RTCA, Incorporated
1140 Connecticut Avenue, N.W., Suite 1020
Washington, D.C. 20036

Change No. 1

-to-

RTCA/DO-197A

Minimum Operational Performance Standards for an Active Traffic Alert and Collision Avoidance System I (Active TCAS I)

RTCA Paper No. 181-97/TMC-275
July 29, 1997

Copies of this document may be obtained from

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p. 10, 2.2.3.2. Change to RF Power levels is follows:

a)From: Maximum RF power: 54 dBm(250W)
Minimum RF power: 50 dBm(100W)

To: Maximum RF power: 56 dBm (400W)
Minimum RF power: 52 dBm (158W)

b)From: Maximum EIRP: 57 dBm (500W)
Minimum EIRP: 53 dBm (200W)

To: Maximum EIRP: 59 dBm (794W)
Minimum EIRP: 55 dBm (316W)

p. 16, 2.2.6. Replace the table with the following:

Number of Airborne TCAS Interrogators (NT)	K Upper Limit for $\Sigma P(k)$ k=1	
	If RR < 240	If RR > 240
0	250	118
1	250	113
2	250	108
3	250	103
4	250	98
5	250	94
6	250	89
7	250	84
8	250	79
9	250	74
10	245	70
11	228	65
12	210	60
13	193	55
14	175	50
15	158	45
16	144	41
17	126	36
18	109	31
19	91	26
20	74	21
21	60	17
≥22	42	12

p. 19, Figure 2-3. Replace Figure 2-3 with the following six-level whisper-shout sequence.

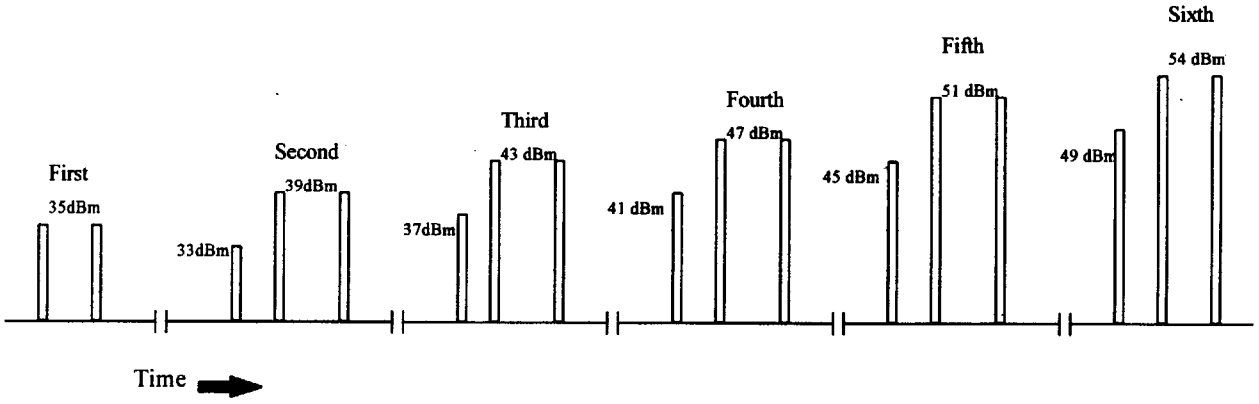


Figure 2-3 Example Whisper-Shout Sequence.
First Pulse of Interrogation Serves as Second Pulse of Suppression

p. 20, Figure 2-4. Replace Figure 2-4 with the following.

Whisper Shout Interrogation Powers	Scan Period	Rate Power Product
250+125+50+20+8+3.2 watts	2 sec.	228 watts/sec
125+50+20+8+3.2 watts	1 sec.	206 watts/sec
125+50+20+8+3.2 watts	2 sec.	103 watts/sec
50+20+8+3.2 watts	1 sec.	81 watts/sec
50+20+8+3.2 watts	2 sec.	41 watts/sec
20+8+3.2 watts	1 sec.	31 watts/sec
20+8+3.2 watts	2 sec.	16 watts/sec
8+3.2 watts	1 sec.	11 watts/sec

p. 51, 2.4.2.5.

Change the Conditions to the following:

Active TCAS I initialized and operating at T=0 seconds. Each of the 22 intruders is assigned a discrete address and transmits only TCAS broadcast interrogations and only at the following times and rates:

Intruders 1-9 every 10 sec starting at T=30 sec.
Intruders 10-16 every 20 sec starting at T=70 sec.
Intruders 17-22 every 20 sec starting at T=130 sec.

The timing of the TCAS broadcast interrogations and the ATCRBS interrogations are controlled to prevent overlap with each other.

Change the Scenario Descriptions to the following:

Scenario Description

Scenario A
250 watts/sec measured at T=20 sec
250 watts/sec measured at T=60 sec
144 watts/sec measured at T=120 sec
42 watts/sec measured at T=180 sec

Scenario B
118 watts/sec measured at T=20 sec
74 watts/sec measured at T=60 sec
41 watts/sec measured at T=120 sec
12 watts/sec measured at T=180 sec

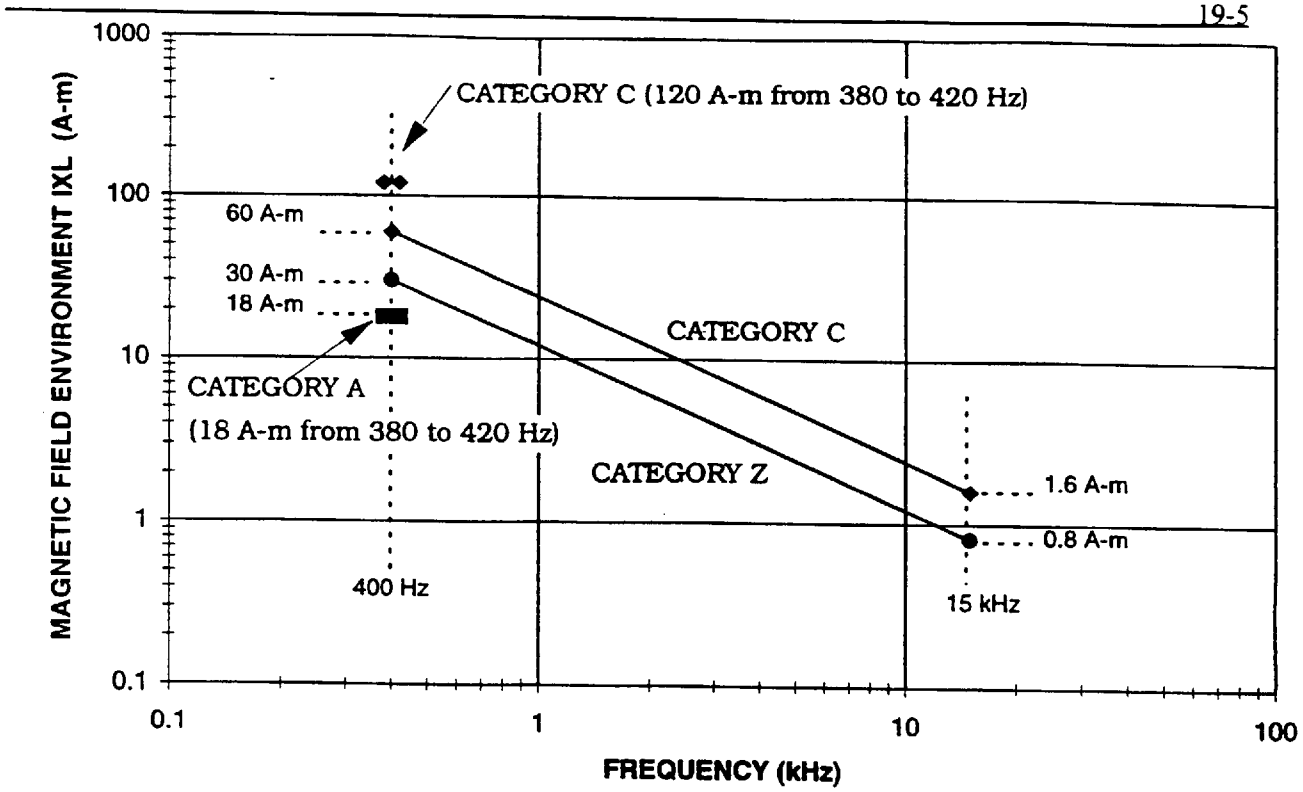


Figure 19-1(a) Audio Frequency Magnetic Field Susceptibility Test Levels

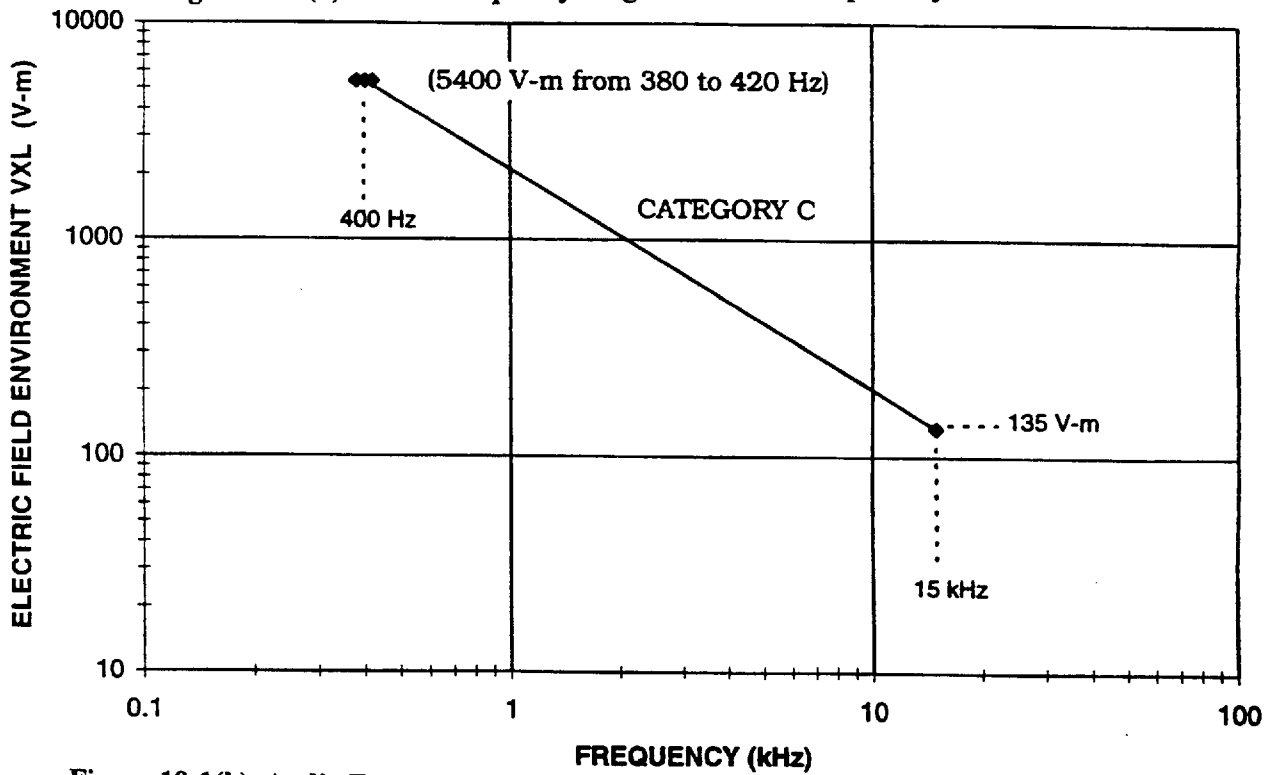
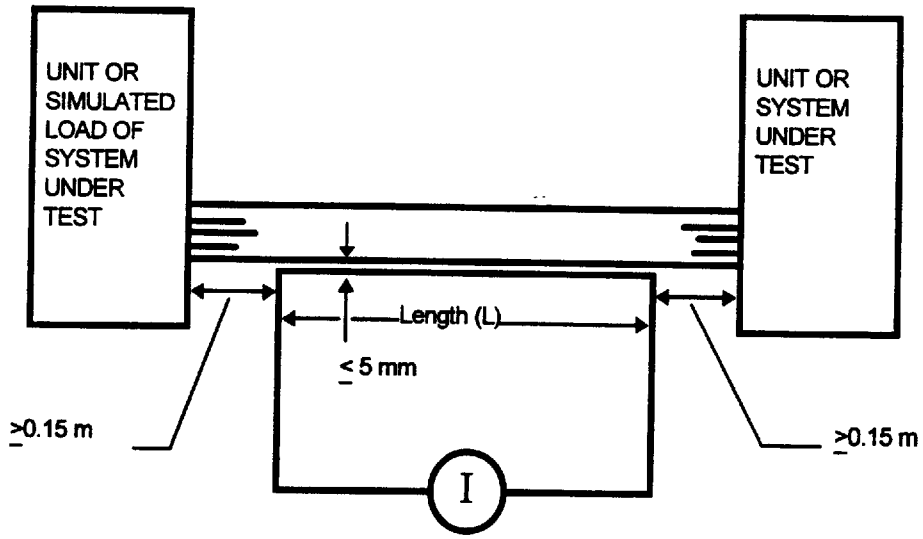


Figure 19-1(b) Audio Frequency Electric Field Susceptibility Test Level-Category C



Note 1: The interconnecting wire bundle shall be spaced a minimum of 50 mm above the ground plane.

Note 2: Magnetic Field Environment = Current (I) x Length (L) (amperes rms x meters)

Figure 19-2 Audio Frequency Magnetic Field Susceptibility Test Setup

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MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AN ACTIVE TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM I (ACTIVE TCAS I)

Page 19, Figure 2-3, EXAMPLE WHISPER-SHOUT SEQUENCE, change the quantity ".35 dBm" between the first two pulses at the left of the figure, to read: "35 dBm".

RTCA Paper No. 479-94/SC147-620
November 22, 1994

MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AN ACTIVE TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM I (ACTIVE TCAS I)

DOCUMENT NO. RTCA/DO-197A
September 12, 1994
Prepared by: SC-147

RTCA

"Requirements and Technical Concepts for Aviation"

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1140 Connecticut Avenue, N.W., Suite 1020
Washington, D.C. 20036

MINIMUM OPERATIONAL PERFORMANCE STANDARDS FOR AN ACTIVE TRAFFIC ALERT AND COLLISION AVOIDANCE SYSTEM I (ACTIVE TCAS I)

RTCA/DO-197A

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Prepared by:
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FOREWORD

This report was prepared by RTCA Special Committee 147 (SC-147) and approved by the RTCA Technical Management Committee (TMC) on September 12, 1994.

RTCA, Incorporated is a not-for-profit corporation formed to advance the art and science of aviation and aviation electronic systems for the benefit of the public. The organization functions as a Federal Advisory Committee and develops consensus based recommendations on contemporary aviation issues. RTCA's objectives include but are not limited to:

- coalescing aviation system user and provider technical requirements in a manner that helps government and industry meet their mutual objectives and responsibilities;

- analyzing and recommending solutions to the system technical issues that aviation faces as it continues to pursue increased safety, system capacity and efficiency;

- developing consensus on the application of pertinent technology to fulfill user and provider requirements, including development of minimum operational performance standards for electronic systems and equipment that support aviation; and

- assisting in developing the appropriate technical material upon which positions for the International Civil Aviation Organization and the International Telecommunication Union and other appropriate international organizations can be based.

The organization's recommendations are often used as the basis for government and private sector decisions as well as the foundation for many Federal Aviation Administration Technical Standard Orders.

Since RTCA is not an official agency of the United States Government, its recommendations may not be regarded as statements of official government policy unless so enunciated by the U. S. government organization or agency having statutory jurisdiction over any matters to which the recommendations relate.

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EXECUTIVE SUMMARY

This document provides Minimum Operational Performance Standards (MOPS) for Active Traffic Alert and Collision Avoidance System I (Active TCAS I) on aircraft up to thirty passenger seats as prescribed by the Federal Aviation Administration (FAA) TCAS rules.

Active TCAS I is an air-to-air interrogation device that provides traffic advice to the flight crew by alerting them to the presence of a nearby transponder-equipped aircraft and advising the crew where to look for the aircraft so that it can be visually acquired and avoided if necessary. Unlike TCAS II and TCAS III, Active TCAS I does not provide conflict resolution advisories.

The following summarizes the operational goals to be met by a minimum performance Active TCAS I system for revenue passenger operations:

a. The systems is capable of providing reliable and timely advice to the pilot by using an audible and visual advisory of the proximity of an intruder aircraft.

b. The system will detect and then timely report the range, altitude (if reported) and relative bearing of the proximate aircraft with high reliability.

c. The probability of displaying false targets will be as low as possible.

d. The system should not increase the traffic on the Secondary Surveillance Radar (SSR) radio frequencies in a manner that degrades the ATC system.

Section 1.0 of this document is intended to provide information needed to understand the rationale for the equipment characteristics and requirements stated in the remaining sections.

Section 2.0 contains the minimum performance standards for the equipment. These standards define the required performance under standard operating conditions and stressed physical environments. Section 2.0 also details the recommended bench test procedures necessary to demonstrate compliance with system performance requirements.

Section 3.0 describes the performance required of the installed equipment. Tests for installed equipment are included to ensure that its performance is acceptable when performance cannot be adequately determined through bench testing.

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1.0 Purpose and Scope

1.1 Introduction

This document sets forth minimum operational performance standards for an Active Traffic Alert and Collision Avoidance System (Active TCAS I) to provide the Proximity Warning Indicator (PWI) function on aircraft with up to 30 passenger seats as required by the Federal Aviation Administration's TCAS Rule.

Active TCAS I is an air-to-air interrogation device that provides traffic advice to the flight crew by alerting them to the presence of a nearby transponder-equipped aircraft and advising the crew where to look for the aircraft so that it can be visually acquired and avoided, if necessary. The pilot must be alerted in time to: a) visually look for the intruding aircraft; b) locate it; c) determine if an avoiding maneuver is necessary; and d) accomplish the avoiding maneuver, if necessary (see Appendix A). Unlike Active TCAS II and Active TCAS III, Active TCAS I does not provide conflict resolution advisories.

A significant amount of data demonstrates that a pilot will visually locate an intruder aircraft more rapidly, under normal as well as poor visibility conditions, when intruder range, relative bearing and altitude information are provided.

For the purpose of this document, "own aircraft" refers to the aircraft equipped with Active TCAS I; "other aircraft" refers to another aircraft that the Active TCAS I aircraft is interacting with.

1.2 Useful Range of a PWI-Operational Environment

Three or four nautical miles is a nominal range at which aircraft can reliably be detected in visual flight conditions with normal in-flight visibility. The maximum range that a pilot can visually detect another aircraft varies as a function of relative motion and the contrast of the other aircraft against the background as seen by the pilot. Most near misses and mid-air collisions occur in the airspace below 10,000 feet MSL.

It is expected that there will continue to be a mix of controlled and uncontrolled aircraft using the same airspace and operating in visual meteorological conditions. Thus, a system that can be installed on an aircraft that enhances the pilot's capability of visually locating other aircraft will be operationally useful.

1.3 Need for Cooperative Equipment

It would be best if the system did not require special cooperative equipment to permit an airborne collision avoidance system to perform its function in a suitable manner. However, numerous studies show that some type of cooperative device is necessary to permit the intruding aircraft to be detected in an operationally useful manner. The preferable cooperative device is the ATCRBS or Mode S transponder, with altitude reporting capability, so the pilot of the Active TCAS I equipped aircraft can be told when and where

to look for the intruding aircraft. Passive techniques such as those described in RTCA DO-184 may be used as an enhancement to the Active TCAS I.

1.4 Contents of This Document

Section 1.0 of this document is intended to provide information needed to understand the rationale for the equipment characteristics and requirements stated in the remaining sections.

Section 2.0 contains the minimum performance standards for the equipment. These standards define the required performance under standard operating conditions and stressed physical environments. Section 2.0 also details the recommended bench test procedures necessary to demonstrate compliance with system performance requirements.

Section 3.0 describes the performance required of the installed equipment. Tests for installed equipment are included to ensure that its performance is acceptable when performance cannot be adequately determined through bench testing.

Compliance with these standards by manufacturers, installers and users is recommended as one means of assuring that the equipment will satisfactorily perform its intended function.

"Active TCAS I equipment" as used herein includes all components or units necessary (as determined by the manufacturer or installer) for the equipment to properly perform its function, with the exception of the transponder. It should not be inferred that each Active TCAS I equipment design will necessarily have all components or units in separate packages. This will depend on the specific design chosen by the manufacturer. The transponder capabilities may be implemented as part of the TCAS avionics package, but the term "Active TCAS I equipment" will refer only to the Active TCAS I portion of the package.

1.5 Operational Goals

The general operational goals of the Active TCAS I are described in the following paragraphs.

1.5.1 Minimum Performance Active TCAS I System

The following summarizes the operational goals to be met by a minimum performance Active TCAS I system:

a. The system must be capable of providing reliable and timely advice to the pilot by using an audible and visual advisory of the proximity of an intruder aircraft.

b. It should report the range, altitude (if reported) and relative bearing of the proximate aircraft to an accuracy of +0.1 nautical mile and within the bearing accuracy of Section 2.2.9.2, with high reliability. If the intruding

aircraft is transponder equipped and within five nautical miles, it should be reliably detected and reported.

c. The data should be timely and not lag more than a second or two behind the actual relative position as seen by the pilot when aircraft are maneuvering during normal flight operations.

d. The probability of displaying false targets should be as low as possible. This requirement tends to oppose the foregoing requirement, which says the display should be timely. A reasonable tradeoff must be found using these two related requirements.

e. The system should not increase the traffic on the Secondary Surveillance Radar (SSR) radio frequencies in a manner that degrades the ATC system.

1.5.2 Operational Enhancements to a Minimum Performance Active TCAS I

The minimum performance Active TCAS I may be enhanced to any degree desired by the supplier or his customers as long as the enhancements do not conflict with the guidelines and requirements set forth in this document.

Operational enhancements to the minimum performance Active TCAS I have been identified. A brief description of these enhancements follows:

a. Display of Mode C Relative Altitude Data

If the Active TCAS I equipped aircraft has a Mode C altitude encoder, the data will be available in digital form and shall be used by the Active TCAS I to display relative altitude data.

Knowing if the equipped aircraft is at or near own aircraft's altitude provides a major operational advantage. Mode C data, when provided by the detected aircraft, will provide a significant operational advantage to the crew since they know more accurately where to look for the other aircraft. Knowing relative altitude will aid visual acquisition of the other aircraft and improve the likelihood that the aircraft being visually tracked is the same one that has been detected and reported by the Active TCAS I. Equally important, if detected altitude of other aircraft offers adequate vertical separation, Active TCAS I can avoid the issuance of a Traffic Advisory.

b. Improved Angle of Arrival Measurement

The minimum Active TCAS I system will provide relative bearing measurement accurate to the requirements of Section 2.2.9.2. Improving the bearing measurement accuracy will decrease the time required by the

pilot to visually acquire the intruding aircraft and improve the probability he will find the aircraft. It will also increase the likelihood that the aircraft visually acquired is the same one that is displayed by the Active TCAS I. If there are several aircraft nearby (perhaps one or more not transponder-equipped), knowing that the one displayed by the Active TCAS I is at a more specific relative bearing will be useful.

c. Interrogator Power

Minimum Active TCAS I is limited in interrogation power and rate by interference limiting standards appropriate for this class of equipment. It is possible to enhance the minimum design by increasing interrogation power and/or rate and thus improve surveillance reliability. This can be done by adding the capability to transmit Mode S broadcasts and thus to operate according to the Active TCAS II interference limiting standards.

1.6 Assumptions and Limitations

1.6.1 Disadvantages of Providing a Longer Range Active TCAS I Capability

If the pilot cannot locate the other aircraft visually and the Active TCAS I display shows that the aircraft is closing and is at the same flight altitude, the pilot may be tempted to use the Active TCAS I system as a means of determining how to avoid the other aircraft. The Active TCAS I capability is not adequate to permit the pilot to select a proper avoiding maneuver without visually acquiring the other aircraft. The longer the range of the Active TCAS I capability, the more targets could be displayed. A longer range Active TCAS I system would increase the interference potential to the SSR RF environment. Active TCAS I systems have definite limitations in the amount of RF energy that can be radiated, even when significantly enhanced. However, experience has shown that there are operational benefits to having various pilot-selectable display ranges.

1.6.2 Transponder Population

When operating in an environment having relatively low interrogation rate and a low density of TCAS interrogators transmitting Mode S broadcasts, the performance of minimum Active TCAS I without enhancements may be expected to be reliable out to a range of five nautical miles for densities up to about 0.08 aircraft per square nautical mile.

It is expected that the maximum traffic density of transponder- equipped aircraft in the airspace of the United States may increase to 0.3 aircraft per square nautical mile at all altitudes. Some of these aircraft will be equipped with Mode S transponders. The Active TCAS I equipment will function in this transponder environment within the limitations set forth in this document.

The interference limiting standards for minimum Active TCAS I have been developed to assure compatible operation with all other equipment in these radio bands, for all values of density up to this maximum, 0.3 aircraft per square nautical mile. Reliable air-to-air

surveillance by minimum Active TCAS I is, however, not expected in such dense environments. The surveillance reliability for a given range and density will depend on certain other environmental characteristics including the total interrogation rate in the vicinity and the density of TCAS interrogators transmitting Mode S broadcasts.

1.7 Test Procedures

The test procedures and associated limits specified throughout this document are intended to be used as one means of demonstrating compliance with the minimum performance parameters. Although specific test procedures are cited, it is recognized that other methods may be preferred. These alternative procedures may be used if they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternative procedures.

The order of tests suggests that the equipment be subjected to a succession of different tests as it moves from design and design qualification into operational use. For example, compliance with the requirements of Section 2.0 should have been demonstrated as a precondition to satisfactory completion of the installed system tests of Section 3.0. The complete tests normally are performed once on each model of equipment to demonstrate compliance with the minimum operational performance standard (MOPS).

1.7.1 Environmental Tests

Environmental tests are specified in Section 2.3. The tests and associated requirements are intended to provide a laboratory means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual operations. Test results may be used by equipment manufacturers as design guidance, in preparation of installation instructions, and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.7.2 Bench Tests

Bench test procedures are specified in Subsection 2.4. These tests are conducted at the equipment level and are intended to provide laboratory means of demonstrating compliance with the requirements of Subsections 2.1 and 2.2. Test results may be used by equipment manufacturers as design guidance for monitoring manufacturing compliance, and in certain cases, for obtaining formal approval of equipment design and manufacture.

1.7.3 Installed System Tests

The installed system test procedures and their associated limit requirements are specified in Section 3.0. Although bench and environmental test procedures are not included in the installed system tests, their successful completion is a precondition to completion of the installed tests. In certain instances, however, installed system tests may be used in lieu of bench test simulation of such factors as power supply characteristics, interference from or

to other equipment installed on the aircraft, etc. Installed tests are normally performed under one or both of two conditions:

a. With the aircraft on the ground and using simulated or operational system inputs, and

b. With the aircraft in flight using operational system signals appropriate to the equipment under test.

Test results may be used to demonstrate functional performance in the environment in which the equipment is intended to operate.

2.0 ACTIVE TCAS I EQUIPMENT REQUIREMENTS AND TEST PROCEDURES

2.1 General Requirements

2.1.1 Airworthiness

Design and manufacture of the equipment shall provide for installation so as not to impair the airworthiness of the aircraft.

2.1.2 General Performance

The equipment shall perform its intended function, as defined by the manufacturers, and its proper use shall not create a hazard to the user of the equipment nor to other users of the National Airspace System.

2.1.3 Federal Communications Commission Rules

The equipment shall comply with all applicable rules of the Federal Communications Commission.

2.1.4 Controls

The number and complexity of the controls shall be reduced to a minimum consistent with safe system operation. Where possible, control functions shall be performed automatically.

2.1.4.1 Operation of Controls

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

2.1.4.2 Accessibility of Controls

Controls that are not normally adjusted in flight shall not be readily accessible to flight crew personnel.

2.1.5 Pilot Advisory Functions

The interface between Active TCAS I and the pilot is defined in an FAA Advisory Circular entitled "Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (Active TCAS I)".

2.1.6 Equipment Configuration

It is the intention of this standard to permit a manufacturer to establish interfaces between Active TCAS I elements and obtain regulatory approval of these components of the total

system. It is the intention of this standard to allow interchangeability of system components thus defined. For example, Active TCAS I with a remote control panel may have several panel configurations available to meet the needs of various aircraft types. The manufacturer is allowed to establish control panel interface standards and receive approval of the various panel designs without performing tests on the total system for each panel design.

2.1.7 Active TCAS I Combined With Other Aircraft Systems

This standard does not preclude combining the Active TCAS I with other aircraft systems, or the use of multifunction antennas, displays or controls. However, any such combination shall not degrade the general performance requirements of the Active TCAS I equipment, the general performance requirements of the system with which the Active TCAS I is combined, any technical performance specification stated elsewhere in this MOPS or any technical performance standard for the other system.

2.1.8 Effects of Test

The equipment shall be designed so that the application of specified test procedures shall not be detrimental to equipment performance following the application of these tests, except as specifically allowed.

2.2 Minimum Performance Standards - Standard Conditions and Signals

2.2.1 Definition of Standard Conditions

Unless otherwise specified, the signal levels specified in this document are defined at an RF reference point at the antenna end of the cable that connects the Active TCAS I interrogator/receiver equipment to its antenna.

2.2.1.1 Measurement Conventions

Pulse Amplitude is measured at the pulse peak.

Pulse Duration is measured between the half voltage points of the leading and trailing edges.

Pulse Rise Time is measured as the time interval between 10 percent of peak amplitude and 90 percent of peak amplitude on the leading edge of the pulse.

Pulse Decay Time is measured as the time interval between 90 percent of peak amplitude and 10 percent of peak amplitude on the trailing edge of the pulse.

Pulse-to-Pulse Intervals are measured between the half voltage points of their leading edges.

2.2.1.2 Performance Compatibility With Own-Aircraft's Transponder

The Active TCAS I equipment may operate in conjunction with and in close proximity to a transponder. The functions of Active TCAS I equipment shall not in any way degrade the

performance of the transponder beyond its specified limits. Therefore, it is the responsibility of the manufacturer to identify all areas where incompatibilities may arise and

to design and construct his equipment so that the transponder and Active TCAS I requirements are met when both equipments are operating.

All of the Active TCAS I requirements stated in this MOPS shall be met when the Active TCAS I equipment is operating in conjunction with a compatible operating transponder, except when the transponder is active. The active state of the transponder is defined as the greater of the time interval between (a) the leading edge of the first transmitted pulse of the transponder reply minus 10 micro-seconds and the trailing edge of the last transmitted pulse of that reply plus 10 microseconds, or (b) the time interval during which a mutual suppression occurs.

2.2.2 Receiver Characteristics

2.2.2.1 In-Band Acceptance

Given a valid transponder reply signal in the absence of interference or overloads, the minimum trigger level (MTL) is defined as the input power level that results in a 90% ratio of decoded to received replies.

The MTL over the frequency range of 1,087 to 1,093 MHz shall be -73 dBm ±3 dB.
For any input signal power level of -78 dBm or less, and in the absence of interference or overloads, and over the frequency range of 1,087 to 1,093 MHz, no more than 10% of replies shall be decoded.

2.2.2.2 Out-of-Band Rejection

The selectivity of the receiver shall be such that an RF CW signal at the receiver input shall result in the following receiver output levels relative to center frequency as a function of input signal frequency offset.

Input Signal Frequency Difference From 1,090 MHz	Output Signal Level Relative to 1,090 MHz
±10 MHz	≤ -20 dB
±15 MHz	≤ - 40 dB
±25 MHz	≤ - 60 dB

2.2.3 Active TCAS I Transmitter Characteristics

2.2.3.1 Transmission Frequency

The transmission frequency of Mode C interrogations shall be 1,030 ±0.1 MHz.

2.2.3.2 Transmitter RF Power Output

When transmitting at full (unattenuated) output power, the peak RF output power delivered to a quarter wave stub antenna shall be within the following limits:

Maximum RF power: 54 dBm (250W)
Minimum RF power: 50 dBm (100W)

In the event that antenna gain differs from that of a quarter wave stub antenna (3 dBi), the power limits shall be adjusted accordingly. These limits are based upon range and interference limiting requirements.

Note: *When transmitting at full (unattenuated) output power, the RF power radiated at the pattern peak shall be within the following limits:*

Maximum EIRP: 57 dBm (500W)

Minimum EIRP: 53 dBm (200W)

It is assumed that the peak gain of a typical quarter wave stub antenna is 3 dBi. EIRP = Effective Isotropic Radiated Power.

2.2.3.2.1 Interrogations Spectrum

The spectrum of an Active TCAS I Mode C interrogation shall not exceed the following:

Frequency Difference (MHz from Carrier)	Maximum Relative Power (dB Down from Peak)
Between 0.7 and 5	3
Between 5 and 20	20
Between 20 and 60	40
Over 60	60

2.2.3.2.2 Unwanted Output Power

When the Active TCAS I interrogator is in the inactive state, the average RF power at any frequency between 960 MHz and 1215 MHz at the terminals of the antenna shall not exceed

-70 dBm. The inactive state is defined to include the entire period between interrogations less 10 microsecond transition periods, if necessary, preceding and following the extremes of the interrogation transmission.

2.2.3.3 Interrogation Interval Jitter

The transmission time of an interrogation sequence in each surveillance update interval shall be intentionally jittered about its nominal surveillance update interval. The jitter shall vary randomly, and be sufficient to prevent synchronous interference with other ground-based and airborne interrogators. The maximum value of the jitter shall not exceed 10% of the nominal update interval.

2.2.3.4 Interrogation Rate

The total interrogation rate shall be controlled by the interference limiting procedures of this standard.

2.2.3.5 Transmitter Pulse Characteristics

ATCRBS interrogations from Active TCAS I shall employ the Mode C format illustrated in Figure 2-1.

The rise and decay times may be less than shown in the following table, provided the sideband radiation does not exceed the spectral limits tabulated in this standard. The amplitude of P_3 shall be within 0.5 dB of the amplitude of P_1.

ACTIVE TCAS I MODE PULSE SHAPES
(All Values in Microseconds)

Pulse Designator	Pulse Duration	Duration Tolerance	Rise Time		Decay Time	
			Min.	Max.	Min.	Max.
P_1, P_3	0.8	$\pm$0.05	0.05	0.1	0.05	0.2

The pulse spacing tolerances shall be as follows:

P_1 to P_3: 21 $\pm$0.10 microseconds

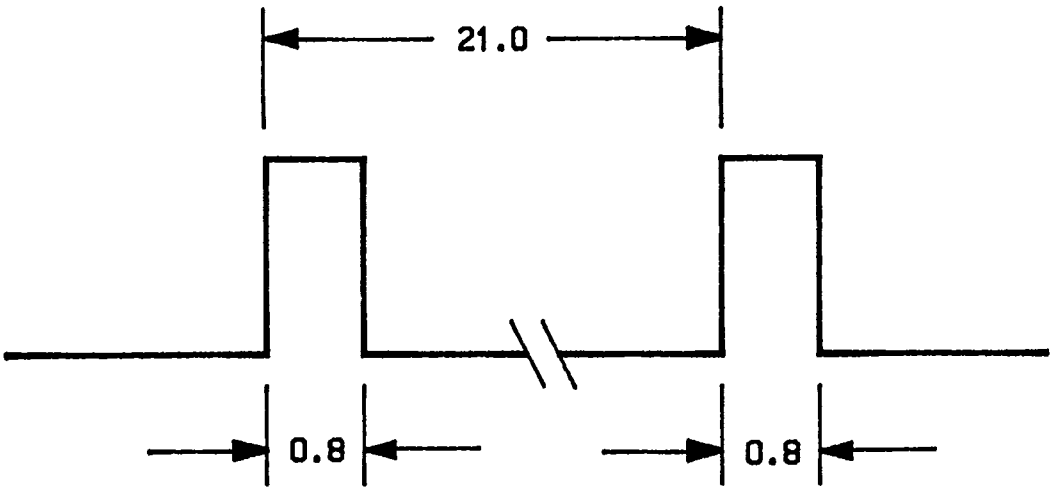

FIGURE 2-1 MODE-C INTERROGATION PULSE SEQUENCE FOR TCAS I

2.2.4 Signal Reception

2.2.4.1 Mode C Reply Reception

All performance requirements shall be met for pulses having the following characteristics:

Pulse amplitude variation: up to ±2 dB, relative to F_1 amplitude.
Pulse rise time: 0.1 microsecond or less.
Pulse decay time: 0.2 microsecond or less.

a. ATCRBS Reply Characteristics. The ATCRBS Mode C received signal is illustrated in Figure 2-2. The Mode C received signal consists of a pair of framing pulses spaced 20.3 ±0.1 microseconds apart. The code pulse positions begin 1.45 ±0.1 microseconds after the leading edge of the first framing pulse and are spaced at 1.45-microsecond intervals thereafter. Each code pulse position has a tolerance of ±0.1 microsecond relative to the first framing pulse and ±0.15 microsecond relative to every other pulse within the reply. All pulses have a width of 0.45 ±0.1 microsecond. A one or zero in the reply code is indicated by the presence or absence of a code pulse, respectively.

b. Criteria for ATCRBS Mode C Pulse Detection. The first qualifying criterion for reception of a Mode C signal shall be the occurrence of a pair of bracket pulse leading edges spaced 20.3 ±0.1 microseconds apart. The pulses shall not be accepted as a bracket pair if their spacing deviates from 20.3 microseconds by 0.242 microsecond or more, OR if either of the bracket pulses occurs within 0.242 microsecond of a previous bracket pulse, OR if the width of either of the pulses is 0.242 microsecond or less. A Mode C code pulse shall be accepted if its leading edge occurs within ±0.1 microsecond of a nominal code pulse position relative to the leading edge of the first bracket pulse. The code pulse shall be rejected if the time of occurrence of its leading edge deviates from a nominal code position by 0.242 microsecond or more, OR if the width of the pulses is 0.242 microsecond or less.

c. Criteria for Acceptance of Garbled Mode C Replies. Active TCAS I shall determine, with an average probability of success of 50%, the correct range and altitude of a Mode C target-of-interest whose reply can be garbled to any extent by two interfering Mode C replies. This performance shall be met for interfering replies with carrier frequencies between 1,087 and 1,093 MHz and amplitudes within 3 dB of the target-of-interest reply and for replies that contain a maximum of six altitude code pulses.

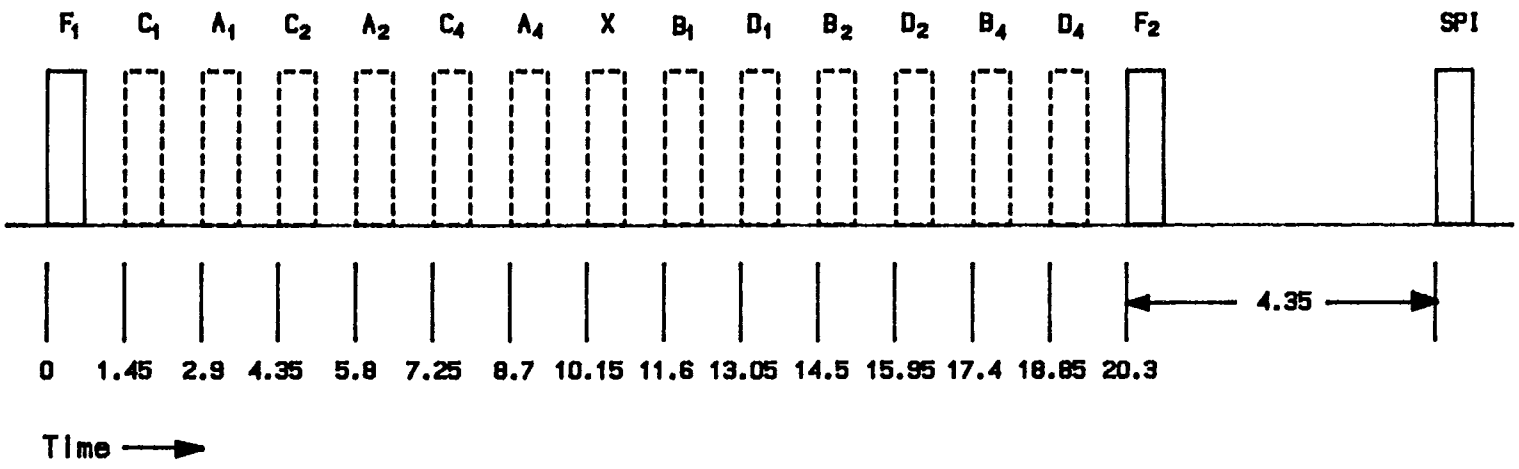

FIGURE 2-2 ATCRBS REPLY

2.2.4.2 Mode S Broadcast Reception

The Active TCAS I shall have the capability to receive 1,030-MHz Mode S broadcast signals for the purpose of obtaining a count of TCAS interrogators in its vicinity. Mode S reception may reside in an associated Mode S transponder, or may be integral to the Active TCAS I equipment, in which case those functions necessary to receive and process Mode S broadcast signals for a TCAS count shall be implemented and tested in accordance with RTCA/DO-181.

2.2.5 Reduction of Multipath Interference

2.2.5.1 Interrogation Link Interference

Active TCAS I shall operate in such a manner as to reduce the effects of interference caused by interrogation link multipath.

Note: The preferred method of reducing the possibility of interrogation mode conversion from Mode C to Mode A is to use a whisper-shout interrogation sequence similar to that described in this standard for control of synchronous interference. The use of whisper-shout transmissions will cause transponders to be interrogated at power levels close to their MTL values. This reduces the possibility that a reflected signal will cause the transponder to reply in other than Mode C.

2.2.5.2 Reply Link Interference

Active TCAS I shall process received signals in such a manner as to prevent detection of multipath signals that are 10 dB or more below the direct reply and that occur during the period of the direct reply. In the process of rejecting low-level multipath, Active TCAS I shall operate in such a manner as to reduce the possibility of eliminating weak intruder replies that occur during the same period of time.

Note: The preferred method of rejecting low-level multipath without discriminating against targets with weak replies is to use an adjustable threshold level, established by the direct reply and lasting for the expected duration of the reflection, in conjunction with a whisper-shout interrogation sequence similar to the one described in this standard for control of synchronous interference. Since many of the same link conditions that cause large differences in received signal strength from targets at the same range also cause large differences in the interrogation power level at the transponder input, the use of a whisper-shout interrogation sequence will tend to eliminate the simultaneous occurrence of strong and weak valid replies.

2.2.6 Interference Limiting

To assure that all interference effects from Active TCAS I equipment are kept to a low level, Active TCAS I equipment shall control its interrogation rate or power or both to conform to the following limits.

These limits are given in terms of

RR = the Mode A/C reply rate of own transponder

NT = the number of airborne TCAS interrogators detected via Mode S broadcast receptions with a receiver threshold of -74 dBm.

The Minimum Active TCAS I shall have the capability to monitor RR and NT and to use this information in interference limiting. Once each scan period, NT shall be updated as the number of distinct TCAS addresses received within the previous 20-second period.

The limits are as follows:

NT	K Upper Limit for Σ P(k) k=1	
	If RR < 240	If RR > 240
0	167	48
1	157	45
2	147	42
3	137	39
4	127	36
5	117	34
6	107	31
7	97	28
8	87	25
9	77	22
10	67	19
11	57	16
12	47	14
13	37	11
14	27	8
>15	17	5

P(k) = power (Watts) of the k^{th} interrogation each second. This is the total radiated power (after all losses in cabling and antenna). If the set of powers is not the same in each 1-second period, then ΣP(k) represents the average value.

K = total number of interrogations in a 1-second period.

Note: *As an alternative to the above, an Active TCAS I may choose to transmit Mode S broadcast signals, in which case it would then appear to be a Active TCAS II and could therefore increase its power-rate limits to the limits specified for a Active TCAS II in RTCA DO-185. If Mode S broadcast signals are utilized, the Mode S address shall be wired or programmed directly into the TCAS I enclosure when a Mode S transponder is not installed in the aircraft.*

Note: *IR = the Mode A/C interrogation reception rate of own transponder may be used instead of RR = the Mode A/C reply rate of own transponder.*

2.2.7 Control of Synchronous Interference

Active TCAS I shall schedule Mode C interrogations within each surveillance update interval in such a manner as to reduce the amount of ATCRBS synchronous interference, caused by aircraft near each other in range, to a level that can be accommodated by the Active TCAS I reply processor.

Specifically, the Active TCAS I interrogation schedule shall prevent, with 90% probability of success, replies from a Mode C aircraft at four nautical mile range from being synchronously garbled by more than two other replies when five additional Mode C aircraft are present and located between 2.3 nm and 5.7 nm range and distributed uniformly over 360 degrees azimuth. This requirement shall apply when the six Mode C aircraft have transponder MTL values, antenna pattern gains, cable losses, and free-space path loses such that the Active TCAS I interrogation power required to elicit a response from the six aircraft is a random variable, uniformly distributed over a 15 dB range.

ATCRBS synchronous interference shall be controlled by transmitting a sequence of interrogations at different power levels during each surveillance update period. Each of the interrogations in the sequence, other than the one at lowest power, is preceded by a suppression pulse (designated S_1) 2 $\pm$0.10 microseconds preceding the P_1 pulse. The pulse duration and tolerance and the rise and fall time values of S_1 are the same as those specified for P_1 and P_3. The combination of S_1 and P_1 serves as a suppression transmission. S_1 is at a power level lower than that of P_1. The minimum time between successive interrogations is one millisecond. All interrogations in the sequence are transmitted within a single surveillance update interval.

Each transponder in the population will respond to at least one interrogation in the sequence, and will usually be turned off by the higher power suppression transmissions accompanying higher-power interrogations in the sequence. Given a situation in which several aircraft are near enough to each other in range for their replies to synchronously interfere, it is unlikely they would all reply to the same interrogation and, as a result, the severity of synchronous interference is reduced. Use of the whisper-shout also reduces the severity of the effects of multipath on the interrogation link.

Because the suppression transmission in each step is always at a lower power level than the associated interrogation, this technique is referred to as whisper-shout. The intended mechanism is that each aircraft replies to only one or two of the interrogations in a sequence. A typical population of ATCRBS transponders at any given range may have a large spread in effective sensitivity due to variations in receivers, cable losses, and antenna shielding.

An example of a whisper-shout sequence appropriate for Active TCAS I is given in Figure 2-3. Figure 2-4 shows interference-limiting stages that would be appropriate for this sequence. Other whisper-shout sequences and techniques may be employed to limit synchronous interference.

2.2.8 Surveillance Track Requirements

2.2.8.1 Surveillance Range

When reply signal strength is adequate, and in the absence of interference, overload, interference-limiting conditions or other degrading effects, the equipment shall be capable of providing active surveillance of Mode C targets within a range of five nautical miles.

2.2.8.2 Surveillance Target Capacity

The track file capacity shall not limit the overall surveillance target capacity of Active TCAS I. The track file shall have the capacity for a minimum of eight targets.

2.2.8.3 Surveillance Track Acquisition

Active TCAS I shall establish a surveillance track on a Mode C target only if replies are received from that target on three consecutive surveillance update intervals and the replies correlate with each other in range and altitude.

2.2.8.4 Surveillance Track Coast Period

Active TCAS I shall discontinue a surveillance track on a Mode C target when no reply has correlated to the track for the greater of three update intervals or six seconds.

2.2.8.5 Surveillance of Non-Altitude-Reporting (NAR) Targets

Active TCAS I shall be capable of establishing tracks on transponder-equipped aircraft that do not have encoding altimeters. Tracking of NAR targets shall be accomplished using only replies having empty brackets (i.e., not containing code pulses).

2.2.9 Bearing Estimation

An integral bearing estimation system shall be provided to obtain bearing data for presentation to the pilot.

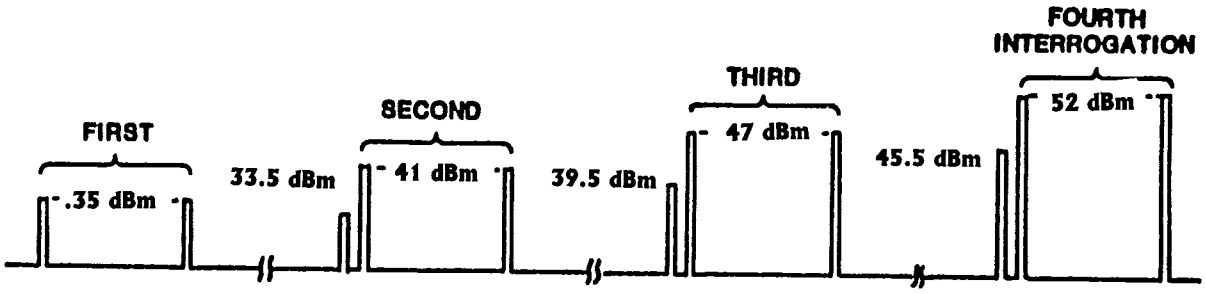

FIGURE 2-3 EXAMPLE WHISPER-SHOUT SEQUENCE.

FIRST PULSE OF INTERROGATION SERVES AS SECOND PULSE OF SUPPRESSION.

FIGURE 2-4: EXAMPLE INTERFERENCE LIMITING STATES APPROPRIATE FOR WHISPER-SHOUT SEQUENCE OF FIGURE 2-3

Whisper Shout Interrogation Powers	Scan Period	Rate Power Product
160 + 50 + 12 + 3 watts	2 sec.	113 watts/sec.
50 + 12 + 3 watts	1 sec.	65 watts/sec.
50 + 12 + 3 watts	2 sec.	33 watts/sec.
12 + 3 watts	1 sec.	15 watts/sec.
12 + 3 watts	2 sec.	8 watts/sec.
12 + 3 watts	3 sec.	5 watts/sec.

2.2.9.1 General Requirements

The bearing estimation function shall be realized using a direction-finding antenna.

2.2.9.2 Bearing Accuracy With Standard Ground Plane

2.2.9.2.1 Bearing Accuracy, -10 to +10 Degrees Elevation

The bearing error shall not exceed 10 degrees rms or 30 degrees peak over all azimuth angles and over elevation angles from -10 degrees to +10 degrees when the antenna is installed at the center of a 1.2 m (4 ft) diameter (or larger) circular ground plane that can be either flat or cylindrical.

2.2.9.2.2 Bearing Accuracy, +10 to +20 Degrees Elevation

For elevation angles from +10 to +20 degrees, the bearing error shall not exceed 15 degrees rms or 45 degrees peak over all azimuth angles under the conditions of subparagraph 2.2.9.2.1.

Note: The bearing estimation system may include a built-in automatic bearing bias correction capability if the bearing bias can become inconsistent with these requirements due to drift or component change. If provided, the automatic calibration shall be accomplished immediately after every power turn-on event.

2.2.10 Active TCAS I Antenna System

The equipment shall transmit interrogations and receive replies from at least one antenna mounted on top of the aircraft.

2.2.10.1 Polarization

The antenna(s) shall be vertically polarized.

2.2.10.2 Radiation Pattern

System requirements are that the antenna radiation pattern cover 360 degrees in azimuth and at least -10 to +20 degrees in elevation. This can be accomplished by either radiating omnidirectionally or by radiating in multiple beams to cover all azimuth directions.

2.2.11 Aircraft Suppression Bus

The Active TCAS I equipment shall issue a 100 $\pm$5 microsecond suppression pulse to other on-board aircraft equipment connected to the suppression bus beginning at each interrogation transmitted.

The equipment shall be designed to accept and respond to suppression pulses from other electronic equipment in the aircraft (to disable it while the other equipment is transmitting). The equipment shall regain normal sensitivity, within 3 dB, not later than 15 microseconds after the end of the applied suppression pulse.

Note: *The suppression duration must be longer than the interrogation to assure that the on-board transponder does not respond to reflections of the Active TCAS I interrogations from the ground. The durations specified above have been determined experimentally to be adequate for this purpose. This document does not establish the design parameters of the interference suppression system other than the durations. However, it is recommended that all sources of interference suppression pulses be DC coupled and sinks be AC coupled. This standardization will prevent source or sink failures from disabling all users of the interference suppression pulses.*

2.2.12 Active TCAS I Pilot Interface

A pilot interface shall be provided.

Note: *An acceptable means of compliance with pilot interface requirements is defined in an FAA Advisory Circular entitled "Airworthiness Approval of Traffic Alert and Collision Avoidance Systems (Active TCAS I)".*

2.2.13 Computer Performance Validation

A means of computer performance testing is required to enable the Active TCAS I computer performance to be validated both under normal bench test conditions and under environmental extremes. As a minimum, the equipment shall include provisions for memory pattern tests, control processing unit (CPU) instruction tests, program memory tests, CPU input/output function tests and CPU timing tests.

2.2.14 Traffic Advisory Criteria

The Active TCAS I equipment shall generate and display advisories against nearby aircraft. The advisory shall provide the crew with the intruder's range, bearing, and for altitude reporting intruders, relative altitude and vertical speed. The criteria for generating these advisories were chosen to provide the crew sufficient time to visually acquire the intruder aircraft prior to the closest approach of the intruder aircraft.

The TCAS equipment shall provide three levels of advisories: Other Traffic, Proximate Advisories (PA), and Traffic Advisories (TA). Other and Proximate traffic are defined by fixed range and altitude thresholds. TAs are issued based on either tau, i.e., the time to closest approach and the time to coaltitude, or proximity to an intruder aircraft. The range tau is defined as the range divided by range rate and the vertical tau is defined as the relative altitude divided by the altitude rate.

There shall be two sensitivity levels (SL). SL A shall reduce the tau values used to determine when a TA should be issued. SL A shall be automatically invoked using the following order of precedence: (1) when the TCAS aircraft is below 2,000 feet above ground level (AGL) (if equipped with a radar altimeter) OR (2) when the landing gear is extended (no radar altimeter installed) OR (3) when the groundspeed is less than 120 knots (no radar altimeter installed and aircraft has fixed gear). SL B occurs under all other flight conditions. A TA shall be issued when the following conditions are satisfied.

Note: *Groundspeed is intended to be used to change sensitivity levels if the data is available within the TCAS processor. It is not the intent of this section to require an additional sensor input to TCAS. In the event a fixed-gear aircraft is not equipped with a radio altimeter and groundspeed is not available, TCAS shall remain in SL B at all times.*

a. SL A. In SL A, a TA shall be issued against a non-altitude reporting intruder when the range tau is less than 15 seconds. A TA shall be issued against an altitude reporting intruder when the range and vertical tau are less than 20 seconds OR the range tau is less than 20 seconds and the intruder's relative altitude is less than 600 feet.

b. SL B. In SL B, a TA shall be issued against a non-altitude reporting intruder when the range tau is less than 20 seconds. A TA shall be issued against an altitude reporting intruder when the range and vertical tau are less than 30 seconds OR the range tau is less than 30 seconds and the intruder's relative altitude is less than 800 feet.

To provide additional protection against intruder aircraft whose range or altitude separation from own aircraft is small and whose range rate or altitude rate is small, fixed thresholds are defined to satisfy both the range and altitude criterion. In SL A, a TA shall be issued anytime an intruder is within 0.20 nm in range and + 600 feet in altitude. In SL B, a TA shall be issued anytime an intruder is within 0.55 nm in range and + 800 feet in altitude.

Once a TA is displayed, it shall be maintained for a minimum of eight seconds and until the range between own aircraft and the intruder aircraft begins to diverge, even though the criteria for a TA may no longer be satisfied. If the surveillance function is unable to continue to track the intruder aircraft, compliance with this requirement is not necessary.

Note: *An Active TCAS I manufacturer may want to consider three means of mitigating undesirable TA's:*

1.<u>Altitude Test</u>

Prior to considering the TA altitude criterion to be satisfied, a test could be made in the logic to estimate the altitude separation that will exist at the closest point of approach (CPA). This can be accomplished by using the tracked altitude rates of both the own and intruder aircraft, along with the

range tau to estimate the altitudes of both aircraft at CPA. If the projected altitude separation at CPA is outside the altitude threshold shown in 2.2.14, the TA altitude criterion would be considered not satisfied, and a TA would not be issued. This test should only be invoked after the TA range criterion are satisfied.

2. Issuing TAs on Coasted Tracks

Consideration should be given to not issuing a TA if the intruder's track has not been updated by a correlated reply within the previous three to four seconds. This applies to both the intruder's range and altitude tracks.

3. Nuisance Alarm Filter

Active TCAS I could contain a filter which inhibits the issuance of TAs against intruders whose range tau has begun to rise when they are more than 1.5 nmi away, but the altitude separation later violates the altitude thresholds of 2.2.14. As long as the range tau continues to rise, and the range remains greater than the fixed threshold of the range criterion, a TA should not be issued against the intruder. If, however, the range tau subsequently decreases, the intruder could again immediately be considered for a TA.

2.2.15 Aural Alert

The display of a TA shall be accompanied by an aural alert to inform the crew a TA has been displayed. The aural alert shall be the message "Traffic-Traffic" spoken once. The aural alert shall be discernible at Vne (Vmo) and with full power applied, whether or not the crew is wearing headphones. The aural alert shall be announced in a high-fidelity, distinguishable voice. The aural annunciation shall be inhibited using the following order of precedence: (1) Below 400 feet AGL when Active TCAS I is installed on an aircraft equipped with a radio altimeter; OR (2) When the landing gear is extended (no radio altimeter installed).

Note: When Active TCAS I is installed on a fixed-gear airplane without a radio altimeter, the aural annunciations will never be inhibited.

2.2.16 Display of Intruders on the Ground

The Active TCAS I equipment shall provide logic to inhibit the display of altitude reporting intruders which are on the ground. This logic shall be used when the TCAS-equipped aircraft is below 1,700 feet AGL. The 1,700 foot threshold shall include hysterisis of + 50 feet.

Note: This represents a requirement for a capability within the Active TCAS I avionics. When Active TCAS I is installed on an aircraft which does not have a radio altimeter, there is not a requirement for this logic to function.

2.2.17 Display Overload

If the number of targets exceeds the display capability, excess targets shall be deleted in the following order.

a. Other traffic beginning with the intruder at the greatest range.

b. Proximate traffic beginning with the intruder at the greatest range.

c. TAs beginning with the intruder having the largest tau. Once a TA has been generated against an intruder, it cannot be removed until the TA criteria are no longer satisfied.

2.3 Equipment Performance - Environmental Conditions

The environmental tests and performance requirements described in this subsection provide a laboratory means of determining the overall performance characteristics of the equipment under conditions representative of those that may be encountered in actual aeronautical operations.

Some of the environmental tests contained in this subsection need not be performed unless the manufacturer wishes to qualify the equipment for that particular environmental condition. These tests are identified by the phrase "When Required." If the manufacturer wishes to qualify the equipment to these additional environmental conditions, then these "when required" tests shall be performed.

The test procedures applicable to a determination of equipment performance under environmental test conditions are contained in RTCA Document DO-160C, "Environmental Conditions and Test Procedures for Airborne Equipment."

Some of the performance requirements in Subsections 2.1 and 2.2 are not tested by the test procedures herein. Moreover, not all tests are required to be done at each of the environmental conditions in RTCA/DO-160C. Judgment and experience have indicated that these particular performance parameters are not susceptible to certain environmental conditions and that the level of performance specified in Subsections 2.1 and 2.2 will not be measurably degraded by exposure to these environmental conditions.

The specified performance tests cover all environmental classes of the Active TCAS I system. Only those tests that are applicable to the class of Active TCAS I system being qualified need be done. Also, additional tests may have to be performed in order to determine performance of particular design requirements that are not specified in this document. It is the responsibility of the manufacturer to determine appropriate tests for these functions.

Specific performance requirements have been included in this section for use in conjunction with the environmental procedures of DO-160C. These requirements have been chosen as a subset of the performance tests of Section 2.4. There is a sufficiently large number of

performance tests in Section 2.4 that it would be impractical to repeat all those tests in conjunction with all of the appropriate environmental procedures.

2.3.1 Environmental Test Conditions

Table 2-1 lists all of the environmental conditions and test procedures (hereafter referred to as environmental procedures) that are documented in DO-160C. Table 2-2 lists the sets of Active TCAS I performance requirements whose associated tests are intended to be run subject to the various environmental procedures of DO-160C. In order to simplify the process of relating the environmental procedures to the Active TCAS I performance tests, Table 2-1 divides the environmental procedures into groups. All of the procedures in a given group are carried out in conjunction with the same set of Active TCAS I performance tests. Using this approach, the environmental procedures fall into six groups.

The Group 1 conditions include temperature, vibration and electrical/electronic susceptibility. Group 2 conditions include humidity, shock and susceptibility to fluids, sand, dust, salt spray, etc. Group 3 includes power input and vibration-related operational conditions. Group 4 includes altitude, decompression, and overpressure conditions. Group 5 covers the input power related condition, and Group 6 includes conditions for the complete unit that are required by DO-160C but are not related to a specific requirement in Subsection 2.2 of this document.

Table 2-2 indicates which of the groups of environmental procedures is related to each set of Active TCAS I performance tests. Each performance test shall be validated under all of the environmental procedures in the groups required for that test as indicated in Table 2-2.

2.3.2 Detailed Environmental Test Procedures

The performance requirements set forth in Subsection 2.2 and the conditions of DO-160C are considered satisfactory for use in determining equipment performance under environmental conditions. Although specific test procedures are associated with each performance requirement, it is recognized that other methods may be satisfactory. These alternative procedures may be used if the manufacturer can show that they provide at least equivalent information. In such cases, the procedures cited herein should be used as one criterion in evaluating the acceptability of the alternative procedures.

TABLE 2-1 ENVIRONMENTAL TEST GROUPS

GROUPS	ENVIRONMENTAL CONDITION	DO-160C SECTION	REMARKS
1	4a Temperature	4.5	
1	18 Audio Freq. Conducted Susc.	18.0	
1	19 Induced Signal Susceptibility	19.0	
1	20 RF Susceptibility	20.0	
1	8 Vibration	8.0	
2	6 Humidity	6.0	
2	7a Operational Shock	7.2	When required
2	10 Waterproofness	10.0	When required
2	11 Fluids Susceptibility	11.0	When required
2	12 Sand and Dust	12.0	When required
2	13 Fungus Resistance	13.0	When required
2	14 Salt Spray	14.0	When required
2	17 Voltage Spike	17.0	
2	16 Power Input - All Others	16.0	
3	8 Vibration	8.0	3 during; 1 after
3	16 Power Input - All Others	16.0	3 during; 2 after
4	4b Altitude	4.6.1	
4	4c Decompression & Overpressure	4.6.2-4.6.3	When required
5	16 Power Input - Momentary Interruptions	16.0	
6	7b Crash Safety	7.3	
6	9 Explosion	9.0	
6	15 Magnetic Effect	15.0	
6	21 Emission of RF Energy	21.0	

Note: *Tests in Group 6 determine the effects of the Active TCAS I system on other equipment (mounts, compass needles, explosive gases and other RF equipment), and therefore do not involve the Active TCAS I performance requirements of this document.*

TABLE 2-2 - PERFORMANCE REQUIREMENTS

REQUIREMENTS PARAGRAPH	DESCRIPTION	REQUIRED ENVIRONMENTAL TEST GROUP (See Table 2-1) 1	2	3	4	5
2.2.1.2	PERFORMANCE COMPATIBILITY WITH OWN-AIRCRAFT'S TRANSPONDER					
2.2.2	RECEIVER CHARACTERISTIC					
2.2.2.1	In-Band Acceptance	X		X		
2.2.2.2	Out-of-Band Rejection	X				
2.2.3	TRANSMITTER CHARACTERISTIC					
2.2.3.1	Transmission Frequency	X		X		
2.2.3.2	RF Peak Output Power	X	X	X	X	
2.2.3.2.1	Interrogation Spectrum	X			X	
2.2.3.2.2	Unwanted Output Power					
2.2.3.3	Interval and Jitter					
2.2.3.4	Interrogation Repetition					
2.2.3.5	Transmitter Pulse Characteristic	X			X	
2.2.4	SIGNAL RECEPTION					
2.2.4.1	Mode C Replies	X		X		X
2.2.4.2	Mode S Broadcast	X		X		X
2.2.5	REDUCTION OF MULTIPATH INTERFERENCE					
2.2.5.1	Interrogation Link Interference					
2.2.5.2	Reply Link Interference					
2.2.6	INTERFERENCE LIMITING					
2.2.7	CONTROL OF SYNCHRONOUS INTERFERENCE					
2.2.8	SURVEILLANCE TRACK REQUIREMENTS					
2.2.8.1	Surveillance Track Range					
2.2.8.2	Surveillance Target Capacity					
2.2.8.3	Acquisition					
2.2.8.4	Coast Period					
2.2.8.5	Surveillance of NAR Targets					
2.2.9	BEARING ESTIMATION					
2.2.9.2	Bearing Accuracy with Standard Ground Plane		X	X		
2.2.10	Active TCAS I ANTENNA SYSTEM					
2.2.10.2	Radiation Pattern		X	X		
2.2.11	AIRCRAFT SUPPRESSION BUS					
2.2.13	SELF TEST AND MONITOR	X	X	X	X	X
2.2.14	TRAFFIC ADVISORY CRITERIA					
2.2.15	AURAL ALERT					
2.2.16	DISPLAY OF INTRUDERS ON GROUND					
2 2.17	DISPLAY OVERLOAD					

2.4 Equipment Test Procedures

2.4.1 Definitions of Terms and Conditions of Test

The following definitions of terms and conditions of tests are applicable to the equipment tests specified herein:

a .Power Input Voltage

All tests shall be conducted with the power input voltage adjusted to design voltage ±2%. The input voltage shall be measured at the input terminals of the equipment under test.

b. Power Input Frequency

(1) For equipment designed to operate from a constant frequency (e.g., 400 Hz) AC source, the input frequency shall be adjusted to within ± 5% of design frequency.

(2) In the case of equipment designed for operation from an AC source of variable frequency (e.g., 300 to 400 Hz), tests shall be conducted with the input frequency adjusted to within 5% of a selected frequency and within the range for which the equipment is designed.

c. 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 application of the specified tests. No adjustments shall be made once the test procedures have started.

d. Test Instrument Precautions

Precautions shall be taken during conduct of the tests to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments, across the input and output terminals of the equipment under test.

e. Ambient Conditions

Ambient tests shall be conducted under conditions of normal room temperature, pressure and humidity. However, the room temperature shall not be lower than +10 degrees C.

f. Connected Loads

All tests shall be performed with the equipment connected to loads having the impedance values for which it is designed.

g. Signal Levels

In the test procedures all signal levels are specified at the antenna end of the antenna-to-TCAS transmission line. This point is referred to as "the RF Reference Point."

2.4.1.1 Standard Test Signals

Unless otherwise specified, the ATCRBS and Mode S test signals applied to the TCAS equipment shall have signal characteristics corresponding to the ATCRBS reply signals generated by transponders conforming to the ATCRBS National Standard, March 8, 1981, and Mode S interrogation signals conforming to the Mode S National Standard, January 3, 1983.

Standard Test Signal Characteristics

a. Radio Frequency

The frequency of the signal generator for Mode C replies shall be 1,090 ±0.1 MHz, unless otherwise specified.

b. CW Output

CW output between pulses shall be at least 60 dB below the peak level of the pulse.

c. Pulse Shape and Position

The specified test signal pulse shapes are summarized below:
(all values in microseconds)

PULSE DURATION	TOLERANCE	RISE TIME MIN.	RISE TIME MAX.	DECAY TIME MIN.	DECAY TIME MAX.	PULSE POSITION TOLERANCE
0.45	±0.05	0.05	0.1	0.05	0.2	±0.05

Note: Interval measurements and rise and fall times are measured by a linear detector.

d. Pulse Top Ripple

Between the 90% voltage amplitude point on the leading and trailing edge of the pulse, the instantaneous amplitude of the pulses shall not fall more than 1 dB below the maximum value.

e. Signal Level

The signal level corresponding to each simulated target will be as specified for each test procedure.

f. Mode S Phase Modulation

The long (30.25 microsecond) P6 pulse used to simulate Mode S broadcast transmissions shall have internal modulation consisting of 180-degree phase reversals of the carrier frequency at the designated times.

g. Mode S Phase Reversal Duration

The duration of the phase reversal shall be less than 0.08 microsecond as measured between the 10 and the 170 degree points of the phase transition. The interval between the 80% points of the amplitude transient associated with the phase reversal shall be less than 0.08 microsecond.

h. Mode S Phase Relationship

The tolerance on the 0 or 180 degree phase relationship between successive chips within the P6 pulse (including the sync reversal) shall be ± 5 degrees.

i. Jitter

The total jitter corresponding to the variation in the delay time between the interrogation signal and the corresponding simulated target reply signal after accounting for the time delay associated with the programmed movement of the target aircraft in space shall not exceed 0.1 microsecond. The time delay shall be measured in accordance with the following:

START TIME REFERENCE	STOP TIME REFERENCE	TOTAL ALLOWABLE JITTER
Leading Edge of P3	Leading Edge of First Reply Pulse	0.1 microsecond

2.4.1.2 Test Equipment Capabilities

The test procedures rely on the availability of test equipment that will interface with all external Active TCAS I input and output ports and that is capable of generating all of the RF test signals specified in each test procedure. These signals include:

a. Replies produced in response to Mode C only all-call interrogations from the Active TCAS I unit under test.

b. TCAS broadcast interrogation signals.

c. ATCRBS interrogations from simulated ground sensor equipment. The test equipment shall be capable of receiving and shall provide means for measuring the characteristics of all output RF signals generated by the Active TCAS I equipment under test.

The amplitude, timing and data content of test signals generated by the test equipment shall be controlled by individual test scenarios to simulate specific target conditions, depending on the requirements of a particular test. The RF characteristics of all simulated test signals generated by the test equipment shall be in accordance with 2.4.1.1, unless otherwise specified in the individual test procedure.

The test equipment shall be capable of generating, and varying over their full range of possible values, the following inputs to the Active TCAS I equipment that are provided by external equipments:

a. Barometric altitude code
b. Pilot manual control.
c. Radio altimeter
d. Landing gear position

The test equipment shall have the following minimum capabilities:

a. Means of generating and varying over its full range of possible values, in response to each Mode-C interrogation from TCAS, a Mode C reply for each simulated target with the characteristics specified in 2.4.1.1 and with the altitude code, signal level and carrier frequency specified in each test procedure. The timing of each reply signal shall be controlled by the test equipment to simulate the target range and relative speed specified in each test procedure.

b. Means of generating garbled Mode C replies in response to a single Mode C interrogation as follows:

   (1) As many as three replies with interleaved or overlapping pulses from a single 1,090 MHz source. Unless otherwise stated the specified range difference between replies shall be maintained to an accuracy of $\pm$0.2 microsecond throughout the scenario.

   (2) Three unequal-amplitude replies with interleaved or overlapping pulses from three separate RF sources that have carrier frequencies of 1,090, 1,087 and 1,093 MHz, respectively. The specified range difference between replies shall be maintained to an accuracy of $\pm$0.2 microsecond throughout the scenario.

c. Means of generating TCAS broadcast interrogation signals from simulated TCAS targets at times specified in the test procedure and with the characteristics specified in the TCAS National Standard.

d. Means of generating barometric data in the format required by the TCAS and with the value specified in each test procedure.

e. Means of accepting and decoding all Mode C interrogation signals from the Active TCAS I unit under test.

f. Means of processing or recording for later processing the data content and arrival time of all interrogation signals received from the Active TCAS I unit under test as well as the data content and transmission time of all reply signals generated by the test equipment.

g. Means of measuring the interrogation power levels including multiple interrogation levels that may be employed.

h. Means of simulating linear movement of targets in slant range. Movement is specified independently in the slant range dimension and the altitude dimension. In slant range, the trajectory is expressed in relative coordinates consisting of initial slant range, minimum slant range and relative speed. However, the relative timing may be offset during a test by a fixed amount. The relative speed remains constant for any given target for the duration of the encounter. The test equipment shall be able to simulate target relative speed from negative 900 kt (decreasing range) to positive 900 kt (increasing range).

Note: *Although the actual motion for the target is linear, the slant range as a function of time behaves as a quadratic. The formula for slant range at time, t, in terms of initial slant range R_o, minimum slant range R_{min}, and relative speed V_R, is*

$$R(t) = [R^2_o - 2 V_R t [R^2_o - R_{min}{}^2]^{1/2} + V_R{}^2 t^2]^{1/2}$$

Range rate is different from relative speed. Range rate is not constant during an encounter with nonzero R_{min}.

i. Means of inhibiting the Mode C replies from a given target during time intervals specified in each test procedure.

j. Means of initiating or terminating Mode C targets at times during a single test as specified in each test procedure.

k. Means of generating altitude codes for individual replies for altitudes from -1,200 to 63,350 ft MSL.

2.4.2 Detailed Test Procedures

2.4.2.1 Transmitter Characteristics

The following procedures verify the proper operation of the Active TCAS I transmitter.

Note: To facilitate transmitter output measurements, the manufacturer is allowed to incorporate a test mode in which the interrogator rate is higher than nominal.

2.4.2.1.1 Transmission Frequency (2.2.3.1)

Equipment Required

Spectrum analyzer (HP 141/8554B, or equivalent).
SPDT switch (RLC Model SM-2-N, or equivalent).
Reference oscillator (1,030 MHz ±1 kHz, 0 dBm output).
10 dB attenuator (Weinschel Model 39-10, or equivalent).
50 dB attenuator (Weinschel Model 50-50, or equivalent).

Measurement Procedure

Connect equipment as shown in Figure 2-5. Set spectrum analyzer controls as follows:

Resolution Bandwidth: 1 kHz
Scan Width: 10 kHz/div
Reference Level: 0 dBm
Display Mode: 10 dB/div
Input Attenuation: 10 dB Enable TCAS interrogations.

Set S2 to reference oscillator. Tune the spectrum analyzer center frequency to place the calibration signal at the center of the display. Set S2 to 50 dB attenuator. Adjust reference level until peak of spectrum is within 1 division of top of display. Switch display mode to 2 dB/div. Observe frequency of spectrum peak.

Note: Verify spectrum analyzer stability by remeasuring reference oscillator frequency at the end of the tests.

2.4.2.1.2 RF Peak Output Power (2.2.3.2)

Equipment Required

Detector video amplifier, DVA (Aertech Model 1204, or equivalent).
Power supply for DVA.
Reference signal generator (HP612A, or equivalent).
Power meter and sensor (HP436A and HP8481A, or equivalent).
Oscilloscope (Tektronix 465, or equivalent).
10 dB attenuator (Weinschel Model 39-10, or equivalent).

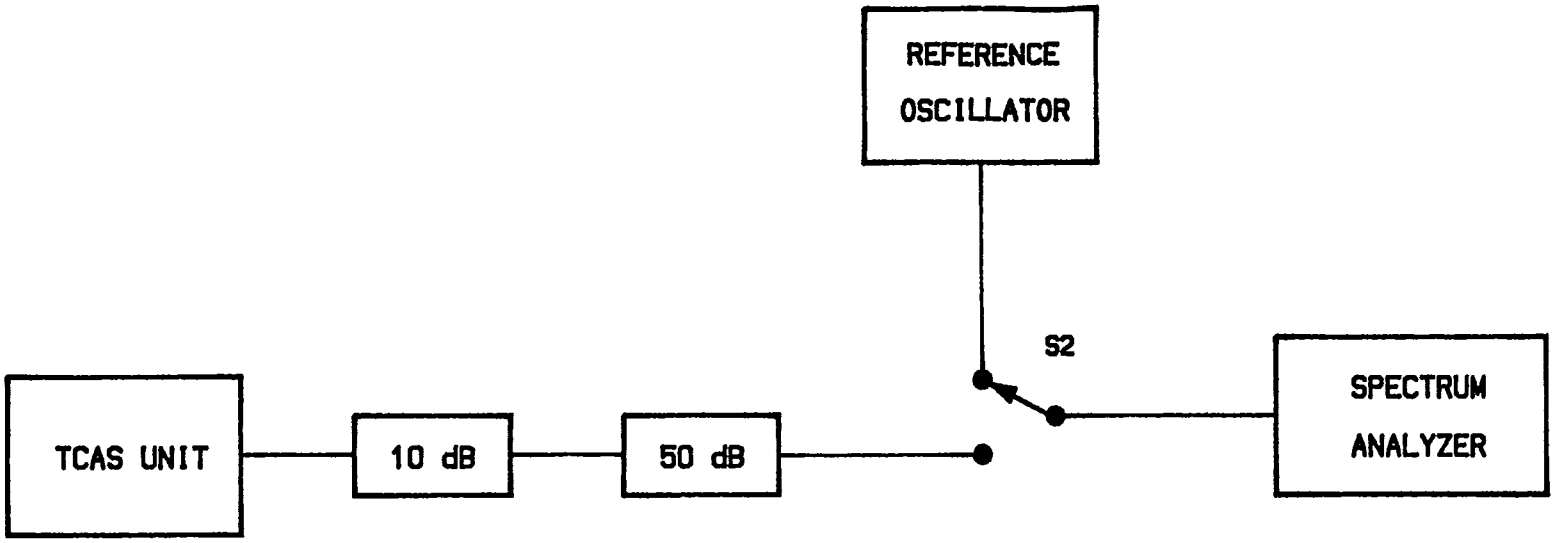

FIGURE 2-5 FREQUENCY TEST SETUP

50 dB attenuator (Weinschel Model 50-50, or equivalent).
SPDT switch (RLC Model SM-2-N, or equivalent).

Measurement Procedure

Connect equipment as shown in Figure 2-6. Enable TCAS interrogations.

Observe the largest pulse of the detected waveform on scope. Set S2 to reference signal generator. Adjust signal generator for same level on scope. The output voltage of the largest pulse shall correspond to a peak transmitter output power at the RF reference point as specified in 2.2.3.2.

2.4.2.1.3 Active TCAS I Transmitter Pulse Characteristics (2.2.3.5)

Equipment Required

Detector video amplifier, DVA (Aertech Model 1204, or equivalent).
Power supply for DVA.
Reference signal generator (HP612A, or equivalent).
Power meter and sensor (HP436A and HP8481A, or equivalent).
Oscilloscope (Tektronix 7603 main frame, 7A13 differential amplifier, 7B50A time base).
Variable attenuator (Weinschel Model 50-50, or equivalent).
10 dB attenuator.
SPDT switch (RLC Model SM-2-N, or equivalent).

Measurement Procedure

Step 1-Pulse Amplitude Variation - Connect equipment as shown in Figure 2-7. Enable TCAS interrogations. Measure pulse amplitudes of P1 and P3.

Step 2-Pulse Shape - Measure pulse shape characteristics of P1 and P3.

Step 3-Pulse Spacing Tolerance - Measure pulse spacing between P1 and P3.

After each step, verify the measurements meet the requirements contained in Section 2.2.3.5.

2.4.2.1.4 Interrogation Spectrum (2.2.3.2.1)

Equipment Required

Spectrum analyzer (HP 141/8554B, or equivalent).
50 dB attenuator (Weinschel Model 50-50, or equivalent).
SPDT switch (RLC Model SM-2-N, or equivalent).
10 dB attenuator (Weinschel Model 39-10, or equivalent).

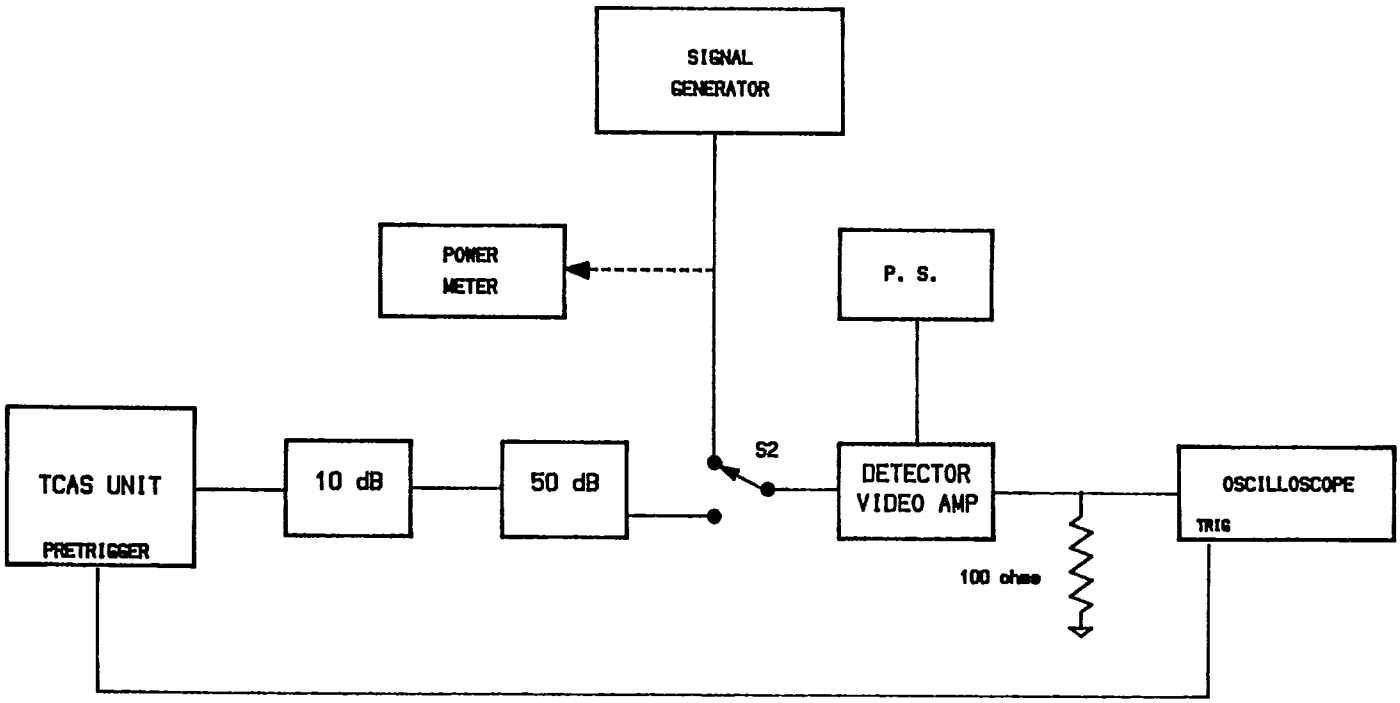

FIGURE 2-6 PEAK POWER TEST SETUP

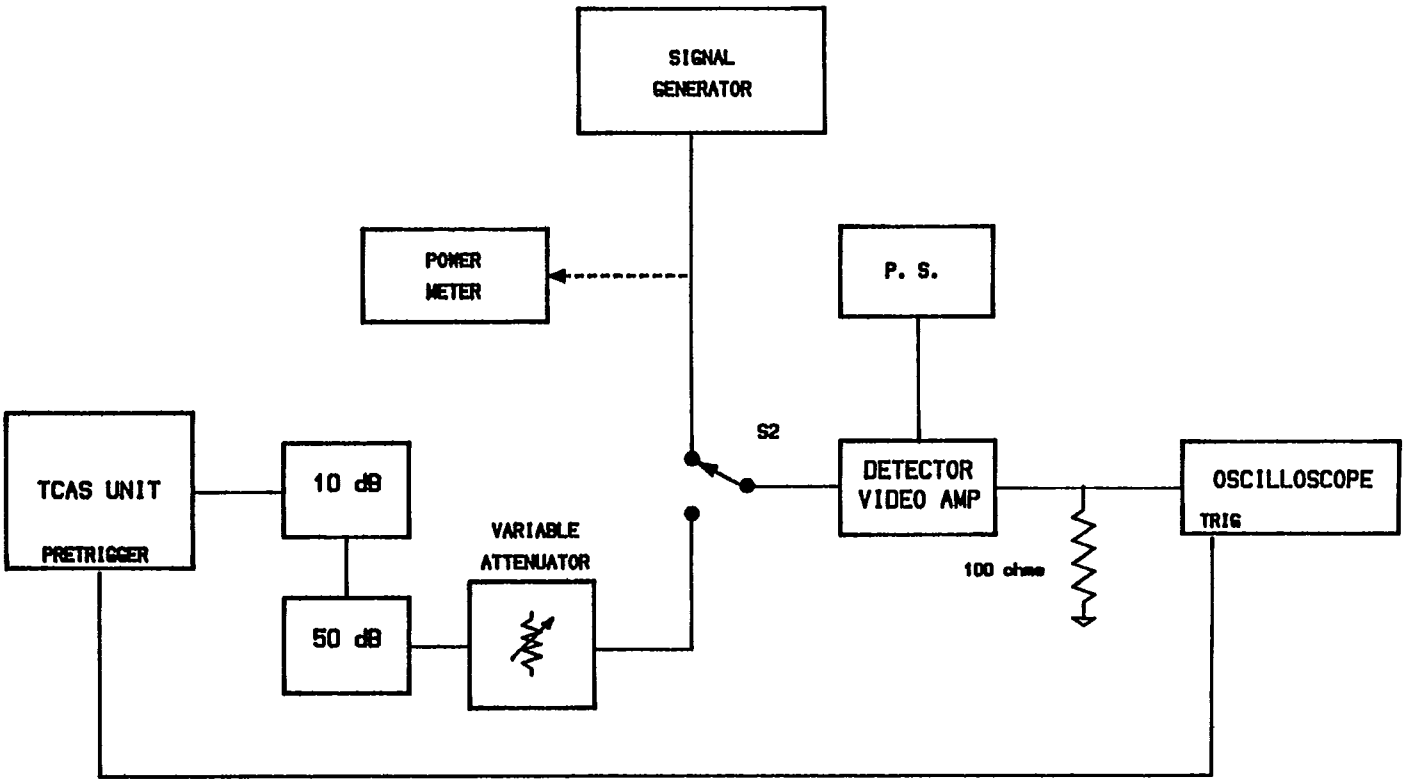

FIGURE 2-7 TRANSMISSION TEST SETUP

Measurement Procedure

Connect equipment as shown in Figure 2-8. Set spectrum analyzer as follows:

Scan Width: 20 MHz/division
Resolution Bandwidth: 100 kHz
Center Frequency: 1030 MHz
Reference Level: -20 dBm

Enable TCAS interrogations. Verify proper signal spectrum bounds.

Note: Adjust spectrum analyzer as necessary to obtain sufficient measurement resolution.

2.4.2.1.5 Unwanted Output Power (2.2.3.2.2)

Equipment Required

Detector video amplifier (Aertech Model 1204, or equivalent).
Power supply for DVA.
Reference signal generator (HP612A, or equivalent).
Power meter and sensor (HP436A and HP8481A, or equivalent).
Oscilloscope (Tektronix 465, or equivalent).
Limiter/preamplifier (Alpha MT 3280 A2 limiter and Watkins-Johnson 6203-433 amplifier, or equivalent).
10 dB attenuator (Weinschel Model 39-10, or equivalent).
SPDT switch (RLC Model SM-2-N, or equivalent).

Measurement Procedure

Connect equipment as shown in Figure 2-9. Disable TCAS interrogations. Measure video detector amplifier output with oscilloscope. Check for spurious pulse output signals by adjusting trigger level in internal sync mode. All detector output signals (both CW and pulse) shall correspond to less than -70 dBm at the TCAS RF reference point.

2.4.2.1.6 Aircraft Suppression Bus (2.2.11)

2.4.2.1.6.1 Suppression Pulse Output

Equipment Required

Oscilloscope (Tektronix 465, or equivalent).

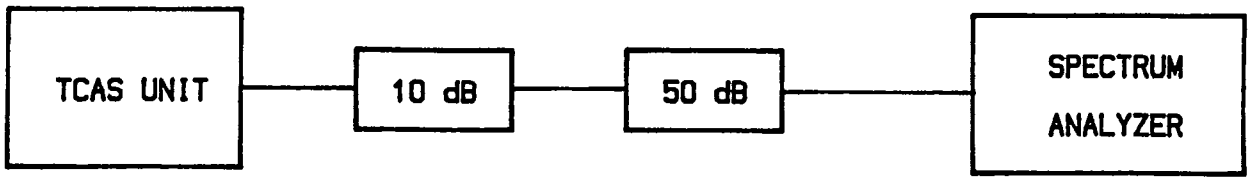

FIGURE 2-8 RF SPECTRUM TEST SETUP

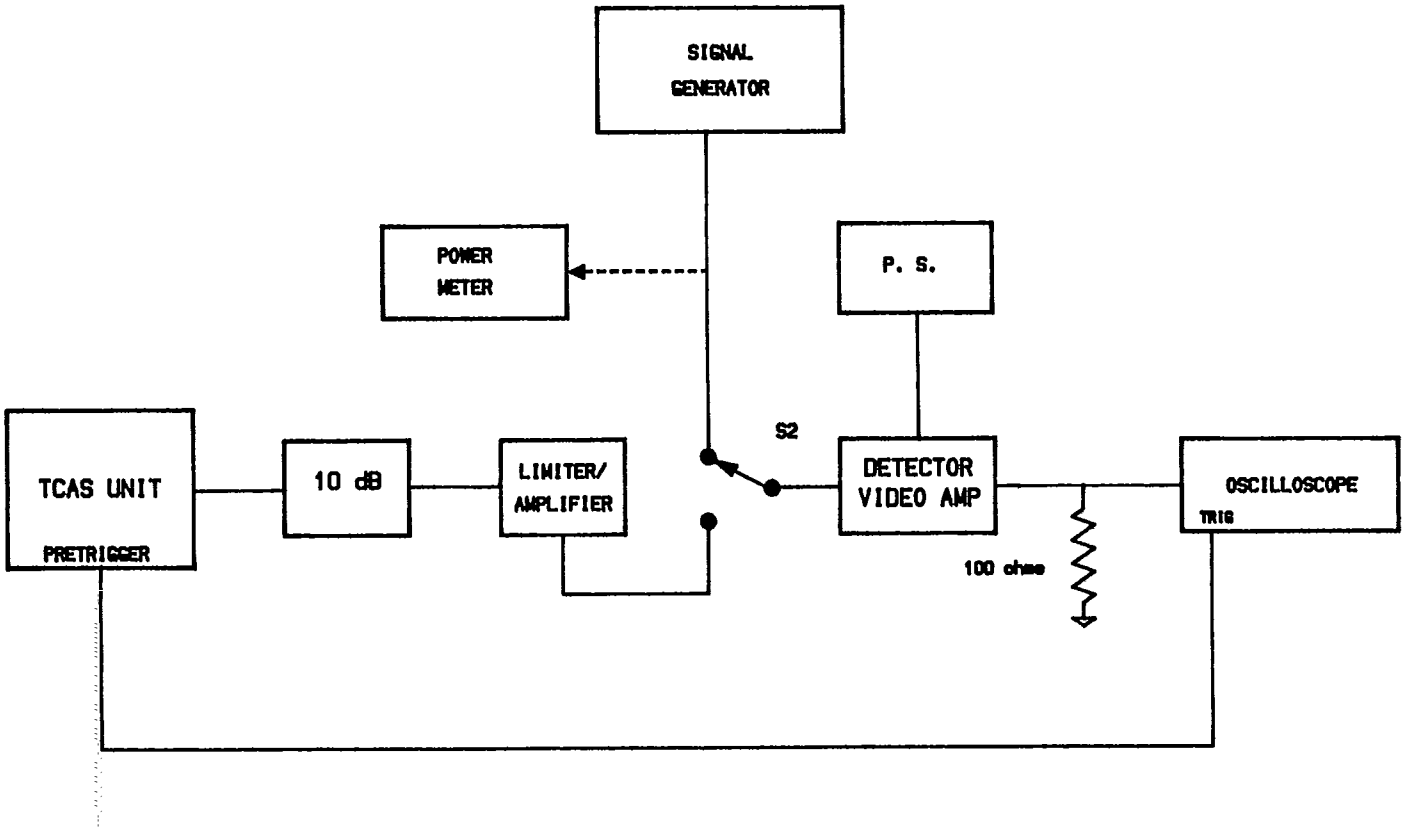

FIGURE 2-9 UNWANTED OUTPUT POWER TEST SETUP

Measurement Procedures

Connect oscilloscope to Active TCAS I unit suppression pulse output. Connect oscilloscope to sync on Active TCAS I unit output. Measure and verify proper suppression pulse width associated with each interrogation.

2.4.2.1.6.2 Response to Received Suppression Pulse

Equipment Required

50 dB attenuator (Weinschel Model 50-50, or equivalent)
10 dB attenuator (Weinschel Model 39-10, or equivalent)
Reference signal generator (HP612A, or equivalent)
Spectrum analyzer (HP 141/8554B, or equivalent)

Measurement Procedures

Connect equipment as shown in Figure 2-10. Enable TCAS interrogations. Set up signal generator to transmit a 100 microsecond suppression pulse to the Active TCAS I suppression pulse input 20 microseconds prior to the scheduled TCAS interrogation. When the suppression pulse is transmitted, verify Active TCAS I interrogations are inhibited and that normal sensitivity is regained within 3 dB, not later than 15 microseconds after the end of the applied suppression pulse. Sensitivity is verified by performing a sensitivity measurement immediately following the suppression pulse.

2.4.2.1.7 Interrogation Repetition Interval (2.2.3.4) and Jitter (2.2.3.3)

Equipment Required

Detector video amplifier, DVA (Aertech Model 1204, or equivalent).
Power supply for DVA.
Reference signal generator (HP612A, or equivalent).
Power meter and sensor (HP436A and HP8481A, or equivalent).
Storage oscilloscope (Tektronix 7603 main frame, 7A13 differential, amplifier, 7B50A time base, 7D11 digital delay).
Variable attenuator (Weinschel model 905, or equivalent).
50 dB attenuator (Weinschel model 50-50, or equivalent).
10 dB attenuator (Weinschel model 39-10, or equivalent).
SPDT switch (RLC Model SM-2-N, or equivalent).

Measurement Procedure

Connect equipment as shown in Figure 2-11. Enable TCAS interrogations. Set digital delay and sweep rate to observe rate and jitter of interrogation pulse sequence. Rate without interference limiting and peak-to-peak jitter shall be as specified in 2.2.3.3 and 2.2.3.4.

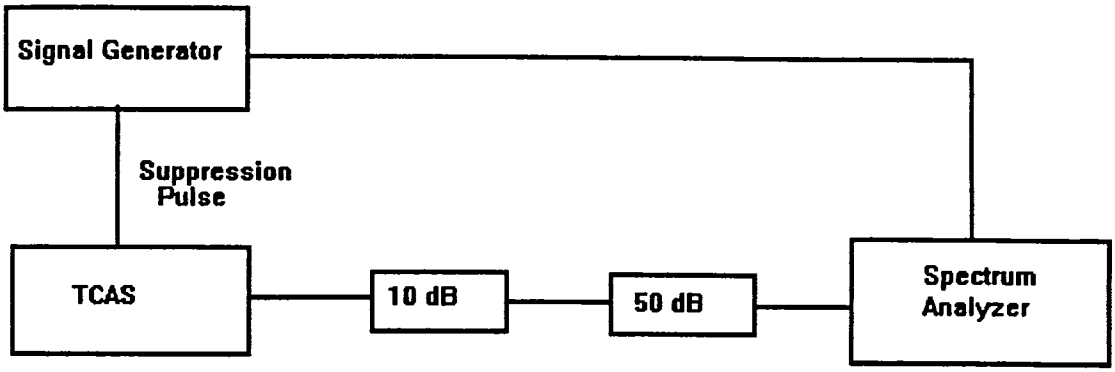

FIGURE 2-10 SUPPRESSION PULSE RECEPTION TEST SETUP

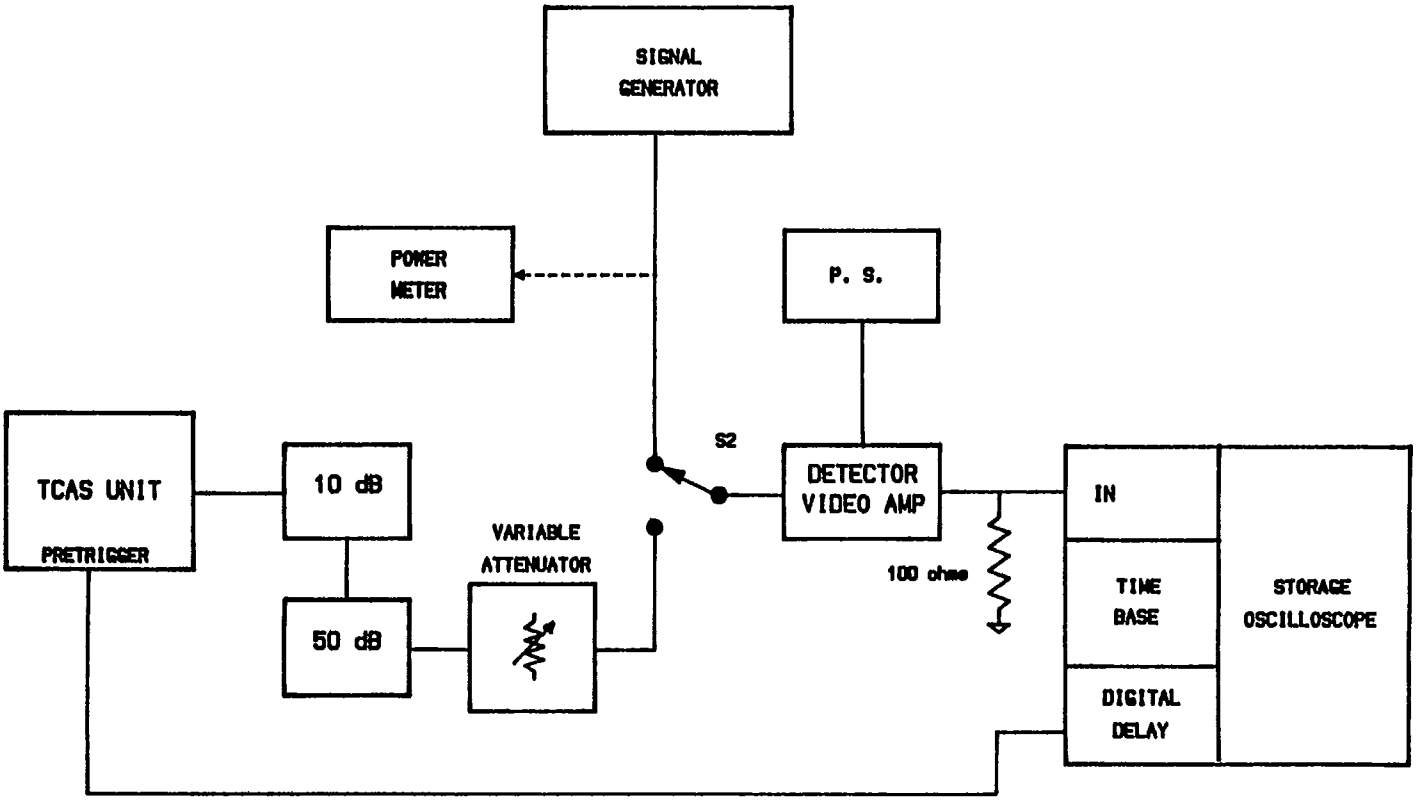

FIGURE 2-11 INTERROGATION RATE JITTER TEST SETUP

2.4.2.2 Active TCAS I Receiver Characteristics (2.2.2)

2.4.2.2.1 In-Band Acceptance (2.2.2.1)

These tests verify the ability of the Active TCAS I Receiver to operate over the frequency band 1087 to 1093 MHz.

Inputs

Active TCAS I Aircraft

Altitude = 9,600 ft (Altitude code = 6760)
Altitude Rate = 0 FPM

Intruder Aircraft

Equipage = Mode C
Altitude = 9,600 ft
Altitude Rate = 0 FPM
Range = 2 nmi at T = 0 sec
Relative Speed = 0 kt
Reply Frequency
Scenario A and C = 1,087 MHz
Scenario B and D = 1,093 MHz
Reply Power
Scenario A and B $\leq$ -70 dBm
Scenario C and D $\geq$ -78 dBm

Test Description

The Active TCAS I initialized and operating at T = 0 seconds. For each scenario, the intruder shall reply once each surveillance update interval for a total of 100 surveillance update intervals in response to TCAS interrogations. The output of the TCAS reply processor shall be monitored to establish a count of correctly decoded intruder replies.

Success: For scenarios A and B, the ratio of correctly decoded intruder replies to total input replies shall be at least 90%. For scenarios C and D, the ratio of correctly decoded intruder replies to total input replies shall not exceed 10%.

2.4.2.2.2 Out-of Band Rejection (2.2.2.2)

This series of tests verifies the proper out-of-band-rejection characteristic of the Active TCAS I receiver.

Inputs

CW RF Signal Source

Frequency Range = 1,060 to 1,120 MHz.
Output Power Level Range = +10 dBm to -70 dBm.

Test Description

With the CW RF source connected to the TCAS RF reference point, observe the Active TCAS I receiver output signal level. Establish the RF source output level setting and the TCAS receiver output level for an input signal level of -50 dBm at 1,090 MHz.

Adjust the input signal frequency to 1,075 MHz and adjust the RF source output level to maintain the Active TCAS I receiver output level constant. Note the RF source output level setting. Repeat the above procedure for input signal frequencies of 1065, 1105, 1115, 1080 and 1100 MHz.

Success: The increase in input signal level required to maintain a constant receiver output level relative to that at 1,090 MHz shall be at least 20 dB for input signals ±10 MHz from 1,090 MHz, at least 40dB for input signals ±15 MHz from 1,090 MHz, and at least 60 dB for input signals ±25 MHz from 1,090 MHz.

2.4.2.3 Signal Reception (2.2.4)

The following procedures verify the ability of the Active TCAS reply I processor to properly detect and decode Mode C reply signals.

2.4.2.3.1 Detection and Decoding of Garbled Mode C Replies (2.2.4.1)

This test will verify the ability of the Mode C reply processor to achieve a minimum level of overall performance in the detection of reply brackets and codes in which the reply pulses have been subjected to varying degrees of garble.

Inputs

Active TCAS I Aircraft

Altitude = 9,400 ft

Intruder 1

Equipage = Mode C
Altitude = 10,100 ft (Altitude code 6530)
Range = 4 nmi
Relative Speed = 0 kt
Reply Power = -50 ±1 dBm

Reply Frequency = 1,090 MHz

Intruder 2

Equipage = Mode C
Altitude = 3,900 ft (Altitude code 4760)
Range = R_i - N x (1.45/24 microseconds), where R_i equals the initial range such that the leading edge of the F1 pulse of Reply 2 occurs 1.45 microseconds later than the leading edge of the F2 pulse of Reply 1, and N equals a parameter value that is incremented from 1 to 720 following each set of generated replies.
Relative Speed = 0 kt for each value of N
Reply Power = -47 ±1 dBm
Reply Frequency = 1,087 MHz

Intruder 3

Altitude = 9,300 ft (Altitude code 6710)
Range = R_i - N x (1.45/12 microseconds), where R_i equals the initial range such that the leading edge of the F1 pulse of Reply 3 occurs 1.45 microseconds later than the leading edge of the F2 pulse of Reply 2, and N equals a parameter value that is incremented from 0 to 720 following each set of generated replies.
Relative Speed = 0 kt for each value of N
Reply Power = -53 ±1 dBm
Reply Frequency = 1,093 MHz

Conditions

Active TCAS I is initialized and operating at T = 0 seconds. Intruder 1, 2, and 3 shall reply once during each surveillance update interval, and to the same interrogation. Each intruder shall be simulated by a separate RF source in order to maintain phase incoherence between the three replies.

Scenario

The value of N in the Intruder 2 and 3 range equation shall be incremented by one after each group of 10 surveillance update intervals. The scenario shall be terminated following the 7,200th surveillance update interval. Incrementing N will cause the replies from Intruders 2 and 3 to move in 1.45/24- and 1.45/12- microsecond steps, respectively, across the reply from Intruder 1 from a further non-overlapping range to a closer non-overlapping range. The output of the TCAS reply processor shall be monitored to establish a count of the replies from Intruder 1 that were detected within 125 feet of the correct range and decoded with the correct altitude.

Success: The ratio of successfully received replies from Intruder 1 to the total number of replies generated by Intruder 1 shall be at least 50%.

2.4.2.4 Reduction of Multipath Interference (2.2.5)

The following procedures verify the ability of Active TCAS I to reduce the effect of multipath reflections on the Mode C interrogation of ATCRBS transponders and on the reception and processing of Mode C replies.

2.4.2.4.1 Interrogation Link Interference (2.2.5.1)

This test verifies that Active TCAS I operates in such a manner as to reduce the possibility of interrogation mode conversion due to uplink multipath.

Inputs

Active TCAS I Aircraft

Altitude = 6,000 ft
Altitude Rate = 0 FPM.

Intruder Aircraft

Equipage = Mode A and Mode C
Altitude = 6,200 ft (Altitude code = 4410)
Altitude Rate = 0 FPM
Range = 4 nmi
Relative Speed = 0 kt

Transponder

Reply Power = -50 ±1 dBm at TCAS RF reference point
Mode A Code = 6600
MTL = -75 ±1 dBm

Conditions

Active TCAS I initialized and operating at T = 0 seconds. The uplink path loss between the TCAS RF reference point and the intruder transponder shall be simulated to provide a level of -64 ±1 dBm at the antenna end of the transponder antenna cable (transponder RF Reference Point) for the highest Active TCAS I power level transmitted.

The resultant difference between the intruder transponder MTL and the highest interrogation power level measured at the transponder RF reference point shall be 11 ±1 dB.

The effect of an uplink multipath condition at the transponder RF reference point shall be simulated such that, for every Active TCAS I Mode C interrogation, a pulse occurs 8 ±0.2

microseconds after the leading edge of the P_1 pulse of the Mode C interrogation. It shall have an amplitude -9 ±1 dB relative to the P_1 pulse and its other pulse characteristics shall be as defined in RTCA DO-181 for a P_3 interrogation pulse.

Scenario Description

Active TCAS I shall interrogate the intruder over a period of 100 surveillance update intervals. The intruder transponder, if simulated, shall provide all of the functions defined in paragraphs 2.7.1 through 2.7.5 of the ATCRBS National Standard. The intruder output shall be monitored to determine the total number of replies generated and the Active TCAS I reply processor output shall be monitored to determine the number of intruder replies that were decoded with the correct altitude.

Success: The intruder shall respond with at least 90 replies over the period of 100 surveillance update intervals and at least 80% of these replies shall be correct Mode C altitude reports.

2.4.2.4.2 Reply Link Interference (2.2.5.2)

This test verifies that Active TCAS I can reject low-level multipath signals without discriminating against weak intruder replies.

Inputs

Active TCAS I Aircraft
Altitude = 6,000 ft
Altitude rate = 0 FPM

Intruder Aircraft 1

Equipage = Mode C
Altitude = 5,800 ft (Altitude code = 4440)
Altitude Rate = 0 FPM
Range = 3 nmi
Relative Speed = 0 kt

Transponder

Reply Power = -50 ±1 dBm at TCAS RF reference point
MTL = -75 ±1 dBm

Multipath Signal From Intruder 1

Identical to Intruder 1 reply except for:

Range = F_1 pulse of multipath signal delayed 0.7 ±0.2 microsecond relative to the F_1 pulse of Intruder 1 reply.

Signal Power = -12 ±1 dB relative to Intruder 1 reply power.

Intruder Aircraft 2

Equipage = Mode C
Altitude = 6,700 ft (Alt. code = 4040)
Altitude Rate = 0 FPM
Relative Speed = 0 kt
Range = F_1 pulse of Intruder 2 reply delayed 5.0 ±1.0 microseconds relative to F_1 pulse of Intruder 1.

Transponder

Reply Power = -12 ±1 dB relative to Intruder 1 reply power.
MTL = -75 ±1 dBm.

Conditions

Active TCAS I initialized and operating at T = 0 seconds. The uplink path loss between the TCAS RF reference point and the Intruder 1 RF reference point shall be simulated to provide an interrogation power level of -61 ±1 dBm at the transponder 1 reference point for the highest Active TCAS I power level transmitted. The absolute difference between this power level and the Intruder 1 MTL shall be 14 ±1 dB.

The uplink path loss between the TCAS RF reference point and the Intruder 2 RF reference point shall be simulated to provide an additional 12 dB loss or a -73 ±1 dBm interrogation power level at the transponder 2 reference point. The absolute difference between this power level and the Intruder 2 MTL shall be 2 ±1 dB.

Scenario Description

Active TCAS I shall interrogate Intruders 1 and 2 over a period of 100 surveillance update intervals. Both intruder transponders, if simulated, shall provide all of the functions defined in paragraphs 2.7.1 through 2.7.5 of the ATCRBS National Standard. The output of the Active TCAS I reply processor shall be monitored to determine the number of replies received from Intruders 1 and 2 and from the simulated multipath reflection signal.

Success: The ratio of successfully decoded replies from Intruder 1 to the total number of replies generated by Intruder 1 shall be at least 90%.

The ratio of successfully decoded replies from Intruder 2 to the total number of replies generated by Intruder 2 shall be at least 80%.

The ratio of decoded replies associated with the multipath reflection to the total number of replies generated by Intruder 1 shall not exceed 20%.

2.4.2.5 Interference Limiting (2.2.6)

This test verifies that Active TCAS I is able to monitor its own transponder reply rate and to derive a count of TCAS aircraft by listening to TCAS broadcast interrogations and, based on these values, adjust its transmit power-rate product to conform to the Active TCAS I interference limits.

Inputs

Active TCAS I Aircraft

Altitude = 8,000 ft.
Altitude Rate = 0 FPM

Intruder Aircraft 1-15

Equipage = Active TCAS II
Range = Not Applicable
Relative Speed = Not Applicable
Altitude = Not Applicable
Altitude Rate = Not Applicable
TCAS Broadcast
Interrogation Power = -50 dBm

ATCRBS Interrogation

Frequency = 1030 MHz
Type = ATCRBS Mode C
Power = -50 dBm
Rate
Scenario A = 230 per second
Scenario B = 250 per second

Conditions

Active TCAS I initialized and operating at T = 0 seconds. Each of the 15 intruders is assigned a discrete address and transmits only TCAS broadcast interrogations and only at the following times and rates:

Intruders 1-5 every 10 sec starting at T = 30 sec.
Intruders 6-10 every 20 sec starting at T = 70 sec.
Intruders 11-15 every 20 sec starting at T = 130 sec.

The timing of the TCAS broadcast interrogations and the ATCRBS interrogations are controlled to prevent overlap with each other.

Scenario Description

The test involves use of an ATCRBS transponder which supplies reply rate information to Active TCAS I. The transponder is interrogated in Mode C at a 230 per second rate in Scenario A and at a 250 per second rate in Scenario B. During each scenario, the value of Total Radiated Power per second from Active TCAS I is measured by summing the transmitter output powers of each Active TCAS I interrogation over a scan period, determining the average per second value and accounting for cable and antenna losses.

Success: The Total Radiated Power per second shall not exceed the following values:

Scenario A
167 watts/sec measured at T = 20 sec
117 watts/sec measured at T = 60 sec
67 watts/sec measured at T = 120 sec
17 watts/sec measured at T = 180 sec

Scenario B
48 watts/sec measured at T = 20 sec
34 watts/sec measured at T = 60 sec
19 watts/sec measured at T = 120 sec
5 watts/sec measured at T = 180 sec

2.4.2.6 Control of Synchronous Interference (2.2.7)

This test verifies that Active TCAS I is able to reduce the synchronous garble to an intruder reply, in an environment in which the intruder is within garble range of five other Mode C aircraft, to a level that can be accommodated by the Active TCAS I reply processor.

Inputs

Active TCAS I Aircraft

Altitude = 6,000 ft
Altitude Rate = 0 FPM

Intruder Aircraft 1 through 6

Equipage = Mode C
Altitude = 3,000 ft to 9,000 ft
Altitude Rate = 0 FPM
Range
Intruder 1 = 4 nmi
Intruder 2-6 = 2.5 to 5.5 nmi
Relative Speed = 0 kt

Transponder MTL:

Intruder 1 = -73 ±1 dBm
2 = -76 ±1 dBm
3 = -79 ±1 dBm
4 = -70 ±1 dBm
5 = -67 ±1 dBm
6 = -64 ±1 dBm

Conditions

Active TCAS I initialized and operating at T=0 seconds. The uplink path loss between the TCAS RF reference point and each intruder transponder shall be simulated to provide an interrogation power level of -59 ±1 dBm at each transponder RF reference point for the highest Active TCAS I power level transmitted. The absolute difference between each intruder transponder MTL and the interrogation power level shall be within ±1 dB of the nominal difference.

Scenario Description

Intruder I is located at a fixed range of four nautical miles with respect to Active TCAS I and within ±3000 feet of Active TCAS I in altitude. Intruders 2 through 6 are located anywhere between 2.3 and 5.7 nmi range and within ±3000 feet of Active TCAS I. All six targets are distributed uniformly over a 360 degrees bearing of Active TCAS I.

The intruder transponders, if simulated, shall provide all of the functions defined in paragraphs 2.7.1 through 2.7.5 of the ATCRBS National Standard.

Active TCAS I shall interrogate each of the intruders over a period of 100 surveillance update intervals. For each TCAS interrogation, the intruder transponders are monitored to determine whether the transponder replied or, if simulated, would have replied to that interrogation.

Success: Given that Intruder 1 replied (or would have replied) to an interrogation, the probability that no more than two additional transponders also replied (or would have replied) to the same interrogation shall be at least 80%.

2.4.2.7 Surveillance Track Requirements (2.2.8)

2.4.2.7.1 Surveillance Track Range, Acquisition and Coast (2.2.8.1, 2.2.8.3 and 2.2.8.4)

This test verifies that Active TCAS I can properly acquire and track altitude reporting target within a range of five nautical miles and, in the absence of target replies, will coast a target for no longer than specified in 2.2.8.4.

Inputs

Active TCAS I Aircraft

Altitude = 6,000 ft
Altitude Rate = 0 FPM

Intruder Aircraft 1

Equipage = Mode C
Range = 5 nmi at T = 0 sec
Relative Speed = -360 kt (0.1 nmi/sec)
Altitude = 6,000 ft
Altitude Rate = 0 FPM
Reply Power = -50 ±1 dBm
Reply Sequence = Replies once each surveillance update in the to Active TCAS I interrogations from T = 0 sec to T = 12 sec and does not reply thereafter.

Intruder Aircraft 2

Equipage = Mode C
Range = 2 nmi at T = 0 sec
Relative Speed = -360 kt (0.1 nmi/sec)
Altitude = 6,000 ft
Altitude Rate = 0 FPM
Reply Power = -50 ±1 dBm
Reply Sequence = Replies once each surveillance update interval to Active TCAS I interrogations from T = 0 to T = 20 sec except every third interval, during which it does not reply.

Conditions

Active TCAS I initialized and operating at T = 0 seconds. Intruder 1 replies once each surveillance update interval from T = 0 sec to T = 12 sec. After T = 12 sec, Intruder 1 does not reply. Intruder 2 replies once in each of the first two surveillance update intervals, does not reply in the third interval, replies the next two, etc. This sequence is repeated until T = 20 sec. The scenario is terminated at T = 30 sec.

Scenario Description

Active TCAS I should acquire and track Intruder 1 until it stops replying at T = 12 sec. Active TCAS I should then coast Intruder 1 track according to 2.2.8.4 and then drop track no later than T = 20 sec. Active TCAS I should not acquire Intruder 2 since it does not reply on three consecutive update intervals.

Success: An examination of surveillance output should indicate that Active TCAS I establishes track on Intruder 1 in five to seven seconds from the start of the scenario and maintains track

on Intruder 1 for an additional 11 to 13 seconds, after which it discontinues track of Intruder 1. Active TCAS I never establishes track on Intruder 2.

2.4.2.7.2 Surveillance of NAR Targets (2.2.8.5)

This test verifies that Active TCAS I is able to acquire and track a non-altitude reporting target.

Inputs

Active TCAS I Aircraft

Altitude = 6,000 ft
Altitude Rate = 0 FPM

Intruder Aircraft

Equipage = Non-Altitude-reporting ATCRBS Transponder
Range = 4 nmi at T = 0 sec
Relative Speed = -360 kt (0.1 nmi/sec)
Altitude = 6,000 ft
Altitude Rate = 0 FPM
Reply Power = + 50 ±1 dBm

Conditions

Active TCAS I initialized and operating at T = 0 seconds. The intruder replies once each surveillance update interval to Active TCAS I interrogations with a Mode C reply that contains only empty brackets (i.e., no altitude code pulses).

Scenario

Active TCAS I and the intruder are closing at 360 kt. Active TCAS I should acquire and track the intruder in range and bearing only, since the intruder reply does not contain altitude information. Scenario terminated at T = 30 sec.

Success: An examination of the Active TCAS I surveillance output should indicate that Active TCAS I establishes a track on the intruder in five to seven seconds after the start of the scenario.

2.4.2.7.3 Surveillance Target Capacity (2.2.8.2)

This test verifies that Active TCAS I has the capacity to track at least eight Mode C aircraft within a range of five nautical miles.

Inputs

TCAS Aircraft

Altitude = 6,000 ft.
Altitude Rate = 0 FPM

Intruder Aircraft 1 through 4

Equipage = Mode C
Range Intruder 1 = 0.20 nm
Intruder 2 = Intruder 2 F_1 pulse delayed 1.5 $\pm$0.2 microseconds relative to Intruder 1 F_2 pulse.
Intruder 3 = Intruder 3 F_1 pulse delayed 0.7 $\pm$0.1 microseconds relative to Intruder 2 F_1 pulse.
Intruder 4 = 4.0 nm
Relative Speed = 0 kt.
Altitude = 6000 feet
Altitude Rate = 0 FPM
Reply Power = -50 $\pm$ 1 dBm

Intruder Aircraft 5 through 8

Intruders 5 through 8 are all located at a range of 0.42 nmi. Each intruder responds to a different whisper-shout level as shown below

Intruder	Whisper-Shout Interrogation Level
5	1
6	2
7	3
8	4

Relative Speed = 0 kt

Altitude

Intruder 1 = 6300 ft. (Altitude code = 4010)
Intruder 2 = 6700 ft. (Altitude code = 4040)
Intruder 3 = 6500 ft. (Altitude code = 4020)
Intruder 4 = 6000 ft. (Altitude code = 4420)
Intruder 5 = 6300 ft. (Altitude code = 4010)
Intruder 6 = 6300 ft. (Altitude code = 4010)
Intruder 7 = 6300 ft. (Altitude code = 4010)
Intruder 8 = 6300 ft. (Altitude code = 4010)

Altitude Rate = 0 FPM
Reply Power = -50 +1 dBm

Conditions

Active TCAS I initialized and operating at T=0 seconds. Each intruder replies once each surveillance update interval to Active TCAS I interrogations.

Scenario

All eight Intruders are stationary relative to Active TCAS I. Intruders 1 and 2 do not overlap. Intruders 2 and 3 interleave. Intruder 4 does not garble any other intruder because of range. Intruders 5 through 8 reply to different whisper shout sequences to prevent garble. The scenario is terminated at T = 30 seconds.

Success: An examination of the Active TCAS I surveillance output indicates that Active TCAS I was able to acquire and track all eight intruders.

2.4.2.7.4 Display Overload (2.2.17)

The purpose of this test is to verify that, when the display capacity of 2.2.17 is exceeded, the TCAS I processor correctly drops intruders from the display according to the criteria of 2.2.17.

Note 1: This test is designed to verify that intruders are dropped form the display in the proper order when necessary. It is NOT a test of the TCAS surveillance, processor, or track file capacity.

Note 2: This test was written assuming that the TCAS display was capable of displaying a maximum of eight intruders. The intruder aircraft are arranged in the priority in which they should be displayed. If an implementation provides for displaying more than eight intruder aircraft, this test will have to be modified by the manufacturer to demonstrate compliance with Section 2.2.17.

Inputs

TCAS Aircraft

Altitude = 6,000 feet
Altitude Rate = 0 FPM

Intruder Aircraft

The following values apply to all intruder aircraft:

Equipage = Mode C
Altitude Rate = 0 FPM

Reply Power = -50 +1 dBm

Intruder 1 (TA)
Range = 5.0 nmi
Altitude = 6,000 feet
Relative Speed = -900 knots
Whisper-shout
interrogation level = 3

Intruder 2 (TA)
Range = 1.7 nmi
Altitude = 6,300 feet
Relative Speed = -240 knots
Whisper-shout
interrogation level = 2

Intruder 3 (TA)
Range = 0.2 nmi
Altitude = 5,800 feet
Relative Speed = 0 knots
Whisper-shout
interrogation level = 1

Intruder 4 (Proximate)
Range = 3.6 nmi
Altitude = 4,000 feet
Relative Speed = 0
Whisper-shout
interrogation level = 3

Intruder 5 (Proximate)
Range= 2.5 nmi
Altitude = 4,800 feet
Relative Speed = 0 knots
Whisper-shout
interrogation level = 2

Intruder 6 (Proximate)
Range = 3.5 nmi
Altitude = 7,100 feet
Relative Speed =0
Whisper-shout
interrogation level = 1

Intruder 7 (Proximate)
Range = 3.9 nmi
Altitude = 7,000 feet

Relative Speed = 0 knots
Whisper-shout
interrogation level = 4

Intruder 8 (Other)
Range = 2.6 nmi
Altitude = 7,500 feet
Relative Speed = 0 knots
Whisper-shout
interrogation level = 3

Intruder 9 (Other)
Range = 3.5 nmi
Altitude = 8,000 feet
Relative Speed = 0 knots
Whisper-shout
interrogation level = 2

Intruder 10 (Other)
Range = 2.0 nmi
Altitude = 5,000 feet
Relative Speed = 0 knots
Whisper-shout
interrogation level = 4

Intruder 11 (Other)
Range = 4.9 nmi
Altitude = 3,300 feet
Relative Speed = 0 knots
Whisper-shout
interrogation level = 1

Intruder 12 (Other)
Range = 4.9 nmi
Altitude = 8,600 feet
Relative Speed = 0 knots
Whisper-shout
interrogation level = 4

Conditions

Active TCAS initialized and operating at T=0. Each intruder replies once each surveillance update interval to the indicated whisper-shout level.

Scenario

The stationary and moving intruders reply to the Active TCAS I interrogations once each surveillance update interval. The scenario is terminated at T=20 seconds.

Success: An examination of the Active TCAS I display indicates that Intruders 9, 10, 11, and 12 are not shown on the display.

2.4.2.7.5 Aural Alert Annunciation (2.2.15)

This test procedure shall verify that a Traffic Advisory is provided for a single level flight intruder.

Scenario A

Own aircraft and the single threat are tracked on a horizontal collision course in level flight. The threat is very slightly above own aircraft.

Input:

Active TCAS I Aircraft

Radio Altitude = 1000 ft
Altitude rate = 0 FPM

Intruder aircraft

Equipage = Mode C
Altitude = 1100 ft
Altitude rate = 0 FPM
Range = 5 nmi at t = 0
Relative Speed = -360 kt from t = 0 to 60 sec

Success: At T = 30 $\pm$ 1.5 seconds the display shall exhibit a TA symbol and an aural "Traffic, Traffic" shall be announced.

Scenario B

Own aircraft and the single threat are tracked on a horizontal collision course in level flight. The threat is very slightly above own aircraft. The scenario is below the aural inhibit altitude.

Input:

Active TCAS I Aircraft

Radio Altitude = 300 ft
Altitude rate = 0 FPM

Intruder aircraft

Equipage = Mode C
Altitude = 400 ft
Altitude rate = 0 FPM
Range = 5 nmi at t = 0
Relative Speed = -360 kt from t = 0 to 60 sec

Success: At T = 30 ± 1.5 seconds the display shall exhibit a TA symbol but no aural shall be announced.

2.4.2.7.6 Intruder on the Ground Logic (2.2.16)

This test procedure shall verify that altitude reporting intruders on the ground are not displayed.

Input:

TCAS Aircraft

Altitude = 2600 ft
Altitude rate = 0 FPM
Radio Altitude = 1600 ft

Intruder aircraft 1

Equipage = Mode C
Altitude = 1000 ft
Altitude rate = 0 FPM
Range = 5 nmi
Relative Speed = -180 knots

Intruder aircraft 2

Equipage = Mode C
Altitude = 3000 ft
Altitude rate = 0 FPM
Range = 5 nmi
Relative Speed = -180 knots

Success: An examination of the surveillance output shall indicate that Intruder 1 was not displayed and Intruder 2 was displayed.

2.4.2.8 Performance Compatibility with Own-Aircraft's Transponder

The following tests verify that under normal operating conditions the transponder and the TCAS functions do not interfere with one another.

2.4.2.8.1 Active TCAS I to Transponder Interference (2.2.1.2)

This test verifies that the Active TCAS I functions do not couple spurious signals into the transponder and thereby degrade its minimum threshold (sensitivity) level.

Scenario: A sensitivity measurement is to be performed on the transponder immediately following completion of the Active TCAS I transmitter active state during which a TCAS interrogation occurred at its maximum output power level value.

If separate antenna ports are provided for the transponder and the Active TCAS I, the external coupling paths between the transponder receiver input and the Active TCAS I transmitter output shall be simulated to represent the estimated maximum coupling with the equipment installed in an aircraft.

2.4.2.8.2 Transponder to Active TCAS I Interference (2.2.1.2)

This test verifies that the transponder functions do not couple spurious signals into the Active TCAS I receiver and thereby degrade its minimum threshold (sensitivity) level beyond the limits specified in 2.2.2.1.

Test Scenario: A sensitivity measurement is to be performed on the Active TCAS I receiver immediately following completion of the transponder active state as defined in 2.2.1.2.

If separate antenna ports are provided for the transponder and Active TCAS I, the external coupling paths between the Active TCAS I receiver input and the transponder transmitter output shall simulate the estimated maximum coupling with the equipment installed in an aircraft.

A TCAS sensitivity measurement shall be conducted in accordance with the procedure specified in 2.4.2.2.1 of this document.

2.4.2.9 Bearing Estimation

2.4.2.9.1 Bearing Accuracy with Standard Ground Plane (2.2.9.2)

The following procedures verify the target bearing accuracy of the bearing antenna and associated processing equipment on an antenna range.

Equipment Required

Antenna pattern range.
Ground plane four feet in diameter or larger.
Reference quarter wave stub.
Means to read bearing estimates for targets.

Set-Up/Calibration for Bearing Accuracy Tests

Install a vertically polarized quarter wave stub antenna in the center of the ground plane. Attach the ground plane to the antenna range turntable. Set the power of the 1,090 MHz test source so that the received signal strength as measured at the stub antenna connector is at the desired power level specified in the test for an elevation of 0 degrees.

Replace the stub with the Active TCAS I antenna and connect it to the Active TCAS I receiver with cables that simulate the actual aircraft installation.

Transmit simulated Mode C replies from a test source as required by each of the following tests.

Accuracy, -10 to +20 Degrees Elevation

This test will verify the bearing accuracy over all azimuths, and over an elevation zone of -10 to +20 degrees.

Inputs

Active TCAS I Aircraft

Altitude = 9,600 ft
Altitude = 0 FPM

Intruder Aircraft

Equipage = Mode C
Altitude = 9,600 ft
Altitude Rate = 0 FPM
Range = 2 nmi
Relative Speed = 0 kt

Conditions

Active TCAS I is initialized at T = 0 seconds. A test source provides one Mode C reply each surveillance update interval and TCAS provides a bearing estimate of the test source azimuth relative to the 0 degree azimuth direction of the TCAS bearing antenna.

Scenario

For each combination of the following conditions, record the error between the bearing estimate and the true bearing at 0 + m x 15 degrees, m = 0,1,...23, azimuth values using 20 bearing measurements at each azimuth position.

Received Level = -51 dBm

Received
Frequency = 1,090 MHz
Elevation Angle = -10, 0, +10, and +20 degrees

Compute the overall RMS error using the 24 x 20 = 480 individual errors at each elevation angle.

Success:

-10 to +10 degrees elevation:

RMS error ≤ 10 degrees
Peak error ≤ 30 degrees

+10 to +20 degrees elevation:

RMS error < 15 degrees
Peak error < 45 degrees

2.4.2.10 Active TCAS I Antenna System (2.2.10)

The following test is designed to verify that the antenna system used with the Active TCAS I equipment meets the antenna pattern specifications stated in 2.2.10.2.

Equipment Required

Antenna pattern range.
Ground plane four feet in diameter or larger.
Reference quarter wave stub antenna.
Antenna pattern recorder and L-Band Receiver.
L-Band source antenna and RF generator.

Measurement Procedure

Install the Active TCAS I antenna in the center of the four-foot ground plane and mount the ground plane on the antenna range turntable. Record 360 degrees azimuth patterns at 1,030, 1,087, and 1,093 MHz at elevation angles of -10 degrees, -5 degrees, 0 degrees, +5 degrees, +10 degrees, +15 degrees, and +20 degrees.

Repeat the measurements with the reference quarter wave stub installed on the four-foot ground plane.

Success: The radiation pattern of the Active TCAS I antenna meets or exceeds the requirements of 2.2.10.

2.4.2.11 Computer Performance Validation (2.2.13)

2.4.2.11.1 Memory Pattern Tests

These tests consist of writing unique patterns of ONES and ZEROES into memory, and then reading these values back out of memory to check for bad bits.

2.4.2.11.2 CPU Instruction Test

These tests check that the CPU instructions are functional.

2.4.2.11.3 Program Memory Tests

These tests check that the software program contained in memory is correct.

2.4.2.11.4 CPU Input/Output Tests

These tests verify the CPU input/output functions.

2.4.2.11.5 CPU Timing Tests

These tests verify that the computer operates within its allowable timing constraints as established by the manufacturer.

2.4.2.11.6 Target Reporting Timing (2.2.12)

When the computer processor has a target that is a candidate for reporting to the pilot, such reporting shall require no more than 100 milliseconds.

2.4.2.12 Traffic Advisory Criteria (2.2.14)

Section 2.2.14 defines the two Sensitivity Levels for Active TCAS I, and defines the conditions under which a Traffic Advisory is issued for each Sensitivity Level. This Section separately tests the correct selection of sensitivity level (2.4.2.12.1) and the correct issuance of a Traffic Advisory for Sensitivity Level A (SLA) (2.4.2.12.2), and for Sensitivity Level B (SLB) (2.4.2.12.3).

2.4.2.12.1 Sensitivity Level Selection

This test verifies that Active TCAS I properly selects the sensitivity level. It consists of 27 scenarios, one scenario for each relevant condition of the sensors determining the Sensitivity Level.

Inputs

Active TCAS I Aircraft

Source of potential Sensitivity Level determinants: Radar Altimeter, Landing Gear Discrete, Groundspeed Sensor, or some combination. The determinants are tested in each of three states:

Radar Altimeter:
High -- Altitude >= 2000 feet AGL.
Low -- Altitude < 2000 feet AGL.
NA -- Radar Altimeter not available.

Landing Gear Discrete:
Up -- Landing gear is retracted.
Down -- Unfixed landing gear not retracted.
NA -- Landing gear fixed, or status not available.

Ground Speed:
High -- Ground speed >= 120 knots.
Low -- Ground speed < 120 knots.
NA -- Ground speed not available.

Intruder Aircraft

Non Altitude Reporting aircraft closing at 360 knots.
The range is 2.6 nmi at the beginning of the scenario, time T = 0. The range is 1.6 nmi at the end of each run, at time T = 10 seconds.

Conditions

Active TCAS I initialized and operating at T = 0 seconds. The average surveillance interval shall be one second. The intruder replies once each surveillance interval. The test is run repeatedly with different choices for the states of the sensitivity level determinants.

Test Description

The test is run for each of the 27 possible combination of sensitivity level determinants. The TCAS processor's output shall be monitored to determine whether a traffic alert occurs.

Success: The TCAS Aircraft shall initiate a Traffic Alert for the Sensitivity Level B scenarios at time T = 6$\pm$ 1.5 seconds. The TCAS Aircraft shall not initiate a Traffic Alert for the Sensitivity Level A scenarios. The Sensitivity Level for each scenario is defined in the table below:

Ground Speed High

Radar Alt. High	SL B	SL B	SL B
Radar Alt. Low	SL A	SL A	SL A
Radar Alt. NA	SL B	SL A	SL B
	Land. Gear Up	Land. Gear Down	Land. Gear NA

Ground Speed Low

Radar Alt. High	SL B	SL B	SL B
Radar Alt. Low	SL A	SL A	SL A
Radar Alt. NA	SL B	SL A	SL A
	Land. Gear Up	Land. Gear Dwn	Land. Gear NA

Ground Speed NA

Radar Alt. High	SL B	SL B	SL B
Radar Alt. Low	SL A	SL A	SL A
Radar Alt. NA	SL B	SL A	SL B
	Land. Gear Up	Land. Gear Dwn	Land. Gear NA

2.4.2.12.2 Traffic Advisory Criteria for SLA

This test verifies that a Sensitivity Level A Active TCAS I correctly initiates a Traffic Advisory. It consists of a single run with the Active TCAS I equipped aircraft encountering six Intruder Aircraft in succession, each testing a different boundary condition for issuing a Traffic Alert.

Inputs

Active TCAS I Aircraft

Sensitivity Level A
Altitude 1000 Feet
Radio Altitude = 1000 Feet

Intruder Aircraft 1

Non Altitude Reporting (NAR)
Range closing at 360 knots
First observed at T=0, range = 2.5 nmi
At T=10, range = 1.5 nmi (tau = 15)
No responses after T=20

Boundary tested: SLA NAR is TA at range tau = 15.

Intruder Aircraft 2

Altitude Reporting
Relative Altitude = 500 feet
Range closing at 360 knots
First observed at T=20, range = 2.5 nmi
At T=25, range = 2.0 nmi (tau = 20)
No responses after T=30

Boundary tested: SLA is TA at alt < 600 and range tau = 20.

Intruder Aircraft 3

Altitude Reporting
Relative Altitude Rate = 3600 FPM, closing
Range Rate = 360 knots, closing
First observed at T=30, relative altitude = 1500, range = 3.0 nmi
At T=40, relative altitude = 900 (tau =15), range =2.0nmi (tau= 20)
No responses after T=50

Boundary tested: SLA is TA at alt tau < 20 and range tau = 20.

Intruder Aircraft 4

Altitude Reporting
Relative Altitude Rate = 3600 FPM, closing
Range Rate = 360 knots, closing
First observed at T=50, relative altitude = 1800, range = 2.5 nmi
At T=60, relative altitude =1200 (tau=20), range =1.5nmi (tau= 15)
No responses after T=70

Boundary tested: SLA is TA at range tau < 20 and alt tau = 20.

Intruder Aircraft 5

Altitude Reporting
Relative Altitude Rate = 0 for 10 seconds, then 1200 FPM, separating

Range Rate = 0 knots
First observed at T=70, relative altitude = 400, range = .15 nmi
At T=80, begin ascent.
At T=90, relative altitude = 600 range = .15 nmi
No responses after T=100

Boundary tested: SLA is TA at range < .2 nmi and alt = 600 feet.

Intruder Aircraft 6

Altitude Reporting
Relative Altitude Rate = 0
Range Rate = 0 for 10 seconds, then 360 knots, separating
First observed at T=100, relative altitude = 500, range = .05 nmi
At T=110, begin departure.
At T=111.5, relative altitude = 500, range = .2 nmi
No responses after T=120

Boundary tested: SLA is TA at alt < 600 feet and range = .2 nmi.

Notes: *At 360 knots, Range Tau in seconds = 10 * (Range in nmi).*
Thus Range Tau = 15 at 1.5 nmi,
Range Tau = 20 at 2 nmi, and
Range Tau = 30 at 3 nmi.

At 3600 FPM, Altitude Tau in seconds = (Relative Altitude in Feet)/60.
Thus Altitude Tau = 15 at 900 Feet, and
Altitude Tau = 30 at 1800 Feet.

Conditions

Active TCAS I initialized and operating at T = 0 seconds. The average surveillance interval shall be one second. Each intruder replies once each surveillance interval from the time of first observation until the intruder stops responding.

Test Description

The TCAS I equipped aircraft encounters a series of six intruder aircraft. The TCAS I tracks each intruder, and classifies the intruder as PA, TA, or Other in accordance with section 2.2.14.

Success: The TCAS shall initiate the TA alert for each intruder within 1.5 seconds of the nominal TA initiation time. The TCAS shall terminate the TA alert at a time within 1.5 seconds of the time required by section 2.2.14. The nominal times are contained in the table below:

Intruder Number	Time of TA Initiation	Time of TA Termination
1	10	23
2	25	33
3	40	53
4	60	73
5	70	106
6	100	111.5

2.4.2.12.3 Traffic Advisory Criteria for SLB

This test verifies that a Sensitivity Level B Active TCAS I correctly initiates a Traffic Advisory. It consists of a single run with the Active TCAS I equipped aircraft encountering six Intruder Aircraft in succession, each testing a different boundary condition for issuing a Traffic Alert.

Inputs

Active TCAS I Aircraft

Sensitivity Level B
Altitude 4000 Feet
Radio Altitude = 2500 Feet

Intruder Aircraft 1

Non Altitude Reporting (NAR)
Range closing at 360 knots
First observed at T=0, range = 3.0 nmi
At T=10, range = 2.0 nmi (tau = 20)
No responses after T=20
Boundary tested: SLB NAR is TA at range tau = 20.

Intruder Aircraft 2

Altitude Reporting
Relative Altitude = 700 feet
Range closing at 360 knots
First observed at T=20, range = 3.5 nmi
At T=25, range = 3.0 nmi (tau = 30)
No responses after T=30

Boundary tested: SLB is TA at alt < 800 and range tau = 30.

Intruder Aircraft 3

Altitude Reporting
Relative Altitude Rate = 3600 FPM, closing
Range Rate = 360 knots, closing
First observed at T=30, relative altitude = 1800, range = 4.0 nmi
At T=40, relative altitude =1200 (tau =20), range =3.0nmi (tau=30)
No responses after T=50

Boundary tested: SLB is TA at alt tau < 30 and range tau = 30.

Intruder Aircraft 4

Altitude Reporting
Relative Altitude Rate = 3600 FPM, closing
Range Rate = 360 knots, closing
First observed at T=50, relative altitude = 2400, range = 3.0 nmi
At T=60, relative altitude =1800 (tau = 30), range=2.0nmi (tau=20)
No responses after T=70

Boundary tested: SLB is TA at range tau < 30 and alt ta = 30.

Intruder Aircraft 5

Altitude Reporting
Relative Altitude Rate = 0 for 10 seconds, then 1200 FPM, separating
Range Rate = 0 knots
First observed at T=70, relative altitude = 600, range = .5 nmi
At T=80, begin ascent.
At T=90, relative altitude = 800 range = .5 nmi
No responses after T=100

Boundary tested: SLB is TA at range < .55 nmi and alt = 800 feet.

Intruder Aircraft 6

Altitude Reporting
Relative Altitude Rate = 0
Range Rate = 0 for 10 seconds, then 360 knots, separating
First observed at T=100, relative altitude = 700, range = .05 nmi
At T=110, begin departure.
At T=115, relative altitude = 700, range = .55 nmi
No responses after T=120

Boundary tested: SLB is TA at alt < 800 feet and range = .55 nmi.

Notes: *At 360 knots, Range Tau in seconds = 10 * (Range in nmi).*
Thus Range Tau = 15 at 1.5 nmi,
Range Tau = 20 at 2 nmi, and
Range Tau = 30 at 3 nmi.

At 3600 FPM, Altitude Tau in seconds = (Relative Altitude in Feet)/60.
Thus Altitude Tau = 15 at 900 Feet, and
Altitude Tau = 30 at 1800 Feet.

Conditions

Active TCAS I initialized and operating at T = 0 seconds. The average surveillance interval shall be one second. Each intruder replies once each surveillance interval from the time of first observation until the intruder stops responding.

Scenario Description

The TCAS I equipped aircraft encounters a series of six intruder aircraft. The TCAS I tracks each intruder, and classifies the intruder as PA, TA, or Other in accordance with section 2.2.14.

Success: The TCAS shall initiate the TA alert for each intruder within 1.5 seconds of the nominal TA initiation time. The TCAS shall terminate the TA alert at a time within 1.5 seconds of the time required by section 2.2.14. The nominal times are contained in the table below:

Intruder Number	Time of TA Initiation	Time of TA Termination
1	10	23
2	25	33
3	40	53
4	60	73
5	70	106
6	100	115

3.0 INSTALLED EQUIPMENT PERFORMANCE

3.1 Test Conditions

3.1.1 Power Input

Ground tests may be conducted using the aircraft's electrical power generating system. Alternately, an appropriate external power supply may be used unless otherwise specified or unless the tested function is known to be dependent upon power source qualities.

3.1.2 Associated Equipment

All electrically operated aircraft systems and equipments shall be operational before conducting electronic interference tests.

3.1.3 Environment

During the following tests, the equipment shall not be subjected to environmental conditions that exceed those specified by the manufacturer.

3.1.4 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.

3.2 Equipment Installation

3.2.1 Equipment Accessibility

The equipment controls and display(s) installed for in-flight operation shall be readily accessible from the normal seated position. The appropriate operator/crew member(s) shall have an unobstructed view of the display(s) when in normal sitting position.

3.2.2 Display Visibility

The display brilliance shall be such that the display can be interpreted under all probable cockpit conditions of ambient light. Filters and brightness adjustments are acceptable means of obtaining adequate display visibility in daylight.

3.2.3 Interference

The equipment shall not be the source of objectionable conducted or radiated interference nor be adversely affected by conducted or radiated interference from other certificated equipment or systems installed in the aircraft.

3.2.4 Physical Installation

Operation of the equipment shall not be adversely affected by aircraft maneuvering or changes in attitude encountered in normal flight operations.

3.2.5 Aircraft Power Source

The voltage and voltage tolerance characteristics of the equipment shall be compatible with the aircraft power source.

3.2.6 Transmission Lines

Transmission lines to the antennas shall have impedance, power handling and loss characteristic in accordance with the specifications of the equipment manufacturer. The Voltage Standing Wave Ratio (VSWR) as seen through the transmission lines shall be within the limits specified by the manufacturer.

3.2.7 Altimetry

The equipment providing pressure altitude data to the Active TCAS I shall satisfy the requirements of Mode C encoding. Verify that it is properly connected to the Active TCAS I unit.

3.3 Minimum Installed Equipment Performance Requirements

When a transmission line is included as part of the installation, all minimum installed system performance requirements must be met. The installed equipment shall meet the requirements of Subsection 2.2. In order to meet these requirements, test results supplied by the equipment manufacturer may be accepted in lieu of tests performed by the equipment installer.

However, performance characteristics such as interaction with other installed equipment and power sources, which cannot be tested by the equipment manufacturer, shall be tested by the installer.

3.4 Test Procedures for Installed Equipment Performance

The test procedures set forth below are considered satisfactory for use in determining required equipment performance when installed in aircraft. Tests are stated in a manner that will make maximum use of test data available before installation on the aircraft. Although specific test procedures are cited, it is recognized that other methods may be preferred by the installer.

3.4.1 Conformity Inspection

Visually inspect the installed equipment to determine the use of acceptable workmanship and engineering practices. Verify that all mechanical and electrical connections have been installed and located in accordance with the manufacturer's requirements.

3.4.2 General Test Procedures

3.4.2.1 Equipment Function

Vary all controls used for in-flight operations through their full range to determine that the equipment is operating according to the manufacturer's instructions and that each control performs its intended function.

3.4.2.2 Interference Effects (Ground Test)

With the Active TCAS I operating, operate each of the other electrically operated aircraft equipments to determine that no significant conducted or radiated interference exists. Evaluate all reasonable combinations of control settings and operating modes. Operate communications and navigation equipment on at least one low-band, one high-band, and one mid-band frequency. Make note of systems or modes of operation that should also be evaluated during flight. If appropriate, repeat tests using emergency power.

Note: *Electromagnetic interference tests are often conducted on all electronics systems in one test series, using procedures established by the aircraft manufacturer. If such tests include the TCAS equipment, no further tests are required.*

3.4.2.3 Accessibility

Determine that all equipment controls and displayed data are readily accessible and easily interpreted.

3.4.3 Flight Test Procedures

This is guidance material which offers examples of flight test procedures for demonstration of selected performance functions.

Flight test of installed systems may be found desirable to confirm or supplement bench and ground tests of installed performance.

3.4.3.1 Displayed Data Readability

Determine that normal conditions of flight do not significantly affect the readability of displayed data.

3.4.3.2 Interference Effects

For those aircraft equipments and systems that can be checked only in flight, determine that no operationally significant conducted or radiated interference exists. Evaluate all reasonable combinations of control settings and operating modes.

Note: *Electromagnetic interference flight tests are often conducted on all electronic systems in one test series, using procedures established by the aircraft manufacturer. If such tests include the Active TCAS I equipment, no further tests are required.*

3.4.3.3 Surveillance

This surveillance flight test is designed to verify that the TCAS equipment, when airborne, is capable of interrogating and detecting the presence of another aircraft with a standard ATCRBS Mode C or Mode S transponder. The following suggested procedure is a typical flight test plan that could be followed in a region of low aircraft traffic density; but any other test that provides equivalent data would be acceptable.

a. For the purpose of this test the Active TCAS I equipment should be capable of providing a read-out of target range, relative bearing and altitude where applicable.

b. A transponder with Mode C capability can be mounted on a building or tower. If the transponder antenna has directional gain (in order to reduce the multipath interference), the ground transponder transmit power and receiver sensitivity must be adjusted accordingly.

c. Set the ground transponder (hereafter called the "target transponder") to operate in Mode C only. Set the altitude at the altitude of the flight test aircraft, which should be no more than 3,000 ft above the target transponder antenna.

d. Fly the aircraft straight and level (at the altitude set into the target transponder) toward the target transponder from a distance greater than five nautical miles.

e. The target transponder altitude setting and range should appear on the TCAS display at a range of approximately five nautical miles. The exact detection range may vary with the flight test antenna gain and multipath conditions. A traffic advisory should be displayed at the appropriate time.

f. The traffic bearing information provided by Active TCAS I shall be examined by the pilot to verify that the installed equipment does not have an excessive bias error or a sense reversal. Assuming no bias error and correct sensing, relative bearing to target should be displayed to the nearest clock position.

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