Range
Commanders
Council

ELECTRONIC TRAJECTORY
MEASUREMENTS GROUP

IRIG STANDARD 257-86

COHERENT C-BAND TRANSPONDER STANDARD

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COHERENT C-BAND TRANSPONDER STANDARD

Prepared by

ELECTRONIC TRAJECTORY MEASUREMENTS GROUP
RANGE COMMANDERS COUNCIL

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SCOPE

The objective of this document is to define minimum transponder parameters in such a manner that any C-band instrumentation radar on any test range may use the transponder. It is not the goal of these standards to require all transponders to use the same pulse code spacing or the same spot frequencies. Rather, it is to establish an envelope of frequencies and codes within which all test ranges may operate. In this way, the goals can be met and yet the interference-free traffic capacity will be larger than if only one system of codes and spot frequencies was used. Many of the parameters can and will undoubtedly be improved.

There are three basic designs of a coherent pulse radar transponder, however only two are in use for trajectory measurement application. Both employ superheterodyne receivers, delay at the intermediate frequency, and heterodyne the signal back to the carrier frequency through the use of a common local oscillator. If the transponder has good stability, the phase of the reply will bear a fixed relationship to the interrogation signal. The difference between the two transponder types occur in the transmitter section. One design achieves power gain by cascading injection locked oscillators. The second employs straight amplification in the transmitter. The standards reflect state-of-the-art capabilities which can be met by either design and are not intended to impose any limitation on improvements resulting from the requirements at a specific location, but reflect the minimum standards required to assure compatible operation with C-band instrumentation radars at all ranges.

Environmental standards are referenced in the basic standards document. The philosophy is that reliability has become an important, if not the most important, single factor in the C-band transponder. The high cost of failure makes it mandatory to include some general and average flight simulation parameters. The environmental standards references are worst case. Each procuring agency must, therefore, choose and modify those environmental standards needed for its unique requirements.

Appendixes have been added to this document for information only and should not be considered part of the basic standards. The transponder antenna is included as a part of the appendixes. Here again, the guidelines are for information only and are not intended to be restrictive. It is believed that in the past too little attention has been directed to the airborne antenna system.

1.0 Coherent Pulse Radar Transponder Standards

1.1 Frequency

1.1.1 Transponder Tuning

The following are desirable, but not necessarily, field adjustable.

1.1.1.1 The receiver shall be continuously tunable from 5400 to 5900 MHz.

1.1.1.2 The transmitter shall be continuously tunable from 5400 to 5900 MHz to agree with the receiver.

1.1.1.3 The transponder local oscillator shall be continuously tunable from 5400 MHz minus the IF frequency to 5900 MHz plus the IF frequency. The transponder shall 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 Under all specified operating environments and after a 3 minute warmup period, the receiver center frequency shall not drift more than 2 MHz from the originally tuned center frequency.

NOTE: RCC Document 250-65 specifies a percentage of the assigned operating frequency.

1.1.2.2 Where applicable and under specified operating environments, the transmitter rest frequency shall not drift more than 3 MHz from the originally tuned frequency. During changes in ambient temperature, the transmitter frequency drift rate shall not exceed 50 KHz per degree centigrade. This shall include any frequency modulation present during the specified environments.

1.1.2.3 Coherent Pull-In Range: The transponder shall reply coherently to valid interrogation at a frequency within 3 MHz of the tuned frequency.

1.1.3 Coherence

1.1.3.1 The phase variation of the reply, with respect to a stable frequency interrogation, shall not exceed 15° for the duration of the reply pulse.

1.1.3.2 The pulse-to-pulse phase variation of the transponder reply with respect to a stable frequency interrogation shall not exceed 30° peak-to-peak over the specified environments.

1.1.3.3 The pulse-to-pulse phase variation of 1.1.3.2 measured at 1000 interrogations per second and averaged over 0.1 second shall not exceed 21.0°.

1.2 Transponder Pulse Characteristics

1.2.1 The transponder shall selectively respond to either a single or a two-pulse coded interrogation signal.

1.2.1.1 The transponder shall reply, if set for single-pulse operation, to a single-pulse interrogation possessing the following characteristics:

Pulse Width:	0.25 ± 0.05 to 1.25 ± 0.05 microseconds
Rise Time:	100 nanoseconds or less

1.2.1.2 The transponder shall reply, if set for a two-pulse operation, to a two-pulse coded interrogation possessing the following characteristics:

Pulse Width:	0.25 to 1.25 microsecond
Rise Time:	100 nanoseconds or less
Code Spacing:	The interrogation code spacing shall be continuously selectable from 3.0 to 12.0 microseconds in 1.0 microsecond intervals. NOTE: Code spacing set at 1.0 microsecond intervals, leading edge to leading edge, and the fixed delay set at exactly 2.5 microseconds will prevent cross interference or premature triggering when two or more transponders are in close proximity.

Code Spacing:	Code spacing, measured from the half power point on the leading edge of the pluses, tolerance shall be as follows:

Tolerance:

a. At ±0.15 microsecond from optimum setting, the transponder shall respond to an input over the dynamic sensitivity range.

b. At ±0.3 microsecond from optimum setting, the transponder shall totally reject the interrogating signal. NOTE: The preselector on the transponder is primarily used to obtain the required image rejection. In order that the intent of RCC Document 250-65 may be served in an increasingly narrowed and crowded frequency spectrum, the requirement for extremely accurate code spacing and decoder slots becomes mandatory.

1.2.2 The reply pulse shall be as follows:

Pulse Width:	Adjustable from 250 to 900 nanoseconds ±10 nanoseconds.
Pulse Width Variation:	Not to exceed 10 nanoseconds from the preset pulsewidth over the operating parameters of paragraph 1.4.2
Rise Time:	Not to exceed 65 nanoseconds measured between the 10% and 90% amplitude points.
Fall Time:	Not to exceed 150 nanoseconds measured between the 90% and 10% amplitude points.
Spectrum:	The RF pulse spectrum in MHz measured at the quarter power (6 dB) point by means of an RF spectrum analyzer shall not exceed 3.0 divided by the pulse width in microseconds.
Spurious Radiation:	Spurious radiation over the band of 0.15 MHz to 17,700 MHz shall 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. NOTE: RCC Document 250-65, para 3.1, specifies that spurious radiation be limited to a level of 55 dB +10 log P_t less than the carrier power and at least 40 dB suppression of carrier harmonics over the band of 100 MHz to 12,400 MHz.

1.3 Single Pulse Rejection: When the transponder set is adjusted for two-pulse interrogation operation, it shall not be triggered by single pulse interrogations at any frequency when such pulses have durations of 12.0 microseconds or less at input power levels up to +10 dBm, measured at the antenna connector.

1.4 Delay

1.4.1 Reply Delay Characteristics: The reply delay is defined as 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% level of the square law detected RF pulse for both the interrogation and reply signals with the 50% level determined by attenuating the predetected RF signal power by 3 dB.

1.4.2 Fixed Delay: The transponder shall have a fixed delay between interrogation and reply pulses. This fixed delay shall be setable to 2.5 microseconds or other customer selected delay (from pulse width +0.5 microseconds to 5.0 microseconds is recommended) with a setability accuracy of 10 nanoseconds measured at an input signal of 0 dBm at the RF connector; at the assigned interrogation frequency, a fixed case mounting point temperature of 77° ±4°F (25° ±2.2°C); and 640 ±1 interrogation per second.

1.4.3 Delay Variation: The variation in delay, referenced to the fixed delay of paragraph 1.4.2, shall not exceed:

(1) 20 nanoseconds for change in signal level between 0 dBm and 5 dB above the transponder sensitivity.

(2) 10 nanoseconds for interrogation rates from 100 to 2600 pps.

(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 1.12.

1.4.4 Reply Delay Jitter Characteristics: 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 shall not exceed 10 nanoseconds rms for any combination of constant interrogation signal level between 0 dBm and 5 dB above the transponder sensitivity, temperature and acceleration as specified in paragraph 1.12, interrogation rates from 100 to 2600 pulses (or code groups) per second, interrogation frequency variations within ±2 MHz of the assigned frequency, rise times of 20 nanoseconds to 65 nanoseconds (50 nanoseconds with rise time variations from 60 to 100 nanoseconds) and input potentials between 22 and 32 volts d.c.

1.5 Recovery Time: The maximum recovery time shall be 50 ±5 microseconds, measured from the half power point on the trailing edge of the first reply to the half power point on the leading edge of the second reply.

1.6 Dynamic Range: The minimum receiver dynamic range shall be from -65 to +20 dBm. All performance specifications shall be met over this range.

1.7 Sensitivity: The minimum input signal level, measured at the transponder antenna terminal, which causes the transponder to reply to at least 99.9% of the interrogations, shall be -70 dBm or less.

1.8 Random Triggering: Random replies shall not exceed 5 pps under any operating environment

1.9 Power Output

1.9.1 Standard Coherent Transponders: The peak power output of the transponder shall be at least 100 watts under all operating environments. The power output shall be measured at the transponder antenna terminal operating into a maximum VSWR of 1.5:1. The transponder shall deliver the maximum power specified at any phase angle associated with the VSWR of 1.5:1 maximum.

NOTE: The power requirement is a recommended figure and not intended to place any restrictions upon the use of higher or lower power. It is believed that a figure of 100 watts peak power will serve most requirements. For long range requirements, peak power up to 1000 watts is within the state-of-the-art. Peak power greater than 1000 watts is costly in terms of dollars and primary power. In most instances careful design of the airborne antenna system will reduce peak power requirements.

1.9.2 Miniature Coherent Transponder: Special mission requirements may require transponder miniaturization. Peak power output for these miniaturized transponders shall be at least 8 watts under all operating conditions. All other conditions established in paragraph 1.9.1 shall apply.

1.10 Pulse Repetition Frequency (PRF)

1.10.1 The transponder shall meet all operating requirements at PRFs from 100 to 2600 pps.

1.10.2 The transmitter shall meet all operating requirements at any duty cycle up to 0.00234.

1.10.3 Over-Interrogation Protection: The transponder shall not suffer permanent damage when subjected to interrogations which exceed the duty cycle limitation. The transponder shall meet all operating requirements within 500 microseconds after the interrogation PRF falls below the maximum specified value.

1.11 Selectivity

1.11.1 The receiver shall provide at least 80 dB of rejection outside of the receiver tuning range from 14 kHz to 10 GHz. The image frequency rejection shall be at least 60 dB.

1.11.2 The receiver bandwidth shall be greater than 8 megahertz and less than 14 megahertz.

1.12 Temperature, Altitude, Vibration, Shock, Acceleration and Humidity: The transponder shall meet all the requirements of MIL-STD 810C. The applicable portions of MIL-STD 810C are listed in Appendix B. Modifications to these test procedures shall be specified by the individual procuring agency.

1.13 Interference Limits: Interference limits shall be as established in accordance with MIL-STD 461B/462, Class 1, Subclass 1A and 1B equipment to include methods CE03, CE06, CS02, CS04, RE02 and RS03 key-up and key-down modes.

1.14 Acoustical: MIL-STD 810C, Method 515.2, Procedure 1, Table 15.2-I, Equipment Category C for 30 minutes.

1.15 Salt Fog: MIL-STD 810C, Method 509.1, Procedure 1;
Fungus: Method 508.1, Procedure 1.

1.16 Grounding: All exterior surfaces of the transponder shall be at ground potential.

1.17 Design Goals

1.17.1 Fall Time: Equal to rise time ±25 nanoseconds.

1.17.2 Delay Variation Due to Signal Level: 10 nanoseconds.

1.17.3 Pulse Width Variation: ±10 nanoseconds

1.17.4 Input Potential: Operation over a range of 22 to 32 volts, d.c.

1.17.5 Delay Variation With Input Potential: Not to exceed 5 nanoseconds with power variation from 22 to 32 volts d.c.

1.17.6 Delay Variations With Pulse Code Variation: Not to exceed 5 nanoseconds with input pulse code variation of ±100 nanoseconds from the selected code setting.

1.17.7 Delay Variation With Interrogation Pulse Rise Time: Not to exceed 10 nanoseconds with rise time variation from 20 to 60 nanoseconds and not to exceed 50 nanoseconds with rise time variation from 60 to 100 nanoseconds.

1.17.8 A combined total variation in delay with all of the above should not exceed 20 nanoseconds, excepting the 50 nanoseconds of paragraph 1.17.7.

1.17.9 Coherence: Pulse to pulse phase variation of the transponder reply with respect to a stable interrogation frequency shall not exceed 21° per second, averaged over 1 second.

APPENDIX A
TRANSPONDER ANTENNAS

1. C-Band Airborne Antenna Systems

1.1 System Requirements

1.1.1 The antenna system shall operate from 5400 to 5900 MHz.

1.1.2 The bandwidth of the antenna system shall be ±250 MHz from the center frequency when measured at the -3 dB points.

1.1.3 The center frequency shall be 5650 MHz.

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

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

1.1.6 The antenna system shall have nominal impedance of 50 ohms.

1.1.7 The airborne transponder antenna system shall be compatible with the ground tracking radar system. If the circular polarization as defined in RCC Document 250-65 is used, deviation from circularity on axis shall be less than 3 dB.

1.1.8 If a requirement exists for either vertical linear or horizontal linear polarization as defined in RCC Document 250-65, paragraph 1.1.7 does not apply.

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

1.1.10 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, and environmental requirements.

1.1.11 Antenna Temperature, Altitude, Vibration, Shock and Humidity. The antenna shall meet all the requirements of MIL-STD 810. The applicable portions of MIL-STD 810 are listed in Appendix B. Modifications to these test procedures shall be specified by the individual procuring agency.

1.1.12 Antenna gain patterns shall be established for each new antenna systems that is flown. 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 radiation sphere in 2-degree increments.

2.1 Design Goal: The vehicle antenna system shall not cause the tracking radar to experience rapid variations in phase or signal strength immediately before or during intervals when accurate position or velocity is required. Signal strength variations should not exceed 3 dB per second and phase variations should not exceed 20° across the antenna aperture of the the tracking radars.

2.2 In situations requiring carrier phase derived range data, it is important that the peak magnitude of phase variation caused by variation in the tracked vehicle aspect angle with respect to the tracking radars be held to the lowest possible value.

APPENDIX B

STANDARDS

1. The latest issue of MIL-STD 810 entitled "Environmental Test Methods and Engineering Guidelines" (Version "D" dated July 1983), recommends that each procuring agency set the environmental stress levels for their applications. This is very important, since design and testing to more severe environmental stress than needed is uneconomical. It is strongly recommended that procuring agencies carefully tailor requirements, particularily for devices serving multiple applications since some stress parameters may interact synergistically. To properly test these parameters it is recommended that the tests be performed following the guidelines of Method 520 of MIL-STD 810D. The combined test should be performed at least for the qualification tests and may be included in the acceptance test ensemble.

The individual tests which may be integrated into Method 520 are:

Low Pressure (Altitude)	Method 500.2
High Temperature	Method 501.2
Low Temperature	Method 502.2
Vibration	Method 514.3
Humidity	Method 507.2

Other environmental stress tests which usually do not interact with other stresses and therefore can most economically be performed individually are:

Acceleration	Method 513.3
Accoustic Noise	Method 515.3
Shock	Method 516.3

During the development of a new transponder, all of the above tests would be performed individually to detect most problems with the integrated tests of Method 520.0 performed as a final test of the design.

2. Reliability: The transponder mean-time-between-failure (MTBF) shall be demonstrated to be at least 30 hours at a 90% level of confidence. This is a minimum requirement and does not preclude longer MTBFs for special long life applications. 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 34 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% 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%.

Minimum Acceptance, t_a=131.82 Hrs
Minimum Rejection, t_r=4 Failures before t=34.5 Hrs

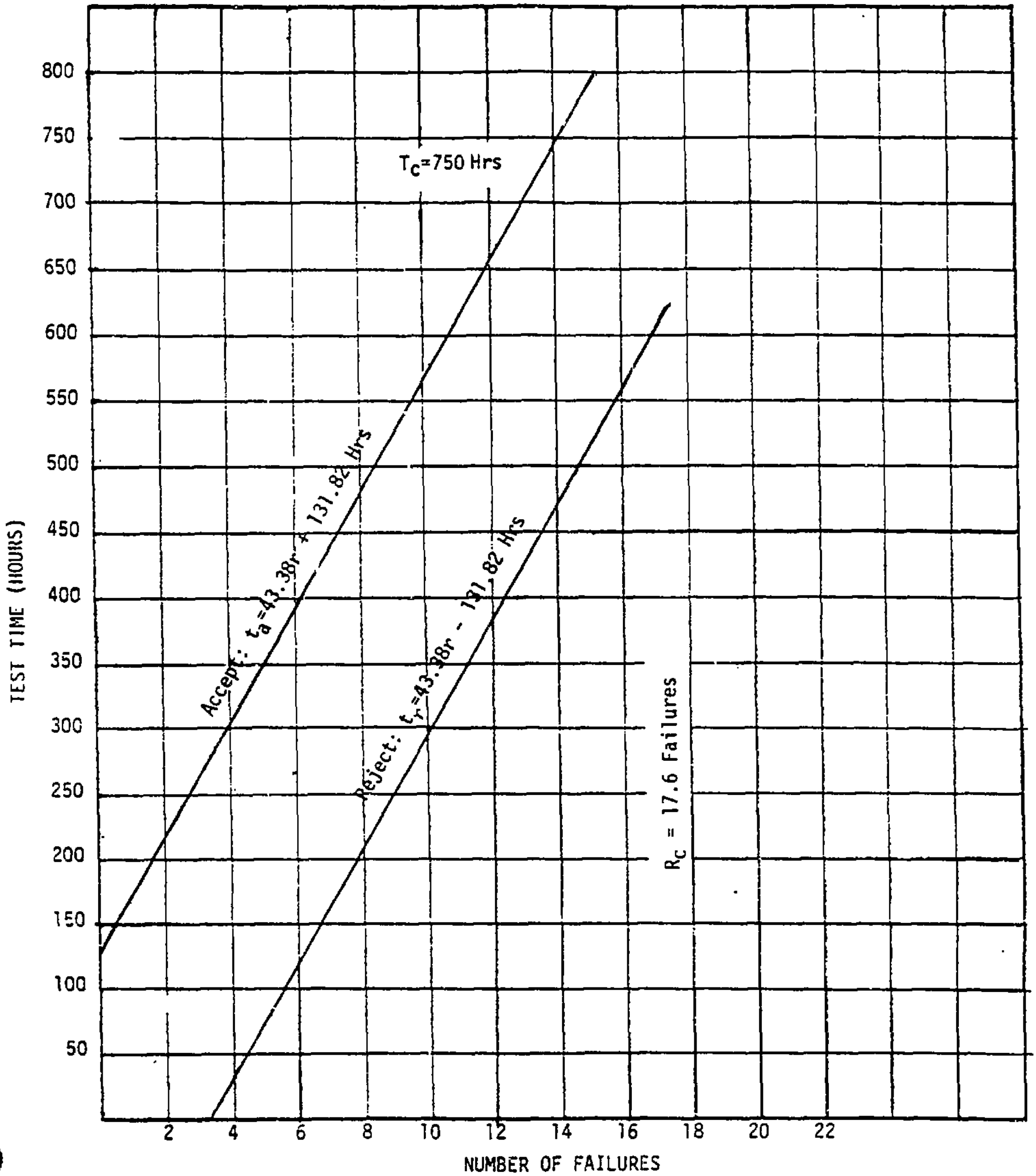
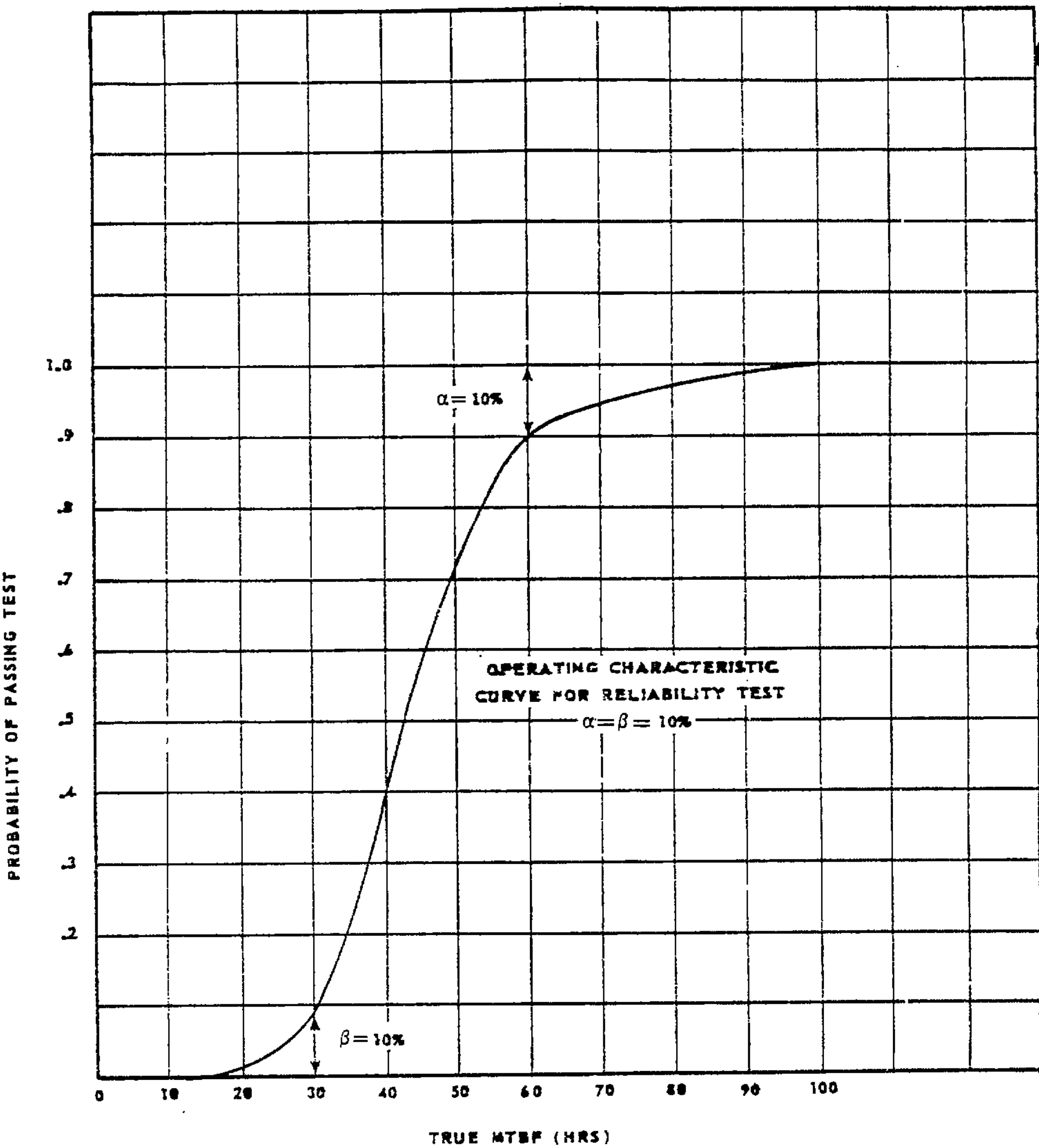


Figure B-1



1.0
.9
.8
.7
.6
.5
.4
.3
.2
PROBABILITY OF PASSING TEST
α = 10%
β = 10%
OPERATING CHARACTERISTIC
CURVE FOR RELIABILITY TEST
α = β = 10%
0
10
20
30
40
50
60
70
80
90
100
TRUE MTBF (HRS)

FIGURE B-2

APPENDIX C
GLOSSARY

1. Pulse Code Modulation: Modulation which involves a pulse code. This is a generic term and additional specification is required for a specific purpose.

2. Sensitivity: Is defined as the minimum signal level, measured at the transponder antenna terminal, which causes the transponder to reply to at least 99.9% of the interrogations.

3. Transponder Delay: The time delay from the leading edge of the last pulse of the interrogation signal, measured at the 50% amplitude point to either the leading edge or the centroid of the transmitted pulse. Centroid is defined as that time within the transmitted pulse which divides the total signal energy in two equal portions.

4. 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 10. (Pulse Width).

5. Pulse Rise Time: The time required for the leading edge of a voltage pulse to increase from 10 percent to 90 percent of the amplitude of the pulse.

6. Pulse Fall Time: The time required for the trailing edge of a voltage pulse to decrease from 90 percent to 10 percent of the amplitude of the pulse.

7. Pulse-Position Modulation: Pulse modulation in which the information to be transmitted is caused to modulate the position in time of a pulse(s).

8. Pulse Repetition Frequency (PRF): The rate (usually given in cycles or pulses per second) at which pulses or pulse groups are transmitted from a radar set.

9. Pulse Time Modulation: Information transmission by means of a pulse code in which the information modulates the time of occurrences of some characteristic of the pulse(s). Pulse duration and pulse position modulation are particular forms of pulse time modulation.

10. Pulse Width: The time interval (pulse duration) during which a pulse exceeds a reference level. For measuring pulse width, the reference level shall be at 50 percent (-3 dB) of the peak value of the detected RF pulse. The 50-percent level shall be established by attenuating the peak value of the detected RF signal by 3 dB.

11. Total Delay Variation: The time difference between the transponder fixed delay and the variations imposed by other transponder characteristics.

12. Rest Frequency: The frequency at which a coherent transponder having an injection locked oscillator transmitter replies when the unit is triggered by an interrogation, whose frequency is beyond the coherent pull-in range, but otherwise valid.

APPENDIX D

COHERENCE TESTING

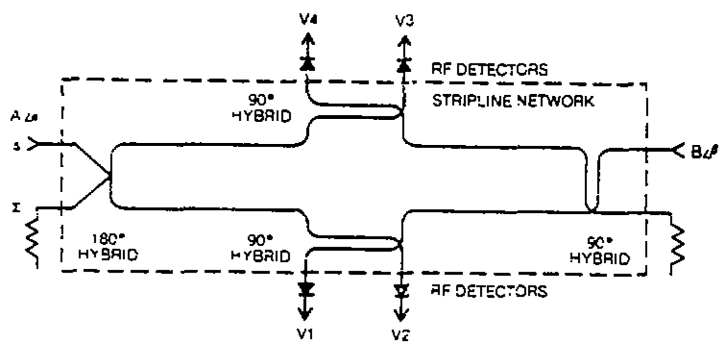
1.0 INTRODUCTION

A very simple method for measuring radar transponder coherence, possessing advantages in cost, reliability, portability, calibration and ease of use has been developed at WSMC. This method is recommended as a standard test technique.

2.0 PHASE COHERENCY TEST METHOD

The technique chosen as a result of an investigation was the so-called I-Q method in which the relative power of two orthogonally phased components of the product of two sinusoidal alternating potentials are measured. This basic technique has been employed in several commercially available network analyzers using continuous wave signals. The network analyzers examined employed one or more tuned circuits which prohibit their application to a pulsed signal measurement due to pulse risetime limitations and partial coherent integration occurring at high PRF's. The broadband stripline assembly selected as suitable for this application was designed for Electronic Counter Measures applications as a direction finder or instantaneous frequency measurement device. A schematic of the phase discriminator used is given below.

Phase Discriminator (Correlator) Network



If two AC signals of approximately equal magnitude and frequency between -45 dBm and +5 dBm are impressed on ports A and B respectively, potentials will appear at the output of the detectors having the following functions:

$V_1^2 = (A^2 + B^2) + 2AB \cos \theta$ $\qquad$ $V_2^2 = (A^2 + B^2) - 2AB \cos \theta$

$V_3^2 = (A^2 + B^2) + 2AB \sin \theta$ $\qquad$ $V_4^2 = (A^2 + B^2) - 2AB \sin \theta$

and: $V_1 - V_2 = 4AB \cos \theta$ $\qquad$ $V_3 - V_4 = 4AB \sin \theta$

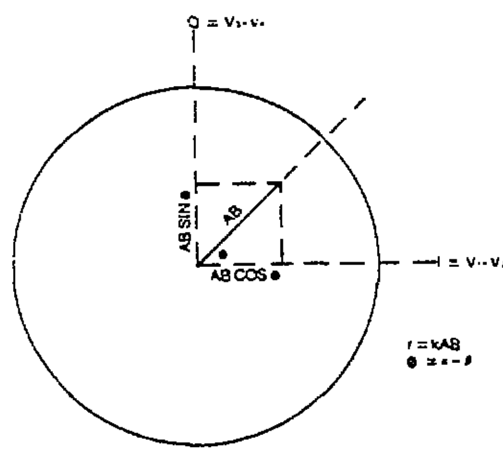
where A and B are the magnitudes of the signals at ports A and B respectively and θ is the relative phase angle between them.

Then

$$\theta = \text{Arc Tan } \frac{V_3 - V_4}{V_1 - V_2}$$

The necessary arithmetic and trigonometry can be accomplished digitally or in an analog method through the use of a differential input X-Y presentation oscilloscope having 2 MHz or wider bandwidth in BOTH channels and 5 millivolt/cm. deflection factor in both channels. V_1 and V_2 outputs are connected to the + and - Y axis inputs and the V_3 and V_4 outputs are fed to the + and - inputs of the X axis. If the inputs to the phase discriminator A and B are fed with signals of about 0 dBm, one CW and one pulsed, the oscilloscope position and gain controls can be adjusted to cause the trace to draw a straight line with one end of the line at the center of the display as in the following sketch, vector AB:

Polar Discriminator Display



If the signal strengths vary, but the phase remains constant, the length of vector AB will vary while the angle θ will remain constant. If the phase varies but the signal strengths remain constant, the vector AB will be of constant length but the angle θ will vary with the phase in a 1:1 relationship (ignoring an error term which will not exceed 8^0 in this implementation).

3.0 APPLICATION OF TEST INDICATION TO PREDICTION OF FLIGHT PERFORMANCE

For the purpose of transponder coherence checking, the absolute phase is unimportant but any change will induce delta range errors in the Range Vernier system and the rate of change of phase will induce velocity errors in the CSP and VESS instrumentation. Rapid phase fluctuations of limited amplitude will result in fineline signal-to-noise ratio reduction for the CSP and Range Vernier causing increasing noise in the data and errors in ambiguity resolution. If the fluctuations are severe, loss of track can result.

Interpretation of the display is quite straightforward. If the vector appears to rotate, it indicates a coherence error. The magnitude of the coherence error in Hertz is given by:

$$\frac{\text{apparent vector rotation in degrees}}{360^\circ\ (\text{time in seconds})} = \text{coherence error in Hertz}$$

to convert the error to feet/second:

$$(\text{error in Hertz}) \ \frac{492}{\text{frequency MHz}} = \text{error in feet/second}$$

The sign of the coherence error is indicated by the direction of rotation. Phase shift within the pulse is indicated by the vector changing from a straight line to a raindrop shape with the point at the center. The magnitude of the phase shift within the reply is given by the angular spacing between two lines passing through the center screen tangent to the rain drop shape. Phase modulation due to vibration or other causes will appear as many vectors clustered in one section of the display with a nondrifting average position. The peak phase modulation can be read directly from the screen but an RMS of the modulation would require that the I and Q signals be digitized and operated on by a small calculator.

4.0 TEST IMPLEMENTATION

Most of the equipment for coherence test, shown in Figure D-1, is already included in transponder test systems. However some items are new such as the phase correlator (Anaren 120757) and the X-Y oscilloscope. Some items have new requirements such as high phase stability (short term) for the interrogation signal source. A specification of 5° peak-to-peak in 5 microseconds should be adequate for most measurements.

In operation, the pulse generator produces a 2 pulse code appropriate to the transponder under test which modulates the signal source operating at the transponder test frequency. The modulated signal is then attenuated to the desired signal strength at the transponder and the transponder reply is routed by the circulator through the reply attenuator to the phase correlator input. The additional isolator is included to assure that the relatively high leakage of some phase correlators does not permit a signal stronger than about -80 dBm to arrive at the transponder via the phase correlator which could seriously interfere with transponder delay measurements in some cases. The reference signal for the phase correlator is derived from the interrogation signal source with a directional coupler or power divider depending upon the power level of the source. Approximately 1 milliwatt is desired at both correlator inputs.

Because of the low duty cycle of the transponder during these measurements, there is danger of burning the oscilloscope cathode ray tube phosphor at center screen where the beam spends most of its time. A third pulse from the pulse generator, delayed by approximately the beacon delay from the second pulse of the interrogation is needed to intensify the beam only when the reply pulse is present to generate the vector display. The display is interpreted in the manner discussed earlier.

The test may be automated with a small controller such as the Hewlett Packard 9845 and the programmable equivalents of the signal source and attenuators, and the addition of analog to digital conversion equipment operating in parallel with the oscilloscope. Retention of the oscilloscope in an automated system is recommended so the operator can assure himself that the system is operating properly before taking data and to simplify balancing of the correlator inputs.

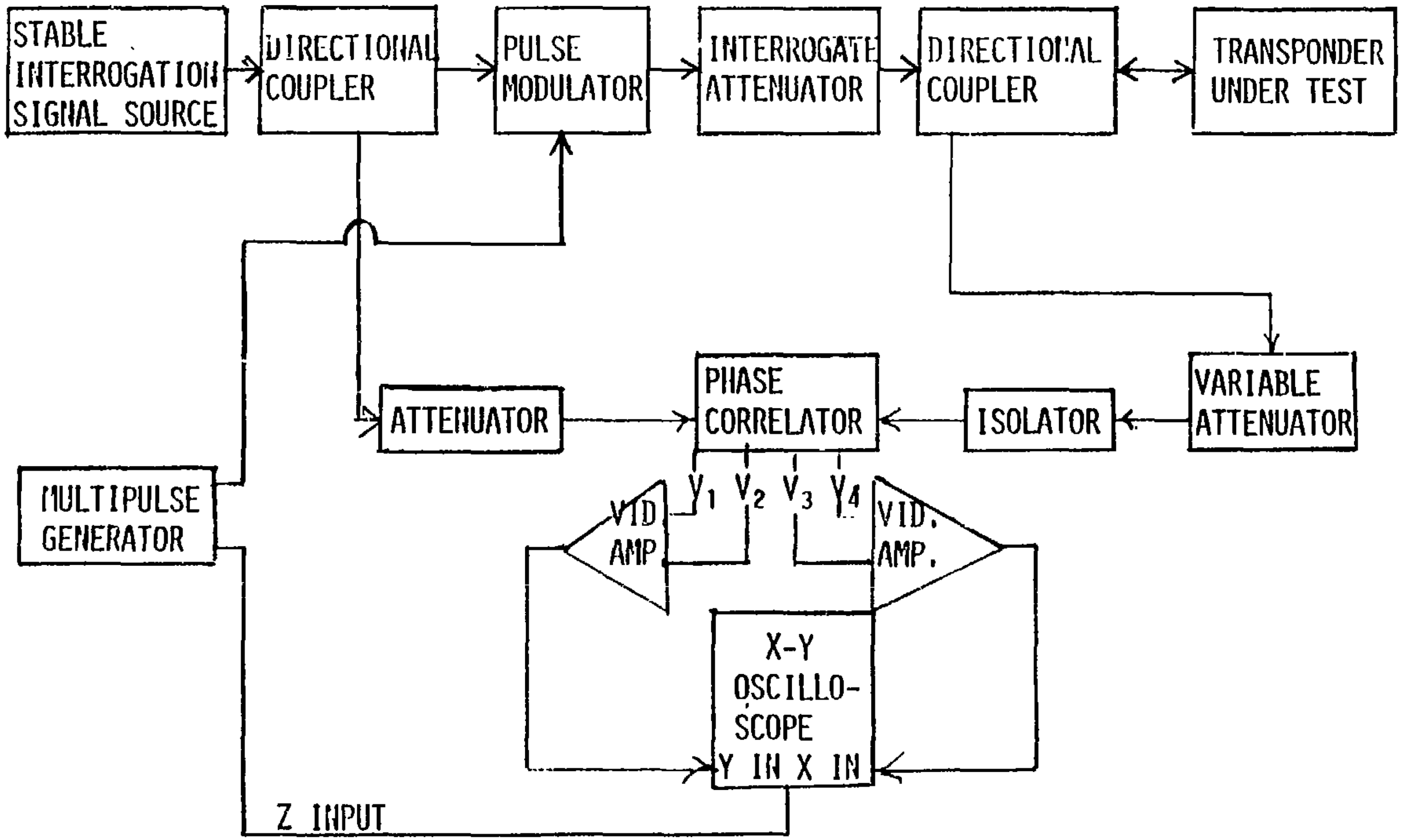


Figure D-1. BASIC COHERENCE TEST METHOD