivers [2] and beam controllers have been integrated with VXI synthesizers [3] to create a high performance test platform for testing complex multi-beam, multi-frequency antennas. The primary focus of technology, however, has been on improving the scan rate or how much data can be acquired in a single scan, either near-field or far-field. A great deal of attention has also been given to improving software for processing, user interface and networking [4]. Less importance, however, has been given to automation of the range operational state such as mode switching between transmit, receive, calibration, AUT, reflectivity, 2nd LO, EIRP, flex cable test, power amplifier and LNA test configurations. In many cases, this has been an acceptable trade-off, since one can often set the range into a particular mode of operation and then complete a large volume of testing in the one mode. While some antennas need only be tested in a single configuration, antenna complexity and performance are increasingly requiring additional modes of test. The old way of manually moving components, cables, and equipment is becoming a very difficult and expensive way to do business.

2.0 Why Automate The Antenna Range?

In spite of the many advantages automation can provide (Figure 1) manual reconfiguration is a fact of life on many large antenna ranges today.

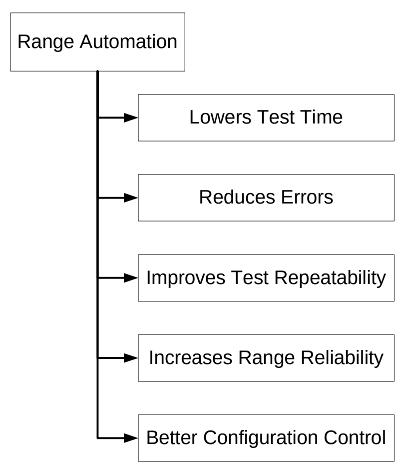

Figure 1 Benefits of Automation

Changing from transmit to receive on a large antenna range, as an example, may involve a few or more than a dozen steps depending on range complexity and size. The procedure may involve moving RF cables, components, instruments and mounting plates. Changing attenuator values and software settings may also be required. After the changes have been made, RF levels need to be rechecked and possibly recalibrated. This can be a time consuming and error-prone process. If testing proceeds with an invalid range setup, the results may be inaccurate. Faulty antennas may be allowed to pass or good antennas may test as failed. In either case, time will be wasted trying to determine the cause of the error. Even if the configuration changes are flawless, the time savings with an automated range can be significant if there are more than a few modes to test. The chart in Figure 2 shows the estimated time savings for an automated range.

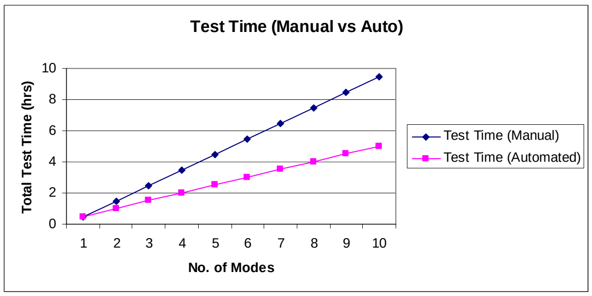

Figure 2 Time Savings - Automated vs. Manual Range

The chart shows an example of expected savings for an automated range based on a scan time of ½ hour and a manual reconfiguration time of ½ hour. As shown, the savings increase with the number of modes to be tested.

Test repeatability is a desirable characteristic that may be difficult to achieve using manual reconfiguration. Even when the range is correctly configured, connector non-repeatability may result in VSWR contributions to range error. If a particular attenuator value is used in one configuration but not the other, care must be taken to ensure the correct value is inserted in each case. Otherwise, signal level changes between tests could cause receiver saturation or inadequate signal-to-noise performance.

Range reliability is also a desirable characteristic that may be impacted during manual reconfiguration. RF connectors are easily damaged if misaligned, over-tightened or mated with an incompatible type. Repeated connect and disconnect cycles reduce the specified connector life. RF cables may be also be damaged when moved or handled indelicately. Depending on the failure mode, a damaged RF connector may create problems that are difficult to isolate and expensive to correct. As an example, a damaged connector on a flexible RF cable would require that the entire cable be replaced. Lead times for flexible RF cables can be six to eight weeks.

Configuration control is made easier with an automated range, since components and cables do not move around with each mode change and the range configuration can be changed with a software command. Tracking the various small cables, components, adapters and attenuators is made easier, since they are contained in easily identifiable modules. This allows a single certification of the range by the quality assurance department rather than having to certify the range for each configuration change.

Smaller antenna ranges, in which all of the instrumentation can be contained in a single rack, more easily lend themselves to automation than the large ranges with equipment in remote locations. For these smaller ranges, a simple GPIB or VXI switch controller may be used to control the required RF switching.

A typical large antenna range, however, may have RF components located in several remote locations subject to change depending on the mode of operation. An RF amplifier or multiplier may be located near the probe. Remote mixers [5], used to reduce the length of the RF cable path, may be located with one near the probe and one near the AUT, but their functions may be reversed when the mode changes. As an example, the reference mixer and coupler may be relocated to either the probe or the AUT depending on the mode of operation. RF sources and amplifiers may also be located on a movable stage. Typically, instrumentation racks do not move during a mode change, but the RF cabling may need to change.

Automation of these remote devices could be done with existing GPIB or VXI controllers, however, controlling the switches over long distances require a high number of switch drivers/cables. In addition, packaging of the control elements is often problematic, since the RF devices do not come with built-in switching and the switches themselves require individual drivers and cables for control over long distances.

NSI has developed the Range Transition Manager (RTM) to overcome these problems.

3. Range Transition Manager Overview

The RTM was developed specifically for the antenna range and includes the building blocks that are often used in the RF design of large ranges. The RTM, as shown in Figure 3, is packaged in a 5U rack mount chassis with eight slots for the individual RF modules.

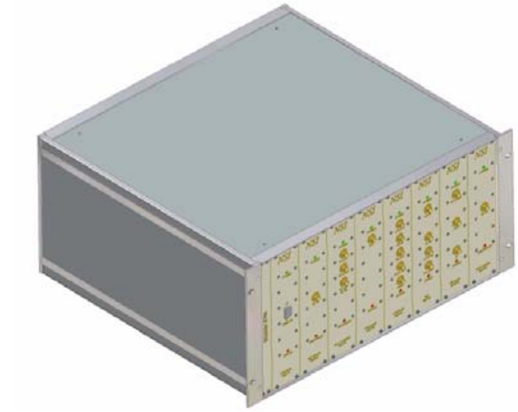

Figure 3 Range Transition Manager

Each module incorporates a particular RF capability and communicates over a common bus with the RTM control module. The eight module types, shown in Table 1, allow the user to mix and match modules within an RTM chassis. Each RTM must have a single control module, which may be located in any slot. A LAN interface allows the RTM control module to communicate with a host computer using an embedded processor to provide commonality and flexibility in automating various range sizes and types. The RTM family of modules provide a comprehensive range of automation capability currently for 0.5 to 18 GHz. Each module is designed for high isolation and low leakage with the RF components contained within a sealed enclosure. Higher frequency modules, in future applications, may be easily mixed with existing modules in the same RTM unit.

Table 1 – RTM Modules

Module Type	Description and Key Specs
CONTROL	Provides interface between host computer and RF modules.
REF MIXER	0.5 to 18 GHz mixer, LO/IF is multiplexed.
2^{ND} LO MIXER	Switchable 5 – 18 GHz mixer for 2^{nd} level downconversion.
TRANSMIT	Switchable 0.5 to 18 GHz amplifier, Gain = 33 dB, P1dB = +15 dBm.
COUPLER	0.5 to 18 GHz coupler with RF switching.
PSA	0 to 110 dB in steps of 1 dB with 4-port RF switch mux.
RECEIVE	Switchable 0.5 to 18 GHz amplifier, Gain = 33 dB, P1dB = +15 dBm, with switched output.
TEST MIXER	0.5 to 18 GHz mixer, LO/IF is multiplexed.

Two or more RTMs may be employed to automate the range configuration, as shown in Figure 4. A LAN hub or switch provides the communications path from the host computer for control of the RTMs. Messages are passed from the host computer to each RTM to command a specific module to a designated state. Status messages are sent to the host computer to confirm the operation. Each module contains a thermal sensor, which may be read by the host computer to monitor environmental stability.

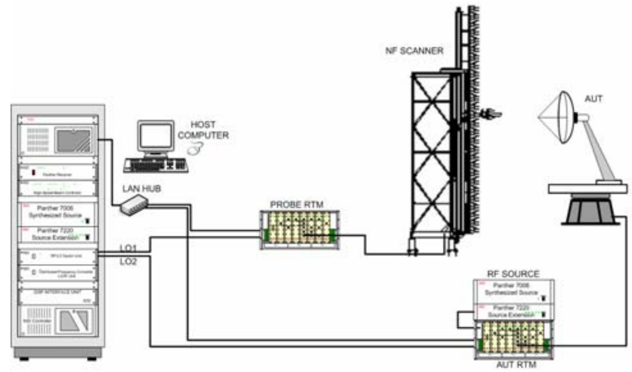

Figure 4 –System Block Diagram using RTMs

The RTMs provide the RF components and switching to allow the system to change modes under software control without changing cables, components or equipment.

4. RTM Hardware Configuration

To address a variety of antenna ranges, each RTM includes RF modules with amplifiers, couplers, mixers, step attenuators and switches as shown in Figure 5.

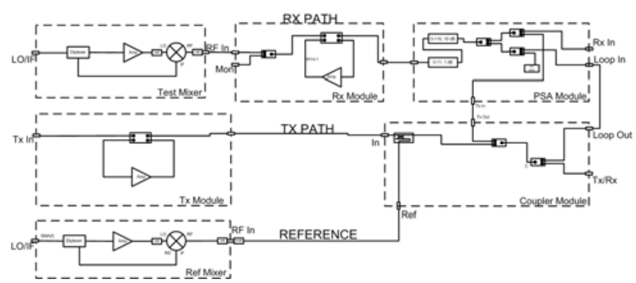

Figure 5 – RTM Block Diagram

The primary signal paths are described in the following paragraphs.

The transmit (Tx) path of the RTM includes a transmit (Tx) module containing a switchable high gain amplifier. The Tx Module is used to overcome the loss of long RF cables. For short ranges, the amplifier may be switched out if it’s not needed. It may also be employed only at higher frequencies where the cable loss is greater. A Coupler Module generates the reference RF signal and includes several switching options. The output of the coupler module is switchable to either the RF test path or to a loopback cable for calibration and monitoring purposes. A reverse signal may also passed to the receive section for reciprocal antennas.

The reference path includes the coupled output, which allows the RF path to be sampled with minimal loss for use a reference. The Reference Mixer Module is provided to sample the coupled signal. Figure 6 shows the internal components of a Mixer Module.

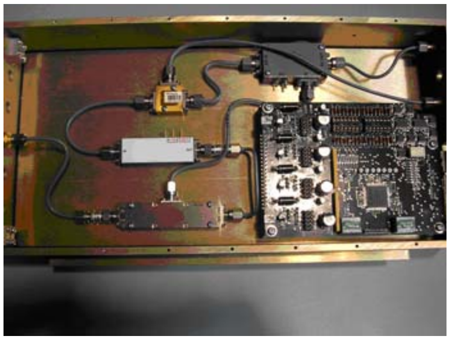

Figure 6 – RTM Mixer Module

The receive path of the RTM includes a Programmable Step Attenuator (PSA) Module with an RF multiplexer at the input. The RF mux allows selection of several inputs depending on the range type and mode of operation. The RTM is capable of interfacing with reciprocal antennas or antennas with separate input and output RF paths. The PSA allows the input signal level to be attenuated from 0 to 110 dB in steps of 1 dB. A Receive (Rx) Module provides a high gain, low noise, switchable amplifier to be employed as a low noise amplifier (LNA) to recover signal level. The last module in the receive path is the test mixer.

The modules of the RTM, as shown in Figure 7, provide flexibility in configuring a system for custom applications. As an example, small ranges may not need both amplifiers or the PSA. Larger ranges may need more than one amplifier in the transmit path or receive path. It is also possible to configure a range with a single RTM, however, automatic switching of transmit and receive modes would require an additional Tx/Rx switch module. Near-field, far-field and compact ranges may each require a different complement of modules.

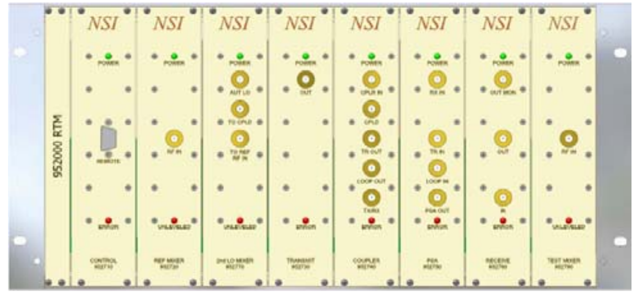

Figure 7 – RTM Modules

Each module has a power and error LED on the front panel. The error LED indicates that a switch has changed to an invalid state indicating a fault. The software is capable of identifying the faulty switch. The RTM has diagnostic capability for verification of communication links and functionality of module control. The control module has an external connector for control of outboard RF switches. The RTM operates on +24 VDC and includes voltage regulation and noise filtering.

5. RTM Control & Software Configuration

Control of the RTM is performed by an embedded processor in the Control Module (CM). Each RTM has one Control Module that provides the LAN interface with the host computer and provides the bus signals to the other RTM modules. Messages received from the host computer are interpreted by the CM, which then generates the necessary commands to the addressed RF module. The CM acts as a server providing responses to messages containing either requests for a change of configuration or status update.

Each RF module contains a unique address and type identifier allowing multiple modules of the same type to co-exist in a single RTM. The host computer software is capable of reading the type identifier of each module to determine how its configuration should be handled.

The RTM host software includes a DLL that allows calls from other applications such as the NSI 2000 scripting language. A stand-alone host application is also provided with the RTM to provide a user-friendly interface for control and monitoring of the RTMs.

6. RTM Options and Future Extensions

A fully automated range would include two RTMs: one placed near the AUT and one near the probe. To switch the RF and LO/IF between the two RTMs, the RF/LO/IF Switch Unit, shown in Figure 8, is available as an option. The RF/LO/IF Switch Unit includes the same embedded processor as the control module and communicates with the host computer over the LAN interface using the RTM messaging protocol.

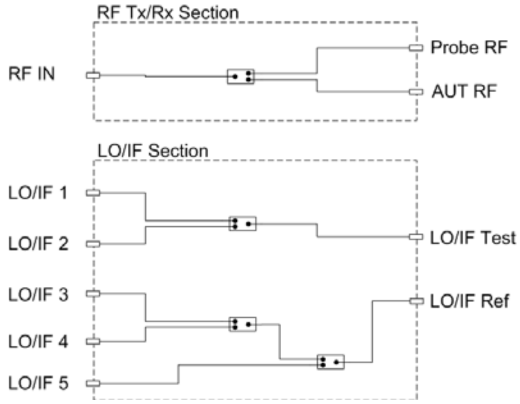

Figure 8 – RF/LO/IF Switch Unit

A second LO mixer option is also available for the RTM to provide for range compatibility with antennas containing internal downconversion stages.

The modular design of the RTM allows ease of future expansion. Future modules may include higher frequency operation, frequency multipliers, higher power amplifiers, additional RF switching and other features.

7. Test Results and Status

An RTM prototype has been built and tested to verify the interfaces and control of key components and switches. The prototype includes the host computer, control module CCAs and RF module CCA. All interfaces were verified and confirmed. An operational RTM unit and additional test results are planned to be available at the AMTA conference.

8. Summary

In summary, the Range Transition Manager is a new product now available to solve the problem of automating the large antenna range. By arranging the RF components in a modular package, the RTM provides the benefits of reduced test time, improved test repeatability and increased range reliability while allowing easier configuration control and certification of the antenna range. The modular RTM design also provides flexibility in range configuration and allows for an organized approach to automation of future upgrades.

9. References

[1] E. S. Gillespie, “A History of Antenna Measurements”, AMTA Proceedings 1998, p.7, Montreal, Quebec, Canada, Oct 1998.

[2] D.S. Fooshe, D. Slater, “Digital Receiver Technology for High-Speed Near-field Antenna Measurements”, AMTA Proceedings 1999, p. 394, Monterey, CA, Oct 1999.

[3] J. Swanstrom, M. Flaherty, “Achieving Faster Measurement Throughput with a VXI-based Microwave Synthesizer”, AMTA Proceedings 1999, p. 406, Monterey, CA, Oct 1999.

[4] D. Lee, S. Mishra, “Automated Antenna Measurements in a Networked Environment”, AMTA Proceedings 1995, p. 64, Williamsburg, VA, Nov 1995.

[5] D. Slater, Near-field Antenna Measurements, p. 63, Artech House, Norwood, MA, 1991

10. Acknowledgements

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