Test Methodology for RF Phase Matched Cables

White Paper

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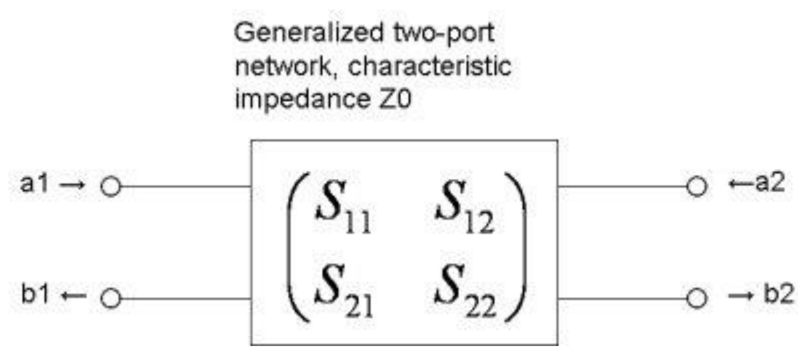
Introduction – This white paper describes a modern test approach to defining the full electrical characteristics of a wideband RF Cable as found in certain N-Channel DF SIGINT sensor systems. These systems are found in multiple Army platforms; i.e. GRCS, ARL, EMARSS. All information and concepts described herein are considered proprietary to Dragoon ITCN.

Requirement- Phased matched RF Coaxial cables play an important part in the realization of modern ISR airborne sensors. In addition to n-channel SIGINT sensors, radars increasingly employ 2 to 3 channels of receivers that require phase-matched cables. In the process of flight testing and fielding these platforms, it has been the experience of this author that detailed characterization of the complex impedance for an aircraft-installed RF coax is highly useful and can result in significant system cost reduction if properly executed. A test fixture that can measure and record very precise complex impedance (attenuation and phase angle over a frequency range) with a graphical representation of VSWR (Smith chart) that can be imprinted on a cable tag with date – would be a highly desirable entry to a Table of Allocation or Standard Test Equipment list that is used to maintain the ISR PME.

Methodology and Technical Approach – This type of complex measurement is typically conducted through the acquisition of vector-error corrected data. In a laboratory, a vector network analyzer would be utilized to collect sets of complex, frequency-dependent parameters commonly called S-Parameters. In the laboratory, there are four sets of Scatter Parameters that can be collected based on the two connection ports of the instrument. In terms of S-Parameters we notate S_{11} representing the reflection of forward energy on Port 1 ($S_{1\_}$) and the measurement of reflected energy on Port 1 ($S_{\_1}$). In the same vein forward energy transmission is notated as S_{12} where energy is transmitted on Port 1 ($S_{1\_}$) and measured on Port 2 ($S_{\_2}$). Typically, cables are measured using the insertion technique whereby the two cable ends are "inserted" between the two ports and an S_{12} measurement performed. This will provide a measurement of power loss over the cable as well as phase shift.



While easily performed in a lab environment, this technique is difficult to perform "at-platform" on the aircraft. The reason for this difficulty is that both ends of the cable under test need to be connected to the same test instrument. With the cables installed on the aircraft it is almost physically impossible to connect both ends to a common instrument. Therefore we propose that instead of using the insertion technique, a more viable approach for obtaining the same information is the reflection technique. The reflection technique uses the S11 measurement to fully characterize the RF cable.

The S_{11} measurement "at-platform" has its own unique set of challenges. Since only one end of the cable is connected to the instrument, the other end must be deliberately mismatched during a series of measurements to provide complex, multi-term equations which can be solved for the measurement parameters of interest. For this S_{11} measurement, the opposite end of the cable under test will be deliberately mismatched by shorting the cable or leaving it as an open circuit. These two mismatches provide two different phase relationships of the reflected signal on the cable. In addition, a measurement with a "perfect" load is performed where no energy is reflected back to the instrument. So to perform the phase measurement on the cables embedded on the aircraft a maintainer would be required to connect one end of the cable to the diagnostic instrument and when prompted, connect an adapter representing an open, then one representing a short and finally one representing a load to the opposite end of the cable under test.

Another challenge in doing "at-platform" diagnostics utilizing S-Parameter measurements is the level of knowledge and training required by the maintainer. As outlined above, the measurement required for each cable is a multi-step process of which careful metrological technique is required to obtain reliable, repeatable results. For this reason, a cable analyzer that automates the process and provides prompts to the maintainer is proposed. In addition, the open, short, load components can be encapsulated into a common module, controlled by the instrument which negates the need for the maintainer to connect multiple test adapters to the cable, reduces chances for operator error during the measurement and finally removes a potential FOD (Foreign Object Debris) source from the flight line.

Finally, the complexity of modern ISR sensors means that the "at-platform" problem encapsulates more than just the cables of interests. These cables are typically connected to antennas which form part of the circuit path of the ISR system. Providing complex measurements of just the cables may not provide a complete or desirable picture of system performance. If it is desirable to leave the antennas connected to the cables during testing, the problem of mis-matching the end of the cable becomes more challenging. Depending on the type of antennas it may be possible to provide test "hats" or fixtures that fit over the aircraft antennas that replace the open, short, load cable terminations. In this manner the instrument would be measuring the power and phase attributes of both the cables and antennas as a subsystem.

As a result an "at-platform" test set could be used to measure multiple cables and antenna sets on an ISR aircraft. In addition to the phase information, VSWR/return loss and cable loss would also be derived that indicates the performance health of the cable and antenna components. This test set will be fully automated to minimize the effort and knowledge required for the maintainer. It will also store measurement results for use in calibration of the ISR platform and maintenance history for the platform and components.

It is the assertion of this paper that by combining the following functional modules in a novel configuration, the resulting test tool can not only fault isolate RF coax cables to extremely accurate degrees, but also provide key complex impedance data for *non-faulty* cables that will serve well the multiple Army platforms that employ phase-matched RF coaxial networks within their sensor systems.

Wideband RF Module	1. Generates stimulus signal and measure response
	2. Creates S-Bridge RF signal path (couplers/isolators)
Controller Card	1. Automates the test with user interface SW
	2. Calibration SW and Firmware to normalize test fixture effects

The desire to encompass the RF cable with the antennas will require further investigation and analysis based on the specific antenna type. Conceptually, a "hat" approach is feasible, but integration of this feature into the test tool will demand a study as befitting a Phase 1 SBIR .

Summary – DragoonITCN is uniquely qualified to fabricate and manufacture the test equipment described herein. Our BCIT product (developed on an AF SBIR) is found worldwide and has an NSN. In cooperation with the RF experts at Pallas Systems, we believe that a practical RF Coax Test Set can be realized in prototype form before EMARSS Milestone C in July 2014. This white paper describes the methodology proposed and attempts to convey the comfort level we have with the technology.