A Low-cost Method for Shielded Enclosure Integrity Monitoring

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INTRODUCTION

After a new enclosure or room is installed, a certification is performed to the applicable standard. After the certification team departs, the responsibility for monitoring the integrity of that enclosure falls squarely on the purchaser. This is a key responsibility, because as the installed base of shielded enclosures and rooms ages, the problem of ensuring their integrity grows.

Even if a service contract for periodic verification is in place, older rooms may develop leaks between integrity checks. How many technicians and engineers have become frustrated attempting to track down an errant signal that was not really being generated, but resulted because a room was leaking? Still, with the expense and bulk of the test equipment required to verify integrity, most users have to be satisfied with periodic checks and regular maintenance intervals.

Full certification test sets that can be used to guarantee shield integrity to MIL-STD-285 or NSA-65-6 cost in excess of $100,000 by the time the required antennas, amplifiers, signal generators and spectrum analyzers have been purchased. Even if this equipment is already on hand, clearing the room to set up the antennas inside and out and expending the time required to make the measurements causes the cost to mount quite rapidly.

A less expensive alternative is to make a single frequency measurement periodically after the room is certified. If the measured data is recorded, the room's degradation can be monitored and maintenance can be performed before any important data is lost or compromised. Until recently, even making single frequency measurements was prohibitively cumbersome.

One approach to monitoring shielded enclosure integrity is to take periodic single frequency measurements.

MEASUREMENT APPROACH

For a single frequency measurement, the equipment mentioned earlier is required. Since the equipment does not need to be as broadband, the cost is reduced and the setup time is minimized. The frequency chosen for the measurement should be high enough that antenna size remains reasonable. If the measuring frequency selected is 10 MHz, the antennas will be bulky and electrically inefficient. Choosing a very high frequency, such as 10 GHz, requires more expensive amplifiers and directional antennas that must be relocated to illuminate individual walls within the enclosure. Some reasonable middle ground must be chosen.

The most effective frequencies for manageable antenna sizes are in the 300 to 1000 MHz range. At these frequencies, quarter-wave vertical antennas range in length from 25 cm at 300 MHz to 7.5 cm at 1 GHz. Any frequency in this range will work well.

The next consideration is the availability of antennas and power amplifiers. Since the system is to be low-cost, commercial band equipment is selected.

Antennas and power amplifiers are available for the land mobile bands at 450 MHz and at 900 MHz. If one must choose between these two equally desirable bands, the one that allows the maximum utility of the end-result equipment should be selected. To provide the most information about room integrity at the lowest manpower expense, the equipment should be portable, preferably handheld. The more portable the antenna, the more thorough the check can be. Unless there is an overriding reason to use 450 MHz, the 900 MHz antennas can provide comparable performance with increased portability. Another distinct advantage of 900 MHz is that the shorter wavelengths allow leaks to be pinpointed with greater precision.

Although directional antennas such as the yagi-uda array or the log periodic array provide additional gain, they must be maneuvered between measurements to illuminate the desired wall, but they are also bulky and difficult to set up for repeatable measurements. The antenna of choice would be a free space dipole, but this antenna must be separated from the other components to reduce distortion of the antenna's radiation pattern. If the whole system is to be compact, the antenna should be a quarter-wave dipole with a ground plane, under which the equipment can be mounted.

Modular amplifiers are avail-

*See Advertisement on Page 243.

able from numerous companies with excellent performance in the 900 MHz band. Amplifiers are available in this band with continuous power ratings to 300 watts. The amount of power required depends upon numerous factors.

The transmitter also needs a very stable signal source. The source should maintain a constant amplitude during the course of the measurement procedures and should stay within the passband of the detector's bandpass filter and final intermediate frequency (IF) filter. Several manufacturers market this kind of equipment. A synthesized signal source is preferred to enable the technician to perform single frequency measurements at multiple frequencies in the same band. This frequency agility also aids the technician in avoiding other strong signals in the 900 MHz band that might interfere with the measurement.

The same antenna that was chosen for the transmit side of the test setup can be used on the receive side. A bandpass filter and preamplifier should also be used to improve measurement sensitivity. The filter will keep other signals in the environment from causing intermodulation interference at the detector. The low-noise preamplifier will overcome the noise floor of the detector and allow a greater shielding effectiveness measurement without increasing the transmit power.

The only other component of this setup is the linear detector. For the measurement to be accurate, this detector should be as selective as possible of the transmitted signal without being so narrow as to require continual realignment. For most applications, a moderately priced spectrum analyzer is the best choice. Spectrum analyzers from major manufacturers can make relative signal measurements that are accurate to within 0.5 dB, which is more than adequate. The only other alternative is a narrowband superheterodyne receiver that is tuned for the specific transmit frequency. This receiver must maintain its detector linearity over a large signal level range and the accuracy of the detector must be carefully controlled. For the data to be most useful, a numeric readout should be available.

Based on the considerations noted above, the block diagram of a proposed measurement system is shown in Figure 1. A simple RF substitution measurement technique will be used for measuring shielding effectiveness. In a typical measurement scenario, the signal is generated outside the enclosure to provide enhanced detector performance, although the transmitting equipment can just as easily be placed inside the enclosure, if security or environmental issues dictate. The signal generator and amplifier generate a signal at a known constant frequency and amplitude. The attenuator is inserted before the antenna, which is situated in front of the room or enclosure and away from large objects that might distort the pattern. In a similar manner, the receive antenna is placed in the center of the room with a clear signal path to the transmit antenna. The detected signal level is measured and recorded. The fixed attenuator at the transmitting antenna is removed and the room or enclosure is sealed. The operator in the room notes and records the new detected power level. With these two pieces of recorded data, the room's shielding performance, or "perf," at that specific frequency can be determined from the following relationship:

$$\text{perf (dB)} = \text{Measurement 1} - \text{Measurement 2} + \text{Attenuation}$$

All values are in dB. "Measurement 1" is the value measured with the enclosure unsealed and "Measurement 2" is the value measured with the room sealed.

The amount of transmit power available and the performance of the filter/preamplifier/detector determine the limits of the measurable performance. Using a modicum of reasonably priced equipment,* measurements in excess of 100 dB of shielding effectiveness can be made with antennas placed up to 2 meters apart. As the antennas are placed further apart (when a larger room is

This example uses a +30 dBm output power into a -3 dBi transmit antenna. The receive antenna is also -3 dBi. The receive bandpass filter has 1 dB of loss. The preamplifier has 30 dB gain with a 3 dB noise figure. The detection bandwidth used at the spectrum analyzer/detector is 20 kHz. Antenna separation is 2 meters.

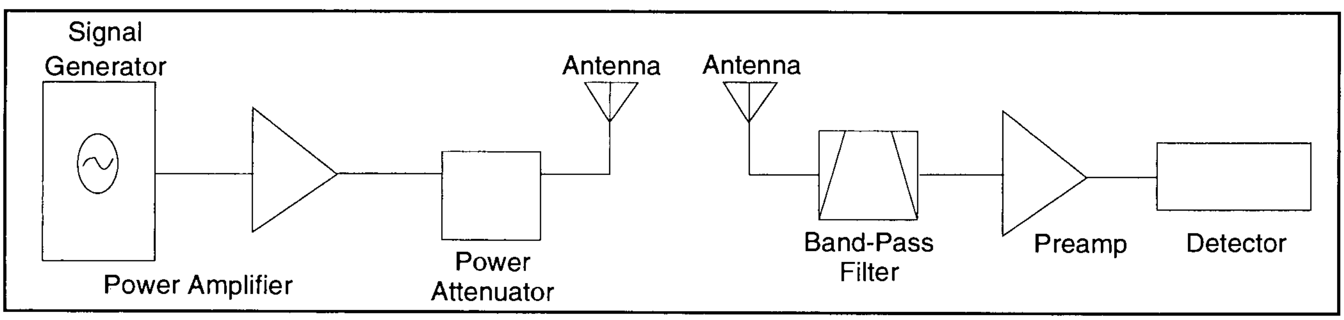

Figure 1. *Single Frequency Test Setup.*

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the safety standards for telecom equipment intended to be connected to the network, and which has an operating voltage-to-ground that does not exceed 200 Vp and 300 Vpp as set by Article 800 of the National Electrical Code. The important thing to be aware of regarding UL 1459 is that there must be some type of current limiting device, which is recommended not to exceed the equivalent of a 1.25-A slow blow fuse.

Bellcore 1089 is similar to but more rigorous than a combination of UL 1459 and FCC Part 68 in that it consists of a power cross test comparable to UL 1459, and a lightning immunity test comparable to FCC Part 68. A standard for telecom equipment being sold to the Regional Bell Operating Companies, Bellcore 1089 is mandated by the customer, not the government.

CONCLUSION

The design engineer has many choices when protecting electronic equipment. In order to narrow the search, the engineer should first determine what is to be accomplished. If quality and performance at an effective price are most important, then thyristors should be considered. If high surge current capabilities (greater than 500 A) are required, then a MOV or gas discharge tube might be most suitable. And finally, if a low voltage solution is necessary (8 V or less) then the avalanche diode will probably be the best choice.

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being measured), the maximum level that can be measured will decrease. Due to increased path loss, the received signal will decrease in amplitude by a factor of 20 dB per decade of antenna separation change; i.e., increasing the separation of the antennas from 2 meters to 20 meters will reduce the maximum shielding measurement level from 100 dB to 80 dB.

Using this portable test setup with the transmitter inside the enclosure allows the operator to localize leaking joint strips, door seals, and electrical/signal penetrations. Since the 900 MHz antennas are small, they can be used on the end of a piece of coaxial cable while monitoring the detected signal level.

CONCLUSION

The importance of frequently measuring shield integrity has often been overshadowed by the cost of these measurements. This article has attempted to demonstrate that an effective figure of merit can be obtained cheaply and effectively. While not all enclosure owners are prepared to support the required components of a do-it-yourself system, an economical commercial solution is available. It should also be noted that these spot measurements are not a substitute for recertification.

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