

MAGNETIC FIELD SHIELDING EFFECTIVENESS OF MAGNAFLEX CONDUIT IN EXTERNAL DIRECT CURRENT MAGNETIC FIELDS

by

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ABSTRACT

This paper addresses the subject of the shielding effectiveness of flexible metal conduit when it is subjected to external dc fields. External dc fields have been known to cause a reduction in the shielding effectiveness of flexible conduit. It is the intent of this paper to provide insight into this effect.

INTRODUCTION

Highly permeable, flexible shielding conduit is used in many shipboard cable installations to reduce the likelihood of electromagnetic interference (EMI). Flexible conduit is utilized to shield lower level systems from ambient magnetic fields. Due to the flexibility of this conduit, cableways can be more easily relocated to avoid strong areas of magnetic fields. In the absence of such shielding, EMI could occur in shipboard electronic systems as a result of inductive coupling of ambient magnetic fields to system cables.

Technical Information regarding the application of shielding conduit in wireway design can be found in the "Handbook of Electromagnetic Shielding Practices," NAVSEA S9407-AB-HBK-010.

The principal effect of magnetic saturation in ferromagnetic materials is a decrease (lowering) of the conduit's magnetic permeability, which results in reduced (poorer) shielding performance.

Previous measurements (reference [1]) have shown that the relative permeability of flexible conduit begins to decrease due to saturation effects at approximately 0.6 Gauss.

This paper presents the results of tests conducted on flexible shielding conduits that were exposed to a dc magnetic field. The shielding effectiveness data, which are provided in this paper, are a measure of the conduit's anticipated shielding performance in the stated test environment.

THEORY

The shielding effectiveness of flexible conduit has been tested and is known over the very low frequency (VLF) range. Knowledge of the shielding properties of conduit is vital when attempting to design an electromagnetic compatible environment.

One of the major factors of shielding effectiveness is absorption loss. The equation for absorption loss is shown as:

$$A = 8.69 \left(\frac{t}{\delta} \right) \quad (1)$$

where t = material thickness and δ = the materials skin depth.

The skin depth is calculated as shown:

$$\delta = \frac{2.6}{\sqrt{f\mu_r\sigma_r}} \text{ in} \quad (2)$$

where μ_r = relative magnetic permeability, σ_r = relative conductivity, and f = frequency.

From equations (1) & (2) the expression for absorption loss can be expressed as:

$$A = 3.34t\sqrt{f\mu_r\sigma_r} \quad (3)$$

Equation (3) shows that shielding effectiveness is related to the relative magnetic permeability of a material. The permeability of a ferromagnetic material is affected by dc magnetic fields. When magnetic saturation occurs the flux density of a material remains constant even when the applied magnetic field (H) is increased. When magnetic fields are increased without corresponding increase in flux density (B), the permeability of the material is reduced and approaches air value. As a materials permeability decreases, its shielding effectiveness is similarly affected.

TEST PROCEDURE

AC TESTING (30 Hz to 30 kHz)

The driver for the Helmholtz coil system (figure 1) was provided by a tracking signal generator from an HP-3585A spectrum analyzer that was fed to a McIntosh Corp. power amplifier. Alternating current (ac) magnetic fields inside the conduit were measured for both longitudinal and transverse orientations of the coil/driver system.

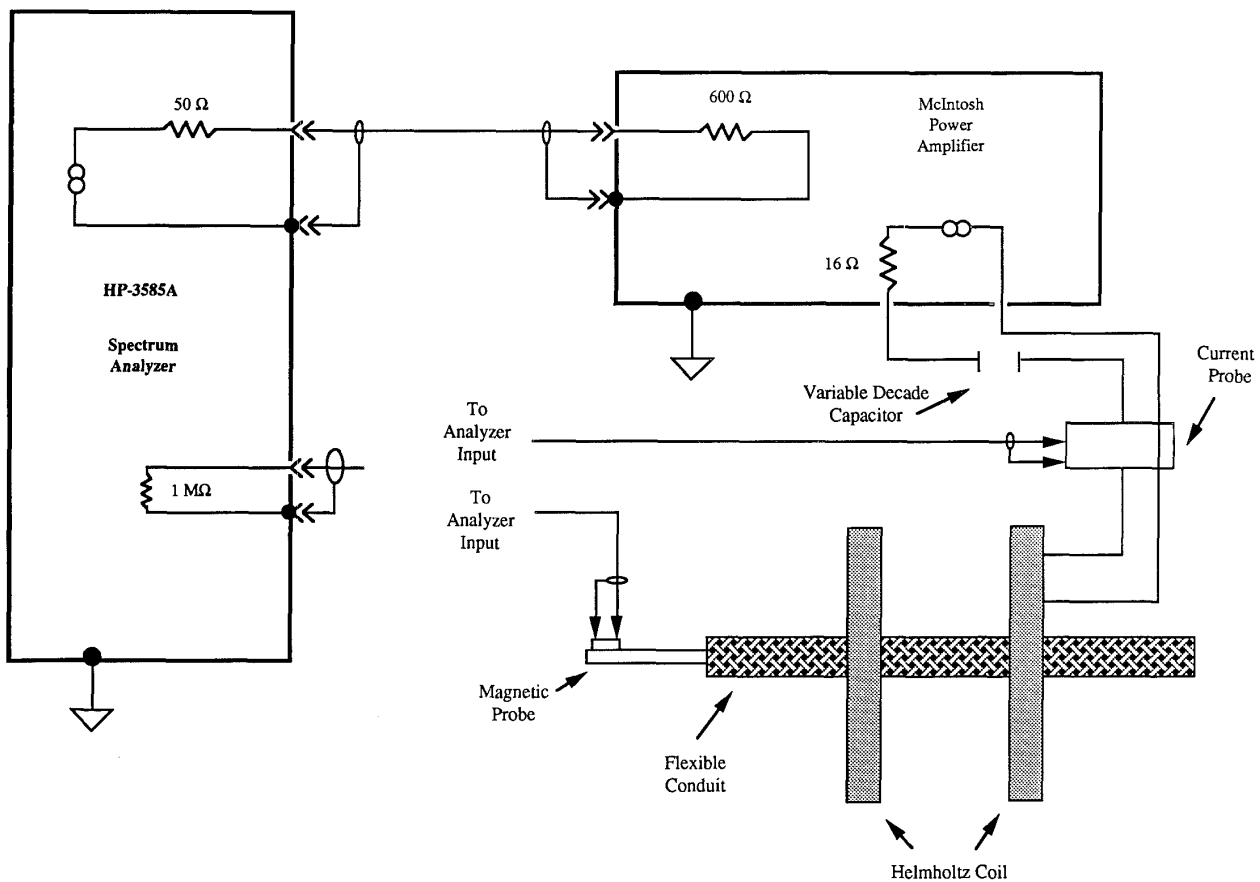


Figure 1: Flexible Conduit Shielding Effectiveness Test Setup

The driven Helmholtz coil exhibits a high inductive reactance at frequencies above 10 kHz. In order to compensate for this, a decade capacitor (figure 1) was placed in series with the coil windings. For frequencies below 10 kHz, the capacitor was not required and was shorted by connecting a wire jumper across the terminals of the capacitor decade box. Capacitor values for frequencies ranging from 10 kHz to 30 kHz are listed in table 1.

FREQUENCY	CAPACITANCE
10 kHz	0.15 μ f
20 kHz	0.02 μ f
30 kHz	0.01 μ f

Table 1. Test Capacitance Values

The output impedance of the amplifier was set at 4Ω from 30 Hz to 1 kHz. To improve the matching impedance of the Helmholtz coil to the power amplifier, the output impedance taps were changed at the higher frequencies (as shown in table 2). The settings in table two were required in order to more efficiently drive the Helmholtz coil because of higher coil impedance with the high frequency drive conditions.

FREQUENCY	IMPEDANCE
2 kHz	8 Ω
4 kHz	50 Ω
10 kHz - 30 kHz	64 Ω

Table 2. Output Impedance Values

The field inside the Helmholtz coil was initially measured with a probe in both the transverse and longitudinal orientations. Provision was made in the test setup for the magnetic field orientation to be varied from a direction parallel to the conduit axis (longitudinal shielding effectiveness) or perpendicular to the axis (transverse shielding effectiveness). The probe was then placed inside the test sample of flexible conduit and the magnetic field inside the conduit was measured. From these measurements the shielding effectiveness of the conduit could be determined.

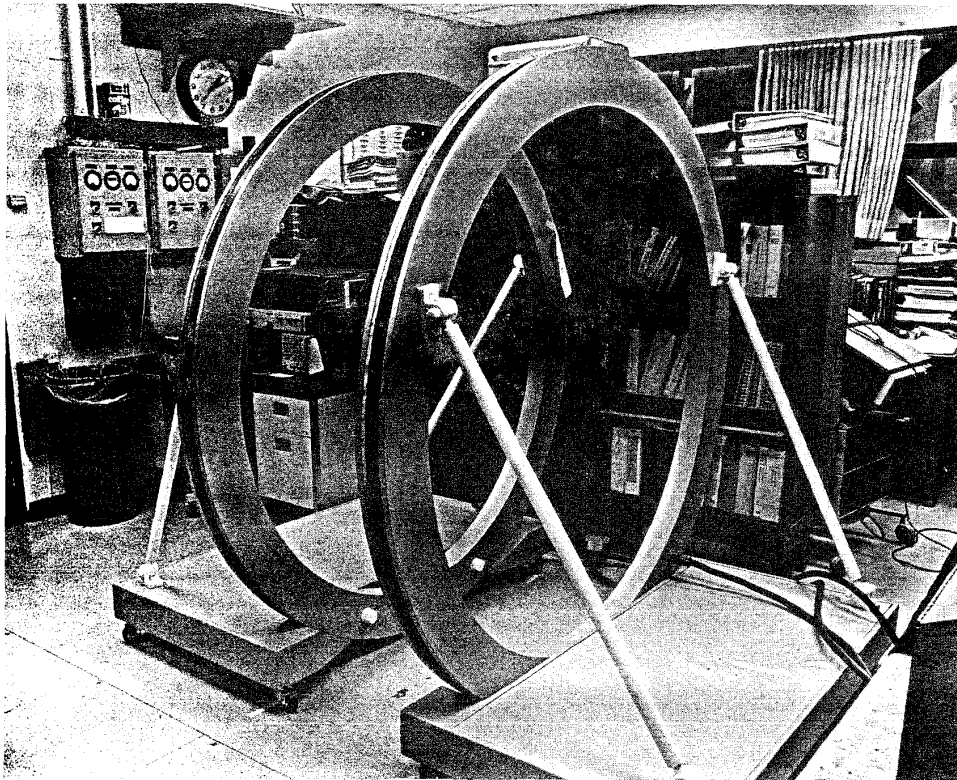


FIGURE 2: 6-ft Diameter Helmholtz Coil

DC TESTING (0 G to 20 G)

For the dc tests, the Helmholtz coils of the ac shielding effectiveness test set up were placed inside a larger coil fixture. This 6-ft diameter fixture (figure 2), with a coil ratio of 1 Gauss per 1.08 amperes (reference [2]) was used to generate a dc magnetic field of 1, 3, 5, 10, 15, and 20 G. The larger coils were driven with an HP-6434B laboratory dc power supply. The ac shielding effectiveness test was repeated at each level of dc field applied. This test measured the degradation of ac shielding effectiveness when subjected to dc fields.

RESULTS

From the initial measurements taken it was apparent that very little degradation in shielding effectiveness occurred when a transverse dc field was applied to the ac test setup. However when a longitudinal dc field was applied to the ac test set up considerable degradation of the shielding effectiveness occurred. Results of conduit samples tested are shown in figures 3 and 4. This data shows that in the longitudinal field, losses in shielding effectiveness of as much as 40 dB occurs. In the transverse field losses in shielding effectiveness was as much as 15 dB. In the case of both the longitudinal and transverse fields the loss in ac shielding effectiveness was directly proportional to the strength of the dc field applied.

ANALYSIS OF RESULTS

Based on the test results reported in this document, the reduced shielding performance of flexible conduit that occurs in an external dc magnetic field is significant enough to warrant users of NAVSEA HBK S9407-AB-HBK-010 (010 Handbook.) to be aware of these changes when implementing the 010 Handbook.

The user of the 010 Handbook should be reminded that the susceptibility of a particular cable to ac magnetic fields is directly related to the effective loop area (ELA) of that cable. Since the ELA aperture presented in the transverse axis is physically much greater than that in the longitudinal axis, it can be concluded that the maximum pickup on a cable is caused by transverse magnetic fields. Due to this factor, the 010 Handbook deals primarily with the spacing and shielding requirements in order to prevent transverse fields from causing ac EMI.

The transverse ac shielding effectiveness of flexible conduit is shown in the 010 Handbook. A graph showing the Relative Shielding Effectiveness of Flexible Metal Conduit With an Applied Longitudinal dc Field (figure 5) is shown for the levels of dc field tested.

When dc fields of up to 20 G are applied to a cable shielded with flexible conduit, the worst possible net affect would be to increase the susceptibility of that cable by 15 dB. Since each susceptor group number is spaced 20 dB from the next, and the maximum reduction of shielding effectiveness due to a dc field is 15 dB, the net effect will be at worst case to increase the susceptibility of the cable and conduit by one group number (e.g. an S4-6 could be pushed to S4-5).

CONCLUSION

Measurements have shown that the shielding effectiveness of flexible metal conduit is reduced when a longitudinal dc field is applied. The tests have also shown that when flexible conduit is used to shield a cable from EMI, the lower value of shielding effectiveness of flexible conduit can cause changes in how the 010 Handbook is implemented.

REFERENCES

- [1] L. J. Dalsass, "Conduit Susceptibility: Magnetic Saturation in Shipboard Flexible Conduit," NUSC Technical Memorandum 821083, Naval Underwater Systems Center, New London, CT, 15 October 1982.
- [2] M. J. Carpenter and L. J. Dalsass, Characteristics of a 6-ft Diameter Helmholtz Coil Test Fixture for Magnetic Field Testing of AN/BSY-2 Equipment, NUSC Technical Document 8465, Naval Underwater Systems Center, New London, CT 11 April 1989.

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