Department of Transportation
**Federal Aviation Administration**
Aircraft Certification Service
Washington, DC

**TSO-C60b**

**Date:** 5/11/88

# Technical Standard Order

## Subject: TSO-C60b, AIRBORNE AREA NAVIGATION EQUIPMENT USING LORAN C INPUTS

a. Applicability.

(1) Minimum Performance Standard. This Technical Standard Order (TSO) prescribes the minimum performance standard that airborne area navigation equipment using Loran C inputs must meet in order to be identified with the applicable TSO marking. Airborne area navigation equipment using Loran C inputs that are to be so identified and that are manufactured on or after the date of this TSO must meet the minimum performance standard Section 2, Radio Technical Commission for Aeronautics (RTCA) Document No. DO-194, "Minimum Operational Performance Standards for Airborne Area Navigation Equipment Using Loran C Inputs," dated November 17, 1986, as amended and supplemented by this TSO.

(i) Waypoint Storage. Add the following requirement to paragraph 2.2.1.6 of RTCA/DO-194:

If the equipment has an approach mode, it shall store the complete sequence of waypoints for a selected approach. The sequence of waypoints shall consist of at least the following:

initial approach fix
final approach fix
missed approach point
missed approach holding point

The receiver must be designed in such a manner that waypoint coordinate data entry will not be possible when the approach mode has been selected. Waypoint coordinates, GRI, triad, and TD correction factors may be included in the equipment data base or manually input as specified in paragraphs 2.2.1.5 and 2.2.1.13.

DISTRIBUTION: ZVS-326; A-W(WS)-3; A-X(CD)-4; A-FFS-1, 2, 3, 7, 8(LTD); A-X(FS)-3; AVN-1(2cys); A-FAC-0(MAX)

(ii) Holding Pattern Maneuvering. Add the following requirement to RTCA/DO-194:

The equipment shall provide the capability to proceed to a selected waypoint and hold on a specified inbound course to the waypoint with repeated crossing of the selected waypoint.

(iii) Failure/Status Indications. Add the following requirement to paragraph 2.2.1.10 of RTCA/DO-194:

In the approach mode, the lack of adequate navigation signals or sources shall be annunciated by means of a flag displayed on the primary navigation display. In other modes, an appropriately located annunciator may be used to satisfy this requirement.

In lieu of the loss of signal and cycle slip requirements specified paragraphs 2.2.1.10(b)(2) and (3) of RTCA/DO-194, substitute the following requirements:

(2) Loss of signal - The equipment shall detect loss of signal within 30 seconds for en route and terminal and 10 seconds for approach.

(3) Cycle slip - The equipment shall detect or correct a cycle slip within 10 minutes with a 90% probability after occurrence for en route and terminal mode operation, and shall present an alarm or correct a cycle slip within 10 seconds in the approach mode. In addition, if the equipment encounters a cycle slip for a station and is switched to approach mode using that station for navigation, the equipment shall, within 10 seconds, present an alarm or have that station back in proper track.

(iv) Table 2-1B, 2D RNAV Loran C equipment Accuracy Requirements and Total System Error Evaluation. In lieu of the oceanic accuracy requirements specified in Table 2-1B of RTCA/DO-194, substitute the following requirement:

| Error Type | Oceanic | |
|---|---|---|
| | XTK | ATK |
| equipment (nmi) | 12.6 | 12.6 |
| FTE (nmi) | 2.0 | N/A |
| Total (nmi) | 12.8 | 12.6 |

(v) Envelope-to-Cycle Discrepancy (ECD). In lieu of paragraph 2.2.3.2 of RTCA/DO-194, substitute the following requirement:

The equipment shall be able to properly acquire and track signals with an ECD of 0 to –2.4 microseconds at signal-to-noise ratios from –6 to –16 dB, and an ECD of –2.4 to +3.5 microseconds at signal-to-noise ratios above –6 dB.

(vi) Table 2-6, Loran Signal test Conditions. In lieu of Table 2-6 of RTCA/DO-194, substituted the following requirement:

Table 2-6, Loran Signal test Conditions

| Test | Test | | Groundwave Noise | | | | | | | | | CRI | | | CWI | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Case | Subject | GRI | $S_m$ | $S_x$ | $S_y$ | $S_n$ | $T_{sw}$* | $S_{sw}$* | $ECD_m$ | $ECD_x$ | $ECD_y$ | $S_{cr}$ | $F_1$ | $S_1$ | $F_2$ | $S_2$ |
| 1 | Dyn. Range | 4990 | 110 | 30 | 30 | 30 | | | +3.5 | 0 | –2.4 | | | | | |
| 2 | ECD | — | 40 | 40 | 40 | 46 | | | 0 | 0 | 0 | | | | | |
| 3 | | ↑ | 40 | 40 | 40 | 46 | | | 0 | –2.4 | 0 | | | | | |
| 4 | | \| | 40 | 40 | 40 | 56 | | | 0 | –2.4 | –2.4 | | | | | |
| **5 | Skywave | \| | 40 | 40 | 40 | 56 | 35 | 46 | 0 | 0 | 0 | | | | | |
| 6 | | \| | 40 | 40 | 40 | 56 | 37.5 | 50 | 0 | 0 | 0 | | | | | |
| 7 | | \| | 40 | 40 | 40 | 56 | 40 | 50 | 0 | 0 | 0 | | | | | |
| 8 | | \| | 40 | 40 | 40 | 56 | 42.5 | 55 | 0 | 0 | 0 | | | | | |
| 9 | | btwn | 40 | 40 | 40 | 56 | 45 | 60 | 0 | 0 | 0 | | | | | |
| 10 | | 7980 | 40 | 40 | 40 | 56 | 50 | 60 | 0 | 0 | 0 | | | | | |
| 11 | | and | 40 | 40 | 40 | 56 | 55 | 65 | 0 | 0 | 0 | | | | | |
| 12 | | 9990 | 40 | 40 | 40 | 56 | 35 | 46 | –2.4 | –2.4 | –2.4 | | | | | |
| 13 | | \| | 40 | 40 | 40 | 56 | 37.5 | 50 | –2.4 | –2.4 | –2.4 | | | | | |
| 14 | | \| | 40 | 40 | 40 | 56 | 40 | 50 | –2.4 | –2.4 | –2.4 | | | | | |
| 15 | | \| | 40 | 40 | 40 | 56 | 42.5 | 55 | –2.4 | –2.4 | –2.4 | | | | | |
| 16 | | \| | 40 | 40 | 40 | 56 | 45 | 60 | –2.4 | –2.4 | –2.4 | | | | | |
| 17 | | \| | 40 | 40 | 40 | 56 | 50 | 60 | –2.4 | –2.4 | –2.4 | | | | | |
| 18 | | \| | 40 | 40 | 40 | 56 | 55 | 65 | –2.4 | –2.4 | –2.4 | | | | | |
| 19 | CWI | \| | 60 | 60 | 60 | 60 | | | 0 | 0 | 0 | | 88.0 | 80 | 76.3 | 80 |
| 20 | | \| | 60 | 60 | 60 | 60 | | | 0 | 0 | 0 | | 119.85 | 80 | 124 | 80 |
| 21 | | \| | 60 | 60 | 60 | 60 | | | 0 | 0 | 0 | | 76.3 | 80 | 113 | 80 |
| 22 | | ↓ | 50 | 50 | 50 | 50 | | | 0 | 0 | 0 | | 48.5 | 110 | 214 | 110 |
| 23 | | — | 80 | 50 | 50 | 50 | | | +1.5 | –2.4 | –2.4 | | | | | |
| 24 | CRI 3/ | 7980 | 110 | 50 | 50 | 50 | | | 0 | –2.4 | –2.4 | 110 | | | | |
| 25 | 4/ | 7930 | 40 | 40 | 40 | 40 | | | 0 | 0 | 0 | 40 | | | | |
| 26 | ECD | 4990 | 30 | 110 | 30 | 30 | | | –2.4 | +3.5 | 0 | | | | | |

Definitions:

| | |
|---|---|
| $S_m$, $S_x$, $S_y$ | Signal strength in dB microvolts per meter of the Master, X and Y stations |
| $S_n$ | Signal strength of atmospheric noise in dB microvolts per meter (see paragraph (a)(1)(vii) of TSO C60b) |
| $T_{sw}$ | Skywave delay with respect to groundwave |
| $S_{sw}$ | Signal strength of skywave in dB microvolts per meter |
| $S_{cr}$ | Cross-rate signal strength in dB microvolts per meter 3/ |
| $F_1$ | Frequency of the i-th CW interferer |
| $S_1$ | Signal strength of the i-th CW interferer in dB microvolts per meter |

* Skywave and signal strength are for secondary signals only, zero for master.

** For cases 5 thru 18, the skywave delay is from the ground wave cycle zero crossing to the skywave cycle zero crossing and the skywave ECD is equal to 0.

3/ Cross-rate GRI = 9960 master

4/ Cross-rate GRI = 7970 master and four secondaries

## NOTES FOR TABLE 2-6:

(1) dB microvolts per meter equals dB above 1 microvolts per meter.

(2) The interference frequencies contained in Table 2-6 are based upon the existing environment at the time of publication. It is recognized that this environment could change over time, including the possible need for more than four notch filters. The

manufacturer may select different/additional interference test frequencies (using the criteria of paragraph 2.2.3.3) if it is shown that the frequencies specified in Table 2-6 are inappropriate.

(vii) 2D Failure Indication. Add the following requirements to paragraph 2.5.2.6 of RTCA/DO-194:

Demonstrate that the equipment displays appropriate warning annunciations whenever accuracy or other status indication (blink, cycle slip, low SNR, loss of signal, etc.) requirements applicable to the selected mode of operation cannot be assured. Test conditions applicable to the particular equipment being evaluated, including limiting SNR and station geometry considerations, shall be established by the equipment manufacturer to verify proper operation. Should the equipment manufacturer establish an operating SNR lower than –16 dB, the noise signal level ($S_n$) of Table 2-6, test cases 4 thru 18, shall be increased to obtain the selected lower SNR level for all tests using these cases.

(viii) Acquisition Under Combined Conditions. In lieu of paragraph 2.5.2.7 of RTCA/DO-194, substitute the following requirement:

The capabilities identified in paragraphs 2.2.3.1 through 2.2.3.5 shall be demonstrated by subjecting the equipment to the following test.

Establish each of the conditions of Table 2-6 for a simulated chain of a master and two secondaries. For each of these conditions have the equipment acquire the signal 10 times. For Test Nos. 5 thru 23, acquisition on the proper cycle shall be achieved within 450 seconds in 9 out of 10 trials and within 600 seconds in 10 out of 10 trials. For Test Nos. 1 thru 4 and 24 thru 26, acquisition on the proper cycle shall be achieved in 10 of 10 trials within 450 seconds.

Proper acquisition may be determined by observing TD values or Lat/Long output displayed by the equipment, and is considered successful if the signal is correctly acquired within the specified time period. Acquisition on the incorrect cycle is considered a failure.

If the equipment uses previous position data as an aid in acquisition, at least 50% of the acquisition tests shall be accomplished without the benefit of this data.

(ix) Cycle Slip. In lieu of paragraph 2.5.2.12 of RTCA/DO-194, substitute the following requirement:

Establish the conditions of Table 2-6, test cases 4 thru 23, with the enroute mode selected and a simulated chain of a master and two secondaries. Raise the noise level 20dB for 10 seconds and during the same interval also change one of the TDs by ±10 microseconds. Observe that within 10 minutes there is an alarm or that the 10 microsecond tracking error has been corrected. The TD change shall be accomplished by altering the TC +10 microseconds 5 times and –10 microseconds 5 times for each test case for a total of 200 trials. The test must be successful (result in an alarm or correction of the error) in at least 9 of 10 trials for each test case with no more than 5 failures overall.

Establish the conditions of Table 2-6 test cases 4, 5, 17, and 23 with the enroute mode selected and a simulated chain of a master and two secondaries. Turn off one secondary signal for 10 seconds and during the same interval, change that secondary TD by ±10 microseconds. Observe that within 10 minutes there is either an alarm or that the 10 microseconds tracking error has been corrected. The TD change shall be accomplished by altering the TD +10 microseconds 5 times and –10 microseconds 5 times for each test case, for a total of 40 trials. The test must be successful (result in an alarm of correction of the error) in at least 39 of the 40 trials.

Set up the equipment as indicated in Figure 2-3, accelerate one secondary station signal while maintaining a known reference. Set the following conditions:

| | | |
|---|---|---|
| GRI | = | 7980 |
| $TD_1$ | = | 28,417 microseconds |
| $TD_2$ | = | 11,128 microseconds |
| SNR | = | The lower of –14dB or 2 dB above any lower operating SNR established by the equipment manufacturer. |

Using the signal test conditions of Table 2-6, test case 4 with $S_n$ adjusted to establish the required SNR, accelerated $TD_2$ at 0.0567 microsecond/second/second or more until $TD_2$ = 11.133 microseconds then decelerate at the same rate until $TD_2$ = 11,138 microseconds. After zero velocity is reached, wait 10 minutes. Observe that the signal is being tracked on the proper cycle or that there is an alarm. Repeat this procedure with $TD_2$ values decreasing to 11,118 microseconds using the same method. Repeat this test a sufficient number of times to establish its success (result in an alarm or correction of the error) 90% of the time with a 95% confidence level. A 95% confidence level can be achieved by conducting 30 trials (each 10 microsecond TD variation constitutes a trial) with zero failures, 48 trials with 1 failure, 63 trials with 2 failures, etc.

If the equipment has an approach mode:

Establish the conditions of Table 2-6, test cases 1, 2, and 23 with a simulated chain of a master and two secondaries. Raise the noise level 35 dB for 10 seconds and during this interval also change one of the TDs by ±10 microseconds. Wait five minutes. Switch to approach mode. Observe that within 10 seconds there is either an alarm or that the 10 microsecond tracking error has been corrected. The TD change shall be accomplished by altering the TD + 10 microseconds 10 times and –10 microseconds 10 times for each test case for a total of 60 trials. All trials must be successful.

Establish the conditions of Table 2-6, test cases 1 and 2 with a simulated chain of a master and two secondaries. Turn off one secondary signal for 10 seconds and during the same interval, change that secondary TD by ±10 microseconds. Wait 5 minutes. Switch to approach mode. Observe that within 10 seconds there is either an alarm or that the 10 microsecond tracking error has been corrected. The TD change shall be accomplished by altering the TD +10 microseconds 10 times and –10 microseconds 10 times for each test case, for a total of 40 trials. All trials must be successful.

Establish the conditions of Table 2-6, test cases 1, 2 and 23 with the approach mode selected and simulated chain of a master and two secondaries. Raise the noise level 35 dB for 10 seconds and during this interval also change one of the TDs by ±10 microseconds. Observe that within 10 seconds there is either an alarm or that the 10 microsecond tracking error has been corrected. The TD change shall be accomplished by altering the TD +10 microseconds 10 times and –10 microseconds 10 times for each test case for a total of 60 trials. All trials must be successful.

(x) Atmospheric Noise Model. In demonstrating compliance with this TSO, the following model may be used to simulate atmospheric noise. The applicant may select a different model provided adequate substantiation is submitted to establish validity of the selected model.

Atmospheric noise is basically composed of two components, one a very weak component which has a Gaussian distribution. This first component may be simulated as follows: Simulated random noise (Gaussian) will be considered to have a uniform power spectral density prior to filtering. After filtering by a single resonator L-C filter having a center frequency of 100 kHz and 3 dB bandwidth of 30 kHz, the noise level is the voltage generated across a 50-ohm resistive load measured on a true rms voltmeter; this noise level is defined as the rms noise level, denoted by X. This component is taken as 15.85% of the total noise power. The remaining 84.15% of the noise power is composed of the second component. This second component is simulated by pulses of 100 kHz, 30 microseconds wide, the rms value of which is A times X. The average number of pulses per second (P) is nominally 50 and lies in the range 40-60. The pulses (tone bursts) are randomly distributed (Poisson) in time. The linear addition of these two components is the simulated atmospheric noise with level N.

(1) $N^2$ = total noise power = $X^2 + (30 \text{ X } 10^{-6})PA^2X^2$

(2) Since $(30 \text{ X } 10^{-6})PA^2 = \dfrac{84.15}{15.85} = 5.309$

Using P = 50 pps and solving (2) for A gives A = 59.9

$N^2$ = total noise power
X = rms value of Gaussian noise
A = relative amplitude of 100 kHz pulse
P = number of pulses per second

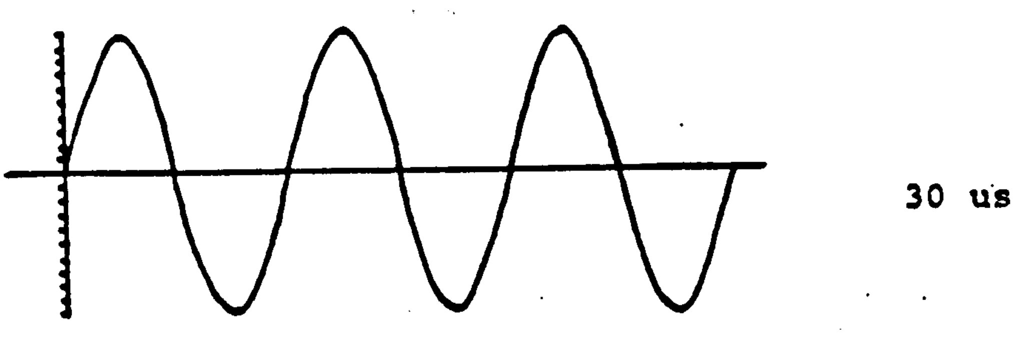
Signal strength in dB microvolts per meter referenced in Table 2-6 and elsewhere shall be converted to voltages at the space coupling node of Figure 2-1 by multiplying by the effective electrical height (in meters) of the simulated antenna. Atmospheric noise in dB microvolts per meter, $S_n$, is converted to voltage by the expression

$$\left[\frac{S_{n\,(dB)} \text{ x effective antenna height}_{(meters)}}{20}\right]$$

$S_{n\ (voltage)} = 10$

Set this value equal to the total noise total noise power, $N^2$, in the atmospheric noise model and solve equation (1) for X. The result is the desired rms value of Gaussian noise measured across the 50-ohm resistive load.

$\sqrt{2}$ AX




100 kHz Tone Burst

(2) Environmental Standard. RTCA Document No. RTCA/DO-194 incorporates as a reference RTCA Document No. DO-160B, "Environmental Conditions and Test Procedures for Airborne Equipment," dated July 1984.

(3) Computer Software. If the equipment design implementation includes a digital computer, the computer software must be verified and validated in an acceptable manner. One acceptable means of compliance for the verification and validation of the computer software is outlined in RTCA Document No. DO-178A, "Software Considerations in Airborne Systems and Equipment Certification," dated March 1985. For those applicants who elect to use RTCA Document No. DO-178A to demonstrate compliance for the verification and validation of the computer software, the following requirements must be met:

(i) RTCA Document DO-178A defines three levels of software: Level 1, Level 2, and Level 3. The applicant must declare the level (or levels) to which the computer software has been verified and validated. This equipment may incorporate more than one software level. The software for navigation functions must be verified and validated to at least Level 2.

(ii) The applicant must submit a software verification and validation plan for review and approval.

NOTE: The Federal Aviation Administration (FAA) strongly recommends early discussion and agreement between the applicant and the FAA on the applicant's proposed software verification and validation plan, and the applicant's proposed software level or levels.

b. Marking. In addition to the marking specified in Federal Aviation Regulations (FAR) Section 21.607(d), the following information shall be legibly and permanently marked on the major equipment components:

(1) Each separate component of equipment that is manufactured under this TSO (antenna, receiver, etc.) must be permanently and legibly marked with at least the name of the manufacturer the TSO number.

(2) With regard to FAR Section 21.607(d)(2), the part number is to include hardware and software identification, or a separate part number may be utilized for hardware and software. Either approach must include a means for showing the modification status.

(3) The level(s) to which the computer software has been verified and validated.

c. Data Requirements.

(1) In addition to FAR Section 21.605, the manufacturer must furnish the Manager, Aircraft Certification Office (ACO), Federal Aviation Administration, having purview of the manufacturer's facilities, one copy each of the following technical data:

(i) Operating instructions.

(ii) Equipment limitations.

(iii) Installation procedures and limitations.

(iv) Schematic drawings as applicable to the installation Procedures.

(v) Wiring diagrams as applicable to the installation procedures.

(vi ) Specifications.

(vii) List of the major components (by part number) that make up the equipment system complying with the standards prescribed in this TSO.

(viii) An environmental qualification form as described in RTCA Document No. DO-160B.

(ix) Manufacturer's TSO qualification test report.

(x) Nameplate drawing.

(xi) The appropriate documentation as defined in RTCA/DO-178A, or equivalent, necessary to support the verification and validation of the computer software to Level 1, Level 2, or Level 3. If the software is verified and validated to more than one level, the appropriate documentation for all such levels must be submitted.

(2) In addition to those data requirements that are to be furnished directly to the FAA, each manufacturer must have available for review by the Manager of the ACO having purview of the manufacturer's facilities, the following technical data.

(i) A drawing list, enumerating all the drawings and processes that are necessary to define the article's design.

(ii) The functional test specification to be used to test each production article to ensure compliance with this TSO.

(iii) Equipment calibration procedures.

(iv) Corrective maintenance procedures (within 12 months after TSO authorization).

(v) Schematic drawings.

(vi) Wiring diagrams.

(vii) Documentation to support the computer software verification and validation plan for Level 1, Level 2, or Level 3 software.

(viii) The appropriate documentation as defined in RTCA/DO-178A, or equivalent, necessary to support the verification and validation of the computer software to Level 1, Level 2, or Level 3. If the software is verified and validated to more than one level, the appropriate documentation for all such levels must be available for review.

(ix) The results of the environmental qualification tests conducted in accordance with RTCA DO-160B.

d. Data to be Furnished with Manufactured Units. One copy of the data and information specified in paragraphs (c)(l)(i) through (viii) of this TSO, and instructions for periodic maintenance and calibration which are necessary for continued airworthiness must go to each person receiving for use one or more articles manufactured under this TSO. In addition, a note with the following statement must be included:

> "The conditions and tests required for TSO approval of this article are minimum performance standards. It is the responsibility of those desiring to install this article either on or within a specific type or class of aircraft to determine that the aircraft installation conditions are within the TSO standards. If not within the TSO standards, the article may be installed only if further evaluation by the applicant documents an acceptable installation and is approved by the Administrator."

e. Availability of Reference Documents.

(1) Copies of RTCA Document Nos. DO-194, DO-160B, and DO-178A may be purchased from the Radio Technical Commission for Aeronautics Secretariat, One McPherson Square, Suite 500, 1425 K Street, NW., Washington, DC 20005.

(2) Federal Aviation Regulations 21, Subpart O, and Advisory Circular 20-110C, "Index of Aviation Technical Standard Orders," may be reviewed at the FAA Headquarters in the Office of Airworthiness, Aircraft Engineering Division (AWS-120), and at all regional ACO's.

/S/ M.C. Beard
Director of Airworthiness