Zero Ground®

EXPANDED FREQUENCY

ELECTROMAGNETIC INTERFERENCE (EMI)

SHIELDING EFFECTIVENESS (SE) TESTING

This White Paper presents an excerpt of results from testing performed in the frequency range of 10KHz – 18GHz.

Products tested are multiple versions of Zero Ground dBzSHIELD® Shielded Flexible Conduits, a COTS product, vs. Unshielded Flexible liquid tight conduit.

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Zero Ground
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dBz SHIELD

INTRODUCTION: FAQ's

Q. *How is Zero Ground dBzSHIELD used?*
A. Signal and power cables are run through dBzSHIELD as a supplemental shield where EMI, RFI and other type of E3 are a concern. dBzSHIELD is used to isolate signal or power cables from influencing or being influenced by other components or systems.

Q. *What is the presently published shielding effectiveness test range for dBzSHIELD?*
A. 1MHz – 1GHz

Q. *Why did Zero Ground conduct this testing to the expanded range of 10KHz – 18GHz?*
A. Zero Ground's COTS product line of dBzSHIELD Shielded Flexible Metallic Liquidtight Conduit has gained broad acceptance across government and defense programs. With an installed base in both fixed and mobile defense programs, Zero Ground dBzSHIELD is the preferred alternative where Mil Spec is not required. Customer interest in utilizing dBzSHIELD for applications where the targeted frequency is lower or higher than 1MHz – 1GHz prompted Zero Ground to conduct this expanded frequency testing. Now this key specifying information is available to those with interference concerns in the expanded frequency range.

Q. *What is significant regarding the expanded test frequency range?*
A. dBzSHIELD test results at 10GHz and 18GHz reported here are the highest frequencies available to design engineers when considering a COTS shielded flexible conduit. Test data for COTS shielded flexible conduit below 1MHz has not been previously available to engineers addressing low frequency interference problems. Perhaps the reason is that this lower frequency testing is challenging to conduct. To the best of our knowledge, the frequency range of 10KHz – 18GHz covers most applications where Mil Spec conduits have historically been used.

Q. How can these test results be compared to Mil Spec requirements for shielded conduits?
A. Zero Ground dBzSHIELD is a COTS product, and was not designed to meet a Mil specification. The metallic core, 2nd shielding layer (90% tinned copper braid) and protective outer jacket construction of dBzSHIELD are similar to the design and materials used in Mil spec conduits. Test methods used for dBzSHIELD expanded

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frequency testing are described in sections 3.0 through 3.2.5 below. dBzSHIELD is an alternative to Mil spec conduit, where Mil spec is not specified.

Q. Can dBzSHIELD be terminated with Mil connectors?
A. Yes, Zero Ground can provide customized adaptors to quickly and securely terminate dBzSHIELD to most round back shell Mil connectors.

Q. How is dBzSHIELD typically terminated?
A. Typical termination is to a COTS standard metallic liquid tight conduit fitting. These fittings drain the shield to ground on both ends, and terminate to a bulkhead or enclosure. The fittings can be assembled quickly with no special tools. Numerous manufacturers can provide high quality, cost-effective fittings.

1.0 OBJECTIVE:

The following report compares the Shielding Effectiveness (SE) of SBS, IBC & BBS shielded flexible conduit from Zero Ground to unshielded flexible conduit. The resulting data can be used to select the appropriate type of conduit to be used for a shielded application.

2.0 DESCRIPTION of DEVICES UNDER TEST:

SBS®: Flexible Shielded Steel Conduit with Tinned Copper Braid and PVC Outer Jacket, SBS 0.500 from Zero Ground used.
IBC®: Flexible Shielded Bronze Conduit with PVC Outer Jacket, IBC 0.500 from Zero Ground used.
BBS®: Flexible Shielded Bronze Conduit with Tinned Copper Braid and PVC Outer Jacket, BBS 0.500 from Zero Ground used.
Unshielded Flex Conduit: Flexible Steel conduit with PVC Outer Jacket, 1/2" Trade size used.

Each test item was cut 48" long, bent as required to fit test fixture, and has appropriate 1/2" connectors on their ends. The flex conduits used T&B metallic liquid tight flexible conduit fittings with conductive caulk. (Used to improve conductivity between the fitting and the flex conduit)

3.0 TEST PROCEDURE:

3.1 Test Equipment

The following test equipment was used to perform the testing:

- Spectrum Analyzer: Hewlett Packard Model HP8562A/B
- Spectrum Analyzer: Hewlett Packard Model E4407B
- Signal Generator: Hewlett Packard Model HP200CD
- Signal Generator: Hewlett Packard Model HP8672A
- Signal Generator: Hewlett Packard Model HP606B
- Power Amplifier: Amplifier Research 40A12
- Power Amplifier: Hughs 1177H04F000
- Power Amplifier: Hughs 8010H15F000
- Magnetic Loop Antennas
- Tuned Dipole Antennas
- Microwave Horn Antennas

3.2 Equipment Set-Up for Shielding Effectiveness Tests

3.2.1 DEFINITION

Shielding Effectiveness (SE) is the ratio of E_1/E_2, where $E_{1,}$ is the voltage induced into the receiving antenna at a specified distance from a transmitting antenna without shielding and E_2 is the voltage induced at the same distance from the transmitting antenna with shielding placed between the two antennas. SE is generally expressed in "dB" (decibel), where SE can be determined by subtracting the shielded measurement from the unshielded measurement.

3.2.2 MAGNETIC FIELD TEST PROCEDURE:

The magnetic field tests were performed using resonant loop antennas. 10 kHz uses a 24" transmit and an 18" receive loop antenna. 150 kHz & 10 MHz use 12" loop transmit & receive antennas. The antennas were co-planar (perpendicular to the shield surface being tested) with a 24" separation (edge to edge of the antennas). The reference (up-calibration) is through the open, unshielded 2' x 2' test window. This results in a reference level different than would be obtained with an open field test which helps compensate for the effects of the shield room on the testing.

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Since the test fixture plate is much less than 1" thick, its thickness is discounted, the transmit and receive loop antennas are then placed 12" from the test plate. For the reference measurement, the antennas are centered on the test window. For the device measurement, the transmit antenna is moved 12" from the test panel and directly in front of the right hand conduit penetration. The receive antenna is moved about the immediate area opposite the transmit antenna to determine the maximum signal level. This maximum value is recorded as the inside measurement.

3.2.3 ELECTRIC FIELD TEST PROCEDURE:

For electric field testing, both the transmitting and receiving antennas are located 41 inch rod antennas for both transmitting and receiving. The antennas were separated by 26 inches for the reference test distance. The reference signal level (without shield in lace) was measured and recorded for the particular frequency under test. The receiving antenna was then taken inside the RF shielded test enclosure and positioned next to the shielded conduit for the test. The transmit antenna was positioned outside the enclosure 12 inches from the test panel and directly in front of the conduit penetrations. The 256 inch antenna test distance was reestablished. The receive antenna we then moved about the immediate area opposite site transmit antenna to determine the maximum signal level. The maximum signal level found was then recorded as the inside measurement.

3.2.4 PLANE WAVE FIELD TEST PRODEDURE:

The plane wave field tests were performed using tuned dipole or horn antennas for both transmit and receive based on the test frequency. The dipole antennas were oriented parallel to the shield surface being tested. The up-calibration measurement was obtained with the transmit and receive antennas separated by 74". The transmit antenna is positioned 72" from the test fixture plane and the receive antenna 2" from the shield plane centered in the test window. Since the test fixture plate is much less than 1" it is treated as zero for this test. The measured signal level from the receive antenna is recorded as the inside measurement.

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3.2.5 DEVICE UNDER TEST SET-UP:

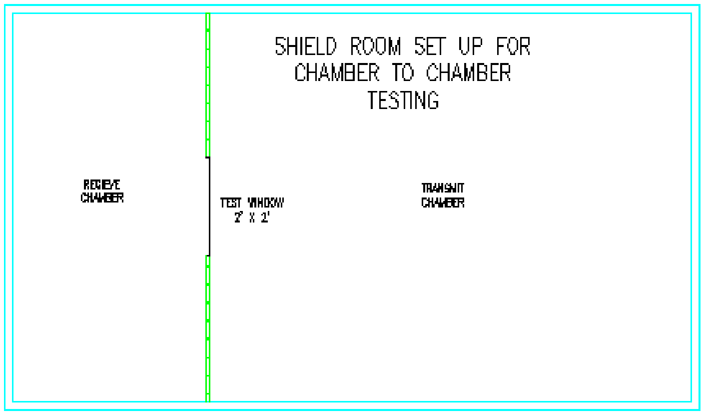

Figure 1: Test Layout, Dual Chamber Shield Room

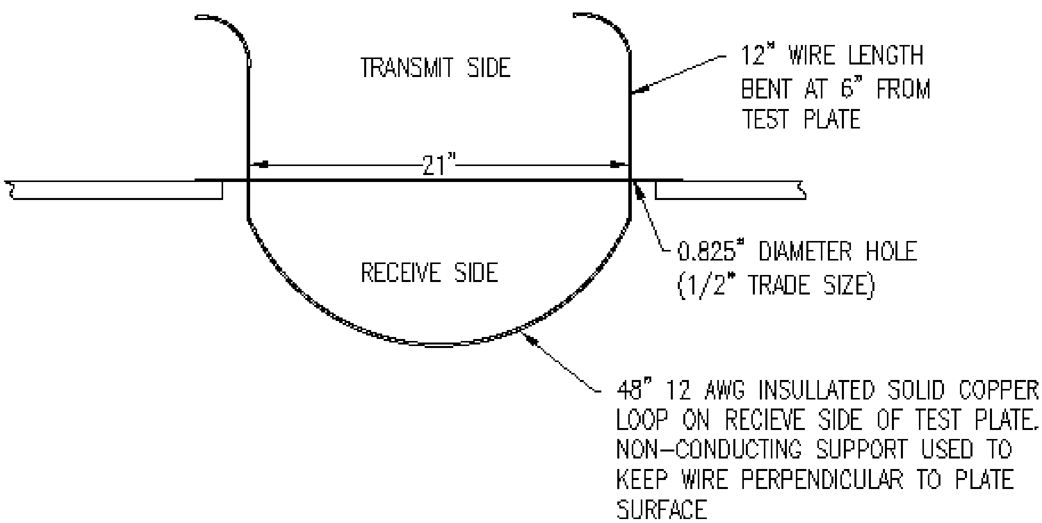

Figure 2: Unshielded Wire Test Setup

3.2.5.1 MAGNETIC FIELD TESTS

For magnetic field testing, both the transmitting and receiving antennas are located 12' from the test located opposite a test plate penetration for the initial reading. This measurement is most influenced by connector leakage. The conduit SE is taken from the highest reading taken away from the test plate penetrations.

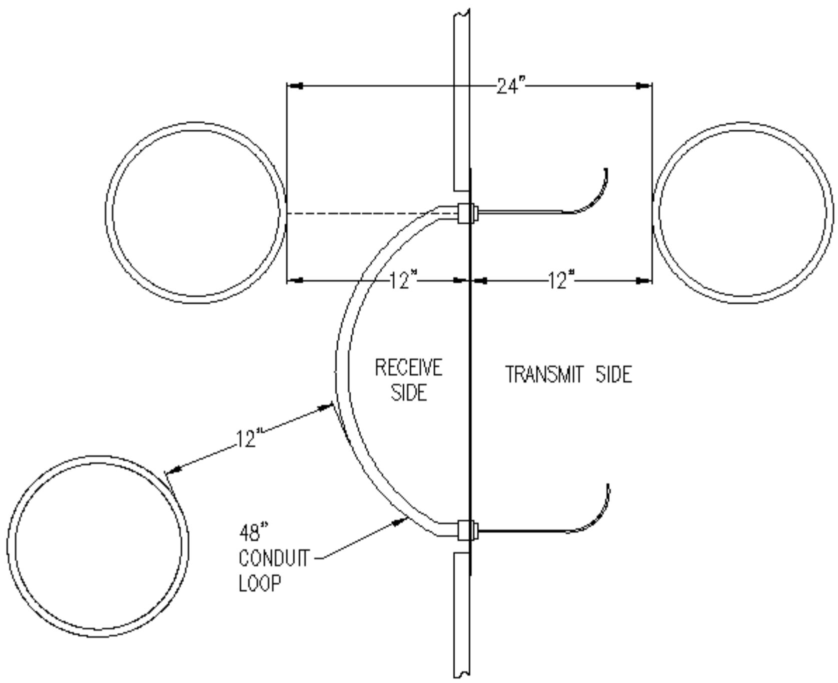

Figure 3: Magnetic Field Test Setup

3.2.5.2 PLANE WAVE FIELD TESTS

For plane wave testing, the transmit antenna is located 72" from the test plate and the receive antenna located 2" from the conduit or wire under test. The receive antenna is at a tangent to the test item. Close to the plate penetration, the measured RF level is highly influenced by any leakage at the penetration. The highest reading distant from the penetration is taken as the shielded measurement.

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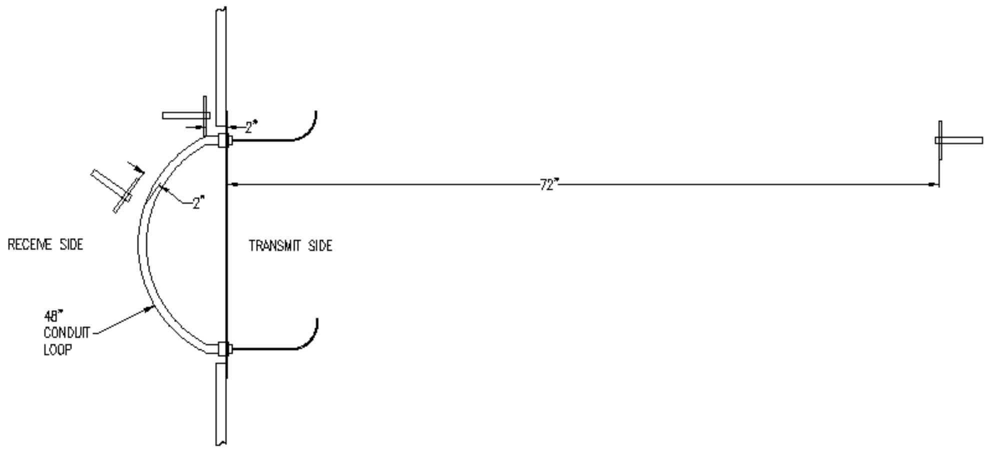

Figure 4: Plane Wave Field Test Setup

3.2.6 FREQUENCIES TESTED:

10 kHz Magnetic
150 kHz Magnetic
1 MHz Electric
10 MHz Electric
100 MHz Plane Wave
450 MHz Plane Wave
1 GHz Plane Wave
5 GHz Plane Wave
10 GHz Plane Wave
18 GHz Plane Wave

All testing was performed based on IEEE 299-2006 (replaced MIL-STD-285) and on ASTM E 1851-04. No known published standard is designed to test this type of shielded device.

4.0 TEST RESULTS

Frequency

CONDUIT TYPE	10 kHz M	150 kHz M	1 MHz E	10 MHz E	100 MHz PW	450 MHz PW	1 GHz PW	10 GHz PW	18 GHz PW
SBS w T&B	67	79	126	98	75	76	66	66	85
IBC w T&B	73	88	126	123	131	99	98	70	88
BBS w T&B	73	92	127	130	136	116	118	74	98
Unshielded Steel w T&B	63	67	110	80	55	65	50	65	82

Attenuation (db)

Figure 1: Test Results Table

<u>Key to Test Method as indicated below Frequency</u>
M = Magnetic Field Test
E = Electric Field Test
PW = Plane Wave Field Test

Readings in light blue columns indicates expanded frequency results

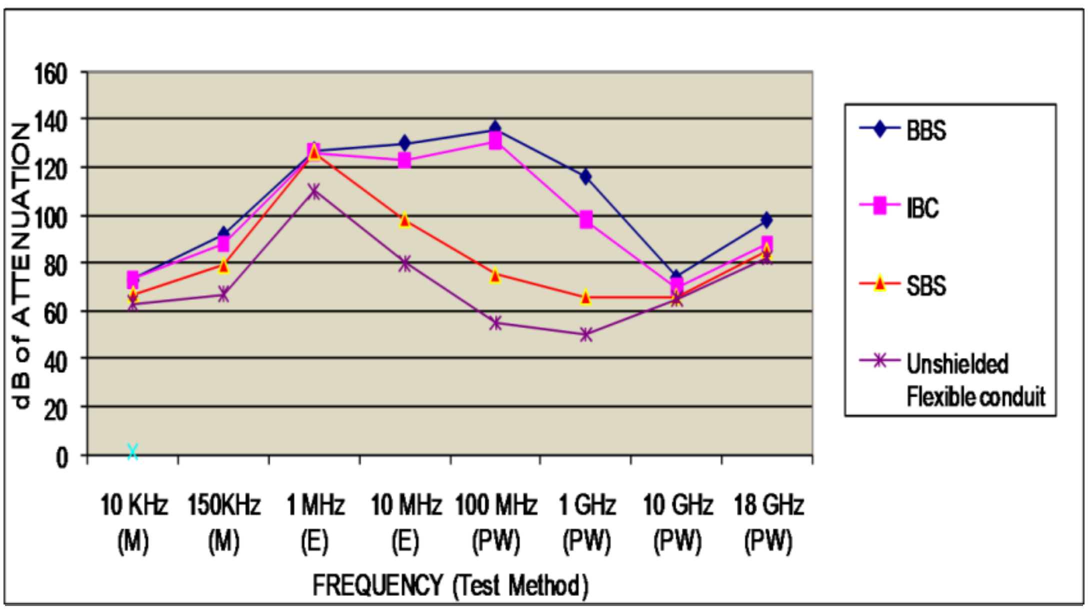

Figure 2: Graph Comparing SE for Multiple Conduit Types

BBS: Interlocked Bronze Core, Tinned Copper Braid and Extruded Jacket
IBC: Interlocked Bronze Core and Extruded Jacket
SBS: Interlocked Steel Core, Tinned Copper Braid and Extruded Jacket
Unshielded Flexible conduit: Interlocked Steel Core and Extruded Jacket

5.0 CONCLUSIONS:

All of the shielded conduits provide a significantly better SE than an unshielded conduit. Inclusion of data below 1MHz and above 1GHz, along with test procedure identification per frequency, allows for more thorough evaluation of anticipated performance of dBzSHIELD Shielded Flexible Conduits in comparison with another shielding method.

Zero Ground will continue to evaluate the need for additional expansion of its tested frequencies for dBzSHIELD shielding effectiveness, and we welcome suggestions from customers regarding specific frequencies of interest.

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