New Criteria for the Selection of Inductive Couplers for Bulk Current Cable Injection Testing per RTCA/DO-160C

DR. CHARLES E. GOLDBLUM
R & B Enterprises

The Radio Technical Commission for Aeronautics (RTCA) issued RTCA/DO-160C "Environmental Conditions and Test Procedures for Airborne Equipment" on December 4, 1989. This document addresses test limits and test procedures for avionics. One of the many challenges for the committee that oversaw authorship of this document was the problem of radiated susceptibility testing. Ideally, all equipment would be qualified to a radio frequency (RF) environment of 200 V/m from 10 kHz to 18 GHz. Due to cost and technical considerations which will not be discussed in this article, two test procedures are included in Section 20 of RTCA/DO-160C.

From 10 kHz to 400 MHz, the equipment under test (EUT) is subjected to continuous wave (CW) bulk current injection of RF signals onto cable bundles. From 30 MHz to the upper frequency limit, the EUT is subjected to antenna generated RF fields. There is an intentional overlap from 30 MHz to 400 MHz.

The inductive couplers required for the bulk current injection testing are often stressed by the increase in temperature due to the losses in the coupling material. This problem is particularly bothersome in the higher frequency range of this test method. The inductive couplers can be permanently damaged if the core temperature exceeds the Curie temperature of the core material.

Vector network analysis techniques can be used to measure the transfer function of an inductive coupler.

A second problem associated with bulk current injection is the impedance mismatch between the output of the RF amplifier and the input of the inductive coupler. Even though the test method accounts for the mismatch by directly measuring forward power into the coupler, this mismatch increases the power requirements of the amplifiers used in the testing.

The coupler data presented in the sales literature do not address these problems. Insertion loss often is presented as a function of frequency, does not yield meaningful information with respect to bulk current injection testing. In order to fill this void of meaningful data in the sales literature, it is proposed that vector network analysis techniques be used to obtain a meaningful transfer function of the inductive coupler under consideration.

An inductive coupler can be considered a two-port network as shown in Figure 1. The currents and voltages on the input and output of the coupler are related through the ABCD parameters of the network, such that

$$\begin{pmatrix} v_1 \\ i_1 \end{pmatrix}_f = \begin{pmatrix} A & -B \\ C & -D \end{pmatrix}_f \begin{pmatrix} v_2 \\ i_2 \end{pmatrix}_f \quad (1)$$

where A,B,C,D and the voltages and currents are, in general, complex quantities. Note that the quantities in equation (1) are a function of frequency. During the calibration procedure in Section 20 of RTCA/DO-160C, the forward power in measured into the coupler and a corresponding current is measured through a 50 Ω non-reactive load. The forward power necessary to achieve the current limit in the specification is recorded. The inductive coupler is then attached to the cables under test, and the amplifier power is adjusted until the calibrated forward power is achieved.

The transfer function of interest relates forward power to the current induced in the calibration load. The magnitude of the forward power is simply $v_1 i_1$. v_2 is related to i_2 through the calibration load such that $v_2 = i_2 R_{cal}$. After a little algebra, the transfer function is

$$\begin{aligned} P_{forward} &= (CR_{cal} - D)(AR_{cal} - B)i_{cal}^2 \\ &= Gi_{cal}^2 \end{aligned} \quad (2)$$

where G is the transfer function of interest. The test setup for measuring the transfer function G is shown in Figure 2.

A second quantity of interest is the impedance mismatch between the inductive coupler and the RF amplifier. Assuming that the output impedance of the amplifier is approximately 50 Ω, the mismatch would then be dominated by the voltage standing wave ration (VSWR) of the inductive coupler. The VSWR can be directly measured by the vector network analyzer. Using this quantity, the relationship between the rated power of the RF amplifier can then be directly related to the current through the 50 Ω calibration load

$$P_{amp} = \frac{(VSWR + 1)^2}{4\ VSWR} G i_{cal}^2 \tag{3}$$

Since the transfer function G and VSWR are functions of frequency, Equation (3) can be rewritten as

$$P_{amp} = G' i2cal \tag{4}$$

A coupler with the largest G or G' over the frequency band of interest should be selected. Figure 3 shows measured values for G for three different couplers. Based on the concept of an optimal transfer function, inductive coupler A is the preferred choice for RTCA/DO-160C conducted susceptibility testing.

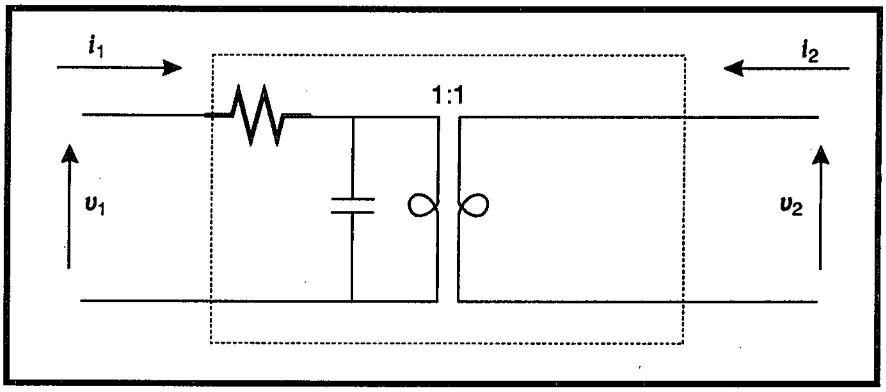

***FIGURE 1**. Typical Equivalent Two-port Representation of an Inductive Coupler.*

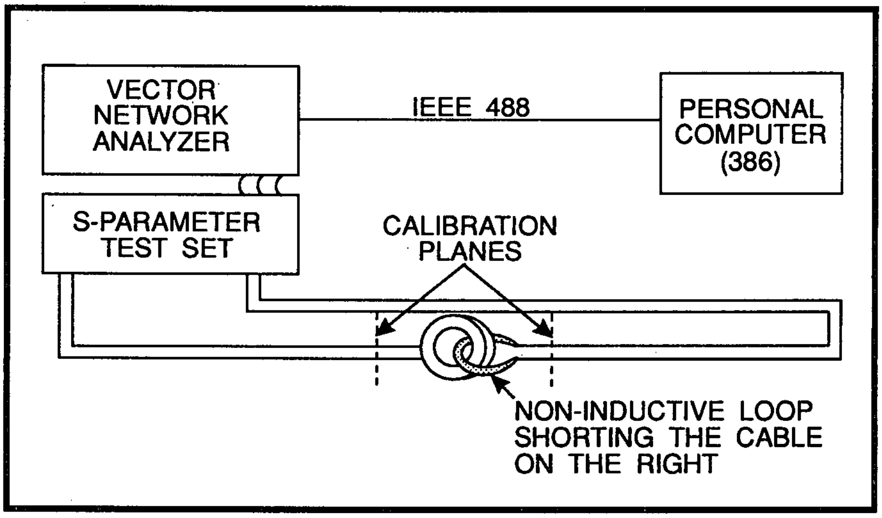

***FIGURE 2**. Test Setup for Measuring the Transfer Function G.*

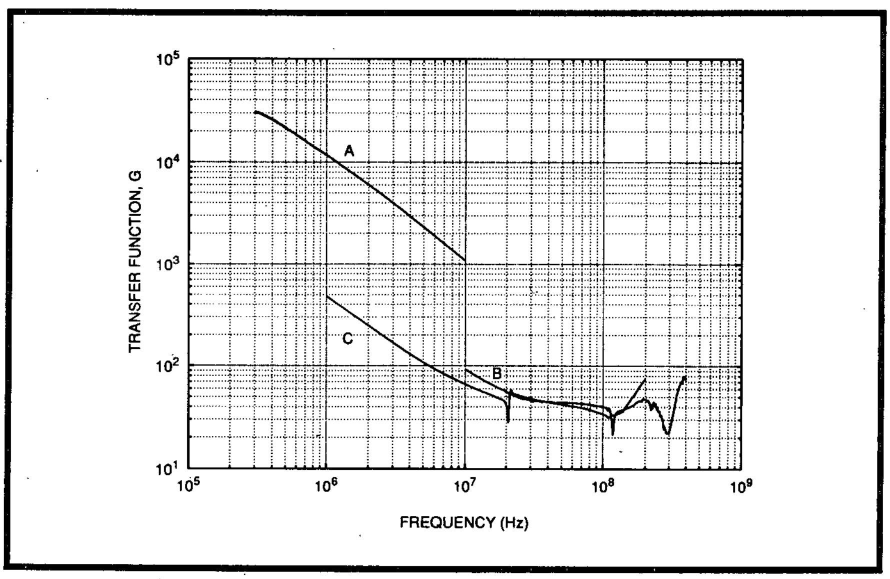

***FIGURE 3**. Transfer Functions of Three Commercially Available Inductive Couplers Used for RTCA/DO-160C Bulk Current Injection Testing.*

---

*Chief Scientist at R&B Enterprises, **CHARLES GOLDBLUM** received his M.S. and Ph.D. degrees from the University of Virginia. He is currently working with the Naval Research Laboratories on multiple R&D programs including the development of a room-size sub-harmonic resonant cavity (a modified mode-stirred chamber).*