

RTCA, Inc.
1828 L Street, NW, Suite 805
Washington, DC 20036-5133, USA

**Minimum Operational Performance Standards
for
Air Traffic Control Radar Beacon System (ATCRBS)
Airborne Equipment**

DRAFT Version 1.0

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Copies of this document may be obtained from

RTCA, Inc.
1828 L Street, NW, Suite 805
Washington, DC 20036-5133, USA

Telephone: 202-833-9339
Facsimile: 202-833-9434
Internet: www.rtca.org

Please call RTCA for price and ordering information

FOREWORD

These Minimum Operational Performance Standards (MOPS) were prepared by RTCA Special Committee 209 (SC-209) and approved by the RTCA Program Management Committee (PMC) on MM DD, YYYY. This document represents the consolidated performance requirements from two sources; RTCA/DO-144, “*Minimum Operational Characteristics for Airborne ATC Transponder Systems*,” dated March 12, 1970, and Change 1 to DO-144, posted as RTCA Paper No. 232-70/EC-643, dated November 5, 1970, and the performance standards referred to in paragraph (a)(1) of Federal Aviation Administration (FAA) Technical Standard Order (TSO) -C74c, dated February 20, 1973

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- 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 (MOPS) 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 (ICAO) and the International Telecommunication Union (ITU) and other appropriate international organizations can be based.

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CHANGE HISTORY

Date / Version	Description
1/19/06, v0.1	Initial version of DO-144 taken from RTCA in hardcopy only and scanned into an electronic file, and OCR'd to produce the first editable electronic copy. Since the original DO-144 was written in Part I, Part II, Part III nomenclature, this was changed to chapters and subsections.
8/3/06, v0.2	Used to create the initial Comparison Matrix of the Outline of DO-144 versus the proposed DO-144A.
10/11/06, v0.3	This is the first version of the draft of DO-144A that has been rearranged into the standard RTCA MOPS format. The structure of the requirements section §2.2 was modeled after that in DO-181 and the corresponding information from DO-144 was copied into the appropriate section. The test procedure section §2.4 was populated with the existing test procedures from DO-144 section §2.3, while keeping the identical outline as was set up for §2.2. Since there were no sections in the original DO-144 dealing specifically with environmental testing, then in this draft, section §2.3 was populated with standard boilerplate text from the RTCA MOPS drafting standard. Section 3.0 of a standard RTCA MOPS document deals with Installed Equipment and in this draft that section has been populated with what was in the original DO-144 for Flight Tests in §2.3.
10/31/06, v0.4	(1) During the review of TSO C74c, it was discovered that there was a "Change" document issued for DO-144, dated 11/5/70. The changes identified in that Change document are implemented into this revision. (2) It was further discovered that the current revision of the Environmental MOPS is DO-160E. Therefore, all references to DO-160 in this document were changed to reference DO-160E, and the appropriate paragraph reference numbers were double checked.
12/18/06, v0.5	ATCRBS Sub-sub team inputs to Section 2.1 and 2.2.
12/23/06, v0.5a	Added Section 2.1.10 regarding interrogator characteristics
1/6/07, v0.5b	Inputs to Section 1.0, and added an Appendix A. place holder to insert tables from ICAO Annex 10, Volume IV, Appendix to Chapter 3
3/12/07, v0.6	Meeting at FAA Tech Center including Pagano, Furr, Wapelhorst and Van Dongen. Relocated some sections to more closely resemble the structure of DO-181.
3/13/07, v0.7	All changes accepted and highlighting removed except for those cases where issues were to be discussed with a wider audience.
v0.8, v0.9	Rich Jennings and Tom Pagano review and edit of test procedures. John Van Dongen review and simplification of the Environmental Test Procedures of §2.3.
April 2008, v1.0	Combination of simplified §2.3 with basic document and minor formatting getting ready for more detailed review of the Working Group during April 16-17, 2008 meeting in DC.

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1 PURPOSE AND SCOPE

1.1 Introduction

This document sets forth minimum operational performance standards for Air Traffic Control Radar Beacon System (ATCRBS) airborne equipment. Incorporated within these standards are system characteristics that will be useful to users of the system as well as designers, manufacturers and installers. These performance standards represent a consolidation of performance requirements from two sources; RTCA/DO-144, “*Minimum Operational Characteristics for Airborne ATC Transponder Systems*,” dated March 12, 1970, and Change 1 to DO-144, posted as RTCA Paper No. 232-70/EC-643, dated November 5, 1970, and the performance standards referred to in paragraph (a)(1) of Federal Aviation Administration (FAA) Technical Standard Order (TSO) -C74c, dated February 20, 1973.

Compliance with the following MOPS is required to achieve at least that minimum performance on which control and separation of aircraft is based and to insure against derogation of service to other users of aviation navigation and communication services. These MOPS are applicable to all users of airborne ATC transponder systems who are required by regulation to participate in the ATC system or who voluntarily choose to do so.

Note: *The use of “shall” in the body of this document indicates a requirement. The use of “should” indicates a characteristic that is highly recommended, but is not required.*

It is recognized that any regulatory application of these standards is the responsibility of appropriate government agencies.

Because the measured values of equipment performance characteristics may be a function of the measurement method, standard test conditions and methods of test are recommended in this document.

This document considers an equipment configuration consisting of: transponder, control panel, antenna and interconnecting cables. It should not be inferred that all ATCRBS airborne equipment will necessarily include all of the foregoing components as separate units; this will depend on the design configuration chosen by the manufacturer.

If the equipment implementation includes a computer software package, the guidelines contained in the most current issue of RTCA/DO-178, Software Considerations in Airborne Systems and Equipment Certification, should be considered.

1.1.1 International Standards

The performance standards of this document also reflect current International Civil Aviation Organization (ICAO) Annex 10, Volume IV, Chapter 3 requirements for airborne systems having only Mode A and Mode C capabilities. [need to check current amendment]

1.1.2 Preparation of Minimum Operational Performance Standards for Airborne Systems

The Federal Aviation Administration is the responsible agency for certain aviation standards. However, FAA's regulatory effort is vastly improved by intelligent utilization of government/industry working arrangements, by which a variety and wealth of talent may be brought to bear on the development of a particular minimum requirement.

Therefore, to implement the concepts that have been outlined, RTCA established Special Committee 209 to update the Minimum Operational Performance Standards for Airborne Transponder System Elements (both ATCRBS and Mode S), together with a method of demonstration of compliance. However, as pointed out in these concepts, concise statements of system characteristics are a prerequisite to meaningful minimum operational characteristics for airborne systems. Accordingly, RTCA SC-209 was directed to consider such system characteristics that exist and to include them in its reports. If none exist, best assumptions were to be formulated by RTCA SC-209 and included in the reports.

1.2 The ATCRBS Secondary Surveillance Radar (SSR) Environment

Although the trend towards equipage of ATCRBS/Mode Select (S) capable transponders is increasing, a large number of aircraft are still equipped with ATCRBS-only capable transponders. Since Mode S transponders are required on aircraft with TCAS, Mode S transponders are installed on a large segment of the aircraft population. However, General Aviation aircraft continue to represent the largest percentage of the aircraft in the airspace and ATCRBS transponders are still the dominant equipage for these aircraft.

The primary purpose of the ATCRBS transponder is to support ATC secondary surveillance radar (SSR) requirements. The ATCRBS SSR environment consists of the airborne ATCRBS transponders, ground interrogator-receiver, processing equipment, and an antenna system. The antenna may or may not be associated with, or slaved to, a primary surveillance radar. In operation, an interrogation pulse-pair transmitted from the interrogator-transmitter unit, via an antenna assembly, triggers each airborne transponder located in the direction of the main beam, causing a multiple pulse reply group to be transmitted from each transponder. These replies are received by the ground receiver and, after processing, are displayed to the controller. Measurement of the round-trip transit time determines the range (ρ) to the replying aircraft while the mean direction of the main beam of the interrogator antenna, during the reply, determines the azimuth (θ). Based on the time spacing of the interrogation pulse-pair transmitted, the airborne transponder provides a multiple-pulse reply that represents either an individualized identity code (Mode A reply) or the aircraft's current pressure altitude (Mode C reply).

The ATCRBS transponder also replies to airborne Mode A and Mode C interrogators, thereby making its presence known to aircraft that are equipped with Traffic Advisory and Collision Avoidance System (TCAS) or Airborne Collision Avoidance System (ACAS).

Additional information on ground and airborne interrogator characteristics is contained in §2.1.10.

1.3 Assumptions

This document defines the basic surveillance and link characteristics of ATCRBS transponders. Adherence to the requirements of this document will meet the needs of the airspace for surveillance of aircraft so equipped. There is no upgrade path for the ATCRBS system going forward as surveillance needs of the future may rely on different technologies.

1.4 Equipage Classes

Class A equipment is intended for installation in aircraft which operate at altitudes above 15,000 feet.

Class B equipment is intended for installation in aircraft which operate at altitudes not exceeding 15,000 feet.

1.5 Test Procedures

The specified test procedures and associated limits are intended as one means of demonstrating compliance with the minimum acceptable performance parameters. Although specific test procedures are cited, it is recognized that other methods may be preferred by the test organization. These alternate methods may be used if they provide at least equivalent information. In such cases, the procedures cited should be used as one criterion in evaluating the acceptability of the alternate 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, the equipment should have demonstrated compliance with the requirements of Section §2.0 as a precondition to satisfactory completion of the installed system tests of Section §3.0.

Three types of test procedures are included which should be used at different stages in the equipment approval cycle. These are discussed in the following paragraphs.

1.5.1 Environmental Tests

Environmental tests are specified in Subsection §2.3. The procedures and their associated limit requirements are intended to provide a means of determining the electrical and mechanical performance of the equipment under environmental conditions expected to be encountered in actual operations. Equipment manufacturers may use test results as design guidance in preparation of installation instructions and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.5.2 Detailed Test Procedures

Detailed test procedures are specified in Subsection §2.4. These tests are conducted at the equipment level and are intended to provide a laboratory means of demonstrating compliance with the requirements of Subsections §2.1 and §2.2. Equipment manufacturers may use test results as design guidance, for monitoring manufacturing

compliance and, in certain cases, for obtaining formal approval of equipment design and manufacture.

1.5.3 Installed System Tests

The installed system test procedures and their associated 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 two conditions:

- a. with the aircraft on the ground and using simulated or operational system inputs, and/or
- 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 intended operational environment.

In addition, the ground test procedures may be used as an optional check of equipment performance following corrective maintenance.

1.6 Definition of Terms

ATCRBS – Air Traffic Control Radar Beacon System.

Desensitization – Temporary reduction of transponder sensitivity after receipt of a signal. This helps to reduce echo (multipath) effects.

Interrogation – A ground or airborne signal propagated toward an ATCRBS transponder to elicit a Mode A or Mode C response.

Mode A Interrogation – A signal to elicit an ATCRBS transponder reply for identity (4096 code) and surveillance.

Mode C Interrogation – A signal to elicit an ATCRBS transponder reply for automatic pressure-altitude transmission and surveillance

Multipath – The propagation phenomenon that results in signals reaching the receiving antenna by two or more paths, generally with a time or phase difference between the two.

National Airspace System (NAS) – The common system of facilities, equipment, regulations, procedures and personnel providing services and standard procedures for the safe and efficient movement of civil and military aircraft within the jurisdiction of the United States.

PAM – Pulse Amplitude Modulation. The modulation technique utilized in both the interrogation and reply signals.

Reply – A signal propagated from the transponder.

Side Lobe Suppression (SLS) Transmission – A transmission intended to prevent responses from transponders not in the main beam of the interrogating antenna.

Special Position Identification (SPI) – A special pulse used in ATCRBS located 4.35 microseconds following the last framing pulse. When used in Mode S, SPI appears as a code in the flight status (FS) field and in the surveillance status subfield (SSS).

2 ATCRBS Transponder Equipment Performance Requirements and Test Procedures

2.1 General Requirements

2.1.1 Airworthiness

In the design and manufacture of the equipment, the manufacturer 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(s), as defined by the manufacturer, and its proper use **shall not** create a hazard to other users of the National Airspace System.

2.1.3 Federal Communications Commission Rules

All equipment **shall** comply with the applicable rules of the Federal Communication Commission.

2.1.4 Fire Protection

All materials used **shall** be self-extinguishing except for small parts (such as knobs, fasteners, seals, grommets and small electrical parts) that would not contribute significantly to the propagation of a fire.

Note: *One means of showing compliance is contained in Federal Aviation Regulations (FAR), Part 25, Appendix F.*

2.1.5 Operation of Controls

The equipment **shall** be designed so that controls intended for use during flight cannot be operated in any position, combination or sequence that would result in a condition detrimental to the reliability of the equipment or operation of the aircraft.

2.1.6 Accessibility of Controls

Controls that do not require adjustment during flight **shall not** be readily accessible to flight personnel.

2.1.7 Flight Crew Control Functions

The following functions shall be provided.

- a. Means of selecting each of the ATCRBS 4096 (Mode A) reply codes, and of indicating the code selected.
- b. Means of selecting the condition in which all transponder functions, other than transmission on the reply frequency and associated self-testing, are operational (i.e.,

the Standby condition). Return to normal operation from this condition shall be possible within five seconds

- c. Means of selecting ATCRBS Mode A and Mode C combined.
- d. Means of initiating the IDENT (SPI) feature.
- e. Means of inhibiting the transmission of the altitude information, while retaining the ATCRBS framing pulses in ATCRBS Mode C replies.

2.1.8 Optional Functions/Interfaces

With the movement toward an Automatic Dependent Surveillance – Broadcast (ADS-B) environment, there are various functions/outputs from the ATCRBS transponder that are in common with ADS-B parameter requirements. For example, the “squawk” or 4096 code, pressure altitude, and an IDENT capability are features used by both ADS-B and ATCRBS in supporting ATC surveillance needs. Equipment manufacturers should consider the development of an output interface to support these and other ADS-B broadcast requirements (e.g., Flight ID) in their future transponder designs.

2.1.9 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 the tests, except as specifically allowed.

2.1.10 Interrogation Characteristics

The following subsections describe the signal in space as it can be expected to appear at the transponder's antenna. Because signals can be corrupted in transmission, tolerances for interrogator performance are more restrictive and should not be derived from this document. The modulation technique utilized in the interrogation signal is known as pulse amplitude modulation (PAM).

2.1.10.1 Interrogation Carrier Frequency

The carrier frequency of received interrogations is:

- a. 1030 \pm 0.20 MHz from ATCRBS interrogators.
- b. 1030 \pm 0.01 MHz from Mode S interrogators.

2.1.10.2 Measurement Convention

The following definitions are in reference to Figure 2-1.

Pulse Amplitude – the peak voltage amplitude (A) of the pulse envelope.

Pulse Rise Time – the time between 0.1A and 0.9A on the leading edge of the pulse envelope.

Pulse Decay Time – the time between 0.9A and 0.1A on the trailing edge of the pulse envelope.

Pulse Duration – the time interval between 0.5A points on leading and trailing edges of the pulse envelope.

Pulse Interval – the time interval between the 0.5A point on the leading edge of the first pulse and the 0.5A point on the leading edge of the second pulse.

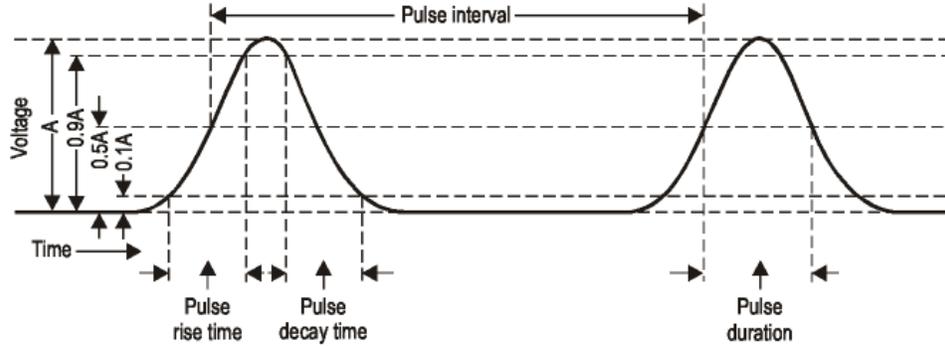


Figure 2-1: Pulse Envelope Conventions

2.1.10.3 Received PAM Signals

The following signals are valid PAM interrogations:

- ATCRBS Mode A (to elicit transponder replies for identity and surveillance)
- ATCRBS Mode C (to elicit transponder replies for automatic pressure-altitude transmission and surveillance)
- ATCRBS Mode A/C/S All-Call (to elicit replies for surveillance of Mode A/C transponders and for the acquisition of Mode S transponders)
- ATCRBS Mode A/C-Only All-Call (to elicit replies for surveillance of Mode A/C transponders. Mode S transponders do not reply)

All of these interrogations use two or more of the four pulses shown in §2.1.10.3.2. The pulses are labeled P₁, P₂, P₃ and P₄.

2.1.10.3.1 Pulse Shapes

The pulse shapes for PAM interrogations are summarized in Table 2.1.10.3.1 (all values are in microseconds).

Table 2.1.10.3.1: Pulse Shapes

Pulse Designator	Pulse Duration	Duration Tolerance	Rise Time Min/Max	Decay Time Min/Max
P ₁ , P ₂ , P ₃	0.8	±0.1	0.05/0.1	0.05/0.2
P ₄ (short)	0.8	±0.1	0.05/0.1	0.05/0.2
P ₄ (long)	1.6	±0.1	0.05/0.1	0.05/0.2

2.1.10.3.2 Pulse Patterns

The pulse patterns of the PAM interrogations are defined in Table 2.1.10.3.2 (all values are in microseconds). The general format of the PAM interrogations is shown in Figure 2-2.

Table 2.1.10.3.2: Pulse Pattern

Interrogation Type	Spacing			
	$P_1 - P_2$	$P_1 - P_3$	$P_3 - P_4$	P_4
ATCRBS Mode A	2 ± 0.15	8 ± 0.2	–	None
ATCRBS Mode C	2 ± 0.15	21 ± 0.2	–	None
ATCRBS Mode A/Mode S All-Call	2 ± 0.15	8 ± 0.2	2 ± 0.05	Long
ATCRBS Mode C/Mode S All-Call	2 ± 0.15	21 ± 0.2	2 ± 0.05	Long
ATCRBS Mode A-Only All-Call	2 ± 0.15	8 ± 0.2	2 ± 0.05	Short
ATCRBS Mode C-Only All-Call	2 ± 0.15	21 ± 0.2	2 ± 0.05	Short

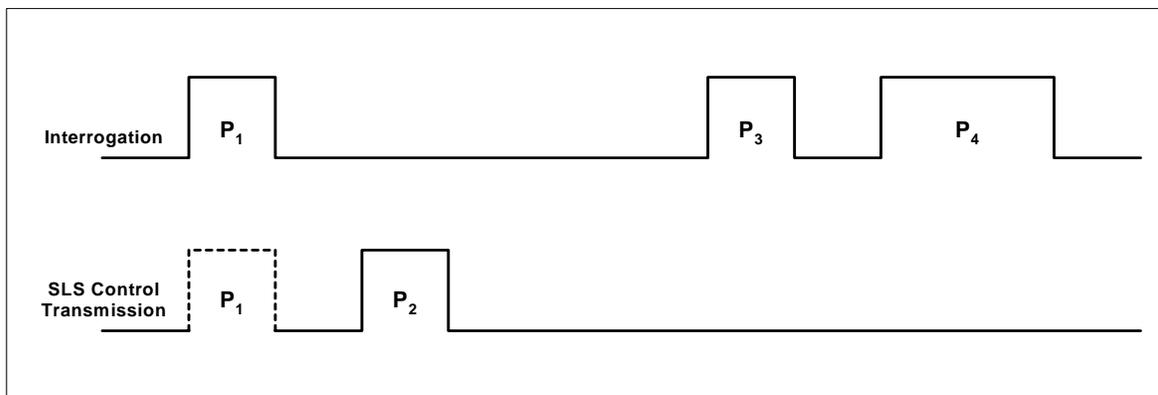


Figure 2-2: General Pulse Patterns for PAM Interrogations

2.1.10.3.3 Relative Pulse Amplitudes

P_2 amplitudes will vary from P_1 .

P_3 amplitudes are $P_1 \pm 1$ dB.

2.1.10.4 Suppression

This characteristic is used to prevent replies to interrogations received via the side lobes of the interrogator antenna, and to prevent Mode A/C transponders from replying to Mode S interrogations. Suppression is in effect when the received amplitude of P_2 is equal to or in excess of the received amplitude of P_1 and spaced 2 ± 0.15 microseconds (see §2.2.5.3).

2.2 Equipment Performance – Standard Conditions

2.2.1 Definition of Standard Conditions

The signal levels specified in this subsection exist at the antenna end of a transponder-to-antenna transmission line of loss equal to the maximum for which the transponder is designed.

***Note:** The transponder will usually be installed with less than the designed maximum transmission line loss. Nevertheless, the standard conditions of this document are based on the maximum design value.*

2.2.2 Receiver Characteristics

2.2.2.1 Interrogation Tolerances

Paragraph §2.1.10 and its subparagraphs define tolerances allowed from the nominal interrogation values. The transponder **shall** be tolerant to all such deviations within the ranges specified in paragraph §2.1.10.

2.2.2.2 Transponder Receiver Operating Frequency and Bandwidth

- a. The receiver nominal center frequency **shall** be 1030 MHz.
- b. With an input signal level 3 dB above the minimum triggering level, the receiver bandwidth **shall** be such that the receiver accepts pulses as outlined in section 2.1.10 with an interrogation center frequency drift of ± 0.2 MHz.
- c. The skirt bandwidth **shall** be such that the sensitivity of the receiver is at least 60 dB down at ± 25 MHz and beyond.

2.2.2.3 Receiver Sensitivity and Dynamic Range

Given an interrogation that requires a reply, the minimum triggering level (MTL) is defined as the minimum input power level that results in a 90 percent reply ratio if the interrogation signal has all nominal pulse spacings and widths and if the replies are the correct replies assigned to the interrogation format.

- a. The minimum triggering level (MTL) of the transponder **shall** be such that replies are generated to 90 percent of the interrogation signals when:

- (1) The two pulses P_1 and P_3 constituting an interrogation are of equal amplitude and P_2 is not detected; and
- (2) The amplitude of these signals received at the antenna end of the transmission line of the transponder is nominally 71 dB below 1 milliwatt with limits between 69 and 77 dB below 1 milliwatt.

Note: *For this MTL requirement, a nominal 3 dB transmission line loss and an antenna performance equivalent to that of a simple quarter wave antenna are assumed. In the event these assumed conditions do not apply, the MTL of the installed transponder system must be comparable to that of the assumed system.*

- b. The variation of the minimum triggering level between modes **shall not** exceed 1 dB for nominal pulse spacings and pulse widths.
- c. The reply characteristics **shall** apply over a received signal amplitude range between minimum triggering level and -21 dBm.
- d. The reply ratio shall not be more than 10 percent for interrogations at signal levels below -81 dBm.
- e. The conditions of “a” through “d” apply when a P_4 pulse is present, either long or short, regardless of amplitude of the P_4 pulse.

2.2.3 Transmitter Characteristics

2.2.3.1 Reply Transmission Frequency

The center frequency of the reply transmission **shall** be 1090 \pm 3 MHz.

2.2.3.2 Transponder Power Output

2.2.3.2.1 Class A Equipment

For this class of equipment, the peak pulse power available at the antenna end of the transmission line of the transponder **shall** be at least 21 dB and not more than 27 dB above 1 watt at any reply rate up to 1,200 per second for a 15-pulse coded reply.

2.2.3.2.2 Class B Equipment

For this class of equipment, the peak pulse power-available at the antenna end of the transmission line of the transponder **shall** be at least 18.5 dB and not more than 27 dB above 1 watt at any reply rate up to 1,000 per second for a 15-pulse coded reply.

Note: *For the power output requirement specified in §2.2.3.2.1 and §2.2.3.2.2, a nominal 3 dB transmission line loss and an antenna performance equivalent to that of a simple quarter-wave antenna are assumed. In the event these assumed conditions do not apply, the peak pulse power of the installed transponder system must be comparable to that of the assumed system.*

2.2.3.3 Emission of Spurious RF Energy

With the transponder operating, but not being interrogated, the level of spurious CW RF energy, as measured at the output terminal of the transponder, over the range 960 to 1215 MHz **shall not** exceed **-70 dBW**.

Note: *Better performance may be required depending on other onboard avionics.*

2.2.3.4 Reply Rate Capability

- a. For Class A equipment (see §1.4), the transponder **shall** be capable of at least 1,200 replies per second for a 15-pulse coded reply.
- b. For Class B equipment (see §1.4), the transponder **shall** be capable of at least 1,000 replies per second for a 15-pulse coded reply.

2.2.3.5 Sensitivity Reduction Reply Rate Control

A sensitivity reduction type reply rate limit control **shall** be incorporated in the transponder. The range of this control **shall** permit adjustment, as a minimum, to any value between 500 and 2,000 replies per second, or to the maximum reply rate capability, if less than 2,000 replies per second, without regard to the number of pulses in each reply. Sensitivity reduction in excess of 3 dB **shall not** take effect until 90 percent of the selected value is exceeded. Sensitivity reduction **shall** be at least 30 dB for rates in excess of 150 percent of the selected value.

→ Editorial Comment: the reduction of 30 dB has been a topic of discussion. This would reduce receiver sensitivity to -41 dBm. This is in the TSO and the SARPs. DO-181 does not specify a specific level of reduction. ←

Note: *The reply rate limit control should be set at 1,200 replies per second, or the maximum value below 1,200 replies per second of which the transponder is capable. (See §2.2.3.4).*

2.2.4 Reply Pulse Characteristics (Signals in Space)

The following subsections describe the reply pulse characteristics. The general format of the reply pulse is shown in Figure 2-3.

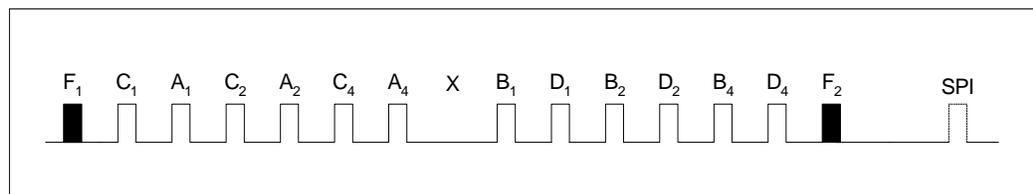


Figure 2-3 ATCRBS Reply Pulse Pattern

2.2.4.1 Framing Pulses

The reply function **shall** employ a signal comprising two framing pulses spaced 20.3 microseconds, as the most elementary code.

2.2.4.2 Information Pulses

Information pulses **shall** be spaced in increments of 1.45 microseconds from the first framing pulse. The designation and position of these information pulses **shall** be as shown in Table 2.2.4.2.

Table 2.2.4.2: Information Pulses

Pulse	Position (microseconds)
F ₁	0.00
C ₁	1.45
A ₁	2.90
C ₂	4.35
A ₂	5.80
C ₄	7.25
A ₄	8.70
X	10.15
B ₁	11.60
D ₁	13.05
B ₂	14.50
D ₂	15.95
B ₄	17.40
D ₄	18.85
F ₂	20.30

2.2.4.3 Special Position Identification (SPI) Pulses

In addition to the information pulses provided, a Special Position Identification (SPI) Pulse, which may be transmitted with the information pulses, **shall** occur at a pulse interval of 4.35 microseconds following the last framing pulse.

The SPI pulse **shall** be initiated by an IDENT switch (see §2.1.7.d). Upon activation of the IDENT switch, the SPI pulse **shall** be transmitted for a period of between 15 and 30 seconds and must be capable of being reinitiated at any time. The SPI pulse **shall not** be included when transmitting Mode C replies.

2.2.4.4 Reply Pulse Shape

All reply pulses **shall** have a pulse duration of 0.45 ± 0.10 microsecond, a pulse rise time between 0.05 and 0.1 microsecond, and a pulse decay time between 0.05 and 0.2 microsecond. The pulse amplitude variation of one pulse with respect to any other pulse in a reply group **shall not** exceed 1 dB. (See §2.1.10.2)

Note: *The intent of the lower limit of rise and decay times (0.05 microseconds) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which theoretically would be produced by a*

trapezoidal wave having 0.05 microsecond rise and decay times and a 0.35 microsecond pulse duration.

2.2.4.5 Reply Pulse Spacing Tolerances

The pulse interval tolerance for each pulse (including the last framing pulse) with respect to the first framing pulse of the reply group **shall** be ± 0.10 microsecond. The pulse interval tolerance of the Special Position Identification Pulse with respect to the last framing pulse of the reply group **shall** be ± 0.10 microseconds. The pulse interval tolerance of any pulse in the reply group with respect to any other pulse (except the first framing pulse) **shall** not exceed ± 0.15 microseconds.

2.2.4.6 Reply Delay and Jitter

The time delay between the arrival at the transponder of the leading edge of P_3 , and the transmission of the leading edge of the first pulse of the reply **shall** be 3 ± 0.5 microseconds. The total jitter of the reply pulse code group with respect to P_3 **shall not** exceed ± 0.1 microseconds. Delay variations between modes on which the transponder is capable of replying **shall not** exceed 0.2 microseconds. These requirements apply for receiver input levels between 3 and 50 dB above minimum triggering level.

2.2.5 Decoding Performance

Unless otherwise specified, the following pulse decoder characteristics **shall** apply over the RF input signal level range from MTL +3 dB to MTL +50 dB and interrogation signal characteristics per §2.1.10.3.

2.2.5.1 Pulse Level Tolerances

When selected to reply to a particular interrogation mode (See §2.1.10.3.2), the transponder **shall** reply (not less than 90 percent efficiency) under each of the following conditions:

- a. The received amplitude of P_3 is in excess of a level 1 dB below the received amplitude of P_1 but no greater than 3 dB above the received amplitude of P_1 .
- b. The received amplitude of a proper interrogation is more than 10 dB above the received amplitude of random pulses where the latter are not recognized by the transponder as P_1 , P_2 , or P_3 .
- c. The conditions of “a” and “b,” apply when a P_4 pulse is present, either long or short, regardless of amplitude of the P_4 pulse.

2.2.5.2 Pulse Position Tolerances

The transponder **shall** accept interrogations as valid if the spacing between P_1 and P_3 is within plus or minus 0.20 microseconds of the nominal spacing.

The transponder **shall not** reply to more than 10 percent of the interrogations under each of the following conditions:

- a. To interrogations when the interval between pulses P_1 and P_3 differs from that defined in §2.1.10.3.2 for the mode selected in the transponder by more than ± 1 microsecond.
- b. Upon receipt of any single pulse which has no amplitude variations approximating a normal interrogation condition.

2.2.5.3 Suppression

Upon receipt of an interrogation complying with the interrogation modes defined in §2.1.10.3, selected manually or automatically, the transponder **shall** be suppressed (not less than 99 percent efficiency) when the received amplitude of P_2 is equal to or in excess of the received amplitude of P_1 and spaced 2 ± 0.15 microseconds.

Notes:

1. *It is not the intent of this paragraph to require the detection of P_3 as a prerequisite for initiation of suppression action.*
 2. *After reception of a valid P_3 pulse the transponder should not initiate suppression based on the reception of a P_4 pulse.*
- a. The transponder suppression **shall** be for a period of 35 ± 10 microseconds.
 - b. The suppression **shall** be capable of being reinitiated for the full duration within two microseconds after the end of any suppression period.
 - c. The transponder **shall not** initiate suppression if the level of P_1 exceeds the level of P_2 by 9 dB or more.
 - d. The transponder **shall not** initiate suppression if no pulse is received at the position 2.0 ± 0.7 microseconds following P_1 .
 - e. The transponder **shall not** initiate suppression if the duration of P_2 is less than 0.3 microseconds.

2.2.5.4 Pulse Duration Discrimination

- a. For all signal levels from MTL to -45 dBm, the transponder shall reply to no more than 10 percent of ATCRBS, ATCRBS-Only All-Call or ATCRBS/Mode S All-Call interrogations if the duration of either the P_1 or the P_3 pulse is less than 0.3 microseconds. .
- b. With the exception of single pulses with amplitude variations approximating an interrogation, any single pulse of duration more than 1.5 microseconds **shall not**

cause the transponder to initiate reply or suppression action over the signal amplitude range of minimum triggering level to 50 dB above minimum triggering level.

2.2.6 Desensitization and Recovery Characteristics

2.2.6.1 Dead Time

After reception of a valid interrogation, the transponder **shall not** reply to any other interrogation at least for the duration of the reply pulse train. This dead time **shall** end no later than 125 microseconds after the transmission of the last reply pulse of the group.

2.2.6.2 Echo Suppression and Recovery

The transponder **shall** contain an echo suppression facility designed to permit normal operation in the presence of echoes of signals-in-space. The provision of this facility **shall** be compatible with the requirements for suppression of side lobes given in §2.2.5.3.

2.2.6.2.1 Desensitization

Upon receipt of any pulse more than 0.7 microseconds in duration, the receiver **shall** be desensitized by an amount that is within at least 9 dB of the amplitude of the desensitizing pulse, but **shall** at no time exceed the amplitude of the desensitizing pulse, with the exception of possible overshoot during the first microsecond following the desensitizing pulse. Single pulses of duration less than 0.7 microseconds are not required to cause the specified desensitization, and **shall not** cause desensitization of duration greater than that permitted herein or by §2.2.6.2.2.

2.2.6.2.2 Recovery

Following desensitization, the receiver **shall** recover sensitivity (within 3 dB of minimum triggering level) within 15 microseconds after reception of a desensitizing pulse having a signal strength up to 50 dB above minimum triggering level. **Recovery shall be nominally linear at an average rate not exceeding 3.5 dB per microsecond. [ICAO Annex 10 and DO-181 says 4.0dB, and in the TSO it is 3.5]**

Note: *Transponders that respond to military modes will recover within 15 microseconds, but may employ methods other than nominally linear recovery.*

2.2.7 Undesired Replies

2.2.7.1 Random Triggering and Suppression Rate

In the absence of valid interrogation signals, the random triggering rate (squitter) of the transponder **shall not** exceed 30 replies and/or suppressions per second as integrated over an interval equivalent to at least 300 random triggers, or 30 seconds, whichever is less.

Note: *When demonstrating compliance to these requirements, the equipment manufacturer should consider possible interference (triggering) caused by equipment typically found in the aircraft of intended installation (e.g., VHF communication, DME, Radio Altimeter, etc.), operating at their maximum interference levels.*

2.2.7.2 Random Triggering in the Presence of CW

The total random triggering on all Mode A and/or Mode C replies **shall not** exceed 10 replies or suppressions per second, averaged over a period of 30 seconds, when operated in the presence of non-coherent CW interference at a frequency of 1030 ± 0.2 MHz and a signal level of -60 dBm, or less.

2.2.7.3 Spurious Responses

All spurious responses, including response to image frequencies, **shall** be such that the sensitivity to such signals is at least 60 dB down from the normal sensitivity of the receiver.

→ Editorial Comment: Is this requirement necessary? It appears to be covered in other requirements (section §2.2.2.2). ←

2.2.8 Transponder Self Test and Monitor

2.2.8.1 Manual Self-Test

- a. When a manual self-test device is provided, it **shall** be limited to intermittent use by a spring-loaded return-to-off switch, or equivalent.
- b. The test interrogation rate **shall not** exceed 450 per second.
- c. The lowest RF level at the input to the antenna required to accomplish the test **shall** be used. The maximum RF level at the input to the antenna **shall not** exceed 40 dB below 1 milliwatt.

2.2.8.2 Automatic Self-Test

- a. When an automatic self-test device is provided, it **shall** be limited to use only in the absence of a valid interrogation. (A minimum period of 15 seconds will be sufficient to establish the absence of ground interrogations).
- b. The maximum test time for the automatic self-test **shall not** exceed 0.1 second in any given 15-second interval.
- c. The test interrogation rate **shall not** exceed 450 per second.
- d. The lowest RF level at the input to the antenna required to accomplish the test **shall** be used. The maximum RF level at the input to the antenna **shall not** exceed 40 dB below 1 milliwatt.

2.2.9 Response to Mutual Suppression Pulses

The equipment shall 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.

2.2.10 Data Handling and Interfaces

2.2.10.1 Code Nomenclature

The code designations **shall** consist of four digits, each of which lies between 0 and 7 inclusive, and is determined by the sum of the pulse subscripts given in Table 2.2.4.2, employed as shown in Table 2.2.10.1:

Table 2.2.10.1: Code Nomenclature

Digit	Pulse Group
First (most significant)	A
Second	B
Third	C
Fourth	D

Examples:

Code 3615 would consist of information pulses A_1, A_2 ($1 + 2 = 3$), B_2, B_4 ($2 + 4 = 6$), C_1 ($1 = 1$), D_1, D_4 ($1 + 4 = 5$).

Code 3600 would consist of information pulses A_1, A_2, B_2 and B_4

Code 2057 would consist of information pulses A_2, C_1, C_4, D_1, D_2 and D_4

Code 0301 would consist of information pulses B_1, B_2 and D_1

2.2.10.2 Identification

The 4096 codes specified in §2.2.10.1 **shall** be manually selectable for reply to interrogations on Mode A.

2.2.10.3 Pressure Altitude Transmissions

- Independently of the other modes and codes manually selected, the transponder **shall** automatically reply to Mode C interrogations.
- The reply to Mode C interrogations **shall** consist of the two framing pulses together with the information pulses specified in §2.2.4.2.
- The transponders **shall** be provided with means to remove the information pulses, but to retain the framing pulses when the provision of subparagraph "f" below is not complied with, in reply to Mode C interrogation.

Note: *The information pulses should be capable of being removed either in response to a failure detection system or manually at the request of the controlling agency.*

- The information pulses **shall** be automatically selected by an analog-to-digital converter connected to a pressure-altitude data source in the aircraft referenced to the standard pressure setting of 29.92 inches of mercury.
- Pressure altitude **shall** be reported in 100-foot increments by selection of pulses as shown in the tables in Appendix A. If the transponder is capable of accepting

altitude sources with better than 100-foot resolution, the pressure altitude-information **shall** be reported in the closest 100-foot increment as specified in Appendix A.

- f. The digitizer code selected **shall** correspond to within ± 125 feet, on a 95 percent probability basis with the pressure altitude information (referenced to the standard pressure setting of 29.92 inches of mercury) used on board the aircraft to adhere to the assigned flight profile.

2.2.11 Antenna

2.2.11.1 Frequency

The antenna **shall** be designed to receive and transmit vertically polarized signals in the frequency range of 1030 to 1090 MHz.

2.2.11.2 Impedance and VSWR

The VSWR produced by the antenna when terminated in a 50-ohm transmission line **shall** not exceed 1.5:1 over the 1030 to 1090 MHz frequency band.

2.2.11.3 Polarization

The antenna **shall** be vertically polarized.

2.2.11.4 Radiation Pattern

The transponder antenna system when installed on an aircraft **shall** have a radiation pattern that is essentially omni-directional in the horizontal plane and should have a vertical beam-width sufficient to provide system operation during normal maneuvers of the aircraft.

2.2.12 Power Interruption

The transponder equipment **shall** regain operational capability to within its operational limits within two seconds after the restoration of power following a momentary power interruption.

***Note:** The transponder equipment is not required to continue operation during momentary power interruptions.*

2.2.13 Diversity

Diversity transponders may be implemented for the purpose of improving surveillance performance. Such systems **shall** employ two antennas, one mounted on the top and the other on the bottom of the aircraft. Appropriate switching and signal processing channels to select the best antenna on the basis of the characteristics of the received interrogation signals **shall** also be provided. Such diversity systems, in their installed configuration, **shall not** result in degraded performance relative to that which would have been produced by a single system having a bottom-mounted antenna.

2.2.13.1 Diversity Antenna Selection and Selection Threshold

a. Diversity Antenna Selection

Antenna selection **shall** be automatic. The transponder **shall** select one of the two antennas on the basis of the relative strengths of the detected interrogation signals, provided that both channels simultaneously receive a valid identical interrogation or pulse pair. Antenna selection and switching may occur after the receipt of the P₃ pulse of a P₁ - P₃ pulse pair, indicating an ATCRBS or ATCRBS/Mode S All-Call interrogation.

The selected antenna **shall** be used, if necessary, to transmit a reply.

b. Selection Threshold

The transponder **shall** nominally select the antenna connected to the RF port having the stronger signal. To allow for unbalance in the characteristics of the two channels, a transition zone ± 3 dB wide is permitted, in which either antenna may be selected.

2.2.13.2 Received Signal Delay Tolerance

If an interrogation is received at either antenna 0.125 microsecond or less in advance of reception at the other antenna, the interrogations **shall** be considered simultaneous and the reply antenna selection criteria **shall** be applied. If an interrogation is received at either antenna 0.375 microsecond or more in advance of reception at the other antenna, the antenna selected for the reply **shall** be the one which received the earlier interrogation. If the relative time of receipt is between 0.125 and 0.375 microsecond, the transponder **shall** select the reply antenna based on either the simultaneous interrogation criteria or the earlier time of arrival.

2.2.13.3 Diversity Transmission Channel Isolation

The peak RF power transmitted from the selected antenna **shall** exceed the power transmitted from the non-selected antenna by at least 20 dB.

2.2.13.4 Reply Delay of Diversity Transponders

The total difference in mean reply delay between the two antenna channels (including the transponder-to-antenna cables) **shall** not exceed 0.08 microsecond for interrogations of equal amplitude. This requirement is applicable to interrogation signal strengths between MTL +3 dB and MTL +50 dB.

Note: *This requirement limits apparent jitter caused by diversity operation and by cable delay differences. The jitter requirements on each individual channel remain as specified for non-diversity transponders. Control of apparent jitter caused by antenna location is specified in §3.1.6.*

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 160E, Environmental Conditions and Test Procedures for Airborne Equipment.

Some of the performance requirements in §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 160E. 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 §2.1 and §2.2 will not be measurably degraded by exposure to these environmental conditions.

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 transponder performance tests have been included in this section for use in conjunction with the environmental procedures of DO 160E. These tests have been judiciously chosen as a subset of the transponder performance tests of §2.4. Normally, a MOPS document does not provide specific equipment performance tests to be used in conjunction with the environmental procedures of DO 160E. However, there is a sufficiently large number of transponder performance tests in §2.4 that it would be impractical to repeat all of those tests in conjunction with all of the appropriate environmental procedures.

2.3.1 Environmental Test Conditions

Table 2.3.1.1 lists all of the environmental conditions and test procedures (hereafter referred to as environmental procedures) that are documented in DO 160E. Table 2.3.1.2 lists the subset of transponder performance tests from section 2.4 that are intended to be run subject to the various environmental procedures of DO 160E. In order to simplify the process of relating the environmental procedures to the transponder performance tests, Table 2.3.1.1 divides the environmental procedures into groups. All of the procedures in a given group are carried out in conjunction with the same set of transponder performance tests. Using this approach, the environmental procedures fall into six groups. The environmental procedures that apply to all of the sets of transponder performance tests fall into group 1. Group 2 procedures apply to 8 of the sets of transponder performance tests. Groups 3, 4, and 5 apply to 4, 3 and 3 of the sets of

transponder performance tests, respectively. (Group 6, which applies to none of the transponder performance tests, includes only environmental procedures that are intended to determine the effect of the transponder on rack mounting hardware, compass needles, explosive gasses, and other RF hardware.)

Table 2.3.1.2 indicates which of the groups of environmental procedures is related to each set of transponder performance tests. Each transponder performance test **shall** be validated under all of the environmental procedures in the groups required for that test as indicated in Table 2.3.1.2.

Table 2.3.1.1: Environmental Test Groups

	ENVIRONMENTAL CONDITION	DO-160E Paragraph	GROUPS	REMARKS
4a	Temperature	4.5	1	
4b	Altitude	4.6.1	4	
4c	Decompression & Overpressure	4.6.2-4.6.3	4	When required
5	Temperature Variation	5.0	3	
6	Humidity	6.0	2	
7a	Operational Shock	7.2	2	When required
7b	Crash Safety	7.3	6	NO XPNDR TESTS
8	Vibration	8.0	3 & 1	3 during; 1 after
9	Explosion	9.0	6	NO XPNDR TESTS
10	Waterproofness	10.0	2	When required
11	Fluids Susceptibility	11.0	2	When required
12	Sand and Dust	12.0	2	When required
13	Fungus Resistance	13.0	2	When required
14	Salt Spray	14.0	2	When required
15	Magnetic Effect	15.0	6	NO XPNDR TESTS
16	Power Input Momentary Interruptions All Others	16.0	5 3 & 2	3 during; 2 after
17	Voltage Spike	17.0	2	
18	Audio Freq. Conducted Susceptibility	18.0	1	
19	Induced Signal Susceptibility	19.0	1	
20	RF Susceptibility	20.0	1	
21	Emission of RF Energy	21.1	6	NO XPNDR TESTS
22	Lightning Induced Transient Susceptibility	22.0	none	Procedure not yet defined

Note: Tests in Group 6 determine the effects of the transponder on other equipment (mounts, compass needles, explosive gasses, and other RF equipment) and therefore do not involve the transponder performance requirements of this document.

Table 2.3.1.2: Performance Test Requirements During Environmental Tests

Test Procedure Paragraph	DESCRIPTION	REQUIRED ENVIRONMENT TEST GROUPS (See Table 2.3.1.1)					
		1	2	3	4	5	6
§2.4.2.2 (1)	Transponder Receiver Operating Frequency	X	X	X			
§2.4.2.3 (1), (5)	Receiver Sensitivity and Dynamic Range	X	X	X			
§2.4.3.1	Reply Transmission Frequency	X	X	X	X		
§2.4.3.2	Transponder Power Output	X	X		X		
§2.4.3.4	Reply Rate Capability	X					
§2.4.4.1	Framing Pulses	X					
§2.4.4.2	Information Pulses	X					
§2.4.4.4	Reply Pulse Shape	X					
§2.4.4.6 (1)	Reply Delay and Jitter	X					
§2.4.5.2 (1)	Pulse Position Tolerance	X	X				
§2.4.5.3 (1), (2), (5)	Side Lobe Suppression	X	X				
§2.4.5.4 (1)	Pulse Duration Discrimination	X	X				
§2.4.6.1	Dead Time	X					
§2.4.6.2.1	Desensitization	X					
§2.4.6.2.2	Recovery Note: It is sufficient for environmental tests to just verify that sensitivity has recovered to within 3 dB of MTL after 15 microseconds. It is not necessary to measure the gradual recovery rate.	X					
§2.4.7.1	Random Triggering	X		X		X	
§2.4.8.1 (1)	Manual Self Test	X	X	X	X	X	
§2.4.10.2	Identification	X	X				
§2.4.10.3	Pressure Altitude	X	X				
§2.4.12	Power Interruption	X	X			X	
§2.4.13	Diversity	X	X				

Note: *It is sufficient to test with standard Mode A and Mode C as required for the environmental tests. It is not necessary to include interrogation types that include a P₄ pulse as may be required for some detailed test procedures.*

2.4 Equipment Test Procedures

Compliance with the Minimum Operational Performance Standards contained in Section §2.2 may be demonstrated by a combination of bench tests of the individual system components (or certification thereof by either the manufacturer or the installer) and flight tests of the entire installed system. A suggested procedure which will minimize the need for extensive evaluation in the field is as follows in the paragraphs below.

2.4.1 Definitions of Terms and Conditions of Test (§2.2.1)

The following are definitions of terms and the conditions under which the tests described in this subsection should be conducted.

- a. Power Input Voltage – Unless otherwise specified, all tests shall be conducted with the power input voltage adjusted to design voltage, plus or minus 2%. The input voltage **shall** be measured at the input terminals of the equipment under test.
- b. Power Input Frequency
 - 1) In the case of equipment designed for operation from an AC source of essentially constant frequency (e.g., 400 Hz), the input frequency **shall** be adjusted to design frequency, plus or minus 2%.
 - 2) In the case of equipment designed for operation from an AC source of variable frequency (e.g., 300 to 1,000 Hz), unless otherwise specified, 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.
- d. Test Equipment – All equipment used in the performance of the tests should be identified by make, model and serial number where appropriate, and its latest calibration date. When appropriate, all test equipment calibration standards should be traceable to national and/or international standards.
- e. Test Instrument Precautions – Adequate precautions shall be taken during the test to prevent the introduction of errors resulting from the connection of voltmeters, oscilloscopes and other test instruments across the input and output impedances of the equipment under test.
- f. Ambient Conditions – Unless otherwise specified, all tests **shall** be made within the following ambient conditions:
 - 1) Temperature: +15 to +35 degrees C (+59 to +95 degrees F).
 - 2) Relative Humidity: Not greater than 85%.
 - 3) Ambient Pressure: 84 to 1-7 kPa (equivalent to +5,000 to -1,500 ft) (+1,525 to -460m).

- g. **Connected Loads** – Unless otherwise specified, all tests **shall** be performed with the equipment connected to loads having the impedance values for which it is designed.
- h. **Standard Interrogation Test Signals**

The nominal interrogation characteristics shall be as specified in subparagraph §2.1.10.3.

The signal measurement convention shall be as specified in paragraph §2.1.10.2.

General Characteristics

- 1) Radio Frequency: The carrier frequency of the signal generator for ATCRBS and ATCRBS/Mode S All-Call interrogation shall be 1030 ± 0.1 MHz.
- 2) CW Output: The CW output between pulses shall be at least 50 dB below the peak level of the pulse.
- 3) Pulse Rise and Fall Time: Rise and fall times shall be as specified in subparagraph 2.1.10.3.1.

Note: Unless otherwise indicated, interval measurements are measured between half voltage points of the respective pulses as detected by a linear detector.

- 4) Pulse Top Ripple: The instantaneous amplitude of the pulses shall not fall more than 1 dB below the maximum value between the 90 percent voltage amplitude point on the leading and trailing edge of the pulse.
- 5) Signal Level: Unless otherwise noted in the measurement procedure, the signal level shall be -60 ± 3 dBm.
- 6) Interrogation Repetition Rate: Unless otherwise noted in the measurement procedure, interrogation rates shall be 450 ± 25 Hz.

2.4.2 Verification of Receiver Characteristics (§2.2.2)

2.4.2.1 Verification of Interrogation Tolerances (§2.2.2.1)

Purpose/Introduction:

Paragraph §2.1.10 and its subparagraphs define a number of deviations allowed in the interrogation values. The transponder shall be tolerant to all such deviations within the ranges specified in §2.1.10.

Measurement Procedures:

The transponder's acceptance of the tolerances specified in §2.1.10 is tested in various test procedures throughout §2.4.

2.4.2.2 Verification of Transponder Receiver Operating Frequency and Bandwidth (§2.2.2.2)

Purpose/Introduction:

- a. The receiver nominal center frequency **shall** be 1030 MHz.
- b. With an input signal level 3 dB above the minimum triggering level, the receiver bandwidth **shall** be such that the receiver accepts pulses as outlined in §2.1.10 with an interrogation center frequency drift of ± 0.2 MHz.
- c. The skirt bandwidth **shall** be such that the sensitivity of the receiver is at least 60 dB down at ± 25 MHz and beyond.

Measurement Procedures:

- (1) Interrogate the transponder at 500 interrogations per second with a Mode A interrogation signal. Vary the RF signal frequency over the range 1029.8 to 1030.2 MHz Determine the variation in RF signal level required to produce 90 percent transponder reply efficiency. Also determine the required maximum RF signal level.
- (2) Interrogate the transponder at 500 interrogations per second with a Mode A interrogation signal. Determine the interrogation signal level (MTL) which results in a transponder reply rate of 450. Set the interrogation frequency to 1055 and 1005 MHz and verify that the transponder sensitivity is at least 60 dB below the MTL level measured at nominal frequency in both cases.

2.4.2.3 Verification of Receiver Sensitivity and Dynamic Range (§2.2.2.3)

Purpose/Introduction:

- a. The minimum triggering level (MTL) of the transponder shall be such that replies are generated to 90 percent of the interrogation signals when:
 - (1) The two pulses P_1 and P_3 constituting an interrogation are of equal amplitude and P_2 is not detected; and
 - (2) The amplitude of these signals received at the antenna end of the transmission line of the transponder is nominally 71 dB below 1 milliwatt with limits between 69 and 77 dB below 1 milliwatt.

Note: *For this MTL requirement, a nominal 3 dB transmission line loss and an antenna performance equivalent to that of a simple quarter wave antenna are assumed. In the event these assumed conditions do not apply, the MTL of the installed transponder system must be comparable to that of the assumed system.*

- b. The variation of the minimum triggering level between modes **shall not** exceed 1 dB for nominal pulse spacings and pulse widths.

- c. The reply characteristics **shall** apply over a received signal amplitude range between minimum triggering level and 50 dB above minimum triggering level.
- d. The reply ratio shall not be more than 10 percent for interrogations at signal levels below -81 dBm.
- e. The conditions of “a” through “d” apply when a P₄ pulse is present, either long or short, regardless of amplitude of the P₄ pulse.

Measurement Procedures:

- (1) Interrogate the transponder with a standard Mode A interrogation at a repetition rate of 500 interrogations per second. Adjust P₁ and P₃ equal in amplitude (no P₂ pulse) and apply a signal level known to be below minimum triggering level. Increase the signal generator output level until the transponder reply rate is 450 replies per second. This is the transponder minimum triggering level (MTL). The installed system MTL (including transmission line loss) should be between 69 and 77 dB below 1 milliwatt.

<u>EXAMPLE:</u>	Transponder MTL	-74 dBm
	Transmission Line Loss	3 dB
	System MTL	-71 dBm

- (2) Repeat step (1) above using a standard Mode C interrogation. The variation in MTL between steps (1) and (2) should not exceed 1 dB.
- (3) Repeat steps (1) and (2) above and include both a narrow and wide P₄ pulse at the nominal position, equal in amplitude to P₁ and P₃.
- (4) Interrogate the transponder with a standard Mode A interrogation at a repetition rate of 500 interrogations per second. Adjust the RF signal level between MTL +3 dB and -21 dBm in 5 dB increments and determine the reply ratio. Repeat with both a narrow and wide P₄ pulse at the nominal position, equal in amplitude to P₁ and P₃.
- (5) Repeat step (4) with a Mode C interrogation.
- (6) Interrogate the transponder with a standard Mode A interrogation at an RF level of -81 dBm. Determine reply ratio and verify that the reply ratio is 10 percent or less.

2.4.3 Verification of Transmitter Characteristics (§2.2.3)

2.4.3.1 Verification of Reply Transmission Frequency (§2.2.3.1)

Purpose/Introduction:

The center frequency of the reply transmission **shall** be 1090 ±3 MHz.

Measurement Procedures:

Set transponder Mode A code to 7777. Interrogate the transponder with a Mode A interrogation and verify that the reply frequency is 1090 ±3 MHz.

2.4.3.2 Verification of Transponder Power Output (§2.2.3.2)**2.4.3.2.1 Verification of Transponder Power Output for Class A Equipment**Purpose/Introduction:

For this class of equipment, the peak pulse power available at the antenna end of the transmission line of the transponder **shall** be at least 21 dB and not more than 27 dB above 1 watt at any reply rate up to 1,200 per second for a 15-pulse coded reply.

Measurement Procedures:

Transponder power output may be determined with a dummy load and power meter which are suitable for use at 1090 MHz.

Set the transponder for a 15-pulse reply (code = 7777 + SPI). Interrogate the transponder with a standard Mode A interrogation and measure the single pulse having the least RF power output. While varying the interrogation rate from 100 interrogations per second to the maximum interrogation rate specified for the transponder, determine that the power output meets the requirements of §2.2.3.2.1.

2.4.3.2.2 Verification of Transponder Power Output for Class B EquipmentPurpose/Introduction:

For this class of equipment, the peak pulse power-available at the antenna end of the transmission line of the transponder **shall** be at least 18.5 dB and not more than 27 dB above 1 watt at any reply rate up to 1,000 per second for a 15-pulse coded reply.

Measurement Procedures:

Transponder power output may be determined with a dummy load and power meter which are suitable for use at 1090 MHz.

Set the transponder for a 15-pulse reply (code = 7777 + SPI). Interrogate the transponder with a standard Mode A interrogation and measure the single pulse having the least RF power output. While varying the interrogation rate from 100 interrogations per second to the maximum interrogation rate specified for the transponder, determine that the power output meets the requirements of §2.2.3.2.2.

2.4.3.3 Verification of Emission of Spurious RF Energy (§2.2.3.3)Purpose/Introduction:

With the transponder operating, but not being interrogated, the level of spurious CW RF energy, as measured at the output terminal of the transponder, over the range 960 to 1215 MHz **shall not** exceed -70 dBw.

Measurement Procedures:

With the transponder operating but not being interrogated and with suitable test equipment connected to the transponder output terminal, scan the band of frequencies from 960 to 1215 MHz. Determine that spurious CW signals do not exceed **-70 dBw**.

Note: *In connection with the recommendation contained in §2.2.3.2 see appropriate FCC Rules and Regulations for tables of frequencies allocated to the aeronautical service.*

2.4.3.4 Verification of Reply Rate Capability (§2.2.3.4)

Purpose/Introduction:

- a. For Class A equipment (see §1.4), the transponder **shall** be capable of at least 1,200 replies per second for a 15-pulse coded reply.
- b. For Class B equipment (see §1.4), the transponder **shall** be capable of at least 1,000 replies per second for a 15-pulse coded reply.

Measurement Procedures:

Set the transponder for a 15-pulse ATCRBS reply. For Class A equipment, interrogate the transponder with a Mode A signal at a constant rate of 1,200 interrogations per second. For Class B equipment, interrogate the transponder with a Mode A signal at a constant rate of 1,000 interrogations per second. Verify that the reply efficiency is not less than 90%.

2.4.3.5 Verification of Sensitivity Reduction Reply Rate Control

Purpose/Introduction:

A sensitivity reduction type reply rate limit control **shall** be incorporated in the transponder. The range of this control **shall** permit adjustment, as a minimum, to any value between 500 and 2,000 replies per second, or to the maximum reply rate capability, if less than 2,000 replies per second, without regard to the number of pulses in each reply. Sensitivity reduction in excess of 3 dB **shall not** take effect until 90 percent of the selected value is exceeded. Sensitivity reduction **shall** be at least 30 dB for rates in excess of 150 percent of the selected value.

Note: *The reply rate limit control should be set at 1,200 replies per second, or the maximum value below 1,200 replies per second of which the transponder is capable. (See §2.2.3.4).*

Measurement Procedure:

- (1) Interrogate the transponder with a Mode A signal at an RF level of 3 dB above minimum trigger level. Adjust the interrogation rate at 1080 interrogations per second or 90% of the transponder's maximum reply rate whichever is less. The reply efficiency should not be less than 90%.
- (2) Increase the interrogation rate to 1800 interrogations per second or 150% of the transponder's maximum reply rate whichever is greater. The RF level to maintain

1080 or the transponder's maximum replies should be no less than 33 dB above MTL.

2.4.4 Verification of Reply Pulse Characteristics (Signals in Space) (§2.2.4)

The reply transmission characteristics can be determined with a demodulating probe and a wide band oscilloscope comparing the reply pulse group waveform against an accurate timing waveform such as from a crystal oscillator.

2.4.4.1 Verification of Framing Pulses (§2.2.4.1)

Purpose/Introduction:

The reply function **shall** employ a signal comprising two framing pulses spaced 20.3 microseconds, as the most elementary code.

Measurement Procedures:

With the transponder interrogated on Mode A and replying on Code 0000, the time interval between the 0.5 amplitude points on the leading edges of the two framing pulses should be within 20.3 ± 0.10 microseconds.

2.4.4.2 Verification of Information Pulses (§2.2.4.2)

Purpose/Introduction:

Information pulses **shall** be spaced in increments of 1.45 microseconds from the first framing pulse. The designation and position of these information pulses **shall** be as shown in Table 2.2.4.2.

Measurement Procedures:

With the transponder replying on Code 7777, the time interval between the 0.5 amplitude points on the leading edge of each pulse, including the last framing pulse, with respect to the first framing pulse should be equal to that listed in §2.2.4.2 with a tolerance of ± 0.1 microsecond. Also, the time interval from any pulse, in the reply group, with respect to any other pulse, except the first framing pulse, should not exceed ± 0.15 microsecond.

2.4.4.3 Verification of Special Position Identification (SPI) Pulse (§2.2.4.3)

Purpose/Introduction:

In addition to the information pulses provided, a Special Position Identification (SPI) Pulse, which may be transmitted with the information pulses, **shall** occur at a pulse interval of 4.35 microseconds following the last framing pulse.

The SPI pulse **shall** be initiated by an IDENT switch (see §2.1.7.d). Upon activation of the IDENT switch, the SPI pulse **shall** be transmitted for a period of between 15 and 30

seconds and must be capable of being reinitiated at any time. The SPI pulse **shall not** be included when transmitting Mode C replies.

Measurement Procedures:

- (1) With the transponder replying with the SPI pulse, the time interval between the 0.5 amplitude points on the leading edge of the second framing pulse and the SPI pulse should be 4.35 ± 0.10 microseconds.
- (2) Interrogate the transponder with a Mode A interrogation signal. With the transponder operating, manually initiate the SPI pulse and verify that the transmission time of the SPI pulse is between 15 and 30 seconds, and that it can be re-initiated immediately.
- (3) While interrogating the transponder with a Mode C interrogation, manually activate the SPI pulse and verify that there is no SPI pulse in the reply.

2.4.4.4 Verification of Reply Pulse Shape (§2.2.4.4)

Purpose/Introduction:

All reply pulses **shall** have pulse duration of 0.45 ± 0.10 microseconds, a pulse rise time between 0.05 and 0.1 microseconds, and a pulse decay time between 0.05 and 0.2 microseconds. The pulse amplitude variation of one pulse with respect to any other pulse in a reply group **shall not** exceed 1 dB.

Measurement Procedures:

With the transponder replying with Code 7777 and the SPI pulse activated, verify the following reply pulse characteristics:

The duration of each reply pulse, as measured between the 0.5 amplitude points on the leading and trailing edge, should be between 0.35 and 0.55 microseconds.

The rise time of each reply pulse, as measured between the 0.1 amplitude and 0.9 amplitude points on the leading edge should be between 0.05 and 0.10 microseconds.

The decay time of each reply pulse, as measured between the 0.9 amplitude and 0.1 amplitude points on the trailing edge should be between 0.05 and 0.20 microseconds.

The amplitude variation of anyone pulse as measured with respect to any other pulse in a reply group should not exceed 1 dB.

Note: *The fundamental requirements of sideband radiation can be met either as described above or by determining that the actual sideband radiation is no greater than that which theoretically would be produced by a trapezoidal wave having 0.05 microsecond rise and decay times and a 0.35 microsecond pulse duration.*

2.4.4.5 Verification of Reply Pulse Interval Tolerances (§2.2.4.5)

Purpose/Introduction:

The pulse interval tolerance for each pulse (including the last framing pulse) with respect to the first framing pulse of the reply group **shall** be ± 0.10 microseconds. The pulse interval tolerance of the Special Position Identification Pulse with respect to the last framing pulse of the reply group **shall** be ± 0.10 microseconds. The pulse interval tolerance of any pulse in the reply group with respect to any other pulse (except the first framing pulse) **shall not** exceed ± 0.15 microseconds.

Measurement Procedures:

These requirements are tested in test procedures §2.4.4.1, §2.4.4.2 and §2.4.4.3.

2.4.4.6 Verification of Reply Delay and Jitter (§2.2.4.6)

Purpose/Introduction:

The time delay between the arrival at the transponder of the leading edge of P_3 , and the transmission of the leading edge of the first pulse of the reply **shall** be 3 ± 0.5 microseconds. The total jitter of the reply pulse code group with respect to P_3 **shall not** exceed ± 0.1 microsecond. Delay variations between modes on which the transponder is capable of replying **shall not** exceed 0.2 microseconds. These requirements apply for receiver input levels between 3 and 50 dB above minimum triggering level.

Measurement Procedures:

- (1) Interrogate the transponder with a Mode A signal. Measure the time interval between the 50% voltage point of the leading edge of P_3 and the 50% voltage point of the leading edge of the first framing pulse at the antenna terminal. Vary the interrogation RF level from 3 to 50 dB above MTL. Verify that the delay is within the limits of 3 ± 0.5 microseconds. Verify that the jitter from the leading edge of P_3 to the leading edge of the first framing pulse does not exceed ± 0.1 microsecond.
- (2) Repeat step (1) using a Mode A-Only All-Call interrogation.
- (3) Repeat steps (1) and (2) for Mode C interrogation types. Verify that the delay variation between all modes does not exceed 0.2 microseconds.

2.4.5 Verification of Decoding Performance (§2.2.5)

2.4.5.1 Verification of Pulse Level Tolerances (§2.2.5.1)

Purpose/Introduction:

When selected to reply to a particular interrogation mode (See §2.1.10.3.2), the transponder **shall** reply (not less than 90 percent efficiency) under each of the following conditions:

- a. The received amplitude of P_3 is in excess of a level 1 dB below the received amplitude of P_1 but no greater than 3 dB above the received amplitude of P_1 .
- b. The received amplitude of a proper interrogation is more than 10 dB above the received amplitude of random pulses where the latter are not recognized by the transponder as P_1 , P_2 , or P_3 .
- c. The conditions of “a” and “b” apply when a P_4 pulse is present, either long or short, regardless of amplitude of the P_4 pulse.

Measurement Procedures:

Interrogate the transponder with a Mode A signal at a repetition rate of 500 interrogations per second and with a level 3 dB above the receiver minimum triggering level.

- (1) Using the nominal pulse interval between P_1 and P_3 for Mode A, vary the amplitude of P_3 between 1 dB below and 3 dB above the amplitude of P_1 . Note the lowest reply rate obtained. Repeat this step for Mode C.
- (2) Repeat step (1) for P_1 amplitudes of 10, 25, and 50 dB above the minimum triggering level.
- (3) Combine the interrogation signal with a non-synchronous 0.8 microsecond pulses at 5000 Hz and at an RF level 10 db below that of P_1 and P_3 and repeat step (1) above.

The reply rates obtained in each case above should be at least 450 replies per second.

2.4.5.2 Verification of Pulse Position Tolerance (§2.2.5.2)

Purpose/Introduction:

The transponder **shall** accept interrogations as valid if the spacing between P_1 and P_3 is within ± 0.2 microsecond of the nominal spacing.

The transponder **shall not** reply to more than 10 percent of the interrogations under each of the following conditions:

- a. To interrogations when the interval between pulses P_1 and P_3 differs from that defined in §2.1.10.3.2 for the mode selected in the transponder by more than ± 1 microsecond.
- b. receipt of any single pulse which has no amplitude variations approximating a normal interrogation condition.

Measurement Procedures:

- (1) Interrogate the transponder with interrogation pulse signals for Mode A and C, at a repetition rate of 500 interrogations per second and with a signal level 3 dB above the receiver minimum triggering level. In the absence of P₂ pulses, slowly adjust the interval between P₁ and P₃ from 7.8 microseconds to 8.2 microseconds and from 20.8 microseconds to 21.2 microseconds, respectively, and note the reply rate in each case.
- (2) Adjust the interval between P₁ and P₃ to 7.0, 9.0, 20.0 and 22.0 microseconds, respectively. Note the reply rate in each case. The reply rate should be no more than 50 replies per second.
- (3) Repeat steps (1) and (2) for amplitudes of 10, 25, and 50 dB above the minimum triggering level.

Note: *The requirement in §2.2.5.2.b is tested in test procedure §2.4.5.4, Step (3).*

2.4.5.3 Verification of Suppression (§2.2.5.3)

Purpose/Introduction:

Upon receipt of an interrogation complying with the interrogation modes defined in §2.1.10.3 selected manually or automatically, the transponder **shall** be suppressed (not less than 99 percent efficiency) when the received amplitude of P₂ is equal to or in excess of the received amplitude of P₁ and spaced 2 ± 0.15 microseconds.

Notes:

1. *It is not the intent of this paragraph to require the detection of P₃ as a prerequisite for initiation of suppression action.*
2. *After reception of a valid P₃ pulse the transponder should not initiate suppression based on the reception of a P₄ pulse.*
 - a. The transponder suppression **shall** be for a period of 35 ± 10 microseconds.
 - b. The suppression **shall** be capable of being reinitiated for the full duration within two microseconds after the end of any suppression period.
 - c. The transponder **shall not** initiate suppression if the level of P₁ exceeds the level of P₂ by 9 dB or more.
 - d. The transponder **shall not** initiate suppression if no pulse is received at the position 2.0 ± 0.7 microseconds following P₁.
 - e. The transponder **shall not** initiate suppression if the duration of P₂ is less than 0.3 microseconds.

Measurement Procedures:

Interrogate the transponder with Mode A interrogation at a repetition rate of 500 interrogations per second and at a signal level of 3 dB above receiver minimum triggering level.

- (1) Adjust P_2 equal in amplitude to P_1 while varying spacing from 1.85 to 2.15 microseconds and note the reply rate. Repeat with P_2 adjusted to 10 dB greater than P_1 and note the reply rate. Both rates should be no greater than 5 replies per second.
- (2) Increase the signal level of P_1 and P_3 20 dB, with P_3 equal in amplitude to P_1 and with P_2 set to an amplitude 9 dB below that of P_1 and P_3 . Vary the interval of P_2 from 1.85 to 2.15 microseconds with respect to P_1 and note the lowest reply rate obtained.
- (3) With the signal level of P_1 and P_3 set as in step (2), set the level of P_2 equal in amplitude to P_1 and P_3 . Set the spacing of P_2 at 1.3 and 2.7 microseconds respectively with respect to P_1 and note the reply rate obtained.
- (4) With the signal level of P_1 , P_2 and P_3 as in step (3), set the width of the P_2 pulse to 0.3 microseconds. With the P_2 pulse in the nominal position, note the reply rate.
- (5) Disable P_3 and readjust P_2 equal in amplitude to P_1 and at nominal spacing. Using a second signal source (set to at least 3 dB above the receiver minimum triggering level) with the interrogation rate synchronized with the first but delayed more than 50 microseconds, interrogate the transponder on Mode A. Gradually shorten the delay until no replies are received from the second interrogation source. Note the interval between P_2 of the first signal source and P_1 of the second signal source. This interval should be between 25 and 45 microseconds.
- (6) Increase the delay time of the second interrogation source by 2 microseconds from that at which no replies were received in step (1) above. There should be at least 450 replies per second from the second interrogation source. Insert a P_2 into the second interrogation source equal in amplitude to P_1 . The reply rate from the second interrogation source should not exceed 5 replies per second.

2.4.5.4 Verification of Pulse Duration Discrimination (§2.2.5.4)

Purpose/Introduction:

- a. For all signal levels from MTL to -45 dBm, the transponder shall reply to no more than 10 percent of ATCRBS, ATCRBS-Only All-Call or ATCRBS/Mode S All-Call interrogations if the duration of either the P_1 or the P_3 pulse is less than 0.3 microseconds. .

- b. With the exception of single pulses with amplitude variations approximating an interrogation, any single pulse of duration more than 1.5 microseconds **shall not** cause the transponder to initiate reply or suppression action over the signal amplitude range of minimum triggering level to 50 dB above minimum triggering level.

Measurement Procedures:

- (1) Interrogate the transponder with Mode A interrogations at a repetition rate of 500 interrogations per second. Adjust P_1 and P_3 (no P_2 pulse) to a width of 0.3 microseconds and set the RF level to minimum triggering level. The reply efficiency should not exceed 10%. Repeat for signal levels between MTL and -45 dBm in 5 dB steps.
- (2) Interrogate the transponder with a single input pulse at 1030 MHz. Vary the pulse width of the interrogation signal from 1.5 to 22 microseconds at input signal levels of 3, 10, 25, and 50 dB above MTL. At each input signal, verify that the transponder does not reply to, and/or is not suppressed by, the interrogation signal.

Note: Pulse duration discrimination for the P_2 pulse is tested in §2.4.5.3 (4).

2.4.6 Verification of Desensitization and Recovery Characteristics (§2.2.6)

2.4.6.1 Verification of Dead Time (§2.2.6.1)

Purpose/Introduction:

After reception of a valid interrogation, the transponder **shall not** reply to any other interrogation at least for the duration of the reply pulse train. This dead time **shall** end no later than 125 microseconds after the transmission of the last reply pulse of the group.

Measurement Procedures:

In the absence of P_2 pulses, interrogate the transponder on Mode A at a repetition rate of 500 interrogations per second and at a signal level at least 3 dB above the receiver minimum triggering level. Using a second signal source (set to a comparable output level) with the interrogation rate synchronized with the first but delayed more than 150 microseconds, interrogate the transponder on Mode C. Gradually shorten the delay until the replies to the Mode C interrogations disappear. Note the interval between the last pulse of the Mode A reply and the first framing pulse of the Mode C reply. The interval should be between 0 and 125 microseconds.

2.4.6.2 Verification of Echo Suppression and Recovery (§2.2.6.2)

2.4.6.2.1 Verification of Desensitization (§2.2.6.2.1)

Purpose/Introduction:

Upon receipt of any pulse more than 0.7 microseconds in duration, the receiver **shall** be desensitized by an amount that is within at least 9 dB of the amplitude of the desensitizing pulse, but **shall** at no time exceed the amplitude of the desensitizing pulse, with the exception of possible overshoot during the first microsecond following the desensitizing pulse. Single pulses of duration less than 0.7 microseconds are not required to cause the specified desensitization, and **shall not** cause desensitization of duration greater than that permitted herein or by §2.2.6.2.2.

Measurement Procedures:

Interrogate the transponder with Mode A interrogation pulse signals at a repetition rate of 500 interrogations per second. Precede P_1 by 2.8 microseconds with a single 0.8 microsecond wide pulse at a signal level of 50 dB above the receiver minimum triggering level. Adjust P_1 and P_3 equal in amplitude and increase the output to a level causing a reply rate of 450 replies per second. This level should be between 34 and 43 dB above the receiver minimum triggering level.

2.4.6.2.2 Verification of Recovery (§2.2.6.2.2)

Purpose/Introduction:

Following desensitization, the receiver **shall** recover sensitivity (within 3 dB of minimum triggering level) within 15 microseconds after reception of a desensitizing pulse having a signal strength up to 50 dB above minimum triggering level. **Recovery shall be nominally linear at an average rate not exceeding 3.5 dB per microsecond. [ICAO Annex 10 says 4.0dB]**

Note: *Transponders that respond to military modes will recover within 15 microseconds, but may employ methods other than nominally linear recovery.*

Measurement Procedures:

Note the signal levels required to just maintain 450 replies per second as the interval between the 0.8 microsecond pulse and P_1 is gradually increased. Also note that the average rate does not exceed 3.5 dB per microsecond as the signal level and interval is changed to just maintain the 450 pulses per second reply rate. At an interval of 15 microseconds, verify that the sensitivity returns to at least minimum triggering level +3 dB.

Note: *An interval corresponding to a normal Mode A interrogation and a side lobe interrogation is excluded.*

2.4.7 Verification of Undesired Replies (§2.2.7)

2.4.7.1 Verification of Random Triggering and Suppression Rate (§2.2.7.1)

Purpose/Introduction:

In the absence of valid interrogation signals, the random triggering rate (squitter) of the transponder **shall not** exceed 30 replies and/or suppressions per second as integrated over an interval equivalent to at least 300 random triggers, or 30 seconds, whichever is less.

Measurement Procedures:

Non-Interference Environment

Set up test equipment to count reply transmissions from the transponder. While not interrogating the transponder, count the number of replies for a minimum of one minute.

2.4.7.2 Verification of Random Triggering in the Presence of CW (§2.2.7.2)

Purpose/Introduction:

The total random triggering on all Mode A and/or Mode C replies **shall not** exceed 10 replies or suppressions per second, averaged over a period of 30 seconds, when operated in the presence of non-coherent CW interference at a frequency of 1030 ± 0.2 MHz and a signal level of -60 dBm, or less.

Measurement Procedure:

Random Trigger Rate

Repeat the procedure provided in §2.4.7.1 while injecting non-coherent CW interference at a frequency of 1030 ± 0.2 MHz at a signal level of -60 dBm.

Count the number of replies for a minimum of one minute and verify that the reply rate does not exceed the specified limits.

2.4.7.3 Verification of Spurious Responses (§2.2.7.3)

Purpose/Introduction:

All spurious responses, including response to image frequencies, **shall** be such that the sensitivity to such signals is at least 60 dB down from the normal sensitivity of the receiver.

Measurement Procedure:

Step 1: ***Brief descriptive title for this test step***

Editorial Comment: Need to resolve comment against requirement.

2.4.8 Verification of Transponder Self-Test and Monitor (§2.2.8)

2.4.8.1 Verification of Manual Self-Test (§2.2.8.1)

Purpose/Introduction:

- a. When a manual self-test device is provided, it **shall** be limited to intermittent use by a spring loaded return-to-off switch, or equivalent.
- b. The test interrogation rate **shall** not exceed 450 per second.
- c. The lowest RF level at the input to the antenna required to accomplish the test **shall** be used. The maximum RF level at the input to the antenna **shall not** exceed 40 dB below 1 milliwatt.

Measurement Procedures:

(1) Self-Test Interrogation/Reply Rate

With equipment connected to the transponder for the purpose of detecting and counting reply rate, activate the self-test function (if provided) of the transponder under test and determine the reply rate to the self-test interrogation.

(2) Self-Test Interrogation Level

With equipment connected to the transponder for the purpose of measuring transmit power, activate the self-test function (if provided) of the transponder under test and determine that the transmit power is within the required limits.

2.4.8.2 Verification of Automatic Self-Test (§2.2.8.2)

Purpose/Introduction:

- a. When an automatic self-test device is provided, it **shall** be limited to use only in the absence of a valid interrogation. (A minimum period of 15 seconds will be sufficient to establish the absence of ground interrogations).
- b. The maximum test time for the automatic self-test shall not exceed 0.1 second in any given 15-second interval.
- c. The test interrogation rate shall not exceed 450 per second.
- d. The lowest RF level at the input to the antenna required to accomplish the test **shall** be used. The maximum RF level at the input to the antenna **shall not** exceed 40 dB below 1 milliwatt.

Measurement Procedures:

- (1) Interrogate the transponder at a nominal interrogation rate of 100 interrogations per second. Stop the interrogations and, using a timing device (such as an oscilloscope) and a suitable RF detector at the transponder output, verify that no test transmissions occur for a period of 15 seconds after the interrogations cease.

- (2) With no external interrogations, observe the output of the RF detector and verify that the automatic self-test transmissions do not occur for more than 0.1 second in any given 15 second interval.
- (3) The test interrogation rate may be measured on the bench using a suitable detector and counter. The interrogation rate averaged over a five second interval should not exceed 450 interrogations per second.
- (4) The test signal level may be measured at the antenna end of the transmission line in the actual aircraft, or on the bench using a length of transmission line equal to that in the airplane. One way to measure the level is to adjust a second test transponder to just trigger at the prescribed radiation limit. Connect this test transponder to the transmission line and determine if it is triggered when the self-testing device of the first transponder is operated.

Note: *Due to the close proximity of the units and because of the high signal level, the transmitter of the first transponder should be disabled. A calibrated attenuator should be placed in the transmission line between the transponders to prevent receiver damage.*

2.4.9 Verification of Response to Mutual Suppression Pulses (§2.2.9)

Purpose/Introduction:

The equipment shall 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.

Measurement Procedures:

Interrogate the transponder with a Mode A interrogation at an RF level of 3 dB above minimum triggering level. Inject a suppression pulse into the transponder with a pulse width of 35 microseconds. Position the leading edge of the suppression pulse at the 50% amplitude point so that it precedes the leading edge of P₁ by 2.0 microseconds. Verify that no reply is generated by the transponder.

Delay the interrogation so the leading edge of P₁ occurs 15 microseconds after the end of the suppression pulse. Verify that the transponder replies to the interrogation.

2.4.10 Verification of Data Handling and Interfaces (§2.2.10)

2.4.10.1 Verification of Code Nomenclature (§2.2.10.1)

Purpose/Introduction:

The code designations **shall** consist of four digits, each of which lies between 0 and 7 inclusive, and is determined by the sum of the pulse subscripts given in Table 2.2.4.2, employed as shown in Table 2.2.10.1.

Measurement Procedures:

These requirements are tested in the test procedure in §2.4.10.2.

2.4.10.2 Verification of Identification (§2.2.10.2)Purpose/Introduction:

The 4096 codes specified in §2.1.10.1 **shall** be manually selectable for reply to interrogations on Mode A.

Measurement Procedures:

Interrogate the transponder with a standard ATCRBS Mode A interrogation. Set identification codes which should result in the setting of each of the identification reply bits one at a time. Verify proper positioning of these bits in the reply.

2.4.10.3 Verification of Pressure Altitude Transmissions (§2.2.10.3)Purpose/Introduction:

- a. Independently of the other modes and codes manually selected, the transponder **shall** automatically reply to Mode C interrogations.
- b. The reply to Mode C interrogations **shall** consist of the two framing pulses together with the information pulses specified in §2.2.4.2.
- c. The transponders **shall** be provided with means to remove the information pulses, but to retain the framing pulses when the provision of subparagraph “f” below is not complied with, in reply to Mode C interrogation.

Note: *The information pulses should be capable of being removed either in response to a failure detection system or manually at the request of the controlling agency.*

- d. The information pulses **shall** be automatically selected by an analog-to-digital converter connected to a pressure-altitude data source in the aircraft referenced to the standard pressure setting of 29.92 inches of mercury.
- e. Pressure altitude **shall** be reported in 100-foot increments by selection of pulses as shown in Appendix A. If the transponder is capable of accepting altitude sources with 25-foot or better resolution, the pressure altitude-information **shall** be reported in the closest 100-foot increment as specified in Appendix A.
- f. The digitizer code selected **shall** correspond to within ± 125 feet, on a 95 percent probability basis with the pressure altitude information (referenced to the standard pressure setting of 29.92 inches of mercury) used on board the aircraft to adhere to the assigned flight profile.

Measurement Procedures:

- (a) Transponder response to Mode C interrogations may be monitored with a demodulator probe and an oscilloscope. A Mode C reply without the digitizer connected to the transponder should consist of the two framing pulses F1 and F2.
- (b) The altitude reporting switch in the "off" position should prevent the transmission of digitizer information pulses but not the transmission of the framing pulses.
- (c) If a digitizer is connected to the transponder, the information pulses will appear in accordance with the pattern represented in **Appendix A**.

Editorial Comment: Wouldn't the Verification of antennas be part of installed system tests in section 3?

2.4.11 Verification of Antennas (§2.2.11)**2.4.12 Verification of Power Interruption (§2.2.12)**Purpose/Introduction:

The transponder equipment **shall** regain operational capability to within its operational limits within two seconds after the restoration of power following a momentary power interruption.

Note: The transponder equipment is not required to continue operation during momentary power interruptions.

Measurement Procedures:

Apply a momentary power interruption to the transponder. Interrogate the transponder with a standard Mode A interrogation at a power level equal to 3 dB above the minimum triggering level. Verify that the transponder is able to reply with at least 90% reply efficiency two seconds after power is restored.

2.4.13 Verification of Diversity (§2.2.13)Purpose/Introduction:

Diversity transponders may be implemented for the purpose of improving surveillance performance. Such systems **shall** employ two antennas, one mounted on the top and the other on the bottom of the aircraft. Appropriate switching and signal processing channels to select the best antenna on the basis of the characteristics of the received interrogation signals **shall** also be provided. Such diversity systems, in their installed configuration, **shall** not result in degraded performance relative to that which would have been produced by a single system having a bottom-mounted antenna.

Diversity Antenna Selection and Selection Threshold

a. Diversity Antenna Selection

Antenna selection **shall** be automatic. The transponder **shall** select one of the two antennas on the basis of the relative strengths of the detected interrogation signals, provided that both channels simultaneously receive a valid identical interrogation or pulse pair. Antenna selection and switching may occur after the receipt of the P₃ pulse of a P₁ - P₃ pulse pair, indicating an ATCRBS or ATCRBS/Mode S All-Call interrogation.

The selected antenna **shall** be used, if necessary, to transmit a reply.

b. Selection Threshold

The transponder **shall** nominally select the antenna connected to the RF port having the stronger signal. To allow for unbalance in the characteristics of the two channels, a transition zone ± 3 dB wide is permitted, in which either antenna may be selected.

Received Signal Delay Tolerance

If an interrogation is received at either antenna 0.125 microsecond or less in advance of reception at the other antenna, the interrogations **shall** be considered simultaneous and the reply antenna selection criteria **shall** be applied. If an interrogation is received at either antenna 0.375 microsecond or more in advance of reception at the other antenna, the antenna selected for the reply **shall** be the one which received the earlier interrogation. If the relative time of receipt is between 0.125 and 0.375 microsecond, the transponder **shall** select the reply antenna based on either the simultaneous interrogation criteria or the earlier time of arrival.

Diversity Transmission Channel Isolation

The peak RF power transmitted from the selected antenna **shall** exceed the power transmitted from the non-selected antenna by at least 20 dB.

Reply Delay of Diversity Transponders

The total difference in mean reply delay between the two antenna channels (including the transponder-to-antenna cables) **shall** not exceed 0.08 microsecond for interrogations of equal amplitude. This requirement is applicable to interrogation signal strengths between MTL +3 dB and MTL +50 dB.

Note: *This requirement limits apparent jitter caused by diversity operation and by cable delay differences. The jitter requirements on each individual channel remain as specified for non-diversity transponders. Control of apparent jitter caused by antenna location is specified in §3.1.6.*

Equipment Required:

Two means of generating identical ATCRBS interrogations that can be delayed from each other from 125 to 375 nanoseconds. These two generators must also have independent control of power level.

Means of determining the antenna terminal that generates the reply.

Means of determining the reply power level on both antennas simultaneously.

Means of determining reply delay for each channel and between channels.

Measurement Procedures:

Note: *Because the specifications for diversity operations are symmetrical in all respects, channels are arbitrarily designated A and B.*

(1) Single Channel Test (See §2.2.13.3 and §2.2.13.4)

When measuring channel A and B parameters take care that any cables used for measurements are of equal length and equal loss. Interrogate channel A only, while monitoring channel A and B. At signal level MTL +3 dB use the following types of interrogations and record the listed observations:

ATCRBS Mode A.

ATCRBS Mode C.

For signal levels of -50 dBm and -21 dBm use an ATCRBS Mode C and record the listed observations.

Observe: Correct reply ratio.
 Correct reply channel.
 Power level of replies from channel A (§2.2.13.3).
 Power level of replies from channel B (§2.2.13.3).

Record: Reply delay for each interrogation signal type and for the signal levels as specified.

Repeat the above test reversing channels.

Compare records of reply delays for conformance with §2.2.13.4.

(2) Selection Test (See §2.2.13.1)

Synchronize the interrogations to channels A and B so that they are 0.125 +0.00/-0.04 microseconds apart where channel A is first.

Use an ATCRBS Mode C at a power level on channel A of MTL and a power level on channel B of MTL +3 dB.

Observe that 90 percent of the replies are on channel B.

Use an ATCRBS Mode C at a power level on channel A of MTL +3 dB and a power level on channel B of MTL.

Observe that 90 percent of the replies are on channel A.

Synchronize the interrogations to channels A and B so that they are 0.125 +0.00/-0.04 microseconds apart where channel B is first.

Use an ATCRBS Mode C at a power level on channel A of MTL and a power level on channel B of MTL +3 dB.

Observe that 90 percent of the replies are on channel B.

Use an ATCRBS Mode C at a power level on channel A of MTL +3 dB and a power level on channel B of MTL.

Observe that 90 percent of the replies are on channel A.

(3) Delay-Selection Test (See §2.2.13.2)

Synchronize the interrogations to channels A and B so that they are 0.375 +.040/-0.00 microseconds apart where channel A is first.

Use an ATCRBS Mode C at a power level on channel A of MTL +3 and a power level on channel B of -50 dBm.

Observe that 90 percent of the replies are on channel A.

Synchronize the interrogations to channels A and B so that they are 0.375 +0.040/-0.00 microseconds apart where channel B is first.

Use an ATCRBS Mode C at a power level on channel A of -50 dBm and a power level on channel B of MTL +3.

Observe that 90 percent of the replies are on channel B.

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3 INSTALLED EQUIPMENT PERFORMANCE

This section states the minimum acceptable level of performance for the equipment when installed in the aircraft. For the most part, installed performance requirements are the same as those contained in Section 2, which were verified through bench and environmental test. However, certain requirements may be affected by the physical installation (e.g., antenna patterns, receiver sensitivity, etc.) and can only be verified after installation. The installed performance limits stated below take in consideration these situations.

3.1 Equipment Installation

The airborne ATC transponder system should have been installed in the aircraft by the use of acceptable workmanship and engineering practices in an airworthy manner, and in accordance with the equipment manufacturer's recommendations as set forth in his equipment installation manual or other appropriate publication. To assure that the airborne ATC transponder system has been properly and safely installed in the aircraft, make a thorough visual inspection thereof and conduct a gross over-all operational/functional check of the system on the ground prior to flight.

3.1.1 Equipment Accessibility

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

3.1.2 Inadvertent Turn Off

Appropriate controls **shall** be provided with adequate protection against inadvertent turn off.

3.1.3 Displays

All installed system displays **shall** be readily visible and readable from the crew member's normal position in all ambient lighting conditions for which system use is required.

Note: *Visors, glareshields or filters may be an acceptable means of obtaining daylight visibility.*

3.1.4 Aircraft Power Source

The voltage and voltage tolerance characteristics of the equipment **shall** be compatible with the aircraft power source of appropriate category as specified in RTCA/DO-160E.

3.1.5 Transmission Line(s)

The transmission line(s) connecting antenna(s) and transponder(s) **shall** have impedance, power handling and loss characteristics in accordance with the equipment manufacturer's specifications.

3.1.6 Antenna Location

a. Single Antenna

The antenna **shall** be installed on the bottom of the aircraft as close to the longitudinal axis of the aircraft as possible.

b. Diversity Transponder Installation

The top and bottom antennas **shall** be mounted as near as possible to the center line of the fuselage. Antennas **shall** be located so as to minimize obstruction to their fields in the horizontal plane.

Recommendation: *The horizontal distance between the top and bottom antennas should not be greater than 7.6 meters.*

Note: *This recommendation is intended to support the operation of any diversity transponder (including cables) with any diversity antenna installation and still satisfy the requirement of §3.1.6 c.*

c. Reply Delay of Diversity Transponders.

The total two-way transmission difference in mean reply delay between the two antenna channels (including the differential delay caused by transponder-to-antenna cables and the horizontal distance along the aircraft centerline between the two antennas) **shall** not exceed 0.130 microseconds for interrogations of equal amplitude. This requirement **shall** hold for interrogation signal strengths between MTL +3 dB and -21 dBm. The jitter requirements on each individual channel **shall** remain as specified for non-diversity transponders (see §2.2.4.6).

Note: *This requirement limits the total apparent jitter caused by antenna switching and by cable and antenna location delay differences.*

3.1.7 Mutual Suppression

If other equipment is installed in the aircraft operating at or near 1030 and 1090 MHz, such as DME, the need for mutual suppression **shall** be determined. When mutual suppression is used, the requirements of §2.2.9 **shall** be met.

3.2 Conditions of Test

The conditions of test stated in the following subparagraphs are applicable to the equipment tests specified in Subsection §3.3. Ground tests may be used for all tests specified.

3.2.1 Power Input

Tests may be conducted using either the aircraft's electrical power distribution system or an appropriate external power supply.

3.2.2 Interference Effects

With the equipment energized from the aircraft's electrical power generating system, individually operate each of the other electrically operated aircraft equipment and systems to determine that no significant conducted or radiated interference exists. Evaluate all reasonable combinations of control settings and operating modes. Operate communication and navigation equipment on at least the low, high and one mid-band frequencies. If appropriate, repeat tests using emergency power source(s).

3.2.3 Environment

During the tests, the equipment **shall not** be subjected to environmental conditions that exceed those in RTCA/DO-160E as specified by the equipment manufacturer.

3.2.4 Adjustment of Equipment

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.

3.2.5 Warm-up Period

Unless otherwise specified, all tests **shall** be conducted after a warm-up period of not more than 15 minutes.

Comment: Is the above reasonable? Shouldn't this be not "less" than 15 minutes? This would mean that after each test, the unit needs to be turned off and returned to cold start conditions before proceeding with the next test.

3.2.6 Radiation Pattern

The antenna **shall** have a radiation pattern that is essentially omni-directional in the horizontal plane and have sufficient vertical beamwidth to assure proper equipment operation during normal aircraft maneuvers.

3.3 Test Procedures for Installed Equipment Performance

The test procedures set forth below are considered satisfactory in determining required installed equipment performance. Testing requirements are stated, in a manner that will make maximum use of bench test data while limiting flight tests to those requirements which cannot be tested conveniently by other means. Although suggested test procedures are cited, it is recognized that other methods may be preferred by the installing activity. These alternate procedures may be used if the installing activity 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 alternate procedures.

Installed equipment performance tests confirm surveillance functions.

Current U.S. operating regulations require tests similar to those described herein be performed bi-annually to ensure against deterioration of performance. Since equipment installation requires initial performance of these tests, they are included herein.

3.3.1 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 made properly and that the equipment has been installed and located in accordance with the manufacturer's recommendations.

3.3.2 Bench Tests

The equipment **shall** have been tested and certified by the equipment manufacturer to demonstrate compliance with the minimum requirements stated in §2.4.

The transponder tests required below may be conducted using portable test equipment.

3.3.3 Reply Frequency

Interrogate the installed transponder and verify that the reply frequency of the system is 1090 ± 3 .

3.3.4 Framing Pulse Spacing

Verify that the time interval between the leading edges of the two framing pulses is 20.3 ± 0.10 microseconds.

3.3.5 Reply Codes

- a. Verify that all Mode A reply pulses listed below in Table 3.3.5 are present.

Table 3.3.5: Mode A Reply Pulses

Pulse	Position (microseconds)	4096 code for this pulse only
F1	0.00	
C1	1.45	0010
A1	2.90	1000
C2	4.35	0020
A2	5.80	2000
C4	7.25	0040
A4	8.70	4000
B1	11.60	0100
D1	13.05	0001
B2	14.50	0200
D2	15.95	0002
B4	17.40	0400
D4	18.85	0004
F2	20.30	
SPI	24.65	

- b. Interrogate the transponder a sufficient number of times to verify that the correct 4096 code is transmitted. Use more than one 4096 code.

3.3.6 Pressure Altitude Transmissions

- a. Verify that the transponder response to Mode C interrogations consists only of framing pulses F1 and F2. If complete altitude reporting capability is provided, the altitude digitizer may not be connected to the transponder at the time of the test.
- b. Verify that the transponder response to Mode C interrogations consists of only framing pulses F1 and F2 with the altitude switch in the “OFF” position.

3.3.7 Altitude Reporting Test

- a. A sufficient number of test points **shall** be checked to ensure that the altitude reporting equipment and transponder perform their intended function through their entire range while ascending or descending. Tests of each altitude code segment of the encoder (2300, 2500, 3800, 4300, 4800, 6800, 14,800 and 30,800 if available) are sufficient to ensure proper operation of each altitude code segment of the encoder.

- b. Verify that the correspondence value of the altimeter system is 125 feet or less.

3.3.8 Reply Pulse Width

Verify that the duration of the F1 and F2 pulses between the 0.5 amplitude points on the leading and trailing edge is 0.45, ± 0.10 microsecond with the transponder replying on Mode A, code 0001, and code 7477.

3.3.9 Receiver Sensitivity

- a. Verify that for ATCRBS interrogations the receiver sensitivity of the system at the antenna end of the transmission line is nominally 71 dB below 1 milliwatt with limits between 69 and 77 dB below 1 milliwatt.
- b. The minimum triggering level (MTL) of the transponder shall be such that replies are generated to 90 percent of the interrogation signals when:
 - (1) The two pulses P₁ and P₃ constituting an interrogation are of equal amplitude and P₂ is not detected; and
 - (2) The amplitude of these signals received at the antenna end of the transmission line of the transponder is nominally 71 dB below 1 milliwatt with limits between 69 and 77 dB below 1 milliwatt.

Note: For this MTL requirement, a nominal 3 dB transmission line loss and an antenna performance equivalent to that of a simple quarter wave antenna are assumed. In the event these assumed conditions do not apply, the MTL of the installed transponder system must be comparable to that of the assumed system.

- c. The variation of the minimum triggering level between modes **shall** not exceed 1 dB for nominal pulse spacings and pulse widths.
- d. The reply characteristics **shall** apply over a received signal amplitude range between minimum triggering level and 50 dB above minimum triggering level.
- e. The suppression characteristics **shall** apply over a received, signal amplitude range between 3 dB above minimum triggering level and 50 dB above minimum triggering level.

3.3.10 Transmitter Power Output

- a. Verify that transponders operating at altitudes above 15,000 feet have a peak pulse power at the antenna end of the transmission line of at least +21 dBW and not more than +27 dBW.
- b. Verify that transponders intended for operation at altitudes not above 15,000 feet have a peak pulse power at the antenna end of the transmission line of at least +18.5 dBW and not more than +27 dBW.

3.3.11 Diversity Antenna Installations

Verify that the antennas on the aircraft are no more than 7.6 meter (25 feet) apart in the horizontal plane. The cables **shall** be essentially of equal electrical length.

3.4 Flight Test Procedures

The following test procedures provide one means of determining installed equipment performance. Although specific test procedures are cited, it is recognized that other methods may be preferred by the installing activity. These alternate 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 alternate procedures. The equipment shall be tested to determine compliance with the minimum requirements stated in §2.2. In order to meet this requirement, test results supplied by the equipment manufacturer or other proof of conformity may be accepted in lieu of bench tests performed by the installing activity.

This guidance material offers examples of flight test procedures for demonstration of selected performance functions. Flight demonstration of installed performance may be required by the aircraft operator or by airworthiness inspection agencies.

A schedule must be arranged with the area air traffic control facility so that a controller is available to observe the transponder reply and communicate with the test aircraft to confirm performance of the transponder.

Select a test area such that line-of-sight signal propagation is assured. Test maneuvers may include standard rate turns through 360 degrees, climbs and descents so that ATC can confirm valid return through normal flight attitudes. Verification of Ident codes selected and reported altitude response to Mode C should be checked.

3.4.1 Ground Pre-Flight Tests

The following transponder characteristic should be determined and the performance level noted:

- (1) Random triggering of the transponder should not exceed 30 replies per second as integrated over an interval equivalent to at least 300 random triggers, or 30 seconds, whichever is less. This should be determined with all possible interfering equipments operating in their normal manner on operational channels of maximum interference, but with the absence of bona fide transponder interrogations. This test can be performed by using an RF detector sufficiently coupled to the antenna to count the rate of non-interrogated replies.
- (2) Receiver/Transmitter system characteristics should be assured by determining the attenuation constant of the installed coaxial transmission line and the characteristics of the antenna. Measure the length of transmission line and refer to suitable handbooks regarding the type of coaxial cable or the transponder

manufacturer's equipment manual to determine the amount, of attenuation in decibels. Inspect the antenna system and carefully observe that the antenna is installed in accordance with the manufacturer's recommendations, and that there are no protrusions from the aircraft which will affect the efficiency of the antenna. The following examples are given to empirically determine the system compliance:

EXAMPLE #1:

Effective radiated power =ERP

$$\text{ERP} = P_T - L + G_A$$

Where: P_T = Power in dBW at the antenna terminal of the transponder. (Refer to §2.3.2.1.14)
 L = Transmission Line Loss
 G_A = Antenna gain above isotropic

Assume the following:

- a) The measured transmitter power at the transponder antenna terminal is 100 watts (+20 dBW). The measured receiver sensitivity is -71 dBm.
- b) 10 feet of RG-8/U = 0.9 dB.
- c) Antenna gain is unity with respect to isotropic which results in 0 dB.

Then:

$$\begin{aligned} \text{Transmitted ERP} &= 20 - 0.9 + 0 \\ &= 19.1 \text{ dBW} \end{aligned}$$

$$\begin{aligned} \text{Effective Receiver Sensitivity} &= -71 + 0.9 - 0 \\ &= -70.1 \text{ dBm} \end{aligned}$$

This example would allow the system to operate in aircraft for altitudes not exceeding 15,000 feet.

EXAMPLE #2:

Assume the following:

- a) The measured transmitter power at the transponder terminal is 29 dBW.
- b) 33 feet of RG-8/U = 3 dB
- c) Antenna gain is unity with respect to isotropic which results in 0 dB.

Then:

$$\begin{aligned} \text{Transmitter ERP} &= 29 - 3 + 0 \\ &= 26 \text{ dBW} \end{aligned}$$

$$\begin{aligned}\text{Effective Receiver Sensitivity} &= -74 + 3 - 0 \\ &= -71 \text{ dBm}\end{aligned}$$

This example would allow the system to operate in aircraft intended to operate at all altitudes.

- (3) Automatic altitude reporting performance should be checked as follows with aircraft on the ground:
 - (a) Set the altimeter normally used to maintain flight altitude to 29.92 inches of mercury (1013.2 millibars).
 - (b) Select 10 or more evenly-spaced altitude test points between zero (sea level) and the maximum operating altitude of the aircraft. Test each of these test points for increasing altitude and for decreasing altitude.
 - (c) Apply pressure to the static system. If separate static systems serve altimeter and digitizer, apply identical pressures simultaneously to each. Approach each test point slowly, decreasing pressure for increasing altitude, and vice versa, until a transition to the test point value occurs in the digital output. Record the pilot's altimeter reading at the instant of transition in the digitizer.
 - (d) The installation is acceptable if the altimeter normally used to maintain flight altitude corresponds with the output of the digitizer within 125 feet at each test point and within ± 62 feet at not less than 70 percent of the test points.
- (4) The performance characteristics of any equipment(s) functioning external to the transponder system shall be evaluated to determine that the algebraic cumulative effective dead time does not exceed the specified limits.

3.4.2 Operational Flight Tests

- (1) Perform the flight test using an ATC facility and procedures. The flight should be conducted from the airport to approximately 25 miles from the ground facility. Put the aircraft through those maneuvers normally associated with take-off, climb, holding procedures, descent and final approach. Determine in the course of these maneuvers that the transponder performs its intended function and is suitable for use in the ATC system.
- (2) If the system includes altitude reporting and while performing (1) above, request ATC to monitor the altitude being reported by the transponder and compare with the altimeter being used to maintain flight altitude.
- (3) Request ATC to verify proper performance while operating on several different codes. Do not use codes 7700 or 7600, unless requested by ATC.

Note: *It should be recognized that some aircraft attitudes with respect to the ground station will cause momentary loss of contact.*

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4 EQUIPMENT OPERATIONAL PERFORMANCE CHARACTERISTICS

4.1 Required Operational Performance Requirements

To ensure the operator that operations can be conducted safely and reliably in the expected operational environment, there are specific minimum acceptable performance requirements that shall be met. The following paragraphs identify these requirements.

4.1.1 Power Inputs

Prior to flight, verify that the equipment is receiving primary input power necessary for proper conditions.

4.1.2 Equipment Operating Modes

The equipment shall operate in each of its operating modes.

4.1.3 Continue with Other Operational Requirements as Necessary

4.2 Test Procedures for Operational Performance Requirements

Operation equipment tests may be conducted as part of normal pre-flight tests. For those tests that can only be run in flight, procedures should be developed to perform these tests as early during the flight as possible to verify that the equipment is performing its intended function(s).

4.2.1 Power Input

With the aircraft's electrical power generating system operating, energize the equipment and verify that electrical power is available to the equipment.

4.2.2 Equipment Operating Modes

Verify that the equipment performs its intended function(s) for each of the operating modes available to the operator.

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Membership

RTCA Special Committee 209

Working Group 2

Minimum Operational Performance Standards

for

Air Traffic Control Radar Beacon System (ATCRBS) Airborne Equipment

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Appendix A

SSR automatic pressure altitude transmission code (pulse position assignment)

The following Table is reproduced from ICAO Annex 10, Volume IV, Appendix to Chapter 3.

RANGE	PULSE POSITIONS <i>(0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)</i>											
	Increments <i>(Feet)</i>	D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
-1 000 to -950	0	0	0	0	0	0	0	0	0	0	1	0
-950 to -850	0	0	0	0	0	0	0	0	0	1	1	0
-850 to -750	0	0	0	0	0	0	0	0	0	1	0	0
-750 to -650	0	0	0	0	0	0	0	0	1	1	0	0
-650 to -550	0	0	0	0	0	0	0	0	1	1	1	0
-550 to -450	0	0	0	0	0	0	0	0	1	0	1	0
-450 to -350	0	0	0	0	0	0	0	0	1	0	1	1
-350 to -250	0	0	0	0	0	0	0	0	1	0	0	1
-250 to -150	0	0	0	0	0	0	0	1	1	0	0	1
-150 to -50	0	0	0	0	0	0	0	1	1	0	1	1
-50 to 50	0	0	0	0	0	0	0	1	1	0	1	0
50 to 150	0	0	0	0	0	0	0	1	1	1	1	0
150 to 250	0	0	0	0	0	0	0	1	1	1	0	0
250 to 350	0	0	0	0	0	0	0	1	0	1	0	0
350 to 450	0	0	0	0	0	0	0	1	0	1	1	0
450 to 550	0	0	0	0	0	0	0	1	0	0	1	0
550 to 650	0	0	0	0	0	0	0	1	0	0	1	1
650 to 750	0	0	0	0	0	0	0	1	0	0	0	1
750 to 850	0	0	0	0	0	0	1	1	0	0	0	1
850 to 950	0	0	0	0	0	0	1	1	0	0	1	1
950 to 1 050	0	0	0	0	0	0	1	1	0	0	1	0
1 050 to 1 150	0	0	0	0	0	0	1	1	0	1	1	0
1 150 to 1 250	0	0	0	0	0	0	1	1	0	1	0	0
1 250 to 1 350	0	0	0	0	0	0	1	1	1	1	0	0
1 350 to 1 450	0	0	0	0	0	0	1	1	1	1	1	0
1 450 to 1 550	0	0	0	0	0	0	1	1	1	0	1	0
1 550 to 1 650	0	0	0	0	0	0	1	1	1	0	1	1
1 650 to 1 750	0	0	0	0	0	0	1	1	1	0	0	1
1 750 to 1 850	0	0	0	0	0	0	1	0	1	0	0	1
1 850 to 1 950	0	0	0	0	0	0	1	0	1	0	1	1
1 950 to 2 050	0	0	0	0	0	0	1	0	1	0	1	0
2 050 to 2 150	0	0	0	0	0	0	1	0	1	1	1	0
2 150 to 2 250	0	0	0	0	0	0	1	0	1	1	0	0
2 250 to 2 350	0	0	0	0	0	0	1	0	0	1	0	0
2 350 to 2 450	0	0	0	0	0	0	1	0	0	1	1	0
2 450 to 2 550	0	0	0	0	0	0	1	0	0	0	1	0
2 550 to 2 650	0	0	0	0	0	0	1	0	0	0	1	1
2 650 to 2 750	0	0	0	0	0	0	1	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
2 750	to	2 850	0	0	0	0	1	1	0	0	0	0	1
2 850	to	2 950	0	0	0	0	1	1	0	0	0	1	1
2 950	to	3 050	0	0	0	0	1	1	0	0	0	1	0
3 050	to	3 150	0	0	0	0	1	1	0	0	1	1	0
3 150	to	3 250	0	0	0	0	1	1	0	0	1	0	0
3 250	to	3 350	0	0	0	0	1	1	0	1	1	0	0
3 350	to	3 450	0	0	0	0	1	1	0	1	1	1	0
3 450	to	3 550	0	0	0	0	1	1	0	1	0	1	0
3 550	to	3 650	0	0	0	0	1	1	0	1	0	1	1
3 650	to	3 750	0	0	0	0	1	1	0	1	0	0	1
3 750	to	3 850	0	0	0	0	1	1	1	1	0	0	1
3 850	to	3 950	0	0	0	0	1	1	1	1	0	1	1
3 950	to	4 050	0	0	0	0	1	1	1	1	0	1	0
4 050	to	4 150	0	0	0	0	1	1	1	1	1	1	0
4 150	to	4 250	0	0	0	0	1	1	1	1	1	0	0
4 250	to	4 350	0	0	0	0	1	1	1	0	1	0	0
4 350	to	4 450	0	0	0	0	1	1	1	0	1	1	0
4 450	to	4 550	0	0	0	0	1	1	1	0	0	1	0
4 550	to	4 650	0	0	0	0	1	1	1	0	0	1	1
4 650	to	4 750	0	0	0	0	1	1	1	0	0	0	1
4 750	to	4 850	0	0	0	0	1	0	1	0	0	0	1
4 850	to	4 950	0	0	0	0	1	0	1	0	0	1	1
4 950	to	5 050	0	0	0	0	1	0	1	0	0	1	0
5 050	to	5 150	0	0	0	0	1	0	1	0	1	1	0
5 150	to	5 250	0	0	0	0	1	0	1	0	1	0	0
5 250	to	5 350	0	0	0	0	1	0	1	1	1	0	0
5 350	to	5 450	0	0	0	0	1	0	1	1	1	1	0
5 450	to	5 550	0	0	0	0	1	0	1	1	0	1	0
5 550	to	5 650	0	0	0	0	1	0	1	1	0	1	1
5 650	to	5 750	0	0	0	0	1	0	1	1	0	0	1
5 750	to	5 850	0	0	0	0	1	0	0	1	0	0	1
5 850	to	5 950	0	0	0	0	1	0	0	1	0	1	1
5 950	to	6 050	0	0	0	0	1	0	0	1	0	1	0
6 050	to	6 150	0	0	0	0	1	0	0	1	1	1	0
6 150	to	6 250	0	0	0	0	1	0	0	1	1	0	0
6 250	to	6 350	0	0	0	0	1	0	0	0	1	0	0
6 350	to	6 450	0	0	0	0	1	0	0	0	1	1	0
6 450	to	6 550	0	0	0	0	1	0	0	0	0	1	0
6 550	to	6 650	0	0	0	0	1	0	0	0	0	1	1
6 650	to	6 750	0	0	0	0	1	0	0	0	0	0	1
6 750	to	6 850	0	0	0	1	1	0	0	0	0	0	1
6 850	to	6 950	0	0	0	1	1	0	0	0	0	1	1
6 950	to	7 050	0	0	0	1	1	0	0	0	0	1	0
7 050	to	7 150	0	0	0	1	1	0	0	0	1	1	0
7 150	to	7 250	0	0	0	1	1	0	0	0	1	0	0
7 250	to	7 350	0	0	0	1	1	0	0	1	1	0	0
7 350	to	7 450	0	0	0	1	1	0	0	1	1	1	0
7 450	to	7 550	0	0	0	1	1	0	0	1	0	1	0
7 550	to	7 650	0	0	0	1	1	0	0	1	0	1	1
7 650	to	7 750	0	0	0	1	1	0	0	1	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)													
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
7 750 to 7 850	0	0	0	1	1	0	1	1	0	0	1	0	0	1
7 850 to 7 950	0	0	0	1	1	0	1	1	0	0	1	0	1	1
7 950 to 8 050	0	0	0	1	1	0	1	1	0	0	1	0	1	0
8 050 to 8 150	0	0	0	1	1	0	1	1	0	0	1	1	1	0
8 150 to 8 250	0	0	0	1	1	0	1	1	0	0	1	1	0	0
8 250 to 8 350	0	0	0	1	1	0	1	0	1	0	1	0	0	0
8 350 to 8 450	0	0	0	1	1	0	1	0	1	0	1	1	1	0
8 450 to 8 550	0	0	0	1	1	0	1	0	1	0	0	1	0	0
8 550 to 8 650	0	0	0	1	1	0	1	0	1	0	0	1	1	1
8 650 to 8 750	0	0	0	1	1	0	1	0	1	0	0	0	0	1
8 750 to 8 850	0	0	0	1	1	1	1	1	0	0	0	0	0	1
8 850 to 8 950	0	0	0	1	1	1	1	1	0	0	0	1	1	1
8 950 to 9 050	0	0	0	1	1	1	1	1	0	0	0	1	0	0
9 050 to 9 150	0	0	0	1	1	1	1	1	0	0	1	1	1	0
9 150 to 9 250	0	0	0	1	1	1	1	1	0	0	1	0	0	0
9 250 to 9 350	0	0	0	1	1	1	1	1	1	1	1	0	0	0
9 350 to 9 450	0	0	0	1	1	1	1	1	1	1	1	1	1	0
9 450 to 9 550	0	0	0	1	1	1	1	1	1	1	0	1	0	0
9 550 to 9 650	0	0	0	1	1	1	1	1	1	1	0	1	1	1
9 650 to 9 750	0	0	0	1	1	1	1	1	1	1	0	0	0	1
9 750 to 9 850	0	0	0	1	1	1	0	1	0	1	0	0	0	1
9 850 to 9 950	0	0	0	1	1	1	0	1	0	1	0	1	1	1
9 950 to 10 050	0	0	0	1	1	1	0	1	0	1	0	1	0	0
10 050 to 10 150	0	0	0	1	1	1	0	1	0	1	1	1	1	0
10 150 to 10 250	0	0	0	1	1	1	0	1	0	1	1	0	0	0
10 250 to 10 350	0	0	0	1	1	1	0	0	0	0	1	0	0	0
10 350 to 10 450	0	0	0	1	1	1	0	0	0	0	1	1	1	0
10 450 to 10 550	0	0	0	1	1	1	0	0	0	0	0	1	0	0
10 550 to 10 650	0	0	0	1	1	1	0	0	0	0	0	1	1	1
10 650 to 10 750	0	0	0	1	1	1	0	0	0	0	0	0	0	1
10 750 to 10 850	0	0	0	1	0	1	0	0	0	0	0	0	0	1
10 850 to 10 950	0	0	0	1	0	1	0	0	0	0	0	1	1	1
10 950 to 11 050	0	0	0	1	0	1	0	0	0	0	0	1	0	0
11 050 to 11 150	0	0	0	1	0	1	0	0	0	0	1	1	1	0
11 150 to 11 250	0	0	0	1	0	1	0	0	0	0	1	0	0	0
11 250 to 11 350	0	0	0	1	0	1	0	1	0	1	1	0	0	0
11 350 to 11 450	0	0	0	1	0	1	0	1	0	1	1	1	1	0
11 450 to 11 550	0	0	0	1	0	1	0	1	0	1	0	1	0	0
11 550 to 11 650	0	0	0	1	0	1	0	1	0	1	0	1	1	1
11 650 to 11 750	0	0	0	1	0	1	0	1	0	1	0	0	0	1
11 750 to 11 850	0	0	0	1	0	1	1	1	1	1	0	0	0	1
11 850 to 11 950	0	0	0	1	0	1	1	1	1	1	0	1	1	1
11 950 to 12 050	0	0	0	1	0	1	1	1	1	1	0	1	0	0
12 050 to 12 150	0	0	0	1	0	1	1	1	1	1	1	1	1	0
12 150 to 12 250	0	0	0	1	0	1	1	1	1	1	1	0	0	0
12 250 to 12 350	0	0	0	1	0	1	1	0	0	0	1	0	0	0
12 350 to 12 450	0	0	0	1	0	1	1	0	0	0	1	1	1	0
12 450 to 12 550	0	0	0	1	0	1	1	0	0	0	0	1	0	0
12 550 to 12 650	0	0	0	1	0	1	1	0	0	0	0	1	1	1
12 650 to 12 750	0	0	0	1	0	1	1	0	0	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)													
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
12 750 to 12 850	0	0	0	1	0	0	1	0	0	1	0	0	0	1
12 850 to 12 950	0	0	0	1	0	0	1	0	0	1	0	0	1	1
12 950 to 13 050	0	0	0	1	0	0	1	0	0	1	0	0	1	0
13 050 to 13 150	0	0	0	1	0	0	1	0	0	1	0	1	1	0
13 150 to 13 250	0	0	0	1	0	0	1	0	0	1	0	1	0	0
13 250 to 13 350	0	0	0	1	0	0	1	0	0	1	1	1	0	0
13 350 to 13 450	0	0	0	1	0	0	1	0	0	1	1	1	1	0
13 450 to 13 550	0	0	0	1	0	0	1	0	0	1	1	0	1	0
13 550 to 13 650	0	0	0	1	0	0	1	0	0	1	1	0	1	1
13 650 to 13 750	0	0	0	1	0	0	1	0	0	1	1	0	0	1
13 750 to 13 850	0	0	0	1	0	0	0	0	0	1	0	0	0	1
13 850 to 13 950	0	0	0	1	0	0	0	0	0	1	0	0	1	1
13 950 to 14 050	0	0	0	1	0	0	0	0	0	1	0	1	1	0
14 050 to 14 150	0	0	0	1	0	0	0	0	0	1	1	1	1	0
14 150 to 14 250	0	0	0	1	0	0	0	0	0	1	1	1	0	0
14 250 to 14 350	0	0	0	1	0	0	0	0	0	0	1	0	0	0
14 350 to 14 450	0	0	0	1	0	0	0	0	0	0	1	1	1	0
14 450 to 14 550	0	0	0	1	0	0	0	0	0	0	0	1	1	0
14 550 to 14 650	0	0	0	1	0	0	0	0	0	0	0	1	1	1
14 650 to 14 750	0	0	0	1	0	0	0	0	0	0	0	0	0	1
14 750 to 14 850	0	0	1	1	0	0	0	0	0	0	0	0	0	1
14 850 to 14 950	0	0	1	1	0	0	0	0	0	0	0	0	1	1
14 950 to 15 050	0	0	1	1	0	0	0	0	0	0	0	0	1	0
15 050 to 15 150	0	0	1	1	0	0	0	0	0	0	1	1	1	0
15 150 to 15 250	0	0	1	1	0	0	0	0	0	0	1	0	0	0
15 250 to 15 350	0	0	1	1	0	0	0	0	0	1	1	0	0	0
15 350 to 15 450	0	0	1	1	0	0	0	0	0	1	1	1	1	0
15 450 to 15 550	0	0	1	1	0	0	0	0	0	1	0	1	1	0
15 550 to 15 650	0	0	1	1	0	0	0	0	0	1	0	1	1	1
15 650 to 15 750	0	0	1	1	0	0	0	0	0	1	0	0	0	1
15 750 to 15 850	0	0	1	1	0	0	1	1	1	1	0	0	0	1
15 850 to 15 950	0	0	1	1	0	0	1	1	1	0	0	1	1	1
15 950 to 16 050	0	0	1	1	0	0	1	1	1	0	0	1	1	0
16 050 to 16 150	0	0	1	1	0	0	1	1	1	1	1	1	1	0
16 150 to 16 250	0	0	1	1	0	0	1	1	1	1	1	0	0	0
16 250 to 16 350	0	0	1	1	0	0	1	1	0	1	0	1	0	0
16 350 to 16 450	0	0	1	1	0	0	1	1	0	1	0	1	1	0
16 450 to 16 550	0	0	1	1	0	0	1	1	0	1	0	0	1	0
16 550 to 16 650	0	0	1	1	0	0	1	1	0	1	0	0	1	1
16 650 to 16 750	0	0	1	1	0	0	1	1	0	1	0	0	0	1
16 750 to 16 850	0	0	1	1	0	1	1	1	0	1	0	0	0	1
16 850 to 16 950	0	0	1	1	0	1	1	1	0	1	0	0	1	1
16 950 to 17 050	0	0	1	1	0	1	1	1	0	1	0	0	1	0
17 050 to 17 150	0	0	1	1	0	1	1	1	0	1	1	1	1	0
17 150 to 17 250	0	0	1	1	0	1	1	1	0	1	1	1	0	0
17 250 to 17 350	0	0	1	1	0	1	1	1	1	1	1	1	0	0
17 350 to 17 450	0	0	1	1	0	1	1	1	1	1	1	1	1	0
17 450 to 17 550	0	0	1	1	0	1	1	1	1	1	0	1	1	0
17 550 to 17 650	0	0	1	1	0	1	1	1	1	1	0	1	1	1
17 650 to 17 750	0	0	1	1	0	1	1	1	1	1	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
17 750 to 17 850	0	0	1	1	0	1	0	1	0	1	0	0	1
17 850 to 17 950	0	0	1	1	0	1	0	1	0	1	0	1	1
17 950 to 18 050	0	0	1	1	0	1	0	1	0	1	0	1	0
18 050 to 18 150	0	0	1	1	0	1	0	1	0	1	1	1	0
18 150 to 18 250	0	0	1	1	0	1	0	1	0	1	1	0	0
18 250 to 18 350	0	0	1	1	0	1	0	0	0	0	1	0	0
18 350 to 18 450	0	0	1	1	0	1	0	0	0	0	1	1	0
18 450 to 18 550	0	0	1	1	0	1	0	0	0	0	0	1	0
18 550 to 18 650	0	0	1	1	0	1	0	0	0	0	0	1	1
18 650 to 18 750	0	0	1	1	0	1	0	0	0	0	0	0	1
18 750 to 18 850	0	0	1	1	1	1	0	0	0	0	0	0	1
18 850 to 18 950	0	0	1	1	1	1	0	0	0	0	0	1	1
18 950 to 19 050	0	0	1	1	1	1	0	0	0	0	0	1	0
19 050 to 19 150	0	0	1	1	1	1	0	0	0	0	1	1	0
19 150 to 19 250	0	0	1	1	1	1	0	0	0	0	1	0	0
19 250 to 19 350	0	0	1	1	1	1	0	1	0	1	1	0	0
19 350 to 19 450	0	0	1	1	1	1	0	1	0	1	1	1	0
19 450 to 19 550	0	0	1	1	1	1	0	1	0	1	0	1	0
19 550 to 19 650	0	0	1	1	1	1	0	1	0	1	0	1	1
19 650 to 19 750	0	0	1	1	1	1	0	1	0	1	0	0	1
19 750 to 19 850	0	0	1	1	1	1	1	1	1	1	0	0	1
19 850 to 19 950	0	0	1	1	1	1	1	1	1	1	0	1	1
19 950 to 20 050	0	0	1	1	1	1	1	1	1	1	0	1	0
20 050 to 20 150	0	0	1	1	1	1	1	1	1	1	1	1	0
20 150 to 20 250	0	0	1	1	1	1	1	1	1	1	1	0	0
20 250 to 20 350	0	0	1	1	1	1	1	0	1	0	1	0	0
20 350 to 20 450	0	0	1	1	1	1	1	0	1	0	1	1	0
20 450 to 20 550	0	0	1	1	1	1	1	0	1	0	0	1	0
20 550 to 20 650	0	0	1	1	1	1	1	0	1	0	0	1	1
20 650 to 20 750	0	0	1	1	1	1	1	0	1	0	0	0	1
20 750 to 20 850	0	0	1	1	1	0	1	0	1	0	0	0	1
20 850 to 20 950	0	0	1	1	1	0	1	0	1	0	0	1	1
20 950 to 21 050	0	0	1	1	1	0	1	0	1	0	0	1	0
21 050 to 21 150	0	0	1	1	1	0	1	0	1	0	1	1	0
21 150 to 21 250	0	0	1	1	1	0	1	0	1	0	1	0	0
21 250 to 21 350	0	0	1	1	1	0	1	1	1	1	1	0	0
21 350 to 21 450	0	0	1	1	1	0	1	1	1	1	1	1	0
21 450 to 21 550	0	0	1	1	1	0	1	1	1	1	0	1	0
21 550 to 21 650	0	0	1	1	1	0	1	1	1	1	0	1	1
21 650 to 21 750	0	0	1	1	1	0	1	1	1	1	0	0	1
21 750 to 21 850	0	0	1	1	1	0	0	0	1	0	0	0	1
21 850 to 21 950	0	0	1	1	1	0	0	0	1	0	0	1	1
21 950 to 22 050	0	0	1	1	1	0	0	0	1	0	0	1	0
22 050 to 22 150	0	0	1	1	1	0	0	0	1	1	1	1	0
22 150 to 22 250	0	0	1	1	1	0	0	0	1	1	0	0	0
22 250 to 22 350	0	0	1	1	1	0	0	0	0	0	1	0	0
22 350 to 22 450	0	0	1	1	1	0	0	0	0	0	1	1	0
22 450 to 22 550	0	0	1	1	1	0	0	0	0	0	0	1	0
22 550 to 22 650	0	0	1	1	1	0	0	0	0	0	0	1	1
22 650 to 22 750	0	0	1	1	1	0	0	0	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)													
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
22 750 to 22 850	0	0	1	0	1	0	0	0	0	0	0	0	0	1
22 850 to 22 950	0	0	1	0	1	0	0	0	0	0	0	0	1	1
22 950 to 23 050	0	0	1	0	1	0	0	0	0	0	0	0	1	0
23 050 to 23 150	0	0	1	0	1	0	0	0	0	0	0	1	1	0
23 150 to 23 250	0	0	1	0	1	0	0	0	0	0	0	1	0	0
23 250 to 23 350	0	0	1	0	1	0	0	0	1	0	1	0	0	0
23 350 to 23 450	0	0	1	0	1	0	0	0	1	0	1	1	1	0
23 450 to 23 550	0	0	1	0	1	0	0	0	1	0	0	0	1	0
23 550 to 23 650	0	0	1	0	1	0	0	0	1	0	0	0	1	1
23 650 to 23 750	0	0	1	0	1	0	0	0	1	0	0	0	0	1
23 750 to 23 850	0	0	1	0	1	0	1	1	1	0	1	0	0	1
23 850 to 23 950	0	0	1	0	1	0	1	0	1	1	1	0	1	1
23 950 to 24 050	0	0	1	0	1	0	1	0	1	1	1	0	1	0
24 050 to 24 150	0	0	1	0	1	0	1	0	1	1	1	1	1	0
24 150 to 24 250	0	0	1	0	1	0	1	0	1	1	1	1	0	0
24 250 to 24 350	0	0	1	0	1	0	1	0	1	0	1	0	0	0
24 350 to 24 450	0	0	1	0	1	0	1	0	1	0	1	1	1	0
24 450 to 24 550	0	0	1	0	1	0	1	0	1	0	0	1	0	0
24 550 to 24 650	0	0	1	0	1	0	1	0	1	0	0	1	1	1
24 650 to 24 750	0	0	1	0	1	0	1	0	1	0	0	0	0	1
24 750 to 24 850	0	0	1	0	1	1	1	1	0	0	0	0	0	1
24 850 to 24 950	0	0	1	0	1	1	1	1	0	0	0	1	1	1
24 950 to 25 050	0	0	1	0	1	1	1	1	0	0	0	1	0	0
25 050 to 25 150	0	0	1	0	1	1	1	1	0	1	1	1	1	0
25 150 to 25 250	0	0	1	0	1	1	1	1	0	1	1	0	0	0
25 250 to 25 350	0	0	1	0	1	1	1	1	1	1	1	0	0	0
25 350 to 25 450	0	0	1	0	1	1	1	1	1	1	1	1	1	0
25 450 to 25 550	0	0	1	0	1	1	1	1	1	1	0	1	0	0
25 550 to 25 650	0	0	1	0	1	1	1	1	1	1	0	1	1	1
25 650 to 25 750	0	0	1	0	1	1	1	1	1	1	0	0	0	1
25 750 to 25 850	0	0	1	0	1	1	0	1	0	0	0	0	0	1
25 850 to 25 950	0	0	1	0	1	1	0	1	0	0	0	0	1	1
25 950 to 26 050	0	0	1	0	1	1	0	1	0	1	0	0	1	0
26 050 to 26 150	0	0	1	0	1	1	0	1	0	1	1	1	1	0
26 150 to 26 250	0	0	1	0	1	1	0	1	0	1	1	0	0	0
26 250 to 26 350	0	0	1	0	1	1	0	0	0	0	1	0	0	0
26 350 to 26 450	0	0	1	0	1	1	0	0	0	0	1	1	0	0
26 450 to 26 550	0	0	1	0	1	1	0	0	0	0	0	1	0	0
26 550 to 26 650	0	0	1	0	1	1	0	0	0	0	0	1	1	1
26 650 to 26 750	0	0	1	0	1	1	0	0	0	0	0	0	0	1
26 750 to 26 850	0	0	1	0	0	1	0	0	0	0	0	0	0	1
26 850 to 26 950	0	0	1	0	0	1	0	0	0	0	0	1	1	1
26 950 to 27 050	0	0	1	0	0	1	0	0	0	0	0	1	0	0
27 050 to 27 150	0	0	1	0	0	1	0	0	0	0	1	1	1	0
27 150 to 27 250	0	0	1	0	0	1	0	0	0	0	1	0	0	0
27 250 to 27 350	0	0	1	0	0	1	0	1	0	1	1	0	0	0
27 350 to 27 450	0	0	1	0	0	1	0	1	0	1	1	1	1	0
27 450 to 27 550	0	0	1	0	0	1	0	1	0	1	0	1	0	0
27 550 to 27 650	0	0	1	0	0	1	0	1	0	1	0	1	1	1
27 650 to 27 750	0	0	1	0	0	1	0	1	0	1	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
27 750	to	27 850	0	0	1	0	0	1	1	1	0	0	1
27 850	to	27 950	0	0	1	0	0	1	1	1	0	1	1
27 950	to	28 050	0	0	1	0	0	1	1	1	0	1	0
28 050	to	28 150	0	0	1	0	0	1	1	1	1	1	0
28 150	to	28 250	0	0	1	0	0	1	1	1	1	0	0
28 250	to	28 350	0	0	1	0	0	1	1	0	1	0	0
28 350	to	28 450	0	0	1	0	0	1	1	0	1	1	0
28 450	to	28 550	0	0	1	0	0	1	1	0	0	1	0
28 550	to	28 650	0	0	1	0	0	1	1	0	0	1	1
28 650	to	28 750	0	0	1	0	0	1	1	0	0	0	1
28 750	to	28 850	0	0	1	0	0	0	1	0	0	0	1
28 850	to	28 950	0	0	1	0	0	0	1	0	0	1	1
28 950	to	29 050	0	0	1	0	0	0	1	0	0	1	0
29 050	to	29 150	0	0	1	0	0	0	1	0	1	1	0
29 150	to	29 250	0	0	1	0	0	0	1	0	1	0	0
29 250	to	29 350	0	0	1	0	0	0	1	1	1	0	0
29 350	to	29 450	0	0	1	0	0	0	1	1	1	1	0
29 450	to	29 550	0	0	1	0	0	0	1	1	0	1	0
29 550	to	29 650	0	0	1	0	0	0	1	1	0	1	1
29 650	to	29 750	0	0	1	0	0	0	1	1	0	0	1
29 750	to	29 850	0	0	1	0	0	0	0	1	0	0	1
29 850	to	29 950	0	0	1	0	0	0	0	1	0	1	1
29 950	to	30 050	0	0	1	0	0	0	0	1	0	1	0
30 050	to	30 150	0	0	1	0	0	0	0	1	1	1	0
30 150	to	30 250	0	0	1	0	0	0	0	1	1	0	0
30 250	to	30 350	0	0	1	0	0	0	0	0	1	0	0
30 350	to	30 450	0	0	1	0	0	0	0	0	1	1	0
30 450	to	30 550	0	0	1	0	0	0	0	0	0	1	0
30 550	to	30 650	0	0	1	0	0	0	0	0	0	1	1
30 650	to	30 750	0	0	1	0	0	0	0	0	0	0	1
30 750	to	30 850	0	1	1	0	0	0	0	0	0	0	1
30 850	to	30 950	0	1	1	0	0	0	0	0	0	1	1
30 950	to	31 050	0	1	1	0	0	0	0	0	0	1	0
31 050	to	31 150	0	1	1	0	0	0	0	0	1	1	0
31 150	to	31 250	0	1	1	0	0	0	0	0	1	0	0
31 250	to	31 350	0	1	1	0	0	0	0	1	1	0	0
31 350	to	31 450	0	1	1	0	0	0	0	1	1	1	0
31 450	to	31 550	0	1	1	0	0	0	0	1	0	1	0
31 550	to	31 650	0	1	1	0	0	0	0	1	0	1	1
31 650	to	31 750	0	1	1	0	0	0	0	1	0	0	1
31 750	to	31 850	0	1	1	0	0	0	1	1	0	0	1
31 850	to	31 950	0	1	1	0	0	0	1	1	0	1	1
31 950	to	32 050	0	1	1	0	0	0	1	1	0	1	0
32 050	to	32 150	0	1	1	0	0	0	1	1	1	1	0
32 150	to	32 250	0	1	1	0	0	0	1	1	1	0	0
32 250	to	32 350	0	1	1	0	0	0	1	0	1	0	0
32 350	to	32 450	0	1	1	0	0	0	1	0	1	1	0
32 450	to	32 550	0	1	1	0	0	0	1	0	0	1	0
32 550	to	32 650	0	1	1	0	0	0	1	0	0	1	1
32 650	to	32 750	0	1	1	0	0	0	1	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)											
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
32 750 to 32 850	0	1	1	0	0	1	1	0	0	0	0	1
32 850 to 32 950	0	1	1	0	0	1	1	0	0	0	1	1
32 950 to 33 050	0	1	1	0	0	1	1	0	0	0	1	0
33 050 to 33 150	0	1	1	0	0	1	1	0	0	1	1	0
33 150 to 33 250	0	1	1	0	0	1	1	0	0	1	0	0
33 250 to 33 350	0	1	1	0	0	1	1	1	1	1	0	0
33 350 to 33 450	0	1	1	0	0	1	1	1	1	1	1	0
33 450 to 33 550	0	1	1	0	0	1	1	1	1	0	1	0
33 550 to 33 650	0	1	1	0	0	1	1	1	1	0	1	1
33 650 to 33 750	0	1	1	0	0	1	1	1	1	0	0	1
33 750 to 33 850	0	1	1	0	0	1	0	1	1	0	0	1
33 850 to 33 950	0	1	1	0	0	1	0	1	1	0	1	1
33 950 to 34 050	0	1	1	0	0	1	0	1	1	0	1	0
34 050 to 34 150	0	1	1	0	0	1	0	1	1	1	1	0
34 150 to 34 250	0	1	1	0	0	1	0	1	1	1	0	0
34 250 to 34 350	0	1	1	0	0	1	0	0	1	0	0	0
34 350 to 34 450	0	1	1	0	0	1	0	0	1	1	1	0
34 450 to 34 550	0	1	1	0	0	1	0	0	0	0	1	0
34 550 to 34 650	0	1	1	0	0	1	0	0	0	0	1	1
34 650 to 34 750	0	1	1	0	0	1	0	0	0	0	0	1
34 750 to 34 850	0	1	1	0	1	1	0	0	0	0	0	1
34 850 to 34 950	0	1	1	0	1	1	0	0	0	0	1	1
34 950 to 35 050	0	1	1	0	1	1	0	0	0	0	1	0
35 050 to 35 150	0	1	1	0	1	1	0	0	0	1	1	0
35 150 to 35 250	0	1	1	0	1	1	0	0	0	1	0	0
35 250 to 35 350	0	1	1	0	1	1	0	1	1	1	0	0
35 350 to 35 450	0	1	1	0	1	1	0	1	1	1	1	0
35 450 to 35 550	0	1	1	0	1	1	0	1	1	0	1	0
35 550 to 35 650	0	1	1	0	1	1	0	1	1	0	1	1
35 650 to 35 750	0	1	1	0	1	1	0	1	1	0	0	1
35 750 to 35 850	0	1	1	0	1	1	1	1	1	0	0	1
35 850 to 35 950	0	1	1	0	1	1	1	1	1	0	1	1
35 950 to 36 050	0	1	1	0	1	1	1	1	1	0	1	0
36 050 to 36 150	0	1	1	0	1	1	1	1	1	1	1	0
36 150 to 36 250	0	1	1	0	1	1	1	1	1	1	0	0
36 250 to 36 350	0	1	1	0	1	1	1	0	1	0	0	0
36 350 to 36 450	0	1	1	0	1	1	1	0	1	1	1	0
36 450 to 36 550	0	1	1	0	1	1	1	0	0	0	1	0
36 550 to 36 650	0	1	1	0	1	1	1	0	0	0	1	1
36 650 to 36 750	0	1	1	0	1	1	1	0	0	0	0	1
36 750 to 36 850	0	1	1	0	1	0	1	0	0	0	0	1
36 850 to 36 950	0	1	1	0	1	0	1	0	0	0	1	1
36 950 to 37 050	0	1	1	0	1	0	1	0	0	0	1	0
37 050 to 37 150	0	1	1	0	1	0	1	0	0	1	1	0
37 150 to 37 250	0	1	1	0	1	0	1	0	0	1	0	0
37 250 to 37 350	0	1	1	0	1	0	1	1	1	1	0	0
37 350 to 37 450	0	1	1	0	1	0	1	1	1	1	1	0
37 450 to 37 550	0	1	1	0	1	0	1	1	1	0	1	0
37 550 to 37 650	0	1	1	0	1	0	1	1	1	0	1	1
37 650 to 37 750	0	1	1	0	1	0	1	1	1	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
37 750 to 37 850			0	1	1	0	1	0	0	1	0	0	1
37 850 to 37 950			0	1	1	0	1	0	0	1	0	1	1
37 950 to 38 050			0	1	1	0	1	0	0	1	0	1	0
38 050 to 38 150			0	1	1	0	1	0	0	1	1	1	0
38 150 to 38 250			0	1	1	0	1	0	0	1	1	0	0
38 250 to 38 350			0	1	1	0	1	0	0	0	1	0	0
38 350 to 38 450			0	1	1	0	1	0	0	0	1	1	0
38 450 to 38 550			0	1	1	0	1	0	0	0	0	1	0
38 550 to 38 650			0	1	1	0	1	0	0	0	0	1	1
38 650 to 38 750			0	1	1	0	1	0	0	0	0	0	1
38 750 to 38 850			0	1	1	1	1	0	0	0	0	0	1
38 850 to 38 950			0	1	1	1	1	0	0	0	0	1	1
38 950 to 39 050			0	1	1	1	1	0	0	0	0	1	0
39 050 to 39 150			0	1	1	1	1	0	0	0	1	1	0
39 150 to 39 250			0	1	1	1	1	0	0	0	1	0	0
39 250 to 39 350			0	1	1	1	1	0	0	1	1	0	0
39 350 to 39 450			0	1	1	1	1	0	0	1	1	1	0
39 450 to 39 550			0	1	1	1	1	0	0	1	0	1	0
39 550 to 39 650			0	1	1	1	1	0	0	1	0	1	1
39 650 to 39 750			0	1	1	1	1	0	0	1	0	0	1
39 750 to 39 850			0	1	1	1	1	0	1	1	0	0	1
39 850 to 39 950			0	1	1	1	1	0	1	1	0	1	1
39 950 to 40 050			0	1	1	1	1	0	1	1	0	1	0
40 050 to 40 150			0	1	1	1	1	0	1	1	1	1	0
40 150 to 40 250			0	1	1	1	1	0	1	1	1	0	0
40 250 to 40 350			0	1	1	1	1	0	1	0	1	0	0
40 350 to 40 450			0	1	1	1	1	0	1	0	1	1	0
40 450 to 40 550			0	1	1	1	1	0	1	0	0	1	0
40 550 to 40 650			0	1	1	1	1	0	1	0	0	1	1
40 650 to 40 750			0	1	1	1	1	0	1	0	0	0	1
40 750 to 40 850			0	1	1	1	1	1	1	0	0	0	1
40 850 to 40 950			0	1	1	1	1	1	1	0	0	1	1
40 950 to 41 050			0	1	1	1	1	1	1	0	0	1	0
41 050 to 41 150			0	1	1	1	1	1	1	0	1	1	0
41 150 to 41 250			0	1	1	1	1	1	1	0	1	0	0
41 250 to 41 350			0	1	1	1	1	1	1	1	1	0	0
41 350 to 41 450			0	1	1	1	1	1	1	1	1	1	0
41 450 to 41 550			0	1	1	1	1	1	1	1	0	1	0
41 550 to 41 650			0	1	1	1	1	1	1	1	0	1	1
41 650 to 41 750			0	1	1	1	1	1	1	1	0	0	1
41 750 to 41 850			0	1	1	1	1	1	0	1	0	0	1
41 850 to 41 950			0	1	1	1	1	1	0	1	0	1	1
41 950 to 42 050			0	1	1	1	1	1	0	1	0	1	0
42 050 to 42 150			0	1	1	1	1	1	0	1	1	1	0
42 150 to 42 250			0	1	1	1	1	1	0	1	1	0	0
42 250 to 42 350			0	1	1	1	1	1	0	0	1	0	0
42 350 to 42 450			0	1	1	1	1	1	0	0	1	1	0
42 450 to 42 550			0	1	1	1	1	1	0	0	0	1	0
42 550 to 42 650			0	1	1	1	1	1	0	0	0	1	1
42 650 to 42 750			0	1	1	1	1	1	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)													
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
42 750 to 42 850	0	1	1	1	0	1	0	0	0	0	0	0	0	1
42 850 to 42 950	0	1	1	1	0	1	0	0	0	0	0	0	1	1
42 950 to 43 050	0	1	1	1	0	1	0	0	0	0	0	0	1	0
43 050 to 43 150	0	1	1	1	0	1	0	0	0	0	1	1	1	0
43 150 to 43 250	0	1	1	1	0	1	0	0	0	0	1	0	0	0
43 250 to 43 350	0	1	1	1	0	1	0	1	0	1	1	0	0	0
43 350 to 43 450	0	1	1	1	0	1	0	1	0	1	1	1	1	0
43 450 to 43 550	0	1	1	1	0	1	0	1	0	1	0	1	0	0
43 550 to 43 650	0	1	1	1	0	1	0	1	0	1	0	1	1	1
43 650 to 43 750	0	1	1	1	0	1	0	1	0	1	0	0	0	1
43 750 to 43 850	0	1	1	1	0	1	1	1	1	1	0	0	0	1
43 850 to 43 950	0	1	1	1	0	1	1	1	1	1	0	1	1	1
43 950 to 44 050	0	1	1	1	0	1	1	1	1	1	0	1	0	0
44 050 to 44 150	0	1	1	1	0	1	1	1	1	1	1	1	1	0
44 150 to 44 250	0	1	1	1	0	1	1	1	1	1	1	0	0	0
44 250 to 44 350	0	1	1	1	0	1	1	0	0	0	1	0	0	0
44 350 to 44 450	0	1	1	1	0	1	1	0	0	0	1	1	1	0
44 450 to 44 550	0	1	1	1	0	1	1	0	0	0	0	1	0	0
44 550 to 44 650	0	1	1	1	0	1	1	0	0	0	0	1	1	1
44 650 to 44 750	0	1	1	1	0	1	1	0	0	0	0	0	0	1
44 750 to 44 850	0	1	1	1	0	0	1	0	0	0	0	0	0	1
44 850 to 44 950	0	1	1	1	0	0	1	0	0	0	0	1	1	1
44 950 to 45 050	0	1	1	1	0	0	1	0	0	0	0	1	0	0
45 050 to 45 150	0	1	1	1	0	0	1	0	0	0	1	1	1	0
45 150 to 45 250	0	1	1	1	0	0	1	0	0	0	1	0	0	0
45 250 to 45 350	0	1	1	1	0	0	1	1	1	1	1	0	0	0
45 350 to 45 450	0	1	1	1	0	0	1	1	1	1	1	1	1	0
45 450 to 45 550	0	1	1	1	0	0	1	1	1	1	0	1	0	0
45 550 to 45 650	0	1	1	1	0	0	1	1	1	1	0	1	1	1
45 650 to 45 750	0	1	1	1	0	0	1	1	1	1	0	0	0	1
45 750 to 45 850	0	1	1	1	0	0	0	0	1	0	0	0	0	1
45 850 to 45 950	0	1	1	1	0	0	0	0	1	0	0	1	1	1
45 950 to 46 050	0	1	1	1	0	0	0	0	1	0	0	1	0	0
46 050 to 46 150	0	1	1	1	0	0	0	0	1	0	1	1	1	0
46 150 to 46 250	0	1	1	1	0	0	0	0	1	0	1	0	0	0
46 250 to 46 350	0	1	1	1	0	0	0	0	0	0	1	0	0	0
46 350 to 46 450	0	1	1	1	0	0	0	0	0	0	1	1	1	0
46 450 to 46 550	0	1	1	1	0	0	0	0	0	0	0	1	0	0
46 550 to 46 650	0	1	1	1	0	0	0	0	0	0	0	1	1	1
46 650 to 46 750	0	1	1	1	0	0	0	0	0	0	0	0	0	1
46 750 to 46 850	0	1	0	1	0	0	0	0	0	0	0	0	0	1
46 850 to 46 950	0	1	0	1	0	0	0	0	0	0	0	1	1	1
46 950 to 47 050	0	1	0	1	0	0	0	0	0	0	0	1	0	0
47 050 to 47 150	0	1	0	1	0	0	0	0	0	0	1	1	1	0
47 150 to 47 250	0	1	0	1	0	0	0	0	0	0	1	0	0	0
47 250 to 47 350	0	1	0	1	0	0	0	0	1	0	1	0	0	0
47 350 to 47 450	0	1	0	1	0	0	0	0	1	0	1	1	1	0
47 450 to 47 550	0	1	0	1	0	0	0	0	1	0	0	1	0	0
47 550 to 47 650	0	1	0	1	0	0	0	0	1	0	0	1	1	1
47 650 to 47 750	0	1	0	1	0	0	0	0	1	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)														
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄	
47 750 to 47 850	0	1	0	1	0	0	1	1	0	0	1	1	0	0	1
47 850 to 47 950	0	1	0	1	0	0	1	1	0	0	1	1	0	1	1
47 950 to 48 050	0	1	0	1	0	0	1	1	0	0	1	1	0	1	0
48 050 to 48 150	0	1	0	1	0	0	1	1	0	0	1	1	1	1	0
48 150 to 48 250	0	1	0	1	0	0	1	1	0	0	1	1	1	0	0
48 250 to 48 350	0	1	0	1	0	0	1	0	0	1	0	0	1	0	0
48 350 to 48 450	0	1	0	1	0	0	1	0	0	1	0	1	1	1	0
48 450 to 48 550	0	1	0	1	0	0	1	0	0	1	0	0	1	1	0
48 550 to 48 650	0	1	0	1	0	0	1	0	0	1	0	0	1	1	1
48 650 to 48 750	0	1	0	1	0	0	1	0	0	1	0	0	0	0	1
48 750 to 48 850	0	1	0	1	0	1	1	1	0	1	1	0	0	0	1
48 850 to 48 950	0	1	0	1	0	1	1	1	0	1	1	0	0	1	1
48 950 to 49 050	0	1	0	1	0	1	1	1	0	1	1	0	0	1	0
49 050 to 49 150	0	1	0	1	0	1	1	1	0	1	1	0	1	1	0
49 150 to 49 250	0	1	0	1	0	1	1	1	0	1	1	0	1	0	0
49 250 to 49 350	0	1	0	1	0	1	1	1	1	1	1	1	1	0	0
49 350 to 49 450	0	1	0	1	0	1	1	1	1	1	1	1	1	1	0
49 450 to 49 550	0	1	0	1	0	1	1	1	1	1	1	0	1	1	0
49 550 to 49 650	0	1	0	1	0	1	1	1	1	1	1	0	1	1	1
49 650 to 49 750	0	1	0	1	0	1	1	1	1	1	1	0	0	0	1
49 750 to 49 850	0	1	0	1	0	1	0	1	0	1	0	0	0	0	1
49 850 to 49 950	0	1	0	1	0	1	0	1	0	1	0	1	0	1	1
49 950 to 50 050	0	1	0	1	0	1	0	1	0	1	0	1	0	1	0
50 050 to 50 150	0	1	0	1	0	1	0	1	0	1	0	1	1	1	0
50 150 to 50 250	0	1	0	1	0	1	0	1	0	1	0	1	1	0	0
50 250 to 50 350	0	1	0	1	0	1	0	1	0	0	0	1	0	0	0
50 350 to 50 450	0	1	0	1	0	1	0	1	0	0	0	1	1	1	0
50 450 to 50 550	0	1	0	1	0	1	0	1	0	0	0	0	1	1	0
50 550 to 50 650	0	1	0	1	0	1	0	1	0	0	0	0	1	1	1
50 650 to 50 750	0	1	0	1	0	1	0	1	0	0	0	0	0	0	1
50 750 to 50 850	0	1	0	1	1	1	1	0	0	0	0	0	0	0	1
50 850 to 50 950	0	1	0	1	1	1	1	0	0	0	0	0	1	1	1
50 950 to 51 050	0	1	0	1	1	1	1	0	0	0	0	0	1	1	0
51 050 to 51 150	0	1	0	1	1	1	1	0	0	0	1	1	1	1	0
51 150 to 51 250	0	1	0	1	1	1	1	0	0	0	1	0	0	0	0
51 250 to 51 350	0	1	0	1	1	1	1	0	1	1	1	0	0	0	0
51 350 to 51 450	0	1	0	1	1	1	1	0	1	1	1	1	1	1	0
51 450 to 51 550	0	1	0	1	1	1	1	0	1	1	0	1	0	1	0
51 550 to 51 650	0	1	0	1	1	1	1	0	1	1	0	1	0	1	1
51 650 to 51 750	0	1	0	1	1	1	1	0	1	1	0	0	0	0	1
51 750 to 51 850	0	1	0	1	1	1	1	1	1	1	1	0	0	0	1
51 850 to 51 950	0	1	0	1	1	1	1	1	1	1	1	0	1	1	1
51 950 to 52 050	0	1	0	1	1	1	1	1	1	1	1	0	1	1	0
52 050 to 52 150	0	1	0	1	1	1	1	1	1	1	1	1	1	1	0
52 150 to 52 250	0	1	0	1	1	1	1	1	1	1	1	1	1	0	0
52 250 to 52 350	0	1	0	1	1	1	1	1	0	0	1	0	0	0	0
52 350 to 52 450	0	1	0	1	1	1	1	1	0	0	1	1	1	1	0
52 450 to 52 550	0	1	0	1	1	1	1	1	0	0	0	1	1	1	0
52 550 to 52 650	0	1	0	1	1	1	1	1	0	0	0	1	1	1	1
52 650 to 52 750	0	1	0	1	1	1	1	1	0	0	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
52 750 to 52 850			0	1	0	1	1	0	1	0	0	0	1
52 850 to 52 950			0	1	0	1	1	0	1	0	0	1	1
52 950 to 53 050			0	1	0	1	1	0	1	0	0	1	0
53 050 to 53 150			0	1	0	1	1	0	1	0	1	1	0
53 150 to 53 250			0	1	0	1	1	0	1	0	1	0	0
53 250 to 53 350			0	1	0	1	1	0	1	1	1	0	0
53 350 to 53 450			0	1	0	1	1	0	1	1	1	1	0
53 450 to 53 550			0	1	0	1	1	0	1	1	0	1	0
53 550 to 53 650			0	1	0	1	1	0	1	1	0	1	1
53 650 to 53 750			0	1	0	1	1	0	1	1	0	0	1
53 750 to 53 850			0	1	0	1	1	0	0	1	0	0	1
53 850 to 53 950			0	1	0	1	1	0	0	1	0	1	1
53 950 to 54 050			0	1	0	1	1	0	0	1	0	1	0
54 050 to 54 150			0	1	0	1	1	0	0	1	1	1	0
54 150 to 54 250			0	1	0	1	1	0	0	1	1	0	0
54 250 to 54 350			0	1	0	1	1	0	0	0	1	0	0
54 350 to 54 450			0	1	0	1	1	0	0	0	1	1	0
54 450 to 54 550			0	1	0	1	1	0	0	0	0	1	0
54 550 to 54 650			0	1	0	1	1	0	0	0	0	1	1
54 650 to 54 750			0	1	0	1	1	0	0	0	0	0	1
54 750 to 54 850			0	1	0	0	1	0	0	0	0	0	1
54 850 to 54 950			0	1	0	0	1	0	0	0	0	1	1
54 950 to 55 050			0	1	0	0	1	0	0	0	0	1	0
55 050 to 55 150			0	1	0	0	1	0	0	0	1	1	0
55 150 to 55 250			0	1	0	0	1	0	0	0	1	0	0
55 250 to 55 350			0	1	0	0	1	0	0	1	1	0	0
55 350 to 55 450			0	1	0	0	1	0	0	1	1	1	0
55 450 to 55 550			0	1	0	0	1	0	0	1	0	1	0
55 550 to 55 650			0	1	0	0	1	0	0	1	0	1	1
55 650 to 55 750			0	1	0	0	1	0	0	1	0	0	1
55 750 to 55 850			0	1	0	0	1	0	1	1	0	0	1
55 850 to 55 950			0	1	0	0	1	0	1	1	0	1	1
55 950 to 56 050			0	1	0	0	1	0	1	1	0	1	0
56 050 to 56 150			0	1	0	0	1	0	1	1	1	1	0
56 150 to 56 250			0	1	0	0	1	0	1	1	1	0	0
56 250 to 56 350			0	1	0	0	1	0	1	0	1	0	0
56 350 to 56 450			0	1	0	0	1	0	1	0	1	1	0
56 450 to 56 550			0	1	0	0	1	0	1	0	0	1	0
56 550 to 56 650			0	1	0	0	1	0	1	0	0	1	1
56 650 to 56 750			0	1	0	0	1	0	1	0	0	0	1
56 750 to 56 850			0	1	0	0	1	1	1	0	0	0	1
56 850 to 56 950			0	1	0	0	1	1	1	0	0	1	1
56 950 to 57 050			0	1	0	0	1	1	1	0	0	1	0
57 050 to 57 150			0	1	0	0	1	1	1	0	1	1	0
57 150 to 57 250			0	1	0	0	1	1	1	0	1	0	0
57 250 to 57 350			0	1	0	0	1	1	1	1	1	0	0
57 350 to 57 450			0	1	0	0	1	1	1	1	1	1	0
57 450 to 57 550			0	1	0	0	1	1	1	1	0	1	0
57 550 to 57 650			0	1	0	0	1	1	1	1	0	1	1
57 650 to 57 750			0	1	0	0	1	1	1	1	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)											
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
57 750 to 57 850	0	1	0	0	1	1	0	1	0	0	0	1
57 850 to 57 950	0	1	0	0	1	1	0	1	0	0	1	1
57 950 to 58 050	0	1	0	0	1	1	0	1	0	0	1	0
58 050 to 58 150	0	1	0	0	1	1	0	1	0	1	1	0
58 150 to 58 250	0	1	0	0	1	1	0	1	0	1	0	0
58 250 to 58 350	0	1	0	0	1	1	0	0	0	1	0	0
58 350 to 58 450	0	1	0	0	1	1	0	0	0	1	1	0
58 450 to 58 550	0	1	0	0	1	1	0	0	0	0	1	0
58 550 to 58 650	0	1	0	0	1	1	0	0	0	0	1	1
58 650 to 58 750	0	1	0	0	1	1	0	0	0	0	0	1
58 750 to 58 850	0	1	0	0	0	1	0	0	0	0	0	1
58 850 to 58 950	0	1	0	0	0	1	0	0	0	0	1	1
58 950 to 59 050	0	1	0	0	0	1	0	0	0	0	1	0
59 050 to 59 150	0	1	0	0	0	1	0	0	0	1	1	0
59 150 to 59 250	0	1	0	0	0	1	0	0	0	1	0	0
59 250 to 59 350	0	1	0	0	0	1	0	1	0	1	0	0
59 350 to 59 450	0	1	0	0	0	1	0	1	0	1	1	0
59 450 to 59 550	0	1	0	0	0	1	0	1	0	0	1	0
59 550 to 59 650	0	1	0	0	0	1	0	1	0	0	1	1
59 650 to 59 750	0	1	0	0	0	1	0	1	0	0	0	1
59 750 to 59 850	0	1	0	0	0	1	1	1	1	0	0	1
59 850 to 59 950	0	1	0	0	0	1	1	1	1	0	1	1
59 950 to 60 050	0	1	0	0	0	1	1	1	1	0	1	0
60 050 to 60 150	0	1	0	0	0	1	1	1	1	1	1	0
60 150 to 60 250	0	1	0	0	0	1	1	1	1	1	0	0
60 250 to 60 350	0	1	0	0	0	1	1	0	0	1	0	0
60 350 to 60 450	0	1	0	0	0	1	1	0	0	1	1	0
60 450 to 60 550	0	1	0	0	0	1	1	0	0	0	1	0
60 550 to 60 650	0	1	0	0	0	1	1	0	0	0	1	1
60 650 to 60 750	0	1	0	0	0	1	1	0	0	0	0	1
60 750 to 60 850	0	1	0	0	0	0	1	0	0	0	0	1
60 850 to 60 950	0	1	0	0	0	0	1	0	0	0	1	1
60 950 to 61 050	0	1	0	0	0	0	1	0	0	0	1	0
61 050 to 61 150	0	1	0	0	0	0	1	0	0	1	1	0
61 150 to 61 250	0	1	0	0	0	0	1	0	0	1	0	0
61 250 to 61 350	0	1	0	0	0	0	1	1	0	1	0	0
61 350 to 61 450	0	1	0	0	0	0	1	1	0	1	1	0
61 450 to 61 550	0	1	0	0	0	0	1	1	0	0	1	0
61 550 to 61 650	0	1	0	0	0	0	1	1	0	0	1	1
61 650 to 61 750	0	1	0	0	0	0	1	1	0	0	0	1
61 750 to 61 850	0	1	0	0	0	0	0	1	0	0	0	1
61 850 to 61 950	0	1	0	0	0	0	0	1	0	0	1	1
61 950 to 62 050	0	1	0	0	0	0	0	1	0	0	1	0
62 050 to 62 150	0	1	0	0	0	0	0	1	1	1	1	0
62 150 to 62 250	0	1	0	0	0	0	0	1	1	1	0	0
62 250 to 62 350	0	1	0	0	0	0	0	0	0	1	0	0
62 350 to 62 450	0	1	0	0	0	0	0	0	0	1	1	0
62 450 to 62 550	0	1	0	0	0	0	0	0	0	0	1	0
62 550 to 62 650	0	1	0	0	0	0	0	0	0	0	1	1
62 650 to 62 750	0	1	0	0	0	0	0	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
62 750 to 62 850			1	1	0	0	0	0	0	0	0	0	1
62 850 to 62 950			1	1	0	0	0	0	0	0	0	1	1
62 950 to 63 050			1	1	0	0	0	0	0	0	0	1	0
63 050 to 63 150			1	1	0	0	0	0	0	0	1	1	0
63 150 to 63 250			1	1	0	0	0	0	0	0	1	0	0
63 250 to 63 350			1	1	0	0	0	0	0	1	1	0	0
63 350 to 63 450			1	1	0	0	0	0	0	1	1	1	0
63 450 to 63 550			1	1	0	0	0	0	0	1	0	1	0
63 550 to 63 650			1	1	0	0	0	0	0	1	0	1	1
63 650 to 63 750			1	1	0	0	0	0	0	1	0	0	1
63 750 to 63 850			1	1	0	0	0	0	1	1	0	0	1
63 850 to 63 950			1	1	0	0	0	0	1	1	0	1	1
63 950 to 64 050			1	1	0	0	0	0	1	1	0	1	0
64 050 to 64 150			1	1	0	0	0	0	1	1	1	1	0
64 150 to 64 250			1	1	0	0	0	0	1	1	1	0	0
64 250 to 64 350			1	1	0	0	0	0	1	0	1	0	0
64 350 to 64 450			1	1	0	0	0	0	1	0	1	1	0
64 450 to 64 550			1	1	0	0	0	0	1	0	0	1	0
64 550 to 64 650			1	1	0	0	0	0	1	0	0	1	1
64 650 to 64 750			1	1	0	0	0	0	1	0	0	0	1
64 750 to 64 850			1	1	0	0	0	1	1	0	0	0	1
64 850 to 64 950			1	1	0	0	0	1	1	0	0	1	1
64 950 to 65 050			1	1	0	0	0	1	1	0	0	1	0
65 050 to 65 150			1	1	0	0	0	1	1	0	1	1	0
65 150 to 65 250			1	1	0	0	0	1	1	0	1	0	0
65 250 to 65 350			1	1	0	0	0	1	1	1	1	0	0
65 350 to 65 450			1	1	0	0	0	1	1	1	1	1	0
65 450 to 65 550			1	1	0	0	0	1	1	1	0	1	0
65 550 to 65 650			1	1	0	0	0	1	1	1	0	1	1
65 650 to 65 750			1	1	0	0	0	1	1	1	0	0	1
65 750 to 65 850			1	1	0	0	0	1	0	1	0	0	1
65 850 to 65 950			1	1	0	0	0	1	0	1	0	1	1
65 950 to 66 050			1	1	0	0	0	1	0	1	0	1	0
66 050 to 66 150			1	1	0	0	0	1	0	1	1	1	0
66 150 to 66 250			1	1	0	0	0	1	0	1	1	0	0
66 250 to 66 350			1	1	0	0	0	1	0	0	1	0	0
66 350 to 66 450			1	1	0	0	0	1	0	0	1	1	0
66 450 to 66 550			1	1	0	0	0	1	0	0	0	1	0
66 550 to 66 650			1	1	0	0	0	1	0	0	0	1	1
66 650 to 66 750			1	1	0	0	0	1	0	0	0	0	1
66 750 to 66 850			1	1	0	0	1	1	0	0	0	0	1
66 850 to 66 950			1	1	0	0	1	1	0	0	0	1	1
66 950 to 67 050			1	1	0	0	1	1	0	0	0	1	0
67 050 to 67 150			1	1	0	0	1	1	0	0	1	1	0
67 150 to 67 250			1	1	0	0	1	1	0	0	1	0	0
67 250 to 67 350			1	1	0	0	1	1	0	1	1	0	0
67 350 to 67 450			1	1	0	0	1	1	0	1	1	1	0
67 450 to 67 550			1	1	0	0	1	1	0	1	0	1	0
67 550 to 67 650			1	1	0	0	1	1	0	1	0	1	1
67 650 to 67 750			1	1	0	0	1	1	0	1	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
67 750 to 67 850			1	1	0	0	1	1	1	1	0	0	1
67 850 to 67 950			1	1	0	0	1	1	1	1	0	1	1
67 950 to 68 050			1	1	0	0	1	1	1	1	0	1	0
68 050 to 68 150			1	1	0	0	1	1	1	1	1	1	0
68 150 to 68 250			1	1	0	0	1	1	1	1	1	0	0
68 250 to 68 350			1	1	0	0	1	1	1	0	1	0	0
68 350 to 68 450			1	1	0	0	1	1	1	0	1	1	0
68 450 to 68 550			1	1	0	0	1	1	1	0	0	1	0
68 550 to 68 650			1	1	0	0	1	1	1	0	0	1	1
68 650 to 68 750			1	1	0	0	1	1	1	0	0	0	1
68 750 to 68 850			1	1	0	0	1	0	1	0	0	0	1
68 850 to 68 950			1	1	0	0	1	0	1	0	0	1	1
68 950 to 69 050			1	1	0	0	1	0	1	0	0	1	0
69 050 to 69 150			1	1	0	0	1	0	1	0	1	1	0
69 150 to 69 250			1	1	0	0	1	0	1	0	1	0	0
69 250 to 69 350			1	1	0	0	1	0	1	1	1	0	0
69 350 to 69 450			1	1	0	0	1	0	1	1	1	1	0
69 450 to 69 550			1	1	0	0	1	0	1	1	0	1	0
69 550 to 69 650			1	1	0	0	1	0	1	1	0	1	1
69 650 to 69 750			1	1	0	0	1	0	1	1	0	0	1
69 750 to 69 850			1	1	0	0	1	0	0	1	0	0	1
69 850 to 69 950			1	1	0	0	1	0	0	1	0	1	1
69 950 to 70 050			1	1	0	0	1	0	0	1	0	1	0
70 050 to 70 150			1	1	0	0	1	0	0	1	1	1	0
70 150 to 70 250			1	1	0	0	1	0	0	1	1	0	0
70 250 to 70 350			1	1	0	0	1	0	0	0	1	0	0
70 350 to 70 450			1	1	0	0	1	0	0	0	1	1	0
70 450 to 70 550			1	1	0	0	1	0	0	0	0	1	0
70 550 to 70 650			1	1	0	0	1	0	0	0	0	1	1
70 650 to 70 750			1	1	0	0	1	0	0	0	0	0	1
70 750 to 70 850			1	1	0	1	1	0	0	0	0	0	1
70 850 to 70 950			1	1	0	1	1	0	0	0	0	1	1
70 950 to 71 050			1	1	0	1	1	0	0	0	0	1	0
71 050 to 71 150			1	1	0	1	1	0	0	0	1	1	0
71 150 to 71 250			1	1	0	1	1	0	0	0	1	0	0
71 250 to 71 350			1	1	0	1	1	0	0	1	1	0	0
71 350 to 71 450			1	1	0	1	1	0	0	1	1	1	0
71 450 to 71 550			1	1	0	1	1	0	0	1	0	1	0
71 550 to 71 650			1	1	0	1	1	0	0	1	0	1	1
71 650 to 71 750			1	1	0	1	1	0	0	1	0	0	1
71 750 to 71 850			1	1	0	1	1	0	1	1	0	0	1
71 850 to 71 950			1	1	0	1	1	0	1	1	0	1	1
71 950 to 72 050			1	1	0	1	1	0	1	1	0	1	0
72 050 to 72 150			1	1	0	1	1	0	1	1	1	1	0
72 150 to 72 250			1	1	0	1	1	0	1	1	1	0	0
72 250 to 72 350			1	1	0	1	1	0	1	0	1	0	0
72 350 to 72 450			1	1	0	1	1	0	1	0	1	1	0
72 450 to 72 550			1	1	0	1	1	0	1	0	0	1	0
72 550 to 72 650			1	1	0	1	1	0	1	0	0	1	1
72 650 to 72 750			1	1	0	1	1	0	1	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
72 750 to 72 850	1	1	0	1	1	1	1	0	0	0	0	0	1
72 850 to 72 950	1	1	0	1	1	1	1	0	0	1	1	1	1
72 950 to 73 050	1	1	0	1	1	1	1	0	0	1	1	0	0
73 050 to 73 150	1	1	0	1	1	1	1	0	1	1	1	0	0
73 150 to 73 250	1	1	0	1	1	1	1	0	1	1	0	0	0
73 250 to 73 350	1	1	0	1	1	1	1	1	1	1	1	0	0
73 350 to 73 450	1	1	0	1	1	1	1	1	1	1	1	1	0
73 450 to 73 550	1	1	0	1	1	1	1	1	1	1	0	1	0
73 550 to 73 650	1	1	0	1	1	1	1	1	1	1	0	1	1
73 650 to 73 750	1	1	0	1	1	1	1	1	1	1	0	0	1
73 750 to 73 850	1	1	0	1	1	1	0	1	0	0	0	0	1
73 850 to 73 950	1	1	0	1	1	1	0	1	0	1	0	1	1
73 950 to 74 050	1	1	0	1	1	1	0	1	0	1	0	1	0
74 050 to 74 150	1	1	0	1	1	1	0	1	0	1	1	1	0
74 150 to 74 250	1	1	0	1	1	1	0	1	0	1	1	0	0
74 250 to 74 350	1	1	0	1	1	1	0	0	0	0	1	0	0
74 350 to 74 450	1	1	0	1	1	1	0	0	0	1	1	1	0
74 450 to 74 550	1	1	0	1	1	1	0	0	0	0	1	0	0
74 550 to 74 650	1	1	0	1	1	1	0	0	0	0	1	1	1
74 650 to 74 750	1	1	0	1	1	1	0	0	0	0	0	0	1
74 750 to 74 850	1	1	0	1	0	1	0	0	0	0	0	0	1
74 850 to 74 950	1	1	0	1	0	1	0	0	0	0	1	1	1
74 950 to 75 050	1	1	0	1	0	1	0	0	0	0	1	0	0
75 050 to 75 150	1	1	0	1	0	1	0	0	0	1	1	1	0
75 150 to 75 250	1	1	0	1	0	1	0	0	0	1	0	0	0
75 250 to 75 350	1	1	0	1	0	1	0	1	0	1	1	0	0
75 350 to 75 450	1	1	0	1	0	1	0	1	0	1	1	1	0
75 450 to 75 550	1	1	0	1	0	1	0	1	0	1	0	1	0
75 550 to 75 650	1	1	0	1	0	1	0	1	0	1	0	1	1
75 650 to 75 750	1	1	0	1	0	1	0	1	0	1	0	0	1
75 750 to 75 850	1	1	0	1	0	1	1	1	1	0	0	0	1
75 850 to 75 950	1	1	0	1	0	1	1	1	1	0	1	1	1
75 950 to 76 050	1	1	0	1	0	1	1	1	1	0	1	0	0
76 050 to 76 150	1	1	0	1	0	1	1	1	1	1	1	1	0
76 150 to 76 250	1	1	0	1	0	1	1	1	1	1	1	0	0
76 250 to 76 350	1	1	0	1	0	1	1	0	0	1	0	0	0
76 350 to 76 450	1	1	0	1	0	1	1	0	0	1	1	1	0
76 450 to 76 550	1	1	0	1	0	1	1	0	0	0	1	0	0
76 550 to 76 650	1	1	0	1	0	1	1	0	0	0	1	1	1
76 650 to 76 750	1	1	0	1	0	1	1	0	0	0	0	0	1
76 750 to 76 850	1	1	0	1	0	0	1	0	0	0	0	0	1
76 850 to 76 950	1	1	0	1	0	0	1	0	0	0	1	1	1
76 950 to 77 050	1	1	0	1	0	0	1	0	0	0	1	0	0
77 050 to 77 150	1	1	0	1	0	0	1	0	0	1	1	1	0
77 150 to 77 250	1	1	0	1	0	0	1	0	0	1	0	0	0
77 250 to 77 350	1	1	0	1	0	0	1	1	1	1	0	0	0
77 350 to 77 450	1	1	0	1	0	0	1	1	1	1	1	1	0
77 450 to 77 550	1	1	0	1	0	0	1	1	1	0	1	0	0
77 550 to 77 650	1	1	0	1	0	0	1	1	1	0	1	1	1
77 650 to 77 750	1	1	0	1	0	0	1	1	1	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)										
	Increments (Feet)	D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
77 750 to 77 850	1	1	0	1	0	0	0	1	0	0	1
77 850 to 77 950	1	1	0	1	0	0	0	1	0	1	1
77 950 to 78 050	1	1	0	1	0	0	0	1	0	1	0
78 050 to 78 150	1	1	0	1	0	0	0	1	1	1	0
78 150 to 78 250	1	1	0	1	0	0	0	1	1	0	0
78 250 to 78 350	1	1	0	1	0	0	0	0	1	0	0
78 350 to 78 450	1	1	0	1	0	0	0	0	1	1	0
78 450 to 78 550	1	1	0	1	0	0	0	0	0	1	0
78 550 to 78 650	1	1	0	1	0	0	0	0	0	1	1
78 650 to 78 750	1	1	0	1	0	0	0	0	0	0	1
78 750 to 78 850	1	1	1	1	0	0	0	0	0	0	1
78 850 to 78 950	1	1	1	1	0	0	0	0	0	1	1
78 950 to 79 050	1	1	1	1	0	0	0	0	0	1	0
79 050 to 79 150	1	1	1	1	0	0	0	0	1	1	0
79 150 to 79 250	1	1	1	1	0	0	0	0	1	0	0
79 250 to 79 350	1	1	1	1	0	0	0	1	1	0	0
79 350 to 79 450	1	1	1	1	0	0	0	1	1	1	0
79 450 to 79 550	1	1	1	1	0	0	0	1	0	1	0
79 550 to 79 650	1	1	1	1	0	0	0	1	0	1	1
79 650 to 79 750	1	1	1	1	0	0	0	1	0	0	1
79 750 to 79 850	1	1	1	1	0	0	1	1	0	0	1
79 850 to 79 950	1	1	1	1	0	0	1	1	0	1	1
79 950 to 80 050	1	1	1	1	0	0	1	1	0	1	0
80 050 to 80 150	1	1	1	1	0	0	1	1	1	1	0
80 150 to 80 250	1	1	1	1	0	0	1	1	1	0	0
80 250 to 80 350	1	1	1	1	0	0	1	0	1	0	0
80 350 to 80 450	1	1	1	1	0	0	1	0	1	1	0
80 450 to 80 550	1	1	1	1	0	0	1	0	0	1	0
80 550 to 80 650	1	1	1	1	0	0	1	0	0	1	1
80 650 to 80 750	1	1	1	1	0	0	1	0	0	0	1
80 750 to 80 850	1	1	1	1	0	1	1	0	0	0	1
80 850 to 80 950	1	1	1	1	0	1	1	0	0	1	1
80 950 to 81 050	1	1	1	1	0	1	1	0	0	1	0
81 050 to 81 150	1	1	1	1	0	1	1	0	1	1	0
81 150 to 81 250	1	1	1	1	0	1	1	0	1	0	0
81 250 to 81 350	1	1	1	1	0	1	1	1	1	0	0
81 350 to 81 450	1	1	1	1	0	1	1	1	1	1	0
81 450 to 81 550	1	1	1	1	0	1	1	1	0	1	0
81 550 to 81 650	1	1	1	1	0	1	1	1	0	1	1
81 650 to 81 750	1	1	1	1	0	1	1	1	0	0	1
81 750 to 81 850	1	1	1	1	0	1	0	1	0	0	1
81 850 to 81 950	1	1	1	1	0	1	0	1	0	1	1
81 950 to 82 050	1	1	1	1	0	1	0	1	0	1	0
82 050 to 82 150	1	1	1	1	0	1	0	1	1	1	0
82 150 to 82 250	1	1	1	1	0	1	0	1	1	0	0
82 250 to 82 350	1	1	1	1	0	1	0	0	1	0	0
82 350 to 82 450	1	1	1	1	0	1	0	0	1	1	0
82 450 to 82 550	1	1	1	1	0	1	0	0	0	1	0
82 550 to 82 650	1	1	1	1	0	1	0	0	0	1	1
82 650 to 82 750	1	1	1	1	0	1	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)													
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
82 750 to 82 850	1	1	1	1	1	1	1	1	0	0	0	0	0	1
82 850 to 82 950	1	1	1	1	1	1	1	1	0	0	0	0	1	1
82 950 to 83 050	1	1	1	1	1	1	1	1	0	0	0	0	1	0
83 050 to 83 150	1	1	1	1	1	1	1	1	0	0	1	1	1	0
83 150 to 83 250	1	1	1	1	1	1	1	1	0	0	1	0	0	0
83 250 to 83 350	1	1	1	1	1	1	1	0	1	1	1	0	0	0
83 350 to 83 450	1	1	1	1	1	1	1	0	1	1	1	1	1	0
83 450 to 83 550	1	1	1	1	1	1	1	0	1	0	1	0	1	0
83 550 to 83 650	1	1	1	1	1	1	1	0	1	0	1	0	1	1
83 650 to 83 750	1	1	1	1	1	1	1	0	1	0	1	0	0	1
83 750 to 83 850	1	1	1	1	1	1	1	1	1	1	0	0	0	1
83 850 to 83 950	1	1	1	1	1	1	1	1	1	1	0	1	1	1
83 950 to 84 050	1	1	1	1	1	1	1	1	1	1	0	1	1	0
84 050 to 84 150	1	1	1	1	1	1	1	1	1	1	1	1	1	0
84 150 to 84 250	1	1	1	1	1	1	1	1	1	1	1	1	0	0
84 250 to 84 350	1	1	1	1	1	1	1	1	0	1	1	0	0	0
84 350 to 84 450	1	1	1	1	1	1	1	1	0	1	1	1	1	0
84 450 to 84 550	1	1	1	1	1	1	1	1	0	1	0	1	0	0
84 550 to 84 650	1	1	1	1	1	1	1	1	0	1	0	1	1	1
84 650 to 84 750	1	1	1	1	1	1	1	1	0	1	0	0	0	1
84 750 to 84 850	1	1	1	1	1	1	0	1	0	0	0	0	0	1
84 850 to 84 950	1	1	1	1	1	1	0	1	0	1	0	0	1	1
84 950 to 85 050	1	1	1	1	1	1	0	1	0	1	0	0	1	0
85 050 to 85 150	1	1	1	1	1	1	0	1	0	1	1	1	1	0
85 150 to 85 250	1	1	1	1	1	1	0	1	0	1	1	0	0	0
85 250 to 85 350	1	1	1	1	1	1	0	1	1	1	1	0	0	0
85 350 to 85 450	1	1	1	1	1	1	0	1	1	1	1	1	1	0
85 450 to 85 550	1	1	1	1	1	1	0	1	1	1	0	1	0	0
85 550 to 85 650	1	1	1	1	1	1	0	1	1	1	0	1	1	1
85 650 to 85 750	1	1	1	1	1	1	0	1	1	1	0	0	0	1
85 750 to 85 850	1	1	1	1	1	1	0	0	1	0	0	0	0	1
85 850 to 85 950	1	1	1	1	1	1	0	0	1	0	0	0	1	1
85 950 to 86 050	1	1	1	1	1	1	0	0	1	0	0	0	1	0
86 050 to 86 150	1	1	1	1	1	1	0	0	1	1	1	1	1	0
86 150 to 86 250	1	1	1	1	1	1	0	0	1	1	0	0	0	0
86 250 to 86 350	1	1	1	1	1	1	0	0	0	0	1	0	0	0
86 350 to 86 450	1	1	1	1	1	1	0	0	0	0	1	1	1	0
86 450 to 86 550	1	1	1	1	1	1	0	0	0	0	0	1	0	0
86 550 to 86 650	1	1	1	1	1	1	0	0	0	0	0	1	1	1
86 650 to 86 750	1	1	1	1	1	1	0	0	0	0	0	0	0	1
86 750 to 86 850	1	1	1	0	1	0	0	0	0	0	0	0	0	1
86 850 to 86 950	1	1	1	0	1	0	0	0	0	0	0	1	1	1
86 950 to 87 050	1	1	1	0	1	0	0	0	0	0	0	1	0	0
87 050 to 87 150	1	1	1	0	1	0	0	0	0	0	1	1	1	0
87 150 to 87 250	1	1	1	0	1	0	0	0	0	0	1	0	0	0
87 250 to 87 350	1	1	1	0	1	0	0	1	1	0	0	0	0	0
87 350 to 87 450	1	1	1	0	1	0	0	1	1	1	1	1	1	0
87 450 to 87 550	1	1	1	0	1	0	0	1	0	1	0	1	0	0
87 550 to 87 650	1	1	1	0	1	0	0	1	0	1	0	1	1	1
87 650 to 87 750	1	1	1	0	1	0	0	1	0	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)											
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
87 750 to 87 850	1	1	1	0	1	0	1	1	1	0	0	1
87 850 to 87 950	1	1	1	0	1	0	1	1	1	0	1	1
87 950 to 88 050	1	1	1	0	1	0	1	1	1	0	1	0
88 050 to 88 150	1	1	1	0	1	0	1	1	1	1	1	0
88 150 to 88 250	1	1	1	0	1	0	1	1	1	1	0	0
88 250 to 88 350	1	1	1	0	1	0	1	0	0	1	0	0
88 350 to 88 450	1	1	1	0	1	0	1	0	0	1	1	0
88 450 to 88 550	1	1	1	0	1	0	1	0	0	0	1	0
88 550 to 88 650	1	1	1	0	1	0	1	0	0	0	1	1
88 650 to 88 750	1	1	1	0	1	0	1	0	0	0	0	1
88 750 to 88 850	1	1	1	0	1	1	1	1	0	0	0	1
88 850 to 88 950	1	1	1	0	1	1	1	1	0	0	1	1
88 950 to 89 050	1	1	1	0	1	1	1	1	0	0	1	0
89 050 to 89 150	1	1	1	0	1	1	1	1	0	1	1	0
89 150 to 89 250	1	1	1	0	1	1	1	1	0	1	0	0
89 250 to 89 350	1	1	1	0	1	1	1	1	1	1	0	0
89 350 to 89 450	1	1	1	0	1	1	1	1	1	1	1	0
89 450 to 89 550	1	1	1	0	1	1	1	1	1	0	1	0
89 550 to 89 650	1	1	1	0	1	1	1	1	1	0	1	1
89 650 to 89 750	1	1	1	0	1	1	1	1	1	0	0	1
89 750 to 89 850	1	1	1	0	1	1	0	1	1	0	0	1
89 850 to 89 950	1	1	1	0	1	1	0	1	1	0	1	1
89 950 to 90 050	1	1	1	0	1	1	0	1	1	0	1	0
90 050 to 90 150	1	1	1	0	1	1	0	1	1	1	1	0
90 150 to 90 250	1	1	1	0	1	1	0	1	1	1	0	0
90 250 to 90 350	1	1	1	0	1	1	0	0	0	1	0	0
90 350 to 90 450	1	1	1	0	1	1	0	0	0	1	1	0
90 450 to 90 550	1	1	1	0	1	1	0	0	0	0	1	0
90 550 to 90 650	1	1	1	0	1	1	0	0	0	0	1	1
90 650 to 90 750	1	1	1	0	1	1	0	0	0	0	0	1
90 750 to 90 850	1	1	1	0	0	1	0	0	0	0	0	1
90 850 to 90 950	1	1	1	0	0	1	0	0	0	0	1	1
90 950 to 91 050	1	1	1	0	0	1	0	0	0	0	1	0
91 050 to 91 150	1	1	1	0	0	1	0	0	0	1	1	0
91 150 to 91 250	1	1	1	0	0	1	0	0	0	1	0	0
91 250 to 91 350	1	1	1	0	0	1	0	1	1	1	0	0
91 350 to 91 450	1	1	1	0	0	1	0	1	1	1	1	0
91 450 to 91 550	1	1	1	0	0	1	0	1	1	0	1	0
91 550 to 91 650	1	1	1	0	0	1	0	1	1	0	1	1
91 650 to 91 750	1	1	1	0	0	1	0	1	1	0	0	1
91 750 to 91 850	1	1	1	0	0	1	1	1	1	0	0	1
91 850 to 91 950	1	1	1	0	0	1	1	1	1	0	1	1
91 950 to 92 050	1	1	1	0	0	1	1	1	1	0	1	0
92 050 to 92 150	1	1	1	0	0	1	1	1	1	1	1	0
92 150 to 92 250	1	1	1	0	0	1	1	1	1	1	0	0
92 250 to 92 350	1	1	1	0	0	1	1	0	0	1	0	0
92 350 to 92 450	1	1	1	0	0	1	1	0	0	1	1	0
92 450 to 92 550	1	1	1	0	0	1	1	0	0	0	1	0
92 550 to 92 650	1	1	1	0	0	1	1	0	0	0	1	1
92 650 to 92 750	1	1	1	0	0	1	1	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
92 750 to 92 850			1	1	1	0	0	0	1	0	0	0	1
92 850 to 92 950			1	1	1	0	0	0	1	0	0	1	1
92 950 to 93 050			1	1	1	0	0	0	1	0	0	1	0
93 050 to 93 150			1	1	1	0	0	0	1	0	1	1	0
93 150 to 93 250			1	1	1	0	0	0	1	0	1	0	0
93 250 to 93 350			1	1	1	0	0	0	1	1	1	0	0
93 350 to 93 450			1	1	1	0	0	0	1	1	1	1	0
93 450 to 93 550			1	1	1	0	0	0	1	1	0	1	0
93 550 to 93 650			1	1	1	0	0	0	1	1	0	1	1
93 650 to 93 750			1	1	1	0	0	0	1	1	0	0	1
93 750 to 93 850			1	1	1	0	0	0	0	1	0	0	1
93 850 to 93 950			1	1	1	0	0	0	0	1	0	1	1
93 950 to 94 050			1	1	1	0	0	0	0	1	0	1	0
94 050 to 94 150			1	1	1	0	0	0	0	1	1	1	0
94 150 to 94 250			1	1	1	0	0	0	0	1	1	0	0
94 250 to 94 350			1	1	1	0	0	0	0	0	1	0	0
94 350 to 94 450			1	1	1	0	0	0	0	0	1	1	0
94 450 to 94 550			1	1	1	0	0	0	0	0	0	1	0
94 550 to 94 650			1	1	1	0	0	0	0	0	0	1	1
94 650 to 94 750			1	1	1	0	0	0	0	0	0	0	1
94 750 to 94 850			1	0	1	0	0	0	0	0	0	0	1
94 850 to 94 950			1	0	1	0	0	0	0	0	0	1	1
94 950 to 95 050			1	0	1	0	0	0	0	0	0	1	0
95 050 to 95 150			1	0	1	0	0	0	0	0	1	1	0
95 150 to 95 250			1	0	1	0	0	0	0	0	1	0	0
95 250 to 95 350			1	0	1	0	0	0	0	1	1	0	0
95 350 to 95 450			1	0	1	0	0	0	0	1	1	1	0
95 450 to 95 550			1	0	1	0	0	0	0	1	0	1	0
95 550 to 95 650			1	0	1	0	0	0	0	1	0	1	1
95 650 to 95 750			1	0	1	0	0	0	0	1	0	0	1
95 750 to 95 850			1	0	1	0	0	0	1	1	0	0	1
95 850 to 95 950			1	0	1	0	0	0	1	1	0	1	1
95 950 to 96 050			1	0	1	0	0	0	1	1	0	1	0
96 050 to 96 150			1	0	1	0	0	0	1	1	1	1	0
96 150 to 96 250			1	0	1	0	0	0	1	1	1	0	0
96 250 to 96 350			1	0	1	0	0	0	1	0	1	0	0
96 350 to 96 450			1	0	1	0	0	0	1	0	1	1	0
96 450 to 96 550			1	0	1	0	0	0	1	0	0	1	0
96 550 to 96 650			1	0	1	0	0	0	1	0	0	1	1
96 650 to 96 750			1	0	1	0	0	0	1	0	0	0	1
96 750 to 96 850			1	0	1	0	0	1	1	0	0	0	1
96 850 to 96 950			1	0	1	0	0	1	1	0	0	1	1
96 950 to 97 050			1	0	1	0	0	1	1	0	0	1	0
97 050 to 97 150			1	0	1	0	0	1	1	0	1	1	0
97 150 to 97 250			1	0	1	0	0	1	1	0	1	0	0
97 250 to 97 350			1	0	1	0	0	1	1	1	1	0	0
97 350 to 97 450			1	0	1	0	0	1	1	1	1	1	0
97 450 to 97 550			1	0	1	0	0	1	1	1	0	1	0
97 550 to 97 650			1	0	1	0	0	1	1	1	0	1	1
97 650 to 97 750			1	0	1	0	0	1	1	1	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
97 750 to 97 850	1	0	1	0	0	1	0	1	0	1	0	0	1
97 850 to 97 950	1	0	1	0	0	1	0	1	0	1	0	1	1
97 950 to 98 050	1	0	1	0	0	1	0	1	0	1	0	1	0
98 050 to 98 150	1	0	1	0	0	1	0	1	0	1	1	1	0
98 150 to 98 250	1	0	1	0	0	1	0	1	0	1	1	0	0
98 250 to 98 350	1	0	1	0	0	1	0	0	0	0	1	0	0
98 350 to 98 450	1	0	1	0	0	1	0	0	0	0	1	1	0
98 450 to 98 550	1	0	1	0	0	1	0	0	0	0	0	1	0
98 550 to 98 650	1	0	1	0	0	1	0	0	0	0	0	1	1
98 650 to 98 750	1	0	1	0	0	1	0	0	0	0	0	0	1
98 750 to 98 850	1	0	1	0	1	1	0	0	0	0	0	0	1
98 850 to 98 950	1	0	1	0	1	1	0	0	0	0	0	1	1
98 950 to 99 050	1	0	1	0	1	1	0	0	0	0	0	1	0
99 050 to 99 150	1	0	1	0	1	1	0	0	0	0	1	1	0
99 150 to 99 250	1	0	1	0	1	1	0	0	0	0	1	0	0
99 250 to 99 350	1	0	1	0	1	1	0	1	0	1	1	0	0
99 350 to 99 450	1	0	1	0	1	1	0	1	0	1	1	1	0
99 450 to 99 550	1	0	1	0	1	1	0	1	0	1	0	1	0
99 550 to 99 650	1	0	1	0	1	1	0	1	0	1	0	1	1
99 650 to 99 750	1	0	1	0	1	1	0	1	0	1	0	0	1
99 750 to 99 850	1	0	1	0	1	1	1	1	1	1	0	0	1
99 850 to 99 950	1	0	1	0	1	1	1	1	1	1	0	1	1
99 950 to 100 050	1	0	1	0	1	1	1	1	1	1	0	1	0
100 050 to 100 150	1	0	1	0	1	1	1	1	1	1	1	1	0
100 150 to 100 250	1	0	1	0	1	1	1	1	1	1	1	0	0
100 250 to 100 350	1	0	1	0	1	1	1	0	0	0	1	0	0
100 350 to 100 450	1	0	1	0	1	1	1	0	0	0	1	1	0
100 450 to 100 550	1	0	1	0	1	1	1	0	0	0	0	1	0
100 550 to 100 650	1	0	1	0	1	1	1	0	0	0	0	1	1
100 650 to 100 750	1	0	1	0	1	1	1	0	0	0	0	0	1
100 750 to 100 850	1	0	1	0	1	0	1	0	0	0	0	0	1
100 850 to 100 950	1	0	1	0	1	0	1	0	0	0	0	1	1
100 950 to 101 050	1	0	1	0	1	0	1	0	0	0	0	1	0
101 050 to 101 150	1	0	1	0	1	0	1	0	0	0	1	1	0
101 150 to 101 250	1	0	1	0	1	0	1	0	0	0	1	0	0
101 250 to 101 350	1	0	1	0	1	0	1	1	1	1	1	0	0
101 350 to 101 450	1	0	1	0	1	0	1	1	1	1	1	1	0
101 450 to 101 550	1	0	1	0	1	0	1	1	1	1	0	1	0
101 550 to 101 650	1	0	1	0	1	0	1	1	1	1	0	1	1
101 650 to 101 750	1	0	1	0	1	0	1	1	1	1	0	0	1
101 750 to 101 850	1	0	1	0	1	0	0	0	0	0	0	0	1
101 850 to 101 950	1	0	1	0	1	0	0	0	0	0	0	1	1
101 950 to 102 050	1	0	1	0	1	0	0	0	0	0	0	1	0
102 050 to 102 150	1	0	1	0	1	0	0	0	0	0	1	1	0
102 150 to 102 250	1	0	1	0	1	0	0	0	0	0	1	0	0
102 250 to 102 350	1	0	1	0	1	0	0	0	0	0	1	0	0
102 350 to 102 450	1	0	1	0	1	0	0	0	0	0	1	1	0
102 450 to 102 550	1	0	1	0	1	0	0	0	0	0	0	1	0
102 550 to 102 650	1	0	1	0	1	0	0	0	0	0	0	1	1
102 650 to 102 750	1	0	1	0	1	0	0	0	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)													
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
102 750 to 102 850				1	0	1	1	1	0	0	0	0	0	1
102 850 to 102 950				1	0	1	1	1	0	0	0	0	1	1
102 950 to 103 050				1	0	1	1	1	0	0	0	0	1	0
103 050 to 103 150				1	0	1	1	1	0	0	0	1	1	0
103 150 to 103 250				1	0	1	1	1	0	0	0	1	0	0
103 250 to 103 350				1	0	1	1	1	0	0	1	1	0	0
103 350 to 103 450				1	0	1	1	1	0	0	1	1	1	0
103 450 to 103 550				1	0	1	1	1	0	0	1	0	1	0
103 550 to 103 650				1	0	1	1	1	0	0	1	0	1	1
103 650 to 103 750				1	0	1	1	1	0	0	1	0	0	1
103 750 to 103 850				1	0	1	1	1	0	1	1	0	0	1
103 850 to 103 950				1	0	1	1	1	0	1	1	0	1	1
103 950 to 104 050				1	0	1	1	1	0	1	1	0	1	0
104 050 to 104 150				1	0	1	1	1	0	1	1	1	1	0
104 150 to 104 250				1	0	1	1	1	0	1	1	1	0	0
104 250 to 104 350				1	0	1	1	1	0	1	0	1	0	0
104 350 to 104 450				1	0	1	1	1	0	1	0	1	1	0
104 450 to 104 550				1	0	1	1	1	0	1	0	0	1	0
104 550 to 104 650				1	0	1	1	1	0	1	0	0	1	1
104 650 to 104 750				1	0	1	1	1	0	1	0	0	0	1
104 750 to 104 850				1	0	1	1	1	1	1	0	0	0	1
104 850 to 104 950				1	0	1	1	1	1	1	0	0	1	1
104 950 to 105 050				1	0	1	1	1	1	1	0	0	1	0
105 050 to 105 150				1	0	1	1	1	1	1	0	1	1	0
105 150 to 105 250				1	0	1	1	1	1	1	0	1	0	0
105 250 to 105 350				1	0	1	1	1	1	1	1	1	0	0
105 350 to 105 450				1	0	1	1	1	1	1	1	1	1	0
105 450 to 105 550				1	0	1	1	1	1	1	1	0	1	0
105 550 to 105 650				1	0	1	1	1	1	1	1	0	1	1
105 650 to 105 750				1	0	1	1	1	1	1	1	0	0	1
105 750 to 105 850				1	0	1	1	1	1	0	1	0	0	1
105 850 to 105 950				1	0	1	1	1	1	0	1	0	1	1
105 950 to 106 050				1	0	1	1	1	1	0	1	0	1	0
106 050 to 106 150				1	0	1	1	1	1	0	1	1	1	0
106 150 to 106 250				1	0	1	1	1	1	0	1	1	0	0
106 250 to 106 350				1	0	1	1	1	1	0	0	1	0	0
106 350 to 106 450				1	0	1	1	1	1	0	0	1	1	0
106 450 to 106 550				1	0	1	1	1	1	0	0	0	1	0
106 550 to 106 650				1	0	1	1	1	1	0	0	0	1	1
106 650 to 106 750				1	0	1	1	1	1	0	0	0	0	1
106 750 to 106 850				1	0	1	1	0	1	0	0	0	0	1
106 850 to 106 950				1	0	1	1	0	1	0	0	0	1	1
106 950 to 107 050				1	0	1	1	0	1	0	0	0	1	0
107 050 to 107 150				1	0	1	1	0	1	0	0	1	1	0
107 150 to 107 250				1	0	1	1	0	1	0	0	1	0	0
107 250 to 107 350				1	0	1	1	0	1	0	1	1	0	0
107 350 to 107 450				1	0	1	1	0	1	0	1	1	1	0
107 450 to 107 550				1	0	1	1	0	1	0	1	0	1	0
107 550 to 107 650				1	0	1	1	0	1	0	1	0	1	1
107 650 to 107 750				1	0	1	1	0	1	0	1	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
107 750 to 107 850			1	0	1	1	0	1	1	1	0	0	1
107 850 to 107 950			1	0	1	1	0	1	1	1	0	1	1
107 950 to 108 050			1	0	1	1	0	1	1	1	0	1	0
108 050 to 108 150			1	0	1	1	0	1	1	1	1	1	0
108 150 to 108 250			1	0	1	1	0	1	1	1	1	0	0
108 250 to 108 350			1	0	1	1	0	1	1	0	1	0	0
108 350 to 108 450			1	0	1	1	0	1	1	0	1	1	0
108 450 to 108 550			1	0	1	1	0	1	1	0	0	1	0
108 550 to 108 650			1	0	1	1	0	1	1	0	0	1	1
108 650 to 108 750			1	0	1	1	0	1	1	0	0	0	1
108 750 to 108 850			1	0	1	1	0	0	1	0	0	0	1
108 850 to 108 950			1	0	1	1	0	0	1	0	0	1	1
108 950 to 109 050			1	0	1	1	0	0	1	0	0	1	0
109 050 to 109 150			1	0	1	1	0	0	1	0	1	1	0
109 150 to 109 250			1	0	1	1	0	0	1	0	1	0	0
109 250 to 109 350			1	0	1	1	0	0	1	1	1	0	0
109 350 to 109 450			1	0	1	1	0	0	1	1	1	1	0
109 450 to 109 550			1	0	1	1	0	0	1	1	0	1	0
109 550 to 109 650			1	0	1	1	0	0	1	1	0	1	1
109 650 to 109 750			1	0	1	1	0	0	1	1	0	0	1
109 750 to 109 850			1	0	1	1	0	0	0	1	0	0	1
109 850 to 109 950			1	0	1	1	0	0	0	1	0	1	1
109 950 to 110 050			1	0	1	1	0	0	0	1	0	1	0
110 050 to 110 150			1	0	1	1	0	0	0	1	1	1	0
110 150 to 110 250			1	0	1	1	0	0	0	1	1	0	0
110 250 to 110 350			1	0	1	1	0	0	0	0	1	0	0
110 350 to 110 450			1	0	1	1	0	0	0	0	1	1	0
110 450 to 110 550			1	0	1	1	0	0	0	0	0	1	0
110 550 to 110 650			1	0	1	1	0	0	0	0	0	1	1
110 650 to 110 750			1	0	1	1	0	0	0	0	0	0	1
110 750 to 110 850			1	0	0	1	0	0	0	0	0	0	1
110 850 to 110 950			1	0	0	1	0	0	0	0	0	1	1
110 950 to 111 050			1	0	0	1	0	0	0	0	0	1	0
111 050 to 111 150			1	0	0	1	0	0	0	0	1	1	0
111 150 to 111 250			1	0	0	1	0	0	0	0	1	0	0
111 250 to 111 350			1	0	0	1	0	0	0	1	1	0	0
111 350 to 111 450			1	0	0	1	0	0	0	1	1	1	0
111 450 to 111 550			1	0	0	1	0	0	0	1	0	1	0
111 550 to 111 650			1	0	0	1	0	0	0	1	0	1	1
111 650 to 111 750			1	0	0	1	0	0	0	1	0	0	1
111 750 to 111 850			1	0	0	1	0	0	1	1	0	0	1
111 850 to 111 950			1	0	0	1	0	0	1	1	0	1	1
111 950 to 112 050			1	0	0	1	0	0	1	1	0	1	0
112 050 to 112 150			1	0	0	1	0	0	1	1	1	1	0
112 150 to 112 250			1	0	0	1	0	0	1	1	1	0	0
112 250 to 112 350			1	0	0	1	0	0	1	0	1	0	0
112 350 to 112 450			1	0	0	1	0	0	1	0	1	1	0
112 450 to 112 550			1	0	0	1	0	0	1	0	0	1	0
112 550 to 112 650			1	0	0	1	0	0	1	0	0	1	1
112 650 to 112 750			1	0	0	1	0	0	1	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂
112 750 to 112 850	1	0	0	1	0	1	1	0	0	0	0	0	1
112 850 to 112 950	1	0	0	1	0	1	1	0	0	0	0	1	1
112 950 to 113 050	1	0	0	1	0	1	1	0	0	0	0	1	0
113 050 to 113 150	1	0	0	1	0	1	1	0	0	0	1	1	0
113 150 to 113 250	1	0	0	1	0	1	1	0	0	0	1	0	0
113 250 to 113 350	1	0	0	1	0	1	1	1	1	1	1	0	0
113 350 to 113 450	1	0	0	1	0	1	1	1	1	1	1	1	0
113 450 to 113 550	1	0	0	1	0	1	1	1	1	1	0	1	0
113 550 to 113 650	1	0	0	1	0	1	1	1	1	1	0	1	1
113 650 to 113 750	1	0	0	1	0	1	1	1	1	1	0	0	1
113 750 to 113 850	1	0	0	1	0	1	0	1	0	1	0	0	1
113 850 to 113 950	1	0	0	1	0	1	0	1	0	1	0	1	1
113 950 to 114 050	1	0	0	1	0	1	0	1	0	1	0	1	0
114 050 to 114 150	1	0	0	1	0	1	0	1	0	1	1	1	0
114 150 to 114 250	1	0	0	1	0	1	0	1	0	1	1	0	0
114 250 to 114 350	1	0	0	1	0	1	0	0	0	0	1	0	0
114 350 to 114 450	1	0	0	1	0	1	0	0	0	0	1	1	0
114 450 to 114 550	1	0	0	1	0	1	0	0	0	0	0	1	0
114 550 to 114 650	1	0	0	1	0	1	0	0	0	0	0	1	1
114 650 to 114 750	1	0	0	1	0	1	0	0	0	0	0	0	1
114 750 to 114 850	1	0	0	1	1	1	1	0	0	0	0	0	1
114 850 to 114 950	1	0	0	1	1	1	1	0	0	0	0	1	1
114 950 to 115 050	1	0	0	1	1	1	1	0	0	0	0	1	0
115 050 to 115 150	1	0	0	1	1	1	1	0	0	0	1	1	0
115 150 to 115 250	1	0	0	1	1	1	1	0	0	0	1	0	0
115 250 to 115 350	1	0	0	1	1	1	1	0	1	1	1	0	0
115 350 to 115 450	1	0	0	1	1	1	1	0	1	1	1	1	0
115 450 to 115 550	1	0	0	1	1	1	1	0	1	0	0	1	0
115 550 to 115 650	1	0	0	1	1	1	1	0	1	0	0	1	1
115 650 to 115 750	1	0	0	1	1	1	1	0	1	0	0	0	1
115 750 to 115 850	1	0	0	1	1	1	1	1	1	1	0	0	1
115 850 to 115 950	1	0	0	1	1	1	1	1	1	1	0	1	1
115 950 to 116 050	1	0	0	1	1	1	1	1	1	1	0	1	0
116 050 to 116 150	1	0	0	1	1	1	1	1	1	1	1	1	0
116 150 to 116 250	1	0	0	1	1	1	1	1	1	1	1	0	0
116 250 to 116 350	1	0	0	1	1	1	1	1	0	0	1	0	0
116 350 to 116 450	1	0	0	1	1	1	1	1	0	0	1	1	0
116 450 to 116 550	1	0	0	1	1	1	1	1	0	0	0	1	0
116 550 to 116 650	1	0	0	1	1	1	1	1	0	0	0	1	1
116 650 to 116 750	1	0	0	1	1	1	1	1	0	0	0	0	1
116 750 to 116 850	1	0	0	1	1	0	1	0	0	0	0	0	1
116 850 to 116 950	1	0	0	1	1	0	1	0	0	0	0	1	1
116 950 to 117 050	1	0	0	1	1	0	1	0	0	0	0	1	0
117 050 to 117 150	1	0	0	1	1	0	1	0	0	0	1	1	0
117 150 to 117 250	1	0	0	1	1	0	1	0	0	0	1	0	0
117 250 to 117 350	1	0	0	1	1	0	1	1	1	1	1	0	0
117 350 to 117 450	1	0	0	1	1	0	1	1	1	1	1	1	0
117 450 to 117 550	1	0	0	1	1	0	1	1	1	0	0	1	0
117 550 to 117 650	1	0	0	1	1	0	1	1	1	0	0	1	1
117 650 to 117 750	1	0	0	1	1	0	1	1	1	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)												
	Increments (Feet)		D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
117 750 to 117 850			1	0	0	1	1	0	0	1	0	0	1
117 850 to 117 950			1	0	0	1	1	0	0	1	0	1	1
117 950 to 118 050			1	0	0	1	1	0	0	1	0	1	0
118 050 to 118 150			1	0	0	1	1	0	0	1	1	1	0
118 150 to 118 250			1	0	0	1	1	0	0	1	1	0	0
118 250 to 118 350			1	0	0	1	1	0	0	0	1	0	0
118 350 to 118 450			1	0	0	1	1	0	0	0	1	1	0
118 450 to 118 550			1	0	0	1	1	0	0	0	0	1	0
118 550 to 118 650			1	0	0	1	1	0	0	0	0	1	1
118 650 to 118 750			1	0	0	1	1	0	0	0	0	0	1
118 750 to 118 850			1	0	0	0	1	0	0	0	0	0	1
118 850 to 118 950			1	0	0	0	1	0	0	0	0	1	1
118 950 to 119 050			1	0	0	0	1	0	0	0	0	1	0
119 050 to 119 150			1	0	0	0	1	0	0	0	1	1	0
119 150 to 119 250			1	0	0	0	1	0	0	0	1	0	0
119 250 to 119 350			1	0	0	0	1	0	0	1	1	0	0
119 350 to 119 450			1	0	0	0	1	0	0	1	1	1	0
119 450 to 119 550			1	0	0	0	1	0	0	1	0	1	0
119 550 to 119 650			1	0	0	0	1	0	0	1	0	1	1
119 650 to 119 750			1	0	0	0	1	0	0	1	0	0	1
119 750 to 119 850			1	0	0	0	1	0	1	1	0	0	1
119 850 to 119 950			1	0	0	0	1	0	1	1	0	1	1
119 950 to 120 050			1	0	0	0	1	0	1	1	0	1	0
120 050 to 120 150			1	0	0	0	1	0	1	1	1	1	0
120 150 to 120 250			1	0	0	0	1	0	1	1	1	0	0
120 250 to 120 350			1	0	0	0	1	0	1	0	1	0	0
120 350 to 120 450			1	0	0	0	1	0	1	0	1	1	0
120 450 to 120 550			1	0	0	0	1	0	1	0	0	1	0
120 550 to 120 650			1	0	0	0	1	0	1	0	0	1	1
120 650 to 120 750			1	0	0	0	1	0	1	0	0	0	1
120 750 to 120 850			1	0	0	0	1	1	1	0	0	0	1
120 850 to 120 950			1	0	0	0	1	1	1	0	0	1	1
120 950 to 121 050			1	0	0	0	1	1	1	0	0	1	0
121 050 to 121 150			1	0	0	0	1	1	1	0	1	1	0
121 150 to 121 250			1	0	0	0	1	1	1	0	1	0	0
121 250 to 121 350			1	0	0	0	1	1	1	1	1	0	0
121 350 to 121 450			1	0	0	0	1	1	1	1	1	1	0
121 450 to 121 550			1	0	0	0	1	1	1	1	0	1	0
121 550 to 121 650			1	0	0	0	1	1	1	1	0	1	1
121 650 to 121 750			1	0	0	0	1	1	1	1	0	0	1
121 750 to 121 850			1	0	0	0	1	1	0	1	0	0	1
121 850 to 121 950			1	0	0	0	1	1	0	1	0	1	1
121 950 to 122 050			1	0	0	0	1	1	0	1	0	1	0
122 050 to 122 150			1	0	0	0	1	1	0	1	1	1	0
122 150 to 122 250			1	0	0	0	1	1	0	1	1	0	0
122 250 to 122 350			1	0	0	0	1	1	0	0	1	0	0
122 350 to 122 450			1	0	0	0	1	1	0	0	1	1	0
122 450 to 122 550			1	0	0	0	1	1	0	0	0	1	0
122 550 to 122 650			1	0	0	0	1	1	0	0	0	1	1
122 650 to 122 750			1	0	0	0	1	1	0	0	0	0	1

RANGE	PULSE POSITIONS (0 or 1 in a pulse position denotes absence or presence of a pulse, respectively)													
	Increments (Feet)			D ₂	D ₄	A ₁	A ₂	A ₄	B ₁	B ₂	B ₄	C ₁	C ₂	C ₄
122 750 to 122 850	1	0	0	0	0	0	1	0	0	0	0	0	0	1
122 850 to 122 950	1	0	0	0	0	0	1	0	0	0	0	0	1	1
122 950 to 123 050	1	0	0	0	0	0	1	0	0	0	0	0	1	0
123 050 to 123 150	1	0	0	0	0	0	1	0	0	0	1	1	1	0
123 150 to 123 250	1	0	0	0	0	0	1	0	0	0	1	0	0	0
123 250 to 123 350	1	0	0	0	0	0	1	0	1	1	1	0	0	0
123 350 to 123 450	1	0	0	0	0	0	1	0	1	1	1	1	1	0
123 450 to 123 550	1	0	0	0	0	0	1	0	1	1	0	1	0	0
123 550 to 123 650	1	0	0	0	0	0	1	0	1	1	0	1	1	1
123 650 to 123 750	1	0	0	0	0	0	1	0	1	1	0	0	0	1
123 750 to 123 850	1	0	0	0	0	0	1	1	1	1	0	0	0	1
123 850 to 123 950	1	0	0	0	0	0	1	1	1	1	0	1	1	1
123 950 to 124 050	1	0	0	0	0	0	1	1	1	1	0	1	0	0
124 050 to 124 150	1	0	0	0	0	0	1	1	1	1	1	1	1	0
124 150 to 124 250	1	0	0	0	0	0	1	1	1	1	1	0	0	0
124 250 to 124 350	1	0	0	0	0	0	1	1	0	1	0	0	0	0
124 350 to 124 450	1	0	0	0	0	0	1	1	0	1	1	1	1	0
124 450 to 124 550	1	0	0	0	0	0	1	1	0	1	0	1	0	0
124 550 to 124 650	1	0	0	0	0	0	1	1	0	1	0	1	1	1
124 650 to 124 750	1	0	0	0	0	0	1	1	0	1	0	0	0	1
124 750 to 124 850	1	0	0	0	0	0	0	1	0	1	0	0	0	1
124 850 to 124 950	1	0	0	0	0	0	0	1	0	1	0	0	1	1
124 950 to 125 050	1	0	0	0	0	0	0	1	0	1	0	0	1	0
125 050 to 125 150	1	0	0	0	0	0	0	1	0	1	0	1	1	0
125 150 to 125 250	1	0	0	0	0	0	0	1	0	1	0	1	0	0
125 250 to 125 350	1	0	0	0	0	0	0	1	1	1	1	0	0	0
125 350 to 125 450	1	0	0	0	0	0	0	1	1	1	1	1	1	0
125 450 to 125 550	1	0	0	0	0	0	0	1	1	1	0	1	0	0
125 550 to 125 650	1	0	0	0	0	0	0	1	1	1	0	1	1	1
125 650 to 125 750	1	0	0	0	0	0	0	1	1	1	0	0	0	1
125 750 to 125 850	1	0	0	0	0	0	0	0	1	1	0	0	0	1
125 850 to 125 950	1	0	0	0	0	0	0	0	1	1	0	0	1	1
125 950 to 126 050	1	0	0	0	0	0	0	0	1	1	0	0	1	0
126 050 to 126 150	1	0	0	0	0	0	0	0	1	1	1	1	1	0
126 150 to 126 250	1	0	0	0	0	0	0	0	1	1	1	0	0	0
126 250 to 126 350	1	0	0	0	0	0	0	0	0	1	0	0	0	0
126 350 to 126 450	1	0	0	0	0	0	0	0	0	1	1	1	1	0
126 450 to 126 550	1	0	0	0	0	0	0	0	0	1	0	1	0	0
126 550 to 126 650	1	0	0	0	0	0	0	0	0	1	0	1	1	1
126 650 to 126 750	1	0	0	0	0	0	0	0	0	1	0	0	0	1