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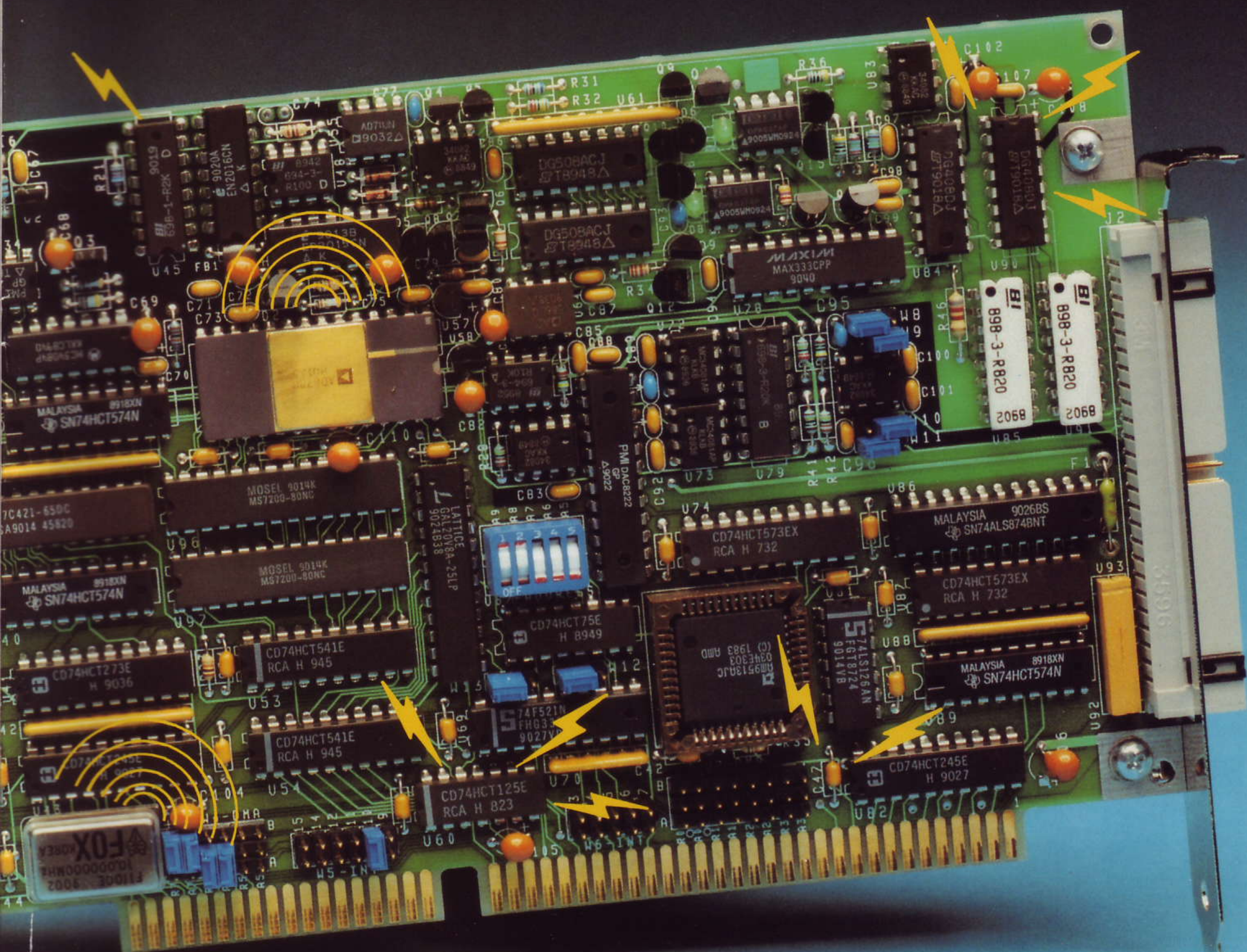

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***Plus* — Radiated Emissions Measurements**

Military Standards Update

Report on Draft Versions of Revisions to MIL-STD-461C and MIL-STD-462

A summary of changes from the present MIL-STDs.

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Drafts of proposed revisions to MIL-STD-461C EMI requirements and MIL-STD-462 test methods have been released for industry review. This article summarizes the changes from the present MIL-STD-461C and MIL-STD-462.

Introduction

Unlike earlier revisions of MIL-STD-461 and Notices to MIL-STD-462, which might be characterized as evolutionary in nature, this revision is revolutionary in both purpose and scope. The change is entirely as great as when the original Tri-Service MIL-STD-461/-462 first replaced the Service unique specifications that had been in use up to that time (1967).

It is evident that a great deal of effort has been put forth to make the specifications more user friendly, and also to make the requirements and test methods more closely support system level EMC goals.

MIL-STD-463 EMI Definitions will be canceled and replaced by ANSI C63.14.

General Changes

Perhaps the most obvious changes are the deletion of the Service or application unique Parts, and the addition of brief *Rationale Appendices* to both standards. There are still Service unique limits in some cases, but they are all lumped together under the appropriate requirement. The Rationale Appendices explain the motivation behind each requirement and test method, and also caution against some of the common pitfalls of testing. In MIL-STD-461, the Rationale Appendix also serves as a basis for tailoring limits. Under the revised MIL-STD-461C, and the new MIL-PRIME philosophy, tailoring EMI limits to meet system level EMC goals will have increased visibility. A thorough understanding of how limits were derived is necessary to justify tailoring those limits for a particular system.[1]

A minor feature of the drafts is a change to the requirements numbering scheme. The four character designation (e.g., CE01) has been replaced by a five character designator (e.g., CE101). Essentially, the numbering scheme starts with a baseline of CE/CS/RE/RS100 rather than the present baseline of CE/CS/RE/RS00 (conducted emissions/conducted susceptibility/radiated emissions/radiated susceptibility).

Specific Changes

This section is organized into two parts. The first deals with changes that affect more than one requirement or test method. The second is a summary of changes to the individual requirements and test methods.

Changes In Emissions and Susceptibility Limits and Measurements

One of the revolutionary changes cited above is the deletion of narrowband/broadband signal analysis in favor of a single limit and standard measurement bandwidths. Minimum scan times are specified as well. Use of the peak detector has been retained. Receiver characteristics are specified to be in accordance with ANSI C63.2. A related break with tradition is a requirement for X-Y graphs of emission data. While this has been the norm at most test facilities for a number of years, the original method was manual recording and data reduction, presented in tabular format. This was the most prevalent form of data presentation in 1967, (date of original release of -461/-462) when the first automated receiver systems were beginning to gain widespread acceptance. The present MIL-STD-462 Notice 2 even has a list of acceptable EMI receivers, of which several are of the manual type.

A procedural change affecting all emissions tests is a requirement to verify the accuracy of the entire measurement setup from end to end prior to performing test measurements. This is an expansion on the old requirement to establish an ambient level at least 6 dB below each limit. Now, in addition to establishing the acceptable ambient, it is also necessary to demonstrate that the entire measurement setup can accurately measure a known input signal (at the standard limit). This is a very helpful quality enhancer which can smoke out such problems as pushed back pins in coax connectors, incorrect receiver settings, or broken components.

For the first time, radiated emission and susceptibility measurements in a partially anechoic chamber are required. These requirements are quite modest, but are a welcome step in the right direction. The absorber material intrinsic property is specified to be 6 dB of absorption for a normally incident 50 MHz plane wave. Position of material in the chamber with respect to EUT and measurement antenna placement are also specified. No quiet zone requirements are levied.

A note of key interest to typical test facilities with shield rooms smaller than 16' W x 16' L x 12' H: A literal interpretation of the draft absorber requirements would lead to the procurement of 4' cones (or ferrite tile absorber — more expensive than cones but easy to retrofit into present chamber). Use of 4' cones requires a new larger shield room. In turn, this may require a larger room or building to house the new shield room. Conversation with the Tri-Service committee revealed that the intention was no more than 2' cones, which could be retrofitted easily into almost any EMI test chamber.

The other truly revolutionary change in

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these drafts is the replacement or augmentation of present requirements by techniques using cable bulk current injection (BCI). BCI techniques have several advantages over traditional methods such as CS02, CS06, and RS03. These advantages are in accuracy, precision and scope of applicability. Accuracy and precision advances relate to obvious factors such as measuring cable currents instead of field strengths. In addition, accuracy and precision are increased because the magnitude of the stress (the standard limit) is better correlated to the real world threat. In the frequency range where BCI augments (overlaps in frequency) RS03, BCI limits can realistically simulate threats which are impossible to do with RS03 test methods.

Scope of applicability is greatly increased: now the CS02 and CS06 replacement tests apply equally to power and signal cables. A forthcoming article in *EMC Test & Design* ("The How and Why of Bulk Current Injection Testing" - September/October 1992) will discuss compelling reasons driving both the military and commercial avionics world to incorporate BCI limits and test methods.

Similar to minimum scan times for emissions measurements, there are minimum susceptibility scan rates and maximum step sizes. There could be some serious capital equipment outlays required here.

An unfortunate lapse under MIL-STD-461C was no requirement for susceptibility signal modulation. The draft version calls out 1 kHz square wave modulation as a default value for tuned frequencies above 10 kHz.

For both RE and RS E-field testing, the 200 MHz - 1 GHz band logconical is replaced by the double ridge guide horn. For those facilities that don't have one, this a $4000 impact. In addition, there are now two polarization sweeps to replace the single circularly polarized sweep of the logconical. And there is the sheer size and mass...

Comparison of Present and Proposed Limits and Test Methods

Table 1 summarizes the changes in the requirements, and the details follow.

CE01 To CE101

"CE01, Conducted Emissions, 30 Hz to 15 kHz, Power Leads" is to become "CE101, Conducted Emissions, 30 Hz to 10 kHz, Power Leads." The limit depends on power type and/or load current. The feedthrough capacitor has been replaced by a 50 μH LISN. This LISN is also used for test method CE102. LISN topology is shown in Figure 1. This LISN has a line-to-ground impedance of 5 Ω at 10 kHz, where the inductor and 8 μF capacitor resonate. Thus it does not adequately control the power source impedance for this test. This is not a new problem. Use of the 10 μF feedthrough capacitor for CE01 has the same drawback.

CE03 To CE102

"CE03, Conducted Emissions, 15 kHz to 50 MHz, Power Leads" is to become "CE102, Conducted Emissions, 10 kHz to 10 MHz, Power Leads."

This limit and test has undergone significant revision. As mentioned above, there is a single limit. (Separate limits for narrowband and broadband emissions are eliminated.) This limit is in terms of voltage measured at the LISN EMI port. Note that the frequency range of the test has been decreased significantly. The limit varies according to the type of power supplied to the EUT, but not according to the load current drawn. In some ways this test method harkens back to the earliest days of EMI specifications, with the dBμV limit and specified bandwidths replacing the use of authorized EMI meters. However, the limit itself is much relaxed from these early specifications in keeping with the better immunity of today's communications electronics equipment. The 50 μH LISN, as compared to the old 5 μH LISN, might be considered to model a much larger power bus. (The 5 μH LISN modeled the 28 Volt dc bus from a 1930s model DC-3 airplane.) In actuality, the draft LISN is a subset of the VDE-CISPR LISN. Facilities which already have such a commercial LISN may now use it for their military tests as well. One problem with LISNs is current carrying capability. Limitations due to inductor size in the past were one of the reasons for the use of the feedthrough capacitor. This problem will be even greater with this LISN, sporting a much larger inductor. High power loads may require special test methods/dispensations.

CE06 To CE106

"CE06, Conducted Emissions, Antenna Terminal, 10 kHz to 12.4 GHz" is to become "CE106, Conducted Emissions, Antenna Terminal, 10 kHz to 40 GHz." There are no substantive changes.

CE07

Requirement CE07, Transient Load Induced Effects on Input Power, is deleted. Manually activated transients are uncontrolled. Transients arising from automatic cycling of equipment modes must meet the steady state limits of CE102.

CS01 To CS101

"CS01, Conducted Susceptibility, 30 Hz to 50 kHz, Power Leads" is to become "CS101, Conducted Susceptibility, 30 Hz to 50 kHz, Power Leads." The limit now depends upon power type. The only substantive method changes are test set up diagrams for injecting CS01 levels in 3 phase wye and delta loads.

CE		CS		RE		RS	
Present	Draft	Present	Draft	Present	Draft	Present	Draft
CE01	CE101	CS01	CS101	RE01	RE101	RS01	RS101
CE03	CE102	CS02	CS114	RE02	RE102	RS02	deleted
CE06	CE106	CS03	deleted	RE03	RE103	RS03	RS103
CE07	deleted	CS04	deleted			RS05	RS105
		CS05	deleted				
		CS06	CS115				
		CS07	deleted				
		CS09	CS109				
		CS10	CS116				
		CS11	CS116				
		CS12	CS116				
		CS13	CS116				

Table 1. Summary comparison of present and draft requirements.

CS02 To CS114

"CS02, Conducted Susceptibility, 50 kHz to 400 MHz, Power Leads" is to become "CS114, Bulk Cable Injection, 10 kHz to 400 MHz."

This is one of the revolutionary changes in the draft. Note that whereas the capacitively injected CS02 *voltage* is necessarily limited to power leads, the BCI CS114 *current* has no such limitation, and is indeed required on all interconnecting leads. A bit of background behind such a big change is perhaps in order. The reader may have pondered the large safety margin inherent in the application of *both* CE03 and CS02 to all military procurements. The Procuring Activities have stated that CS02 is not meant to simulate power bus ripple, but rather the effects of high power electromagnetic transmissions coupling to a power bus. This answers the "safety margin" question, but it begs another, "If these fields are coupling to power leads, then aren't they also coupling to interconnecting signal lines as well? And, if the coupling to signal leads is handled by RS03, then why doesn't RS03 suffice for power leads as well?" These questions will be addressed in the September/October issue article "The How and Why of Bulk Current Injection Testing" mentioned earlier. Also see Reference 2. It suffices for now to say that there are compelling reasons driving the military and commercial avionics worlds to incorporate BCI limits and test methods.

The BCI test requires current injection devices, which are similar to current probes except they can handle larger amounts of RF power in the windings. Two injection devices are required to cover the complete frequency range of this test. Considerably more power is required for this test than for CS02. However, if a test facility has a 20 V/m RS03 capability, no new amplifiers should be necessary.

CS03, CS04, CS05

CS03, CS04, and CS05 are Conducted Susceptibility, Antenna Terminals, 30 Hz to 10 GHz, Intermodulation, Rejection of Undesired Signals, and Cross Modulation (respectively). These requirements are deleted in the draft in favor of specific requirements in procurement specifications.

CS06 To CS115

"CS06, Conducted Susceptibility, Spike, Power Leads" is to become "CS115, Conducted Susceptibility, Bulk Current Injection, Impulse Excitation." Exactly as in the case of CS02, this new BCI requirement applies to both power leads and signal lines. The impulse generator is a 50 Ω device, not a low impedance device as presently. The author is not aware of a single piece of test equipment on the market presently meeting this requirement, although the current and

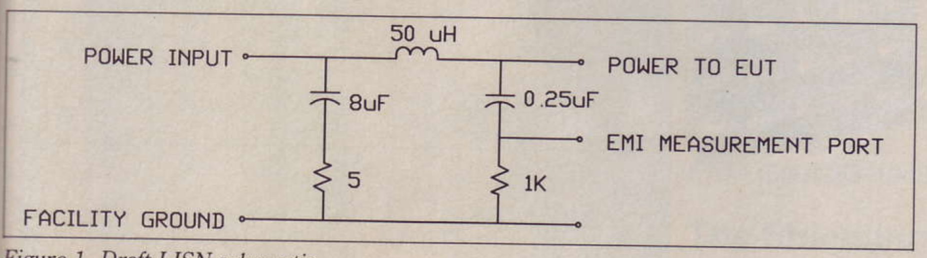

Figure 1. Draft LISN schematic.

voltage requirements are within the range of the present CS06 spike generators. With the exception of the output impedance, which is easily solved, only the pulse width must be changed (shortened).

CS07

Requirement CS07, Conducted Susceptibility, Squelch Circuits, is deleted.

CS09 To CS109

"CS09, Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz" is to become "CS109, Conducted Susceptibility, Structure Current, 60 Hz to 100 kHz." There are no substantive changes.

CS10, CS11, CS12, CS13 To CS116

"CS10, CS11, CS12, CS13, Conducted Susceptibility, Damped Sinusoidal Transients, Pin and Cable Injection, 10 kHz to 100 MHz" are to become "CS116, Conducted Susceptibility, Sinusoidal Transients, Cables and Power Leads, 10 kHz to 100 MHz."

This particular application of BCI differs only in degree, not in kind from the superseded requirements. These requirements were already of the BCI type, but the accuracy and repeatability were not as good. Notice that one requirement and test method has replaced four. Actually, the limit is different for the Air Force than for the Army and Navy in the new draft. The limits are quite similar to those today.

RE01 To RE101

"RE01, Radiated Emissions, 30 Hz to 30 kHz, Magnetic Field" is to become "RE101, Radiated Emissions, 30 Hz to 30 kHz, Magnetic Field." The limit has changed and, in addition to the retained 7 cm test distance, there is a new 50 cm test distance with a new limit about 34 dB below the new 7 cm limit, independent of frequency. There are different limits for the different Services. The Air Force does not have a limit.

RE02 To RE102

"RE02, Radiated Emissions, 14 kHz to 10 GHz, Electric Fields" is to become "RE102, Radiated Emissions, Electric Field, 10 kHz to 18 GHz."

Again, note the change to a single limit with prescribed measurement bandwidths. (Separate limits for narrowband and broadband emissions are eliminated.) The limits have changed substantially. For equipments installed within electrically conductive structures, the VLF portion of the limit has been relaxed. The VHF/ UHF bands haven't changed much. In the HF band, there is a slight relaxation, except that for equipment mounted externally to the structure the HF limit is tighter. The Army does not discriminate between internal and external equipments and the limit is a combination of VLF relaxation and the tighter HF limit. If one considers the nature of Army weapon systems such as attack helicopters and motorized vehicles such as the HUMVEE and the likely shielding effectiveness the Army position is understandable.

RE03 To RE103

"RE03, Spurious and Harmonic Emissions, 10 kHz to 40 GHz" is to become "RE103, Radiated Emissions, Antenna Spurious and Harmonic Outputs, 10 kHz to 40

GHz." There are no substantial changes.

RS01 To RS101

"RS01, Radiated Susceptibility, 30 Hz to 50 kHz, Magnetic Field" is to become "RS101, Radiated Susceptibility, Magnetic Field, 30 Hz to 50 kHz." The Navy RS101 limit is 10 dB above the Navy RE101 limit. The Army version has a smaller margin with respect to the Army RE101 limit. Both of these limits are higher than the present RS01 limit. A new receive loop is specified whose purpose is calibration of the transmit loop. This new loop is similar to, but smaller than the present RE01 loop. The RE01 receive loop and the RS01 transmit loop have not changed.

RS02

Requirement RS02, Radiated Susceptibility, Magnetic Induction Field, is deleted. It is quite adequately replaced by the various BCI requirements.

RS03 To RS103

"RS03, Radiated Susceptibility, 14 kHz to 18 GHz, Electric Field" is to become "RS103, Radiated Susceptibility, Electric Field, 10 kHz to 40 GHz."

The limits have changed substantially and are much more dependent on equipment application. No limits are above 200 V/m. Limits also vary according to frequency. A test method change requires real time monitoring and leveling of the field intensity below 1 GHz. This necessitates the use of electrically short sensing devices small enough to fit in the EUT test setup and not load the field. (Use of antennas for this function is not allowed.)

RS05 To RS105

"RS05, Radiated Susceptibility, Electromagnetic Pulse Field, Transient" is to become "RS105, Radiated Susceptibility, Transient Electromagnetic Field."

The limit waveform is changed. The maximum amplitude increases slightly. The rise time is specified as a not to exceed (with the NTE value similar to the present risetime.) The fall time is greatly shortened. There should be less total energy in this waveform. There are no substantial test method changes.

References

1. Javor, Ken, *A Guide to Understanding and Tailoring EMI Limits and Test Methods*. Available from EMC Services, P.O. Box 2504, Huntsville, AL 35804-2504. Phone (205) 461-0241.
2. "MIL-STD-461D Testing" Seminar Notebook. EMC Services.