Hand-held instruments aid shipboard RF measurements

Portable instruments can simplify RF and microwave measurements aboard Navy ships hindered by cramped quarters, high levels of stray RF energy and difficulty in reaching problem transmission lines.

By Steve Thomas

Of all the environments in which microwave measurements are made, those performed aboard Navy ships provide some of the most daunting challenges. In addition to the cramped quarters where many systems must be tested, the sheer volume and diversity of RF systems add measurement convenience to the list of key attributes that a measurement system must have. What's more, the potential number of interferers and high ambient levels of electromagnetic energy onboard ship require RF measurement systems to have the greatest possible resistance to EMI corruption. All of these challenges point to the increased use of portable, hand-held instruments that combine high performance, the ability to reach the most inaccessible areas and virtual immunity to high levels of RF energy.

RF measurements in Navy ships have always presented unique obstacles. Today's ships have a complex electromagnetic environment, populated by radar, electronic warfare, electronic countermeasures, communications and fire control systems. Each has specific test requirements that can require a large number of instruments dedicated to specific tasks, which makes a hand-held instrument that has multiple measurement capabilities attractive.

The situation is almost certainly to become even more complex in the future. This is because of the Navy's goal of producing an "all-electric" ship, the first of which will be its next generation of combat vessels (initially destroyers), collectively called DD/X. The new warships, which bear a striking resemblance to a futuristic concept rather than an actual vessel, are being designed to dramatically reduce and ultimately eliminate the various types of power systems employed throughout the Navy.

For example, the propulsion system will be driven by electric motors rather than diesel engines and will be integrated for the first time with all other shipboard components that require power, some of which are hydraulically or steam operated today. This means that electrical power, and potentially interference, will be everywhere. Even electrically discharged weapons may replace chemical-propellant-based guns.

Figure 1. Battery-powered test instruments such as Anritsu's Spectrum Master can make the same RF measurements as laboratory or production test equipment.

The final, and perhaps most formidable aspect from a test and measurement viewpoint, is the development of directed-energy weapons (DEW), either laser or microwave, that can disable electronic equipment by emitting intense pulses of energy. The RF energy from these weapons enters the target through antennas or wiring, power cables, poorly shielded frames and various types of cables.

These factors produce an environment where many instruments simply cannot function. As a result, hand-held instruments with high immunity to incursion of RF energy have become more and more popular in the Navy, driven by the need to make measurements at any time under any conditions.

Fortunately, the measurement process has become easier over the years with the maturation of hand-held, battery-operated instruments that have the high performance, interference resistance, and ease of use that are essential when working in close quarters. Nearly any type of measurement, from simple VSWR and insertion loss to detailed spectral analysis, can be performed without the need for constructing a "portable" test system comprising multiple large instruments. In addition, distance-to-fault measurement capability can precisely identify the location of a problem along the transmission line so it can be repaired before a disruption of system operation occurs.

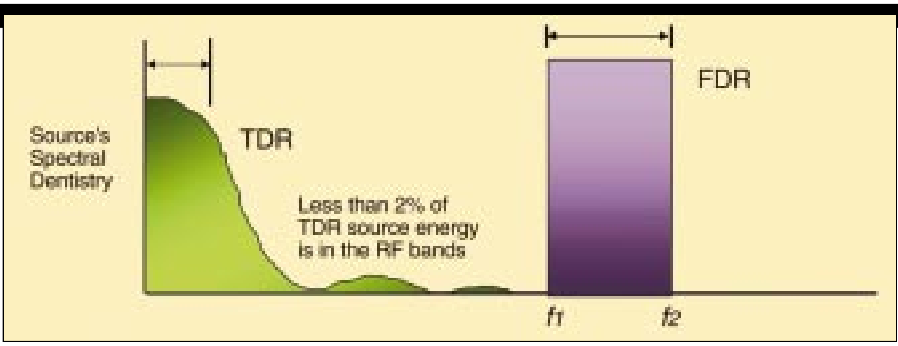

Figure 2. Frequency-domain reflectometry (FDR) more accurately locates an RF transmission-line fault than the older time-domain reflectometry (TDR).

Keeping track

Ships at sea face an array of hostile environments, including salt spray that can quickly corrode RF connectors, cables and antennas. In addition, cables aboard ship are routed through areas where they can inadvertently be damaged by almost limitless implements. Corrosion can cause connectors to form a dissimilar metal-to-metal contact. This "diode" causes passive intermodulation distortion and adjacent-channel power problems for digitally modulated signals. This is but one of many problems that can occur along the transmission path. Finally, even movement of the ship can affect the quality of connections over time.

The best way to prevent these conditions from reducing system performance or causing failures is through periodic inspection and tracking of performance trends. This task, which admittedly requires a disciplined routine carried out on a regular basis, can in many cases prevent failures by identifying disturbing trends.

Ideally, the first test should be performed when the ship is commissioned. Practically speaking, however, a reference point should be made when the transmission path is performing to its rated specifications. The measurements are recorded and stored on a PC where they can be compared to the results of subsequent measurements. Increased VSWR, reduced power output and the appearance of spurious signals can all be harbingers of incipient failure. And they can be dealt with before a significant reduction in performance has been observed.

Unlike the typical "static" base-station field service scenario, in which conditions change slowly with time (unless hastened by vandalism or lightning), RF conditions onboard ship can change rapidly and frequently. As a result, the intervals between preventive inspections on Navy ships should be shorter than those of their terrestrial counterparts.

The shipboard environment presents unique challenges for maintenance technicians that call for periodic inspection at regular intervals so complete system failures can be avoided. This will be even more important in coming years, as larger numbers and types of RF-based systems are deployed in next-generation ships.

Hand-held measurement equipment (Figure 1) makes this task considerably easier because it can be taken virtually anywhere on the ship and can make every required measurement. Such instruments store a large amount of measurement data, which can be downloaded to a notebook or other computer for analysis.

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Finding fault

The ability to find out where a problem is occurring along a transmission line, from the point at which it exits the transmitter or receiver to the antenna itself, is as mandatory as conducting RF measurements. Return loss measurements alone can measure the magnitude of signal reflections but cannot identify the precise location of a fault along the transmission path. Aboard ships, where coaxial cables can take circuitous paths to their termination point, pinpointing the exact location of a discontinuity is essential. This is made possible with two techniques: time-domain reflectometry (TDR) and frequency-domain reflectometry (FDR). While TDR was once employed for finding RF faults, its inherent characteristics make it best suited only for short cable runs at frequencies below about 200 MHz.

In contrast to TDR, which injects DC pulses, FDR sweeps a transmission path at RF frequencies that can be tailored to those of interest by the user, making it possible to identify frequency-selective characteristics. The spectral magnitude of TDR output pulses rolls off rapidly, so at high frequencies, less than 2% of its energy is distributed at RF frequency ranges (Figure 2). Its DC stimulus reflects little energy at RF faults, and almost all of its source energy is reflected by the antenna or any in-line, frequency-selective device. In RF transmission systems, these devices, such as combiners, filters or quarterwave lightning arrestors, are common.

With FDR, the instrument feeds a swept-frequency signal into the transmission line and an integral receiver measures the interference pattern generated when the swept RF source output signal adds and subtracts with reflected signals from faults and other reflective characteristics within the tested transmission line. The vector addition of the signals creates a ripple pattern vs. frequency, and a Fast Fourier transform (FFT) calculates the distance-to-fault. The number of ripples in the return loss (or power) vs. frequency display is directly proportional to the electrical distance to the reflective point on the transmission line. This electrical distance indication is inherently accurate and suffers no accuracy degradation due to TDR-type time base controls.

FDR is National Institute of Standards and Technology (NIST)-traceable and includes RF measurements such as insertion loss, gain and RF power, along with return loss and VSWR. Problems caused by corrosion, tiny connector pin gaps, and damaged

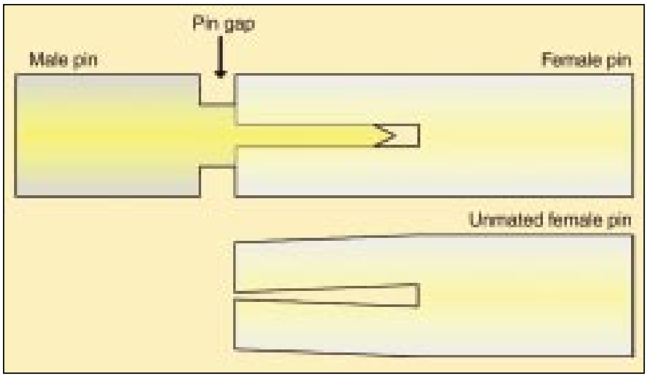

Figure 3. Corrosion on connector pins in a harsh shipboard application causes transmission line mismatches that can result in signal losses.

RF components are easily seen using FDR, which is also well suited to measurements that involve frequency-related problems such as small dimensional changes along the path of the RF conductor that show up as significant changes in characteristic impedance. FDR also compensates for the inherent insertion loss of RF cables, so it does not affect return loss measurement, making it easy to identify problems such as moisture collection or antennas damaged by lightning.

As corrosion occurs on connector pins, the diameter of the pin increases, the surface becomes rough and contact resistance increases (Figure 3). The mating of corroded connectors is, therefore, less than ideal because the female contacts are pushed farther out than they should be, creating a low impedance area immediately adjacent to the higher impedance area caused by the pin gap. This mismatch, coupled with increased loss due to high contact resistance, can greatly increase the loss through a corroded connector.

In short, FDR-based distance-to-fault techniques can detect minute problems. Problems such as vapor intrusion, loose connectors, antenna bandwidth drift, corroded conductors, or damaged lightning arrestors can be identified before severe damage or failure occurs so that corrective action can be taken.

Immunity to interference

As previously noted, interference is a given on board a Navy ship. The hand-held instruments in use for shipboard RF measurements have been designed to reject even high levels of interference through the use of AC detection or auto-zeroing, along with phase-tracking vector receivers and spread-spectrum techniques. Over the years, the resistance of these instruments to high-level electromagnetic fields has grown stronger. In addition, they can tolerate input signals as high as +43 dBm (20 W) without damage and can provide high levels of resistance to co-channel interference.

Range of measurements

Early portable RF measurement equipment was basically formed from “bench-bound” instruments pressed into service in the field. To make a wide range of measurements, almost all of the contents of the bench top had to be hauled along, connected by a maze of coaxial (and sometimes waveguide and semi-rigid) transmission lines, set up, and calibrated.

Fortunately, this is no longer the case, thanks in part to advances in semiconductor, signal processing, display, and computer technology. Today, virtually every RF measurement that can be conducted in a lab or in production can be made with similar levels of accuracy by small, battery-operated equipment. These instruments have been continually enhanced as technology allows and are at least as valuable onboard ship as they are in their original application: measurements at cell phone tower sites.

The most fundamental measurements performed by these instruments are those for return loss (VSWR) and insertion loss, both of which can be easily performed over a range of frequencies. The results of the measurement are displayed on an LCD, and as many as 200 measurement traces can be stored within the instrument. Vector-corrected calibration is performed electronically with integral software, which reduces a once formidable task to simplicity. In addition to basic measurements, the instruments can be configured with an additional port to perform isolation, gain and insertion loss measurements when duplexed antennas must be verified. Measuring the isolation of antennas during the regular maintenance schedule makes it possible to identify changes in antenna position that can affect radiation pattern and overall performance. This measurement also can be used to determine the transmit and receive isolation of duplexers and filters.

The latest hand-held spectrum analyzers bring the capabilities of benchtop instruments to the field as well. In addition to typical spectrum analysis functions, they can measure carrier-to-interference and adjacent-channel power ratio, perform interference analysis and calculate occupied bandwidth. They can also perform amplifier transmission response. Features typical of bench-top instruments are also present, including display of multiple traces, markers, and connectivity via USB or RS-232C ports. Most measurement tasks are handled by presets to reduce the amount of setup and measurement time.

Once data has been captured, Windows-based software is available that can make it much easier to spot deteriorating conditions and perform various types of analysis on a PC. For example, the results of regular distance-to-fault measurements can be displayed simultaneously, which allows them to be directly compared. DE

ABOUT THE AUTHOR

Steve Thomas is a product manager at Anritsu Company in Morgan Hill, Calif. He has been involved in various aspects of RF and microwave test equipment and measurement for more than 30 years. He is licensed as an amateur radio operator under call sign N6ST and has been active since 1962.