A New Apparatus for Detecting Flaws of a Seam in a Shielded Enclosure

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Abstract

A prototype flaw detector was designed and constructed, with results showing the apparatus’ promising applicability in detecting flaws of a seam in a shielded enclosure without exciting the seam from the opposite side. The apparatus provides a convenient means to check a seam formed between two contact surfaces of metallic conductors from dc to over 1 GHz. The apparatus can be designed so that it can be used on various types of seams. The prototype flaw detector is designed to be used on a flat or bivelvel surface, but a fairly simple design change will allow the apparatus to be used on seams at a curved surface or at a right angle. Preliminary test results on the performance of the flaw detector is presented.

Introduction

Shielding Effectiveness Test Procedures

Current state of the art in detecting flaws of a seam of a shielded enclosure involves measuring the shielding effectiveness, using an antenna to illuminate a seam and its vicinity under test, and using a probe or an antenna to detect the leaked energy at the opposite side. A few widely accepted standards that use this type of technique are MIL-STD-285 [1], NSA NO. 65-6 (U) [2], and MIL-STD-907B [3]. One major deficiency associated with this measurement technique is that all seams and walls have to be accessible from both sides for testing; therefore, inaccessible areas are largely ignored or exempt from the testing. And this measurement technique has other problems. First, the technique is being used to verify proper installation of the shield; however, it is not really appropriate for checking shield integrity or detecting flaws of a seam for the following reasons: (1) the receiving antenna not only captures the field that has leaked through the area being tested, but it also captures fields leaked through other seams, including fields reflected off the surrounding walls, ceiling, and floor that have reached the receiving antenna; and (2) a comprehensive test plan needs to be developed and carefully executed to avoid uncertainties in measurement caused by resonances, antiresonances, standing wave, and antenna misalignment, as well as impedance change between calibration measurement and attenuation measurement. Second, it takes two to three people to conduct this very time consuming test. Third, some concern has been expressed about the hazards of the high level of radiation. Fourth, communication between technicians—who are separated by a metallic wall—is difficult since the entire shielded enclosure must be completely fabricated before the test and any entries or apertures must be closed. Finally, since a shielded enclosure is not transparent to human eye, one must mark the test points to align the antennas, which leaves room for error through misalignment.

Transfer Impedance

Electromagnetic energy can penetrate into a shielded enclosure through various coupling mechanisms: diffusion through the shield wall, electric and magnetic field coupling through an aperture, or through a flaw in the shield construction. But in today’s high quality shielded enclosure, the main focus is on electromagnetic energy coupling through flaws in a shield, such as a seam with a damaged gasket or a hairline crack. Schelkunoff [4] and other researchers have analyzed the penetration of electromagnetic energy and the performance of a shielded enclosure and have shown that the coupling mechanism can be represented by transfer impedance. Madle [5] designed a fixture to measure gasketed panel assembly transfer impedance. The fixture has been used extensively over the years by design engineers who require parameters such as contact pressure, mechanical rigidity, and spacing of panel joints. The transfer impedance can be defined as

$$Z_t = \frac{V_{in}}{J_y} \text{ Ω-m},$$

where $J_y$ is the induced surface current density on exterior of a shielded enclosure and $V_{in}$ is the induced voltage inside the shielded enclosure across the seam from points C to D as shown in figure 1. An incident electromagnetic field induces surface currents that travel across a seam from points A to B. A voltage $V_{out}$ will be developed across the seam between points A and B and is essentially the same as $V_{in}$ across the seam from points C to D. It means that the induced voltage can be measured on either side of the enclosure.

Design of the Apparatus

The prototype flaw detector shown in figures 2 and 3 induces currents on the surface of a conducting sheet when connected to an oscillator and built-in electrodes detect voltage developed across a seam. The extrusion at the center of the apparatus and a very thin dielectric material between them provide a high impedance path to the
return currents, forcing the surface currents to flow on the surface of the metallic sheet containing the seam under test. One end of the twisted pair is soldered to small electrodes that are mounted on the bottom of the dielectric rods and the other end is connected to a coaxial connector. To test a seam, the apparatus needs to be placed over the seam such that the dielectric material is parallel with the seam and placed just above the seam. Next, a continuous wave signal source is connected to the input connector using a coaxial cable and a termination resistor is connected to the output connector. The electrode output is connected to a detector. The apparatus can be moved along a seam continuously for a given frequency to detect flaws along the seam by monitoring detector output. To isolate the detector, a unity gain amplifier having high input impedance can be used if the input impedance of the detector is not much higher than that of the seam under test.

An equivalent lumped circuit diagram of the apparatus (when placed over a highly conducting sheet containing a seam) is shown in figure 4. The left side of the figure is the sinusoidal voltage source \( V_i \) and source impedance \( Z_i \); \( Z_e \) represents the equivalent impedance provided by the apparatus. \( R_t \) is the termination resistance. \( Z_z \) represents the equivalent impedance of a seam and a portion of the conducting sheet enclosed by the apparatus. To excite a seam properly, one must ensure that enough currents will flow across the seam by adjusting the capacitance, a predominant factor in \( Z_e \) provided by the apparatus. The capacitance can be adjusted by using a dielectric material with a different dielectric constant and by changing the contact surface area between the extrusion and the dielectric material. A simple analysis shows that matching the impedance of the apparatus to a signal source impedance appears difficult to achieve; moreover, preliminary measurements suggest it is not very important. The prototype apparatus' characteristic impedance is about 110 Ω when the apparatus is placed over a good conducting plate. Thus, the design parameters of the apparatus are fairly easy to obtain for a given range of frequency. It is highly desirable to place a thin dielectric sheet over the area being tested or over the bottom portion of the apparatus where the apparatus touches the metallic surface, so that direct resistive contact between the apparatus and the metallic surface does not occur. It is anticipated that the apparatus can be used well beyond 1 GHz (perhaps to tens of gigahertz), but a miniature apparatus should be used for frequencies beyond 1 GHz.

**Test Results**

Preliminary tests were conducted using two pieces of 1.6-mm-thick copper plate as a sample seam and the results are shown in figure 5. Graph 1 was measured by placing the apparatus over a seam having approximately a 0.08-mm gap. Graph 2 was measured over a seam formed by overlapping the two copper plates about 1 cm and placing about 2.3 kg weight over the apparatus. Graph 3 was obtained by placing the apparatus over a plate having no seam.

**Conclusion**

Preliminary test results show promising applicability of the apparatus in detecting the flaws of a seam. However, more work is needed to refine the design of the apparatus.

**References**

[1] MIL-STD-285, “Attenuation Measurements for Enclosures, Electromagnetic Shielding, for Electronic Test Purposes, Method of,” August 1956.

[2] NSA NO. 65-6, “National Security Agency Specification for RF Shielded Enclosures for Communications Equipment (U),” October 1964.

[3] MIL-STD-907B, “Military Standard Engineering and Design Criteria for Shelters, Expandable and Non-Expandable,” September 1985.

[4] S. Schelkunoff, “Electromagnetic Waves,” D. Van Nostrand Co., Inc., January 1943.

[5] P. J. Madle, “Transfer Impedance and Transfer Admittance Measurements on Gasketed Panel Assemblies, and Honeycomb Air-Vent Assemblies,” 1976 IEEE Intl. Symp. Electromagnetic Compatibility, 1976.