Shielding Effectiveness Automated Monitoring System (SEAMS)

SARA SEAMS Transmit and Receive Chassis with Optional Antennas (HF-SA-6L)

Exceptional Performance from the Leader in HEMP Protection

SARA

ABOUT MIL-STD-188-125-1/2 HARDNESS SURVEILLANCE AND SARA

Scientific Applications and Research Associates, Inc. (SARA) offers a Shielding Effectiveness Monitoring System (SEAMS) designed to provide remote automatic or commanded MIL-STD-188-125-1/2 compliant shielding effectiveness measurements to assess the status and possible degradation of a shield over long periods of time.

Critical military, government, and civilian assets – particularly critical communications, are often required to be High Altitude Electromagnetic Pulse (HEMP) survivable. Assessment of low-risk, high-confidence HEMP survivability, based on testing, documentation of hardening, and inspections are described in MIL-STD-188-125-1/2, Appendix A. The MIL-STD outlines the performance requirements of a HEMP-protection subsystem by specifying the allowable leakage of external fields through the shield and penetrations, called the Shielding Effectiveness (SE). In addition, periodic testing must be conducted to ensure that the protection remains adequate, called Hardness Surveillance. MIL-STD-188-125-1, hardened systems also are normally equipped with a Shielding Effectiveness Leak Detection System (SELDS), which can monitor SE but may not fulfill all of the requirements of Appendix A SE measurements. These systems are intended to provide detection of either faults or degradation to the shield through regularly scheduled hardness surveillance measurements. SARA has developed the Shielding Effectiveness Automated Measurement System (SEAMS) to provide a fully automated surveillance system which fulfills all of the measurement requirements of Appendix A SE measurements. SEAMS is capable of nearly continuous monitoring of a shielded enclosure and can operate automatically or in a commanded mode to report those measurements in an easy-to-interpret chronologically stamped data format over a standard IP network infrastructure.

All SEAMS units include a 1 year limited warranty, operations manuals, and optional on-site training at customer facilities. All SEAMS systems are fabricated in Colorado Springs, CO.

SEAMS Overview

Theory of Operation

The SEAM System is comprised of two major systems: the transmit (TX) system and the receive (RX) system. The TX and the RX systems combine to perform a radiative insertion loss measurement of the shielded enclosure, as described in MIL-STD-188-125-1/2. The TX system is designed to reside inside the shielded enclosure and produce a frequency hopping non-modulated transmit RF signal that is monitored by the RX system outside the shield. The TX unit is placed inside the shield to preclude the need for any federal frequency authorization to use the system. The TX levels are low and not expected to cause interference on other devices inside the shielded enclosure. This can be verified with the specific system installation so that the lower TX power does limit the margin to the required 80 dB of SE recommended by MIL-STD-188-125-1/2. Several levels of transmit power are available and can be tailored to fit customer requirements for limited exposure of equipment. These two units (RX and TX systems) form a functionally complete SEAMS system when paired with antennas. The SEAMS system is capable of working with most antennas. Larger antennas provide greater sensitivity allowing lower TX radiated power. The SARA developed antennas, HF-SA-6L and HF-SA-17L, are capable of meeting the MIL-STD-188-125-1/2 measurement requirements for SE in most ambient EM environments. The 6L antenna is low profile, measuring only 6” x 1” and the 17L is 17” x 2 ¾”. The installation requirements greatly affect the choice of antenna and the gain performance is dependent on the antenna choice.

The SEAMS hardware and the 6” antennas are shown in Figure 1 on the next page.

Figure 1. SEAMS TX/RX (Top Right and Left), HF-SA-6L (Bottom)

The TX and RX systems require 1 - 2 U of space within a standard (19" or 23") rack, depending on the testing specifications and the number of antennas (1-5 antennas are typically employed for a cabinet type installation). Both systems can be powered with -48 VDC inputs or standard 120 VAC while consuming 170 W for the TX unit and 100 W for the RX unit. The power requirements can be tailored to customer requirements. The primary internal components of SEAMS are the spectrum analyzer, tracking generator, and local control PC. The local control PC operates on Linux CentOS 7 or Windows 7 and commands the various components in the system including the tracking generator, spectrum analyzer, and relays to switch antenna positions. The tracking generator (TG) drives the internal systems antenna (through a 100 mW 30 dB amplifier). The external signal strength is monitored at the same frequency as the transmit system by a spectrum analyzer (SA). The difference between the in-situ measured external RF signal and the calibration signal (previously recorded) provides a measurement of the effectiveness of the shield (expressed as a ratio in dB). A block diagram of the systems constituent components and operating configuration can be seen in the following image.

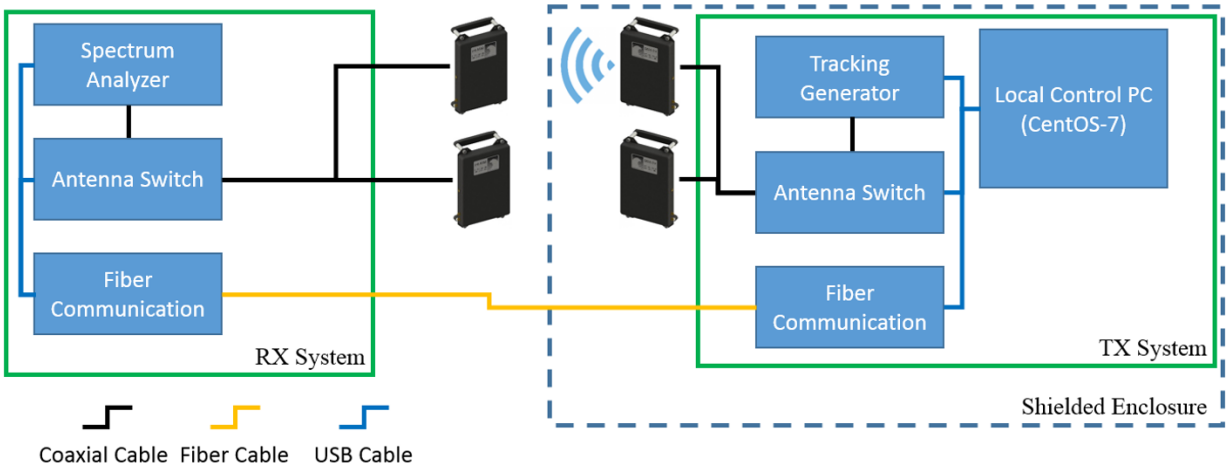

Figure 2. SEAMS Block Diagram

SEAMS is intended to work with an independent "host control/scheduling" computer. The host control computer runs the SEAMS Measurement and Reporting Software (MaRS) whose primary function is to schedule measurement sweeps, and report data and status information from a network deployment of SEAM systems. MaRS is designed to run on any Windows 10 computer with limited hardware requirements. MaRS can manage more than 300 independent SEAM systems displaying status of the systems and cabinets as well as providing historical reports of the cabinet's SE metrics from an easy to use GUI. The following block diagram depicts a fully operational deployment of SEAMS systems including external antennas and a host control PC running MaRS.

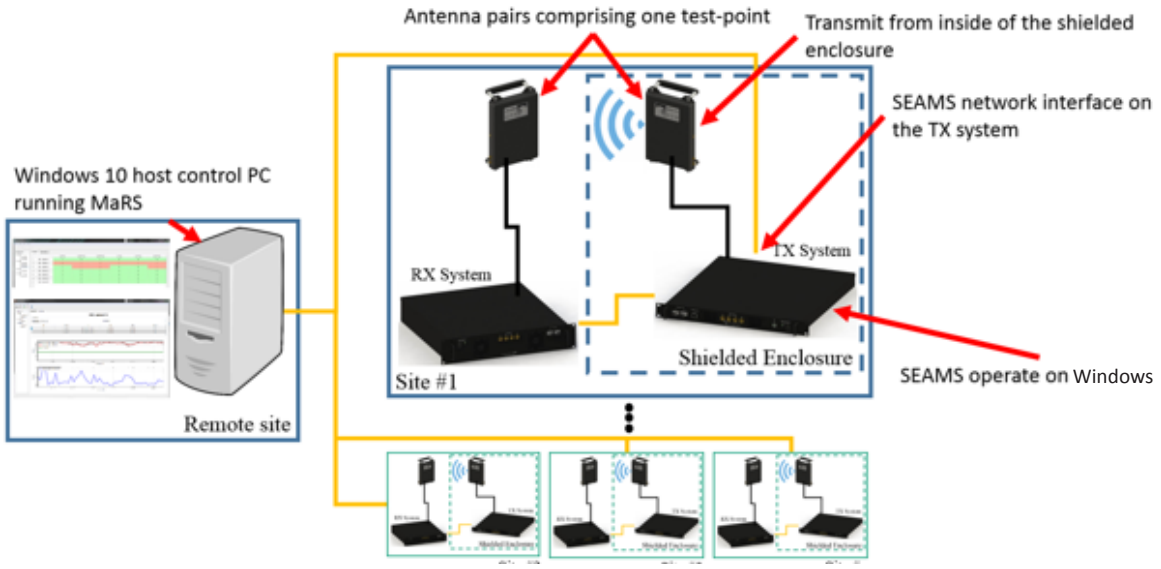

Figure 3. Block Diagram of Typical SEAMS Deployment

SEAMS Features

SEAMS is a highly configurable SELDS that can be tailored to meet almost any need. The system can be configured in size and was designed to operate in a standard 23" telcom network cabinet. However, the system can also fit a standard 19" server cabinet or can be configured to operate as an "on the shelf" system. SEAMS was designed to operate off -48 VDC but can be configured to operate at 120 VAC. Depending on the RF noise environment a larger amplifier can be installed. A single SEAMS system can measure up to 24 antenna pairs, allowing for a variety of SE measurement configurations, from a cabinet with 2-5 antennas to a room with 24 antennas. Obviously, the number of antennas the system is asked to support greatly affects size and power consumption. A table listing the prominent features can be found below.

Autonomous Operation	Once the system is configured, the system can be set to gather data independent of user interaction. The data can be reviewed at a later time.
Remote Operation	The system can be operated remotely via gigabit Ethernet.
Selectable Frequency Range and Number of Points	The frequency range and number of points are selectable by the user.
Upgradeable Internal Storage	The PC based system operates on the latest PCI based solid state drives and is configurable by the user.
Highly Configurable	Antenna configurations (up to 12 pairs). RF Output Power Size Power Supply.

Figure 4. Table of Primary Features

SEAMS can support manifold optional features that expand the system's base functionality. The additional optional features include physical security hardness upgrades, out-of-the-box STIG compliance, and a multitude of external hardware monitors. In addition to the current list of optional features, SEAMS is has multiple internal I/O's that can be configured, at the time of order, to suit the customer's needs.

The physical security hardness upgrades include tamper prevention and tamper indicators. To prevent tampering, the systems are fully sealed and riveted so that it is impossible to access the internal components – such as USB ports or network ports – without drilling the rivets and damaging the case. Additionally, any USB or network port that is not actively communicating is disabled; for example, when the PC is not currently communicating with spectrum analyzer, the comm port for the SA is disabled by the master PC. Also, if the master PC does not detect the proper devices on the proper comm ports, the master PC disables all comm ports and notifies the user. A list of the current available additional features can be found in the table below.

Physical Security Harding	Tamper indicators and tamper protection
Out-of-the-box STIG Compliance	The system can be configured with STIG parameters provided by the customer during fabrication
MOV Fuse Monitoring	The ability to detect a failure of a series fuse with an MOV on the input filer of the cabinet
Door Open Interrupt TX switch	The ability to disable the system immediately upon the shielded cabinet door opening during a test and report to the user
External Manual Button for Test Pause / Resume	The RX system can be outfitted with a button to pause / resume any testing in progress
Multiple System Health Diagnostics	Full bandwidth (10kHz-1GHz) RF over fiber sweep of amplifiers and switches. Narrow band "canary antenna" TX / RX basic operability check
Front Panel Display	Interface on the TX system to display system statistics and diagnostic data
Configurable Peripheral Hardware Monitors	250VAC / 30VDC / 10A dry-contacts or 0-3.3V 10 bit ADC input to the system can be configured to the user's requirements during fabrication

Figure 5. Table of Ancillary Features

Performance Example – HF-SA-6L / 100 mW TX Amp

The ability for any SELD system to detect a fault in a shielded enclosure is ultimately limited by dynamic range. Dynamic range is defined as the maximum signal a system can detect vs. the smallest detectible signal in an environment free of non-system introduced RF noise. In real world applications the dynamic range of a system is rarely the limiting factor in detectability of faults, usually it is limited by the surrounding ambient noise such as radio stations and other high power, high frequency noise sources. A common measurement that does include the surrounding noise environments is labeled measurement range. The measurement range of a system is defined as the maximum signal that can be received vs. the smallest signal including the ambient signal in the surrounding environment. Measurement range is a realized number that changes depending on the surrounding environment. While SEAMS has a high dynamic range of 140 dB, it is important to demonstrate that the SEAM system can detect faults in a shielded enclosure in real world scenarios.

In order to demonstrate SEAMS ability to detect faults in the real world environment, two faults were simulated on an empty RF shielded enclosure: the Wire Through WaveGuide (WTWG) and the finger stock fault. The WTWG is a 10 gauge wire placed in the waveguide with 1" out on each end (the green wire in the bottom left figure). The finger stock fault is a 2" long slip of paper between the finger stock of the door and frame (white paper in the bottom right figure on the next page).

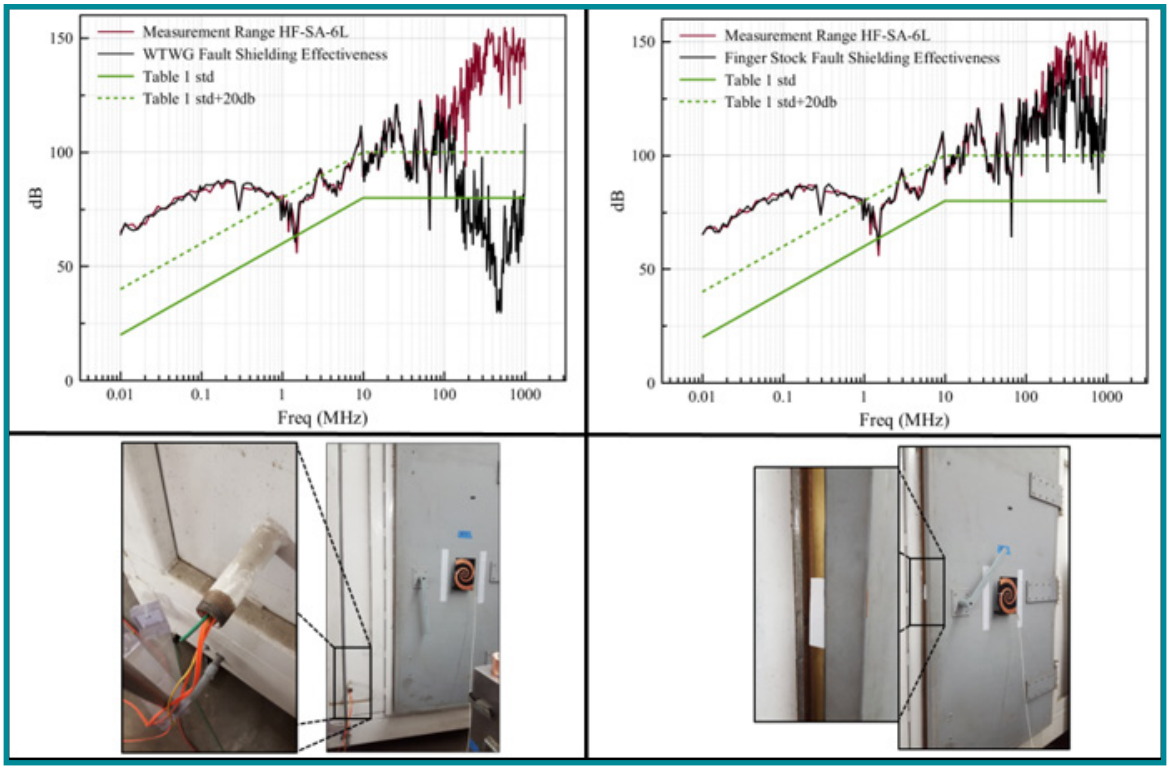

Figure 6. Detectability of SEAMS and HF-SA-6L with 100 mW amplifier (Left: simulated WTWG fault / Right: simulated finger stock fault)

The figures above demonstrate the fault detectability of SEAMS in a real world environment (high RF noise background). SEAMS, in the scenario above, was configured with a 100 mW of transmit power (the lowest power offering) and the un-shielded version of the system. This example also used the smaller, SARA developed 6" antenna (HF-SA-6L); the HF-SA-17L has a greater gain response and is also an option in the SEAMS. When combining the 1W TX amplifier, the advanced shielding, and the HF-SA-17L, the system offers increased measurement capability.

SEAMS was able to detect a deviation from the measurement range in both cases. The WTWG shielding effectiveness (top left figure, black trace) showed deviation from the measurement range starting at 100 MHz and dropped as low as 30 dB. The finger stock fault shows the shielding effectiveness (top right figure, black trace) deviate from the measurement range at 10 MHz and drops to 100 dB. The example demonstrates the ability of the system to detect large and small faults in non-ideal circumstances.

SEAMS Dynamic Range

When the system is coupled with 1W TX amplifier, the advanced shielding, and the HF-SA-17L in the same noise environment as the previous example, the system is capable of producing the DR and MR as shown in the following plot.

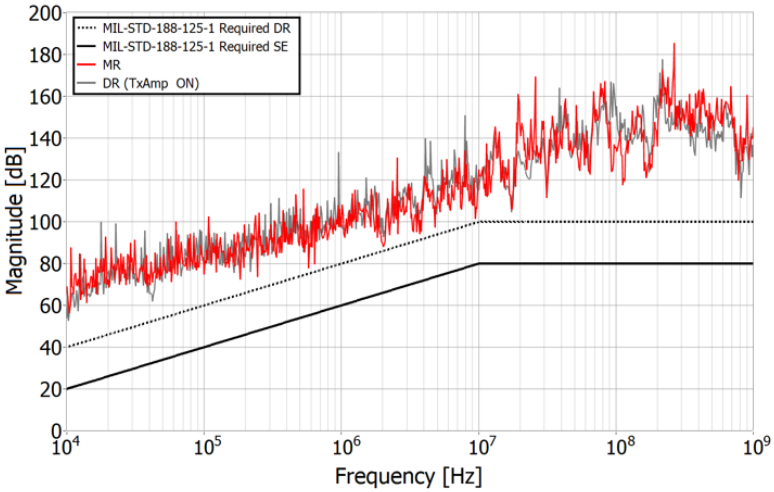

Figure 7. Dynamic Range of SEAMS with a HF-SA-17L, 1W TX Power Amplifier, and Advanced Shielding.

SEAMS Specifications	
*Dimensions (TX System)	19” 1RU Rack Mount
*Dimensions (RX System)	19” 2RU Rack mount
Weight (TX System)	~ 13.5 lbs
Weight (RX System)	~ 12 lbs
Operating Temperature	00C – 700C
Power Consumption (TX System)	170 W
Power Consumption (RX System)	100 W
*Operating Voltage (Both Systems)	48 VDC / – 48VDC / 120VAC
**Compliance	MIL-STD-188-125-1/2
Dynamic Range (10 Hz RBW / 100 MHz)	-140 dB
Frequency Range	10 Hz – 4.4 GHz
Step Size	10 Hz – 10 MHz
Sweep Time	~150 ms/point
*Transmit Amplitude Range	-10 dBm to 20 dBm
*Standard TX Power	100 mW
*Max Antenna Pairs	24
Calibration Interval	1 Year
*Operating System	Windows 7 / Windows 10
*Standard RAM	4 GB
*Standard Storage	500 GB
CPU	Intel Celeron
*Network Connectivity	Gigabit Ethernet / Gigabit Fiber
*Configurable Parameters **Compliant in the 1W TX Amplifier + Extra Shielding Edition	

Figure 8. SEAMS Specification Table

SEAMS / Antennas Standard Models	
Model	Features
Base	Supports 4 Antenna Pairs 100 mW TX Power
Advanced	Supports 4 Antenna Pairs 1 W TX Power Advanced System Shielding
HF-SA-6L	Compact Magnet Mounting Available
HF-SA-17L	Improved Frequency Response Mounting Stands Available
Only supports standard antenna sweeps, no additional features included	Quantity price breaks available. All system are built to order. The specific price varies depending on COTS components availability / pricing.

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