A Large Three-Axis DC Magnetic Field Susceptibility Test System

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The size of the L-TAMFST provides the dual benefits of a more realistic test bed and reduced equipment qualification time.

Introduction

This article describes the development and operation of a large three-axis magnetic field susceptibility test system (L-TAMFST). L-TAMFST is used primarily to perform DC magnetic field susceptibility testing on equipment planned for installation on naval ships. Unique features include its relatively large size and ability to accurately simulate the shipboard magnetic field environment. L-TAMFST can accommodate equipment enclosures as large as 6 ft x 2 ft x 2 ft, and is capable of generating static or time-varying DC magnetic fields directed at virtually any angle. This article describes the system hardware, control system and operator interface, analytical models used for development, and sample test results.

Overview

The susceptibility of electronic equipment to magnetic fields is becoming increasingly important in military and industrial applications where strong fields may be present (e.g., ships, factories, power plants, etc.). For some equipment, such as computer cathode ray tube (CRT) monitors, relatively weak magnetic fields are a concern as well. The presence of such fields can skew CRT images, alter display colors and, in some instances, cause short- and/or long-term damage. Therefore, it is important to subject the equipment under test (EUT) to the anticipated magnetic field environment prior to its actual installation.

The L-TAMFST system is an outgrowth of the smaller three-axis TAMFST system developed by the Naval Undersea Warfare Center (NUWC) for testing individual computer monitors.[1] L-TAMFST was designed to conduct magnetic field susceptibility testing on fully populated equipment racks or enclosures. Its large size provides the dual benefit of a more realistic test bed and reduced equipment qualification test time since multiple components may be tested together in their as-built configuration.

L-TAMFST is capable of generating static or time-varying DC magnetic fields with a magnitude greater than 20 Oersteds (Oe). The time varying fields may be ramped at rates exceeding 20 Oe per second, or dynamically rotated around any of the fixture's three axes at rates as high as 20 degrees per second. The magnetic field may be uniform throughout the test volume, or have a gradient. The combination of these fields effectively emulate the conditions that may be experienced in the actual operating environment.

Hardware Configuration

The L-TAMFST hardware configuration is shown in Figure 1. The test fixture consists of nine coils (only eight shown) that are independently controlled. A computer controls the power supplies and relays which interface with the coils. This configuration enables the operator to precisely control the magnetic field test environment.

The L-TAMFST control system was developed using a commercially available data acquisition system (DAS). The DAS runs on a Macintosh computer, but could be operated from a PC or workstation. The DAS provides a user-friendly interface between the operator and the test system. Major components of the user interface control panel are shown in Figure 2.

The control panel interface allows the operator to access several predefined test scenarios and to specify field strength, orientation, angular rate of rotation, gradient and test duration. The operator has the ability to create and store unique test scenarios (e.g., angular rotation patterns, timed events, etc.). The control panel provides feedback to the operator by displaying the current flowing through each coil and the resultant magnetic field.

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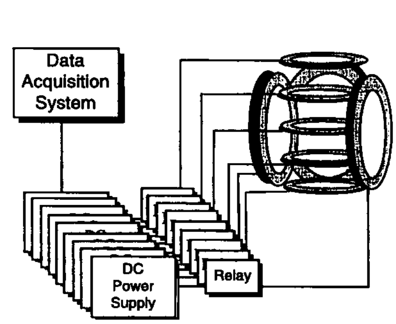

Figure 1. *L-TAMFST Hardware Configuration.*

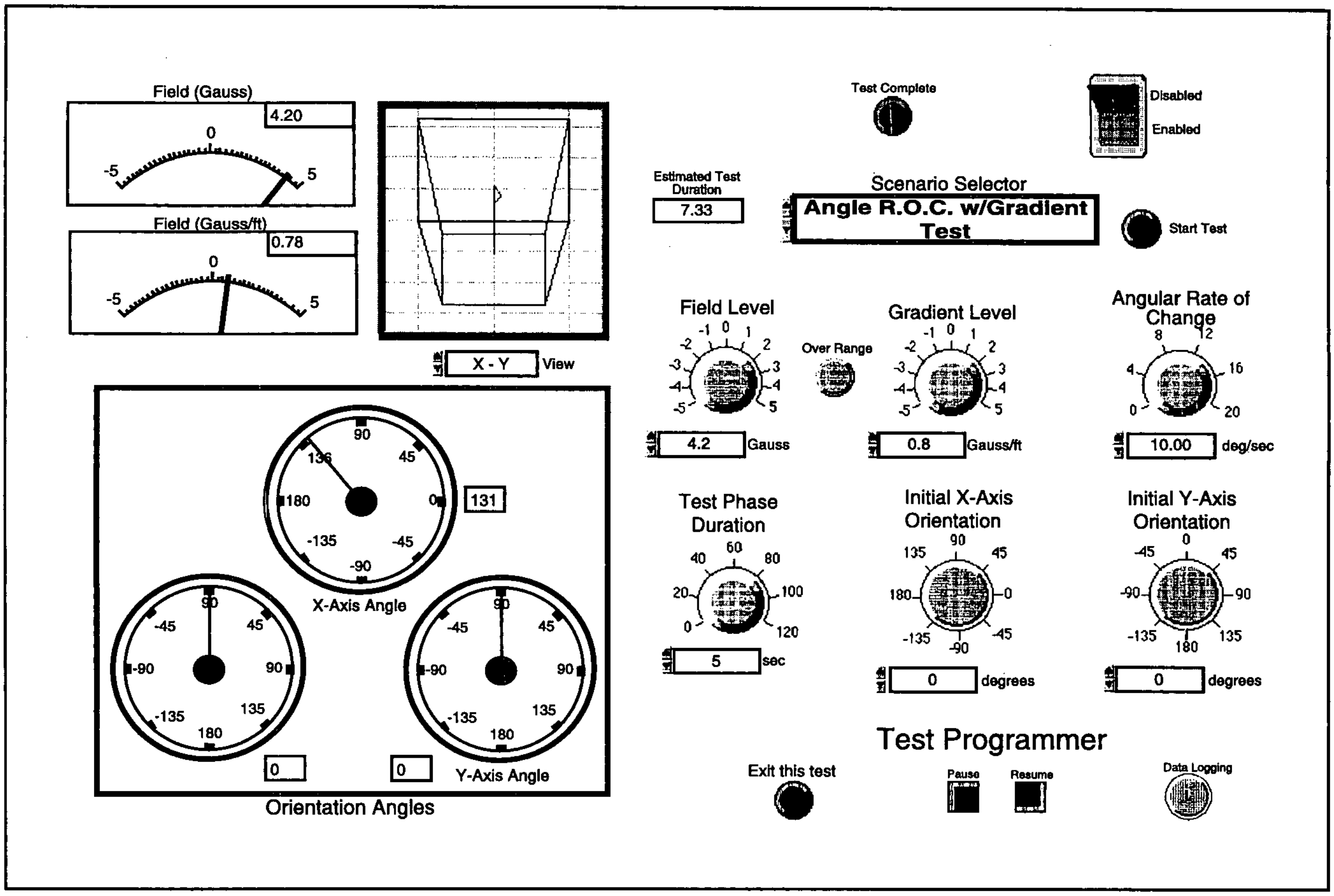

Figure 2. *L-TAMFST Control Panel.*

The DAS is comprised of a series of software modules that provide the user interface, calculate the coil currents in real time, and provide the instrumentation control. Computer communications with the power supplies and relays is by means of an IEEE-488 bus.

The currents required to generate a specific field profile are computed based upon a coil factor that establishes the relation between the applied coil current and the magnetic field produced by the coil. The factors for each coil are used to create a system of linear equations which are solved for a specified field level and direction, to obtain the required current (including polarity) for each coil. The rotating fields are generated by time sequencing the currents applied to two axes at a time. This produces a rotation about the third axis.

L-TAMFST utilizes nine DC power supplies with power ratings that range from 2.5 to 5 kW. A separate supply is used to drive each coil. The power supplies operate in the constant current mode to compensate for changes in coil resistance due to conductor temperature changes. Each power supply interfaces with its coil by means of a relay.

The relays serve two purposes. In addition to providing a safety mechanism by isolating the power supplies from the coils (if necessary), they operate in a tri-state mode and are used to reverse the current polarity. This is necessary for changing the field direction. The nine-coil test fixture is comprised of two pairs of large coils in both the axial (X) and transverse (Y) directions, and five coils stacked in the vertical (Z) direction (Figure 3).

The four large coils are approximately 6 ft in diameter. The five vertical coils have a diameter of approximately 4 ft. This configuration provides a relatively uniform test volume of 6 ft x 2 ft x 2 ft.

Each coil has approximately 100 turns of 1/4" x 1/4" bar conductors and has a DC resistance of approximately 0.5 ohms. The large coils are each mounted to an individual base for ease of movement. The vertical coils are supported by four wooden dowels with nylon fasteners that allow coil disassembly for EUT setup and removal.

Analytical Model

The magnetic field generated by Helmholtz coils can be modeled using several techniques. One closed form solution for the magnetic field produced by a single axis Helmholtz coil is:[2]

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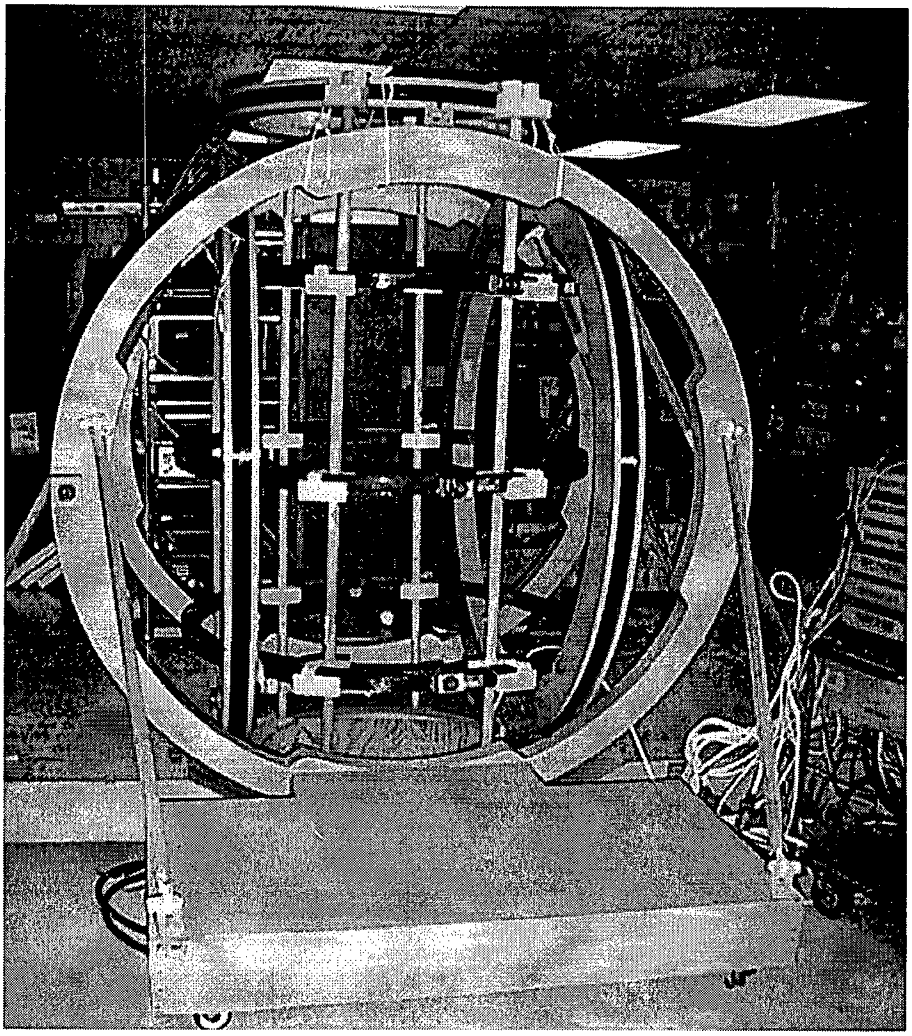

Figure 3. *L-TAMFST Coils.*

$$B_z=\frac{\mu_0 N I a^2}{2}\left(\frac{1}{(z^2+a^2)^{3/2}}+\frac{1}{((d-z)^2+a^2)^{3/2}}\right)$$

where

B_z = Magnetic flux density (Teslas)
μ_0 = Permeability of free space (Henrys/meter)
I = Current (amps)
N = Number of turns
d = Coil separation (meters)
a = Coil radius (meters)
z = Distance along common axis (meters)

Field uniformity can be computed by iterating the above equation over the axial distance z. For example, Figure 4 illustrates the field uniformity between two coils with a diameter of 2 meters separated by a distance of 1 meter. The magnetic field is relatively uniform for the center half of the volume enclosed by the two coils.

For a multiple coil system, the aforementioned equation can be factored and vectored to estimate the contributions produced by each of the individual coils. The effects of changing the drive currents to the individual coils can also be calculated.

Sample Test Results

Magnetic field susceptibility testing is often required for equipment installed on naval ships. Normally, DOD-STD-1399 Section 070[3] is invoked. That standard requires equipment to be exposed to static and time varying (ramped) magnetic fields from three orthogonal directions. L-TAMFST satisfies the requirements of DOD-STD-1399 Section 070. A system such as L-TAMFST offers the advantage of being able to expose the EUT to more realistic conditions where gradient magnetic fields may be experienced from any direction. Also, the effect of fields whose vector orientation varies with time (i.e., rotating fields) can be determined without disturbing the EUT or its cabling. Computer CRT monitors are particularly susceptible to the effects of magnetic fields. The distortion caused by the magnetic fields can vary significantly depending on the orientation of the impinging magnetic field. Examples of the variation are illustrated in Figures 5 and 6.

Figure 5 shows a monitor subjected to a vertical DC magnetic field of 5 Oe. There is minor discoloration (i.e., purple) along the lower right edge of the red test screen.

Figure 6 shows the same monitor subjected to a 5-Oe DC magnetic field applied at 65 degrees from vertical. There is severe color discoloration. The regions of color change have been highlighted. The color codes are: P = purple, Y = yellow, G = green, R = red. The test screen should be red.

Thus, magnetic fields of equal magnitude produced drastically different effects depending on angle of incidence. Since the automated test setup was able to apply the field at virtually all angles, the worst case susceptibility was noted. This would have gone undetected with the traditional DOD-STD-1399 test method.

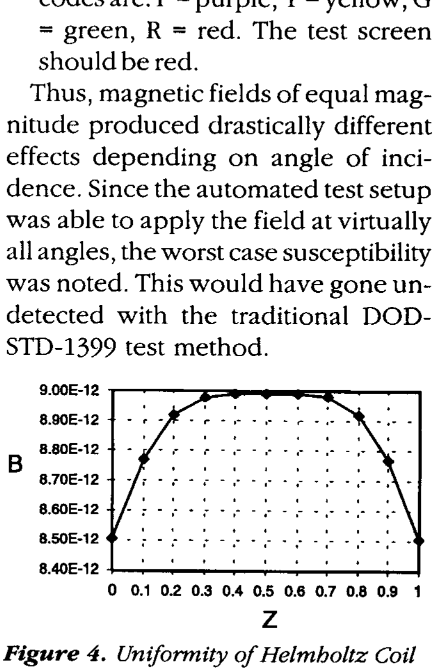

Figure 4. *Uniformity of Helmholtz Coil Field.*

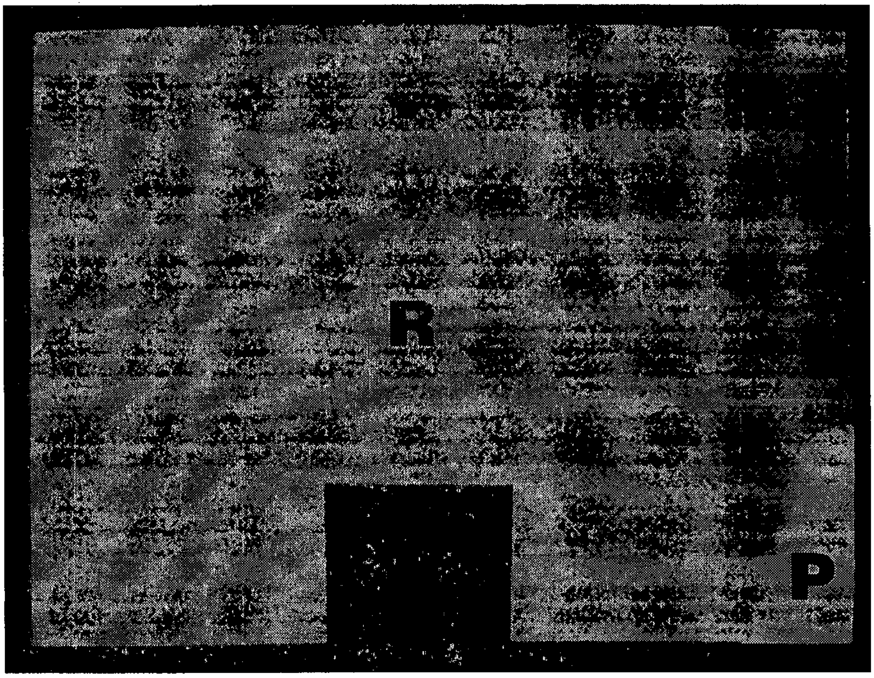

Figure 5. *Field Applied in Vertical Direction.*

Conclusion

An automated, multi-axis Helmholtz coil test fixture accurately simulates the shipboard magnetic field environment and provides a good means to determine whether or not electronic equipment will function properly onboard naval ships or in a harsh industrial environment. The large size of the fixture enables fully populated equipment racks to be tested in their entirety, thereby reducing equipment qualification test time.

Acknowledgment

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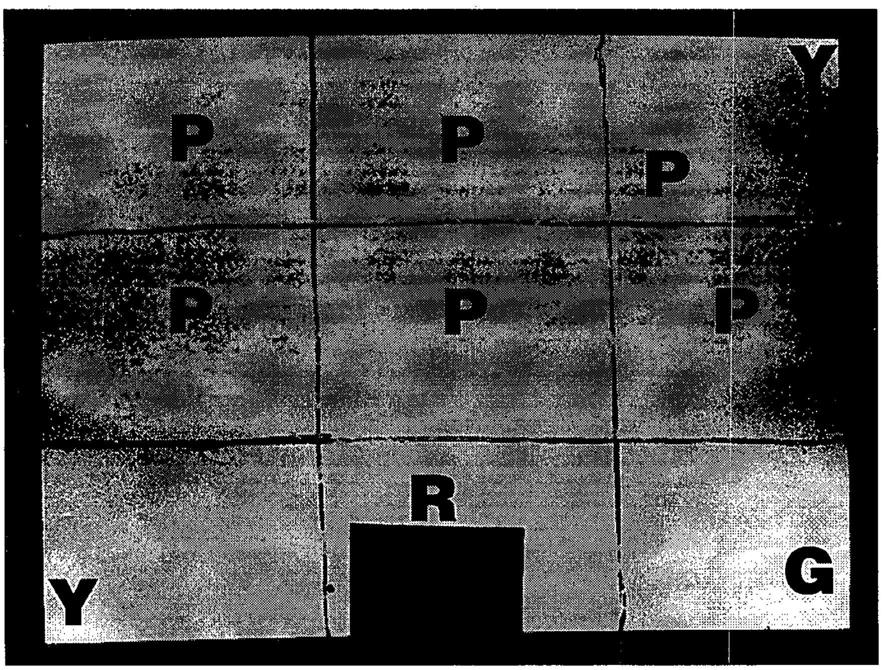

Figure 6. *Field Applied 65 Degrees from Vertical.*