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Most of the modern noncoherent pulse transponders available today are the result of commercial development with guidance from the US government in terms of specifications or user requirements. These standards are written to accommodate the present state-of-the-art technology in both the radar and the transponder fields.

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ELECTRONIC TRAJECTORY MEASUREMENTS GROUP

NONCOHERENT TRANSPONDER STANDARDS

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KWAJALEIN MISSILE RANGE
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IRIG STANDARD 254-94

NONCOHERENT TRANSPONDER STANDARDS

APRIL 1994

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INTRODUCTION

Instrumentation tracking radars are a major factor in range tracking today at virtually every training and test range in the United States. As the growth potential of instrumentation radars advanced so have transponder requirements. Several years ago a pulse transponder was "nice to have" if it could be kept operational. Today, it is a mandatory item aboard most missiles, aircraft, and instrumented sea-going test beds and must operate nearly perfect under the most severe environmental and physical stress.

Most of the modern noncoherent pulse transponders available today are the result of commercial development with guidance from the U.S. government in terms of specifications or user requirements. The transponder manufacturing field is small and limited to companies who have become strongly entrenched over the years. As a general statement, most of these companies meet or exceed the standards set forth in this document. These standards have been written to accommodate the present state-of-the-art technology in both the radar and the transponder fields. Not all existing instrumentation radars are completely compatible with all existing transponders.

These standards were orginally written for transponders operating in the frequency range of 5.2 to 5.295 GHz. However, because of the large number of instrumentation radars and transponders operating in the frequency range of 8.5 to 10 GHz, an expansion of these standards is necessary to encompass not only these transponders but all transponders that may be used as range instrumentation. This Electronic Trajectory Measurements Group (ETMG) recommended standard is primarily for establishing and preserving the compatibility of noncoherent pulse transponders with present and future range instrumentation radars. The words, "transponder" and "beacon," while not actually the same are, by common usage, close synonyms. However, in this document, the instrument will be referred to as a transponder.

This document is presented as a standard, because the transponder field has become large enough to merit its own standards document. At the same time, the radar field has become even larger and more complex. It does not mean that the transponder is no longer a part of the instrumentation radar system, but rather to imply that the field is large enough to be treated as a separate subject. This separation will facilitate subsequent reviews of these standards. Coherent pulse transponder standards are not included in this document.

Comments and recommendations for improving this document should be sent to

Secretariat
Range Commanders Council
STEWS-RCC
White Sands Missile Range, New Mexico 88002-5110

SCOPE

This document defines the minimum transponder parameters in such a manner that any instrumentation tracking radar on any test range may use the transponder. It is not the goal of these standards to require all transponders to meet the requirements. **Rather, it is to establish an envelope of parameters which test ranges may use as a guide for transponder procurement.** Many of the parameters can, and undoubtedly, will be improved.

It should be pointed out that specific differences exist between these standards and those presented in RCC document 250-91, *Frequency Standards for Radar Transponders*. These differences are noted as they occur and result primarily from a basic difference in philosophy between the two documents. The standards presented in document 250-91 represent a special case where the primary requirement is to obtain interference-free operation by efficient use of the radio-frequency spectrum. The standards in this document reflect state-of-the-art capabilities and are not intended to impose any limitation on improvements resulting from the requirements at a specific location, but rather reflect an effort to present the minimum standards required to provide operation at all ranges.

Environmental standards are referenced in appendix B. The philosophy is that reliability and stability have become several of the most important factors in the performance of the transponder. The high cost of failure makes it mandatory to include some general and average flight simulation parameters. Because environmental standards referenced are worst case, each procuring agency must choose and modify these standards as required for its own unique requirements.

Appendixes have been added to this document for information only. However, the ancillary devices for command control and telemetry are flight proven, and the guidelines presented in appendix A represent minimum requirements. The transponder antenna system requirements are also included. Here again, they are for information only and are not intended to be restrictive.

Additional transponder information is contained in RCC document 308-93, *Range Safety Transponder Catalog*. The catalog contains a listing of the most commonly used transponders and their operating specifications.

In the following paragraphs, the transponder parameters are defined so that any instrumentation tracking radar on any test range may use the transponder.

1. Noncoherent Pulse Radar Transponder Standards

1.1 Frequency

1.1.1 Transponder Tuning Range

1.1.1.1 The transponder receiver should be continuously tunable over the frequency range of the transponder.

1.1.1.2 The transponder transmitter should be continuously tunable over the frequency range of the transponder.

1.1.1.3 The transponder local oscillator should be continuously tunable over the frequency range from minus the IF frequency at the low end to plus the IF frequency at the high end. The transponder should meet all operating requirements with the local oscillator tuned either above or below the received signal.

1.1.2 Transponder Frequency Accuracy

1.1.2.1 The transponder receiver should not exhibit a frequency drift greater than +2 MHz from the tuned center frequency under all operating conditions.

1.1.2.2 The transponder transmitter should not exhibit a frequency drift greater than +3 MHz from the tuned center frequency under specified operating conditions. During changes in ambient temperature, the coefficient of frequency drift of the transmitter should not exceed 50 kHz per degree celsius.

1.1.2.3 The average frequency in any 50 nanosecond section of the transmitted pulse should not deviate by more than 500 kHz from the average frequency in any other 50 nanosecond section of the pulse measured at 1000 reply pulses per second.

1.1.3 Transponder Frequency Separation

The minimum frequency separation between transmitter and receiver should be at least 25 MHz for transponders operating in the 5.2 to 5.925 GHz frequency range, 50 MHz for transponders operating in the 2.3 to 3.7 GHz and 8.5 to 10 GHz frequency range, and 30 MHz for transponders operating in the 15.725 to 15.925 GHz frequency range.

NOTE

The 228C, 229X, 302C-8, and 345C transponders are designed to operate with 0 MHz separation.

1.1.4 Fixed 5.2 to 5.925 GHz Frequencies

1.1.4.1 Transmitter Fixed Frequencies. The transponder transmitter frequency shall be tuned to a set frequency within 5.4 to 5.9 GHz as required and shall be tunable within a 100 MHz range above and below the set frequency +2 MHz.

1.1.4.2 Receiver Fixed Frequencies. The transponder receiver frequency shall be tuned to a set frequency within 5.4 to 5.9 GHz as required and shall be tunable within a 100 MHz range above and below the set frequency +3 MHz.

1.2 Transponder Pulse Characteristics

1.2.1 Unless the transponder is specifically designed for single-pulse operation, it should respond to either a single- or two-pulse coded interrogation signal.

1.2.1.1 If set for single-pulse operation, the transponder receiver should reply to a single pulse interrogation possessing the following characteristics:

Pulse Width	Rise Time
0.25 to 5 microseconds	100 nanoseconds or less

1.2.1.2 If set for a two-pulse operation, the transponder receiver should reply to a two-pulse coded interrogation possessing the following characteristics:

Pulse Width	Rise Time	Code Spacing	Decoder Limits
0.25 to 1 microsecond	100 nanoseconds or less	The interrogation code spacing should be continuously variable from 1.5 to12 microseconds	Respond to an interrogation within +0.15 microsecond of the code space setting and ignore, but not reject, interrogations at +0.30 microsecond or greater from the code space setting

1.2.2 The transponder output pulse should possess the following characteristics:

Pulse Width if	
Fixed:	+40 percent of the fixed width.
Adjustable:	240 to 520 nanoseconds.
Rise Time:	Not to exceed 100 nanoseconds measured between the 10 and 90 percent amplitude points.
Fall Time:	Not to exceed 200 nanoseconds measured between the 90 and 10 percent amplitude points.
Variation:	Not to exceed 10 nanoseconds.
Spectrum:	The RF pulse spectrum in MHz (measured at the quarter power (6 dB) point by means of an RF spectrum analyzer) should not exceed 3 divided by the pulse width in microseconds. The main lobe spectrum should exhibit a symmetrical sin x/x distribution of frequency. The spectrum should have symmetrical distribution of the side lobes with well-defined nulls and no side lobe should be greater than -10 dB with respect to the main lobe.
Spurious Radiation:	Spurious radiation over the band of 0.15 to 15,950 MHz should be limited to at least 60 dB suppression of transmitter harmonics and at least 80 dB below the power radiated at the frequency to which the transmitter is tuned.

1.3 <u>Single-Pulse Rejection</u>. When the transponder is adjusted for two-pulse interrogation operation, it should not be triggered by single-pulse interrogations when such pulses have durations as great as 12 microseconds at a power input level up to +20 dBm.

1.4 Transponder Delay

1.4.1 <u>Reply-Delay Characteristics</u>. The reply delay is the time interval from the leading edge of the last interrogation signal to the leading edge of the transponder reply pulse. The reply delay shall be measured at the 50 percent level of the square law detected RF pulse for both the interrogation and reply signals with the 50 percent level determined by attenuating the predetected RF signal power by 3 dB.

Fixed Delay: Continuously adjustable from 1.5 to 6 microseconds with 20-nanosecond (3.3 yards) resolution.

Variation: With reference to the fixed delay variation should not exceed

(1) 50 nanoseconds over the dynamic range of the transponder receiver.

(2) 10 nanoseconds for interrogation rates from 10 to 2600 Hz.

(3) 10 nanoseconds for received frequencies within +2 MHz of the tuned receiver frequency.

(4) 10 nanoseconds over each of the environmental parameters listed in paragraph 1.16.

(5) 5 nanoseconds for input power potential variations from 22 to 32 Vdc.

(6) 5 nanoseconds for input pulse code variations of +50 nanoseconds from the selected code setting.

(7) 10 nanoseconds for interrogation pulse rise-time variation from 20 to 60 nanoseconds and 50 nanoseconds with rise-time variation from 60 to 100 nanoseconds.

(8) The reply-delay jitter (defined as as pulse-to-pulse delay variation with constant input parameters) should not exceed 10-nanosecond (1.6 yards) for each of the above.

1.4.2 Delay Jitter. Reply delay jitter shall be defined as high-frequency random variations in the transponder reply delay whose long-term variation is 0 +2 nanoseconds. The transponder delay jitter should not exceed 10 nanoseconds root mean square (rms) for any combination of constant interrogation signal level between 0 and 5 dBm above the transponder minimum triggering level (that signal level at which the transponder will reply to 99 percent of the interrogation pulses), temperature and acceleration as specified in paragraph 1.16, interrogation rates from 10 to 2600 pulses (or code groups) per second, interrogation frequency variations within +2 MHz, rise-time variations of 20 to 60 nanoseconds (50 nanoseconds with rise-time variations from 60 to 100 nanoseconds), and input potentials between 22 and 32 Vdc.

1.5 Recovery Time. The recovery time of the transponder should be no greater than 50 microseconds. For lockout protection, the transponder shall provide for no response during the 50 microseconds recovery time of the transmitter.

1.6 Dynamic Range. The minimum dynamic range of the transponder receiver should be from -65 to +20 dBm.

1.7 Sensitivity. The minimum signal level, measured at the transponder antenna terminal, causes the transponder to reply to at least 99 percent of the interrogations. This signal will be considered the minimum detectable signal and will comply with paragraph 1.6.

1.8 Random Triggering. The transponder should not generate random replies at a rate greater than 5 pulses per second (pps) under any operating conditions.

1.9 Power Output

1.9.1 Standard Transponders. The peak power output of the transponder should be at least 100 watts under all operating conditions. The power output should be measured at the transponder antenna terminal operating to a maximum Voltage Standing Wave Ratio (VSWR) of 1.5:1. The transponder should deliver the maximum power specified at any phase angle associated with the VSWR of 1.5:1 maximum.

NOTE

The power requirement is a standard figure and not intended to place any restrictions upon the use of more or less power.

1.9.2 Miniature Transponders. Special mission requirements may require transponder miniaturization. Peak-power output for these miniaturized transponders shall be at least 5 watts (37 dBm) under all operating conditions. All other conditions established in subparagraph 1.9.1 should apply.

1.10 Pulse Repetition Frequency (PRF)

1.10.1 The transponder should meet all operating requirements at PRFs from 10 to 3000 pps.

1.10.2 The transponder should meet all operating requirements at any duty cycle up to 0.002.

1.10.3 The transponder should not suffer permanent damage when subjected to interrogations which exceed the duty-cycle limitation. The transponder should meet all operating requirements within 50 microseconds after the interrogation PRF falls to the maximum specified value.

1.11 Selectivity

1.11.1 The receiver rejection should provide at least 30 dB of rejection outside of the receiver tuning range. The image frequency rejection should be at least 60 dB.

1.11.2 The receiver bandwidth should be greater than 8 MHz and less than 14 MHz for transponders operating in the 1.215 to 1.4 GHz, 2.3 to 3.7 GHz, 5.2 to 5.925 GHz, and 8.5 to 10 GHz ranges, and greater than 15 MHz and less than 25 MHz for transponders operating in the 15.725 to 15.925 GHz range.

1.12 Antenna Input/Output Terminal Impedance. The transponder antenna terminal should have an input/output of 50 ohms, nominal.

1.13 Input d.c.Power. The transponder should operate over a range of 22 to 32 Vdc. Reverse-polarity protection should be provided to prevent permanent damage to the transponder upon application of reverse polarity dc input voltage.

1.14 Grounding. All exterior surfaces of the transponder should be at ground potential.

1.15 Soldering. All solder connections should meet the requirements of MIL-STD-2000, *Standard Requirements for Soldered Electrical and Electronic Assemblies*.

1.16 Temperature, Altitude, Vibration, Shock, Acceleration and Humidity. The transponder should meet all the requirements of MIL-STD-810, *Environmental Test Methods and Engineering Guidelines*. The applicable portions of MIL-STD-810 are listed in appendix B.

1.17 Interference Limits. Interference limits should be as established in accordance with MIL-STD-461, *Control of Electromagnetic Interference Emissions and Susceptibility, Requirements for the VSMF,* and 462, *Electromagnetic Interference Characteristics, Measurement of VSMF,* class 1, subclass 1A and 1B equipment including methods CE03, CE06, CS02, CS04, RE02, and RS03 key-up and key-down modes.

1.18 Acoustical. MIL-STD-810, method 515.2, procedure 1, table 15.2-I, equipment category C for 30 minutes.

1.19 Salt Fog. MIL-STD-810, method 509.1, procedure 1; Fungus: method 508.1, procedure 1.

APPENDIX A

TRANSPONDERS, TELEMETRY, AND ANTENNAS

APPENDIX A
TRANSPONDERS, TELEMETRY, AND ANTENNAS

In the first section, radar transponder command and control are briefly discussed. Section 2 contains the airborne antenna system requirements.

1.1 Radar Transponder Command and Control

Several types of command, control, and limited uplink/downlink telemetry have been designed and implemented using tracking radar and noncoherent beacons. It is certain because of the relative ease with which these systems can be implemented that additional design and additional applications will be implemented. These command, control, and limited uplink/downlink telemetry designs will have either a general or specialized use. If the use of the design is general, the transponder shall be compatible with existing tracking systems or switch restorable to such compatibility. If the design is specialized and will be used at a single locale, the requirement for general compatibility is waived.

2.1 Airborne Antenna System Requirements

2.1.1 The bandwidth of the antenna system shall be measured at the 3-dB points and be equal to the bandwidth of the transponder.

2.1.2 The center frequency of the antenna system shall be the center frequency of the transponder operating frequency band.

2.1.3 The antenna system shall be such that the center frequency and bandwidth shall not change more than ±0.1 percent under all operating conditions.

2.1.4 The Voltage Standing Wave Ratio under all operating conditions shall be less than 1.5:1.

2.1.5 The antenna system shall have an impedance of 50 ohms measured at the input jack of the power divider in cases of multi-element systems.

2.1.6 The antenna system shall be compatible with the ground tracking radar system. If the circular polarization is used as defined in RCC document 250-91, *Frequency Standards for Radar Transponders,* deviation from circularity on axis shall not be more than 3 dB.

2.1.7 If a requirement exists for either vertical-linear or horizontal-linear polarization as defined in RCC document 250-91, subparagraph 2.1.6 of this document does not apply.

2.1.8 The antenna system shall operate without damage or arching with an input up to 1500 watts peak RF power at 760 mm Hg atmospheric pressure, measured at the antenna connector.

2.1.9 The coaxial cabling and connectors which join the antenna elements to the power divider shall be miniaturized and of the lightest weight consistent with the power handling, VSWR, frequency, and environmental requirements.

2.1.10 The antenna shall meet all the requirements of MIL-STD-810E with regard to temperature, altitude, vibration, shock, and humidity. The applicable portions of MIL-STD-810E are listed in appendix B. Modifications to these test procedures shall be specified by the individual procuring agency.

2.1.11 Antenna gain patterns shall be established for each new system. The gain of the antenna relative to a standard reference, isotropic or dipole, shall be established. The measurements shall be made at relevant frequencies and polarizations over a 360° range in 10° increments.

APPENDIX B

TRANSPONDER ENVIRONMENTAL STANDARDS

APPENDIX B
TRANSPONDER ENVIRONMENTAL STANDARDS

1.1 The MIL-STD-810E, Environmental Test Methods and Engineering Guidelines, recommends that each procuring agency set the environmental stress levels for their own applications. It is strongly recommended that procuring agencies carefully tailor environmental requirements to ensure the equipment is designed and tested for resistance to the environmental stresses it will encounter during its life cycle. To properly test these parameters, it is recommended that the tests be performed following the guidelines of method 520.1 of MIL-STD-810E. The combined test should be performed for the qualification and acceptance tests at least.

1.1.1 Individual tests which may be integrated into method 520.0 are

a.	Low Pressure (Altitude)	Method 500.3
b.	High Temperature	Method 501.3
c.	Low Temperature	Method 502.3
d.	Vibration	Method 514.4
e.	Humidity	Method 507.3

1.1.2 Other environmental stress tests that should be performed individually are

a.	Acceleration	Method 513.4
b.	Acoustic Noise	Method 515.4
c.	Shock	Method 516.4

1.1.3 During the development of a new transponder, all of the above tests should be performed individually to detect most problems. The integrated tests of method 520.1 should be performed as a final test of the design.

2.1 Reliability. The transponder mean-time-between-failure (MTBF) shall be demonstrated to be at least 30 hours at a 90 percent level of confidence. This minimum requirement does not preclude longer MTBFs.

The reliability, as shown on figure B-1, indicates that if no failures occur during the first 131 hours and 50 minutes or if the t_a line is crossed, the test is successfully completed. If four failures occur prior to 344 hours and 30 minutes of testing or if the t_r line is crossed, the reliability is not satisfied. In addition, the test is forced to completion after 750 hours of test time or 18 failures. Figure B-2 is an operating characteristic curve which indicates that if the true MTBF is equal to 30 hours, there is a 10 percent chance that the reliability test will be successfully completed. If the true MTBF is equal to 60 hours, the expectation for satisfactory completion is 90 percent.

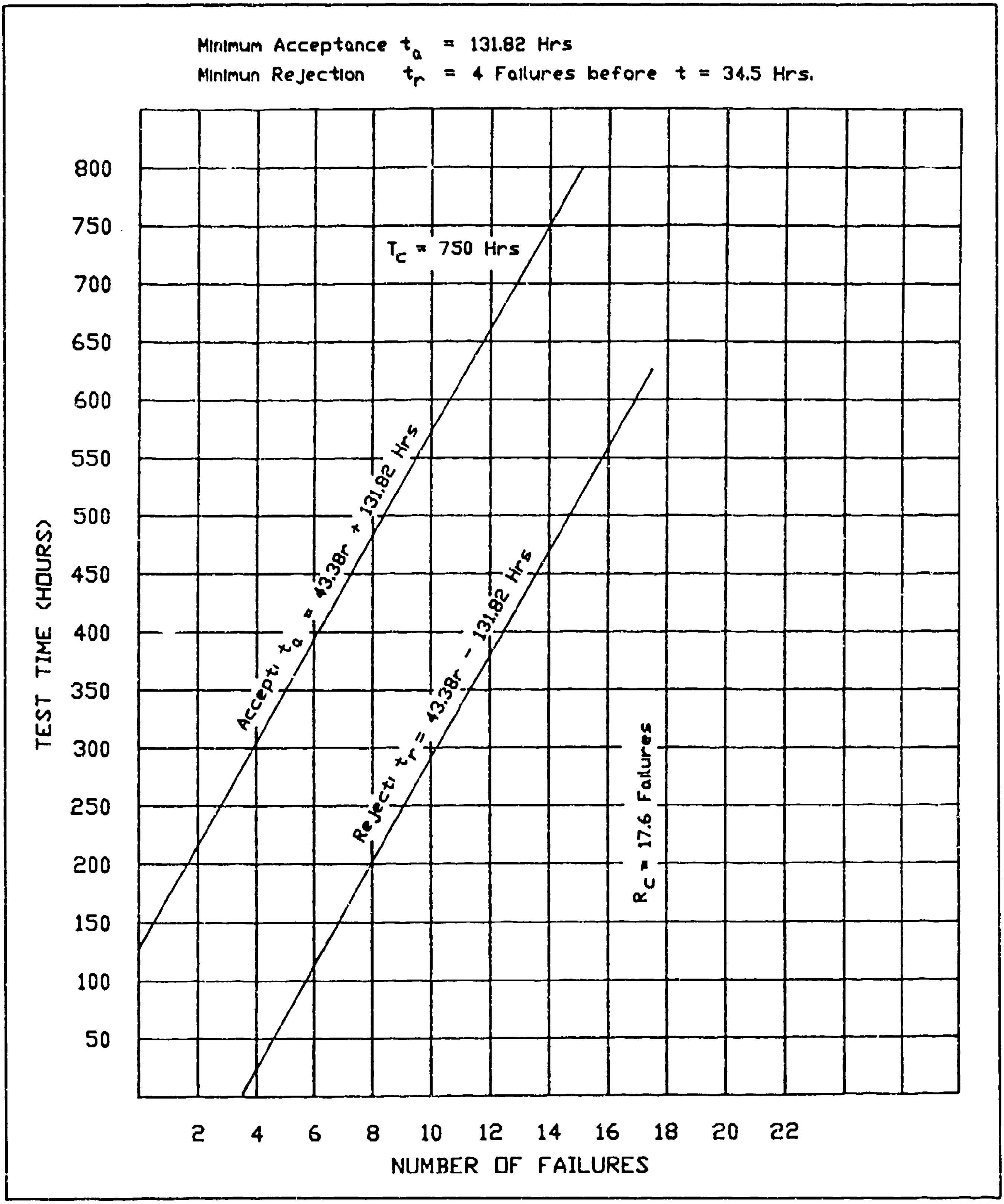


Figure B-1. Reliability test.

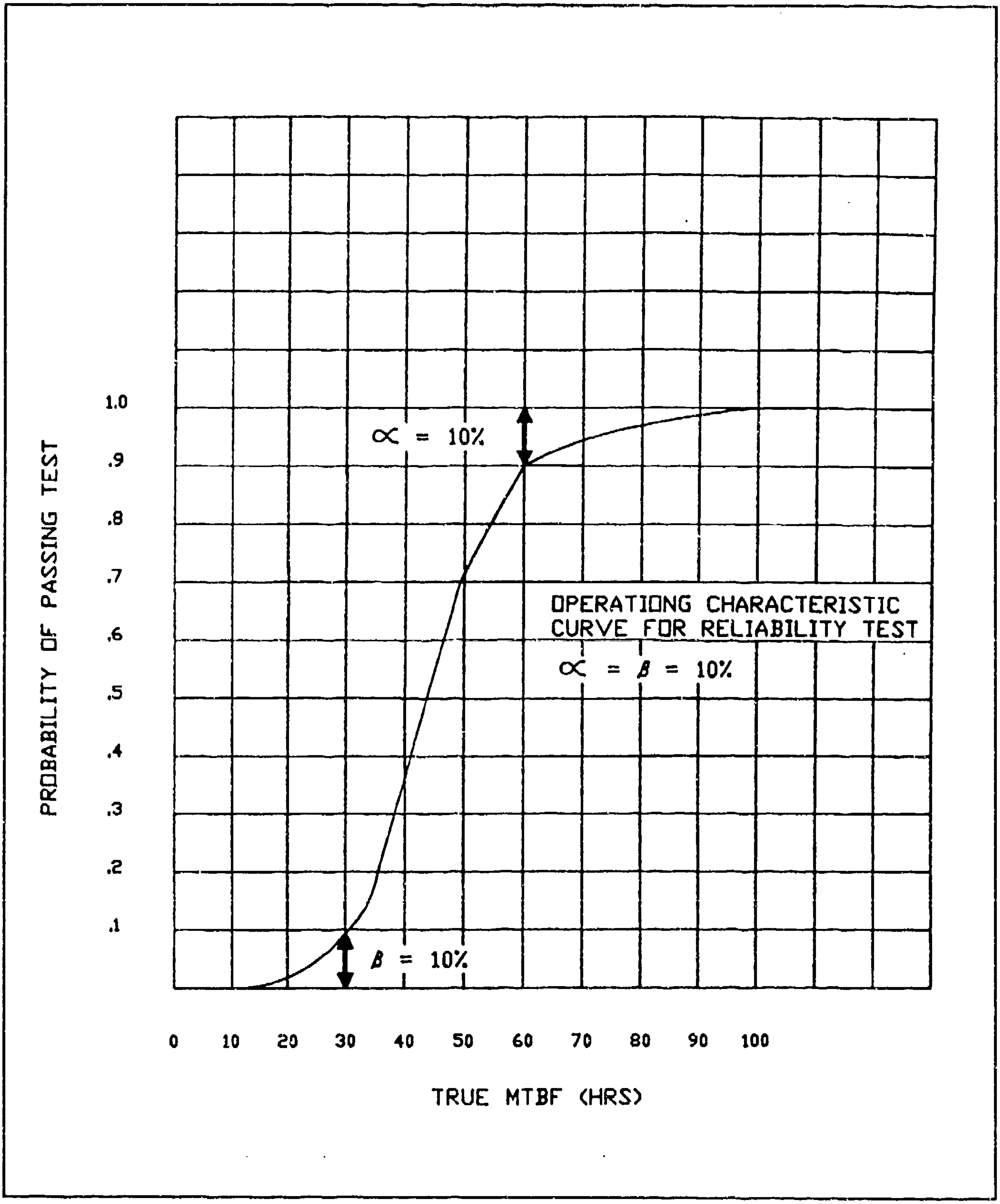


Figure B-2. Operating characteristic curve for reliability test.

GLOSSARY

dynamic range - The range of input signal level to which the transponder will reply to 99 percent of interrogation pulses without receiver saturation.

minimum triggering level - That signal level to which the transponder will reply to 99 percent of the interrogation pulses.

transponder delay - The time delay from the leading edge of the last pulse of the interrogation signal, measured at the 50-percent amplitude point which triggers a transmitter, to the 50-percent amplitude point of the transmitter response pulse or from the centroid of the last interrogation signal to the centroid of the transmitter response signal. Centroid is defined as that time within the signal that divides the total signal energy in two equal portions.

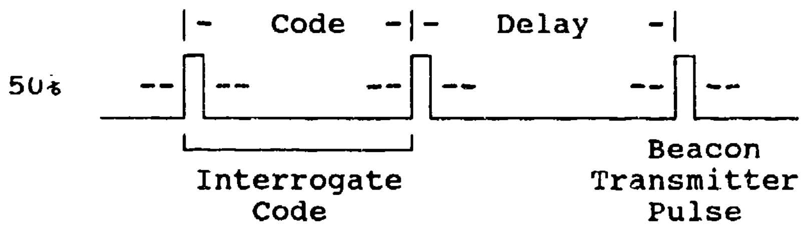
pulse delay (spacing) - The time interval between 50-percent amplitude points on the leading edge of the voltage pulses being measured. The measurement method shall be as indicated below in 8. Pulse Width.

pulse fall time - The time required for the trailing edge of a voltage pulse to decrease from 90 to 10 percent of the amplitude of the pulse.

pulse repetition frequency (PRF) - The rate at which pulses or pulse groups are transmitted from a radar set.

pulse rise time - The time required for the leading edge of a voltage pulse to increase from 10 to 90 percent of the amplitude of the pulse.

pulse width - The time interval (pulse duration) at the 50 percent (-6 dB) of the peak value of the pulse. The 50-percent level of a detected RF pulse shall be established by attenuating the peak value of the RF signal by 6 dB.



receiver bandwidth - The frequency range of optimum performance for a receiver determined by the interrogation pulse width and factory set. The BW (Hz) = 1/Interrogation pulse width (seconds).