EMC requirements for avionics: RTCA/DO-160D, Change No. 3

Multiple-burst and Multiple-stroke lightning tests are now included.

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RTCA/DO-160D, Environmental Conditions and Test Procedures for Air-borne Equipment, prepared by RTCA Special Committee 135, was issued on July 29, 1997, and superseded RTCA/DO-160C, Change Nos. 1, 2, and 3.[1, 2]

DO-160D covers standard procedures and environmental test criteria for testing airborne electronic equipment (avionics) for the entire spectrum of aircraft, from light general aviation aircraft and helicopters through the "Jumbo Jet" and SST classes of aircraft.

The document includes 25 sections and three Appendices, but it is Sections 15 through 23 and Section 25 that cover EMC. Examples of tests covered include temperature, vibration, power input, radio frequency susceptibility, lightning induced transients, and electrostatic discharge.

Coordinated with the European Organization for Civil Aviation Electronics (EUROCAE), RTCA/DO-160D and its European twin, EUROCAE/ED-14D, are identically worded. DO-160D is also recognized by the International Organization for Standardization (ISO) as the de facto international standard ISO-7137.

Change No. 1 to DO-160D, issued December 14, 2000, revised Section 8 – Vibration, and Section 20 – Radio Frequency Susceptibility (Radiated and Conducted). Change No. 2 to DO-160D, issued June 12, 2001, revised Section 16 – Power Input, and Section 18 – Audio Frequency Conducted Susceptibility – Power Inputs. Change No. 3 to DO-160D, issued December 5, 2002, revised Section 22 – Lightning Induced Transient Susceptibility, primarily to add procedures, waveforms, and test levels for multiple burst and multiple stroke test methods.

A review of the revised DO-160D Section 22 follows, along with an update on future revisions to DO-160.

SECTION 22: LIGHTNING INDUCED TRANSIENT SUSCEPTIBILITY

These tests determine whether the equipment-under-test (EUT) can operate as specified during and/or after various lightning induced transient waveforms are injected into connector pins, interconnecting cables, and power leads. The three test methods used are pin injection, cable induction, and ground injection. The pin injection method is normally used to show damage tolerance, while the cable induction and ground injection methods are normally used to show upset tolerance when the transients are applied to interconnecting cable bundles.

Change No. 3 adds multiple burst and multiple stroke tests for interconnecting cable bundles, using either cable induction or ground injection. New Waveform Set designators (G through K) were also added to cover the new tests.

PIN INJECTION TESTS

Three different test waveforms are used for pin injection testing:

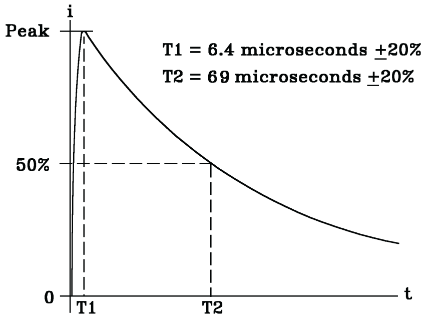

Figure 1. Test waveform 1.

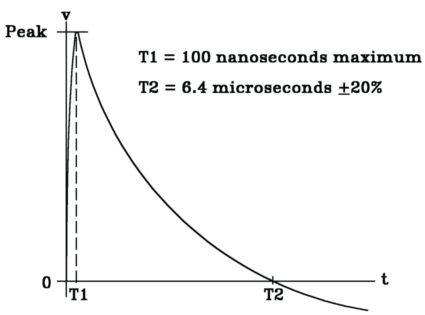

Figure 2. Test waveform 2

- *Waveform 3* – A damped sinusoidal waveform at 1.0 MHz (Figure 3)
- *Waveform 4* – A fast rise time double exponential voltage waveform (Figure 4)
- *Waveform 5A* – A slow rise time, double exponential waveform (Figure 5)

Test levels for the different pin injection waveforms are given in Table 1.

The test level is defined as an open circuit voltage (Voc) with a specified source impedance from the generator. For example, *Waveform 3*, test level 2 specifies Voc as 250 volts, with a short circuit current (Isc) of 10 amps. The ratio of Voc to Isc yields a generator source impedance requirement of 25 ohms. The generator is adjusted to pro-

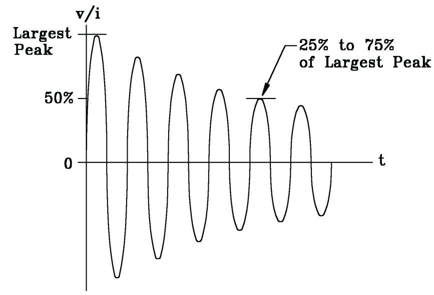

Figure 3. Test waveform 3.

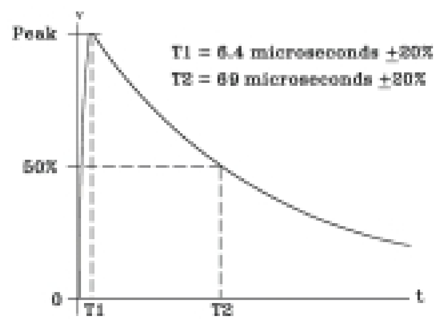

Figure 4. Test waveform 4.

duce *Waveform 3* with these specified characteristics, and then a minimum of ten transients of each polarity are applied directly to the interface pins.

Unless it is a very simple device (with electromechanical or passive circuitry only), the EUT is normally tested with power applied, so that the circuits being tested are biased as they would be in normal operation. Change No. 3 adds a requirement to calibrate and test with the power supply in the circuit, with an appropriate transient current bypass circuit across the output terminals of the supply.

A dielectric withstand or hi-pot test may be used as an alternative to the normal pin injection test, but only for simple devices. The hi-pot test voltage

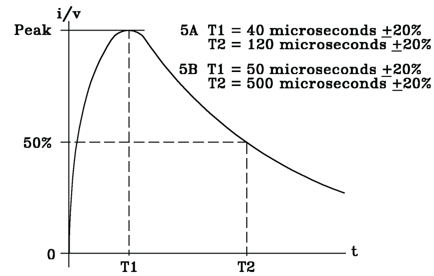

Figure 5. Test waveform 5.

level must be at the same or a higher level as the highest peak voltage specified for the waveform set for which compliance is being claimed.

After each of the pins has been tested, the EUT is evaluated to determine if its performance has degraded.

CABLE BUNDLE TESTS

Five different test waveforms are used for cable bundle testing:

- *Waveform 1* – A fast rise time, double exponential current waveform (Figure 1).
- *Waveform 2* – A very fast rise time double exponential voltage waveform (Figure 2).
- *Waveform 3* – A damped sinusoidal waveform at 1 and 10 MHz (Figure 3).
- *Waveform 4* – A fast rise time, double exponential voltage waveform (Figure 4).
- *Waveform 5A* – A slow rise time, double exponential waveform (Figure 5).

Cable bundle tests are performed using either cable induction or ground injection to couple the transient waveforms into the interconnecting cable bundles and power leads. A Line Impedance Stabilization Network (LISN)

Level	Waveforms		
	3	4	5A
	Voc/Isc	Voc/Isc	Voc/Isc
1	100/4	50/10	50/50
2	250/10	125/25	125/125
3	600/24	300/60	300/300
4	1500/60	750/150	750/750
5	3200/128	1600/320	1600/1600

Table 1. Pin injection test levels.

Level	Waveforms				
	1	2	3	4	5A
	V_L/I_T	V_T/I_L	V_T/I_L	V_T/I_L	V_L/I_T
1	50/100	50/100	100/20	50/100	50/150
2	125/250	125/250	250/50	125/250	125/400
3	300/600	300/600	600/120	300/600	300/1000
4	750/1500	750/1500	1500/300	750/1500	750/2000
5	1600/3200	1600/3200	3200/640	1600/3200	1600/5000

Table 2. Single stroke test levels.

must be inserted in series with each power lead and ungrounded power return lead, with a 10-μF capacitor connected between the power input of the LISN and the ground plane for AC-powered equipment, or with a 33,000-μF capacitor connected across the power inputs of the LISNs for DC-powered equipment. Unless otherwise specified, interconnecting cables shall be at least 3.3 meters in length, and power leads shall be no more than 1 meter in length for these tests.

For each waveform, either a voltage or current test level is given, along with a current or voltage limit. For example, *Waveform 2*, test level 3, specifies a voltage test level (VT) of 300 volts and a current limit (IL) of 600 A. Thus, during the test, the generator level is increased until the peak voltage measured on a single turn monitor loop placed through the injection probe reaches 300 volts or until the monitored induced current in the cable or lead reaches the 600 A-limit.

Cable bundle tests may be performed using the single stroke method only or by using a combination of the single stroke, multiple stroke, and multiple burst methods.

Single Stroke

The single stroke test method is designed to represent the internal aircraft wiring response to the most severe external aircraft lightning strike. A single occurrence (stroke) of the specified test waveform is applied to the cable bundle or wire-under-test and is repeated for a total of 10 applications in each polarity. No time interval between strokes is specified, but typically all 10 strokes are applied within 10 minutes. Test levels for the different single stroke waveforms are given in Table 2.

Multiple Stroke

The multiple stroke test method is designed to represent the induced effects to internal aircraft wiring in response to an external aircraft lightning strike that is composed of a first return stroke immediately followed by multiple return strokes. The multiple stroke test waveform is composed of a first (or initial) stroke at the specified voltage or current test level, followed by 13 subsequent strokes at half the first stroke level. The intervals between each of the 14 strokes are to be "random" (better described as "irregular") and to last no less than 10 milliseconds, and no more than 200 milliseconds (Figure 6). The specified test waveform is applied to the cable bundle or wire-under-test and is repeated for a total of 10 applications in each polarity. No time interval between applications is specified, but typically all 10 applications are applied within 10 minutes. Test levels for the different multiple stroke waveforms are given in Table 3.

Multiple Burst

The multiple burst test method is designed to represent the induced effects to internal aircraft wiring caused by an external aircraft lightning strike of a multiple burst nature. The multiple burst test waveform is composed of three bursts, with each burst composed of 20 strokes of *Waveform 3*, at the specified voltage test level. The intervals between each of the 20 strokes are to be "random" (better described as "irregular") but to last no less than 50 microseconds and no more than 1000 microseconds (Figure 6). The intervals between each of the three bursts are to be "random" (better described as "irregular") and to last no less than 30 milliseconds and no more than 300 milliseconds (Figure 7). The specified test waveform is applied to the cable bundle or wire-under-test and is repeated for at least 5 minutes in each polarity. The time interval between applications is specified at 3 seconds. Test levels for the different multiple burst waveforms are given in Table 4.

Cable Induction

This test method uses an injection probe to induce the transient waveforms into interconnecting cables and power leads. The induced current is monitored during the test using a current probe with a high coupling factor so as not to load down the cable or lead under test. The current probe output is connected to a digital oscilloscope to capture and save the test waveforms. The voltage applied to the EUT during the test is monitored using a monitor loop installed in the injection transformer along with the cable or lead under test. A high voltage/high impedance probe is attached to the monitor loop, and this probe is also connected to the digital oscilloscope to capture and save the test waveforms.

Ground Injection

This test method is very similar to the cable induction method, except that the transient waveform is applied between the EUT case and the ground plane, after the EUT has been isolated from the ground plane by lifting all local grounds and returns and by insulating the case from the ground plane. The injected transient is thus forced into the cable shields and any other return path it can find back to the ground plane. The voltage developed between the EUT and the ground plane is monitored during the test, as well as the current through the cable(s) under test. The test levels are specified and determined in the same way as used in the cable induction method.

EQUIPMENT CATEGORIES

The three-pin injection test waveforms are grouped together in two waveform sets (A and B), and the five cable bundle test waveforms are grouped together in four single stroke waveform sets (C through F). New for Change No. 3 are four combined single stroke, multiple stroke, and multiple burst waveform sets (G through K) for cable bundles.

Category designations consist of five characters that describe the pin and cable test waveform sets and test levels. For example, the category A3G43 indicates:

A – Pin Test Waveform Set A
3 – Pin Test level 3
G – Cable Bundle Waveform Set G

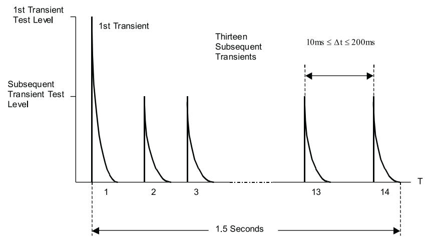

Figure 6. One multiple stroke application.

4 – Cable Bundle Single and Multiple Stroke Test level 4
3 – Cable Bundle Multiple Burst Test, level 3.

A designator of Z in any part of the category description is used to indicate a non-standard test waveform or level, and a designator of X is used to indicate no test is required.

THE LATEST FROM SPECIAL COMMITTEE 135

At the most recent (September 2002) meeting of SC-135, a timetable for the next round of revisions to DO-160 was proposed, and a tentative meeting schedule set with a goal of completing the next version, DO-160E, by the end of 2003. Almost every section of DO-160D has revisions pending and/or under discussion, and several new sections have been proposed to cover such things as Solar Radiation and Insulation Resistance. The next meeting of SC-135 will be held jointly with EUROCAE at their headquarters in Paris, in March 2003.

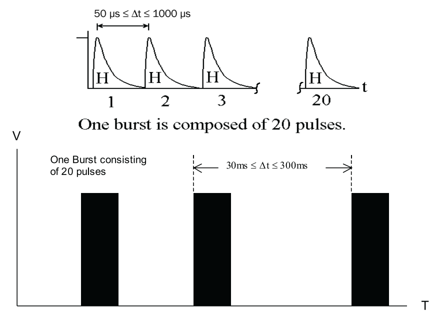

Figure 7. One multiple burst application.

SUMMARY

RTCA/DO-160 and its European twin, EUROCAE/ED-14, are the world standards for electromagnetic compatibility requirements for aircraft electronic equipment. DO-160D, Change No. 3, revised Section 22 to include detailed procedures, test waveforms, and test levels for multiple burst and multiple stroke lightning induced transient susceptibility. Since both aviation technology and EMC testing methodology are evolving at a rapid rate, work continues on the next revision (DO-160E).

Level	Waveforms
	3
	V_T/I_L
1	60/1
2	150/2.5
3	360/6
4	900/15
5	1920/32

Table 4. Multiple burst test levels.

REFERENCES

1. RTCA/DO-160D, "*Environmental Conditions and Test Procedures for Airborne Equipment.*" RTCA, Inc. (July 29, 1997).
2. RTCA/DO-160C, "*Environmental Conditions and Test Procedures for Airborne Equipment.*" RTCA, Inc. (December 4, 1989).

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Level		Waveforms				
		1	2	3	4	5A
		V_L/I_T	V_T/I_L	V_T/I_L	V_T/I_L	V_L/I_T
1	First Stroke	50/50	50/50	100/20	25/50	20/60
	Subsequent Stroke	25/25	25/25	50/10	12.5/25	10/30
2	First Stroke	125/125	125/125	250/50	62.5/125	50/160
	Subsequent Stroke	62.5/62.5	62.5/62.5	125/25	31.25/62.5	25/80
3	First Stroke	300/300	300/300	600/120	150/300	120/400
	Subsequent Stroke	150/150	150/150	300/60	75/150	60/200
4	First Stroke	750/750	750/750	1500/300	375/750	300/800
	Subsequent Stroke	375/375	375/375	750/150	187.5/375	150/400
5	First Stroke	1600/1600	1600/1600	3200/640	800/1600	640/2000
	Subsequent Stroke	800/800	800/1600	1600/320	400/800	320/1000

Table 3. Multiple stroke test levels.