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

TSO-C87

Date: 2/1/66

Technical Standard Order

Subject: TSO-C87, AIRBORNE LOW-RANGE RADIO ALTIMETER

TITLE 14–AERONAUTICS AND SPACE

Chapter 1–Federal Aviation Agency [Docket No. 6545; Amendment 37-4]

PART 37–TECHNICAL STANDARD ORDER

Airborne Low-Range Radio Altimeter Equipment

The purpose of this amendment is to add a new Technical Standard Order (TSO) for Airborne Low-Range Radio Altimeter Equipment to Part 37 of the Federal Aviation Regulations. This TSO contains the minimum performance standards which such equipment must meet in order for the manufacturer to identify it with the applicable TSO marking.

The amendments set forth hereinafter are based on, and reflect the pertinent comments received concerning Notice 65-8, published 30 F.R. 4206, March 31, 1965. Except as modified by the following discussion, the reasons for these amendments are those contained in the notice.

In connection with the foregoing, comments were received pointing out certain problems which would be encountered in demonstrating the accuracy for radio-altimeters in-flight measurements must be made, a relaxation of the in-flight accuracy requirements was suggested in recognition of the additional instrumentation errors associated with in-flight measurements. Moreover, because of the difficulties of measurement of some of the parameters it was recommended that the various measurement conditions need not be applied simultaneously but may be combined by analytical methods. Finally, since some of the in-flight testing could introduce hazards to those conducting the tests at very low altitudes, it was suggested that the TSO permit showing of compliance with the accuracy requirements by suitable combination of direct measurement data from laboratory tests, supplemented by appropriate in-flight measurements, calculations and extrapolations where it is no practical to obtain direct measurements. It was intended in the proposal to permit the use of other methods and laboratory test procedures in meeting the standard. The Agency, therefore, agrees that in-flight and laboratory data with calculations and extrapolations are acceptable to substantiate the performance of the equipment under various measurement conditions. Furthermore, the Agency believes that the regulation should permit the data to be obtained under individual measurement conditions and the results combined by analytical methods to determine overall performance under combinations of measurement conditions. However, the Agency considers that is these procedures are followed, the accuracy requirements of the proposal can be met without additional allowance for instrumentation errors. The requirements of paragraph 2.0 of the standard have been clarified in accordance with the foregoing.

A comment was also received to the effect hat the requirements of the proposed paragraph 2.1, Accuracy of Pilot's Display, with the changes in vertical velocity specified under paragraph 2.4, Time Constant, may not provide satisfactory operation for aircraft approaches over built-up areas where buildings appear at random within the altimeter beam. It was suggested that there would be a danger of frequent loss of lock in a system just meeting these minimum performance requirements. However, the Agency is aware that on the final approach to landing, where operation of the radio altimeter would become critical, the terrain is generally flat and relative free of buildings or high objects which could contribute to a frequent loss of lock in a system meeting the minimum standards.

In response to a comment received, a clarifying sentence has been added to the note following Table I in paragraph 2.1, stating that the altitude presented by the radio altimeter may be offset by the vertical distance between the antennas and the terrain at touchdown. This will allow the instrument to be calibrated to read zero with the aircraft in a touchdown attitude which is the way the altimeter is normally used.

According to one commentor, the proposed requirement for accuracy of radio altitude display is too restrictive and would rule out the use of radio altitude displays incorporated as part of the flight director display. It was suggested that a note be added to the standard which would, in effect, permit the use of a flight director display in lieu of the indicator provided for the radio altimeter. The basic radio altimeter indicator, which provided altitude information with the required accuracy, is used to alert the pilot when the minimum decision altitude is reached. Since integrated flight director instruments do not provide the required accuracy for this function, we do not concur that the proposal should be changed as suggested.

Several comments recommended that the performance requirements for the Failure Warning System set forth in paragraph 2.6 of the minimum standards be changed to simplify the conditions under which the system must alarm. The comments also recommended the deletion of the requirement that the radio altimeter be designed so that the indicator pointer would move off scale and be masked upon activation of the warning system. After consideration of these comments and after further study by the Agency, the proposed requirements concerning the failure warning system have been changed as recommended. In this connection, the Agency now believes that the failure warning system need only indicate to the pilot or any system utilizing the altimeter data when there is a loss of power or a loss of signal or altitude sensing capability within the manufacturer's stated operating altitude range. Moreover, the proposed visual alarm indicator characteristic requirements have been changed to delete the requirement concerning the masking of the indicator pointer of the digits, if a digital indicator is used. These changes represent a relaxation of the requirements set forth in Notice 65-8, while at the same time, providing the necessary warning system.

In the proposal, a self-test feature was not required for the radio altimeter. However, the proposal did contain minimum performance standards for such a feature if it were provided. In response to comments received the Agency has subsequently determined that the proposed requirement that the self-test feature be so designed that it would not cause a response in the auto-pilot or any other system is not appropriately a design requirement by rather an installation requirement. Moreover, it now appears that the performance standards proposed for the self-test feature are not necessary by the standard need only require that any probable malfunction of the self-test feature will not degrade the performance of the radio altimeter.

The maximum altitude range for the radio altimeter has bee changed to 500 feet in response to comments received. At the time the notice was issued, it was felt that the pilot should have accurate altitude information from 1,200 feet to touchdown for a safe instrument approach under Category II minimums. Experience since than has shown that accurate altitude information from 500 feet to touchdown is sufficient.

A recommendation was made that the vibration requirements of Categories A and F of the FAA Environmental Test Procedures for Airborne Electronic Equipment should be increased since they are less than the vibrations which have been measured in some light helicopters in the low frequency range. The Agency is aware that a vibration environment more severe than that set forth in the Environmental Test Procedures may exist for light helicopters. However, the comment did not contain sufficient data to support the recommended change and the Agency has not had sufficient experience on which to base such a change. Therefore, the recommended change has not been made pending further study by the Agency.

A comment was received listing various features as being desirable for radio altimeters from an operational standpoint and recommending that such features be included in the required minimum standards. While certain of the features listed were provided for in the proposed minimum performance standards, the Agency does not have sufficient justification to warrant establishing the remaining features as minimum requirements. Moreover, a change incorporating such features as minimum standards would be outside the scope of Notice 65-8.

A comment was received recommending that the Technical Standard Order be limited in scope to equipment used in air carrier aircraft. In response to this comment, it should be pointed out that TSO's are directions to manufactures holding authorizations under the system. As Part 37 indicates, the minimum performance standards set forth in the manufacturer must show compliance in order to identify his article with the applicable TSO marking. The Technical Standard Order system merely provides one means by which equipment is approved and unless the operating rules require that equipment be TSO-approved, an operator may use any approved equipment. For this reason, reference to the type of operations in which such equipment might be used was not incorporated into the applicability provision of the TSO on radio altimeters as set forth in Notice 65-8 and the recommended change has not been made to the final rule.

With respect to the provisions of Appendix A of the proposed minimum standards, a comment was made that the simulator described in paragraph 1.6 of the appendix is not practical for simulation of high altitudes due to excessive attenuation in long coaxial cables. It was suggested that if the higher altitude simulations are desired, the paragraph be rewritten to be more general in it instrumentation requirements reflecting the basic necessity to test the altimeter for adequate RF sensitivity and sufficient readout accuracy. Paragraph 1.6 describes an acceptable altitude simulator, which simulates the operation of the radio altimeter at low altitudes where precise altitude measurements are required. Therefore, the Agency considers the standard adequate as proposed.

There were a number of comments based on the recommendation that the value selected for the vertical incidence unit scattering radar cross section of the ground, 0^{-}_{0} (0), be changed from 0.006 to 0.08. However, the Agency does not consider such a change to be appropriate. A considerable amount of data accumulated for both pulse and FM/CW radio altimeters in the 4,200-4,400 Mc region involving many flight tests over a wide variety of terrain and practical problems of adjustment, maintenance, and calibration was used in arriving at a value of , 0^{-}_{0} (0) = 0.006. The recommended value of 0^{-}_{0} (0) = 0.08 would result in derogation of the equipment and could result in unsatisfactory operation of the equipment under all operating conditions which may be encountered is service. Therefore, the Agency does not consider this recommended change or any of the changes related to such recommendation appropriate as amendments to the proposal.

In addition to the foregoing, there were several minor changes made in the proposed standard for the purpose of clarifying the requirements or correcting typographical errors in the notice.

This amendment is issued under the authority of sections 313(a) and 601 of the Federal Aviation Act of 1958 (49 U.S.C. 1354 and 1421).

In consideration of the foregoing and pursuant to the authority delegated to me by the Administrator (25 F.R. 6489) Part 37 of the Federal Aviation Regulations (14 CFR Part 37), is amended by adding a new § 37.195 as set forth below effective February 1, 1966.

Issued in Washington, D.C., on December 8, 1965.

C.W. Walker,
Acting Director,
Flight Standards Service.

§ 37.195 Airborne Low-Range Radio Altimeters — TSO-C87.

(a) *Applicability.* This Technical Standard Order prescribes the minimum performance standards which airborne low-range radio altimeter equipment must meet in order to be identified with the applicable TSO marking. New models of the equipment which are to be so identified and which are manufactured on or after the effective date of this section must meet the Minimum Performance Standards For Airborne Low-Range Radio Altimeters set forth at the end of this section.

(b) *Markings*. (1) In addition to the markings required by § 37.7, the equipment must be marked to indicate the environmental extremes over which it has been designed to operate. There are six environmental procedures outlined in the "Environmental Test Procedures for Airborne Electronic Equipment" which have categories established. These must be identified on the nameplate by the words "Env. Cat." followed by six letters which identify the categories designated in the document. Reading from left to right, the category designations must appear on the nameplate in the following order so that they may be readily identified —

(i) Temperature-altitude category;

(ii) Vibration category;

(iii) Audio-frequency magnetic field susceptibility category;

(iv) Radio-frequency susceptibility category;

(v) Emission of spurious radio-frequency energy category; and

(vi) Explosion category.

(2) A typical nameplate identification might be as follows: Env. Cat. DBAAAX.

(3) If a manufacturer desires to substantiate his

equipment under two categories, he must mark the nameplate with both categories in the space designated for that category by placing one letter above the other in the following manner:

Env. Cat. ABAAAX
D

(c) *Data requirement.* In accordance with §37.5, the manufacturer must furnish to the Chief, Engineering and Manufacturing Branch, Flight Standards Division, Federal Aviation Agency, in the region in which the manufacturer is located, the following technical data:

(1) Manufacturer's operating instructions and equipment limitations.

(2) Installation procedures with applicable schematic drawings, wiring diagrams, and specifications. Any limitations, restrictions, or other conditions pertinent to installation must be indicated.

(3) One copy of the manufacturer's test report.

(d) *Previously approved equipment.* Airborne low-range radio altimeter models approved prior to the effective date of this section may continue to be manufactured under the provisions of their original approval.

MINIMUM PERFORMANCE STANDARDS FOR AIRBORNE LOW-RANGE RADIO ALTIMETERS

1.0 *General Standards.*

1.1 *Rating of Components.* The equipment shall not incorporate any component of such rating that, when the equipment is operated throughout the range of the specified environmental tests, the rating established by the manufacturer of the component is exceeded. For electron tubes and transistors, either the tube or manufacturer's continuous commercial service rating, his established pulse rating, or his approved rating as applied to the particular application, whichever is appropriate, shall apply, except for the heaters and filaments. The voltage applied to the heaters and filaments of electron tubes shall be within 5 percent of the manufacturer's rating, or at a value approved by the tube manufacturer for the particular service, when the equipment is operated under standard operating conditions. When the heaters and filaments are connected in series, the 5 percent tolerance shall apply to the sum of their voltage ratings.

1.2 *Operation of Controls.* The operation of controls intended for use during flight, at all possible position combinations and sequences, shall not result in a condition whose presence or continuation would be detrimental to the continued performance of the equipment.

1.3 *Accessibility of Controls.* Controls which are not normally adjusted in flight shall not be readily accessible to flight personnel.

1.4 *Effects of Tests.* Unless otherwise stated, the application of the specified tests shall produce no subsequently discernible conditions which would be detrimental to the continued performance of the equipment.

2.0 *Minimum Performance Standards Under Standard Conditions*

The test procedures applicable to the determination of the performance of airborne low-range radio altimeter equipment under standard conditions are set forth in Appendix A of this standard. Test procedures which provide equivalent information may be used. Compliance with the performance requirements may be shown by an appropriate combination or data obtained from the laboratory and/or flight measurements. Calculations and extrapolations employing the basic test data may be used to make a direct determination of equipment performance by means of these basic test procedures.

2.1 *Accuracy of Pilot's Display.* The altitude information displayed for the pilot's use shall not exhibit errors in excess of those set forth in Column 1 of Table I for 95 percent of all observations conducted under any combination of the measurement conditions listed with the table.

NOTE: The above measurement conditions need not be applied simultaneously by may be combined by analytical methods.

TABLE I. - ACCURACY REQUIREMENTS AND MEASUREMENT CONDITIONS

Altitude (ft)*	*Vertical velocity (ft./sec.)*	*Column 1- Pilot's display*	*Column 2- Precision equipment output (ft.)*
3 to 100	0 to 15	±5 ft.	±3 ft
100 to 500	0 to 20	±5 %	±3 %
500 to that altitude for which the equipment is designed	0 to 20	±7 %	±5 %

*That "one-way" distance measured form the antenna to the terrain. The altitude may be offset by a distance equal to the vertical distance between the antennas and the terrain at touchdown.

Measurement Conditions:

(1) Lateral velocities from 0 to 50 feet per second.

(2) Longitudinal velocities from 0 to 300 feet per second.

(3) Pitch angel range of 0 to ±15 degrees.

(4) Roll angel range of 0 to ±20 degrees.

(5) Vertical velocity from 0 to 15 feet per second up to 100 feet and 0-20 feet per second above 100 feet.

NOTE: Conditions 1 though 5 above include all associated Doppler shift and step errors.

Further, the equipment shall continue to function and provide altitude information which exhibits no errors in excess of ±20 percent of the indicated altitude for 95 percent of all observations at bank angles from 20 to 30 degrees.

2.2 *Accuracy of the Precision Equipment Output.* The equipment need not provide as a condition of compliance with this minimum performance standard a precision equipment output for use in conjunction with autopilots, flight directors, or similar flight control computing devices. However, the altitude data supplied by such outputs, where provided, shall not exhibit errors in excess of those set forth in Column 2 of Table I for 95 percent of all observations conducted under any combination of the measurement conditions listed in 2.1.

2.3 *Precision Equipment Output Noise.* The r.m.s. noise content of the data provided by the precision equipment output shall be less than 0.25 foot at all altitudes up to 100 feet.

2.4 *Time constant.* When the equipment is abruptly subjected to an altitude change of not more than 10 percent of the indicated altitude or 20 feet whichever is smaller the transfer function time constant of the precision equipment output shall not exceed 0.1 second. Further, for transients of 20 feet or less at altitudes of 200 feet or less the system shall not lose lock. If the equipment should lose lock due to loss of signal at altitudes above 200 feet and up to the maximum altitude for which it is designed, it shall recapture the signal in less than one second.

2.5 *Rate Data.* The equipment need not provide a rate data output as a conditions of compliance with this minimum performance standard. However, those altimeters which do have rate outputs shall comply with the following requirements regarding range and accuracy for at least 95 percent of all observations for heights form the terrain to the antenna in the range from:

RATE DATA

Altitude (ft.)	*Range (ft./sec.)*	*Accuracy (ft./sec.)*
3-100	0-15	±(1.5ft.+0.01h+0.1/r/)
100-200	0-20	±(2.0ft.+0.01h+0.1/r/)

Where:
h = altitude in feet.
/r/ = absolute value of rate (feet/sec.).

2.6 *Failure Warning System.*

(a) *Warning conditions.* A failure warning system shall be incorporated in the equipment to indicate to the pilot, and to any systems which may be utilizing the altimeter data, the existence of the following conditions:

(1) Loss of power.

(2) Loss of signal or altitude sensing capability when within the manufacturer's stated operating altitude range.

(b) *Warning indication characteristics.* An indication plainly discernible under all normal flight conditions shall be provided. If a flag is used, it shall be as large as practicable commensurate with the display.

2.7 *Self Test Feature.* If a self test-feature is provided, any probable malfunction of the self-test feature shall not degrade the performance of the radio altimeter.

2.8 *Transmitting Operating Frequency.* The transmitter shall be operated within a frequency band available for the operation of airborne radio altimeters in the Aeronautical Radio Navigation Service and in accordance with applicable Federal Aviation Agency and Federal Communications Commission Rules and Regulations.

2.9 *Maximum Altitude Range.* To satisfactorily perform its intended function, the maximum range shall be at least 500 feet.

3.0 *Minimum Performance Standards Under Environmental Conditions.* Unless otherwise specified, the test procedures applicable to a determination of performance of radio altimeter equipment under environmental conditions are set forth in the FAA Document for "Environmental Test Procedures for Airborne Electronic Equipment", dated August 31,1962.

3.1 *Temperature-Altitude.*

(a) Low Temperature - When subjected to this test:

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedure set forth in 2.2 of Appendix A.

(3) All mechanical devices shall perform their intended functions.

(b) High Temperature -

(1) When the equipment is operated at the High Short-Time Operating Temperature:

(a) The requirements of paragraphs 2.1 and 2.2 shall not be degraded by more than a factor of 2 from the values set forth using the procedures set forth in 2.2 and 2.3 respectively, of Appendix A.

(b) The requirements of paragraph 2.6 shall be met.

(c) All mechanical devices shall operate satisfactorily.

(2) When the equipment is operated at the High Operating Temperature:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

(c) Decompression (Applicable only to Category D equipment of temperature-Altitude Test) - When the equipment is subjected to this test:

(1) The requirements of paragraphs 2.1 and 2.3 shall be met using the procedures set forth in 2.2 and 2.3, respectively, of Appendix A.

(2) All mechanical devices shall perform their intended functions.

(d) Altitude-When the equipment is subjected to this test:

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

3.2 *Humidity.* After subjection to this test and:

(a) Within 15 minutes from the time that primary power is applied:

(1) The requirements of paragraph 2.6 shall be met.

(2) All mechanical devices shall operate satisfactorily.

(b) Within 4 hours from the time that primary power is applied:

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

(a) Following the application of the Operational Shocks.

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

(b) Following the application of the Operational Shocks, the equipment shall have remained in its mounting and no part of the equipment or its mounting shall have become detached and free of the shock test table or the equipment under test.[1]

3.4 *Vibration.* When subjected to this test:

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

3.5 *Temperature Variation.* When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) All mechanical devices shall perform their intended functions.

3.6 *Power Input Variation.* When subjected to this test:

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) All mechanical devices shall perform their intended functions.

3.7 *Low Voltage.*

(a) When the equipment is subjected to the first part of the low voltage test procedure set forth in 9.2a, of Environmental Test Procedures for Airborne Electronic Equipment document.

(1) The equipment shall operate electrically and mechanically.

(2) The requirements of paragraph 2.6 shall be met.

(b) When the equipment is subjected to the second part of the low voltage test procedure set forth in 9.2b(1), of Environmental test Procedures for Airborne Electronic Equipment document.

(1) The requirements of paragraphs 2.3 and 2.6 shall be met.

(2) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

(c) When the equipment is subjected to the third part of the low voltage test procedure set forth in 9.2b(2), of Environmental Test Procedures for Airborne Electronic Equipment documents, there shall be no evidence external to the equipment of the presence of fire or smoke.[1]

3.8 *Conducted Voltage Transient.*

(a) Subsequent to the subjection of the intermittent transient test, the requirements of paragraphs 2.1 and 2.3 shall be met using the procedures set forth in 2.2 of Appendix A.

(b) When being subjected to the repetitive transient test the requirements of paragraphs 2.3 and 2.6 shall be met.

3.9 *Conducted Audio-Frequency Susceptibility.* When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

3.10 *Audio-Frequency Magnetic Field Susceptibility.* When subjected to this test:

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

3.11 *Radio-Frequency Susceptibility (Radiated and Conducted).* When subjected to this test:

[1] The application of this test may result in damage to the equipment under test. Therefore, it may be conducted after the other tests are completed

(a) The requirements of paragraphs 2.3 and 2.6 shall be met.

(b) The requirements of paragraphs 2.1 and 2.2 shall be met using the procedures set forth in 2.2 of Appendix A.

3.12 *Explosion (When Required).* During the application of this test the equipment shall not cause detonation of the explosive mixture within the test chamber.

3.13 *Emission of Radio-Frequency Energy.* The levels of conducted and radiated spuriou7s radio-frequency energy emitted by the equipment shall not exceed those levels specified in Appendix A to the Federal Aviation Agency document, "Environmental Test Procedures for Airborne Electronic Equipment", dated August 31, 1962 for the aircraft category for which the equipment is designed.

APPENDIX A

1.0 *Test Conditions.* The following definitions of terms and conditions of test are applicable to the test procedures specified herein.

1.1 *Power Input Voltage-Direct Current.* Unless otherwise specified, when the equipment is designed for operation from a direct current power source, all measurements shall be conducted with the power input voltage adjusted to 13.75 volts, ±2 percent for 12-14 volt equipment, or to 27.5 volts, ±2 percent for 24-48 volt equipment. The input voltage shall be measured at the receiver power input terminals.

1.2 *Power Input Voltage-Alternating Current.* Unless otherwise specified, when the equipment is designed for operation from an alternating current power source all tests shall be conducted with the power input voltage adjusted to design voltage ±2 percent. In the cast of equipment designed for operation from a power source of essentially constant frequency (e.g., 400c.p.s.), the input frequency shall be adjusted to design frequency ±2 percent. In the case of equipment designed for operation from a power source of variable frequency (e.g., 350 to 1,000 c.p.s.), tests shall be conducted with the input frequency adjusted to within 5 percent of a selected frequency within 5 percent of a selected frequency within the range for which the equipment is designed.

1.3 *Adjustment of Equipment.* The circuits of the equipment under test shall be properly aligned and otherwise adjusted in accordance with the manufacturer's recommended practices prior to the application of the specified tests.

1.4 *Ambient Conditions.* Unless otherwise specified, all tests shall be conducted under conditions of ambient room temperature, pressure, and humidity. However, the room temperature shall be not lower than 10° C.

1.5 *Warm-up Period.* Unless otherwise specified, all tests shall be conducted after a warm-up period of not less than fifteen (15) minutes.

1.6 *Description of Test Equipment.*

(a) Altitude Simulator. The altitude simulator consists of variable and fixed RF attenuators, and coaxial cables or other suitable delays to simulate the various altitudes. The simulator must accept the altimeter energy, attenuate and delay the RF energy and present the delayed signal of the altimeter receiver. The test equipment must also include provision to simulate the cross-coupling which exists between separate transmitter and receiver antennas. The simulator should be calibrated to provide the desired altitude of an accuracy of better than 1 percent and the appropriate attenuation to within ±2.5 dB. The variable attenuator shall be calibrated in radar cross-section $[s_o(o)]$* between the values of 0.003 and 1.0.

(b) Digital Voltmeter.

(c) AC VTVM.

(d) Demodulator. The Demodulator consists of a

* Defined in Appendix B.

synchronous detector excited by an a.c. reference voltage. The bandwidth of the Demodulator should exceed 5 c.p.s. Ripple rejection should exceed 60 de. Means to set the Demodulator gain to unity should be provided. Means to balance the Demodulator output to zero should be provided.

(e) Filter. See Figure 2 or 3.

(f) Alarm Signal Monitor. The Alarm Signal Monitor consists of a simple indicator such as a pilot lamp.

(g) Remodulator. The Remodulator is an electronic or electromechanical switch excited by an a.c. reference voltage. It converts low frequencies to suppressed carrier modulation where the carrier frequency is the a.c. reference voltage. Means to set the Remodulator gain to unity should be provided.

2.0 *Test Procedures.* The test procedures set forth herein are satisfactory for use in determining the performance of airborne low-range radio altimeters. Test procedures which provide equivalent information may be used.

2.1 *Accuracy (In-Flight).*

(a) Altitude Information. With the equipment installed in an aircraft, operate the equipment in flight over a runway or other smooth surface at altitudes and descent rates in accordance with paragraph 2.1. Determine the true altitude of the aircraft by theodolite or other means and compute the accuracy of the altitude information from the altimeter. Extrapolation of the test data by theoretical means, from the results so obtained, is permissible in order to demonstrate compliance with the standards in paragraphs 2.1 and 2.2.

(b) Altitude Rate Information. With the equipment installed in an aircraft, operate the equipment in flight over a runway or other smooth surface at altitudes and descent rates in accordance with paragraph 2.5. Determine the true descent rate of the aircraft and compute the accuracy of the altitude rate information from the altimeter. Extrapolation of test data by theoretical means, from the results so obtained, is permissible in order to demonstrate compliance with the standards in paragraph 2.5.

2.2 *Altitude Accuracy and Loop Gain.*

(a) Equipment Required: Altitude Simulator, Digital Voltmeter or AC VTVM, Flag Monitor. The choice of voltmeters depends on the voltage output of the altimeter which could be a.c. or d.c.

(b) Measurement Procedures. Connect the equipment as shown in Figure 1. Set the altitude simulator to a specified altitude and a radar cross section [s_o (o)] of 0.1. Monitor the altitude output with the voltmeter and verify altimeter calibration. Monitor pilots indicator and warning signal. Vary radar cross section [s_o (o)] over the range of 1.0 to 0.01. Altitude indication should remain within the limits specified. Altimeter can lose track and indicate fail for [s_o (o)] below 0.01. Adjust the altitude simulator to another altitude and repeat the above measurements. Note in Appendix B a different total attenuation is required to permit the radar cross section [s_o (o)] dial to remain in calibration.

2.3 *Altitude Noise.*

(a) Equipment Required: Altitude Simulator, Digital Voltmeter, Remodulator, AC VTVM, Filter.

If the altitude output is an a.c. voltage the following additional equipment is required:

Demodulator

(b) Measurement Procedure. Connect the equipment as shown in Figure 2 or 3. Set the altitude simulator to a specified altitude and a scattering radar cross section corresponding to [s_o (o)] of 0.01. Read the r.m.s. voltage indicated by the a.c. VTVM. Convert to altitude noise in feet. The measurement should be repeated at one other simulated altitude.

2.4 *Time Constant.*

(a) Equipment required: Altitude Simulator.

(b) Test Procedure. Couple the radio altimeter to the altitude simulator. To an equivalent altitude of 100 to 200 feet. Insert a change in the delay equivalent to 10 percent of the indicated altitude. The analog output of the altimeter shall be observed and shall reach 63 percent of the ultimate change in 0.1 second or less with less than 5 percent overshoot. Consideration must be given to the time required for switching the delay in and/or out in the above measurement.

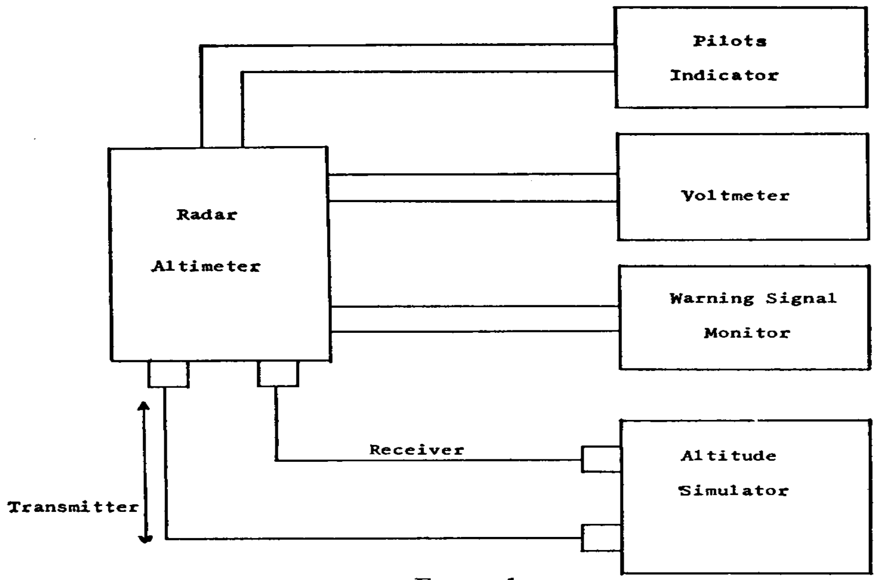


FIGURE 1

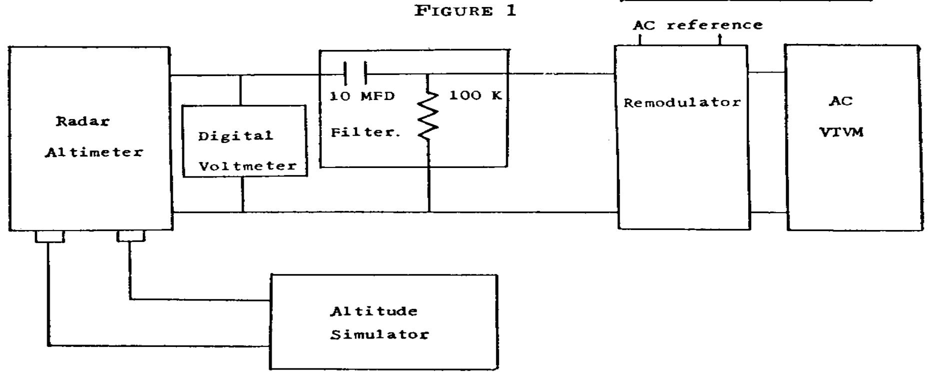


FIGURE 2—DC altitude output.

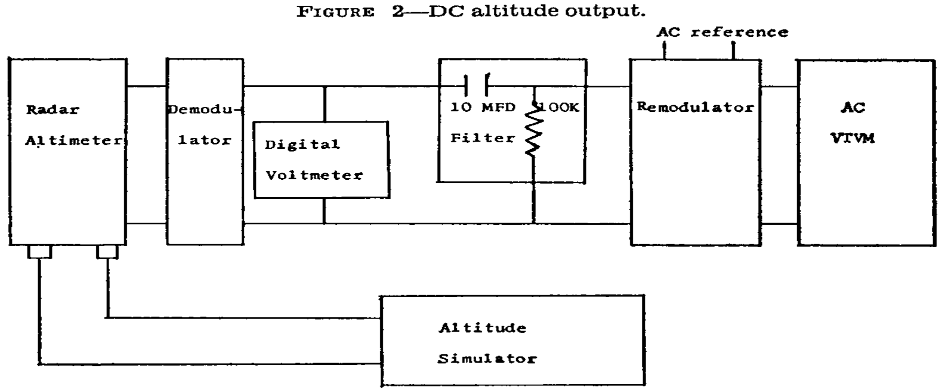


FIGURE 3—AC altitude output.

APPENDIX B
DETERMINATION OF
EXTERNAL LOOP LOSS
(DERIVATION)

1.0 *Definition of External Loop Loss.* In the useful signal path, i.e., transmitting antenna to ground to receiving antenna, the External Loop Loss is defined for average power in c-w systems and peak power in pulse systems. The external loop loss is the ratio of the available power entering the receiving antenna aperture to the power leaving the transmitter antenna aperture.

2.0 *Characteristics of External Loop Loss.* The loss defined above is independent of antenna and transmission line losses, inefficiencies, and mismatches. It deals only with the geometric power gain, (G), the beam patterns of the antennas, and the characteristics of the ground. Further, it is independent of the signal processing characteristics of the altimeter and may be measured, essentially, with a attenuator only.

3.0 *External Loop Loss, Beam Limited Case.* The basic formulation for external loop loss depicts a beam limited case in which it is assumed that transmitting and receiving apertures are identical. The analytical expressions for this case is:

$$L = \frac{G\lambda^2 \sigma_o(O)F}{16\pi^2 H^2} = \frac{A\sigma_o(o)F}{4\pi H^2} \qquad 3.1$$

where G is the power gain of either antenna (defined in terms of the actual beam pattern), λ is the wavelength, H is the altitude, $\sigma_o(o)$ is the vertical incidence unit scattering radar cross section of the ground, and F is a normalized function of H. Limitations on roll and pitch under 100 feet of altitude and the effect of finite separation of transmitting and receiving antennas is accounted for by F. A is defined as $\frac{G\lambda^2}{4\pi}$.

4.0 *External Loop Loss, Pulse Limited Case.* In the pulsed altimeter, the external loop loss is described by Eq. (3.1) below the critical altitude, i.e., that altitude above which the performance is pulse limited. Defining the critical altitude, H_c, as

$$H_c = \frac{c\tau G}{4} \qquad 4.1$$

where c is the velocity of light and τ is the pulse length. The external loop loss is defined above H_c by extending the loss.

$$\frac{G\lambda^2 \sigma_o(O)F}{16\pi^2 H_c^2}$$

according to a $1/H^3$ law.

5.0 *Essentials of F or F(H).*

$$F(H)=M(H)\ V^*(H) \qquad 5.1$$

5.1 <u>M(H)</u>

The function M(H) takes care of the fact that pitch and roll maneuvering becomes progressively limited for altitudes below 100 feet. The choice for $\sigma_o(o)$ includes margin for pitch and roll to the 3 dB limits of the beamwidth for altitudes above 100 feet. It is expected that at 3 feet of altitude, however, pitch and roll will be very limited ad well within the 3 dB beam limits. Accordingly, it is proposed to decrease the required loop loss by 0 dB at 100 feet and 6 dB at 3 feet, the variation between 3 feet and 100 feet to be linear in dB, i.e.,

$$10\ \log\ M(H) = -\frac{6}{97}H + 6\frac{18}{97} \qquad 5.2$$

5.2 V*(H)

This quantity takes care of the effects of antenna spacing.

$$V^* = \frac{2\left[\cos^{-1}\alpha - \alpha\sqrt{1-\alpha^2}\right]}{\pi\left(1+\alpha^2 \tan^2\theta_o\right)^{\frac{5}{2}}} \quad 0 \le \alpha \le 1, \qquad 5.3$$

where

$$\alpha = \frac{D}{2H\ \tan\theta_o}, \qquad 5.4$$

D is the antenna spacing, and

$2\theta_0$ is the beamwidth.

6.0 *Curves of External Loop Loss.* All that remains is to make a choice for loss calculated is just sufficient to insure reliable operation over all terrain even for pitch and roll maneuvers out to the 3 dB beamwidths. A considerable amount of data accumulated for both pulse and FM/CW altimeters in the 4200-4400 mc region involving many flight tests over a wide variety of terrain and practical problems of adjustment, maintenance and calibration of radio altimeters indicates a choice of

$$\sigma_0(0) = 6\text{x}10^{-3}. \qquad 6.1$$

With respect to making a choice for the 1600-1660 mc range, it cannot be done on the basis of extensive flight data. Accordingly, it will be necessary to extrapolate from the 4200-4400 mc data. The trend of change of $\sigma_0(\theta)$ with frequency is slow; $\sigma_0(o)$ tending to decrease with frequency but $\sigma_0(\theta)$ tending to vary more slowly with β as the frequency decreases. The first effect definitely increases loop loss; the second effect can be assumed to cancel each other and that one may then choose the same value of $\sigma_0(o)$ for both frequency ranges. The curves which follow are based on this assumption.

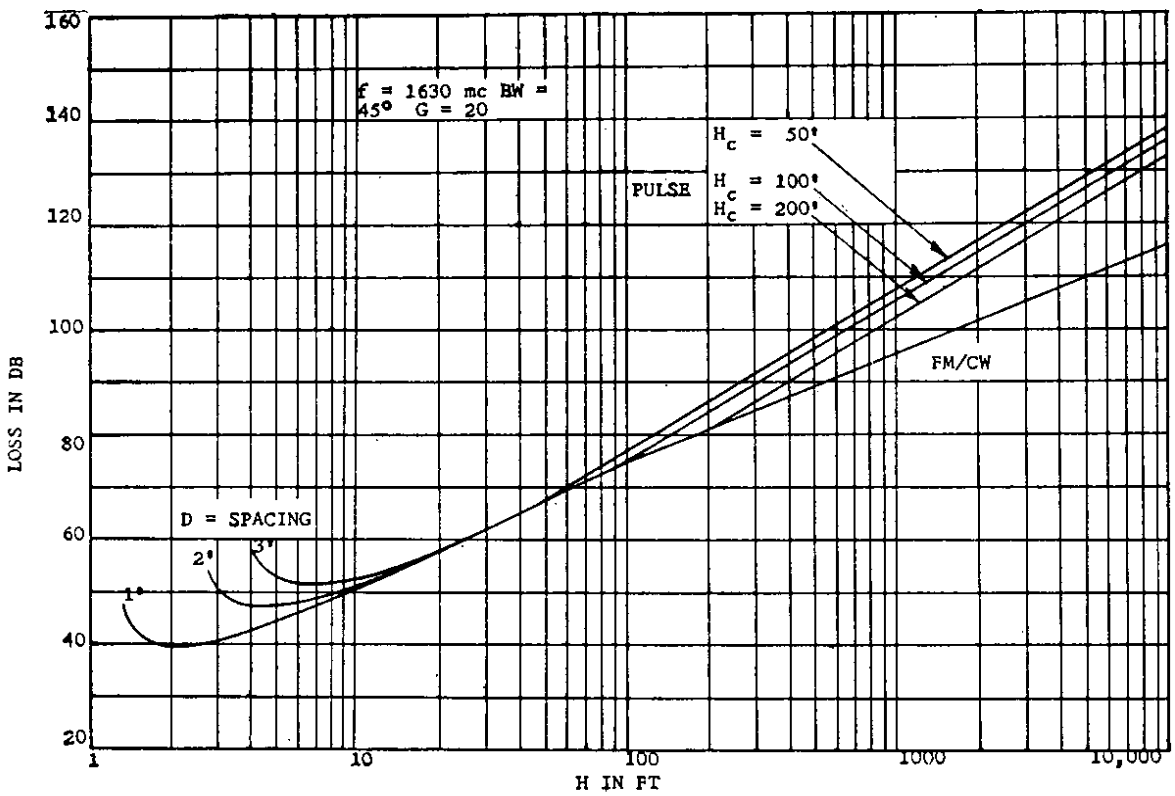


FIGURE 1—External loop loss.

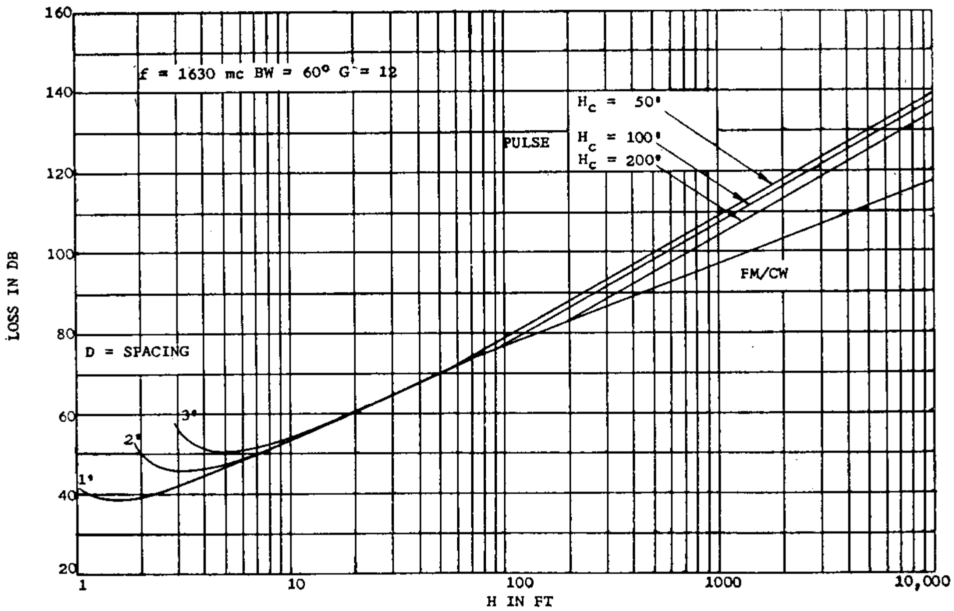


FIGURE 2—External loop loss.

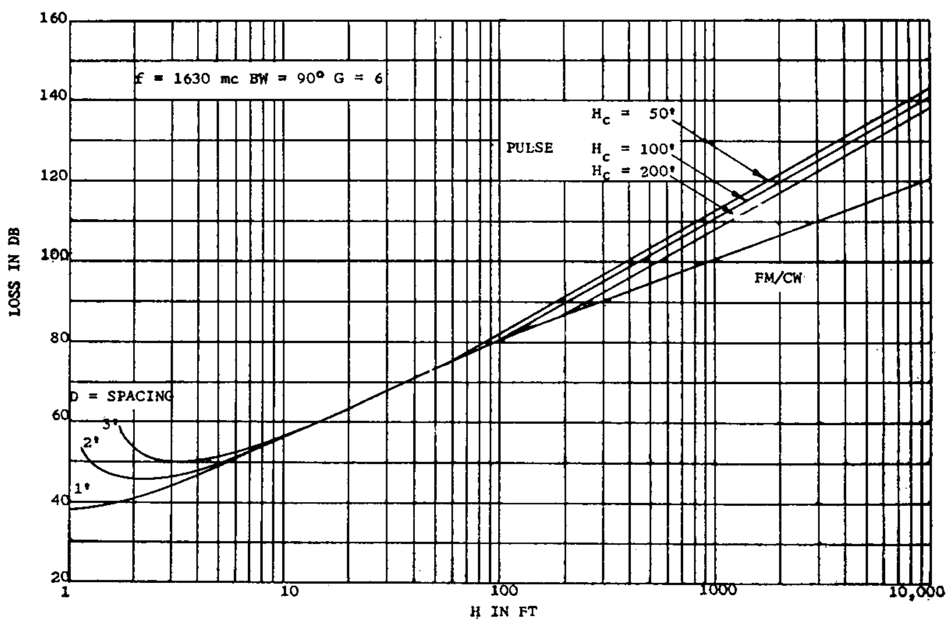


FIGURE 3—External loop loss.

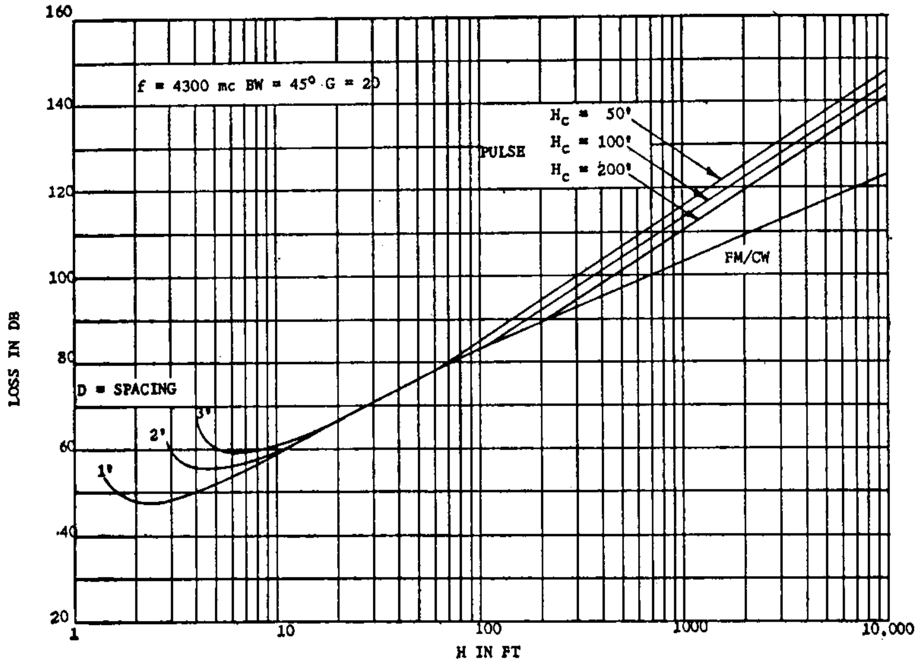


FIGURE 4—External loop loss.

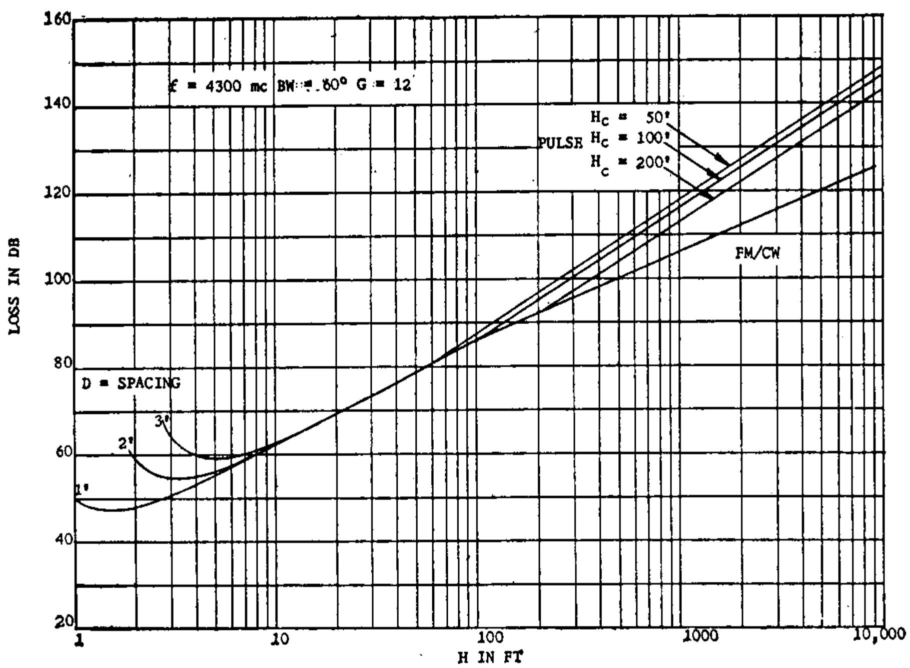


FIGURE 5—External loop loss.

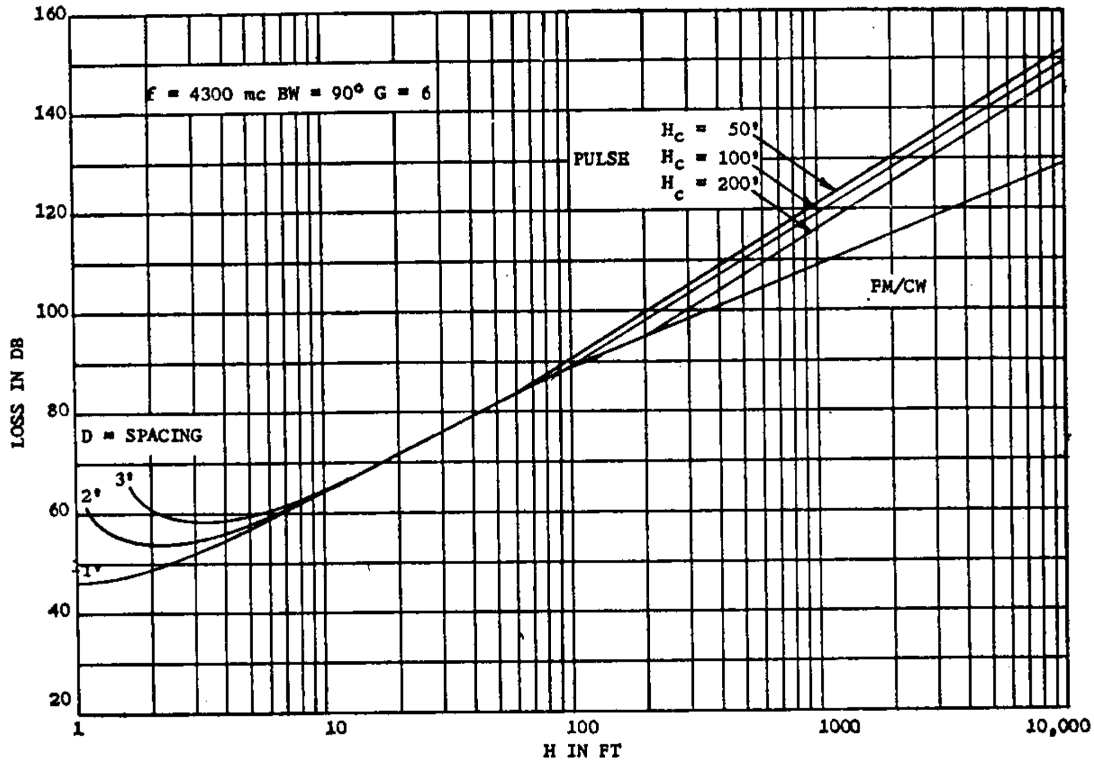


FIGURE 6—External loop loss.

FEDERAL AVIATION AGENCY DOCUMENT FOR ENVIRONMENTAL TEST PROCEDURES FOR AIRBORNE ELECTRONIC EQUIPMENT

1.0 *Purpose.* This report sets forth Environmental Test Procedures applicable to airborne electronic equipment. The purpose of these tests is to provide a laboratory means of determining the performance characteristics of the equipment under conditions representative of those which may be encountered in actual aeronautical operations.

2.0 *Definition of Terms.*

2.1 *Equipment Temperature Stabilization.* Equipment temperature stabilization is that condition wherein (1) the temperature of the largest internal mass is within ±3° C. of the specified value when the equipment is not operating, or (2) the crest temperatures of the largest internal mass do not differ by more than 5° C. when the equipment is operating.

2.2 *Maximum Duty Cycle.* Maximum duty cycle is the relationship between the maximum length of time for which an equipment is designed to deliver its rated output power and the length of time during which "standby" power only may be applied when such "ON-OFF" operation is periodic.

2.3 *Not Operating.* Not operating is that condition wherein no power is applied to the equipment.

2.4 *Controlled Temperature Location.* Controlled temperature location is a space within an aircraft in which the temperature of the air is maintained, either manually or automatically, within the limits specified in the appropriate category of Table 1 of paragraph 4.0, Temperature-Altitude Test.

3.0 *Conditions of Test.*

3.1 *Connection of Equipment.* Connect the equipment mechanically and electrically as recommended by the manufacturer, including any cooling provisions, to the extent necessary to make such tests and measurements as are required to determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions," of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

3.2 *Order of Tests.* The tests may be conducted in any desired order, with the exception that the humidity test shall not be conducted prior to the temperature-altitude and the vibration tests. The purpose of this exception is to determine whether materials used to protect circuit elements from moisture have lost their protective function due to deterioration from exposure to either extreme temperatures or to vibration.

3.3 *Measurement of Temperature of Air in Test Chamber.*

a. The temperature of the air in the test chamber shall be measured at such a location within the test chamber that the temperature of the air so measured is representative of that immediately surrounding the equipment. Measurement of chamber wall temperature is not suitable, due to temperature lag and heat transfer through the chamber wall.

b. Means of circulating the air in the test chamber may be employed to approximate a uniform air temperature condition throughout the chamber. When such means are employed, the air blast shall not be directed upon the equipment under test.

3.4 *Ambient Room Temperature.* When tests are conducted under "ambient room temperature," the ambient room air temperature shall be between +10° C. and +40° C.

3.5 *Power Input Voltage.* Unless specified otherwise, all tests shall be conducted with the power input voltage adjusted to design voltage ±2 percent. The input voltage shall be measured at the equipment power input terminals.

3.6 *Power Input Frequency.*

a. In the case of equipment designed for operation from an a.c. power source of essentially constant frequency (e.g., 400 c.p.s.), the input frequency shall be adjusted to design frequency ±2 percent, unless otherwise specified.

b. In the case of equipment designed for operation from an a.c. power source variable frequency (e.g., 300 to 1,000 c.p.s.), tests shall be conducted with the input frequency adjusted to within 5 percent of a selected frequency and within the input power frequency range for which the equipment is designed, unless otherwise specified.

4.0 *Temperature-altitude Test.* Several temperature-altitude test procedures are specified,[1] according to the category for which the equipment is designed to be used, as follows:

Category A - Equipment intended for installation in nonpressurized and noncontrolled temperature locations in aircraft which operate at altitudes up to 45,000 feet m.s.l.

Category B - Equipment intended for installation in nonpressurized and noncontrolled temperature locations in aircraft which operate at altitudes up to 30,000 feet m.s.l.

Category C - Equipment intended for installation in nonpressurized and noncontrolled temperature locations in aircraft which operate at altitudes up to 20,000 feet m.s.l.

Category D - Equipment intended for installation in controlled temperature and pressurized locations in aircraft which the pressures are no lower than that which is equivalent to an altitude of 15,000 feet m.s.l.

[1] The temperature-altitude test and the temperature variation test may be combined, if desired. See paragraph 8.1, Alternate Test Procedure.

Category E - Equipment intended for installation in nonpressurized but controlled temperature locations in aircraft which operate at altitudes up to 20,000 feet m.s.l.

Category F - Equipment intended for installation in nonpressurized but controlled temperature locations in aircraft which operate at altitudes up to 12,000 feet m.s.l.

4.1 *Test Procedure (Low Temperature).* Stabilize the equipment temperature at the appropriate (depending upon category used) Low Not Operating Temperature specified in Table 1 at Ambient room atmospheric pressure, with equipment not operating.[2] Maintain this stabilized temperature for 30 minutes; then stabilize the equipment temperature at the appropriate Low Operating Temperature specified in Table 1 at ambient room atmospheric pressure, with the equipment not operating. Then operate the equipment at maximum duty cycle for a period of 15 minutes, beginning with the "ON" cycle in the case of equipment designed for intermittent duty service. Maintain the temperature of the air in the test chamber within 3° C. of the Low Operating Temperature of Table 1. Determine the compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.[3]

4.2 *Test Procedure (High Temperature).*

a. At ambient room pressure, with the equipment not operating, stabilize the equipment temperature to within 3° C. of the appropriate High Not Operating Temperature of Table 1. After 30 minutes, adjust the test chamber air temperature to within 3° C. of the High Short-time Operating Temperature specified in Table 1. Operate the equipment at maximum duty cycle for 30 minutes. Determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions," of the appropriate FAA airborne electronic equipment Minimum Performance Standards during this 30-minute period.

NOTE: The purpose of this test is to simulate temperature conditions which may be encountered in aircraft while on the ground in certain geographical areas.

b. With the equipment operating, adjust the test chamber air temperature to within 3° C. of the appropriate High Operating Temperature specified in Table 1 at ambient room pressure. After the equipment temperature has become stabilized, operate the equipment for two (2) hours and determine compliance with the applicable standards of Paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions," of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

4.3 *Test Procedure(Altitude).*

a. Operate the equipment at maximum duty cycle. Decrease the atmospheric pressure to within 5 percent of the appropriate Test Altitude specified in Table 1. Conduct this test at ambient room temperature. Determine compliance with the applicable standards of Paragraph 3.0, "Minimum performance Standards under Environmental Test Conditions," of the appropriate

[2] This is not intended to be a temperature shock test. The rate at which the temperature of the equipment under test is reduced from ambient to the appropriate Low Not Operating Temperature specified in Table 1 is optional

[3] Optionally, the tests specified in this paragraph (4.1.) may be commenced with the initial temperature of the equipment at any value between the appropriate Operating and Low Not Operating Temperatures specified in Table 1.

FAA airborne electronic equipment Minimum Performance Standards.

b. This test is intended for application only to Category D equipment. With the equipment operating at the Test Altitude specified in Table 1, reduce the atmospheric pressure to that equivalent to the Decompression Test Altitude specified in Table 1. This reduction in pressure shall be effected within a time period not to exceed 15 seconds. Maintain this reduced pressure for at least 10 minutes, then increase the pressure to that equivalent to the Test Altitude specified in Table 1. Conduct this test at ambient room temperature. Determine compliance with the applicable standards of paragraph 3.0, “Minimum Performance Standards under Environmental Test Conditions,” of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

TABLE 1. - ALTITUDE-TEMPERATURE CRITERIA

Condition		Cat. A	Cat. B	Cat. C	Cat. D	Cat. E	Cat. F
Maximum operating altitude		45,000'	30,000'	20,000'	*15,000	20,000'	12,000'
Test altitude		55,000'	35,000'	25,000'	*20,000	25,000'	15,000'
Decompression test altitude		- - - - - -	- - - - - -	- - - - - -	40,000'	- - - - - -	- - - - - -
Not operating	Low	–62°C.	–50°C.	–50°C.	–50°C.	–40°C.	–40°C.
temperature	High	+71°C.	+71°C.	+71°C.	+71°C.	+71°C.	+71°C.
Short-time operating high temperature		+71°C.	+71°C.	+71°C.	+60°C.	+50°C.	+45°C.
Operation	Low	–54°C.	–46°C.	–40°C.	–15°C.	–15°C.	–15°C.
temperature	High	+55°C.	+55°C.	+55°C.	+55°C.	+40°C.	+40°C.

* The maximum operating altitude and test altitude of Cat. D equipment represent atmospheres established by pressurization
.

5.0 *Humidity Test.* Subject the equipment to an atmosphere having a relative humidity of between 95 percent and 100 percent and an ambient temperature of 50° C. ±3° C. for a period of 48 hours. During this 48-hour period, no electrical or mechanical power shall be applied to the equipment. At least once each hour, the relative humidity shall be 100 percent with condensation on the equipment. At the end of the 48-hour exposure period, remove the equipment from the test chamber and drain off (do not wipe) any condensed moisture. Within 5 minutes after removal of the equipment form the test chamber, apply standard primary test voltage(s) to the equipment. Allow 15 minutes following the application of primary power for the equipment to warm-up. Immediately following the warm-up period, determine compliance with the applicable standards of paragraph 3.0, “Minimum Performance Standards under Environmental Test Conditions” of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

6.0 *Shock Test.*

6.1 *Operational Shocks.*

a. Secure the equipment to a shock table by the mounting means intended for use in service installations. Apply to the shock table, with the equipment mounted in each of the following six positions, three shocks each having a peak acceleration of at least 6G and a time duration of at least 10 milliseconds.

(1) Normal upright.

(2) Suspended upside down.

(3) At positions such that the longitudinal axis of the equipment successively forms angles of plus 90° and a minus 90° (two positions) with the plane of the table.

(4) At positions such that the lateral axis of the equipment successively forms angles of plus 90°

(two positions) with the plane of the table.

b. After application of the shocks, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

6.2 *Crash safety shocks.* Apply, in each of the six equipment positions listed in paragraph 6.1, one shock having a peak acceleration of at least 15G and a time duration of at least 10 milliseconds. After application of the six shocks, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

NOTE: During this test, an equivalent weight may be substituted for the electrical and mechanical components normally mounted within or on the equipment case. Such equivalent weight shall approximate the weight of the components which it replaces and shall be so located that the center of gravity of the equipment is essentially unchanged. The equivalent weight shall not contribute to the strength of the equipment case or its mounting fastenings to a greater extent than the components it replaces.

7.0 *Vibration Test.*

7.1 *Test Procedure.*

a. So secure the equipment under test to a vibration table that sinusoidal vibratory motion is exerted parallel to the longitudinal[4] axis of the equipment. The equipment shall be affixed to the vibration table by the means specified by the equipment manufacturer for service installations. Connect the equipment for proper operation. Start it operating in its principal mode. (Multipurpose equipments, such as transceivers, shall be tested in all modes.)

b. With the equipment operating, vary the vibration frequency from 10 to 55 to 10 c.p.s. in a time period of from 1 to 3 minutes[5] at an amplitude appropriate to the category of equipment under test. (refer to Table2). Continue vibrating the equipment in this manner for a period of at least ninety (90) minutes.

c. Determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA airborne electronic equipment Minimum Performance Standards.

d. Repeat the procedures specified in paragraphs 7.1 a., b., and c., with the vibratory motion applied in a direction parallel to the lateral axis of the equipment.

e. Repeat the procedures specified in paragraphs 7.1 a., b., and c., with the vibratory motion applied in a direction parallel to the vertical axis of the equipment.

f. If the equipment is to be tested under a vibration category which requires vibration tests in the 55 to 500 cycle frequency range, repeat all of the above test procedures, but starting at 55 cycles and running to 500 cycles, and returning to 55 cycles with the excursion so adjusted for each frequency as to produce the constant acceleration figure specified in Table 2.[6]

TABLE 2. - CATEGORIZATION OF AIRCRAFT VIBRATION CHARACTERISTICS BY AIRCRAFT TYPES AND LOCATIONS THEREIN

Aircraft Description	Fuselage	Instrument panels (vibration protected or otherwise) and isolated racks	Any location not Specified
Rotary wing			

[4] Optionally, vibratory motion may be first applied to any axis of the equipment, i.e., lateral, vertical or longitudinal. Any sequence thereafter is permissible.

[5] Either a linear or logarithmic sweep (scan) may be used.

[6] Optionally, the tests specified in paragraphs 7.1 a., b., c., d., e., and f., may be combined, if desired, with a total sweep time of from 2 to 6 minutes and a total time of 180 minutes.

aircraft------	A	F	A
Turbo engine fixed wing aircraft------	B	C	A
Piston engine fixed wing aircraft, heavy multi-engine type (over 12,500 lbs.)---------	E	F	D
Piston engine fixed wing aircraft, light multi-engine type (under 12,500 lbs.)-	F	F	E
Piston engine fixed wing aircraft, light single en-gine type (under 12,500 lbs.)-	F	F	F

7.2 *Vibration Characteristics of Categories:*

Category A - Constant total excursion of 0.030" from 10 to 55 c.p.s. with a maximum acceleration of 5G; and Constant acceleration of 5 G from 55 to 500 c.p.s.

Category B - Constant total excursion of 0.020" from 10 to 55 c.p.s. with a maximum acceleration of 3G; and Constant acceleration of 1.5 G from 55 to 500 c.p.s.

Category C - Constant total excursion of 0.010" from 10 to 55 c.p.s. with a maximum acceleration of 1.5G; and Constant acceleration of 0.25 G from 55 to 500 c.p.s.

Category D - Constant total excursion of 0.030" from 10 to 55 c.p.s. with a maximum acceleration of 5G.

Category E - Constant total excursion of 0.020" from 10 to 55 c.p.s. with a maximum acceleration of 3G.

Category F - Constant total excursion of 0.010" from 10 to 55 c.p.s. with a maximum acceleration of 1.5G.

8.0 *Temperature Variation Test.* Stabilize the equipment temperature at the appropriate Operating Low Temperature specified in Table 1, at ambient room atmospheric pressure with the equipment not operating.[7] Operate the equipment at maximum duty cycle for a period of 15 minutes, beginning with "ON" cycle in the case of equipment designed for intermi9ttent duty service, with the voltage and frequency of the primary power source adjusted to standard values. Increase the temperature of the air in the test chamber to the Operating High Temperature specified in Table 1, at a rate[8] not exceeding 1° C. per minute. In the interval between the time that the equipment temperature stabilizes at the appropriate Operating Low Temperature and the time it stabilizes at the appropriate Operating High Temperature, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards.

8.1 *Alternate Test Procedure.* It is permissible to combine the temperature variation test and the temperature-altitude test. In this case, proceed as follows:

(1) Conduct that portion of the temperature-altitude test specified in paragraph 4.1.

(2) Increase the temperature of the air in the test Chamber to the High Operating Temperature specified in the applicable category of Table 1 at a rate[9] not exceeding 1° C. per minute. In the interval between the time that the equipment temperature stabilizes at the appropriate Low Operation Temperature and the time it stabilizes at the appropriate High Extended-time Operating on Temperature, determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions, of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards.

[7] The purpose of this test is to determine certain performance characteristics of the equipment at various temperatures between the Operating Low Temperature and the Extended-time Operation High Temperature specified in the applicable Category of Table 1.

[8] If desired, this rate may, if necessary, be reduced to zero to permit measurements to be taken.

[9] If desired, this rate may, if necessary, be reduced to zero to permit measurements to be taken.

(3) Conduct those portions of the Temperature-Altitude Test specified in paragraphs 4.2a, through 4.3b.

9.0 *Power Input Test.*

9.1 *Power Input Variation Test.*

a. Adjust the primary power input as follows:

(1) In the case of equipment designed to operate from a d.c. power source, and adjust the primary power voltage to 110 percent of the design voltage.

(2) In the case of equipment designed to operate from a.c. primary power sources of essentially constant frequency, such as 400 c.p.s. adjust the primary power voltage to 110 percent of the design voltage and the frequency to 105 percent of design frequency. The crest factor shall be 1.4, ±10 percent.

(3) In the case of equipment designed to operate from a.c. primary power sources of variable frequency, such as 300 to 1,000 c.p.s., adjust the primary power voltage to 110 percent of design voltage and the frequency to the highest for which the equipment is designed. The crest factor shall be 1.4, ±10 percent.

NOTE: For the purposes of this test, equipment which derives a.c. power form an inverter provided exclusively for the equipment shall be considered as d.c. operated.

b. Operate the equipment at maximum duty cycle for 30 minutes, with the primary power adjusted as specified in paragraph 9.1a. Determine compliance with the applicable standards of paragraph 3.0, "Minimum Test Conditions," of the appropriate FAA airborne electronic equipment Minimum Performance Standards during this 30-minute period.

c. Adjust the primary power input as follows:

(1) In the case of equipment designed to operate from a d.c. power source, adjust the primary power voltage to 90 percent of the design voltage.

(2) In the case of equipment designed to operate from a.c. primary power sources of essentially constant frequency, such as 400 c.p.s., adjust the primary power voltage to 90 percent of the design voltage and the frequency to no higher than 95 percent of design frequency. The crest factor shall be 1.4 ±10 percent.

(3) In the case of equipment designed to operate from a.c. primary power sources of variable frequency, such as 300 to 1,000 c.p.s., adjust the primary power voltage to 90 percent of design voltage and the frequency to the lowest for which the equipment is designed. The crest factor shall be 1.4 ±10 percent.

NOTE: For the purposes of this test, equipment which derives a.c. power from an inverter provided exclusively for the equipment shall be considered as d.c. operated.

d. Operate the equipment at maximum duty cycle for a period of 30 minutes with the primary power adjusted as specified in paragraph 9.1c. Determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FA airborne electronic equipment Minimum Performance Standards during this 30-minute period.

9.2 *Low voltage Test.*

a. A.C. and D.C. Equipment. Operate the equipment at maximum duty cycle for a period of at least 30 minutes at an input power voltage(s) 80 percent of standard test voltage(s) in the case of d.c. equipment, or 87½ percent of standard test voltage(s) in the case of d.c. equipment, and determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance standards under Environmental Test conditions," of the appropriate FAA airborne Electronic Minimum Performance Standards.

(1) With the equipment operating, decrease the input power voltage(s) from 80 percent of standard test voltage(s) to 50 percent of stan-

dard test voltage(s) at a rate not greater than 2 percent of the standard test voltage(s) per minute and continue operating the equipment for a period of at least 10 minutes at the 50 percent input power level. with the equipment still operating, adjust the input power voltage(s) to 100 percent of standard test voltage(s) and determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions," of the appropriate FAA Airborne Electronic Minimum Performance Standards.[10]

(2) With the equipment operating, reduce the input power voltage(s) from 100 percent to 50 percent of standard test voltage(s) and continue the reduction of the input power voltage(s) from the 50 percent level to zero input voltage(s) at a rate not greater than 2 percent of the standard test voltage(s) per minute. Determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions," of the appropriate FAA Airborne Electronic Minimum Performance Standards.[11]

NOTE: for the purposes of this test, equipment which derives a.c. power from an inverter provided exclusively for the equipment shall be considered as d.c. operated.

10.0 *Conducted Voltage Transient Test.*

10.1 *Intermittent Transients.* With the equipment operating at its normal input voltage(s), apply to each of the d.c. primary input power leads a series of positive and negative voltage transients having the characteristics (amplitude and wave form) appropriate to the applicable normal d.c. input voltages specified in Figure 1, for a period of at least ten (10) seconds and at a rate of not less than two (2) transients per second. Immediately after the 10-second period, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental test Conditions," of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. The positive and negative transients should be developed, applied and monitored in a manner similar to that shown in Figures 2 and 3.

10.2 *Repetitive Transients.* With the equipment operating at its normal input voltage(s), apply to each of the d.c. primary input power leads a series of positive voltage transients having the characteristics (amplitude and wave form) appropriate to the applicable normal d.c. input voltages specified in Figure 1 at a rate of not less than two (2) transients per second and, simultaneously, determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. The positive voltage transients should be developed, applied and monitored in a manner similar to that shown in Figure 2.[12]

11.0 *Conducted Audio-Frequency Susceptibility Test.*

11.1 *D.C. Input Power Leads.* Apply a sine wave audio frequency signal in series with each ungrounded

[10] The purpose of this test is to determine those conditions resulting from decreased voltage(s) (such as relay chatter), the presence or continuation of which would contribute to malfunctioning of the equipment at standard test voltage(s).

[11] The purpose of this test is to determine whether the reduction of the input power voltage(s) from standard test voltage(s) to zero input voltage(s) produces evidence, external to the equipment, of smoke or fire.

[12] This test applies to equipment designed to utilize d.c. primary power which is furnished by the aircraft's electrical system. Equipment designed to operate solely on a.c. primary power need not be subjected to this test.

d.c. input power lead. While varying the audio frequency of the applied signal between 200 and 20,000 cycles per second, maintain the r.m.s. amplitude of this signal at not less than 5 percent of the nominal d.c. input voltage and determine compliance with the applicable standards of paragraph 3.0, "Minimum Performance Standards Under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. When conducting this test, all equipment interconnecting cables and RF transmission lines shall be in accordance with the manufacturer's installation wiring diagram and shall use shielded or twisted wires only where specified. Where no length of interconnecting cables is specified, the cables shall be at least five (5) feet long. Any inputs or outputs from or to other equipment(s) normally associated with the equipment(s) normally associated with the equipment under test shall be adequately simulated.

11.2 *A.C. Input Power Leads.* Apply a sine wave audio frequency signal in series with each ungrounded a.c. input power lead. With the frequency of this signal successively adjusted to the second harmonic of the a.c. power frequency and to each next higher order harmonic up to 9,000 cycles, maintain the r.m.s. amplitude of this signal at not less than 5 percent of the nominal a.c. input voltage and determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards Under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. When connection cables and RF transmission lines shall be in accordance with the manufacturer's installation wiring diagram and shall use shielded or twisted wires only where specified. Where no length of interconnecting cables is specified, the cables shall be at least five (5) feet long. Any inputs or outputs from or to other equipment(s) normally associated with the equipment under test shall be adequately simulated.

12.0 *Audio Frequency Magnetic field Susceptibility Test.*

12.1 *Categories of Equipment.* For the purpose of this test, equipment is categorized as follows:

Category A - Equipment which is intended for installation in an aircraft which has an a.c. power source having a rating of 250 VA (volt-amperes) or greater.

Category B - Equipment which in intended for installation in an aircraft which has an a.c. power source having a rating of less than 250 VA, or which has no a.c. power source whatever.

12.2 *Test Procedure.*

Category A - Expose the equipment under test to an audio frequency magnetic field which is generated by a 400 c.p.s. current of at least 20 amperes (r.m.s.) flowing in a straight wire radiator, which is within 12 inches of the periphery of the unit of equipment under test, and determine compliance with the applicable standards of paragraph 3.0 "Minimum Performance Standards Under Environmental Test Conditions" of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards. During this test, the radiator shall be so oriented with respect to each external surface of each unit as to cause maximum interference, The length of the radiator shall be such that it extends a distance of at least 2 feet (laterally) beyond the exposed surface of the unit under test. The leads supplying current to the radiator shall be routed at least 2 feet away from any part of the unit under test and from the radiator itself. All units of the equipment under test shall be individually tested.

Category B - No test of Category B equipment is required.

13.0 *Radio Frequency Susceptibility Test (Radiated and Conducted).* For the purposes of this test,[13] equipment is categorized as follows:

Category A - Equipment which is intended for installation in aircraft having a Maximum Weigh of more than 12,500 pounds.

Category B - Equipment which is intended for installation in aircraft having a Maximum Weight of 12,500 pounds, or less.

13.1 *General Requirements.*

(a) The equipment under test shall be set upon a ground plane and operated in accordance with the following criteria:

[13] See "Introduction" of Appendix A for information on the relationship between the emission of spurious radio frequency energy from electrical and electronic equipment installed in an aircraft and the levels of radio frequency susceptibility signals used in this test procedure.

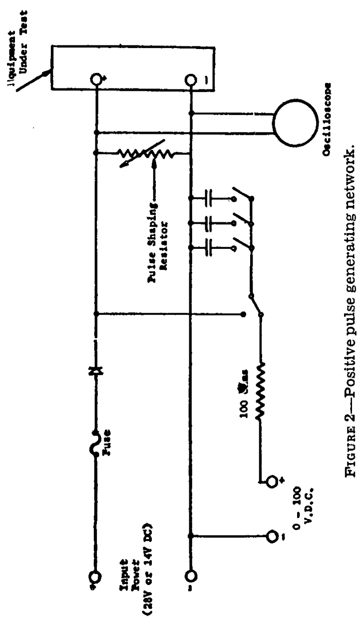


FIGURE 2—Positive pulse generating network.

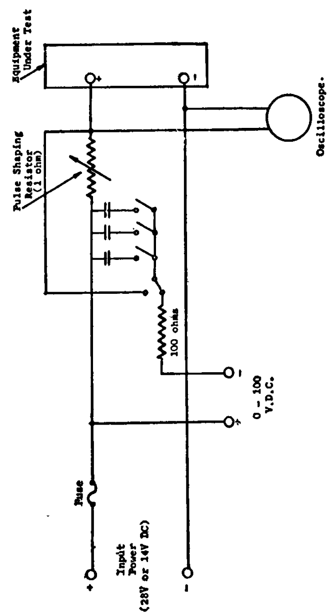
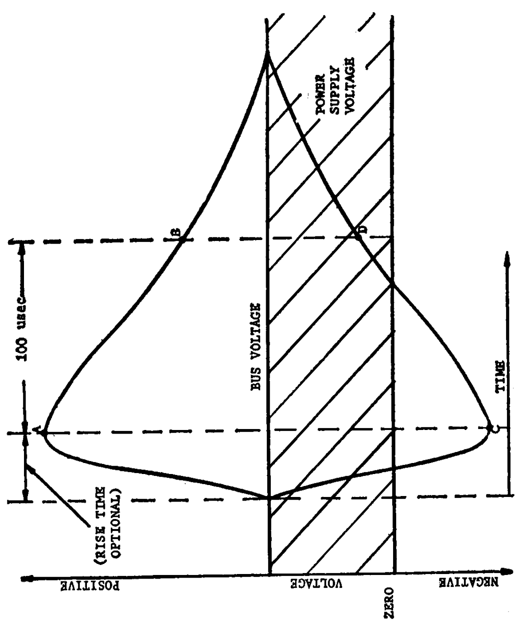


FIGURE 3—Negative pulse generating network.



Normal Bus Voltage	Intermittent Transient Test Voltage		Repetitive Transient Test Voltage	
	Point A	Point B	Point A	Point B
28	+78	+46	+48	+35
14	+39	+23	+24	+17
	Point C	Point D		
28	-22	+10		
14	-11	+5		

FIGURE 1—Transient voltage characteristics.

(1) Ground Plane. - A copper or brass ground plane, 0.01 inch thick minimum for copper, 0.025 inch thick minimum for brass, 12-square feet or more in area with a minimum width of 30 inches, shall be used. In all cases where a shielded room is employed, the ground plane shall be bonded to the shielded room at intervals no greater than 3 feet, and at both ends of the ground plane.

(2) Shock and Vibration Isolators. - The equipment under test shall be secured to mounting bases incorporating shock or vibration isolators, if such mounting bases are specified by the equipment manufacturer. The bounding straps furnished with the mounting base shall be connected to the ground plane. Where mounting

bases do not incorporate bonding straps, bonding straps shall not be used in the test setup.

(3) Bonding. - Only the provisions included in the design of the equipment and specified in the installation instructions shall be used to bond units, such as equipment and specified in the installation instructions shall be used to bond units, such as equipment case and mount, together or to the ground plane. Where bonding straps are required to complete the test setup they shall have a length not greater than 5 times the width, shall have a minimum thickness of 0.025 inch, and shall be copper or brass metal straps, not braid. Connections made with such bond straps shall have clean metal-to-metal contact.

(4) External Ground Terminal. - When an external terminal is available for a ground connection on the equipment under test, this terminal shall be connected to the ground plane if the terminal is normally grounded in the installation. If the installation conditions are unknown, the terminal shall not be grounded.

(5) Interconnecting Cables. - All equipment interconnecting cables and RF transmission lines shall be in accordance with the manufacturer's installation wiring diagram and shall use shielded or twisted wires only where specified. There no length of interconnecting cables is specified, the cables shall be at least five (5) feet long. Any inputs or outputs from or to other equipment associated with the equipment under test shall be adequately simulated.

(6) Dummy Antennas. - The dummy antenna shall have electrical characteristics which closely simulate those of the normal antenna, and should be shielded. It shall contain electrical components which are used in the normal antenna (such as filters, crystal diodes, synchros, motors, etc.)

b. Test instruments shall be set up and operated in accordance with the following criteria:

(1) Bonding. - Interference meters used for measurement during the "conducted" test shall not be bonded to the ground plane except through the interconnecting coaxial cable. The counterpoise on rod antennas shall be bonded to the ground plane with a strap of such length that the rod antenna can be positioned correctly. The strap shall be as wide as the counterpoise.

(2) Powerline Stabilization Network. - One stabilization network shall be inserted in each ungrounded primary input power lead of the equipment under test. The network shall be constructed in accordance with Figure 4. The input impedance characteristics of the stabilization network are shown in Figure5.

(3) Antenna Orientation and Positioning in Shielded Enclosures. - The rod or dipole antenna shall be located as shown in Figures 6 or 7. The rod antenna shall be so placed that the antenna is in a vertical position. The rod antenna shall be located at the point where maximum radiation pickup is obtained when it is moved along a line parallel with the edge of the ground plane. Those measurements which use a resonate dipole antenna shall have the dipole positioned parallel with the edge of the ground plane. The dipole antenna shall be centered 12 inches ±1 inch above the level of the ground plane. The rod or the dipole antenna shall be located at the distance from the equipment under test specified in Figures 6 and 7. When the dimensions of the dipole antenna become smaller than the test layout, the antenna shall be moved parallel to the edge of the ground plane to keep its sensitive elements adjacent to the point of maximum radiation. At frequencies form 25 up to and including 35 megacycles, the measurements shall be taken with the dipole antenna adjusted to resonance at 35 megacycles. The dipole an-

tenna shall be adjusted to resonance at all frequencies above 35 megacycles. In screen room tests, the antennas shall be at least 1 foot away from any wall.

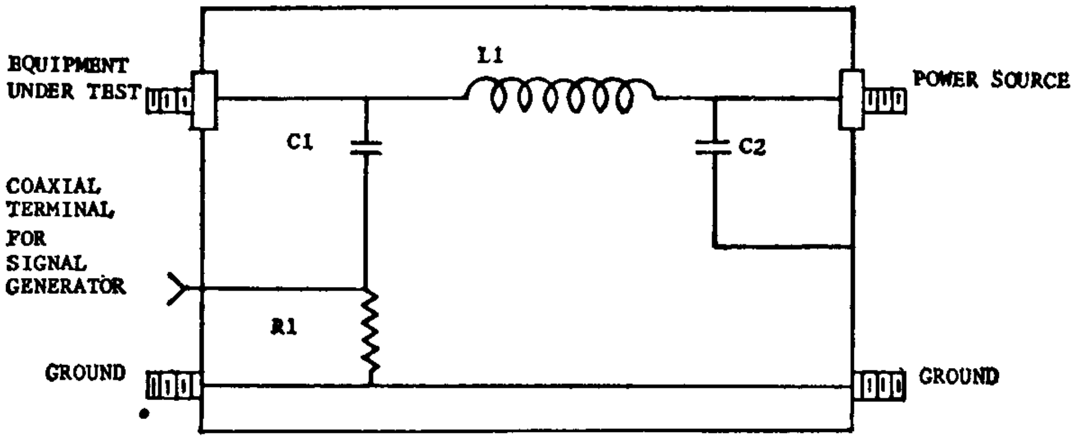
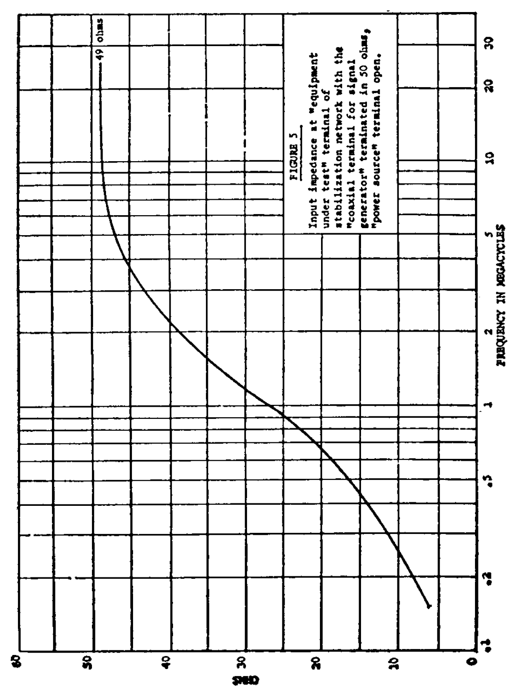


FIGURE 4.—Powerline stabilization network schematic diagram.

ENCLOSURE DATA: 14 GAGE (B & S) ALUMINUM SUGGESTED SIZE 9¾ IN. BY 4 BY 4 IN.
FORM DATA: 5¼ IN. LENGTH, 3 IN. DIA (OD), .125 IN. WALL DRILL ⅜ IN. HOLE 5/16 IN. FROM EACH END.
COIL DATA: L1=5 MICROHENRIES, 13 TURNS SINGLE LAYER, 4 IN. WINDING LENGTH.
WIRE DATA: AWG 6, 600 VOLT, .310 IN. DIA (OD). (FOR 50 AMPERE NETWORK.)
CAPACITOR: C1 SHALL BE MOUNTED ON 1 IN. INSULATING BLOCK ABOVE GROUND.
CAPACITOR DATA: C1=.1 UF, 600-VOLT DC, BATHTUB.
C2=1 UF, 600-VOLT DC, BATHTUB, SINGLE TERMINAL CASE MOUNTED ON GROUND.
RESISTOR DATA: R1=5,000-OHM, 5-WATT CARBON.

1. The values given for the component parts of the network are nominal. Regardless of the construction or deviation from nominal values, the network must have an impedance within 20 percent of that given in Figure 5.
2. Connecting leads to condensers and resistors should be as nearly as possible to zero length.
3. Networks may also be constructed having a 1-ohm series resistor between the line and capacitor C2. This 1-ohm resistor shall be made up from ten 10-ohm, 1-watt composition resistors.
4. The data given in this figure is suitable for the construction of 50-ampere networks. Other current-carrying networks may be constructed by changing the wire size given for the coil and the size of the over-all enclosure.
5. The 50-ohm transmission line should be extended within the enclosure right up to the location where it connects with capacitor C1.



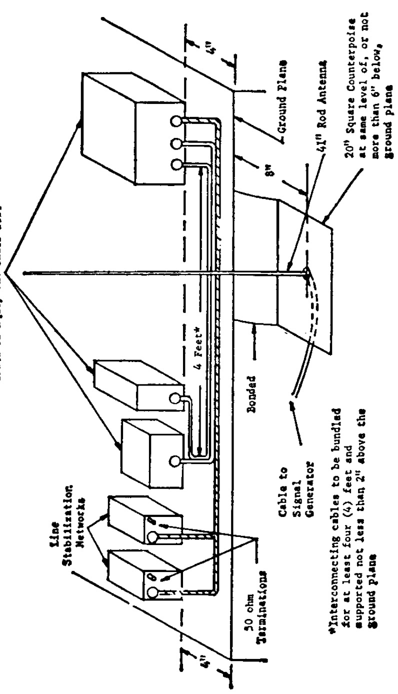


FIGURE 6—Location of rod antenna and arrangement of equipment.

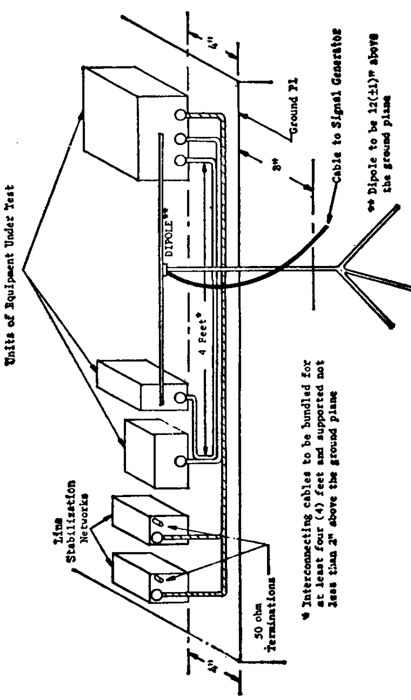


FIGURE 7—Location of dipole antenna and arrangement of equipment.

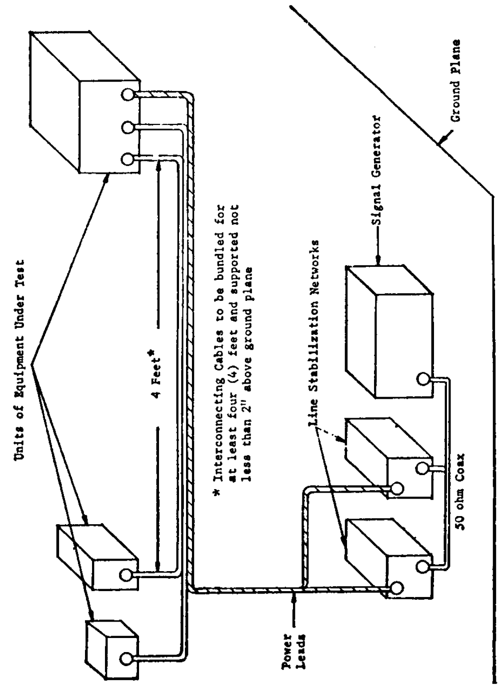


FIGURE 8—Arrangement of equipment for conducted RF susceptibility test.

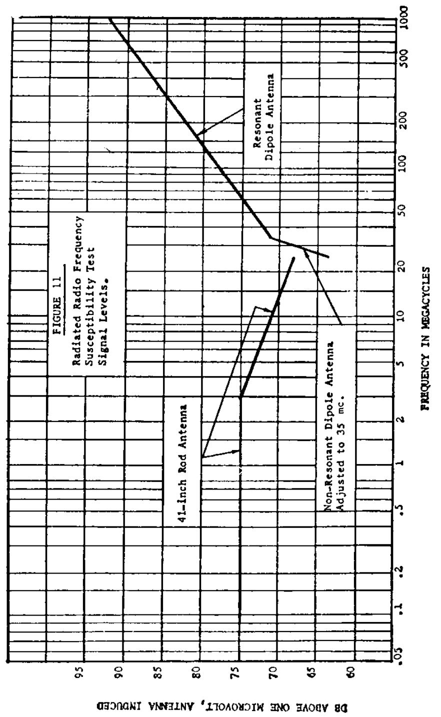


FIGURE 11
Radiated Radio Frequency Susceptibility Test Signal Levels.
Resonant Dipole Antenna
Non-Resonant Dipole Antenna Adjusted to 35 mc.
41-Inch Rod Antenna
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT, ANTENNA INDUCED

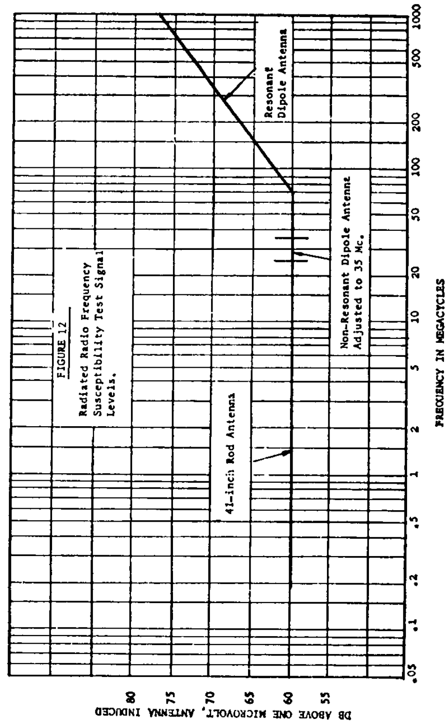


FIGURE 12
Radiated Radio Frequency Susceptibility Test Signal Levels.
Resonant Dipole Antenna
Non-Resonant Dipole Antenna Adjusted to 35 Mc.
41-inch Rod Antenna
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT, ANTENNA INDUCED

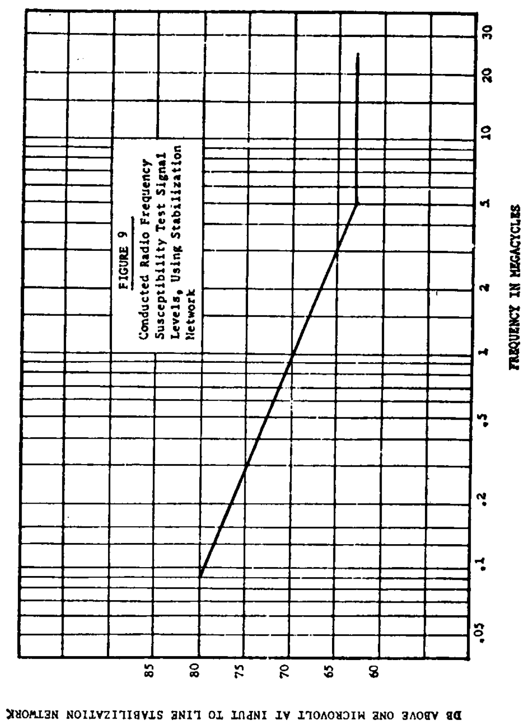


FIGURE 9
Conducted Radio Frequency Susceptibility Test Signal Levels, Using Stabilization Network
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT AT INPUT TO LINE STABILIZATION NETWORK

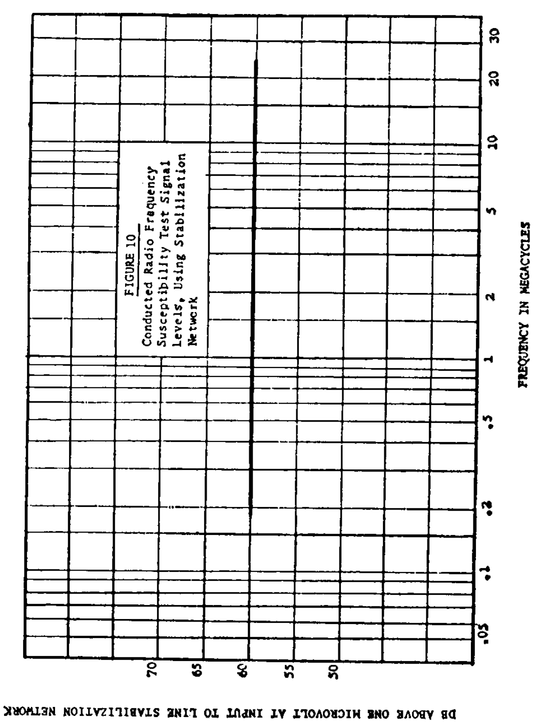


FIGURE 10
Conducted Radio Frequency Susceptibility Test Signal Levels, Using Stabilization Network
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT AT INPUT TO LINE STABILIZATION NETWORK

13.2 *Conducted Radio Frequency Susceptibility Test.* With the equipment under test arranged in a manner similar to that shown in Figure 8 apply through the powerline stabilization network an RF signal modulated 30 percent at 1,000 c.p.s. between each ungrounded primary input power lead and ground. Determine compliance with the applicable standards of paragraph 3.0 “Minimum Performance Standards under Environmental Test Conditions” of the appropriate FAA Airborne Electronic Equipment Minimum Performance Standards when the signal range specified in Figure 9 or Figure 10 for category A and Category B installation, respectively. The output impedance of the signal generator shall be 50 ohms. The voltages specified shall be those which exist across the 50 ohm signal generator output when no load is connected to the signal generator. All equipment interconnecting cables shall have 4 feet of their length bundled together and supporter 2 inches above the ground plane, as shown in Figure 8.

13.3 *Radiated Radio Frequency Susceptibility Test.* Expose the equipment under test to a radio frequency field, the levels of which (versus frequency) are specified in Figures 11 and 12 for Category A and Category B installations, respectively. The voltages specified in Figures 11 and 12 are those existing across the radiating antenna terminals. The test signal shall be modulated 30 percent at 1,000 c.p.s. The type of radiating antenna to be employed is related to the frequency of the test signal as follows:

Frequency	*Type of antenna*
90 kc. to 25 mc - - - - - -	41 inch rod antenna
25 mc. to 35 mc - - - - - -	Dipole antenna adjusted to resonance at 35 mc.
35 mc. to 1,000 mc - - - -	Dipole antenna adjusted to resonance at test frequency.

Care should be taken to use matching networks when required. The equipment under test, the radiating antenna and the line stabilization networks shall be arranged in accordance with Figure 6, when using the rod antenna, and Figure 7, when using the dipole antenna. During this test, determine compliance with the applicable standards of paragraph 3.0 “Minimum Performance standards under Environmental Test Conditions” of the appropriate FA Airborne Electronic Equipment Minimum Performance Standards

14.0 *Explosion Test.*

14.1 *Application and Conditions of Test.*

(1) It is recognized that installation practices in civil aircraft and in noncivil transport aircraft normally do not require the installation of equipment in locations where an explosive atmosphere may exist in the course of normal aircraft operations. For such installations, the Explosion Test is not applicable and the equipment is designated as Category “X” equipment.

(2) It is also recognized that, in special applications and in special purpose aircraft, equipment may be installed in locations where an explosive atmosphere may exist in the curse of normal aircraft operations. For these installations, the Explosion Test is applicable and the equipment is designated as Category “E: equipment.

b. Apparatus. The test chamber shall be a type capable of providing the test environment. A suitable test chamber is described in Military Specification MIL-C-9435.

c. Fuel. The fuel used shall be 100/130 octane gasoline.

d. Failure Criteria. If the equipment causes explosion at any of the test altitudes, it shall be considered to have failed to pass the test and no further trials need be attempted.

e. Applicability Exceptions. Sealed equipment, connecting wires, and cables shall be considered explosion-proof and require no test.

f. General Conditions.

(1) When necessary, large items of electrical equipment, such as motors, large relays, etc., shall be prepared for explosion-proof testing by drilling and tapping openings in the fuel vapor air mixture circulating system and for mounting a spark plug. The spark plug is used only for igniting the vapor air mixture in the equipment to insure the presence of an explosive mixture inside the equipment on test. Small items of equipment such as switches, circuit breakers, etc., shall not be drilled and tapped for mounting a spark plug when it is not predicable.

(2) When the explosion-proof test of paragraph 14.2a.(2) is being performed, dust or other auxiliary covers not intended to be explosion-proof may be removed or loosened to facilitate penetration of the explosive mixture.

14.2 *Test Procedures.*

a. Procedure I. This procedure is designed to determine the explosion producing characteristics of equipment not provided with cases designed to prevent flame or explosion propagation.[14]

(1) Preparation for Test.

(a) The equipment shall be installed in the test chamber i such a manner that normal electrical operation is possible and that mechanical controls may be operated through the pressure seals from the exterior of the chamber. All external covers of the equipment shall be removed or opened to insure adequate circulation of the explosive mixture. Large equipment, comprising multiple units, may be tested one or more units at a time by extending electrical connections through the cable port to units located externally.

(b) The equipment shall be operated to determine that it is functioning properly and to observe the location of any sparking or high temperature components which may constitute potential explosion hazards.

(c) Mechanical loads on drive assemblies and servo-mechanical and electrical loads on switches and relays may be simulated when necessary, if proper precaution is given to duplicating the normal load in respect to torque, voltage, current, inductive reactance, etc. In all instances, it is preferable to operate the equipment as it normally functions in the system during service use.

(2) Test Procedure. The test shall be conducted at test altitudes of ground level to 5,000 feet, 20,000 feet, and 40,000 feet, except that the highest test altitude shall not exceed the design requirement of the equipment.

(a) The test chamber shall be sealed and the ambient temperature within shall be raised to +71 ±3° C., or to the maximum temperature for which the equipment is designed to operate (if lower than 71° C.). The temperature of the test item and the chamber walls shall be permitted to rise to within 11° C. of that of the chamber ambient air, prior to introduction of the explosive mixture.

(b) The internal test chamber pressure shall be reduced sufficiently to simulate an altitude approximately 10,000 feet above the desired test altitude. The quantity of fuel, as determined from Figure 13 shall be introduced into the chamber. A time of 3 ±1 minutes shall be allowed for the introduction and vaporization of the fuel. Air shall be admitted into the chamber until a simulated altitude of t,000 feet above the test altitude is attained.

(c) Operation of the equipment shall then be commenced, all making and breaking electrical contacts being actuated. If high temperature components are present a warm-up time of 15 minutes shall be permitted. If no explosion results, air shall be admitted into the chamber so as to steadily reduce the altitude below the desired test altitude to an elevation 5,000 feet below

[14] See additional test procedure under paragraph 14.2b.

that altitude. The operation of the equipment shall be continuous throughout this period of altitude reduction and all making and breaking electrical contacts shall be operated as frequently as possible.

(d) If by the time the simulated altitude has been reduced to 5,000 feet below the test altitude, no explosion has occurred as a result of operation of the equipment, the potential explosiveness of the air-vapor mixture shall be verified by attempting to ignite the mixture with the igniter furnished with the chamber. It the air-vapor mixture is not found to be explosive, the test shall be considered void and the entire procedure repeated.

b. Procedure II. This procedure is designed to determine the flame and explosion arresting characteristics of equipment cases which are designed to prevent the propagation of internal case explosions.[15]

(1) Preparation for Test.

(a) The case, with the equipment in position within, shall be installed in the explosion chamber. The sting shall be accomplished without consideration of the equipment operating characteristics; accordingly, the equipment need not be operated. Adequate circulation of the explosive mixture throughout the case shall be provided by optional means.

(b) If it is necessary to drill the case for insertion of a hose from a blower, adequate precaution shall be taken to prevent ignition of the explosive mixture by backfire or release of pressure through the supply hose. The case volume shall not be altered by more than ±5 percent by any modification to facilitate the introduction of explosive vapor.

(c) A positive means of igniting the explosive mixture within the case shall be provided. The case may be drilled and taped for the spark plug or the spark plug may be mounted internally.

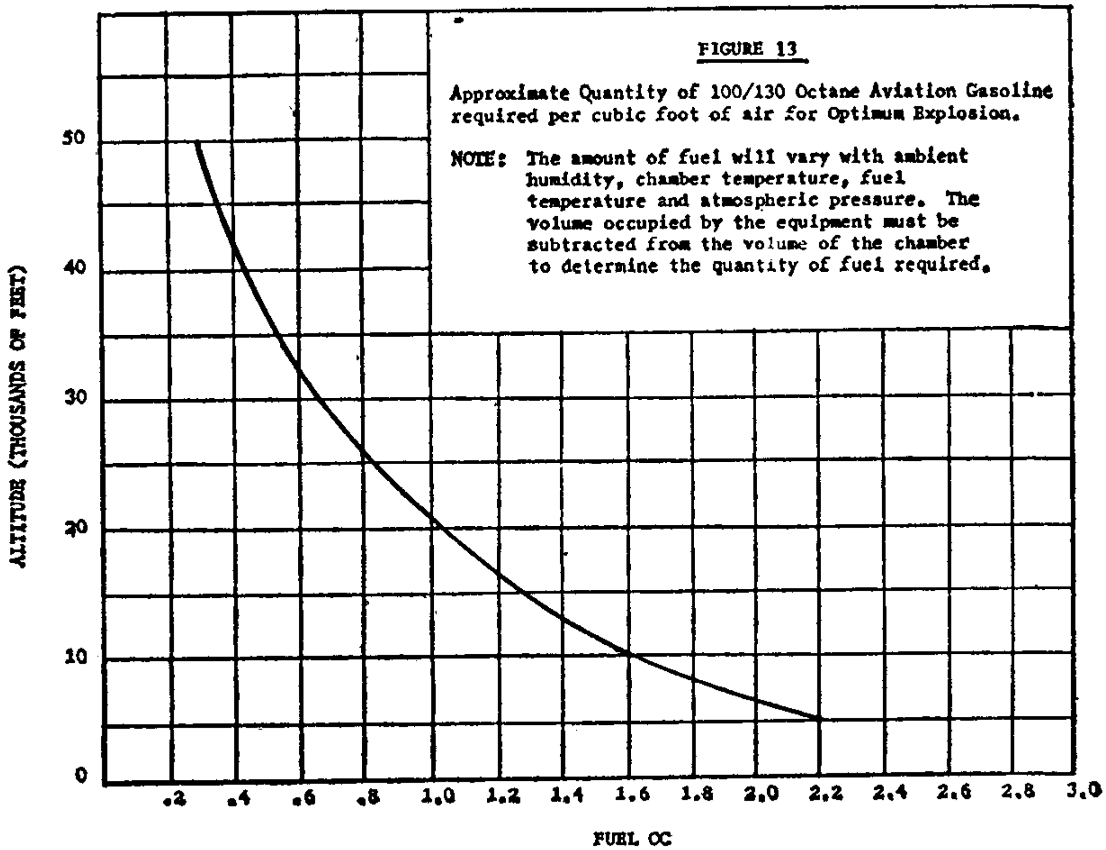
(2) Test Procedure. The test shall be accomplished as follows:

(a) The chamber shall be sealed and the internal pressure reduced sufficiently to simulate an altitude between local ground level and 5,000 feet. The ambient chamber temperature shall be at least 25° C. An explosive mixture shall be obtained within the test chamber. (See paragraph 14.2a.(2)(b).

(b) The internal case ignition source shall be energized, in order to cause an explosion within the case. The occurrence of an explosion within the case may be detected by use of a thermocouple inserted in the case and connected to a sensitive galvanometer outside the test chamber. If ignition of the mixture within the case does not occur immediately, the test shall be considered void and shall be repeated with a new explosive change.

(c) At least five internal case explosions shall be accomplished at the test altitude selected. If the case being tested is small (not in excess of one-fiftieth of the test chamber volume) and if the reaction within the case upon ignition is of an explosive nature without continued burning of the mixture as it circulates into the case, more than one internal case explosion but not more than five may be produced without recharging the entire chamber. Ample time must be allowed between internal case explosions for replacement of burnt gases with a fresh explosive mixture within the case. If the internal case explosions produced did not cause a main chamber explosion, the explosiveness of the fuel-air mixture in the main chamber is not found to be explosive, the test shall be considered void and the entire procedure repeated, using an explosive mixture.

[15] See additional test procedure under paragraph 14.2a.



APPENDIX A

STANDARDS ON EMISSION OF SPURIOUS RADIO FREQUENCY ENERGY (CONDUCTED AND RADIATED INTERFERENCE) AND ASSOCIATED TEST PROCEDURES

The problem of describing the gross radio frequency interference environment (RF Conducted and Radiated Susceptibility Test) in an aircraft is inseparably related to the delineation of the maximum level of spurious radio frequency energy that any one electrical or electronic equipment in that aircraft will emit. It is concluded, therefore, that if the foregoing RF Conducted and Radiated Susceptibility Tests are to achieve their intended purposes, a compatible standard on the maximum permissible level of spurious emission of radio frequency energy from any one electrical or electronic equipment in an aircraft must be applied to that equipment.

Accordingly, one of the following standards (and associated test procedure), as appropriate for the maximum weight of the aircraft in which the electrical/electronic equipment is intended to be installed must be applied to each unit of equipment incorporated in such installation:

1.0 *Standards on Emission of Spurious Radio Frequency Energy*.

a. Categories of Equipment.

Category A - Equipment intended for installation in aircraft having a Maximum Weight of more than 12,500 pounds.

Category B - Equipment intended for installation in aircraft having a Maximum Weight of 12,500 pounds, or less.

b. Conducted RF Interference. Radio interference voltages generated by the equipment within the frequency ranges and in excess of the values shown in Figures 16, 17, 18, and 19 for Categories A and B, respectively, shall not appear on any power line normally connected to an aircraft bus or other equipment.

c. Radiated RF Interference. Radiated interference fields generated by the equipment within the frequency ranges and in excess of the values shown in Figures 20, 21, 22, and 23 for Categories A and B, respectively, shall not be radiated from any unit, cable (including, but not limited to, control, pulse, i-f, video, antenna transmission and power cables) or interconnecting wiring. This requirement includes, but is not limited to, oscillator radiation, other spurious emanations and broadband interference. This does not include radiation emanating from antennas or, in the case of transmitters, and radiation on the selected frequency ±50 percent of the band of frequencies between adjacent channels.

NOTE: The emission of spurious radio-frequency energy from the equipment resulting form manual operation of switches, but not including any electrical or electromechanical operations resulting from manual operation of switches, may exceed the limits stated in paragraphs 1.0b. and 1.0c. if its duration does not exceed one second.

2.0 *Test Procedure.*

a. Equipment Required.

(1) Interference measuring instrument. - Empire Devices Model NF-105 (including heads and antennas), or equivalent.

(2) Line stabilization networks that meet the requirements of paragraph 2.b.(2)(b.)

b. General Requirements.

(1) The equipment under test shall be set up on a ground plane and operated in accordance with the following criteria:

(a) Ground Plane. - A copper or brass ground plane, 0.01 inch thick minimum for copper, 0.025 inch thick minimum for brass, 12-square feet or more in area with a minimum width of 30 inches, shall be used. In all cases where a shielded room is employed, the ground plane shall be bonded to the shielded room at intervals no greater than 3 feet and at both ends of the ground plane.

(b) Shock and Vibration Isolators. - The equipment under test shall be secured to mounting bases incorporating shock or vibration isolators, if such mounting bases are specified by the manufacturer. The bonding straps furnished with the mounting base shall be connected to the ground plane. Where mounting bases do not incorporate bonding straps, bonding straps shall not be used in the test setup.

(c) Bonding. - Only the provisions included in the design of the equipment and specified in the installation instructions shall be used to bond units, such as equipment case and mount, together or to the ground plane. Where bonding straps are required to complete the test setup they shall have a length not greater than 5 times the width, shall have a minimum thickness of 0.025 inch, and shall be copper or brass metal straps, not braid. Connections made with such bond straps shall have clean metal-to-metal contact.

(d) External Ground Terminal. - When an external terminal is available for a ground connection on the equipment under test, this terminal shall be connected to the ground plane if the terminal is normally grounded in the installation. If the installation conditions are unknown, the terminal shall not be grounded.

(e) Interconnecting Cables. - All equipment interconnecting cables and RF transmission lines shall be in accordance with the manufacturer's installation wiring diagram and shall use shielded or twisted wires only where specified. Where no length of interconnecting cables shall be at least five (5) feet long. Any inputs or outputs from or to other equipment associated with the equipment under test shall be adequately simulated.

(f) Dummy Antennas. - The dummy antenna shall have electrical characteristics which closely simulate those of the normal antenna, and should be shielded. It shall contain electrical components which are used in the normal antenna (such as filters, crystal diodes, synchros, motors, etc.)

(2) Test instruments shall be set up and operated in accordance with the following criteria:

(a) Bonding. - Interference meters used for measurement during the "conducted" test shall not be bonded to the ground plane except throughout the interconnecting coaxial cable. The counterpoise on rod antennas shall be bonded to the ground plane with a strap of such length that the rod antenna can be positioned correctly. The strap shall be as wide as the counterpoise.

(b) Powerline Stabilization Network. - One stabilization network shall be inserted in each ungrounded primary input power lead of the equipment under test. The network enclosure shall be bonded to the ground plane. The network shall be made in accordance with Figure 14. The input impedance characteristics of the stabilization network are shown in figure 15.

(c) Antenna Orientation and Positioning in Shielded Enclosures. - The rod or dipole antenna shall be located as shown if Figures 25 or 26. The rod antenna shall be so placed that the antenna is in a vertical position. The rod antenna shall be located at the pint where maximum radiation pickup is obtained when it is moved along a line parallel with the edge of the ground plane. Those measurements which use a resonant dipole antenna shall have the dipole positioned parallel with the edge of the ground plane. The antenna shall be centered 12 inches ±1 inch above the level of the ground plane. The rod or the dipole antenna shall be located at the distance form the equipment under test specified in Figures 25 or 26. When the dimensions of the dipole antenna become smaller than the test layout, the antenna shall be moved parallel to the edge of the ground plane to keep its sensitive elements adjacent to the point of maximum radiation. At frequencies from 25 up to and including 35 megacycles, the measurements shall be taken with the dipole antenna adjusted to resonance at 35 megacycles. The dipole antenna shall be adjusted to resonance at all frequencies above 35 megacycles. In screen room tests, the antennas shall be at least 1 foot away form any wall.

c. Detailed Procedure.

(1) Conducted Interference.

(a) Set up equipment in accordance with Figure 24.

(b) Search the frequency range specified for the applicable category for each equipment configuration required.

(2) radiated Interference.

(a) Set up the equipment in accordance with Figure 25.

(b) Search the frequency range specified in the applicable category for each equipment configuration required.

(c) Set up the equipment in accordance with Figure 26.

(d) Search the frequency range specified for the applicable category for each equipment configuration required.

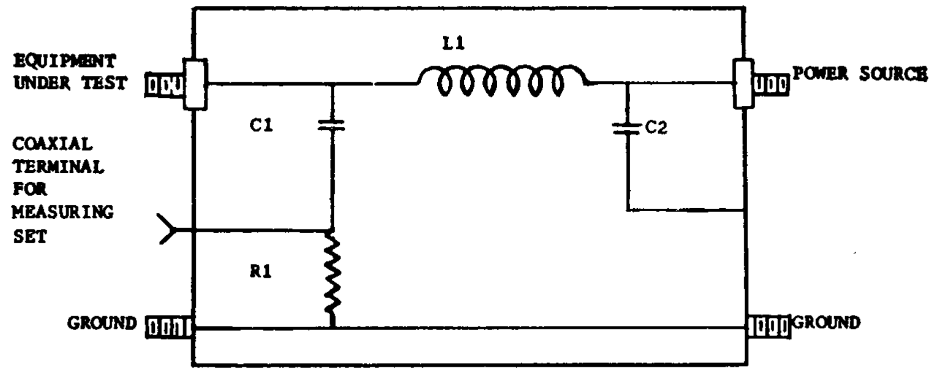


FIGURE 14.—Powerline stabilization network schematic diagram.

ENCLOSURE DATA: 14 GAGE (B & S) ALUMINUM SUGGESTED SIZE 9¾ IN. BY 4 BY 4 IN.
FORM DATA: 5¼ IN. LENGTH, 3 IN. DIA (OD), .125 IN. WALL DRILL ¾ IN. HOLE ⁷⁄₁₆ IN. FROM EACH END.
COIL DATA: L1=5 MICROHENRIES, 13 TURNS SINGLE LAYER, 4 IN. WINDING LENGTH.
WIRE DATA: AWG 6, 600 VOLT, .310 IN. DIA (OD). (FOR 50-AMPERE NETWORK.)
CAPACITOR: C1 SHALL BE MOUNTED ON 1 IN. INSULATING BLOCK ABOVE GROUND.
CAPACITOR DATA: C1=.1 UF, 600,VOLT DC, BATHTUB.
C2=1 UF, 600-VOLT DC, BATHTUB, SINGLE TERMINAL CASE MOUNTED ON GROUND.
RESISTOR DATA: R1=5,000-OHM, 5-WATT CARBON.

1. The values given for the component parts of the network are nominal. Regardless of the construction or deviation from nominal values, the network must have an impedance within 20 percent of that given in Figure 15.
2. Connecting leads to condensers and resistors should be as nearly as possible to zero length.
3. Networks may also be constructed having a 1-ohm series resistor between the line and capacitor C2. This 1-ohm resistor shall be made up from ten 10-ohm, 1-watt composition resistors.
4. The data given in this figure is suitable for the construction of 50-ampere networks. Other current-carrying networks may be constructed by changing the wire size given for the coil and the size of the over-all enclosure.
5. The 50-ohm transmission line should be extended within the enclosure right up to the location where it connects with capacitor C1.

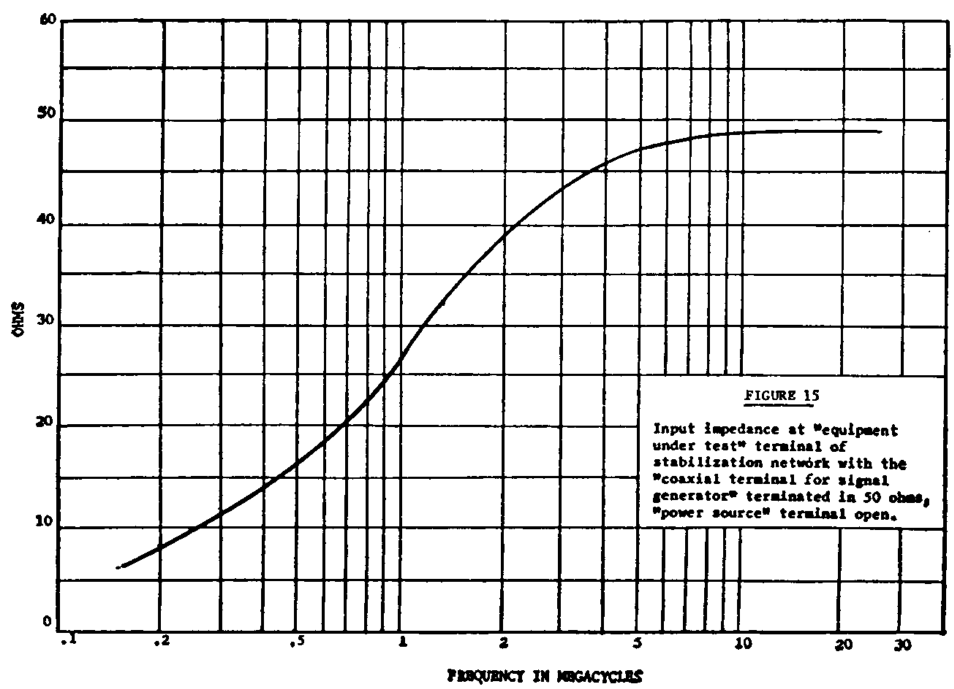


FIGURE 15

Input impedance at "equipment under test" terminal of stabilization network with the "coaxial terminal for signal generator" terminated in 50 ohms, "power source" terminal open.

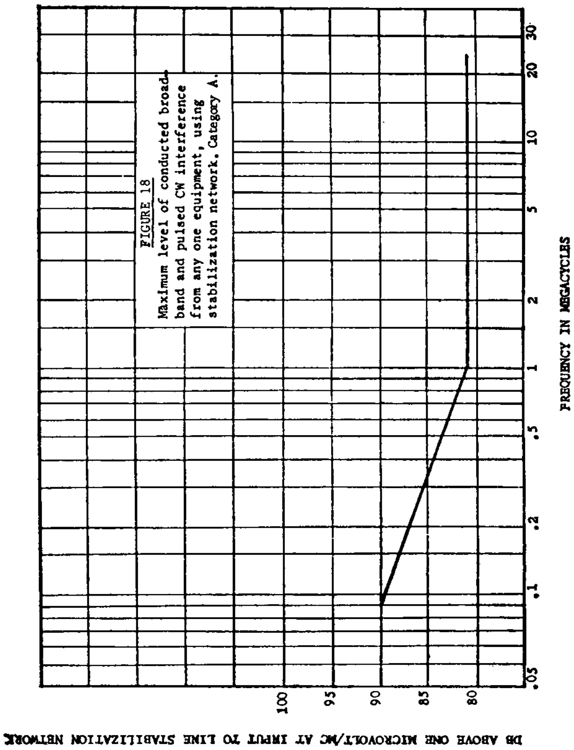


FIGURE 18
Maximum level of conducted broad-band and pulsed CW interference from any one equipment, using stabilization network. Category A.
FREQUENCY IN MEGACYCLES
.05 .1 .2 .5 1 2 5 10 20 30
100 95 90 85 80
DB ABOVE ONE MICROVOLT/MC AT INPUT TO LINE STABILIZATION NETWORK

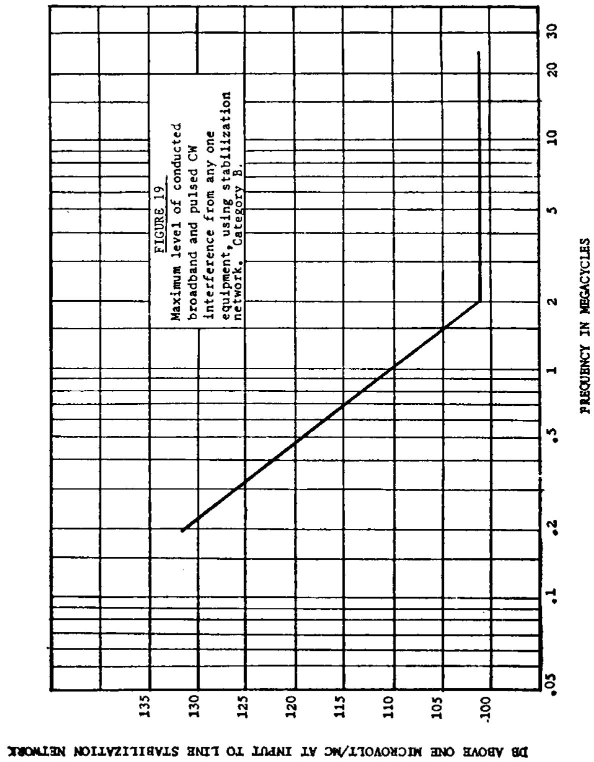


FIGURE 19
Maximum level of conducted broadband and pulsed CW interference from any one equipment, using stabilization network. Category B.
FREQUENCY IN MEGACYCLES
.05 .1 .2 .5 1 2 5 10 20 30
135 130 125 120 115 110 105 100
DB ABOVE ONE MICROVOLT/MC AT INPUT TO LINE STABILIZATION NETWORK

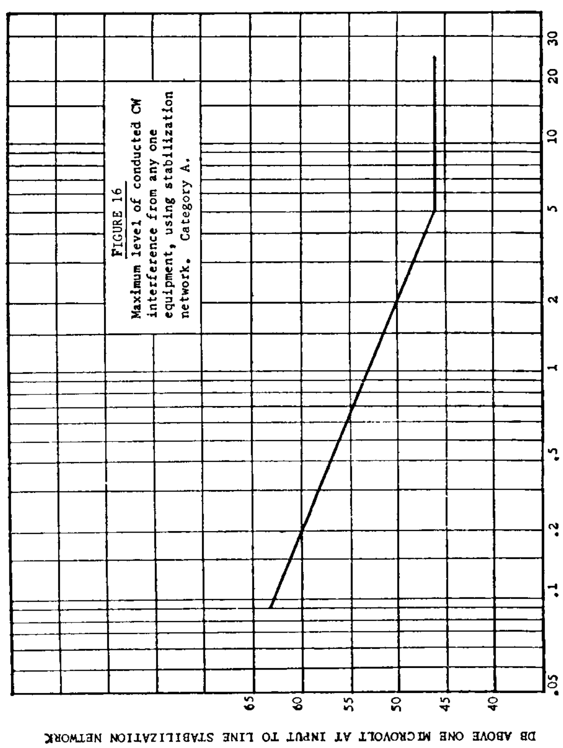


FIGURE 16
Maximum level of conducted CW interference from any one equipment, using stabilization network. Category A.
.05 .1 .2 .5 1 2 5 10 20 30
65 60 55 50 45 40
DB ABOVE ONE MICROVOLT AT INPUT TO LINE STABILIZATION NETWORK

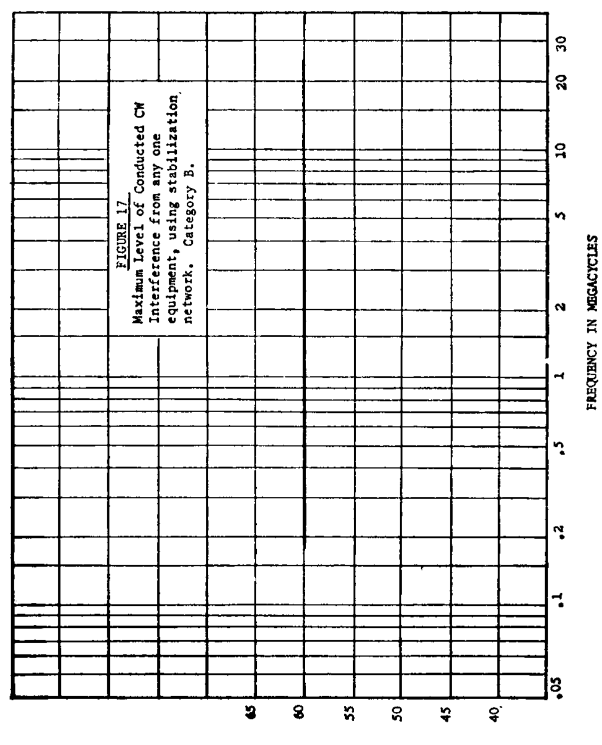


FIGURE 17
Maximum Level of Conducted CW Interference from any one equipment, using stabilization network. Category B.
FREQUENCY IN MEGACYCLES
.05 .1 .2 .5 1 2 5 10 20 30
65 60 55 50 45 40
DB ABOVE ONE MICROVOLT AT INPUT TO LINE STABILIZATION NETWORK

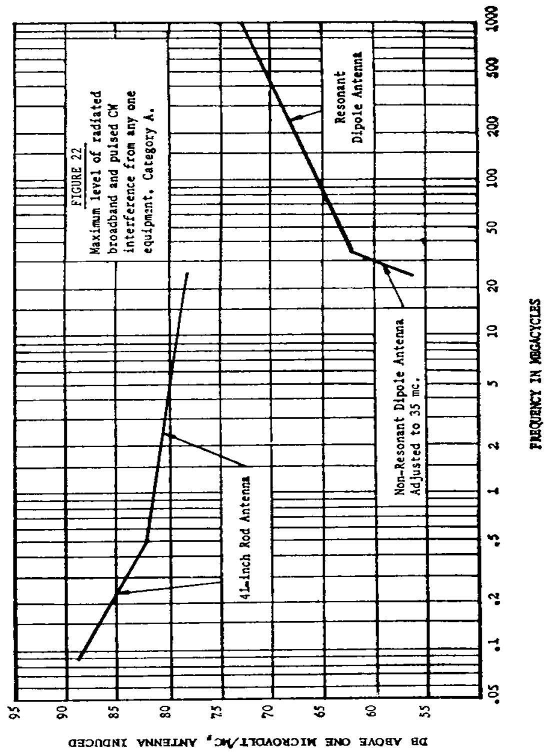


FIGURE 22
Maximum level of radiated broadband and pulsed CW interference from any one equipment, Category A.
Resonant Dipole Antenna
41-inch Rod Antenna
Non-Resonant Dipole Antenna Adjusted to 35 mc.
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT/MC, ANTENNA INDUCED

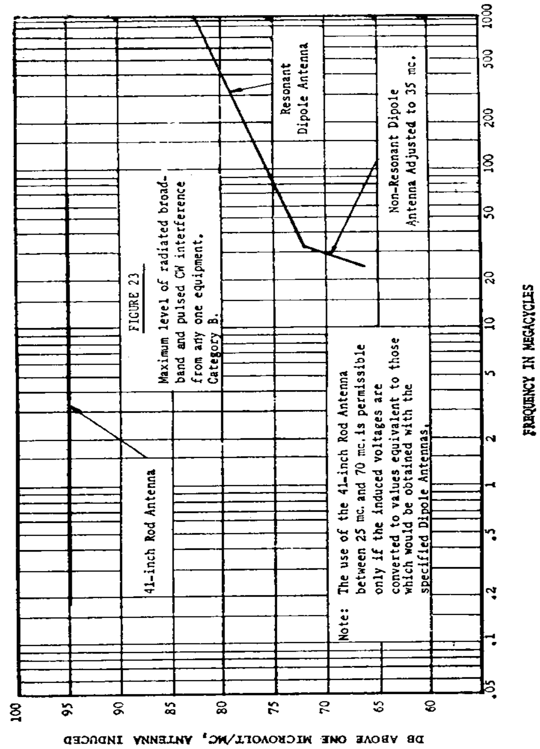


FIGURE 23
Maximum level of radiated broadband and pulsed CW interference from any one equipment. Category B.
Resonant Dipole Antenna
Non-Resonant Dipole Antenna Adjusted to 35 mc.
41-inch Rod Antenna
Note: The use of the 41-inch Rod Antenna between 25 mc. and 70 mc. is permissible only if the induced voltages are converted to values equivalent to those which would be obtained with the specified Dipole Antennas.
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT/MC, ANTENNA INDUCED

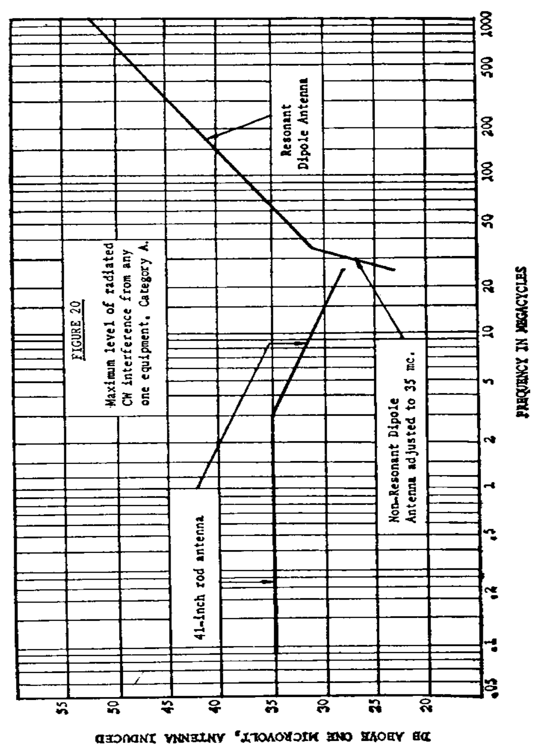


FIGURE 20
Maximum level of radiated CW interference from any one equipment. Category A.
Resonant Dipole Antenna
41-inch rod antenna
Non-Resonant Dipole Antenna adjusted to 35 mc.
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT, ANTENNA INDUCED

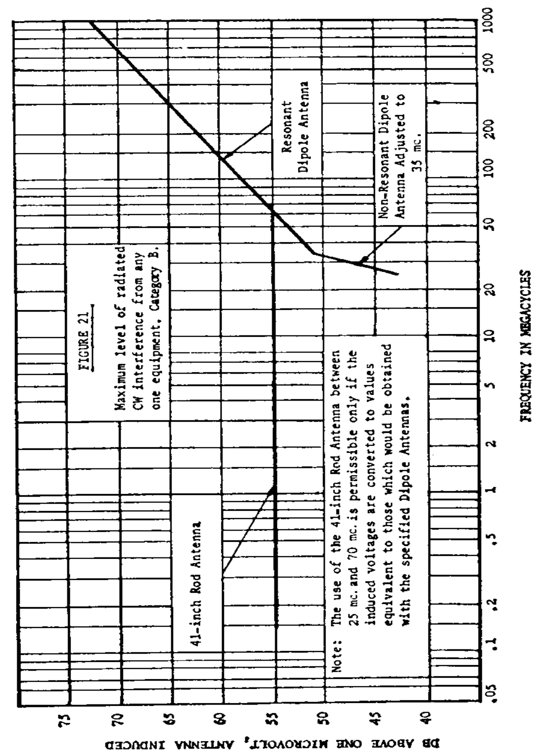


FIGURE 21
Maximum level of radiated CW interference from any one equipment. Category B.
Resonant Dipole Antenna
Non-Resonant Dipole Antenna Adjusted to 35 mc.
41-inch Rod Antenna
Note: The use of the 41-inch Rod Antenna between 25 mc. and 70 mc. is permissible only if the induced voltages are converted to values equivalent to those which would be obtained with the specified Dipole Antennas.
FREQUENCY IN MEGACYCLES
DB ABOVE ONE MICROVOLT, ANTENNA INDUCED

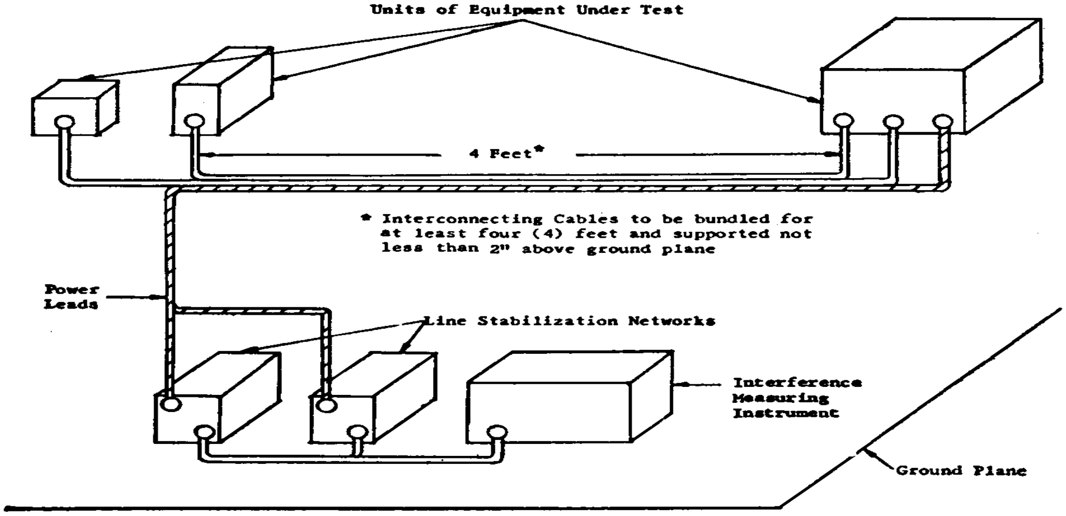


FIGURE 24—Arrangement of equipment for conducted RF interference test.

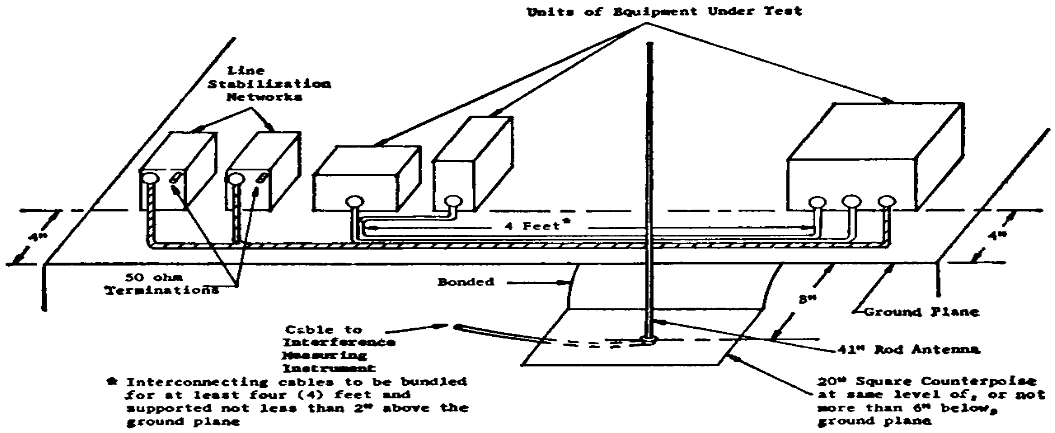


FIGURE 25—Location of rod antenna and arrangement of equipment.

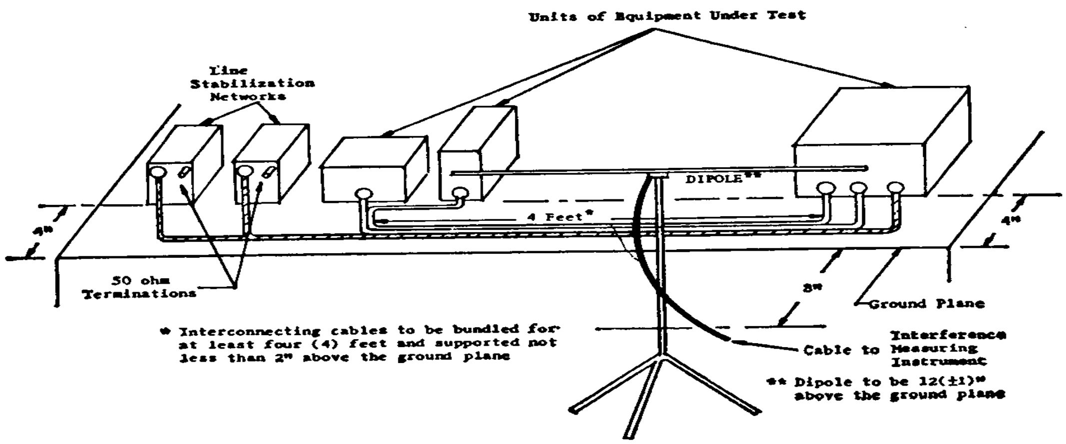


FIGURE 26—Location of dipole antenna and arrangement of equipment.