CS12 AND CS13: SHORTCOMINGS AND SOLUTIONS

The CS12 and CS13 electromagnetic pulse (EMP) test specifications include test methods that are not realistic or practical. Modifications are suggested.

Mark J. Komp, R & B Enterprises, West Conshohocken, PA

The U.S. Air Force EMP Specifications, Methods CS12 and CS13, were released in MIL-STD-461C, Notice 2 and MIL-STD-462, Notice 6, dated October 15, 1987. The Air Force thereby joined the Navy in specifying subsystem level EMP tests. Unfortunately, the newly issued standard does not include practical test methods.

Previously, the U.S. Navy had issued EMP test method specifications CS10, CS11 and RS05 in MIL-STD-461C and in Notice 5 to MIL-STD-462. Whereas the Navy had designated the *limited* applicability of CS11 and RS05 and the *case-by-case* applicability of CS10, the Air Force has stipulated that CS12 and CS13 apply to *all* equipment and subsystems procured for Air Force use that fall within three of the eight class A1 equipment and subsystem categories: A1a-Air launched missiles, A1b-Equipment installed on aircraft (internal or external to airframe), and A1g-Jet Engine accessories.

The CS12 requirement, a bulk cable injection test performed on interconnecting and power cables, is the same for all of the equipment categories. The requirement for CS13, a single/multiple wire unit injection test applicable for interconnecting and power leads, is also the same for all equipment categories. A radiated test method, RS06, is also included in MIL-STD-461C, Notice 2 and MIL-STD-462, Notice 6. Contrary to poplar belief RS06 is not an EMP test, but actually details a chattering relay test. It has no connection with the EMP phenomena and therefore will not be addressed in this article.

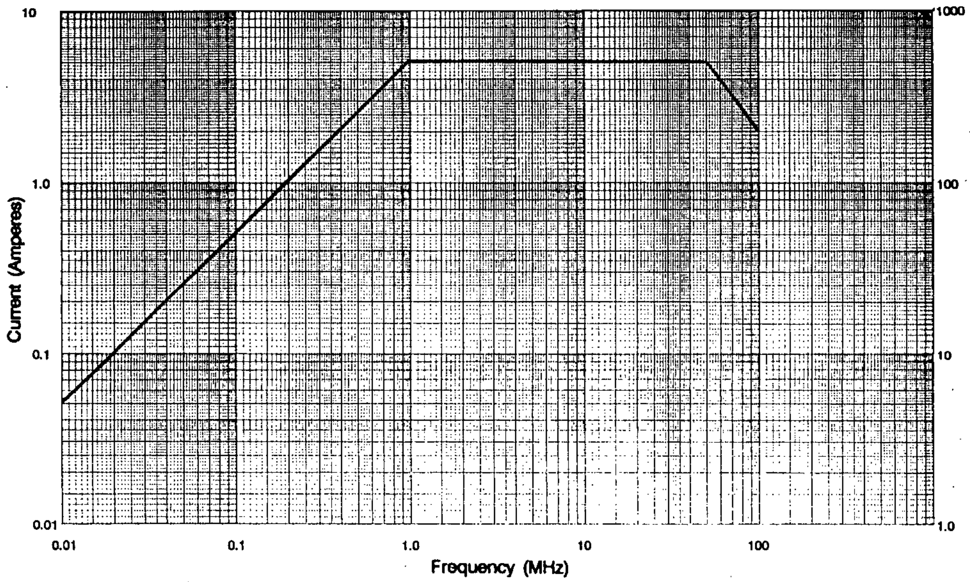

Figure 1. CS13 Voltage Limit.

The test parameters for CS12 and CS13 are very similar. They both incorporate a damped sinusoidal waveform with a damping factor of 20±5. They have a maximum peak current of 5 A derated with frequency, as shown in Figure 1. CS12 imposes a limit of 1500 V on any pin in the cable under test. The CS13 voltage limit follows the same derating curve as the current limit, with a maximum peak voltage of 500 V. This limit is shown by the right vertical axis in Figure 1. A damping factor of 20±5 is also imposed on the test waveform. The above limits apply only to injection levels for CS12 and only for calibration levels for CS13.

CS12 has no calibration procedure. The waveform limits must be achieved on the cable under test with the equipment to be tested arranged according to the test configuration shown in Figure 2. The equipment under test (EUT) is bonded to a ground plane with cables terminated with dummy loads or test support equipment. Testing is performed with line impedance stabilization networks (LISNs) connected to the power lines. The coupling device,

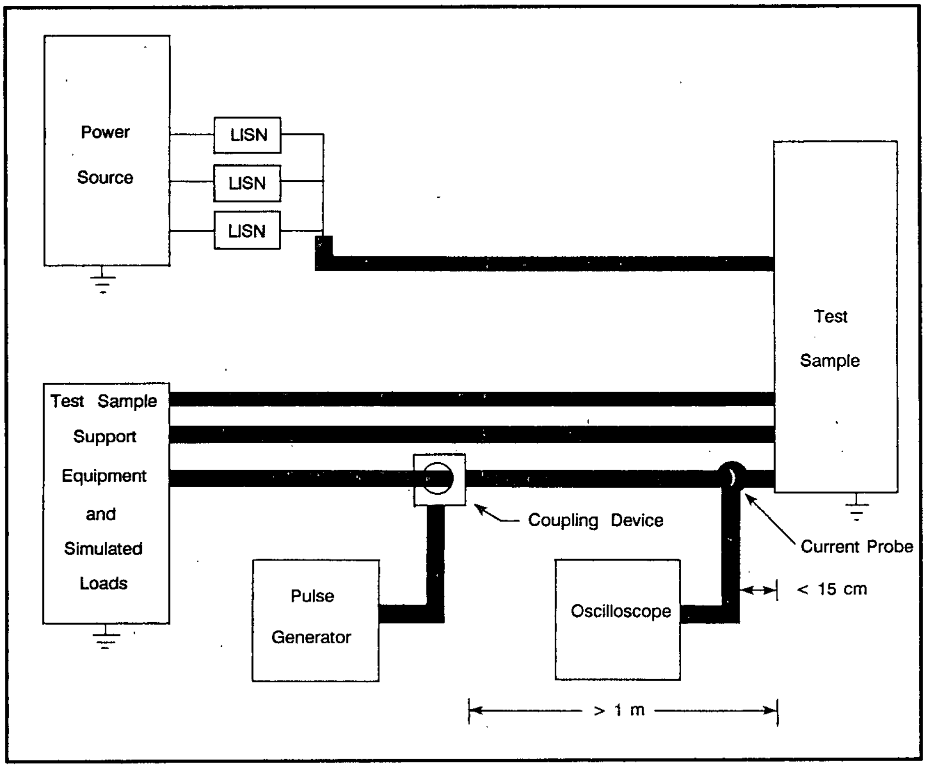

Figure 2. Typical CS12 Test Setup.

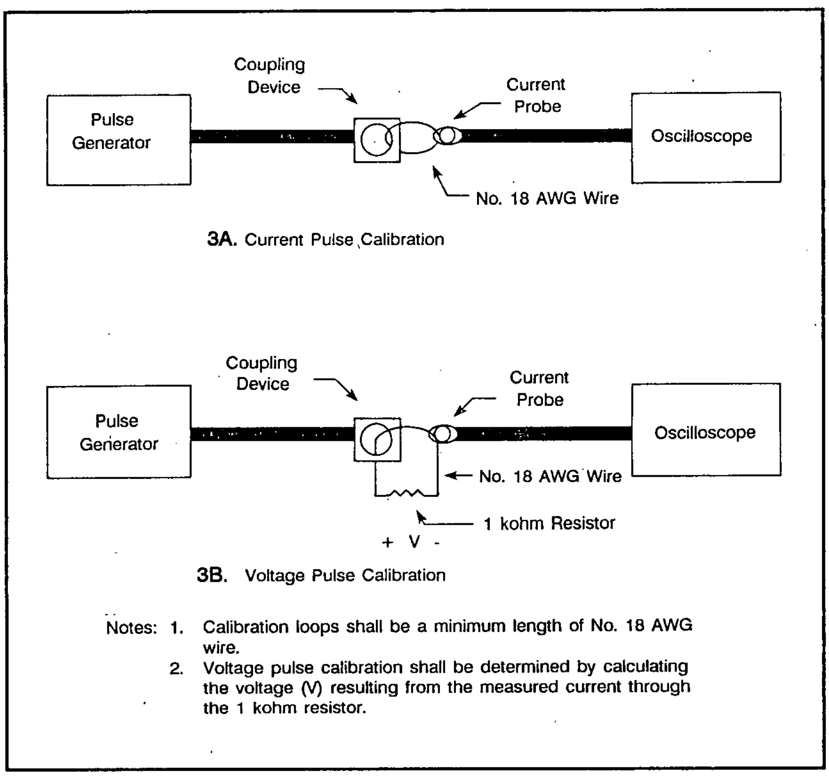

Figure 3. Typical CS13 Calibration Setup.

connected to the output of the damped sinusoid generator, is placed around the cable under test one meter from the connector on the EUT. The monitoring current probe is placed no further than 15 cm from the EUT. An oscilloscope is used to monitor the injected waveforms.

Injection levels for CS12 begin with the generator's output set at its lowest setting. The output is increased until the bulk cable current level is reached, or 1500 V is achieved on any pin in the cable between the pin and its lowest impedance return path. Once the injected waveform meets all of the required limits, the cable is then subjected to applications of this waveform for 5 minutes at a repetition rate of one pulse per second. This is done for both positive and negative polarities. The injection test is repeated on each cable at each test frequency. The required test frequencies are 10 kHz, 100 kHz, 1 MHz, 10 MHz, 100 MHz, and any of the EUT's critical frequencies.

The calibration procedure specified in CS13 has two parts. First a calibration is performed through a short circuited loop as shown in Figure 3A. The coupling device and current probe are placed around a shorted loop of minimum length of No. 18 AWG wire. The generator's output is increased until the current limit is reached. Once this occurs, the settings of the generator are noted and then returned to minimum output. The coupler and current probe are taken off the shorted loop and placed around a minimum length loop of No. 18 AWG wire that contains a 1 kΩ resistor, as seen in Figure 3B. The generator output settings are then increased until the voltage limit is met. The voltage is calculated from the measured current through the 1 kΩ resistance in the usual manner. The generator is set at the higher of the two calibrations settings for the injection procedure.

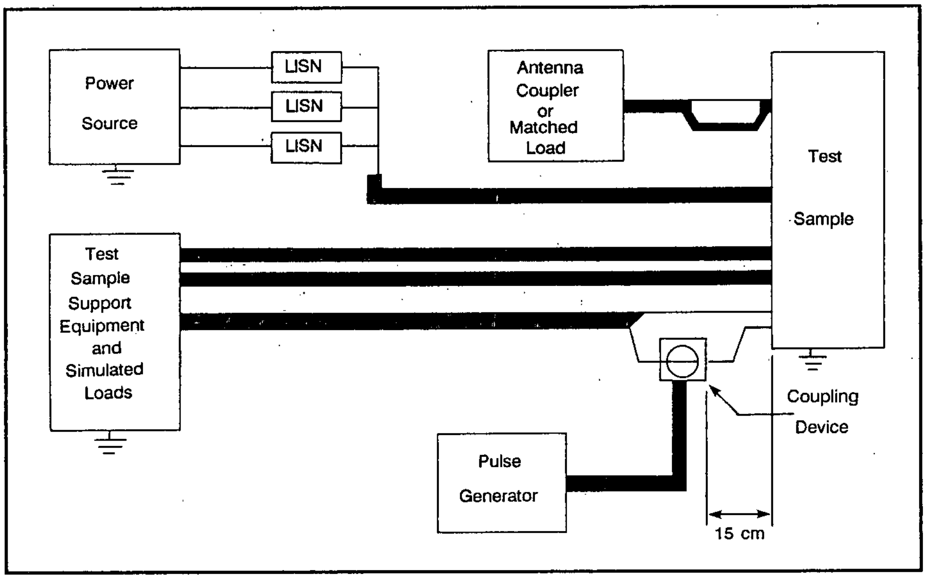

Figure 4. Typical CS13 Test Setup.

Figure 4 displays the CS13 injection setup. The coupler is placed around the lead under test 15 cm from the EUT. Power lines have LISNs attached. Other lines are terminated with actual or dummy loads. The lead under test is injected at the higher calibration setting. The lead is subjected to 50 pulses in each of two polarities at a repetition rate of one per second. The test is repeated on each single wire and/or multiple wire unit at each of the required (10 kHz, 100 kHz, 1 MHz, 10 MHz, and 100 MHz) and critical test frequencies. The calibration procedure is repeated prior to injection at each of the frequencies.

Although the above procedures appear to be fairly straightforward, they may be impossible to follow. In the performance of a CS12 test, a great number of problems can arise. First, since no calibration procedure exists, the waveform limits must be met on the cable. This may be impossible if the cable is terminated in nonlinear loads or if the cable's characteristic impedance is such that the proper waveform cannot be achieved. The measurement of 1500 V on any pin may not be impossible, but it is impractical. If a cable with a large number of pins is being tested, and/or if the pins exhibit a nonlinear response with respect to frequency or voltage, the attempted measurement can take many times longer than the actual test itself.

Where the absence of a calibration procedure is a problem with CS12, the calibration procedure outlined in CS13 poses problems. One problem lies with the specified wire; the wire length necessary for a loop to accommodate a coupler and a current probe will result in an inductance too large to obtain a signal that will meet the waveform requirements at the higher frequencies, especially 100 MHz. The two calibration settings also pose a problem. Since the coupler used will have a fairly low transfer impedance in order to couple the necessary levels, it will require only a very low generator output level to drive the current limit through a short circuit. The setting at which the voltage limit is imposed across the kΩ resistor will always be the higher setting and therefore the one always used for injection. If injection into a very low impedance pin is then performed at this level, a current much higher than the current limit will be obtained. The determination of the calibration voltage at the lower frequencies may be impossible as well. At 10 kHz, for instance, it is necessary to measure 5 mA through 1 kΩ, which is a very difficult, if not impossible, task for many oscilloscopes.

Several glaring omissions also plague these test procedures. The operational modes in which the EUT should be tested are not specified. Cable configuration to minimize interaction, such as a minimum height above the ground plane, is also not dictated. Specifications for the voltage probe, current probe and oscilloscope necessary to accurately measure the test transients are lacking. Using improper probes and oscilloscopes could obviously greatly affect the test results. The wrong current probe could act like a choke in the line under test, cause distortion, saturate and cause other problems. Using probes and oscilloscopes with insufficient bandwidths will not allow the calibrated or injected signal to be viewed, measured or recorded properly and could greatly affect the level and severity of the transient injected into the EUT.

Until necessary revisions are released, several guidelines, implemented at the test plan writing stage, will facilitate CS12 and CS13 test performance. First, a calibration procedure for CS12 must be written. This procedure should be based on existing effective ones. For simplicity's sake a calibration procedure incorporating the best features of CS10/CS11 and a modified CS13 (detailed below) may be used. Calibration can be performed for short circuit current and open circuit voltage. Injection would then begin at the short circuit current level and the generator output increased until either the current limit is reached or the open circuit voltage calibration level (of CS13 or a derated 1500 V) is achieved. The cable would be tested to the remainder of the present injection procedure.

The CS13 calibration procedure requires a number of corrections and modifications. The 18 AWG wire loop must be replaced with a low inductance network, which should incorporate provisions for the short and open circuit calibrations. The short circuit current is measured with a current probe as before. However, the open circuit voltage should be measured on an open circuit with a device designed to do so -- a voltage probe. The probe used should have a 100:1 attenuation, and a bandwidth of at least 200 MHz. Both calibrations can still be performed, but when injecting, the current setting is the starting point, and the output is increased until the current limit or the voltage setting is obtained.

Other important concerns to be addressed in the test plan writing stage and in future revisions for both test methods include precisely detailed test setups, especially grounding techniques and cable configurations. Current probes should be specified to have a flat frequency response in the range over which they are used. Good measurement practice dictates that the measuring device should have an input bandwidth of at least twice the highest frequency to be measured. Since the fastest signal involved in MIL-STD-461C/462 EMP testing is a 100 MHz transient, the oscilloscope used to measure this signal must have at least a 200 MHz bandwidth. If a digitizing oscilloscope is used, its sampling rate should be at least ten times the highest frequency to be measured, or 1 GSa/s. The sampling rate should also be variable so that the low frequency transients may be recorded. Obviously, if a 10 kHz signal is sampled at 1 GSa/s the oscilloscope's memory will be filled before the entire wave form is captured.

Although many serious problems and omissions exist, CS12 and CS13 tests can be performed before the necessary revisions are made if these problems are addressed at the test plan writing stage. The plan's author will need a thorough understanding of EMP testing and an appreciation of the guidelines set forth in this article. Ultimately, the necessary revisions must be incorporated into the existing test procedures to form a wholly realistic and meaningful test specification. ■

Continued from page 96

CONCLUSIONS

The linear amplifier is a very attractive pulsed-power source for many direct-drive applications. Typically available units provide drive levels meeting essentially all the needs of direct pin-injection testing, many of the bulk-drive requirements, and some of the surface-injection needs. The linear amplifier allows the use of essentially any arbitrary waveform and wide variation of individual waveform parameters. The use of complex waveforms is simplified with generation at low levels with linear amplification to required drive levels. However, the basic cost of a linear amplifier is substantially higher than that of the more common energy storage pulsed-power sources.

There is a compromise between output level and waveform fidelity. At output levels approaching the specified limits of an amplifier, distortion will generally be quite noticeable. Operation of the amplifier in a push-pull configuration will improve the waveform fidelity, but will result in somewhat lower peak output drive than available from a simple parallel configuration.

In the development of a testing program utilizing a linear amplifier source, several system-level considerations must be addressed. Personnel safety must be a primary consideration. Care must be exercised to control feedback instability and screening may be necessary. A well configured ac power distribution system is required and provisions for heat removal must be included. ■

ACKNOWLEDGEMENT

The author would like to thank Mr. Jerry Gibson and Mr. Mike Saavedra of EG&G Special Projects for their help in collecting and preparing the data presented in this paper. The author would also like to thank EG&G Special Projects in Albuquerque, NM for making available the facility test equipment and actual production direct-drive systems used in the collection of the performance data reported in this article.

REFERENCES

1. Helene, Frederick L., *MIL-STD-461C*, ITEM, 1986, pp. 108-112, 318-321.
2. SAE AE4L Committee, *AE4L-81-2*, December, 1981.
3. Ginzton, Edward L., William R. Hewlett, et al., Distributed Amplification, Proceedings of the IRE, August, 1948, pp. 956-969.
4. National Fire Protection Association, National Electrical Code, (ANSI/NFPA 70) Quincy, NFPA, 1984 Edition, 1983.
5. Gruchalla, M. E., *Grounding In Instrumentation Systems*, Measurements and Control, Issue 102, 1983, pp. 136-151.