Range Commanders Council

TELEMETRY GROUP

Document 118-79

TEST METHODS FOR TELEMETRY SYSTEMS AND SUBSYSTEMS

VOLUME IV

TEST METHODS FOR DATA MULTIPLEX EQUIPMENT

WHITE SANDS MISSILE RANGE
KWAJALEIN MISSILE RANGE
YUMA PROVING GROUND
ELECTRONIC PROVING GROUND
DUGWAY PROVING GROUND

NAVAL AIR WARFARE CENTER - WEAPONS DIVISION
ATLANTIC FLEET WEAPONS TRAINING FACILITY
NAVAL AIR WARFARE CENTER - AIRCRAFT DIVISION
NAVAL UNDERSEA WARFARE CENTER DIVISION, NEWPORT

45TH SPACE WING
AIR FORCE DEVELOPMENT TEST CENTER
30TH SPACE WING
CONSOLIDATED SPACE TEST CENTER
AIR FORCE FLIGHT TEST CENTER
AIR FORCE TACTICAL FIGHTER WEAPONS CENTER

This page intentionally left blank

DOCUMENT 118-79

TEST METHODS FOR TELEMETRY SYSTEMS AND SUBSYSTEMS

VOLUME IV

TEST METHODS FOR DATA MULTIPLEX EQUIPMENT

PREAMBLE

TELEMETRY GROUP
INTER-RANGE INSTRUMENTATION GROUP
RANGE COMMANDERS COUNCIL

Published by

Secretariat
Range Commanders Council
White Sands Missile Range,
New Mexico 88002

This page intentionally left blank

Table of Contents

List of Figures

List of Data Sheets

This page intentionally left blank

Preface

This document provides test methods only. No attempt has been made to establish an accept or reject criteria. Guidance for consistency of test setup and evaluation of results is included. Equipment model numbers have been intentionally omitted. Since step-by-step test equipment operating instructions are not provided, it is anticipated that supplemental test procedures may have to be prepared by the user to augment this document.

Every attempt has been made to ensure that the format of the volumes which now comprise RCC Document 118 series, Test Methods for Telemetry Systems and Subsystems, is consistent. Pages in each volume are numbered to reflect the volume (Roman numeral) and chapter (Arabic numeral) where each appears. For example, page I-1-3 is Volume 1, Chapter 1, page 3. Figures and tables are numbered to agree with the test or paragraph in which they are addressed. Appendixes are numbered to agree with the volume in which they appear, i.e., appendix I-A is appendix A of Volume 1. Pages to appendixes are numbered accordingly, i.e., I-A-1, I-A-2, I-A-3, etc. Data sheets, when required, follow the appropriate test and are numbered to correspond to that test.

It is hoped that this format better accommodates future additions or deletions to the volumes. Please forward any comments and recommendations which concern the contents and/or format of these volumes to the RCC Secretariat.

Secretariat, Range Commanders Council
ATTN: TEDT-WS-RCC
White Sands Missile Range, NM 88002
Phone: COM (575) 678-1107; DSN 258-1107
FAX: COM (575) 678-7519; DSN 258-7519
Email: usarmy.wsmr.atec.list.rcc@mail.mil

This page intentionally left blank

CHAPTER 1

FREQUENCY DIVISION MULTIPLEX (FDM) TEST PROCEDURES

1.0 General

The following test evaluates system performance characteristics. The end product of the frequency division multiplex (FDM) test is a plot or tabulation of (S+N)/N ratios vs. the equivalent received power flux (J_a) at the surface of the receiving antenna for selected notch frequencies. It is assumed that prior to conducting the FDM system test, the prerequisite tests for determing J_a have been completed.

1.1 Noise Power Ratio (NPR) Test

1.1.1 Purpose - This test determines the ratio of noise in the test channel when all channels are loaded with white noise, to noise in the test channel when all channels, except the test channel, are fully noise loaded.

1.1.2 Test Equipment:

Noise source
Noise receiver
Band reject filters
Band-pass filters

1.1.3 Test Method:

1.1.3.1 Setup - Connect the test equipment as shown in figure 1.1-l to apply the general NPR procedure illustrated in figure 1.1-2.

1.1.3.2 Conditions - The test equipment used and test conditions employed should meet the following criteria:

1.1.3.2.1 The notch frequencies shall include 14, 34, 70, 105, 152, and 185 kHz. The capability shall be provided for additional notches at higher and lower notch frequencies as required.

1.1.3.2.2 Base-band frequencies shall include 12-108 kHz, 12-156 kHz and 12-204 kHz.

1.1.3.2.3 The notch filter shall be down at least 70 dB over a bandwidth of at least 3 kHz. The change in power between notch in and notch out shall be less than 1 dB for all base bands listed in subparagraph 1.1.3.2.2.

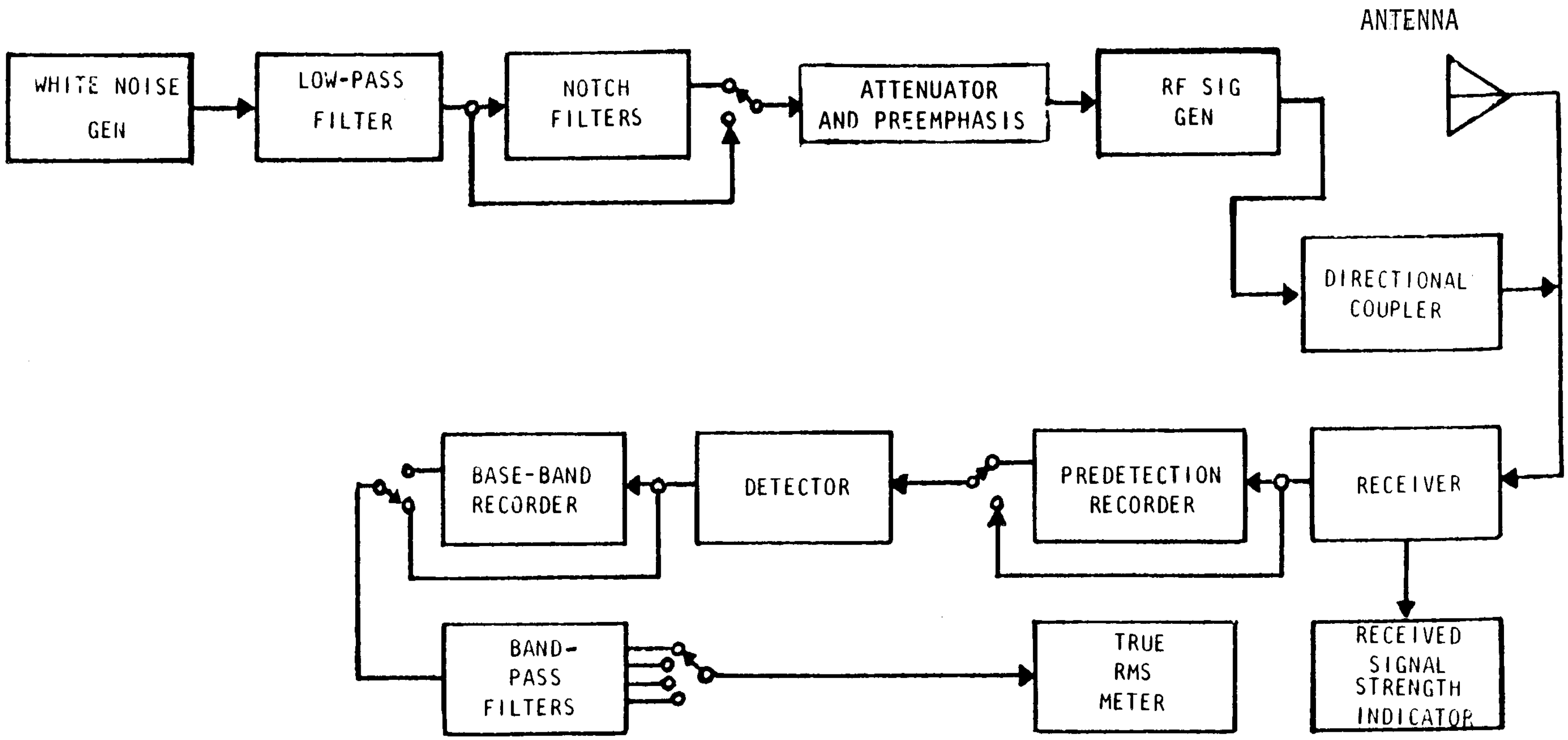


Figure 1.1-1 Block Diagram of Frequency Division System Test.

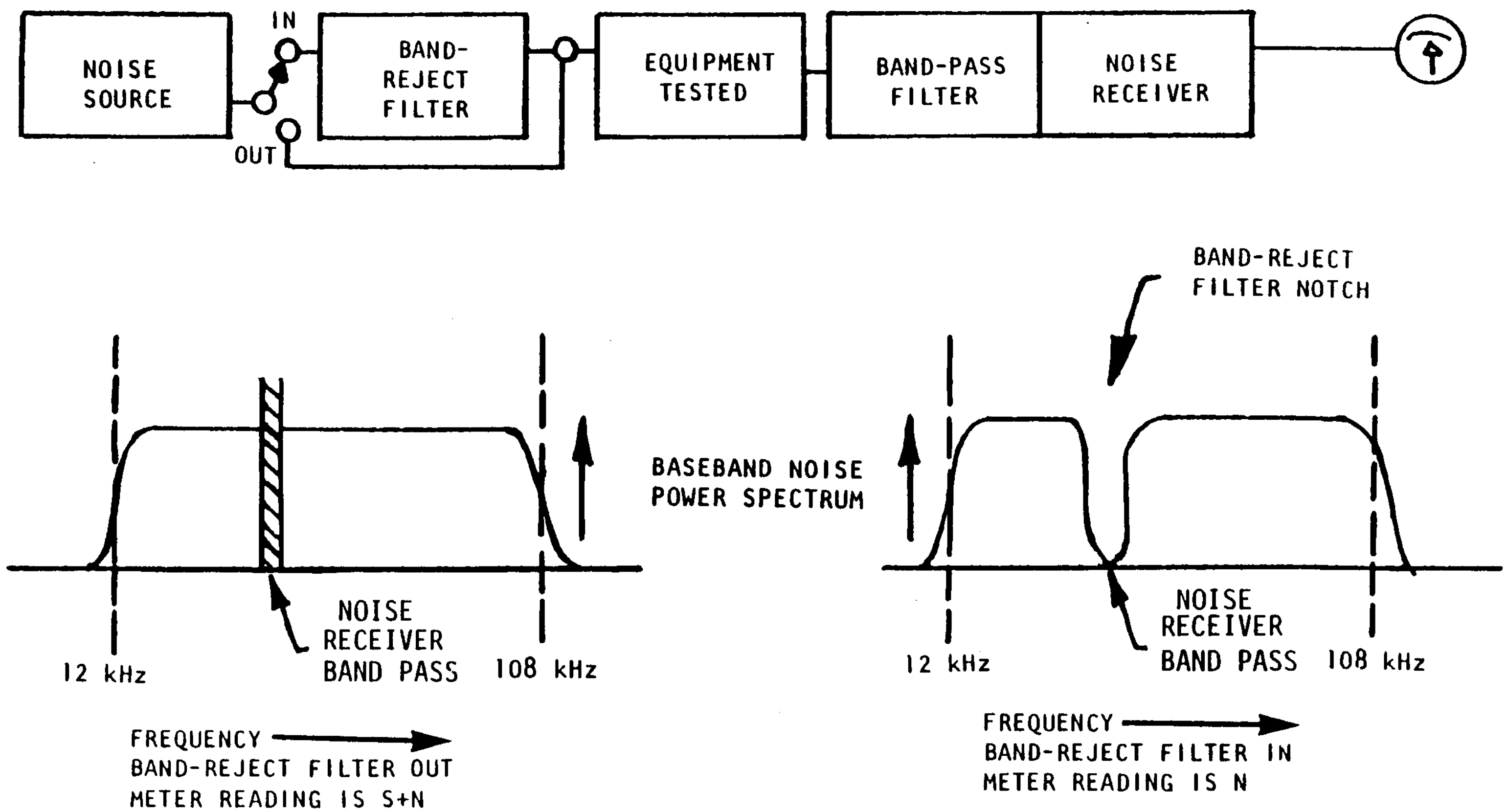


Figure 1.1-2 NPR Test.

1.1.3.2.4 The effective bandwidth of the band-pass filter shall be 1 kHz.

1.1.3.2.5 The back-to-back (S+N)/N of the notch noise tester shall be at least 65 dB for all notch frequencies.

1.1.3.2.6 With the test RF-FM signal generator and the test FM receiver, the (S+N)/N shall be at least 50 dB for all notch frequencies under the following conditions:

1.1.3.2.6.1 The base-band signal shall be contained between 12 kHz and 200 kHz with flat taper.

1.1.3.2.6.2 The rms, carrier deviation shall be at least 150 kHz rms.

1.1.3.2.6.3 A large SNR (40 dB or more) shall be in the receiver IF. The signal generator shall cover the telemetry band of interest with a frequency stability consistent with RCC Document, IRIG 106, "Telemetry Standards."

1.1.3.2.6.4 The scale resolutions for all (S+N)/N measurements shall be less than 1 dB.

1.1.3.3 <u>Procedure</u> - The following example demonstrates the procedure used for this test.

1.1.3.3.1 The signal generator output level was set to produce an SNR of 20 dB in the intermediate frequency amplifier. In simulating a, mission format for this test, the rms carrier deviation was set to 93 kHz, and the base band used was 108 kHz.

1.1.3.3.2 The NPR observed in the various notches is shown in figure 1.1-3 a. and figure 1.1-3 b.

1.1.3.4 <u>Data Reduction</u> - Plot or tabulate NPR as the ordinate and notch frequency as the abscissa for each IF SNR. Refer to figure 1.1-4.

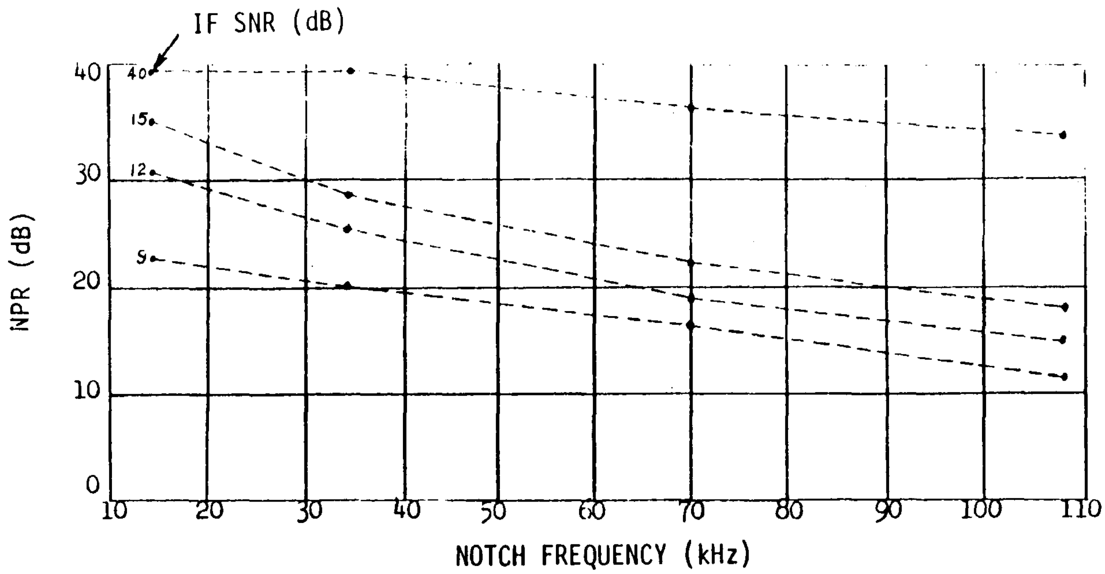


Figure 1.1-3 a. Example of NPR Test - Flat Taper.

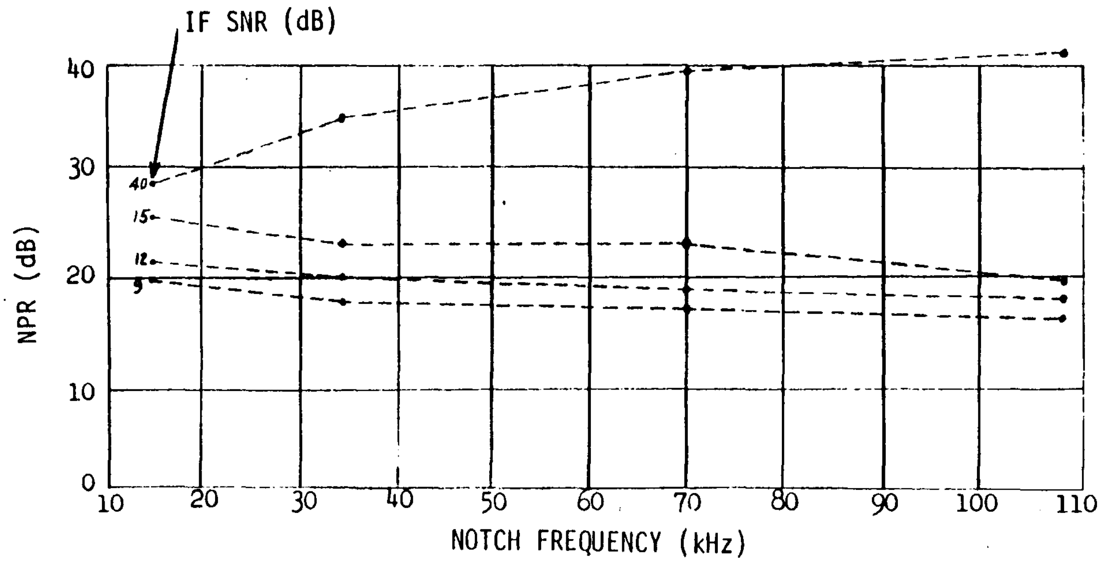


Figure 1.1-3 b. Example of NPR Test - 6 dB/Octave Preemphasis.

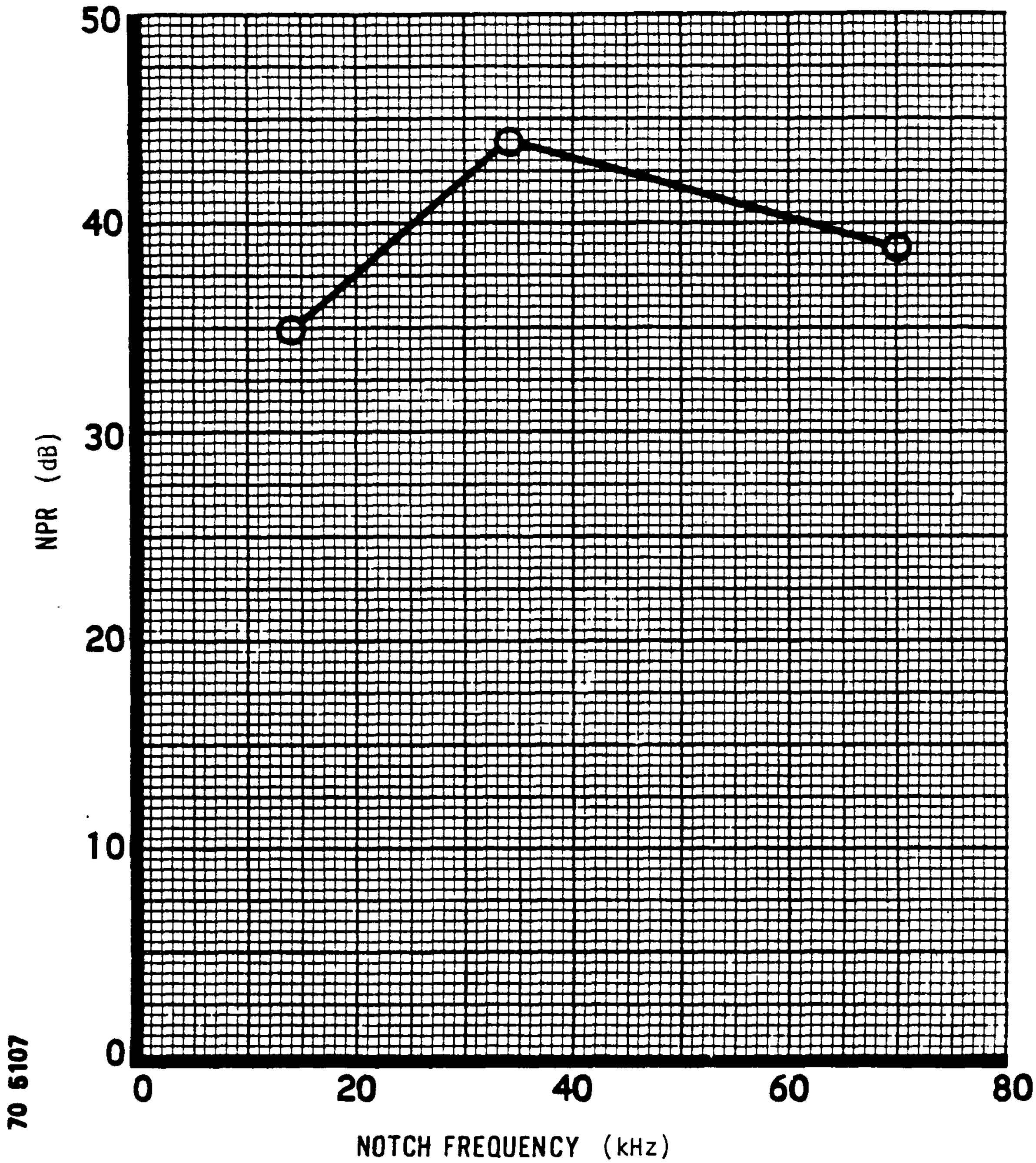


Figure 1.1-4 Noise Power Ratio versus Notch Frequency.

CHAPTER 2

TIME DIVISION MULTIPLEX (TDM) SYSTEMS

2.0 General

2.0.1 System tests are those that include the entire telemetry ground station from the input to the antenna to the output of the system. More specifically, time division multiplex (TDM) system tests test the ground system to characterize its performance when the telemetry data format is a TDM format. The performance of the TDM system is plotted against the equivalent received power flux density falling at the surface of the receiving antenna. Since no single test may completely describe the performance of the ground system in support of a specific TDM format, several tests may be necessary as is the case in pulse code modulation (PCM).

2.0.2 System tests involve carrier modulated signals which are generally frequency or phase modulated although other types of modulation can also be used. Specific test signals are either pulse code modulation (PCM) or pulse amplitude modulation (PAM). It is assumed that prior to conducting TOM system tests, the prerequisite tests for determining J_a, the power flux density (watts/m^2) at the surface of the receiving antenna, have been completed.

2.0.3 The RF test equipment for generating frequency (or phase) modulated TDM signals should cover the telemetry band of interest and should provide the capability to satisfy the mission requirements. Suggested test equipment requirements are:

2.0.3.1 Base-band response from d.c. to 1 MHz flat to ±2 dB.

2.0.3.2 Peak-to-peak frequency modulation capability adjustable from 700 Hz to 7 MHz.

2.0.3.3 Peak frequency deviation meter to cover this range with an error not more than 10 percent of the meter reading.

2.0.3.4 Peak-to-peak carrier phase modulation from $\pi/2$ to π radians continuously adjustable.

2.0.3.5 Peak phase deviation meter to cover this range with not more than 3 percent error.

2.1 PCM Testing

2.1.1 Bit Error Probability (BEP) Tests

2.1.1.1 BEP vs. Equivalent Received Power Flux (J_a)

2.1.1.1.1 Purpose - This test characterizes the performance of a telemetry receiving system when the signal data is PCM. It also involves the measurement of BEP vs. J_a. Three separate test configurations apply to measuring BEP. They are test conditions A, B, and C and are presented in subparagraphs 2.1.1.2, 2.1.1.3, and 2.1.1.4, respectively.

2.1.1.1.2 Test Equipment:

RF signal generator - employ the same generator used in the calculation of α in RF systems' tests described in IRIG 118-79, Volume II. Only the modulation signal needs to be changed.

BEP measuring equipment refer to test configuration A, B or C.

2.1.1.1.3 Test Method:

2.1.1.1.3.1 Setup - none

2.1.1.1.3.2 Conditions - Refer to subparagraph 2.0.3.

2.1.1.1.3.3 Procedure:

2.1.1.1.3.3.1 Determine the carrier predetection bandwidth, PCM wave-form test patterns, type and depth of modulation, bit rate, and range of BEP values to be tested.

2.1.1.1.3.3.2 Point the antenna at the quiet sky and at least 3-antenna beamwidths from any radio sources and set up in the mission configuration.

2.1.1.1.3.3.3 Vary the output (P_s) of the RF test signal generator using the a determined by the RF systems' test procedure. Tabulate BEP vs. P_s vs. J_a.

2.1.1.1.3.4 Data Reduction - Tabulate and plot BEP and P_S Calculate and plot J_a as shown in the following sample.

BEP	P_s (dBw)	(Calculated) J_a watts /m^2 (dB)
10^{-1}	-102	-139.5
10^{-2}	-97	-134.5
10^{-3}	-94	-131.5
10^{-4}	-92.5	-130.0
10^{-5}	-91	-128.5

The third column is calculated using α as determined in IRIG 118-79, Volume I, Appendix I-A. A plot is made of BEP vs. J_a in dB (watts m^{-2}) as shown in figure 2.1.1.1-1. A data sheet can be easily prepared as shown above with plotting done on standard 5-cycle semi-logarithmic paper.

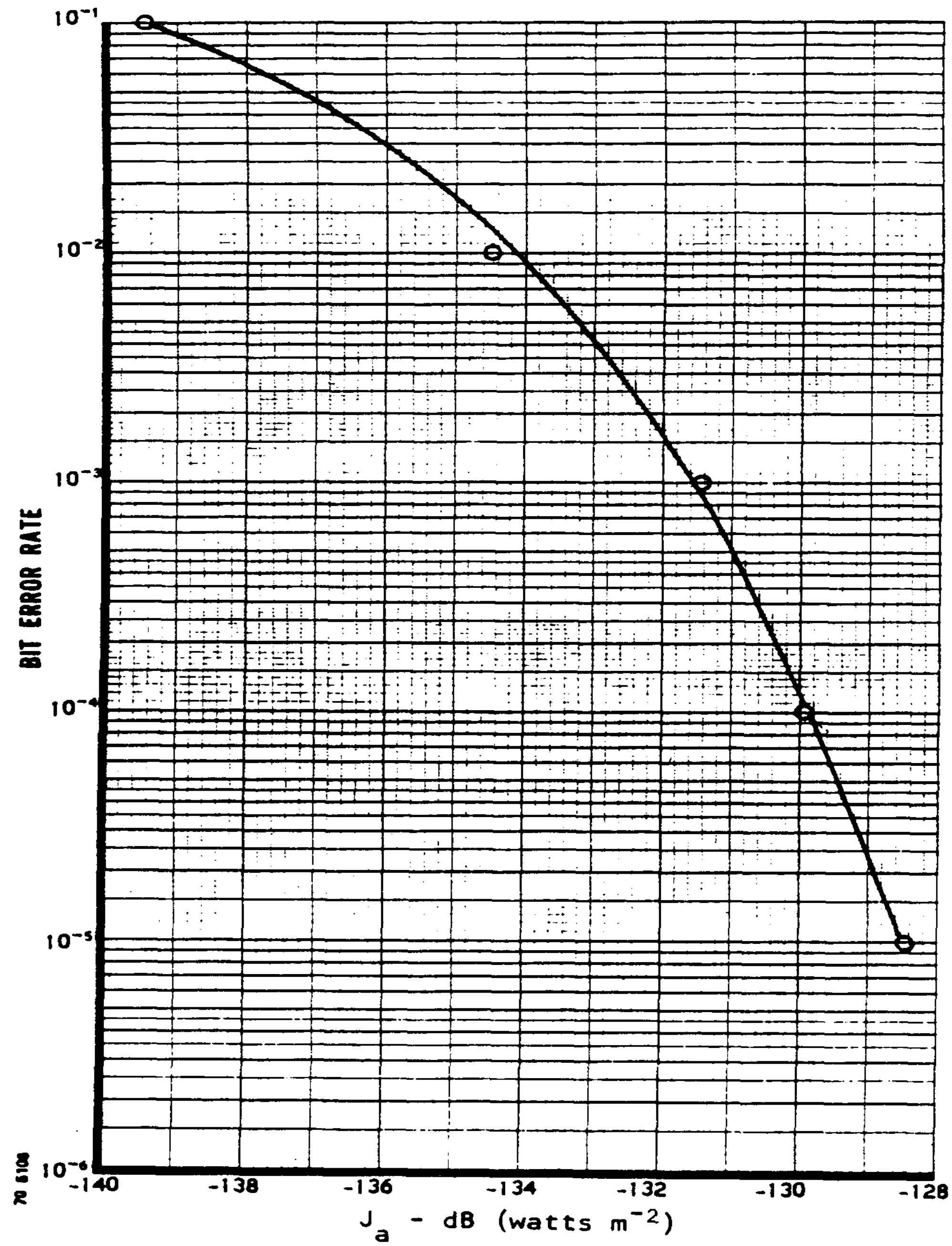


Figure 2.1.1.1-1 Bit Error Probability versus Power Flux Density.

2.1.1.2 BEP Test Configuration A

2.1.1.2.1 Purpose - This test measures BEP using a PCM simulator.

2.1.1.2.2 Test Equipment:

PCM pattern simulator
Low-pass filter
RF signal generator
Error comparator
Error counter

2.1.1.2.3 Test Method:

2.1.1.2.3.1 Setup - Connect the test equipment as shown in either figure 2.1.1.2-1 or 2.1.1.2-2.

2.1.1.2.3.2 Conditions - Refer to subparagraph 2.0.3.

2.1.1.2.3.3 Procedure:

This test is used in stations where a PCM simulator, bit synchronizer, error comparator, and error counter exist. Two variations of this test can be run, i.e., real time as shown in figure 2.1.1.2-1 or post time as shown in figure 2.1.1.2-2, using a recorded pattern. Both variations allow closed-loop testing of the system. If the PCM test pattern is pre- or postdetection recorded on magnetic tape and played back through the system bit synchronizer as shown in figure 2.1.1.2-2, a pattern regenerator should be utilized. This regenerator could be the same PCM simulator utilized for generating the PCM test pattern, provided that a clock input and frame synchronization input to the simulator are available for loading and synchronization purposes.

2.1.1.2.3.4 Data Reduction - Use the same data sheets discussed in subparagraph 2.1.1.1.3.4. Tabulate BEP and P_s. Calculate J_a and tabulate along with BEP and B_s. Plot BEP vs. J_a.

2.1.1.3 BEP Test Configuration B

2.1.1.3.1 Purpose - This test measures BEP using a pseudo noise (PN) test pattern generated by a maximal length shift register.

2.1.1.3.2 Test Equipment - Configure an 11-position shift register for maximal length operation as shown in figure 2.1.1.3-1. Use the resistor with an external clock as the PN test pattern source.

2.1.1.3.3 Test Method:

2.1.1.3.3.1 Setup - Connect the test equipment as shown in figure 2.1.1.3-2.

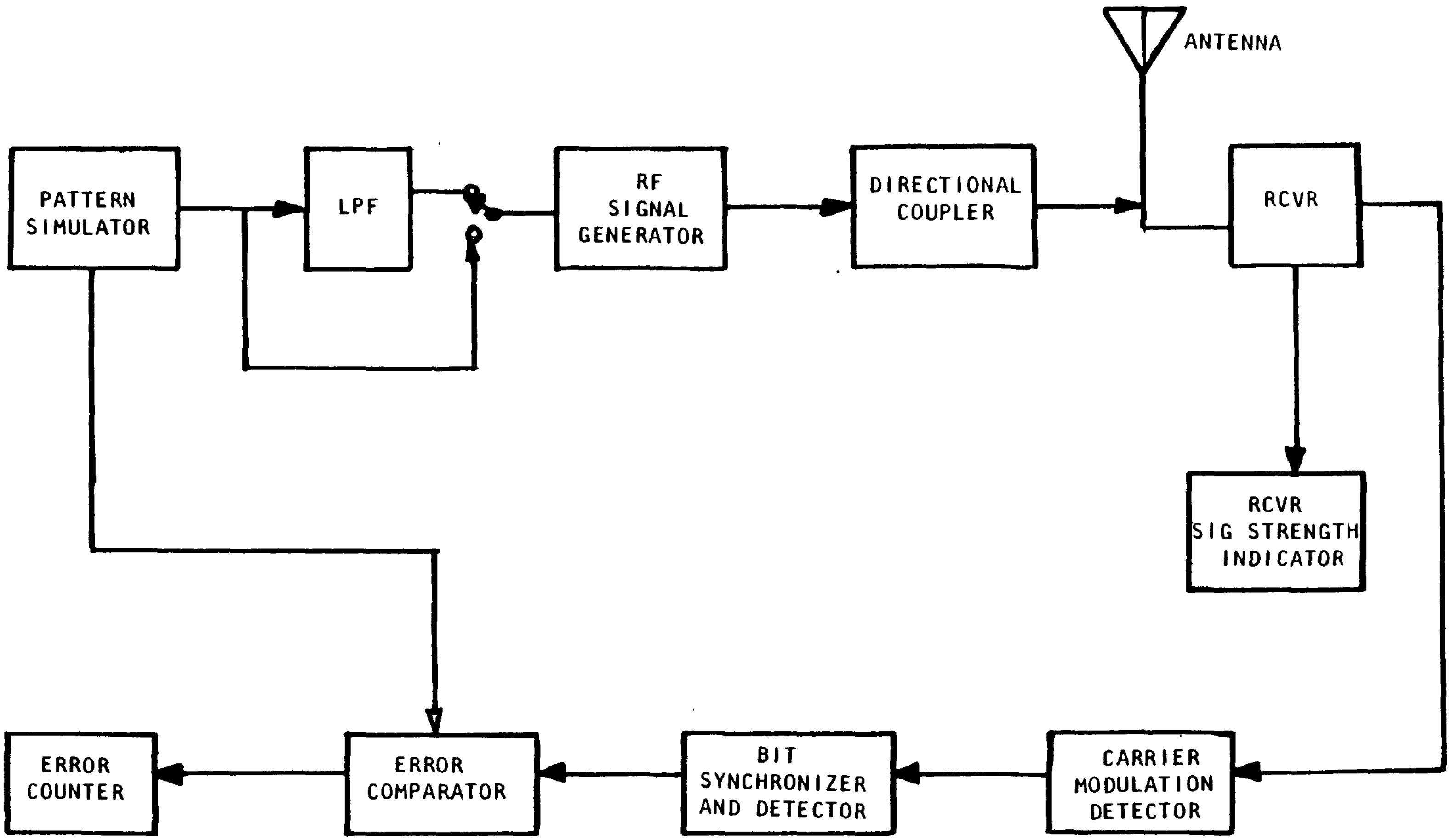


Figure 2.1.1.2-1 PCM Simulator Method (Real Time).

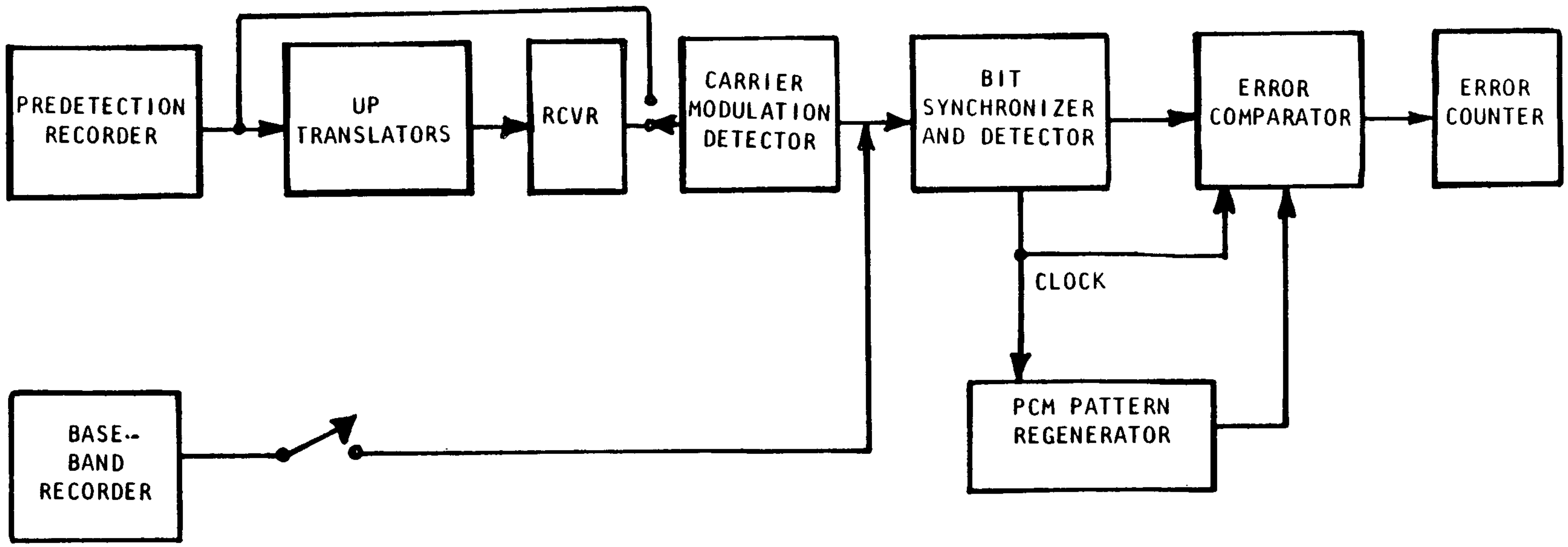


Figure 2.1.1.2-2 PCM Simulator Method (Post Time).

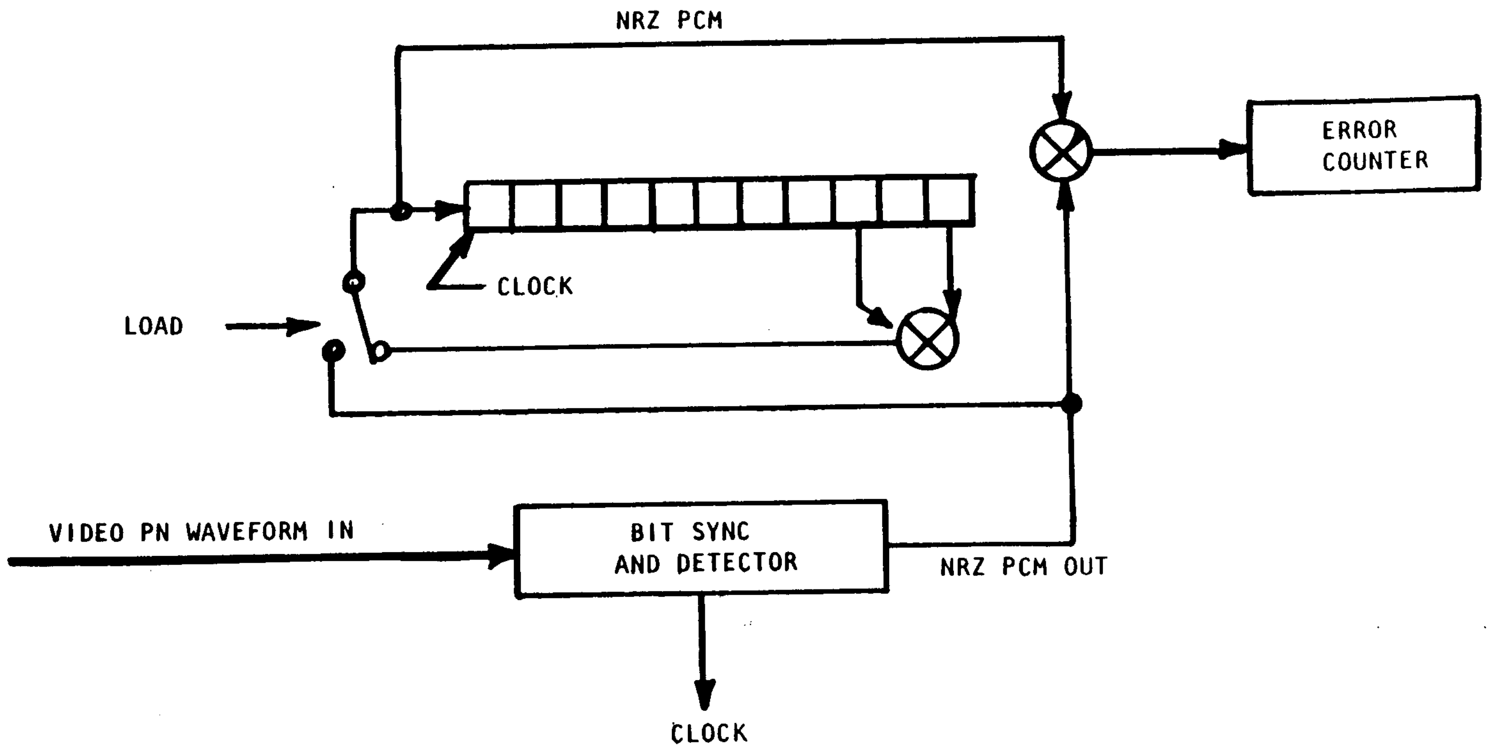
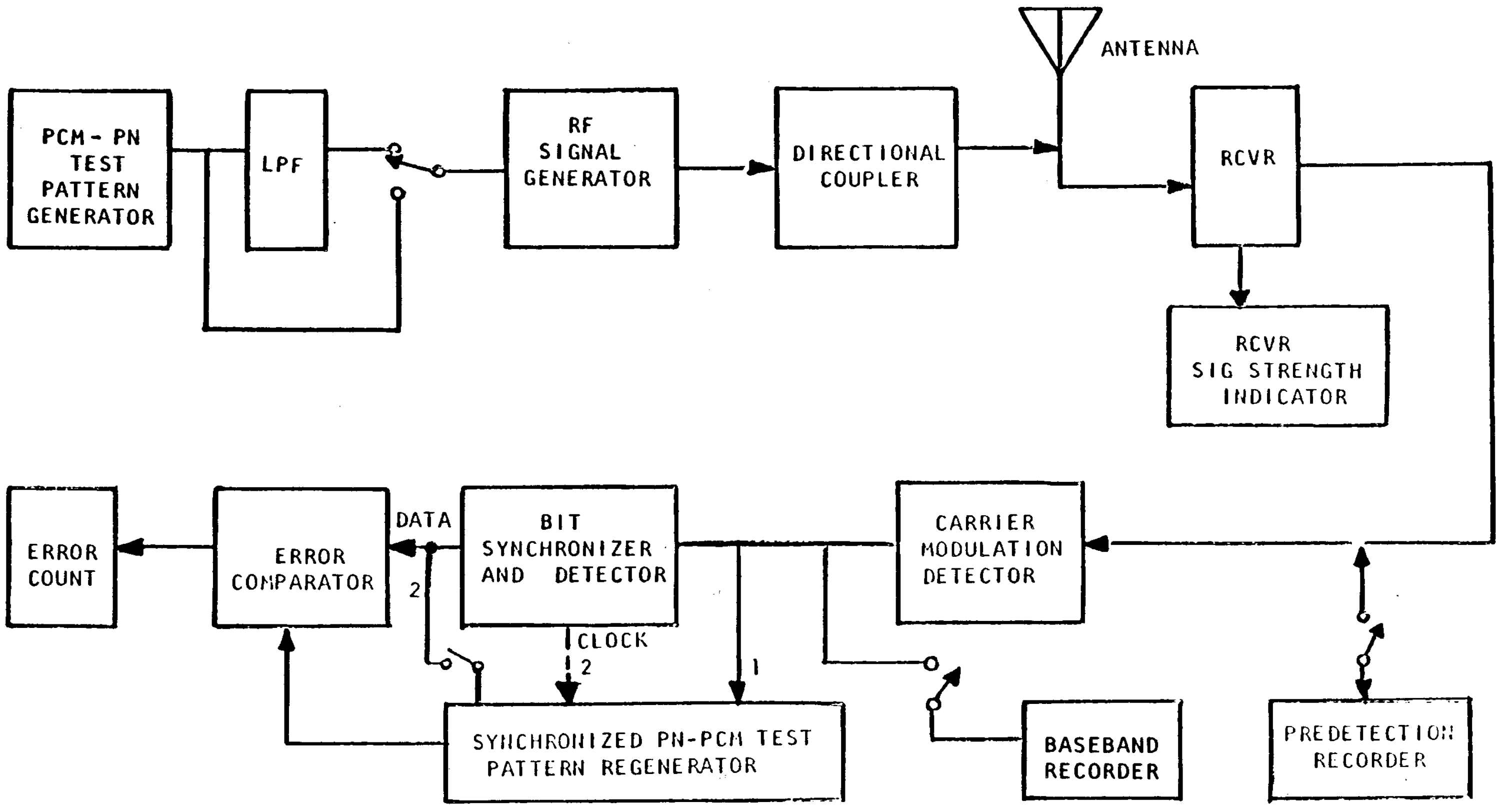


Figure 2.1.1.3-1 Noncoherent PN-PCM Synchronizer.



1 USE IN COHERENT SYNCHRONIZATION

2 USE IN NONCOHERENT SYNCHRONIZATION

Figure 2.1.1.3-2 Autocorrelation Method.

2.1.1.3.3.3 Procedure:

2.1.1.3.3.3.1 It is recommended that a PN test pattern be utilized whenever possible. One reason for this is that a PN sequence can be generated and synchronized economically by a shift register with feedback configured for a maximum length sequence. The number of positions in the shift register and the feedback connections uniquely determine the test pattern which has been adopted by ranges and users and allows the exchange of test data without ambiguity. In this connection an 11-position shift register is recommended with feedback summed modulo two from positions 9 and 11. The sequence will be 2047 bits long which corresponds roughly to the frame lengths used for nonreturn to zero (NRZ) and exercises the low-frequency response of elements of the system. This is important because with NRZ the lack of d.c. response causes zero wander of the bit stream in accordance with the fractional amount of near-d.c. power lost. In addition, the sequence will contain 11 binary ls followed by 9 binary 0s, thus exercising the bit synchronizer with only 1 NRZ transition in 19 bits, 3 in 29 bits, 5 in 39 bits, 7 in 49 bits, etc.

2.1.1.3.3.3.2 The synchronization of the PN-PCM test pattern regenerator shown in figure 2.1.1.3-1 is discussed in the reference. Because of the autocorrelation properties of a PN sequence, it is possible to synchronize a slave shift register to an incoming PN bit stream (plus noise) by cross correlation. This is carried out by coherent or non-coherent methods. The test data given in the reference indicate that the noncoherent method is adequate for tests in which the BEP is less than 0.01.

2.1.1.3.3.3.3 The noncoherent method of synchronization makes use of the clock from a data bit synchronizer. Since data bit transitions occur at random, a nonlinear operation is required in the data bit synchronizer to generate discrete frequency components at the bit rate and its harmonic. Figure 2.1.1.3-1 is a schematic of the noncoherent PN synchronizer. The clock from the bit synchronizer is used to drive the shift register and the NRZ bit stream out of the bit detector, and is used to load the shift register by throwing the switch to the load position. The switch is then thrown to the feedback position, and, if there are no errors in the loaded bits, the shift register is in lock with the input PN waveform. It will stay in lock until bit slippage occurs in the bit synchronizer. If one or more errors are loaded into the register, the shift register is not locked, and because of the autocorrelation properties of the PN sequence, the error rate is nearly 50 percent. If the error rate for example is 10^{-2}, the register is locked. If it is not locked, (error rate approximately 0.5), the switch is returned to the load position and the process repeated until lock is obtained. In operational hardware, the whole loading operation can be done automatically.

2.1.1.3.3.4 Data Reduction - Use the same data sheets discussed in subparagraph 2.1.1.1.3.4. Tabulate BEP and P_s. Calculate J_a and tabulate along with BEP and P_s. Plot BEP vs. J_a.

2.1.1.4 BEP Test Configuration C

2.1.1.4.1 Purpose - This test measures BEP using operational hardware, i.e., a PCM test set.

2.1.1.4.2 Test Equipment:

PCM test set

2.1.1.4.3 Test Method:

2.1.1.4.3.1 Setup - Connect the test equipment as shown in figure 2.1.1.3-2. The test set transmitter portion in this case will serve as the PCM/PN test pattern generator and the test set receiver portion will serve as the synchronized PN-PCM test pattern regenerator.

2.1.1.4.3.2 Conditions - Refer to subparagraph 2.0.3. In addition, PCM test sets which utilize PN autocorrelation methods with either coherent or noncoherent synchronization should have the following characteristics:

2.1.1.4.3.2.1 The test PN sequence shall be 2047 bits in length.

2.1.1.4.3.2.2 The PN generator shall include an internal clock continuously variable over the range of 10 bits/sec to 10^6 bits/sec. The stability shall conform to IRIG Standards for PCM which are contained in IRIG Standard 106. Provisions for acceptance of external clock shall be included.

2.1.1.4.3.2.3 Provision shall be made for including in the test format an arbitrary word of not more than 33 bits at selectable integer multiples of the PN sequence period.

2.1.1.4.3.2.4 Two bit pulse waveforms shall be selectable; namely, NRZ and split phase.

2.1.1.4.3.2.5 The PN test receiver shall include a PN sequence synchronizer, error comparator and error counter with a capacity for at least 1000 errors.

2.1.1.4.3.2.6 The PN test receiver shall provide PN sequence pattern and bit clock outputs.

2.1.1.4.3.2.7 The PN test receiver shall employ an integrate-and-dump bit detector using the bit clock output from subparagraph 2.1.1.4.3.2.6.

2.1.1.4.3.2.8 The PN receiver shift register clock shall be derived by efficient utilization of the autocorrelation of the PN waveform.

2.1.1.4.3.2.9 Provisions shall be made to indicate the time required to accumulate the bit error count.

2.1.1.4.3.3 Procedure - N/A

2.1.1.4.3.4 Data Reduction - Use the same data sheets discussed in subparagraph 2.1.1.1.3.4. Tabulate BEP and P_s. Calculate J_a and tabulate along with BEP and P_s. Plot BEP vs. J_a.

2.1.2 Other PCM System Tests

2.1.2.1 In addition to BEP system testing, other tests may be conducted using similar test methods. The use of the PCM test set is recommended for conducting bit slippage probability tests, bit synchronization acquisition tests and bit jitter tests.

2.1.2.2 The test set pattern generator shall be used in conjunction with the same RF generator used in the determination of α and J_a. The major difference between system testing and component testing using PCM test sets is that system testing uses the received signal power flux density (J_a) as the independent variable and component testing uses the predetected IF SNR as the independent variable.

2.1.2.3 It may be necessary to conduct all of the tests mentioned in subparagraph 2.1.2.1 as system tests. For any given ground station configured in support of a PCM format, it may be advantageous to conduct only BEP tests with the option of introducing base-line wander and AM effects to create a more realistic situation. Refer to chapter 4 of this volume for the test procedures for bit synchronizers which use PCM test sets.

2.2 PAM Testing

2.2.1 Test methods for PAM systems have not been established but may be included in later revisions of Document 118. Test sets such as those used for PCM systems are not readily available for PAM systems.

2.2.2 Some of the problems which can occur in PAM systems due to signal degradation include noise on the analog outputs, drift of the reference levels and loss of frame synchronization. As a minimum test, the performance of the PAM decommutator should be monitored as input levels are varied and noise is introduced.

REFERENCE

Lindsey, W.C., "Bit Synchronization System Performance Characterization, Modeling, and Tradeoff Study," Pacific Missile Test Center, Point Mugu, California, Technical Publication, TP-73-18, 4 September 1973.

This page intentionally left blank

CHAPTER 3

SUBCARRIER OSCILLATORS

3.0 General

3.0.1 The purpose of subcarrier oscillator (SCO) evaluation is the acquisition and distribution of performance information that will be useful to groups engaged in telemetry and missile instrumentation activities. To be of maximum benefit, published performance information on a given model should be in a form that can be readily compared with information on other SCO models which may have been tested by other groups. Uniformity of test procedures used by testing groups is important for obtaining valid comparisons of SCO performance and for performing periodic checks on installed equipment, or acceptance tests on new equipment. The SCOs to be evaluated by this procedure are used for multiplexing data within a telemetry ground station.

3.0.2 Performance tests are recommended for all IRIG subcarrier bands intended for use in the particular application. To minimize measurement errors, energize the test equipment from a regulated line and conduct the tests in a room where ambient temperature variations are small. When tests require the measurement of voltages or currents with a high order of precision or when the measurement of low-level voltages or currents is required, particular care should be given to the design of the test setup to avoid the error-producing effects of ground-loop currents. The use of an isolation power transformer is desirable. Observe the practice of bringing all ground leads to one common point.

3.0.3 To assure uniformity of testing, the following setup procedures and preliminary adjustments should be completed before the individual tests are conducted.

3.0.3.1 Place the SCOs under test in a temperature-controlled chamber, and maintain the chamber at 30º C±1ºC (303.2K±lK) unless otherwise indicated in the test procedure. If a temperature chamber is not available, ambient temperature variations must be kept as small as possible so that the effects of controlled test parameter variations are not influenced by temperature fluctuations. For similar reasons, the supply voltages for the SCOs under test must be carefully adjusted and regulated.

3.0.3.2 Adjust the supply voltage(s) to the level(s) recommended by the manufacturer and allow a 15-minute warm-up. Adjust the appropriate controls on the SCO so that the input signal voltage level and excursion recommended by the manufacturer will produce full IRIG bandwidth output frequency excursion centered within the band. Also adjust the amplitude control to produce the maximum output signal amplitude. Apply the maximum output load comparable to the application.

3.0.4 Make certain the test equipment selected for each test is commensurate with the range, precision and input and/or load impedance requirements, and the SCO manufacturer's specifications. The input signal source output impedance is especially important when testing

SCOs employing solid-state design, where reverse leakage currents may be present at the input terminals.

3.0.5 Recommended formats for publishing and reporting the results of telemetry SCO performance measurements are shown under each test. The primary purpose of the formats is to provide uniform methods of presenting measurement data. The validity of performance characteristics such as linearity are consistently presented in the same style and may be found in approximately the same part of the report, regardless of the source of publication. Data Sheet 3.0.1 provides space for a brief description of the model under test along with definitions of test procedures. The formats were designed to make maximum use of graphical and tabular data presentations. Supplementary notes appear when required to explain data irregularities or to provide additional performance information.

DATA SHEET 3.0.1 SCO PERFORMANCE EVALUATION

IDENTIFICATION	DATE
(Report Number)	

A. EQUIPMENT TESTED

1. DESCRIPTION

TYPE	MODEL	SERIAL NUMBER (S)
(Telemetry Subcarrier Oscillator)	(XXXXXXXX)	(XXXXX.XX)

MANUFACTURER	HOW PROCURED
(Company Name)	(Contract? Loan? Other?)

SIZE	WEIGHT
(h x w x d) (Dimensions in cm (in))	

INSTALLATION
(What type of mounting? How many units does mounting adapter or subchassis accommodate? What are the dimensions of the mounting adapter of subchassis?)

2. CHARACTERISTICS

INPUT RANGE (Required input voltage excursion for band-edge-to-bandedge subcarrier excursion. Input voltage corresponding to center frequency (reference level). Single-ended or differential input? Input impedance?)

OUTPUT RANGE (Are all IRIG bands available? Output amplitude adjustments? Output impedance? Sense: does output frequency increase or decrease with positive-going input voltage? Note: Differential input will require more definition.)

OSCILLATOR TYPE	CIRCUITRY
(Multivibrator? Tuned-circuit? Other?)	(Solid-state? Vacuum tube? Hybrid?)

OUTPUT FILTER
(Low-pass? Band-pass? None?)

POWER REQUIREMENTS
(Voltage and current requirements? Does SCO include regulator? If regulator is not included, what are regulation requirements of external power source?)

B. TEST CONDITIONS

(Tests are conducted in IRIG bands &(2,3kHz±7,5%), 14(22 kHz±7,5%), A(22 kHz±15%), and E(70 kc ±15%). Unless otherwise indicated, the following standard test conditions were observed in each performance measurement.)

INPUT EXCURSION	SUBCARRIER DEVIATION
(x.x volts peak-to-peak)	(IRIG Standards: ±7,5% or ±15% as appropriate)
OUTPUT AMPLITUDE CONTROL	**OUTPUT LOAD**
(Set to maximum position)	
WARMUP	**SUPPLY VOLTAGE**
	(y, y volts with z % regulation)

AMBIENT TEMPERATURE
(xx K) (xx°C)

REMARKS (General information. Test conditions or circumstances which are not described elsewhere in the report)

3.1 Control Range(s)

3.1.1 Purpose - This test determines the ranges of controls which are provided to adjust deviation sensitivity, reference frequency and output level.

3.1.1.1 The sensitivity control adjusts the magnitude of input voltage excursion required to produce full IRIG bandwidth output frequency excursion. The reference frequency control adjusts the output frequency which is produced when the input signal terminals are shorted. Depending upon the manufacturer's design, the nominal reference frequency may correspond to the center of the band or to either of the band edges. The output level control adjusts the amplitude of the subcarrier output signal.

3.1.1.2 Certain models may feature all three of the controls, while other models may have only one or two controls. Still other models may have a control to adjust each of the band-edge frequencies but no reference frequency control. The following test procedure applies to models which include the three controls listed in subparagraph 3.1.1.

3.1.2 Test Equipment:

D.C. signal source
D.C. voltmeter
Frequency counter
A.C. voltmeter (true rms)

3.1.3 Test Method:

3.1.3.1 Setup - Connect the test equipment as shown in figure 3.1-1.

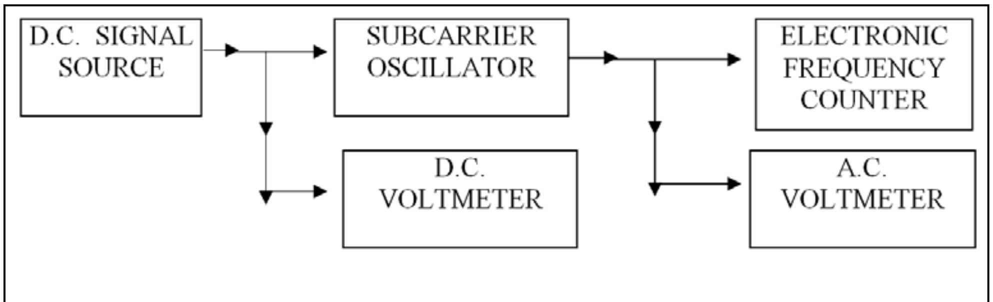


Figure 3.1-1 Control Range(s)

3.1.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.1.3.3 Procedure:

3.1.3.3.1 Measure the input voltage excursion required to produce a full bandwidth output frequency excursion with the sensitivity control set first to the maximum mechanical position and then to the minimun mechanical position.

3.1.3.3.2 Short-circuit the input terminals and measure both the minimum and maximum frequency produced by adjusting the reference frequency control through its full mechanical range.

3.1.3.3.3 Apply a d.c. input voltage to produce an output frequency corresponding to the band center. Measure both the minimum and maximum output signal amplitude for both minimum and maximum settings of the output level control.

3.1.3.3.4 Record data on Data Sheet 3.1.1.

DATA SHEET 3.1.1 CONTROL RANGE

CONTROL RANGES

BAND	SENSITIVITY *(VOLTSp.p/BANDWIDTH)*		REFERENCE FREQUENCY *(Hz)*		OUTPUT AMPLITUDE *(VOLTS RMS)*	
	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM	MAXIMUM	MINIMUM
7						
14						
A						
E						

NOTE:

3.2 Linearity

3.2.1 Purpose - This test determines the deviation of the output frequency vs. the input voltage characteristics from a straight line drawn through the end points (band edges).

3.2.2 Test Equipment:

Variable d.c. source
Precision voltmeter
Electronic frequency counter

3.2.2.1 Setup - Connect the test equipment as shown in Figure 3.2-1.

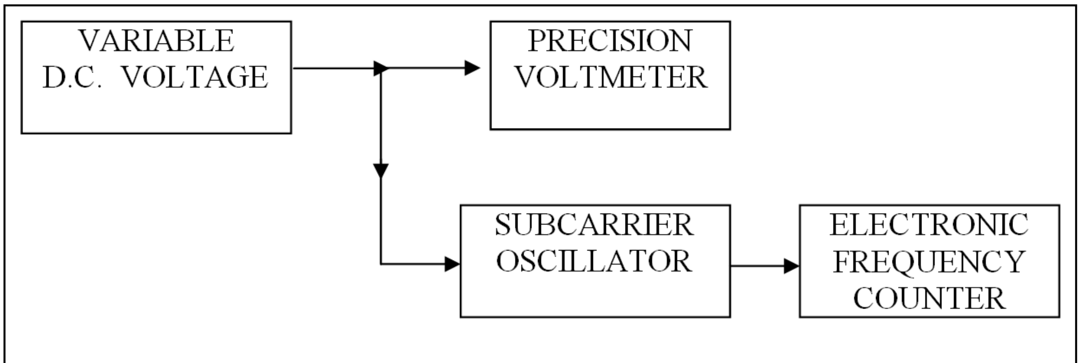


Figure 3.2-1 Linearity Measurement.

3.2.2.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.2.2.3 Procedure:

3.2.2.3.1 Measure the input voltages required to produce 11 equally spaced output frequencies covering the subcarrier band by using the precision voltmeter and the frequency counter.

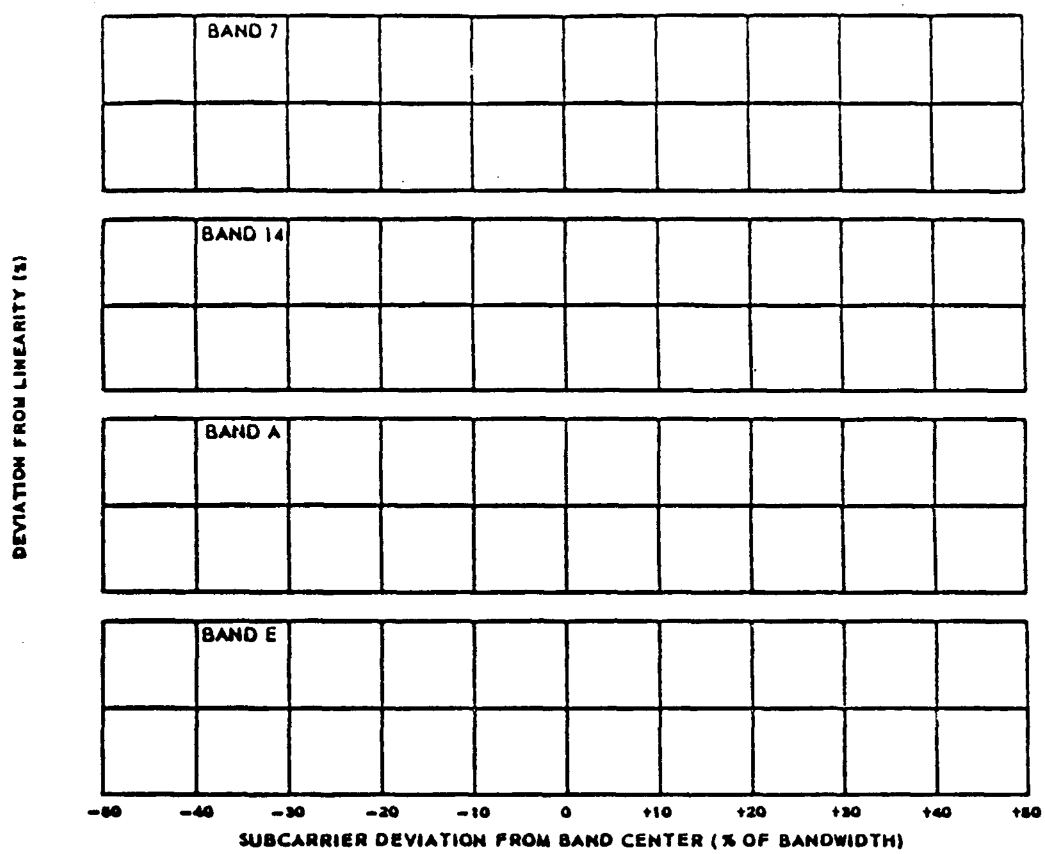
3.2.2.3.2 The measured data can be plotted on a scale with greatly increased resolution if an arbitrary slope (approximating the data slope) is first subtracted from the data. A straight line can then be passed through the end points and the deviation of each data point from the straight line can be determined with much higher resolution.

3.2.2.3.3 Express deviation from linearity as a percentage of bandwidth. Give such deviation a positive sign when, for a selected input voltage level, the output frequency is greater than the corresponding point on the line through the end points.

3.2.2.3.4 Record data on Data Sheet 3.2.1.

DATA SHEET 3.2.1 LINEARITY

2. LINEARITY



NOTE

3.3 Amplitude Modulation (AM)

3.3.1 Purpose - This test determines the change of output signal amplitude as the subcarrier frequency is changed through the band from one band edge to the other.

3.3.2 Test Equipment:

D.C. signal source
Electronic frequency counter
A.C. voltmeter (true rms)

3.3.3. Test Method:

3.3.3.1 Setup - Connect the test equipment as shown in figure 3.3.-1.

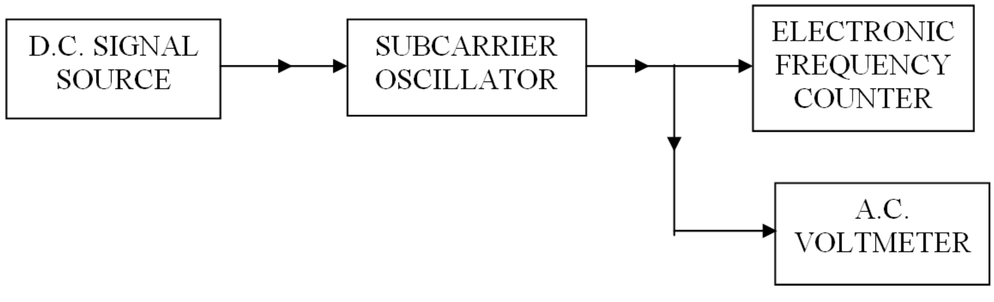


Figure 3.3-1 Amplitude Modulation.

3.3.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.3.3.3 Procedure:

With the input amplitude adjustment set at maximum, vary the d.c. input signal to cause the output frequency to cover the full excursion from one band edge to the other and measure the minimum and the maximum output signal amplitudes within the band.

3.3.3.3.1 Calculate percent AM from the equation:

$$\% \text{ AM} = ((E_{max}-E_{min})/(E_{max}+E_{min}))\text{x } 100$$

3.3.3.3.2 Adjust the output frequency to band center and reduce the output signal amplitude to 70 percent of its former value. Repeat the measurements of AM as outlined above.

3.3.3.3.4 Record data on Data Sheet 3.3.1.

DATA SHEET 3.3.1 AMPLITUDE MODULATION

AMPLITUDE MODULATION

AMPLITUDE MODULATION (%)		
BAND	AT MAXIMUM OUTPUT AMPLITUDE	AT 70% OUTPUT AMPLITUDE
7		
14		
A		
E		

NOTE:

3.4 Output Distortion

3.4.1 Purpose - This test determines the distortion of the output subcarrier waveform at selected output amplitudes and output loads (sine-wave outputs only). Use either a distortion analyzer or a wave analyzer to measure output distortion. If a distortion analyzer is used, the effects of all of the distortion producing components (within the bandwidth of the test instrument) are lumped together. If a wave analyzer is used, it is necessary to search for and measure the amplitude of the individual distortion components and then calculate the distortion. This test may be conducted concurrently with measurement of output loading, test 3.7.

3.4.2 Test Equipment:

D.C. signal source
Electronic frequency counter
Distortion analyzer or wave analyzer

3.4.3 Test Method:

3.4.3.1 Setup - Connect the test equipment as shown in figure 3.4-1.

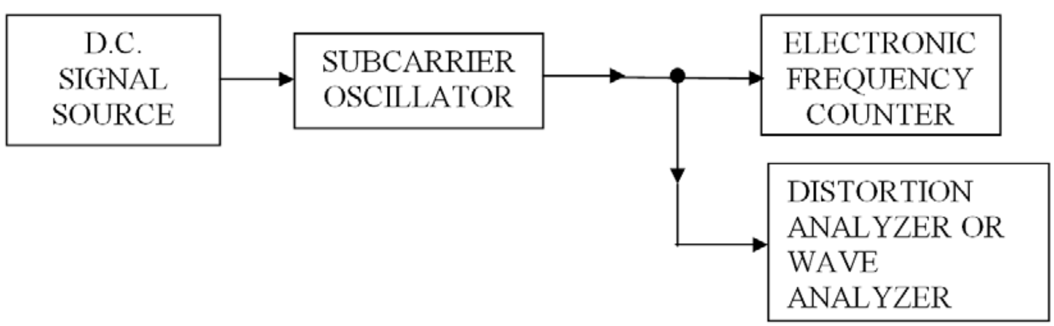


Figure 3.4-1 Output Distortion.

NOTE

In making these measurements, care should be taken to use short, unshielded leads between the output terminal and the measuring instruments, since capacitive loading is one of the test parameters. Terminate the oscillator with a 2kΩ resistive load or lower, depending on its application.

3.4.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.4.3.3 Procedure:
3.4.3.3.1 With the output amplitude adjustment set at maximum, apply d.c. input voltages to produce output frequencies corresponding to band center, lower band edge and upper band edge, respectively. Measure the output distortion at each of these frequencies.

3.4.3.3.2 Reduce the output subcarrier amplitude to 70 percent of maximum amplitude and repeat the measurements outlined in step 3.4.3.3.1.

3.4.3.3.3 Readjust the output amplitude to maximum and apply a nominal capacitive load to the output terminals (in addition to the resistive load) consistent with the intended application.

3.4.3.3.4 Perform distortion measurements at the 3 frequencies corresponding to band center, lower band edge and upper band edge.

3.4.3.3.5 In the same manner, make distortion measurements with capacitive loads above and below the nominal value selected in subparagraph 3.4.3.3.3.

3.4.3.3.6 Record data on Data Sheet 3.4.1.

DATA SHEET 3.4.1 OUTPUT DISTORTION

OUTPUT DISTORTION

OUTPUT AMPLITUDE (% OF MAX.)	RESISTIVE LOAD (OHMS)	CAPACITIVE LOAD (pF)	OUTPUT DISTORTION (%) BAND			
			E	A	14	7
(AT BAND CENTER)						
100		0				
70		0				
100		100				
100		500				
100		1000				
(AT UPPER BAND EDGE)						
100		0				
70		0				
100		100				
100		500				
100		1000				
(AT LOWER BAND EDGE)						
100		0				
70		0				
100		100				
100		500				
100		1000				

NOTE

3.5 <u>Effect of Source Impedance</u>

3.5.1 <u>Purpose:</u>

3.5.1.1 This test determines the change of output frequency as a function of source impedance variations and determines the current that is fed back from the input terminals into the source.

3.5.1.2 This test is particularly important on solid-state models which receive input signals from variable-resistance transducers. Evaluation groups may also wish to conduct tests at temperatures which simulate selected systems applications in addition to room temperature tests.

3.5.2 <u>Test Equipment:</u>

Resistance decade box
Electronic frequency counter
D.C. null voltmeter

3.5.3 <u>Test Method:</u>

3.5.3.1 <u>Setup</u> - Connect the test equipment as shown in figure 3.5-1.

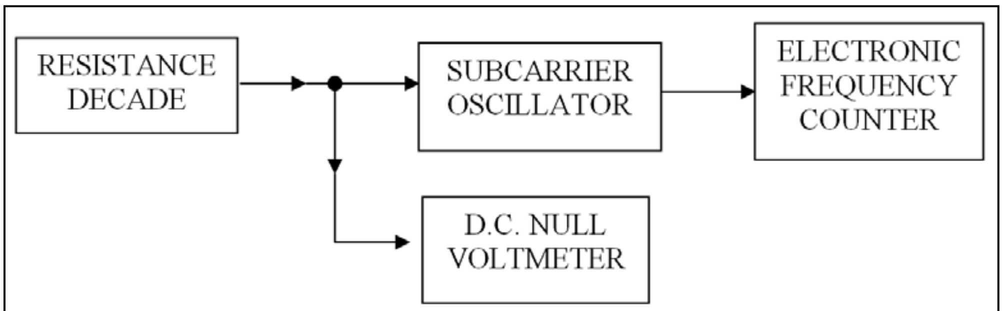


Figure 3.5-1 Effect of Source Impedance.

3.5.3.2 <u>Conditions</u> - Refer to subparagraphs 3.0.2 through 3.0.4.

3.5.3.3 <u>Procedure:</u>

3.5.3.3.1 Short the input terminals and measure the output frequency.

3.5.3.3.2 Adjust the variable resistance decade to 100Ω. Measure the voltage appearing at the SCO input terminals (use a null voltmeter) and measure the output frequency.

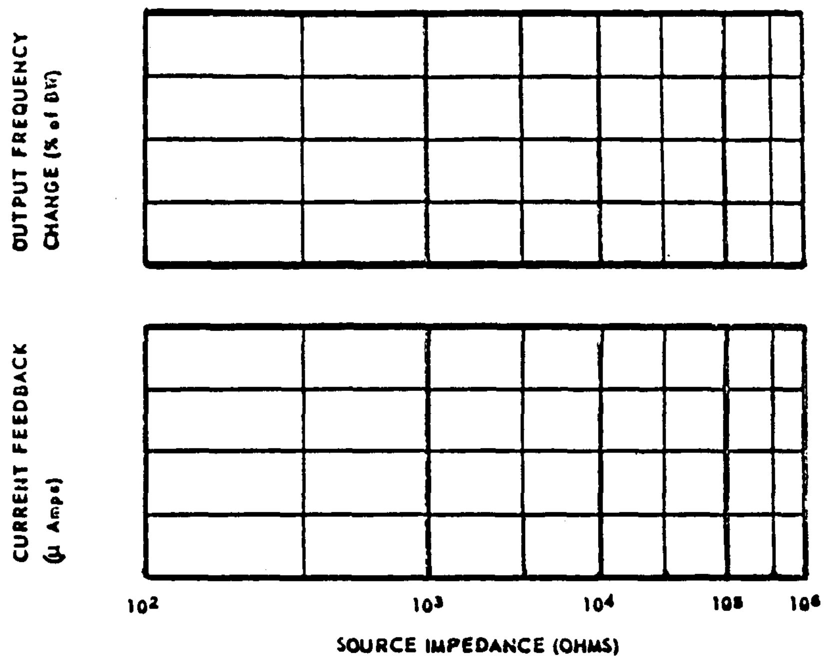
3.5.3.3.3 In the same manner, measure the input voltages and output frequencies with the following resistance values applied to the input: lkΩ, 10kΩ, 100kΩ, 1MΩ, and 10MΩ.

3.5.3.3.4 Use the frequency measured with the input shorted as a reference for calculations and express frequency changes in percent of bandwidth. Calculate the feedback current for each of the input resistance levels.

3.5.3.3.5 Record data on Data Sheet 3.5.1.

DATA SHEET 3.5.1 EFFECT OF SOURCE IMPEDANCE

EFFECT OF SOURCE IMPEDANCE



NOTE

3.6 Effect of Grounding Input (Differential-Input Models Only)

3.6.1 Purpose - This test measures the effects of grounding the input terminals on the subcarrier output frequency and amplitude.

NOTE

In making these measurements, care should be taken to use short, unshielded leads between the output terminals and the measuring instruments, since capacitive loading is one of the test parameters.

3.6.2 Test Equipment:

D.C. signal source
D.C. voltmeter
Electronic frequency counter
A.C. voltmeter (true rms)

3.6.3 Test Method:

3.6.3.1 Setup - Connect the test equipment as shown in figure 3.6-1.

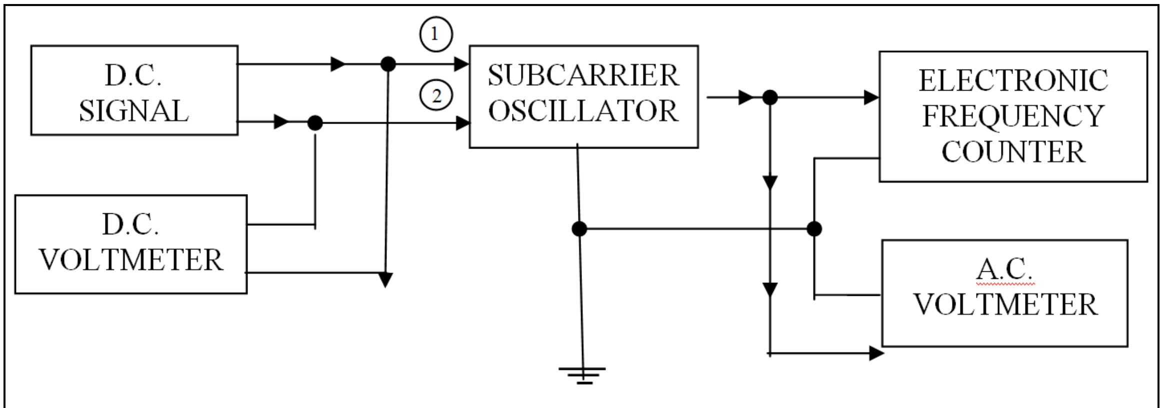


Figure 3.6-1 Effect of Grounding Input.

3.6.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.6.3.3 Procedure:

3.6.3.3.1 Ground the chassis of the SCO.

3.6.3.3.2 Apply the input voltages recommended by the manufacturer for subcarrier frequencies corresponding to lower band edge, band center and upper band edge. Do not ground input terminals. Measure the output subcarrier frequencies and amplitudes corresponding to each of these inputs.

3.6.3.3.3 Ground input terminal number 1 and apply the same input voltages used in step 3.6.3.3.2 and again measure the output frequencies and amplitudes.

3.6.3.3.4 Repeat step 3.6.3.3.3 with input terminal number 2 grounded rather than input terminal number 1.

3.6.3.3.5 Using the frequencies and amplitudes measured in step 3.6.3.3.2 as references for calculations, express the frequency changes as percentages of IRIG bandwidth and express amplitude changes directly in percent.

3.6.3.3.6 Record data on Data Sheet 3.6.1.

DATA SHEET 3.6.1 EFFECT OF GROUNDING INPUT

EFFECTS OF GROUNDING INPUT *(Differential-Input Models Only)*

BAND	OUTPUT FREQUENCY CHANGE (% of BW)			OUTPUT AMPLITUDE CHANGE (%)		
	LOWER BAND EDGE	BAND CENTER	UPPER BAND EDGE	LOWER BAND EDGE	BAND CENTER	UPPER BAND EDGE
INPUT NUMBER 1 GROUNDED						
7						
14						
A						
E						
INPUT NUMBER 2 GROUNDED						
7						
14						
A						
E						

NOTE

3.7 Effect of Output Loading

3.7.1 Purpose - This test determines the effects of output loading (both resistive and capacitive) on the amplitude and frequency of the output signal. This test may be conducted concurrently with measurement of output distortion, test 3.4.

3.7.2 Test Equipment:

D.C. signal source
D.C. voltmeter
Resistance decade
Capacitance decade
Electronic frequency counter

3.7.3 Test Method:

3.7.3.1 Setup - Connect the test equipment as shown in figure 3.7-1.

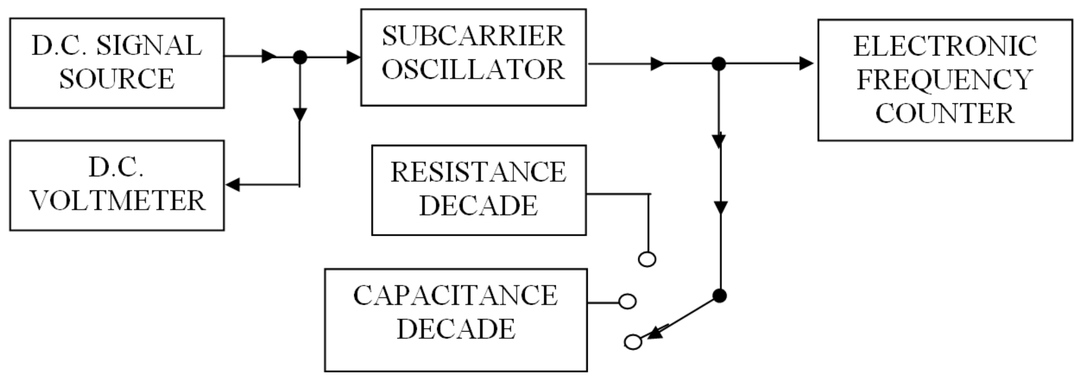


Figure 3.7-1 Effect of output loading.

3.7.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.7.3.3 Procedure:

3.7.3.3.1 Adjust the d.c. input signal to a level that will produce an output frequency corresponding to band center.

3.7.3.3.2 Measure the frequency and amplitude of the output signal with no load applied to the output.

3.7.3.3.3 Use the same input level applied in step 3.7.3.3.1 to measure the output frequencies and amplitudes for the resistive output loads selected in subparagraph 3.4.3.3 or others consistent with the intended applications.

3.7.3.3.4 Remove the resistive load and recheck the output frequency and amplitude and readjust the d.c. input signal, if necessary, to produce band-center frequency.

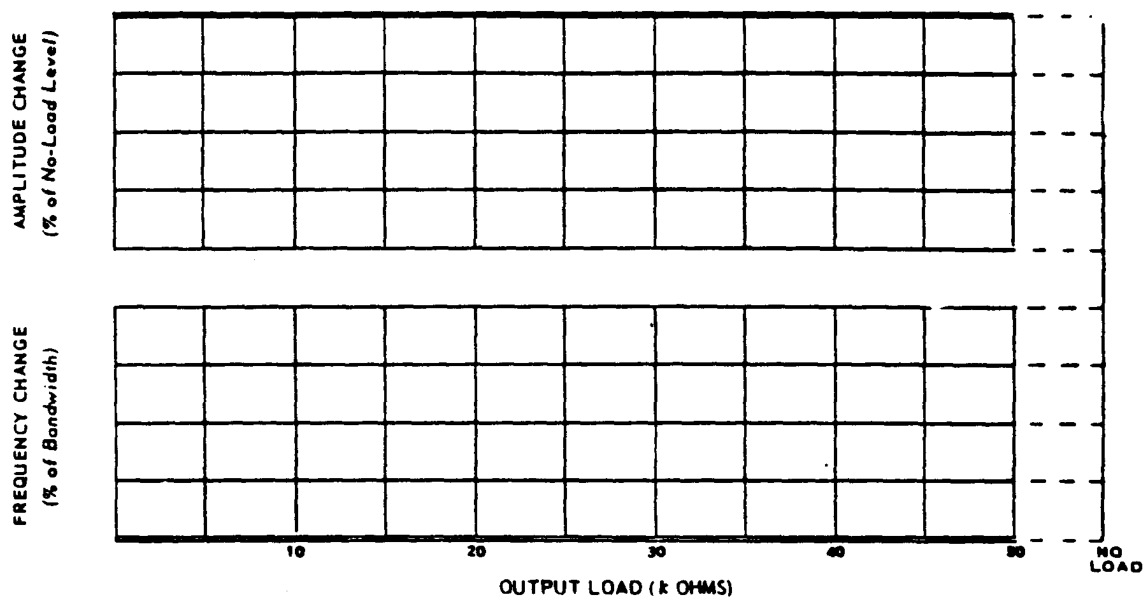
3.7.3.3.5 Using the same input level applied in subparagraph 3.7.3.3.4, measure the output frequencies and amplitudes for capacitive output loads selected in subparagraph 3.4.3.3.

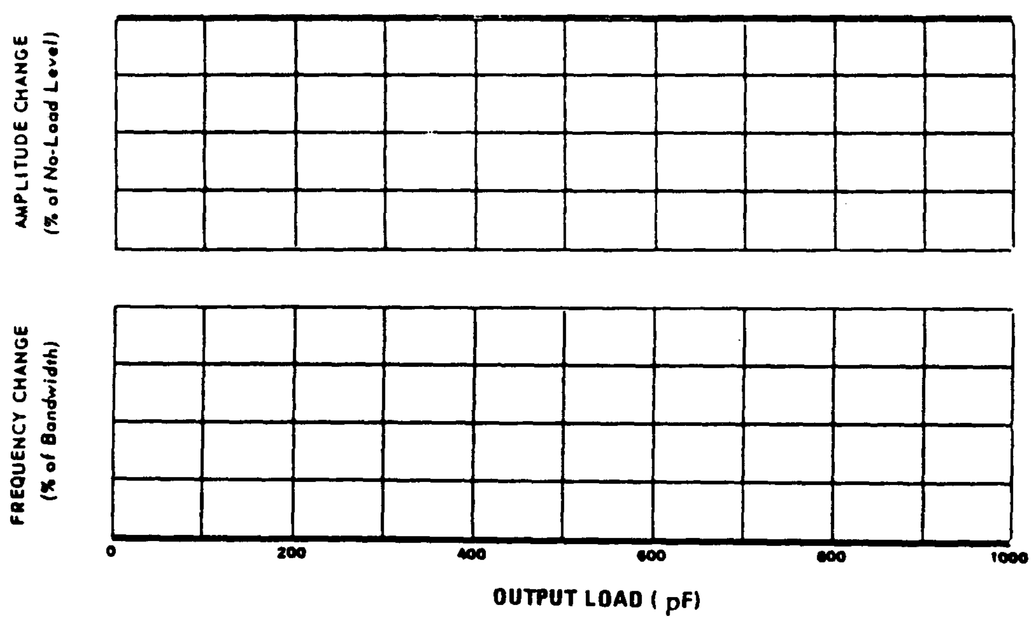
3.7.3.3.6 Use the frequencies and amplitudes measured under no-load conditions as references for calculations and express frequency changes in percent of bandwidth and express amplitude changes directly in percent.

3.7.3.3.7 Record data on Data Sheet 3.7.1.

DATA SHEET 3.7.1 OUTPUT LOADING

OUTPUT LOADING





3.8 Modulation Feedthrough

3.8.1 Purpose - This test determines the amplitude of the modulation-frequency component appearing at the SCO output.

3.8.2 Test Equipment:

A.C. signal source
Electronic frequency counter
A.C. voltmeter (true rms)
Wave analyzer

3.8.3 Test Method:

3.8.3.1 Setup - Connect the test equipment as shown in figure 3.8-1.

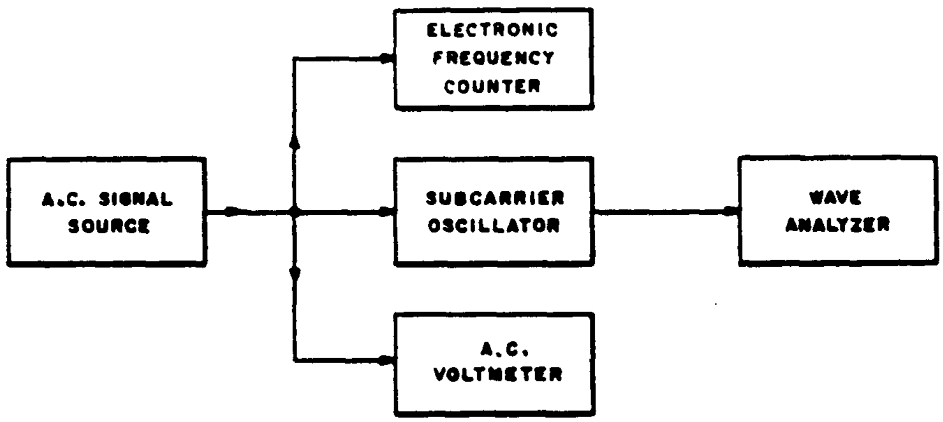


Figure 3.8-1 Modulation Feedthrough.

3.8.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.8.3.3 Procedure:

3.8.3.3.1 Adjust the frequency of the signal source to correspond to the maximum modulation frequency for a modulation index of 1. Adjust the peak-to-peak amplitude for the a.c. signal to produce full bandwidth subcarrier deviation.

3.8.3.3.2 Measure the amplitude of the modulation frequency component appearing at the SCO output terminals using a wave analyzer or similar frequency-selective voltmeter.

3.8.3.3.3 Repeat step 3.8.3.3.2 at modulation frequency of one-half of that selected in step 3.8.3.3.1 and then repeat step 3.8.3.3.2 at a frequency one-tenth of that selected in step 3.8.3.3.1.

3.8.3.3.4 Modulation feedthrough is expressed in db below the subcarrier and is calculated from the ratio of subcarrier component to the modulation component appearing at the output terminals.

3.8.3.3.5 Record data on Data Sheet 3.8.1.

DATA SHEET 3.8.1 MODULATION FEEDTHROUGH

MODULATION FEEDTHROUGH

BAND	MODULATION FEEDTHROUGH (dB below subcarrier) (f_1 = mod freq for deviation ratio = 1)		
	f_1	$0,5f_1$	$0,1f_1$
7			
14			
A			
E			

NOTE

3.9 Long-Term Stability Vs. Time

3.9.1 Purpose - This test determines warm-up, reference frequency variations and sensitivity variations as a function of time.

3.9.1.1 Sensitivity instability is defined as the variation of full-scale output frequency excursion (resulting from full-scale input voltage excursion) expressed as a percentage of full-scale output excursion measured at an elapsed time of 30 minutes.

3.9.1.2 Reference frequency shift is defined as the variation of output frequency for 0 input expressed as a percentage of full-scale output frequency excursion measured at an elapsed time of 30 minutes.

3.9.1.3 Sensitivity change is given a positive sign when full-scale output excursion is greater than that measured at the reference time of 30 minutes.

3.9.1.4 Reference frequency shift is given a positive sign when the output frequency is greater than that measured at the reference time of 30 minutes.

3.9.2 Test Equipment:

Reference voltage source
Programmer (optional)
Electronic frequency counter
Printer

The block diagram (figure 3.9-1) includes a programmer which switches the SCO input voltages and provides a count command to the electronic counter. A printer is also shown associated with the counter. Although the test can be conducted without these two items of test equipment, they are included for convenience.

3.9.3 Test Method:

3.9.3.1 Setup - Connect the test equipment as shown in figure 3.9-1.

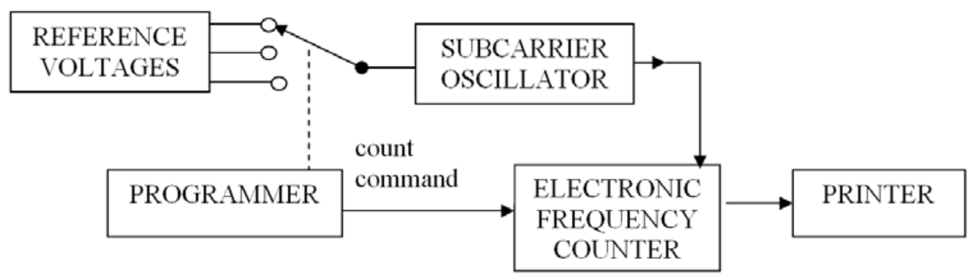


Figure 3.9-1 Stability versus Time.

3.9.3.2 Conditions - Measurements are conducted over a period of 8 hours and elapsed time is measured from cold start. Nominal settings of the sensitivity control and the reference frequency control should approximate those which will produce full bandwidth output frequency excursion, centered within the band, after 30 minutes or more of operation. Additional test conditions are contained in subparagraphs 3.0.2 through 3.0.4.

3.9.3.3 Procedure:

3.9.3.3.1 Adjust the reference voltages to the preselected levels for output frequencies corresponding to the lower band edge, band center and upper band edge.

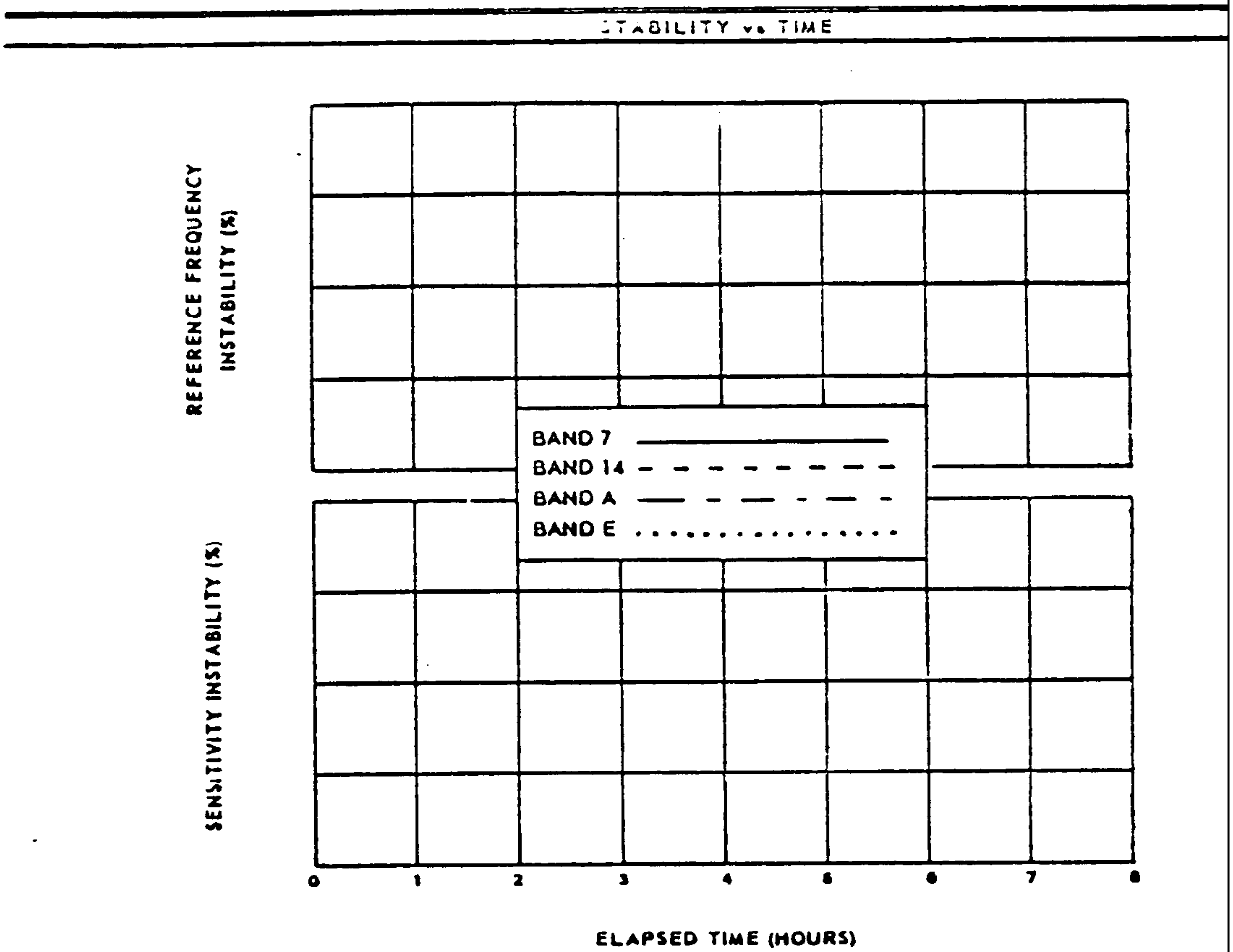
3.9.3.3.2 Energize the SCO and measure the output frequencies for each of the 3 input voltages at an elapsed time of 1 minute. Make similar measurements at 1-minute intervals for the first 10 minutes.

3.9.3.3.3 After 10 minutes, make measurements at 5-minute intervals until 1 hour has elapsed.

3.9.3.3.4 After 1 hour, make measurements at 30-minute intervals until 8 hours have elapsed.

3.9.3.3.5 Record data on Data Sheet 3.9.1.

DATA SHEET 3.9.1 STABILITY VERSUS TIME



NOTE

3.10 Effect of Supply Voltage Variation and Ripple

3.10.1 Purpose - This test determines the effect of supply voltage changes and ripple on output frequency and amplitude.

3.10.2 Test Equipment:

D.C. voltage source
D.C. voltmeter
A.C. supply
Ripple source
Electronic frequency counter
Subcarrier discriminator
A.C. voltmeter (true rms)

3.10.3 Test Method:

3.10.3.1 Setup - Connect the test equipment as shown in figure 3.10-1.

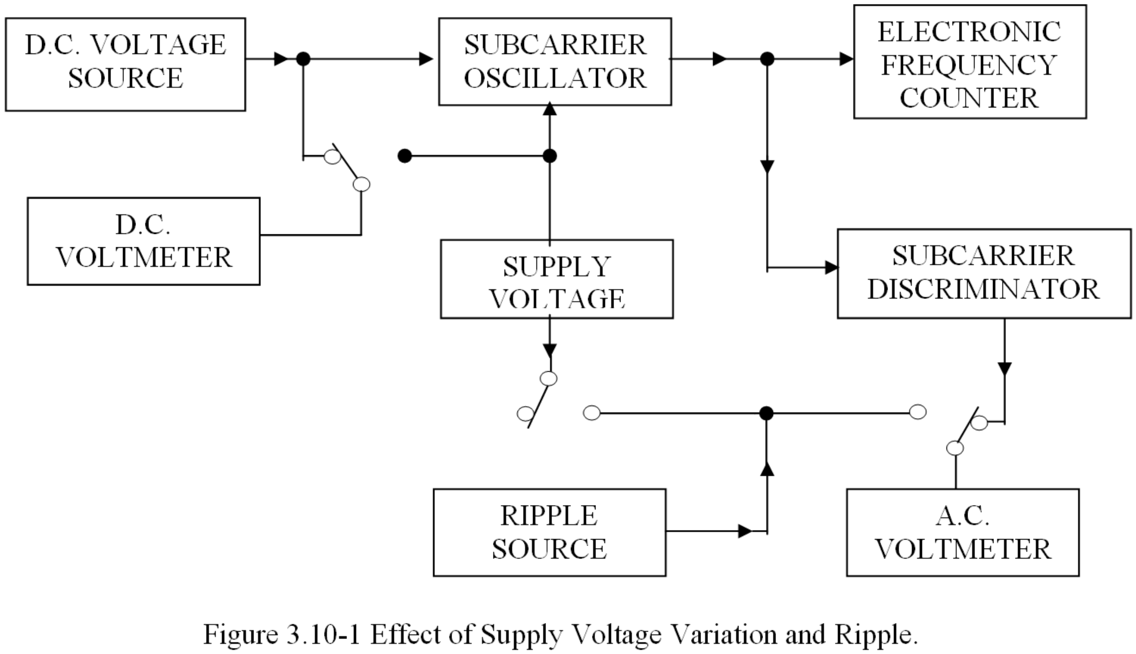


Figure 3.10-1 Effect of Supply Voltage Variation and Ripple.

3.10.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.10.3.3 Procedure:

3.10.3.3.1 Adjust the supply voltage to the nominal value recommended by the manufacturer (do not apply a ripple voltage).

3.10.3.3.2 Adjust the d.c. input signal to the SCO to produce first the lower band-edge frequency, then band center and finally upper band edge. Measure the subcarrier output frequencies and amplitudes at each of these voltage settings. (Note the input voltages required to produce each of the 3 output frequencies.)

3.10.3.3.3 Reduce the supply voltage by 10 percent of the nominal level and again measure the output frequencies and amplitudes for each of the 3 input signal voltage levels used in the previous measurement.

3.10.3.3.4 Make similar measurements with the supply voltages changed by –5 percent, +5 percent, +10 percent, and back to nominal level again. (The measurement range may be expanded to simulate selected system applications.)

3.10.3.3.5 Use the frequencies and amplitudes measured in step 3.10.3.3.2 as references to calculate the frequency changes in percent of bandwidth and calculate the amplitude changes directly in percent. These changes will be given a positive sign when they represent an increase in magnitude.

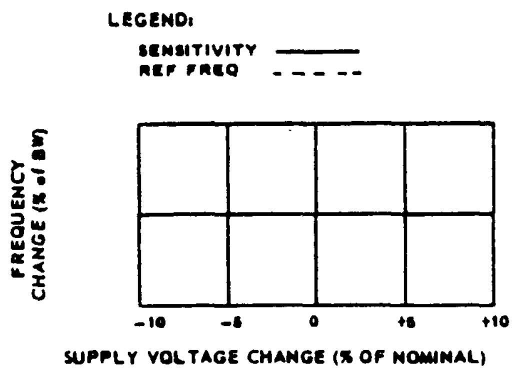
3.10.3.3.6 Apply nominal supply voltage to the SCO, adjust the d.c. input signal to produce center frequency output and superimpose sinusoidal signals of appropriate ripple frequencies on the supply voltage. Adjust the rms value of the ripple to 2 percent of the nominal supply voltage and measure the frequency deviation of the SCO (the output excursion of the SCO is proportional to the SCO deviation).

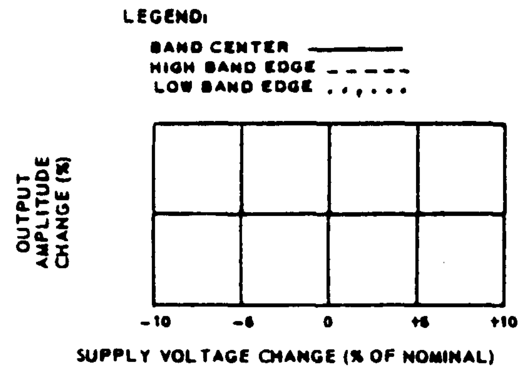
3.10.3.3.7 Express the peak-to-peak frequency deviations as percentages of bandwidth.

3.10.3.3.8 Record data on Data Sheet 3.10.1.

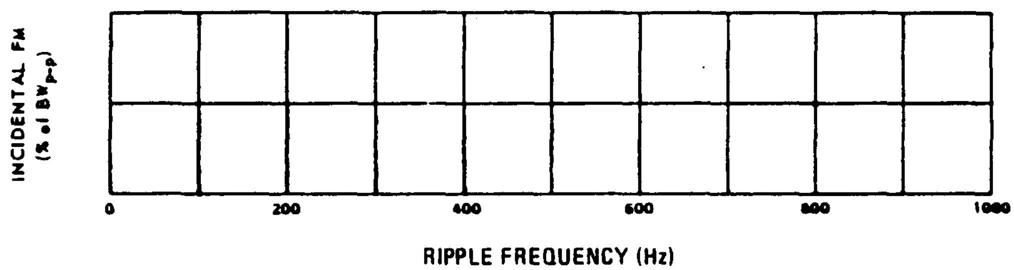
DATA SHEET 3.10.1 EFFECT OF SUPPLY VOLTAGE VARIATION

EFFECT OF SUPPLY VOLTAGE VARIATION





NOTE



NOTE

3.11 Common-Mode Rejection (For Differential-Input Models Only.)

Common-mode rejection is the ratio of subcarrier bandwidth to subcarrier deviations, expressed in dB.

3.11.1 Purpose - This test determines the effect on output frequency resulting from application of a common signal to both input terminals.

3.11.2 Test Equipment:

A.C. signal source
A.C. voltmeter (true rms)
D.C. signal source
D.C. voltmeter
Low-noise subcarrier discriminator
Electronic frequency counter

3.11.3 Test Method:

3.11.3.1 Setup - Connect the test equipment as shown in figure 3.11-1.

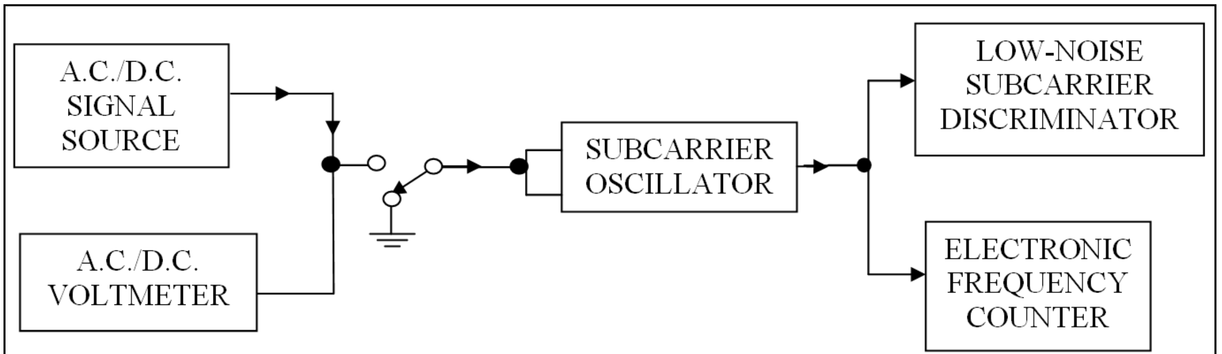


Figure 3.11-1 Common-Mode Rejection.

3.11.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.11.3.3 Procedure:

3.11.3.3.1 With the SCO terminals shorted together and connected to ground, measure the subcarrier output frequency.

3.11.3.3.2 Remove the ground applied in subparagraph 3.11.3.3.1 and connect the shorted input terminals to a d.c. voltage (reference to ground) and adjust the d.c. voltage to equal the magnitude of the full-scale differential input recommended by the manufacturer.

3.11.3.3.3 Measure the subcarrier output frequency, first with a positive polarity applied to the input and then with a negative polarity applied to the input.

3.11.3.3.4 Connect an a.c. voltage source to the shorted input terminals and adjust the peak-to-peak amplitude of the a.c. signal to equal the magnitude of the full-scale differential input recommended by the manufacturer.

3.11.3.3.5 Adjust the frequency of the a.c. input signal to that which produces a deviation ratio of 1 for the band under test. Use a low-noise subcarrier discriminator to measure the frequency deviation of the SCO output caused by the common-mode signal. Repeat the measurement at frequencies of 60 Hz and 400 Hz if these frequencies fall within the modulation-frequency range of the SCO under test. The discriminator must be calibrated at each of the modulation frequencies.

3.11.3.3.6 Compare the frequencies measured in step 3.11.3.3.3 with that measured in step 3.11.3.3.1 and calculate the output frequency deviations. Frequency deviations in subparagraph 3.11.3.3.5 are obtained from measuring the output of the calibrated discriminator.

3.11.3.3.7 Record data on Data Sheet 3.11.1.

DATA SHEET 3.11.1 COMMON - MODE REJECTION

COMMON - MODE REJECTION

BAND	COMMON - MODE REJECTION (dB)				
	D.C		A.C.		
	+D.C.	–D.C.	DEVIATION RATIO = 1	60 Hz	400Hz
7					
14					
A					
E					

3.12 Stability Vs. Temperature

3.12.1 Purpose - This test determines reference-frequency shift, sensitivity variations and output amplitude changes as a function of temperature.

3.12.2 Test Equipment:

D.C. signal source
D.C. voltmeter
Temperature chamber
A.C. voltmeter (true rms)
Electronic frequency counter

3.12.3 Test Method:

3.12.3.1 Setup - Connect the test equipment as shown in figure 3.12-1.

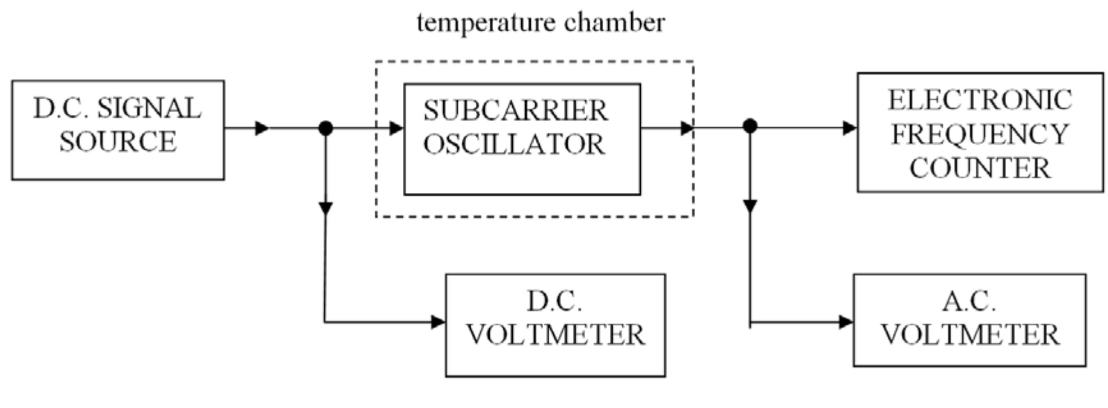


Figure 3.12-1 Stability versus Temperature.

3.12.3.2 Conditions - Refer to subparagraphs 3.0.2 through 3.0.4.

3.12.3.3 Procedure:

3.12.3.3.1 Adjust the temperature chamber to 30ºC (303.2K) and allow the SCO to stabilize for not less than 15 minutes.

3.12.3.3.2 Apply the input voltages recommended by the manufacturer to produce output frequencies corresponding to lower band edge, band center and upper band edge. Measure the output frequencies and amplitudes corresponding to each of these inputs.

3.12.3.3.3 Using the same inputs which were applied in step 3.12.3.3.2, repeat the measurements at chamber temperatures corresponding to the appropriate temperature extremes. Allow sufficient time at each temperature for the unit to stabilize before measurements are made.

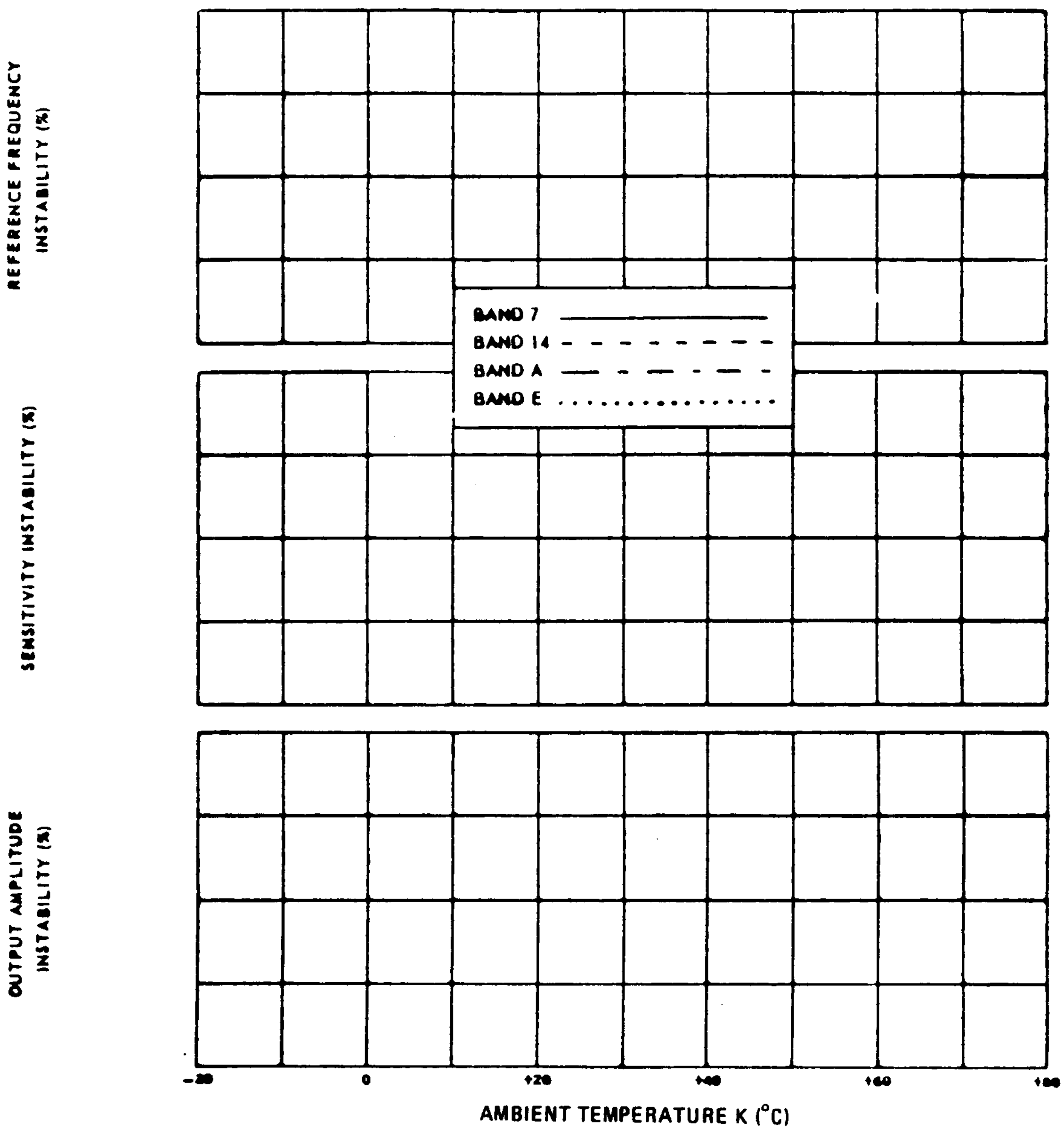
3.12.3.3.4 Use the frequencies and amplitudes measured at 30ºC (303.2 K) as references for calculations and express frequency changes in percent of bandwidth and amplitude changes directly in percent.

3.12.3.3.5 Calculate the reference frequency shift and sensitivity changes. Reference frequency shift is given a positive sign when the output frequency is greater than that measured at the temperature of 30ºC (303.2 K). Sensitivity change is given a positive sign when full-scale output excursion is greater than that measured at 30ºC (303.2 K).

3.12.3.3.6 Record data on Data Sheet 3.12.1.

DATA SHEET 3.12.1 STABILITY VERSUS TEMPERATURE

STABILITY vs TEMPERATURE



NOTE

3.13 Effect of Vibration

3.13.1 Purpose - This test determines the effect of vibration on output frequency and output amplitude.

3.13.2 Test Equipment:

D.C. signal source
Subcarrier discriminator
Electronic frequency counter
Vibration facility capable of providing the vibration amplitude acceleration levels over the frequency ranges specified for the intended application.

3.13.3 Test Method:

3.13.3.1 Setup - Connect the test equipment as shown in figure 3.13-1. The SCO should be securely mounted to the vibrator in a properly designed test fixture which will not impart vibration amplifications to the SCO. If a companion modular rack adapter is used for mounting the SCO in the actual application, the adapter should be included in the vibration setup.

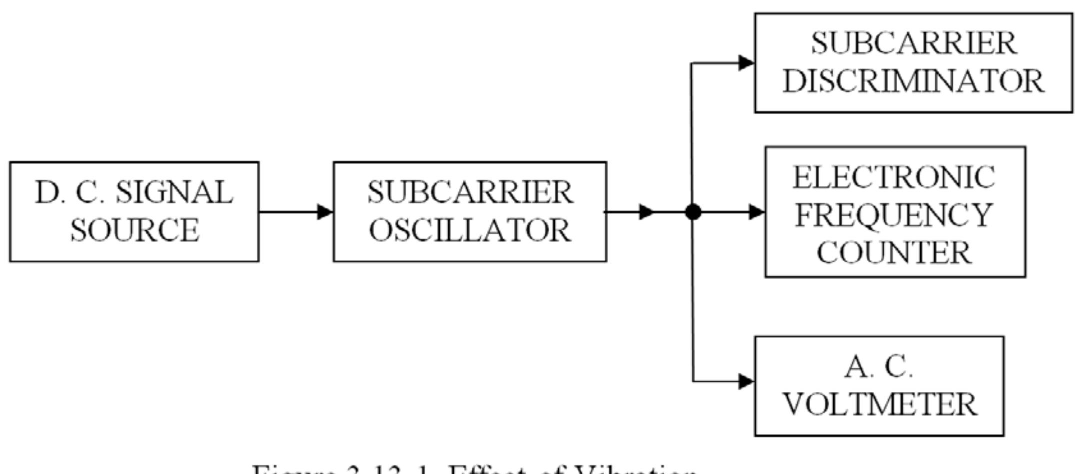


Figure 3.13-1 Effect of Vibration.

3.13.3.2 Conditions - An environment should be selected which is representative of the intended application. This environment could be selected from a standard such as MIL-STD-810. In addition, refer to subparagraphs 3.0.2 through 3.0.4.

3.13.3.3 Procedure:

3.13.3.3.1 Conduct a resonant search in accordance with MIL-STD-810, Method 514.2, to determine the vibration frequencies at which the greatest output frequency and amplitude changes occur.

3.13.3.3.2 Adjust the d.c. signal source to produce band-center frequency. Adjust the output amplitude to maximum and record the amplitude.

3.13.3.3.3 Conduct a resonant dwell in accordance with MIL-STD-810, Method 514.2.

3.13.3.3.4 Observe the output of the subcarrier discriminator to determine the incidental FM caused by vibration.

3.13.3.3.5 Stop the vibration and measure the output frequency and output amplitude. Compare these measurements with those made in subparagraph 3.13.3.3.2 to determine frequency shift and amplitude change. Express frequency changes in percent of bandwidth and express amplitude changes in percent of original amplitude.

3.13.3.3.6 Record data on Data Sheet 3.13.1.

DATA SHEET 3.13.1 EFFECT OF VIBRATION

13. EFFECT OF VIBRATION

BAND	VIBRATION FREQUENCY (Hz)	INCIDENTAL F - M (%)	FREQUENCY SHIFT (%)	AMPLITUDE CHANGE (%)
7				
14				
A				
E				

NOTE

CHAPTER 4

BIT SYNCHRONIZERS

4.0 General

In the series of test procedures which follow, the PCM test set is the central feature of the test setups. Commercially available telemetry PCM test sets usually incorporate the IRIG Standard PN sequence with self-synchronized PN receiver function. These sets vary somewhat as to criteria for receiver PN lock, the restart function, and such special functions as addition of base-band noise and offset, frequency modulation of internal clock, variable delay of clock and bit stream, phase comparison of input and output bit clocks, etc. Depending upon which PCM test set is available, certain external functions such as gating and delay may be required for the bit slippage and acquisition tests. Detailed circuits for these functions are given in appendixes IV-B and IV-C. Figure 4.0-1 is a generalized block diagram of functions which can be utilized to perform the tests herein.

NOTE

> *Since, as stated above, not all commercial models incorporate all of the functions internally, it may be necessary to perform some of these functions by the use of peripheral equipment*

Because the full capability of the test set will not be required in any single test procedure, the full functional block diagram (figure 4.0-1) will not be repeated; only simplified block diagrams will be included with each individual test procedure. It may not be necessary to conduct all of the tests described in this chapter for any one bit synchronizer if it is used for a specific application. The test procedures are presented in two parts: Part I, Testing with Gaussian Noise; and Part II, PCM/FM Testing. Definitions for bit slippage probability (BSP) and acquisition testing are given in appendix IV-C.

4.0.1 Standard Test Conditions for Testing with Gaussian Noise

The following discussion applies to preparing standard test conditions for Part I, Testing with Gaussian Noise. Regardless of the test approach used, it is important to preserve uniformity of testing so that valid comparisons and evaluations of a wide range of system designs may be accomplished. Therefore, the following standard test conditions should be determined for the following parameters and should be observed unless the individual test description requires otherwise. It is assumed that the instruction manual for the test set is available; therefore, instructions for operating the test set will not be repeated in the individual test procedures.

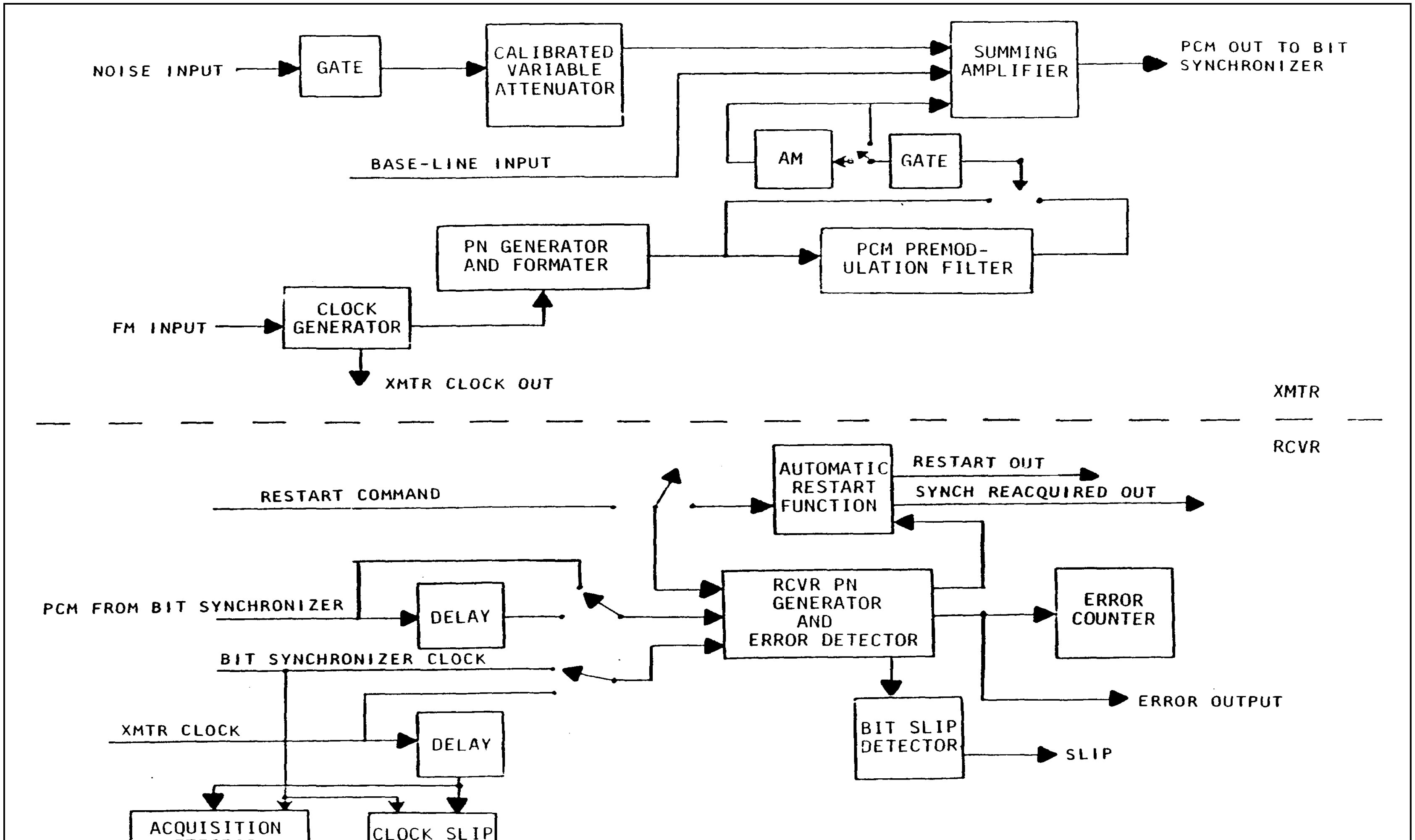


Figure 4.0-1 PCM Test Set.

4.0.1.1 Bit Synchronizer:

PCM signal input level
Bit rate
Loop width
Tracking bandwidth
Bit detector type of clock (internal)
Input code

4.0.1.2 PCM Test Set:

Offset
FM input
Code
Pattern Pseudo random: Use of the 2047-bit maximal length sequence is recommended. See Chapter 2, subparagraph 2.1.1.3.2 for details.

NOTE

Testing with fixed patterns may be necessary for specific applications.

Bit rate clock

NOTE

A PCM test set may possess two characteristics which must be checked before conducting bit synchronizer performance tests. The internal reference clock may contain excessive jitter components and the accuracy of the bit rate switch settings may be inadequate. When excessive clock jitter exists, it is recommended that an external reference clock be used; particularly when testing bit synchronizers with narrow loop bandwidth settings. The bit rate of the PCM output may be adjusted using one of the following methods:

METHOD 1:
Connect a variable d.c. voltage source to the FM input of the PCM test set and adjust the voltage until the required bit rate is obtained.

METHOD 2:
Adjust the bit rate on the PCM test set until the desired bit rate is indicated on a frequency counter. Disregard the bit rate indicated by the PCM test set display when using this method.

METHOD 3:

Connect an external clock generator to the external clock input of the PCM test set. Measure the bit rate at the clock output of the PCM test set with a frequency counter.

NOTE

Measures should be taken to assure that phase errors are not introduced by the test setup, e.g., when the setup includes a premodulation filter. Measurement difficulties may occur when detection circuitry is phase sensitive.

4.0.1.3 Premodulation Filter

Filter type	-	linear-phase, low-pass
Cutoff frequency (–3 dB)	-	0.75 times the bit rate, or as required

4.0.1.4 Noise Signal - gaussian

4.0.1.5 Noise Signal Filter:

Type: constant amplitude ($\geq$ 4 pole)
Cutoff frequency (–3 dB): equal to the bit ratefor calibration

4.0.2 Standard Test Conditions for PCM/FM Testing

The following parameters must be added to the standard test conditions in subparagraph 4.0.1 for preparing the standard test conditions for Part II, PCM/FM testing.

4.0.2.1 FM Test Link:

Frequency deviation: Peak-to-peak
Predetection (IF) bandwidth: 3-dB points, kHz
Post detection bandwidth: 3-dB points, kHz

4.0.2.2 Figures 4.0.2-1 and 4.0.2-2 are block diagrams of the PCM/FM test setup. Two options are shown. Figure 4.0.2-1 makes use of equipment normally used in connection with predetection recording. The band pass filter (BPF) shown in figure 4.0.2-1 is used to confine the noise bandwidth to the neighborhood of the predetection band of the discriminator to prevent overloading the input circuits. The bandwidth of the BPF should be set to approximately twice the bandwidth of the discriminator and centered on the band of the discriminator. Figure 4.0.2-2 makes use of RF equipment.

4.1 Part I. Testing with Gaussian Noise

Part I describes the test procedures to be used to determine if a selected bit synchronizer has the required characteristics essential for telemetry applications when the input signal contains additive gaussian noise.

4.1.1 PCM Test Set Calibration

4.1.1.1 Purpose - The SNR is an important parameter in many of the performance tests conducted on PCM bit synchronizers. Calibration of the PCM test set is necessary for obtaining an accurate SNR to allow comparison of performance in satisfying performance specifications or evaluating competing designs.

4.1.1.2 Test Equipment:

4.1.1.2.1 Procedure 1:

Noise source - a flat frequency response from d.c. to > five times the bit rate
Premodulation filter - as required
Low-pass filter - cutoff frequency setable to the bit rate
True rms voltmeter
Oscilloscope
Frequency counter
Stable oscillator - as required
PCM test set

4.1.1.2.2 Procedure 2: Same as Procedure 1 test equipment except replace PCM test set with summing amplifier and calibrated attenuator.

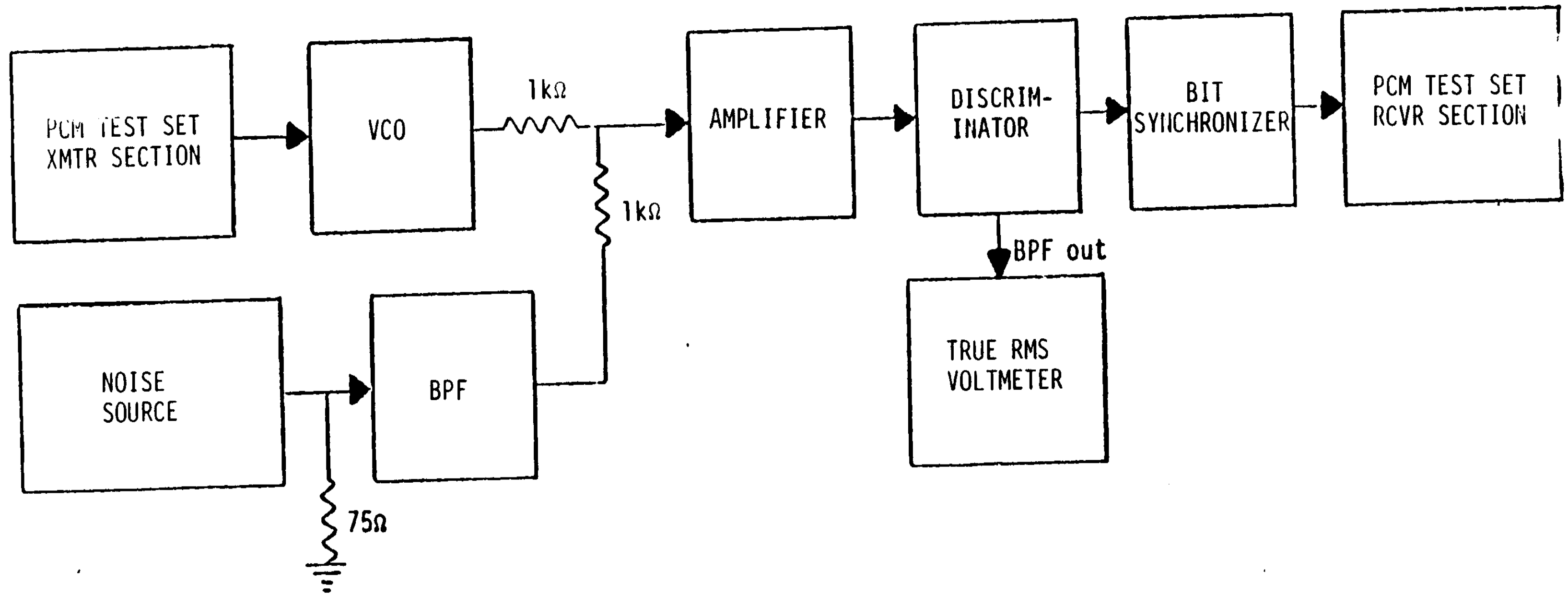


Figure 4.0.2-1 Test Setup Using Predetection Carrier Frequencies.

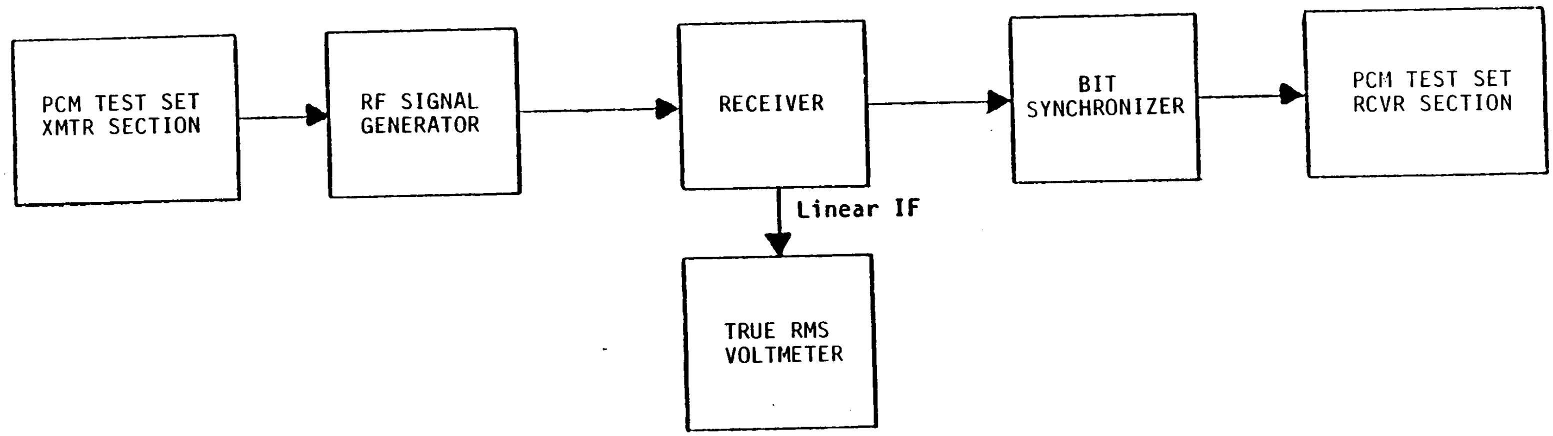


Figure 4.0.2-2 Test Setup Using Signal Generator and Receiver.

4.1.1.3 Test Method:

4.1.1.3.1 Procedure I - Internal Noise Attenuator

4.1.1.3.1.1 Setup - Connect the test equipment as shown in figure 4.1.1-1.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.1.3.1.2 Make the following adjustments on the PCM test set to set the PCM level:

a. Set output signal for PCM only
b. Turn off noise source
c. Bypass or disconnect premodulation filter
d. Adjust the PCM amplitude with an oscilloscope or true rms voltmeter until the required peak-to-peak signal voltage is measured at the PCM output of the test set.

4.1.1.3.1.3 Connect the premodulation filter into the test setup. Observe the peak-to-peak amplitude of the filtered PCM bit stream with an oscilloscope. Adjust the output level control on the tunable filter to maintain the peak-to-peak voltage of the signal as established in step 4.1.1.3.1.2 d.

4.1.1.3.1.4 Make the following adjustments on the PCM test set to obtain the noise level:

a. Turn off the PCM signal
b. Turn on the noise source to the PCM test set
c. Set the noise source for a cutoff frequency equal to five times the bit rate selected.
d. Select the 0-dB SNR setting.
e. Monitor the input noise signal and the PCM output of the test set on an oscilloscope.
f. Set the noise source output level control to maximum. If noise amplitude limiting exists, reduce the output of the noise source until the noise signal is not limited in amplitude at either monitoring point as referenced in step 4.1.1.3.1.4 e.
g. Perform the noise amplitude limiting test for each bit rate selected.
h. Set the cutoff frequency of the noise source low-pass filter to a value which is equal to the selected PCM bit rate, e.g., a 100 kb/s bit rate would require a 100-kHz low-pass filter setting.
i. Adjust the noise input variable attenuator of the PCM test set until an rms voltage equal to the rms voltage of the unfiltered PCM bit stream is measured at the tunable filter output.
j. Observe the signal at the PCM output of the PCM test set with an oscilloscope. The noise signal must not be amplitude limited. If limiting is present, repeat all calibration steps in subparagraph 4.1.1.3.1.4.

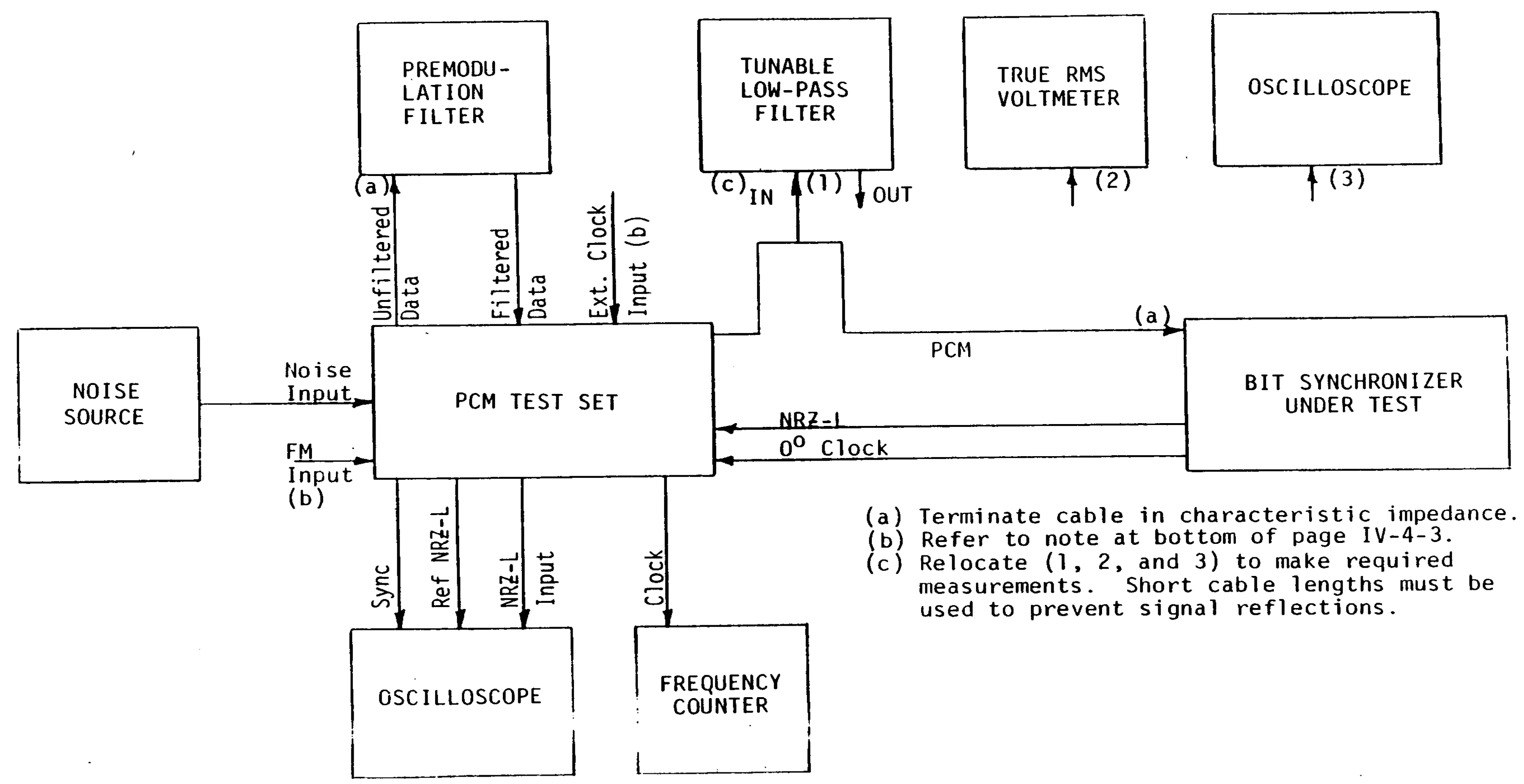


Figure 4.1.1-1 Calibration of PCM Test Set with Internal Noise Attenuator.

4.1.1.3.1.5 Turn on the PCM signal. SNR calibration is complete.

4.1.1.3.2 Procedure 2 - External Noise Attenuator

4.1.1.3.2.1 Setup - Connect the test equipment as shown in figure 4.1.1-2.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.1.3.2.2 Select the desired logic at the output of the transmitter PN generator, i.e., transistor-transistor logic (TTL), balanced, etc., and set the desired premodulation filter cutoff frequency and output amplitude.

4.1.1.3.2.3 Set the cutoff frequency of the noise filter to produce a noise bandwidth (B_n) of approximately five times the bit rate. (A Butterworth type of filter with sharp rolloff can be used, in which case the noise bandwidth is approximately 3 dB.)

4.1.1.3.2.4 Set the maximum attenuation in the calibrated noise attenuator (should be at least 40 dB below the PCM output). Measure the true rms value of the PCM at the output of the summing amplifier.

4.1.1.3.2.5 Decrease the noise attenuation until the true rms voltmeter reading increases 3 dB. At this point, the SNR in Bn is 0 dB. Record the noise attenuator setting. The level should be set so that the noise attenuator setting is about 10 dB.

NOTE

Unless the summing amplifier is an operational amplifier, the output impedance levels of the premodulation filter and the calibrated noise attenuator must remain constant.

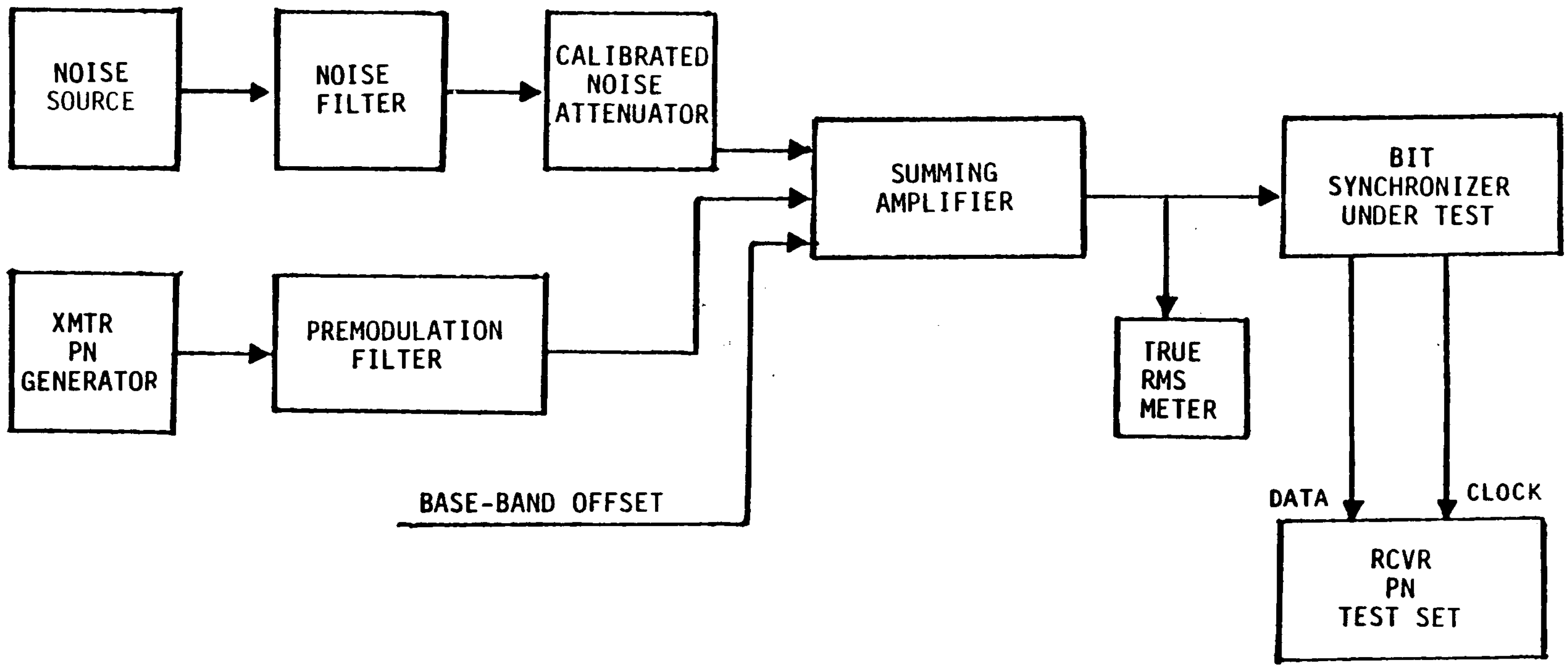


Figure 4.1.1-2 SNR Calibration for the Case in which the Noise Attenuator and Summing Amplifier are External to the PCM Test Set.

4.1.1.3.2.6 Observe the waveform at the output of the summing amplifier to determine if limiting is occurring. If so, reduce the PCM level and repeat the steps in subparagraphs 4.1.1.3.2.4 and 4.1.1.3.2.5. A further check in linearity is carried out by the method given in subparagraph 4.2.1.3.1.5 for the calibration of predection SNR in the PCM/FM tests.

4.1.1.3.2.7 The SNR in a bandwidth equal to the bit rate (f_b) is given in dB by

$$SNR_{f_b} = SNR_{B_n} + 10 \log_{10} (B_n / f_b)$$

For example, if $B_n = 5f_b$, then 7 dB must be added to SNR_{B_n} to give SNR f_b.

4.1.2 Bit Error Probability (BEP) Test

4.1.2.1 Purpose - This test determines the BEP characteristics of a bit synchronizer as a function of the input SNR.

4.1.2.2 Test Equipment:

4.1.2.2.1 Test setup 1 - The following is used in the test setup shown in figure 4.1.2-1.

Noise source
Premodulation filter
Frequency counter
PCM test set (attenuator, PN sequence transmitter and receiver)

4.1.2.2.2 Test setup 2 (figure 4.1.2-2) - Same as test setup 1 test equipment except replace PN PCM test set with summing amplifier and calibrated attenuator.

4.1.2.3 Test Method:

NOTE

It may be necessary to repeat the calibration procedure detailed in subparagraph 4.1.1 periodically during this test.

4.1.2.3.1 Setup - Connect the test equipment as shown in figure 4.1.2-1 or figure 4.1.2-2.

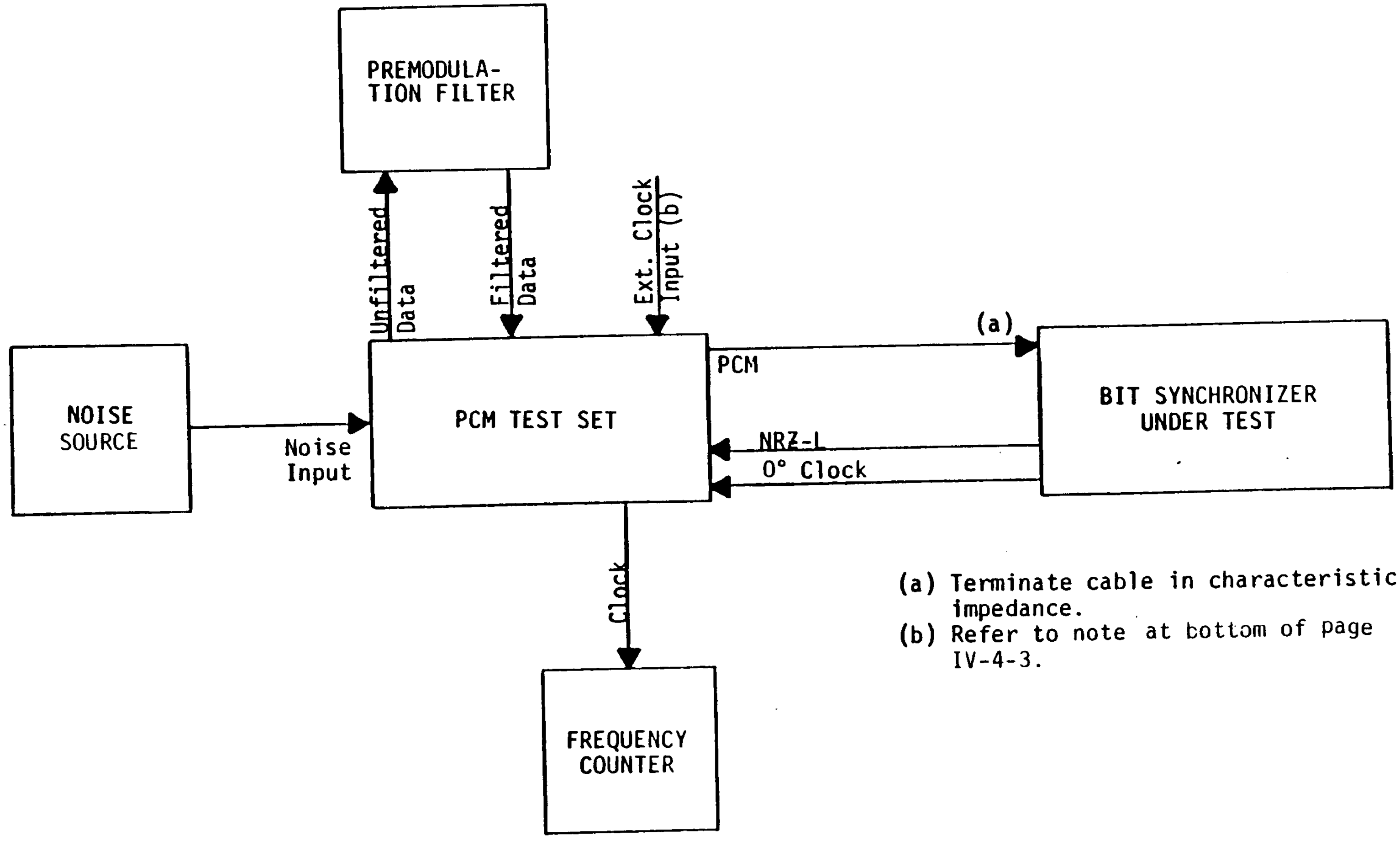


Figure 4.1.2-1 Bit Error Probability Test Setup.

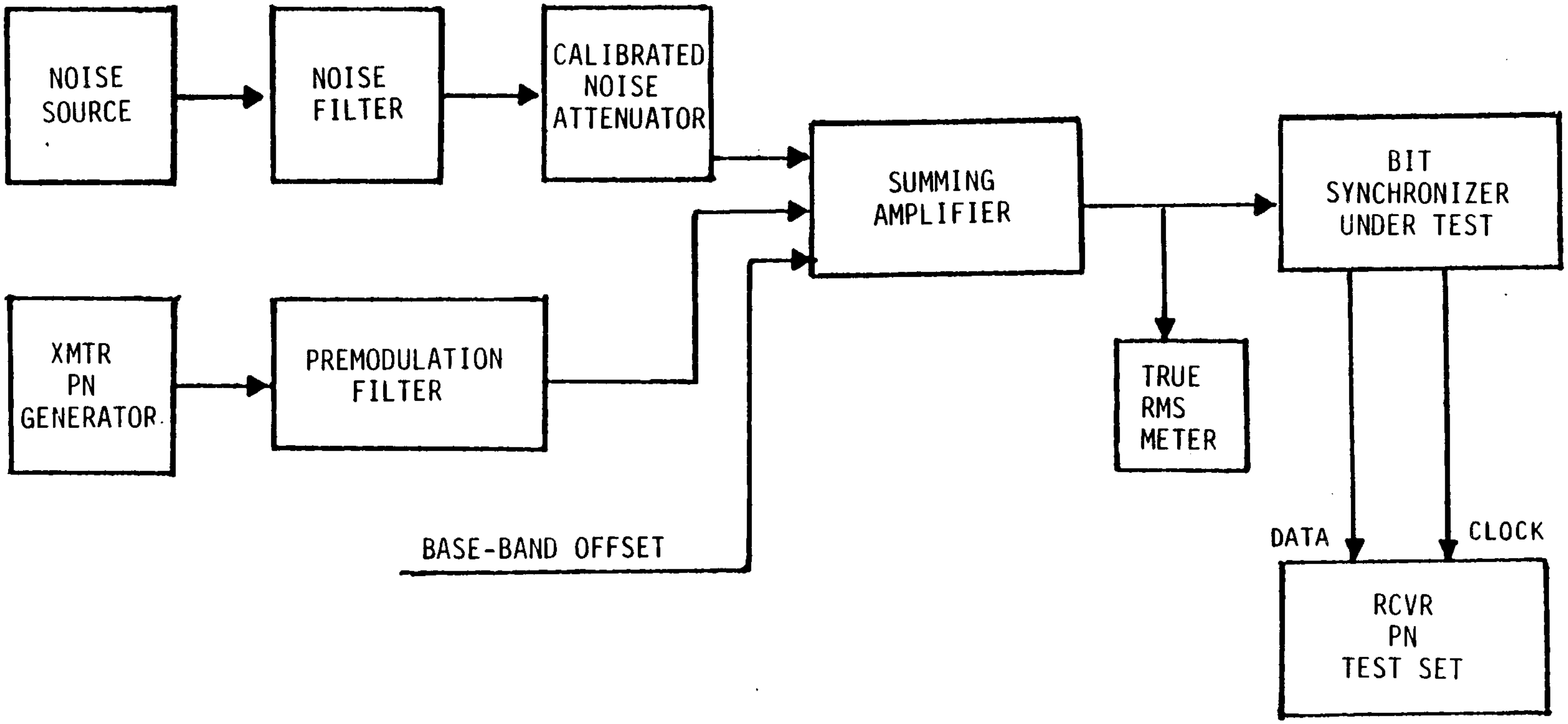


Figure 4.1.2-2 Bit Error Probability Test Setup for the Case in which the Noise Attenuator and Summing Amplifier are External to the PCM Test Set.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions: for testing with gaussian noise.

4.1.2.3.2 Calibrate the test setup for output SNR in accordance with the calibration instructions detailed in subparagraph 4.1.1.

4.1.2.3.3 Adjust the test set to measure bit errors in the measurement intervals shown on Data Sheet 4.1.2.1.

4.1.2.3.4 Set the test setup for an output SNR of 0 dB and measure total bit errors (sum of the ls and 0s in error). It may be desirable to individually measure the ls in error and the 0s in error to determine, the performance symmetry of the bit synchronizer. Calculate and record the BEP from the relationship:

$$\text{BEP} = \frac{\text{Number of Bit Errors Measured}}{\text{Number of Bits Transmitted During Measurement Interval}}$$

Repeat the measurement of bit errors and BEP calculations for the other values of SNR shown on Data Sheet 4.1.2.1.

4.1.2.4 <u>Data Reduction</u>: - Record data on Data Sheet 4.1.2.1. An example of Data Sheet 4.1.2.1 use is shown in figure 4.1.2-3 and a corresponding sample data plot is shown in figure 4.1.2-4.

DATA SHEET 4.1.2.1 BIT ERROR PROBABILY TEST

Test: 4.1.2 Bit Error Probability Test

Manufacturer__________________Model ______________ Serial No. ____________________

Tested by ____________________________

Date_________________________________

SAMPLE DATA NOT TO BE USED FOR EQUIPMENT SPECIFICATIONS

Bit Synchronizer Input Signal Conditions						
PCM Signal				Noise Signal (Gaussian)		Premodulation Filter
Bit Rate (kB/s)	Amplitude (^{V}p-?)	Code	Word Pattern	Cal. B.W. (kHz)	Cal. (V rms)	Cutoff Freq. (kHz)
100	1.0	NRZ-L	PR	100	0.5	75

Bit Synchronizer Settings		
Detector Type	Loop B.W (% Bit Rate)	Tracking Range (% Bit Rate)
F/S	0.1	1.0

SNR	Bit Error Probability			Measurement Interval * (Period 10^N Bits)
(dB)	Total (1s + 0's)	1's	0's	N
0	$1.1x10^{-1}$	$5.3x10^{-2}$	$5.5x10^{-2}$	5
+3	$4.2x10^{-2}$	$2.0x10^{-2}$	$2.2x10^{-2}$	5
+6	$8.7x10^{-3}$	$4.0x10^{-3}$	$4.7x10^{-3}$	5
+9	$6.4x10^{-4}$	$2.6x10^{-4}$	$3.8x10^{-4}$	6
+12	$9.9x10^{-6}$	$1.9x10^{-6}$	$5.4x10^{-6}$	8

*Refer to Volume IV, Appendix IV-A for detailed explanation.

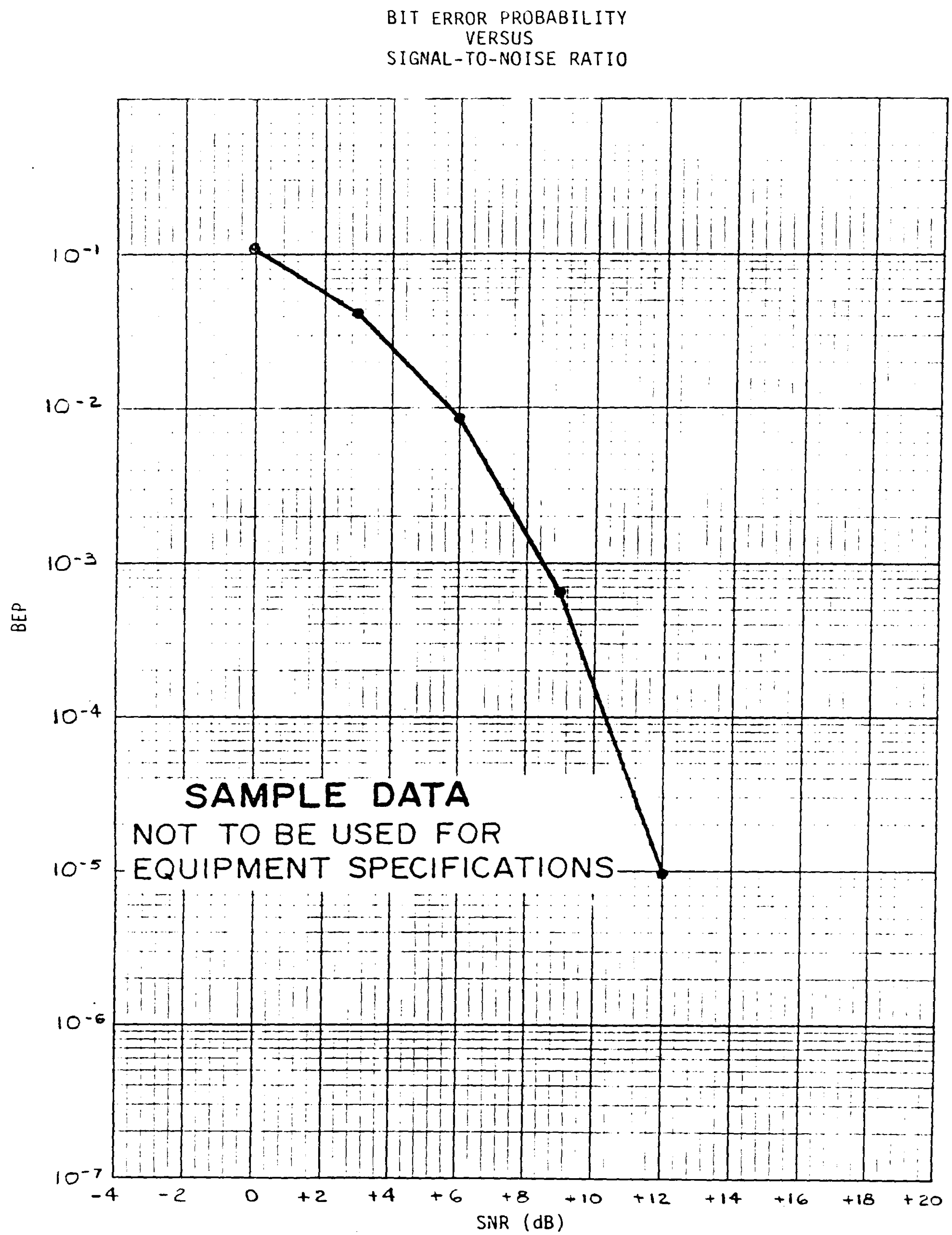


Figure 4.1.2-4 Sample Data Plot Presentation of Data Sheet 4.1.2.1.

DATA SHEET 4.1.2.1 BIT ERROR PROBABILY TEST

Test: 4.1.2 Bit Error Probability Test

Manufacturer ________________ Model________________Serial No. ________________

Tested by__________________________, ____________________________________

Date______________________________

Bit Synchronizer Input Signal Conditions						
PCM Signal				Noise Signal (Gaussian)		Premodulation Filter
Bit Rate (kB/s)	Amplitude ($V_{p\text{-}p}$)	Code	Word Pattern	Cal. B.W. (kHz)	Cal. (V rms)	Cutoff Freq. (kHz)

Bit Synchronizer Settings		
Detector Type	Loop B.W (% Bit Rate)	Tracking Range (% Bit Rate)

SNR	Bit Error Probability			Measurement Interval * (Period 10^N Bits)
(dB)	Total (1s + 0's)	1's	0's	N
0				5
+3				5
+6				5
+9				6
+12				8

*Refer to Volume IV, Appendix IV-A for details explanation.

4.1.3 Bit Slippage Probability (BSP) Test

4.1.3.1 Purpose - This test determines the BSP characteristics of a bit synchronizer as a function of the input SNR. There are two basic procedures given here for this test. Laboratory tests comparing the two procedures indicate that both agree to within the limits of measurement error. The choice of procedure will depend primarily on the test equipment available. Procedure 1 compares the phase of the reference clock with the phase of the bit synchronizer output clock. If the phase difference exceeds ±360°, bit slippage has occurred.

NOTE

In some commercially available PCM test sets which are internally mechanized for this test, the criterion is ±180°. Although it is possible for the instantaneous phase to exceed 180° and then, because of additional perturbation, to pull back without slippage, tests have shown that the phase is most likely to subsequently exceed ±360°, thus producing bit slippage.

Procedure 2 uses the loss of PCM test set synchronization to indicate slippage.

4.1.3.2 Test Equipment:

4.1.3.2.1 Procedure 1:

Noise source
Premodualtion filter
Frequency counter
PCM test set

4.1.3.2.2 Procedure 2:

Noise source
Noise attenuator
Premodulation filter
Summing amplifier
PN sequence transmitter/receiver

4.1.3.3 Test Method:

4.1.3.3.1 Procedure 1:

4.1.3.3.1.1 Setup Connect the test equipment as shown in figure 4.1.3-1.

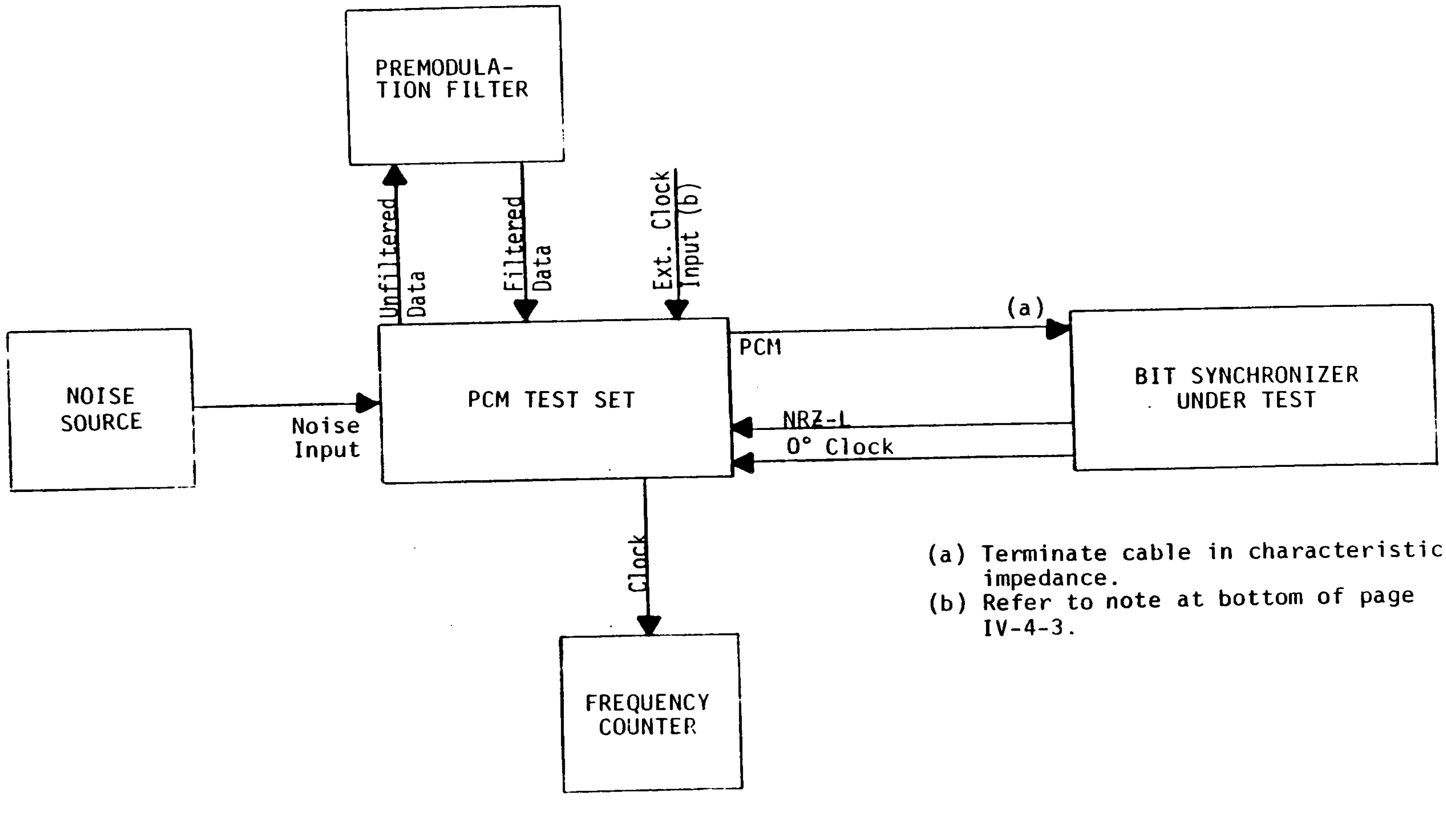


Figure 4.1.3-1 Bit Slippage Probability Test Setup for Procedure 1.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.3.3.1.2 Calibrate the PCM test set for an output SNR in accordance with the calibration instructions detailed in subparagraph 4.1.1.

4.1.3.3.1.3 Adjust the PCM test set to measure bit (clock) slips for the measurement intervals shown on Data Sheet 4.1.3.1.

4.1.3.3.1.4 Set the PCM test set for an output SNR of 0 dB, and measure the total number of bit (clock) slips (both plus and minus). It may be desirable to individually measure the plus slips and the minus slips to show performance trends. Most bit synchronizer designs exhibit a tendency to slip only in one direction rather than randomly. Calculate the BSP from the relationship:

$$\text{BEP} = \frac{\text{Number of Bit Slips Measured}}{\text{Number of BitsTransmitted During Measurement Interval}}$$

4.1.3.3.1.5 Repeat the measurement of bit slips and calculation of BSP for the other SNRs shown on Data Sheet 4.1.3.1.

4.1.3.3.2 Procedure 2:

4.1.3.3.2.1 Setup - Connect the test equipment as shown in figure 4.1.3-2.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.3.3.2.2 Calibrate the test setup for output SNR in accordance with the calibration instructions.

4.1.3.3.2.3 Adjust the test set to count the number of restarts in the measurement intervals shown on Data Sheet 4.1.3.1. A restart is defined as a valid resynchronization of the receiver PN generator to the data.

4.1.3.3.2.4 Set the test setup for an SNR of 9 dB and count the number of restarts. Calculate the BSP from the relationship:

$$\text{BSP} = \frac{\text{Number of Restarts Counted}}{\text{Number of Bits Transmitted During Measurement Interval}}$$

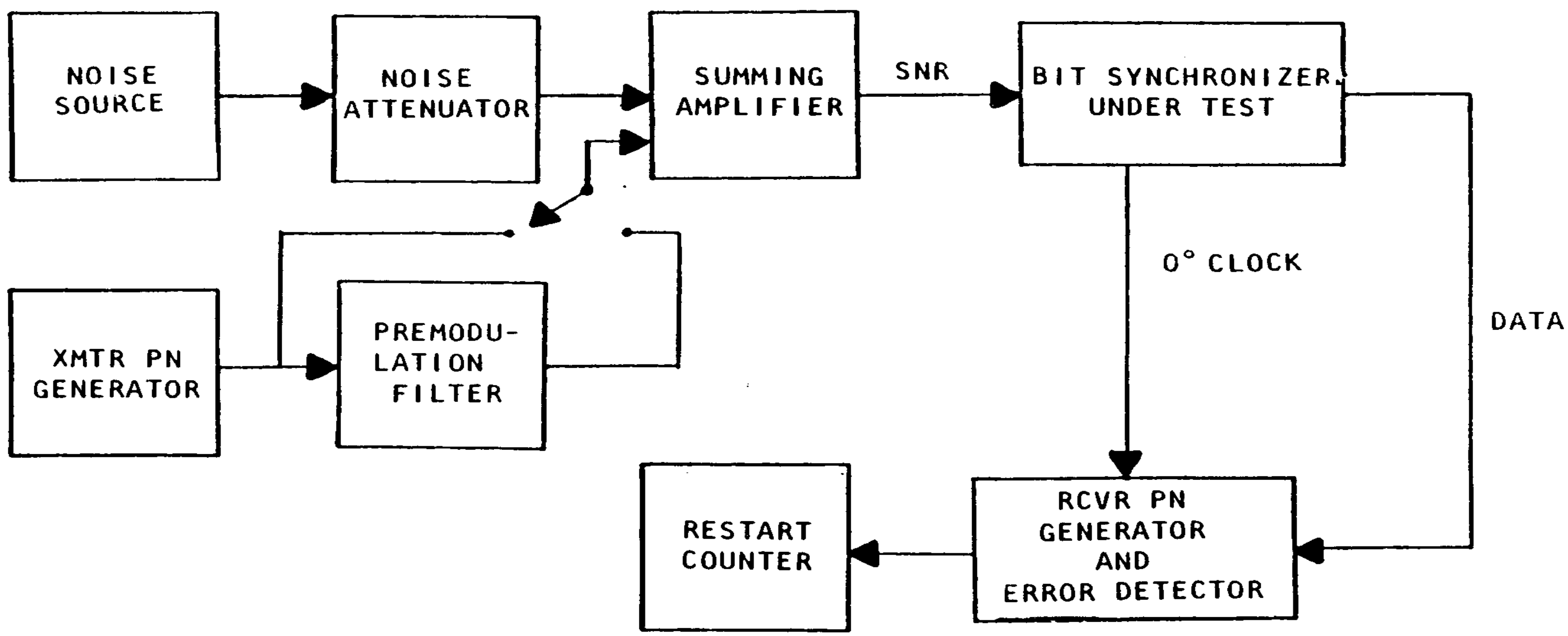


Figure 4.1.3-2 Bit Slippage Probability Test Setup for Procedure 2.

4.1.3.3.2.5 Repeat the count of restarts and calculation of BSP for the other SNRs shown on Data Sheet 4.1.3.1.

NOTE

At high BEP, the number of restarts measured will be too large because unsuccessful tries are counted and because in some test sets it is also possible for errors to trigger the restart without slippage. The counts of synchronization reacquired will give results closer to the true value. Generally, the "plus slips" and "minus slips" count is not a reliable estimate of the number of restarts.

4.1.3.4 Data Reduction - Record data on Data Sheet 4.1.3.1. An example of Data Sheet 4.1.3.1 use is shown in figure 4.1.3-3 and a corresponding sample data plot is shown in figure 4.1.3-4.

DATA SHEET 4.1.3.1 BIT SLIPPAGE PROBABILITY

Test: 4.1.3 Bit Slippage Prob

Manufacturer ________ Serial No. ________

Tested by ________

Date ________

Bit Synchronizer Input Signal Conditions						
PCM Signal				Noise Signal (Gaussian)		Premodulation Filter
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal. (V rms)	Cutoff Freq. (kHz)
100	1.0	NRZ-L	PR	100	0.5	75

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)
F/S	1.0	10.0

SNR	Bit Slippage Probability			Measurement Interval * (Period 10^N Bits)
(dB)	TOTAL (+ and −)	+	−	N
0	9.07×10^{-2}	3.0×10^{-6}	9.04×10^{-2}	7
+3	2.91×10^{-2}	4.8×10^{-5}	2.90×10^{-2}	7
+6	2.42×10^{-5}	6.0×10^{-7}	2.0×10^{-5}	7
+9	$< 1 \times 10^{-7}$	$< 1 \times 10^{-7}$	$< 1 \times 10^{-7}$	7
+12	$< 1 \times 10^{-7}$	$< 1 \times 10^{-7}$	$< 1 \times 10^{-7}$	7
+15	$< 1 \times 10^{-7}$	$< 1 \times 10^{-7}$	$< 1 \times 10^{-7}$	7

*A measurement interval of 1×10^7 bits will provide reliable data measurement repeatability for BSP $\geq 1 \times 10^{-6}$.

NOTE: Additional measurements may be required where the slope of the data changes abruptly.

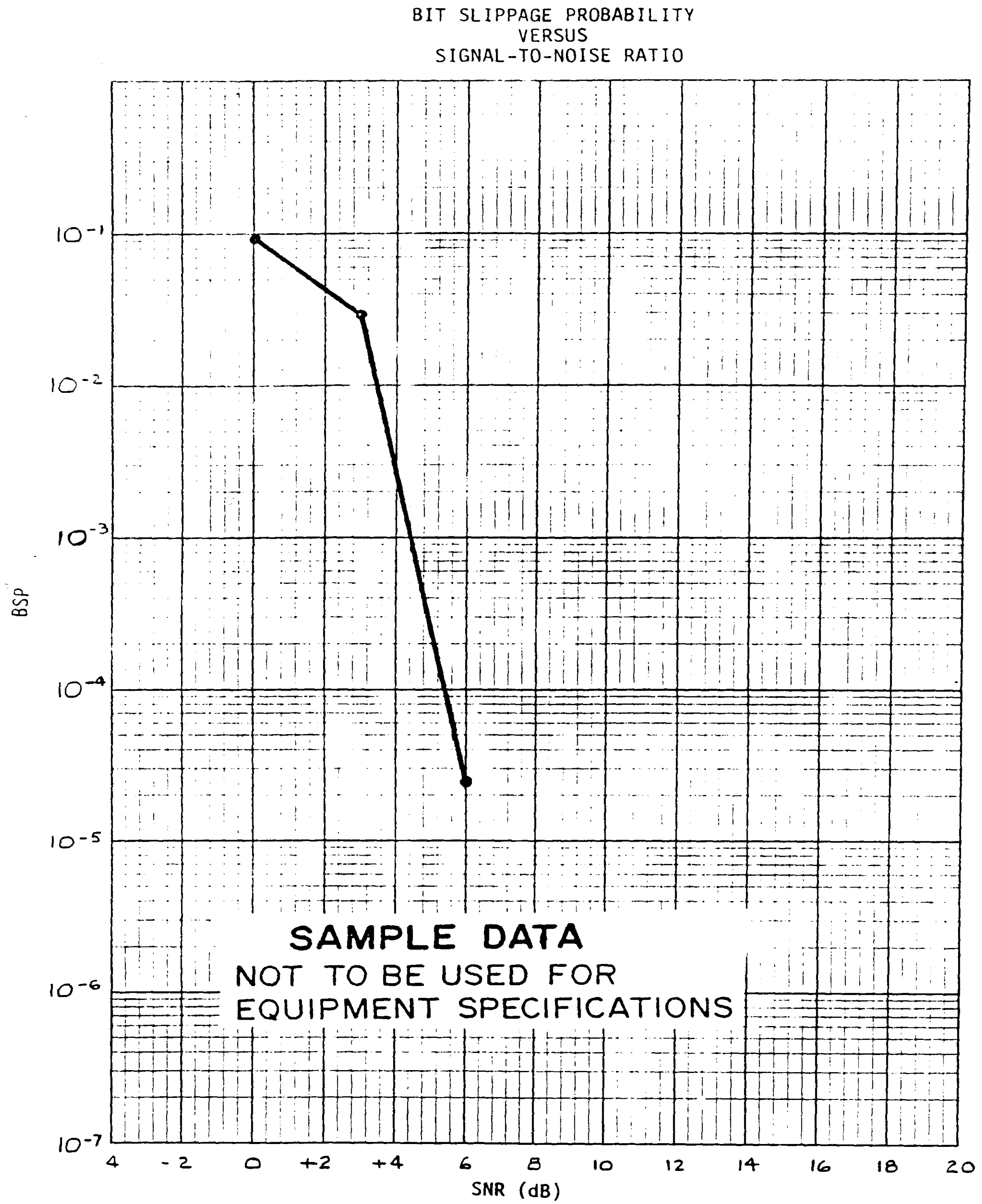


Figure 4.1.3-4 Sample Plot Presentation of Data Sheet 4.1.3.1.

DATA SHEET 4.1.3.1 BIT SLIPPAGE PROBABILITY

Test: 4.1.3 Bit Slippage Probability

Manufacturer ________________ Model ________________ Serial No. ____________________

Tested by ____________________, ____

Date ____________________

Bit Synchronizer Input Signal Conditions						
PCM Signal				Noise Signal (Gaussian)		Premodulation Filter
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal. (V rms)	Cutoff Freq. (kHz)

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)

SNR	Bit Slippage Probability			Measurement Interval * (Period 10^N Bits)
(dB)	TOTAL (+ and -)	+	-	N
0				7
+3				7
+6				7
+9				7
+12				7
+15				7

*A measurement interval of 1×10^7 bits will provide reliable data measurement repeatability for BSP $\geq 1 \times 10^{-6}$.

NOTE: Additional measurements may be required where the slope of the data changes abruptly.

4.1.4 Acquisition Test

4.1.4.1 Purpose - This test determines the average number of bit periods required to achieve clock synchronization (ACQ) from the time data is applied. There are two procedures given for this test. Laboratory tests have shown that the results obtained using either procedure are in agreement to within the error bounds. The choice of procedure will depend mainly on the test equipment available. Procedure 1 compares the phase of the reference clock with the phase of the bit synchronizer output clock. When the phase difference remains within a range, such as ±90°, acquisition is achieved. Procedure 2 uses the drop of BEP from 0.5 to the value characteristic of the input SNR.

4.1.4.2 Test Equipment:

4.1.4.2.1 Procedure 1:

Noise source
Premodulation filter
Frequency counter
PCM test set

4.1.4.2.2 Procedure 2:

Noise source
Summing amplifier
PCM data
Digital delay
Oscilloscope
PN sequence transmitter/receiver

4.1.4.3 Test Method:

4.1.4.3.1 Procedure 1:

4.1.4.3.1.1 Setup - Connect the test equipment as shown in figure 4.1.4-1.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.4.3.1.2 Calibrate the PCM test set for an output SNR in accordance with the calibration instructions detailed in subparagraph 4.1.1.

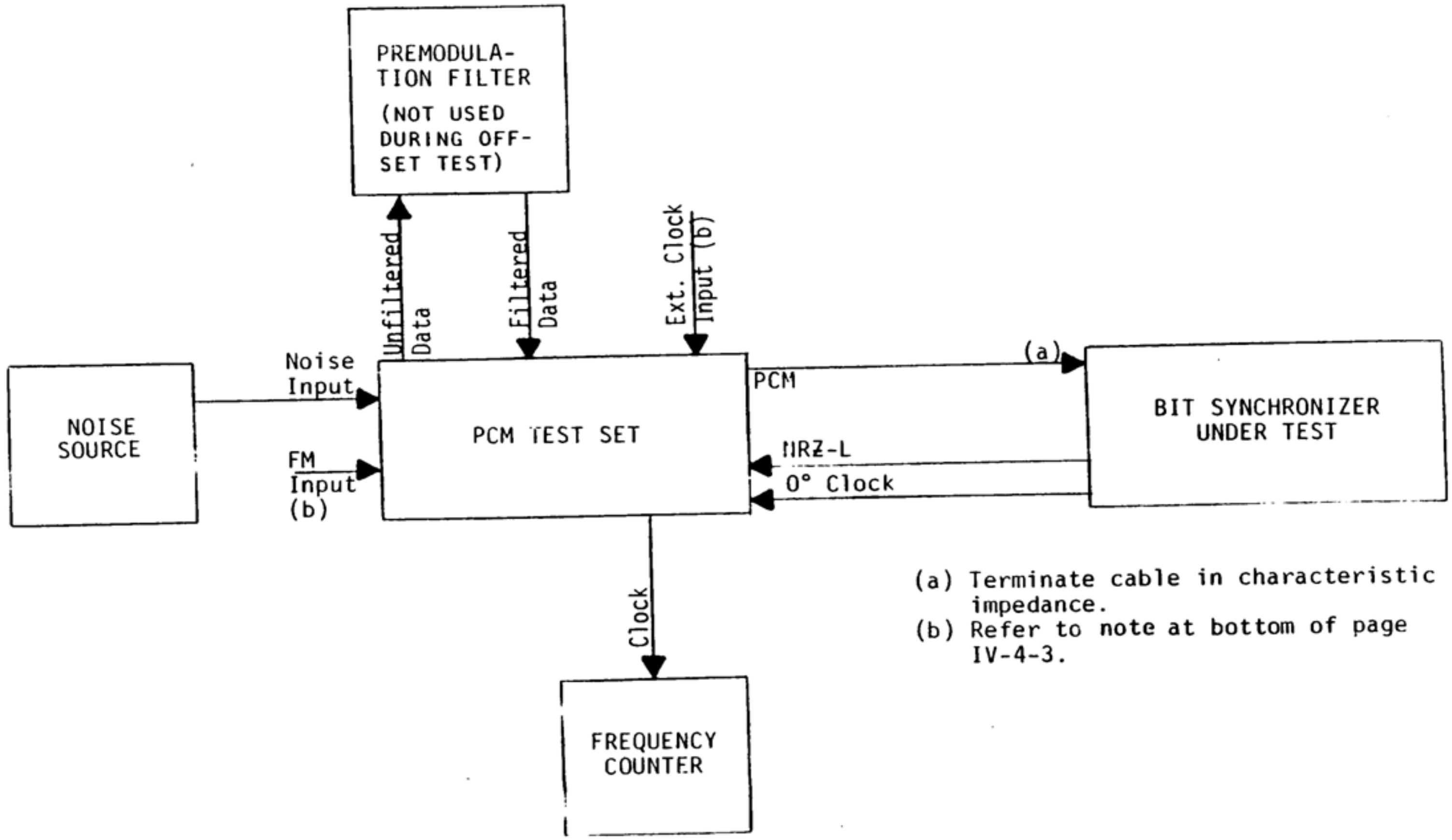


Figure 4.1.4-1 Acquisition Test Setup for Procedure 1.

4.1.4.3.1.3 Set the PCM output SNR to 0 dB and set the PCM test set to measure the number of bit periods required to achieve ACQ.

NOTE

Measures should be taken to assure that phase errors are not introduced by the test setup, e.g., when the setup includes a premodulation filter. Measurement difficulties may occur when detection circuitry is phase sensitive.

4.1.4.3.1.4 Monitor the clock output of the PCM test set with a counter to assure that the bit rate is correct. If the bit rate is not within the desired accuracy limit, use one of the methods contained in subparagraph 4.0.1.2 to adjust the bit rate.

4.1.4.3.1.5 Repeat measurements of the number of bit periods required to achieve ACQ for other SNR settings shown on Data Sheet 4.1.4.1.

4.1.4.3.1.6 Measure acquisition bit periods at selected SNRs for the bit rate offsets shown on Data Sheet 4.1.4.2. Note that the premodulation filter is not used during acquisition tests with bit rate offsets.

4.1.4.3.2 <u>Procedure 2:</u>

4.1.4.3.2.1 <u>Setup</u> - Connect the test equipment as shown in figure 4.1.4-2.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.4.3.2.2 Calibrate the test setup for output SNR in accordance with the calibration instructions detailed in subparagraph 4.1.1.

4.1.4.3.2.3 Use an oscilloscope to compare the phase of the transmitter PN generator clock with large SNR to the phase of the bit synchronizer clock output. Select the phase of the output bit clock of the bit synchronizer which is within ±45° of the transmitter clock.

4.1.4.3.2.4 Set the PCM output SNR to the minimum SNR indicated on Data Sheet 4.1.4.1 which can be acquired by the bit synchronizer. Note setting of noise attenuator.

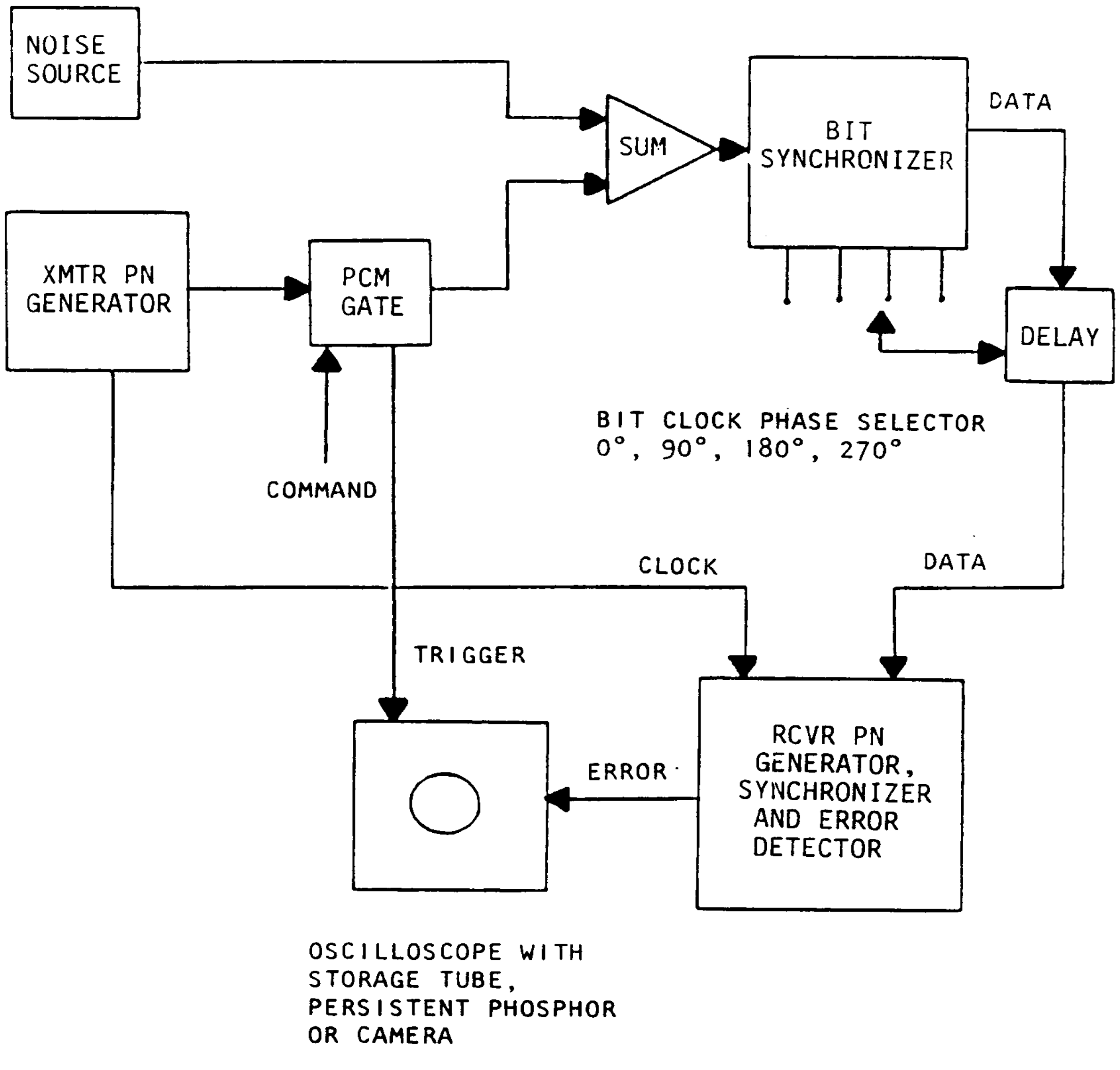


Figure 4.1.4-2 Acquisition Test Setup for Procedure 2.

4.1.4.3.2.5 To obtain initial synchronization of the receiver PN generator, increase noise attenuation to give a large SNR. Turn on the PCM gate to let the bit stream pass through. This will lock the receiver PN generator. It will stay in lock regardless of PCM input because the transmitter PN generator clock is fed directly to the receiver PN generator.

4.1.4.3.2.6 Disable the automatic restart function in the receiver PN generator.

NOTE

Since some PCM test sets do not incorporate a disable switch, it is necessary to install a switch to break the automatic restart command function. Generally, the manual "reset" button also reloads and starts the PN generator on make or break.

4.1.4.3.2.7 Turn off the PCM gate.

4.1.4.3.2.8 Set the oscilloscope for single sweep and adjust the sweep rate for display of acquisition. (See appendix IV-C.)

4.1.4.3.2.9 Set noise attenuator to the value given in step 4.1.4.3.2.4. Turn on the PCM gate. Observe time of acquisition from the oscilloscope display and record in terms of the number of bits on Data Sheet 4.1.4.1.

4.1.4.3.2.10 Repeat step 4.1.4.3.2.9 for the other SNR settings shown on Data Sheet 4.1.4.1.

4.1.4.3.2.11 Measure acquisition bit periods at selected SNRs for the bit rate offsets shown on Data Sheet 4.1.4.2.

NOTE

By using a linear gate for the noise source in figure 4.1.4-2 and bypassing the PCM gate, the circuit can be used to measure BSP.

4.1.4.3.3 <u>Data Reduction</u> - Record data on Data Sheet 4.1.4.1 or 4.1.4.2 as appropriate. Examples of inputs to Data Sheets 4.1.4.1 and 4.1.4.2 are shown in figures 4.1.4-3 and 4.1.4-4 respectively. Corresponding sample data plots are shown in figures 4.1.4-5 and 4.1.4-6.

DATA SHEET 4.1.4.1 ACQUISITION TEST

Test: 4.1.4 Acquisition Test

Manufacturer ______________ ...rial No. ______________

Tested by ______________ ______________

Date ______________

Bit Synchronizer Input Signal Conditions						
PCM Signal				Noise Signal (Gaussian)		Premodulation Filter
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal. (V rms)	Cutoff Freq. (kHz)
100	1.0	NRZ-L	PR	100	0.5	75

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)
F/S	0.1	1.0

SNR (dB)	ACQUISITION BITS										
	Total Bits (avg)*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
0	9.9X10³ **	**	**	**	**	**	**	**	**	**	**	
+3	9.9X10³ **	**	**	**	**	**	**	**	**	**	**	
+6	8.4X10³	5.4X10³	9.9X10³ **	9.9X10³ **	9.9X10³ **	9.9X10³ **	5.6X10³	8.5X10³	9.9X10³ **	6.2X10³	9.2X10³	
+9	526	367	394	570	371	608	545	327	393	620	572	
+12	261	410	416	495	0	201	0	514	171	409	0	
+15	196	345	0	182	0	412	24	0	396	410	190	
PCM only	133	204	130	0	21	91	0	152	91	170	474	

*Record the calculated average for 10 discrete measurements.
**Limit of test set readout.

NOTE: Additional measurements may be required where the slope of the data changes abruptly.

DATA SHEET 4.1.4.2 ACQUISITION TEST

Test: 4.1.4 Acquisition Test

Manufacturer ______________ Serial No. ______________

Tested by ______________ ______________ ______________

Date ______________

Bit Synchronizer Input Signal Conditions							
PCM Signal				Noise Signal (Gaussian)		Premod Filter	SNR
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal (V rms)	Cutoff Freq (kHz)	dB
100	1.0	NRZ-L	PR	100	0.5	None	15

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)
F/S	0.1	1.0

Bit Rate Offset (% Trackng Range)	Acquisition Bits										
	Total bits (avg) *	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
+100%	9.9×10^3 **	** 9.9×10^3	** 9.9×10^3	** 9.9×10^3	**	**	**	**	**	**	**
+80%	6.7×10^3	6.9×10^3	6.6×10^3	6.8×10^3	6.7×10^3	6.8×10^3	6.6×10^3	6.9×10^3	6.7×10^3	6.7×10^3	6.8×10^3
+60%	3.7×10^3	3.7×10^3	3.8×10^3	3.6×10^3	4.2×10^3	3.7×10^3	3.7×10^3	3.8×10^3	3.6×10^3	3.5×10^3	3.5×10^3
+40%	1.7×10^3	1.9×10^3	1.9×10^3	1.5×10^3	1.9×10^3	1.7×10^3	1.9×10^3	1.5×10^3	1.8×10^3	1.6×10^3	1.8×10^3
+30%	1.2×10^3	1.4×10^3	944	941	939	1.2×10^3	1.2×10^3	1.3×10^3	1.2×10^3	1.3×10^3	1.2×10^3
+20%	524	456	440	456	438	533	730	447	874	495	374
+10%	59	0	33	56	0	0	119	147	50	188	0
0%	78	156	0	0	0	0	71	149	141	132	131
-10%	70	0	0	0	204	0	350	0	0	70	84
-20%	94	0	0	0	162	0	446	282	0	0	54
-30%	58	35	0	258	0	0	0	201	83	0	0
-40%	63	0	81	244	78	0	0	0	74	154	0
-60%	700	370	1×10^3	422	779	797	618	610	829	839	734
-80%	1.7×10^3	1.6×10^3	1.6×10^3	1.9×10^3	1.8×10^3	1.8×10^3	1.6×10^3	1.8×10^3	1.7×10^3	1.7×10^3	1.8×10^3
-100%	3.7×10^3	3.9×10^3	3.6×10^3	3.9×10^3	3.5×10^3	3.9×10^3	3.6×10^3	3.7×10^3	3.9×10^3	3.7×10^3	3.6×10^3

*Record the calculated average for 10 discrete measurements.
**Limit of test set readout.

NOTE: Additional measurements may be required where the slope of the data changes abruptly.

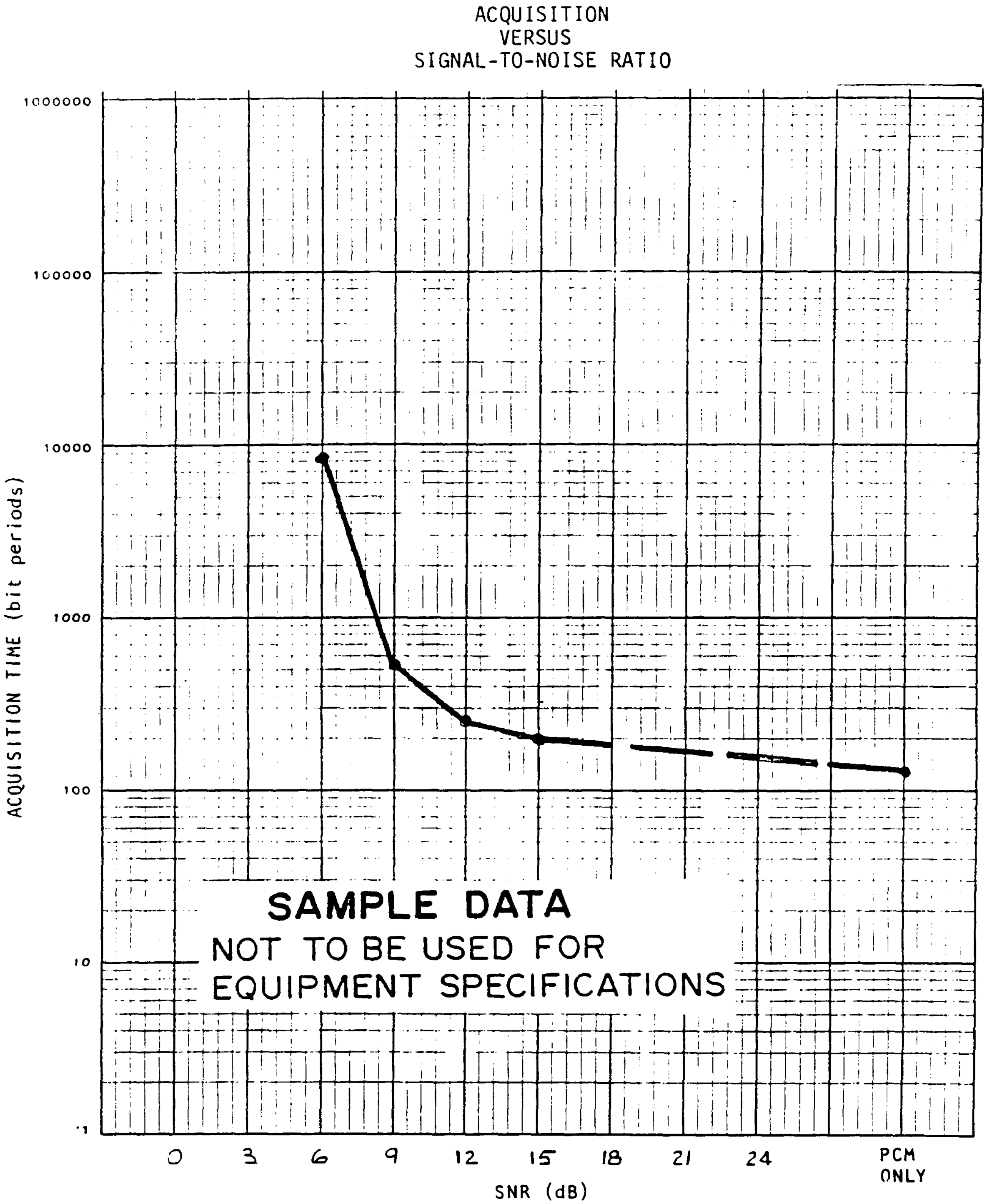


Figure 4.1.4-5 Sample Plot Presentation of Data Sheet 4.1.4.1.

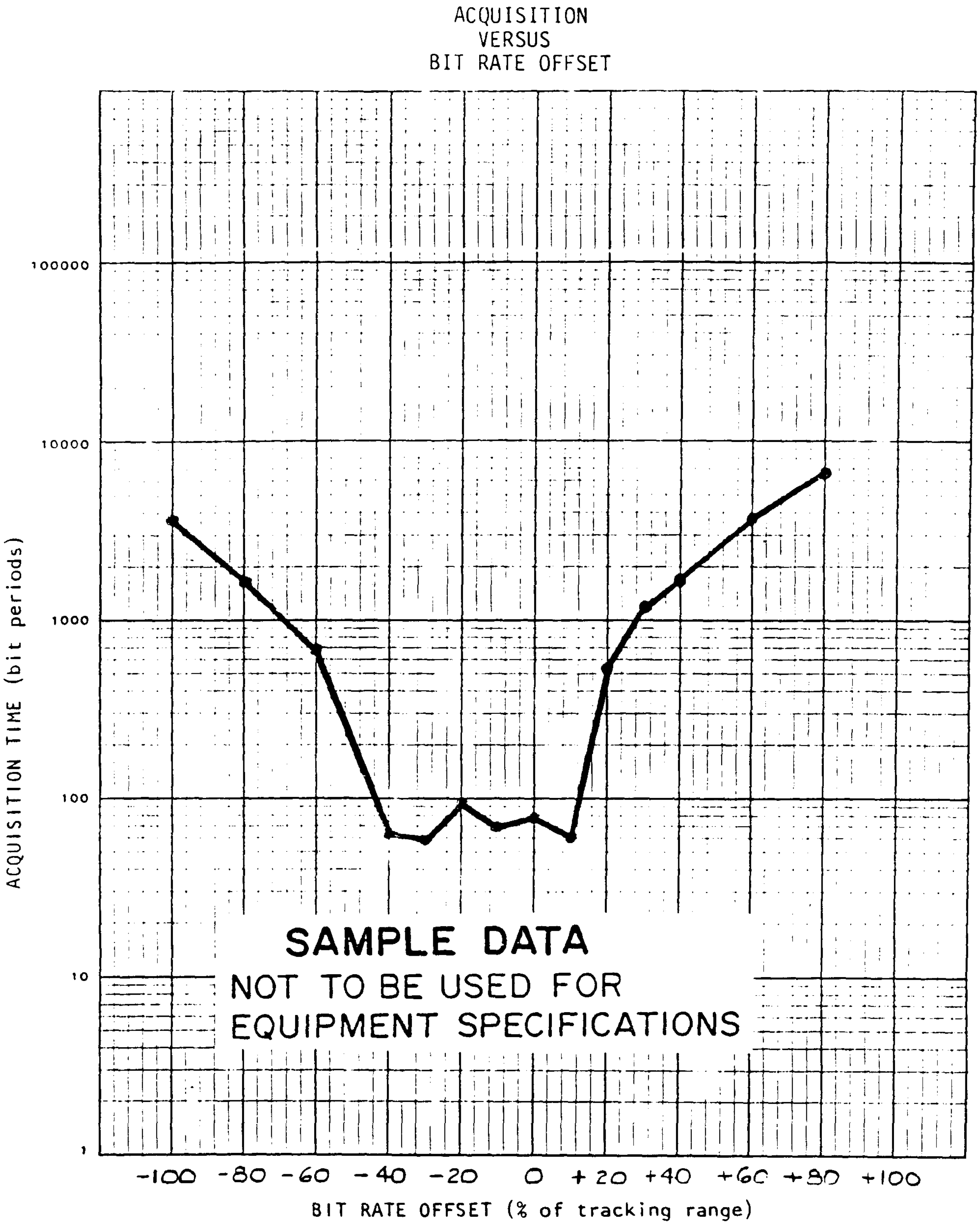


Figure 4.1.4-6 Sample Plot Presentation of Data Sheet 4.1.4.2.

DATA SHEET 4.1.4.1 ACQUISITION TEST

Test: 4.1.4 Acquisition Test

Manufacturer ________________ Model ______________ Serial No. ________________

Tested by ____________________, ____

Date ___________________

Bit Synchronizer Input Signal Conditions						
PCM Signal				Noise Signal (Gaussian)		Premodulation Filter
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal. (V rms)	Cutoff Freq. (kHz)

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)

SNR (dB)	ACQUISITION BITS											
	Total Bits (avg)*	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	
0												
+3												
+6												
+9												
+12												
+15												
PCM only												

*Record the calculated average for 10 discrete measurements.

NOTE: Additional measurements may be required where the slope of the data changes abruptly.

DATA SHEET 4.1.4.2 ACQUISITION TEST (WITH BIT RATE OFFSET)

Test: 4.1.4 Acquisition Test (with Bit Rate Offset)

Manufacturer ________________ Model ______________ Serial No. ________________

Tested by ____________________, ____

Date ____________________

Bit Synchronizer Input Signal Conditions							
PCM Signal				Noise Signal (Gaussian)		Premod Filter	SNR
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal (V rms)	Cutoff Freq (kHz)	dB
						None	

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)

Bit Rate Offset (% Trackng Range)	Acquisition Bits										
	Total bits (avg) *	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
+100%											
+80%											
+60%											
+40%											
+30%											
+20%											
+10%											
0%											
-10%											
-20%											
-30%											
-40%											
-60%											
-80%											
-100%											

*Record the calculated average for 10 discrete measurements.

NOTE: Additional measurements may be required where the slope of the data changes abruptly.

4.1.5 Jitter Test

4.1.5.1 Purpose - This test determines the effects of bit jitter on ACQ in the bit synchronizer. The criterion of performance is the BSP.

4.1.5.2 Test Equipment:

4.1.5.2.1 The following is used in the test setup shown in figure 4.1.5-1 (Method I):

Noise source
Premodulation filter
Frequency counter
PCM test set
Signal generator
Noise source (jitter source)

4.1.5.2.2 The following is used in the test setup shown in figure 4.1.5-2 (Method II):

Noise source
Premodulation filter
Frequency counter
Signal generator (jitter frequency source)
Signal generator (external clock source which can be frequency modulated)
BER test set (transmitter and receiver)
Calibrated attenuator
Noise source (jitter source)

4.1.5.3 Test Method:

4.1.5.3.1 Setup - Connect the test equipment as shown in figure 4.1.5-1 or 4.1.5-2. (The test method is the same for either test setup.)

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.5.3.2 Calibrate the test setup output of SNR in accordance with the calibration instructions detailed in subparagraph 4.1.1.

4.1.5.3.3 Adjust the test setup to measure bit (clock) slips or restarts in the measurement intervals shown on Data Sheet 4.1.5.1.

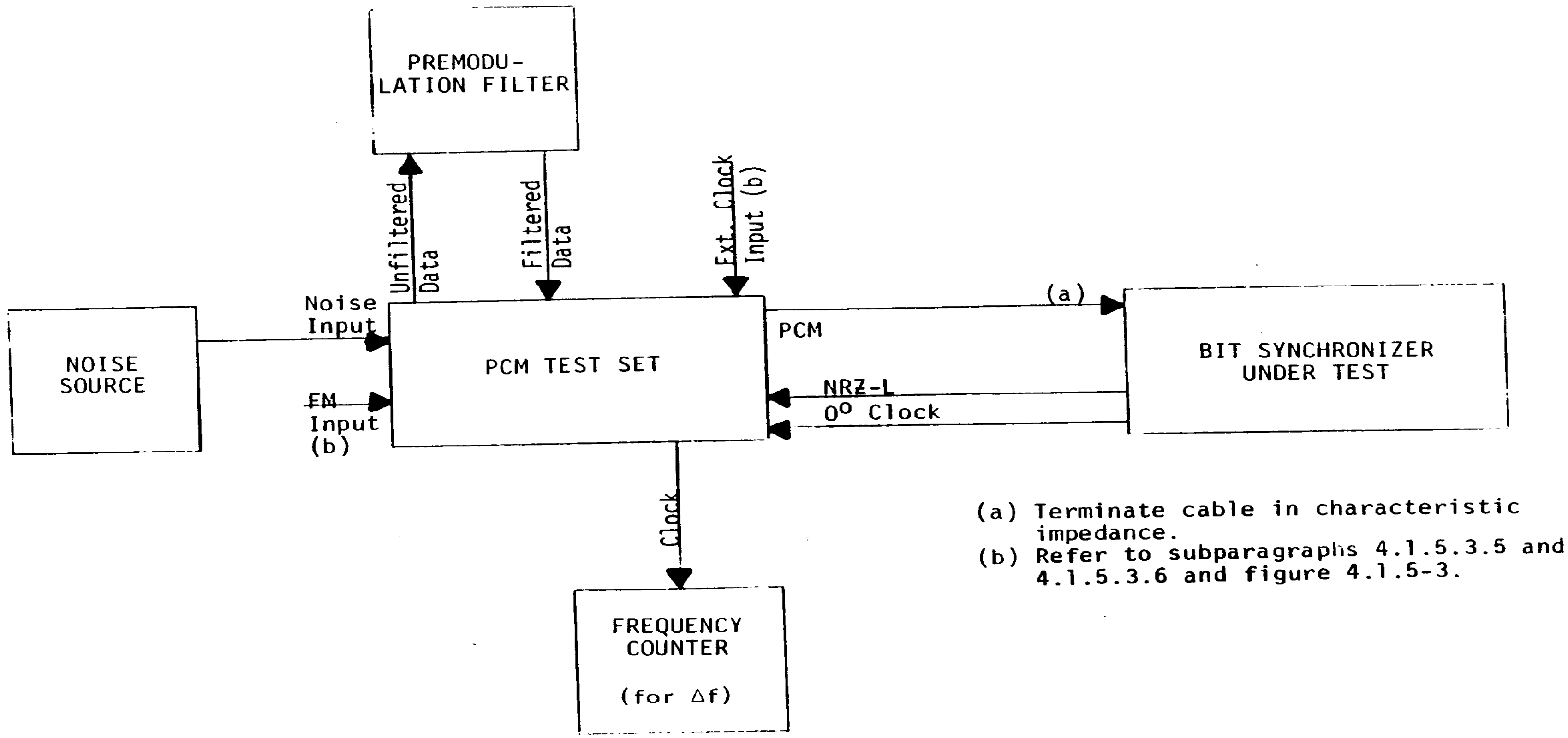


Figure 4.1.5-1 Jitter Test Set-up Using PCM Test Set (Method I).

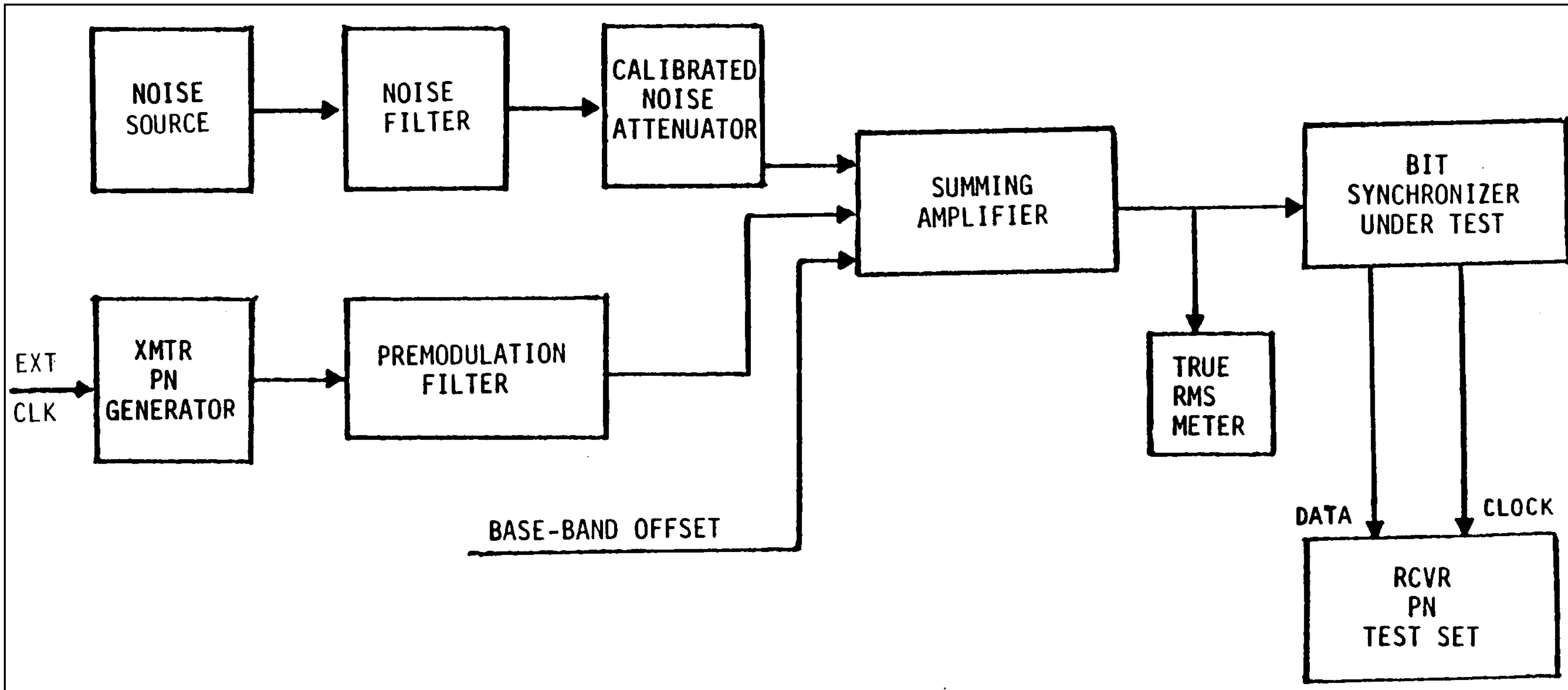


Figure 4.1.5-2 Jitter Test Setup for the Case in which the Noise Attenuator and Summing Amplifier are External to the PCM Test Set (Method II).

NOTE

Measures should be taken to assure that phase errors are not introduced by the test setup, e.g., when the setup includes a premodulation filter. Measurement difficulties may occur when detection circuitry is phase sensitive.

4.1.5.3.4 Adjust the test setup for the desired SNR and measure the total number of bit (clock) slips (both plus and minus).

NOTE

The steps in subparagraph 4.1.5.3.5 and 4.1.5 3.6. describe two methods which may be used to jitter the PCM output of tile test setup. The equipment setup for each method is shown in figure 4.1.5-3.

4.1.5.3.5 For Method I, make the following adjustments to obtain the desired bit rate:

4.1.5.3.5.1 Connect the signal generator to the FM input of the PCM test set and set the generator d.c. offset and output amplitude to 0.

4.1.5.3.5.2 Monitor the clock output of the PCM test set with a frequency counter.

4.1.5.3.5.3 Adjust the bit rate of the PCM test set until the counter indicates the desired bit rate.

4.1.5.3.6 For Method II, make the following adjustments to obtain the desired bit rate when using an external clock generator (square-wave signal):

4.1.5.3.6.1 Set the signal generator, d.c. offset and signal amplitude to 0 and connect to the voltage control generator input of the external clock generator.

4.1.5.3.6.2 Monitor the clock output of the PCM test set with a frequency counter.

4.1.5.3.6.3 Adjust the frequency control of the external clock generator until the counter connected to the clock output of the PCM test set indicates the required bit rate.

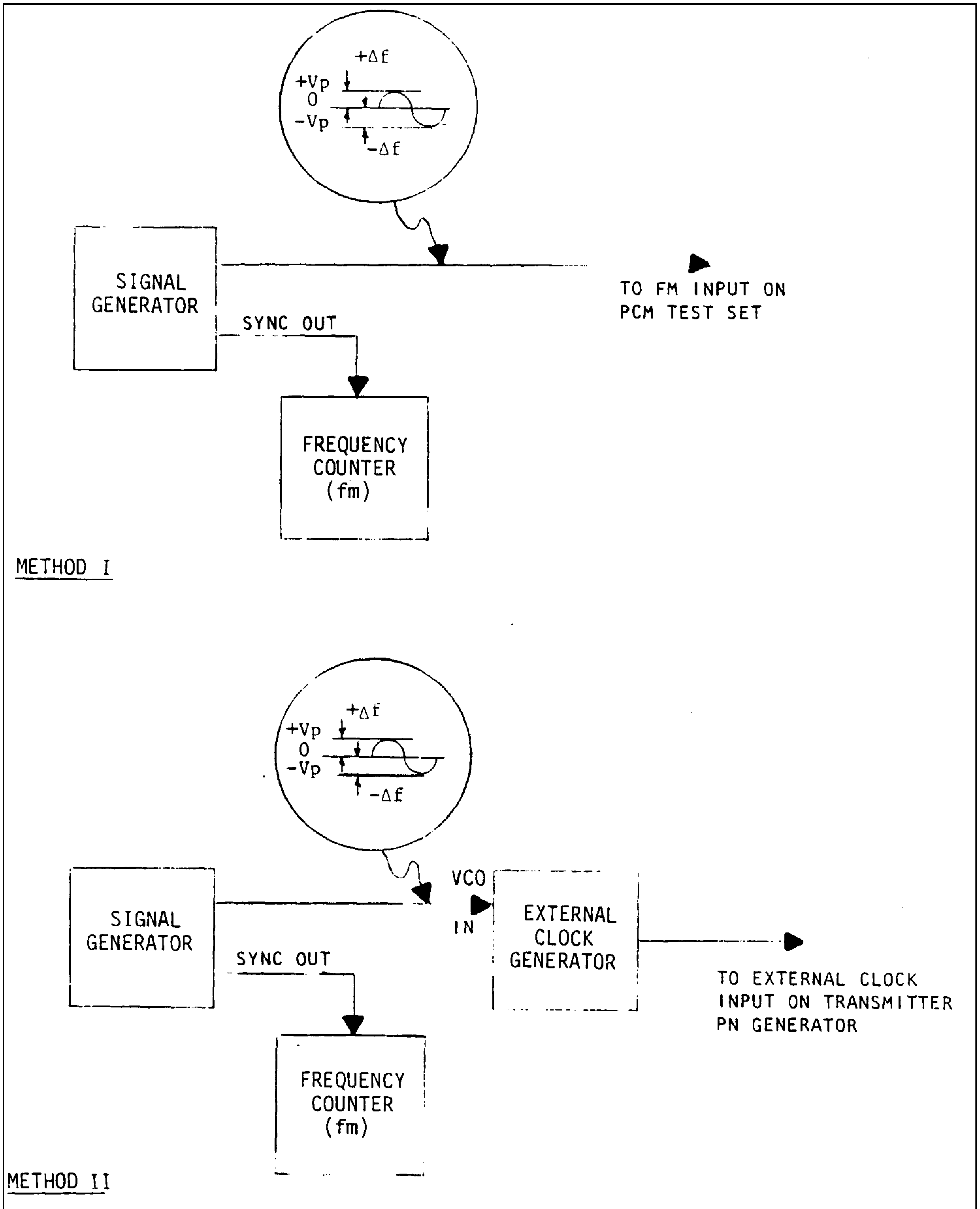


Figure 4.1.5-3 Bit Rate Jitter (methods).

4.1.5.3.7 Adjust the frequency of the signal generator for the desired rate of jitter (f_m). Measure f_m accurately with the counter.

4.1.5.3.8 Adjust the amplitude of the signal generator output until the peak deviation of the bit rate (Δf) causes a BSP in the range of 1×10^{-6} to 1×10^{-5}.

$$BSP = \frac{\text{Total Bit Slips Measured}}{\text{Number of Bits Transmitted During Measurement Interval}}$$

NOTE

The following method may be used to determine Δf:

1. *Adjust the output amplitude of the signal generator to zero.*
2. *Adjust the d.c. offset of the signal generator (use a direct-coupled oscilloscope) to equal the peak amplitude of the waveform which produced the BSP just measured.*
3. *Calculate Δf from the change in the PCM test set clock frequency.*

4.1.5.3.9 Repeat the measurements for other combinations of f_m and Δf as desired.

4.1.5.3.10 Repeat the entire test for other values of output SNR, if needed.

4.1.5.3.11 For the noise jitter test, replace the signal generator (a.c./d.c.) in figure 4.1.5-3 with a shaped noise source to simulate jitter as required. (See appendix IV-C for suggested circuits.) Replace the frequency counter (for f_m) in figure 4.1.5-3 with a true rms voltmeter. Use the calibration determined in subparagraph 4.1.5.3.8 to calculate the percent of rms jitter of the bit clock. For example, let V_{dc}=offset from the signal generator required to produce Δf. Then the jitter is modulation sensitivity $S_j = \Delta f / V_{dc}$ Hz per volt. The rms jitter is then equal to $S_j V_{rms}$ Hz, where V_{rms} is the voltage output of the shaped noise generator as read by the true rms voltmeter. The percentage of jitter is given by 100 $S_j V_{rms} / f_b$, where f_b =bit rate.

NOTE

A flutter meter can be used to measure the percentage of jitter directly.

4.1.5.3.12 Adjust the rms voltage at the output of the shaped noise generator to produce a BSP in the range of 10^{-6} to 10^{-5} as in step 4.1.5.3.8.

4.1.5.3.13 Repeat the test for other values of the output SNR as required.

4.1.5.4 <u>Data Reduction</u> - Record data on Data Sheet 4.1.5.1. An example of Data Sheet 4.1.5.1 use is shown in figure 4.1.5-4 and a corresponding sample data plot is shown in figure 4.1.5-5.

DATA SHEET 4.1.5.1 JITTER TEST

Test: 4.1.5 Jitter Test

Manufacturer ______________ ______ Serial No. ______________

Tested by ______________ ______________________________

Date ______________

SAMPLE DATA
NOT TO BE USED FOR
EQUIPMENT SPECIFICATIONS

Bit Synchronizer Input Signal Conditions							
PCM Signal				Noise Signal (Gaussian)		Premod Filter	SNR
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal (V rms)	Cutoff Freq (kHz)	dB
100	1.0	NRZ-L	PR	100	0.5	75	9

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)
F/S	0.3	3.0

Jitter		BSP	Measurement Interval * (Period 10^N Bits)
f_m (Hz)	Δf (Hz)	Hold constant in range $10^{-5} \geq BSP \geq 10^{-6}$	N
0.1	3000	1×10^{-6}	6
1.0	3000	1×10^{-6}	6
10	3000	2×10^{-6}	6
20	3200	4×10^{-6}	6
30	2600	1×10^{-5}	6
50	1500	7×10^{-6}	6
100	812	1×10^{-5}	6
300	466	1×10^{-6}	6
700	1000	1×10^{-6}	6
1000	1700	1×10^{-5}	6
2000	3400	1×10^{-5}	6

*Measurement interval provides reliable repeatability for BSP $\geq 1 \times 10^{-6}$.

<u>NOTE:</u> *Additional measurements may be required where the slope of the data changes abruptly.*

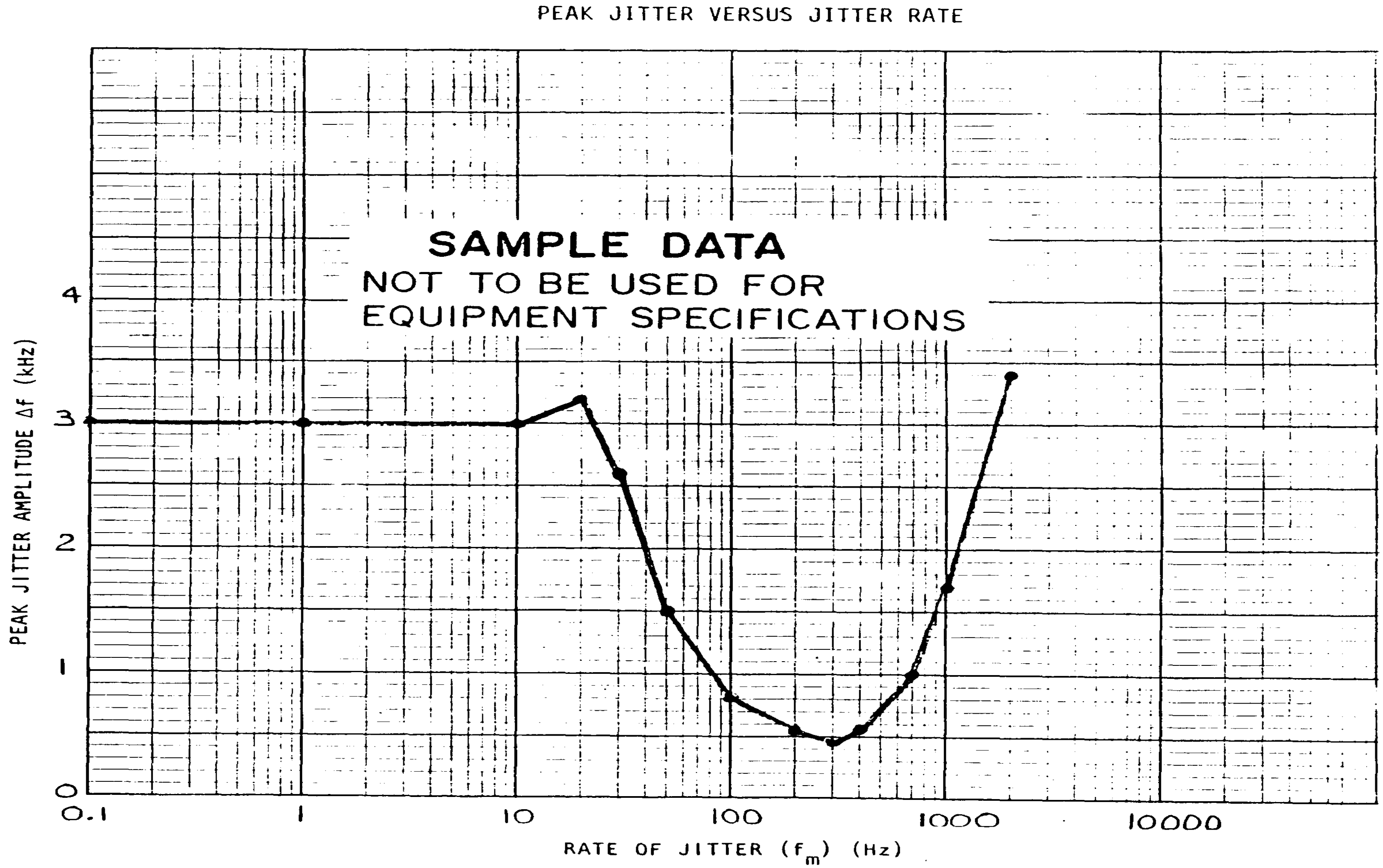


Figure 4.1.5-5 Sample Plot Presentation of Data Sheet 4.1.5.1.

DATA SHEET 4.1.5.1 JITTER TEST

Test: 4.1.5 Jitter Test

Manufacturer ________________ Model ______________ Serial No. _______

Tested by ____________________, ____________________________________

Date ____________________

Bit Synchronizer Input Signal Conditions							
PCM Signal				Noise Signal (Gaussian)		Premod Filter	SNR
Bit Rate (kB/s)	Amplitude (V_{p-p})	Code	Word Pattern	Cal. B.W. (kHz)	Cal (V rms)	Cutoff Freq (kHz)	dB

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Trackng Range (% Bit Rate)

Jitter		BSP	Measurement Interval * (Period 10^N Bits)
f_m (Hz)	Δf (Hz)	Hold constant in range $10^{-5} \geq BSP \geq 10^{-6}$	N
			6
			6
			6
			6
			6
			6
			6
			6
			6
			6
			6

*Measurement interval provides reliable repeatability for BSP $\geq 1 \times 10^{-6}$.

NOTE: *Additional measurements may be required where the slope of the data changes abruptly.*

4.1.6 Bit Stream Base-Line Wander and AM Test

4.1.6.1 Purpose - This test determines the effects of bit stream base-line wander and AM. Base-line wander results from passage of the bit stream through devices lacking d.c. response, such as tape recorders and capacity-coupled circuits, and from incidental PM or FM in transmitters. A principal cause of bit stream AM is tape bounce.

4.1.6.2 Test Equipment:

4.1.6.2.1 The following are used in the test setup shown in figure 4.1.6-1.

Noise source
Low-pass filter
Signal generator (for base-line input)
Signal generator (for AM input)
Amplitude modulator
Premodulation filter
True rms voltmeter
Frequency counter
PCM test set

4.1.6.2.2 The test setup shown in figure 4.1.6-2 uses the same equipment listed in subparagraph 4.1.6.2.1 except it replaces the PCM test set with a PCM BER test set, a calibrated noise attenuator and a summing amplifier.

4.1.6.3 Test Procedures:

4.1.6.3.1 Setup - Connect the test equipment as shown in figure 4.1.6-1 or 4.1.6-2.

NOTE

Refer to subparagraph 4.0.1 for standard test conditions for testing with gaussian noise.

4.1.6.3.2 Calibrate the PCM test set output SNR in accordance with the calibration instructions detailed in subparagraph 4.1.1.

4.1.6.3.3 Adjust the frequency and amplitude of the oscillator feeding the base-line input as required. Adjust the frequency and amplitude of the oscilloscope feeding the AM modulator as required. Use the oscilloscope to verify that the requirements are met.

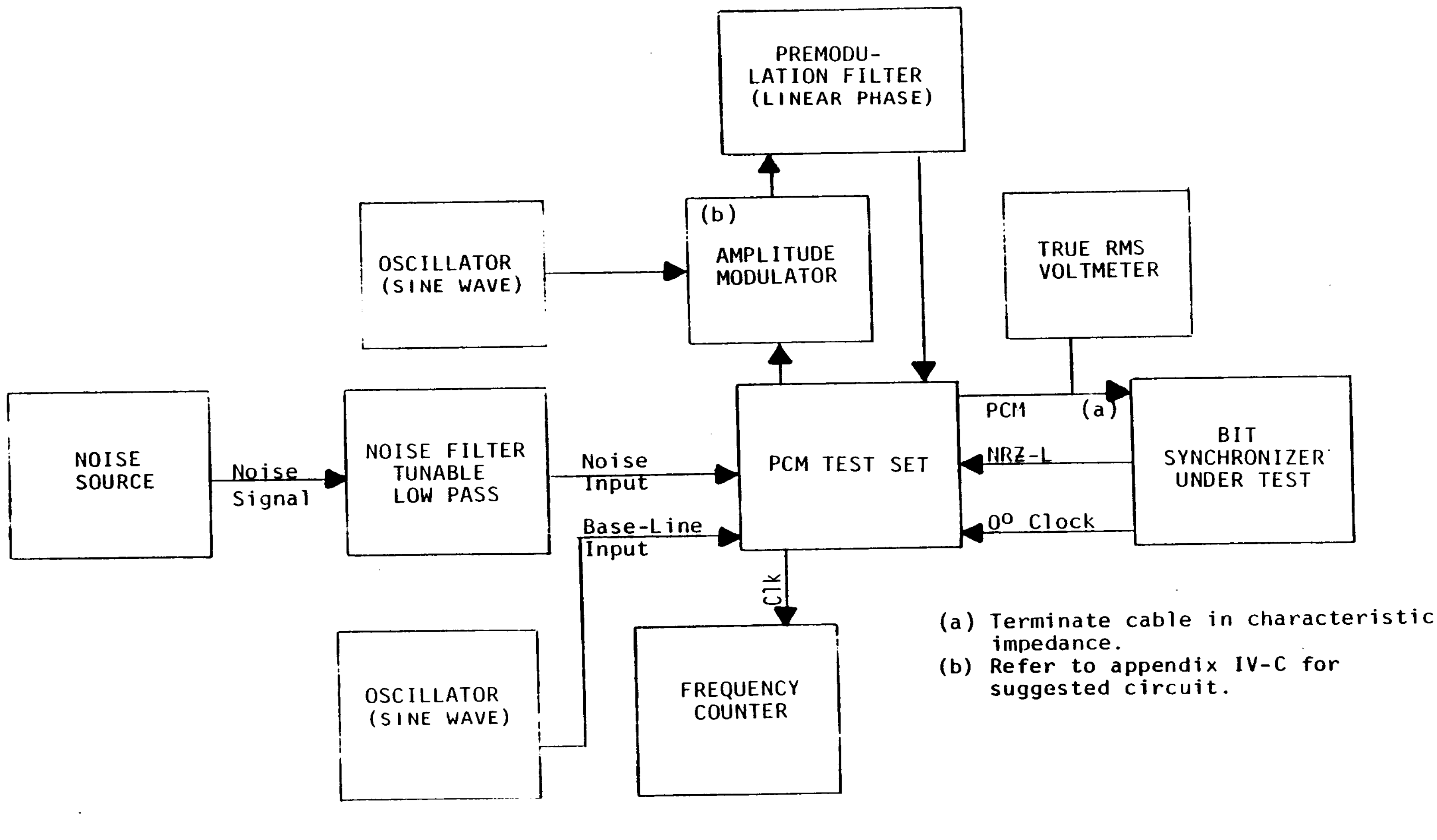


Figure 4.1.6-1 Bit Stream Base-Line Wander and AM Test Setup with PCM Test Set.

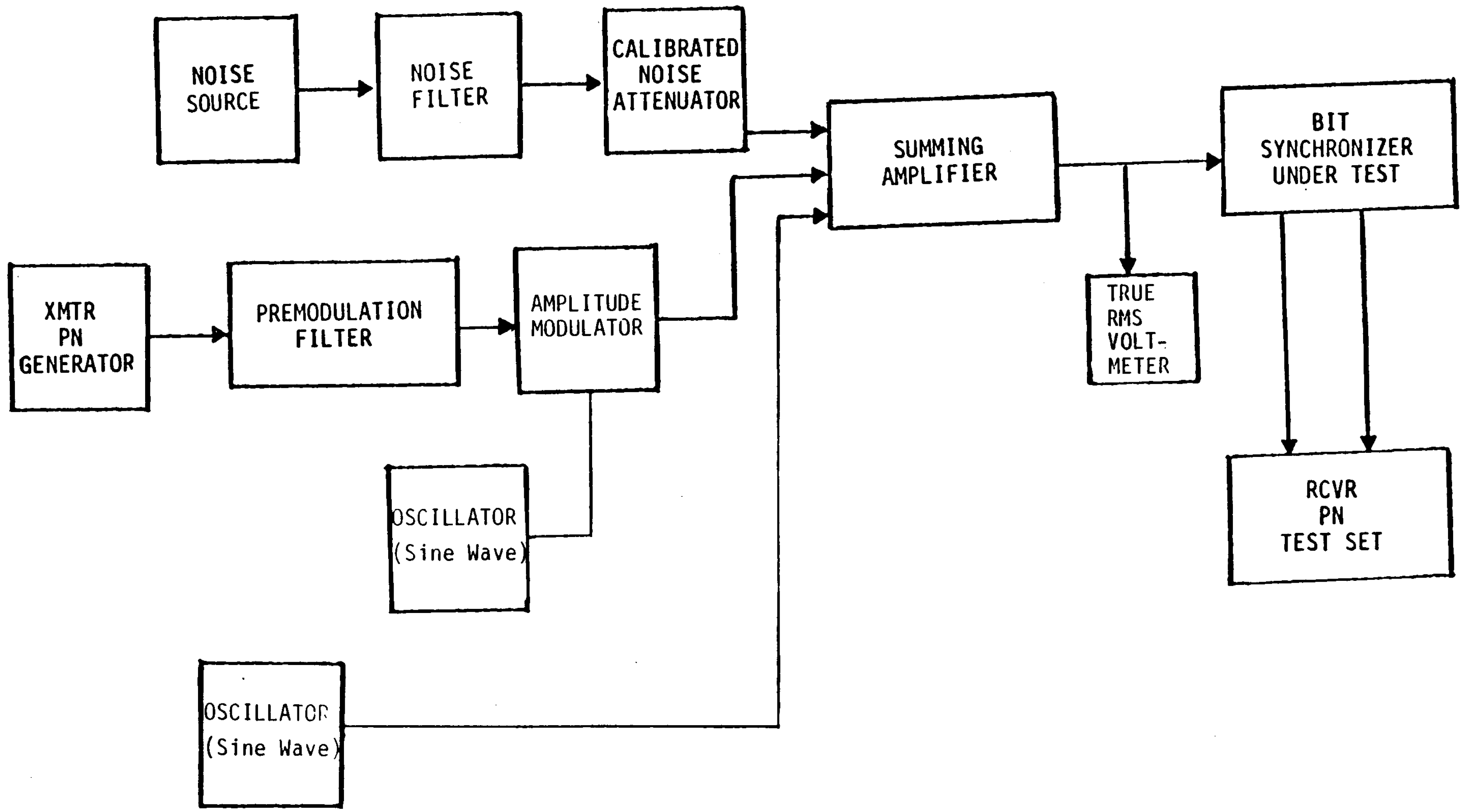


Figure 4.1.6-2 Bit Stream Base-Line Wander and AM Test Setup for the Case in which the Noise Attenuator and Summing Amplifier are External to the PCM Test Set.

NOTE

Percent AM and base-line wander are defined as follows:

$$\text{Percent AM} = \frac{(\text{Crest Amp1.}) - (\text{Trough Ampl.})}{(\text{Crest Ampl.}) + (\text{Trough Ampl.})} \times 100$$

$$\text{Percent Base-Line Wander} = \frac{(\text{p-p})\ \text{Base-Line Wander}}{(\text{p-p})\ \text{Bit Pulse Height}} \times 100$$

4.1.6.3.4 Perform the bit error test, the bit jitter test, the bit slippage test and the acquisition test.

4.1.6.4 Data Reduction - Record data on Data Sheets 4.1.6.1, 4.1.6.2, 4.1.6.3, or 4.1.6.4 as appropriate. Examples of inputs to these data sheets are shown in figures 4.1.6-3 through 4.1.6-6 and corresponding sample data plots are shown in figures 4.1.6-7 through 4,1 .6-10.

NOTE

The results of Part I can be interpreted directly in terms of $\pm\pi/2$ PCM/FM with the carrier coherently detected if the SNR of Part I is replaced with the SNR in a predetection bandwidth equal to the bit rate.

DATA SHEET 4.1.6.1 BEP TEST WITH BIT STREAM AM

Test: 4.1.6 Bit Stream Base-Line Wa...

SAMPLE DATA
NOT TO BE USED FOR EQUIPMENT SPECIFICATIONS

Manufacturer ____________ ______ Serial No. __________

Tested by _______ ____________________

Date __________

Bit Synchronizer Input Signal Conditions								
PCM Signal				FM Link Settings			AM	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq. % Bit Rate
100	∞	NRZ	PR	140	180	70	50	5

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)
FS	0.3	3.0

Sig. Gen. Mfg. DCS
Model GOV-4 Serial No. 94386
Rcvr. Mfg. EMR
Model 4142 Serial No. 219
Carrier Freq. 450 KHz

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3	9×10^{-2}	9×10^{-2}	5
6	2.5×10^{-2}	2.3×10^{-2}	5
9	1.7×10^{-3}	1.4×10^{-3}	6
12	2.5×10^{-5}	5×10^{-6}	8
15			8

DATA SHEET 4.1.6.2 BEP TEST WITH BASE-LINE WANDER ADDED TO BIT STREAM

Test: 4.1.6 Bit Stream Base-Line W

Manufacturer ____________ ______ Serial No. __________

Tested by ________ ____________________________

Date __________

Bit Synchronizer Input Signal Conditions								
PCM Signal				FM Link Settings			BLW	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq. % Bit Rate
100	∞	NRZ	PR	70	360	70	50	0.25

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)
FS	# 1	–

Sig. Gen. Mfg. DCS

Model GDV-4 Serial No. 94381

Rcvr. Mfg. EMR

Model 4142 Serial No. 219

Carrier Freq. 450 KHz

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3	1.2×10^{-1}	1.0×10^{-1}	5
6	1.5×10^{-2}	1.2×10^{-2}	5
9	7.0×10^{-4}	4.5×10^{-4}	6
12	5.3×10^{-6}	1.7×10^{-6}	8
15			8
18			8

DATA SHEET 4.1.6.3 BEP TEST WITH BASE-LINE WANDER ADDED TO AM BIT STREAM

Test: 4.1.6 Bit Stream Base-Line W- -est

Manufacturer ______ Serial No. ______

Tested by ______

Date ______

SAMPLE DATA
NOT TO BE USED FOR
EQUIPMENT SPECIFICATIONS

Bit Synchronizer Input Signal Conditions											
PCM Signal				FM Link Settings			BLW		AM	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq % Bit Rate	%	Freq. % Bit Rate
100	∞	NRZ	PR	70	360	70	50	0.25	50	0.02

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)
FS	# 4	

Sig. Gen. Mfg. DCS
Model GOV-4 Serial No. 94386
Rcvr. Mfg. EMR
Model 4142 Serial No. 219
Carrier Freq. 450 KHz

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3			5
6			5
9	2.0×10^{-3}	4.5×10^{-4}	6
12	5.5×10^{-5}	1.7×10^{-6}	8
15	1.1×10^{-5}		8
18	3×10^{-6}		

DATA SHEET 4.1.6.4 BIT ERROR PROBABILITY TEST WITH AM PLUS BASE-LINE WANDER PLUS JITTER

Test: 4.1.6 Bit Stream Base-Line W

Manufacturer __________ Serial No. __________

Tested by __________

Date __________

Bit Synchronizer Input Signal Conditions										
PCM Signal				FM Link Settings			BLW		AM	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq % Bit Rate	%	Freq. % Bit Rate
100	∞	NRZ	PR	70	360	70	50	0.25	50	0.02

Bit Synchronizer Settings			Jitter	Jitter
Detector Type	Loop BW (% Bit Rate)	Tracking Range (%Bit Rate)	6 dB Point (%Bit Rate)	% (rms) Bit Rate
FS	#4	–	2	1

Sig. Gen. Mfg. DCS

Model GDV-4 Serial No. 94386

Rcvr. Mfg. EMR

Model 4142 Serial No. 219

Carrier Freq. 450 KHz

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3			5
6			5
9	1.0×10^{-2}	4.5×10^{-4}	6
12	6.0×10^{-4}	1.7×10^{-6}	8
15	1.8×10^{-5}		8
18	2×10^{-6}		

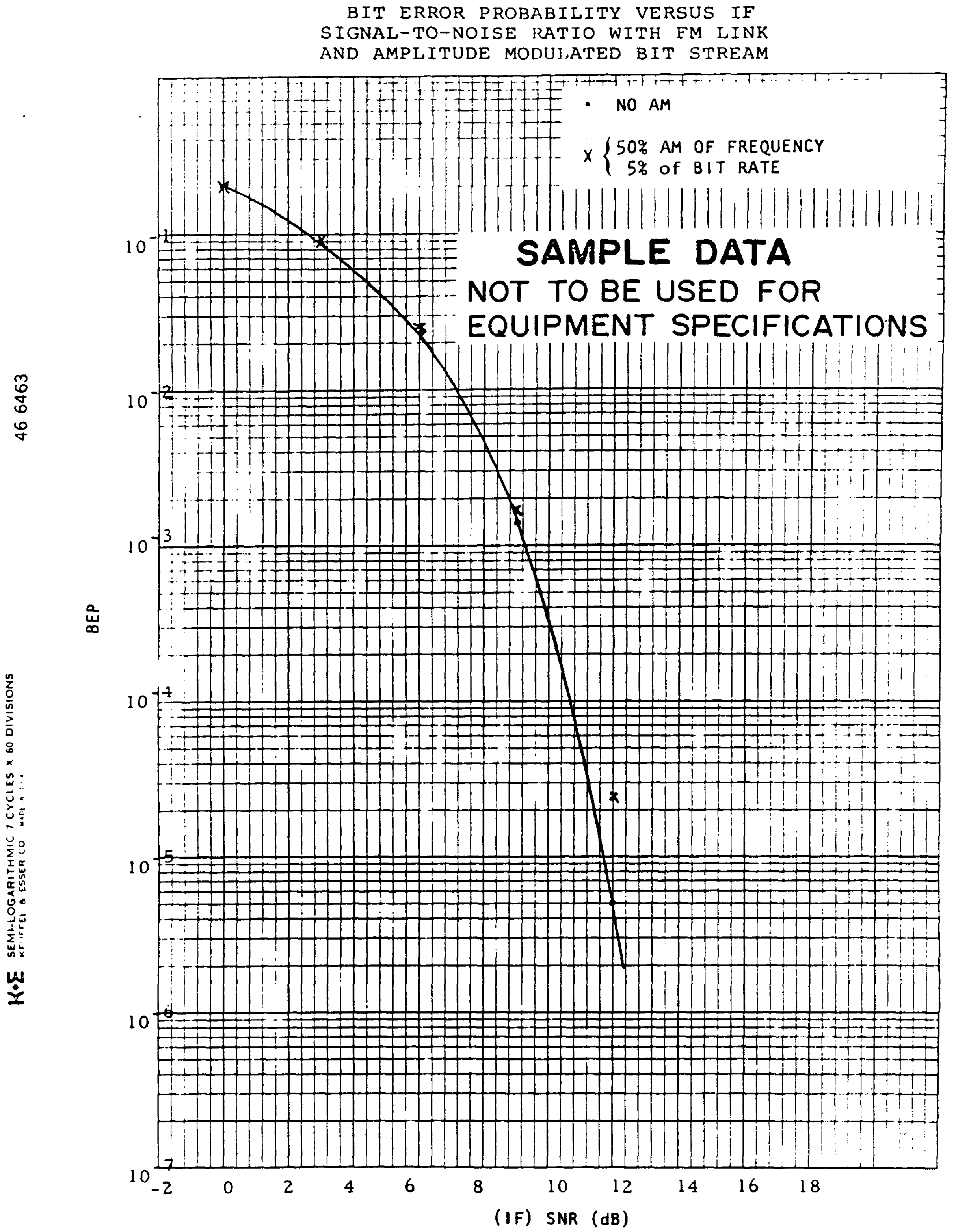


Figure 4.1.6-7 Sample Plot Presentation of Data Sheet 4.1.6.1.

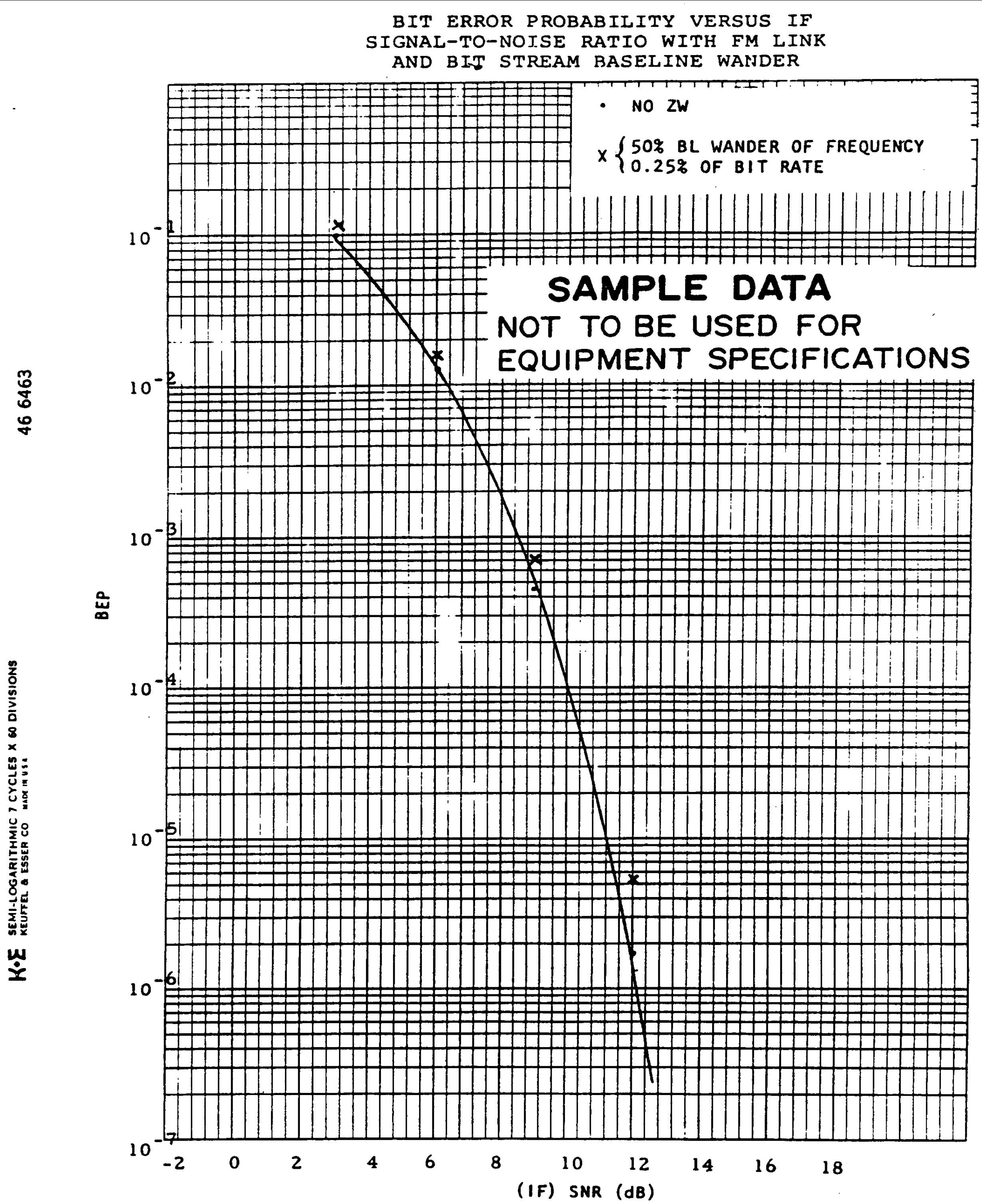


Figure 4.1.6-8 Sample Plot Presentation of Data Sheet 4.1.6.2.

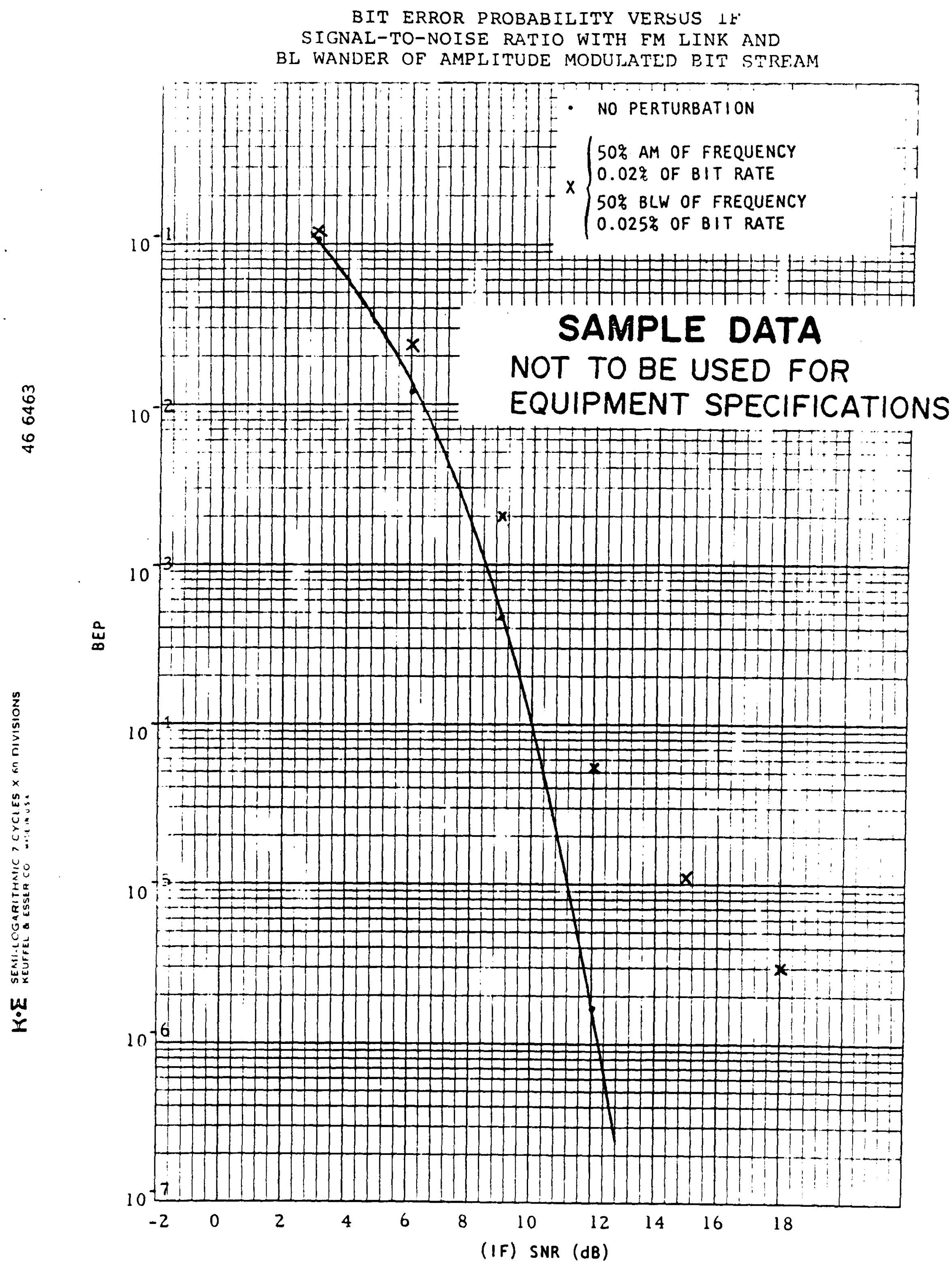


Figure 4.1.6-9 Sample Plot Presentation of Data Sheet 4.1.6.3.

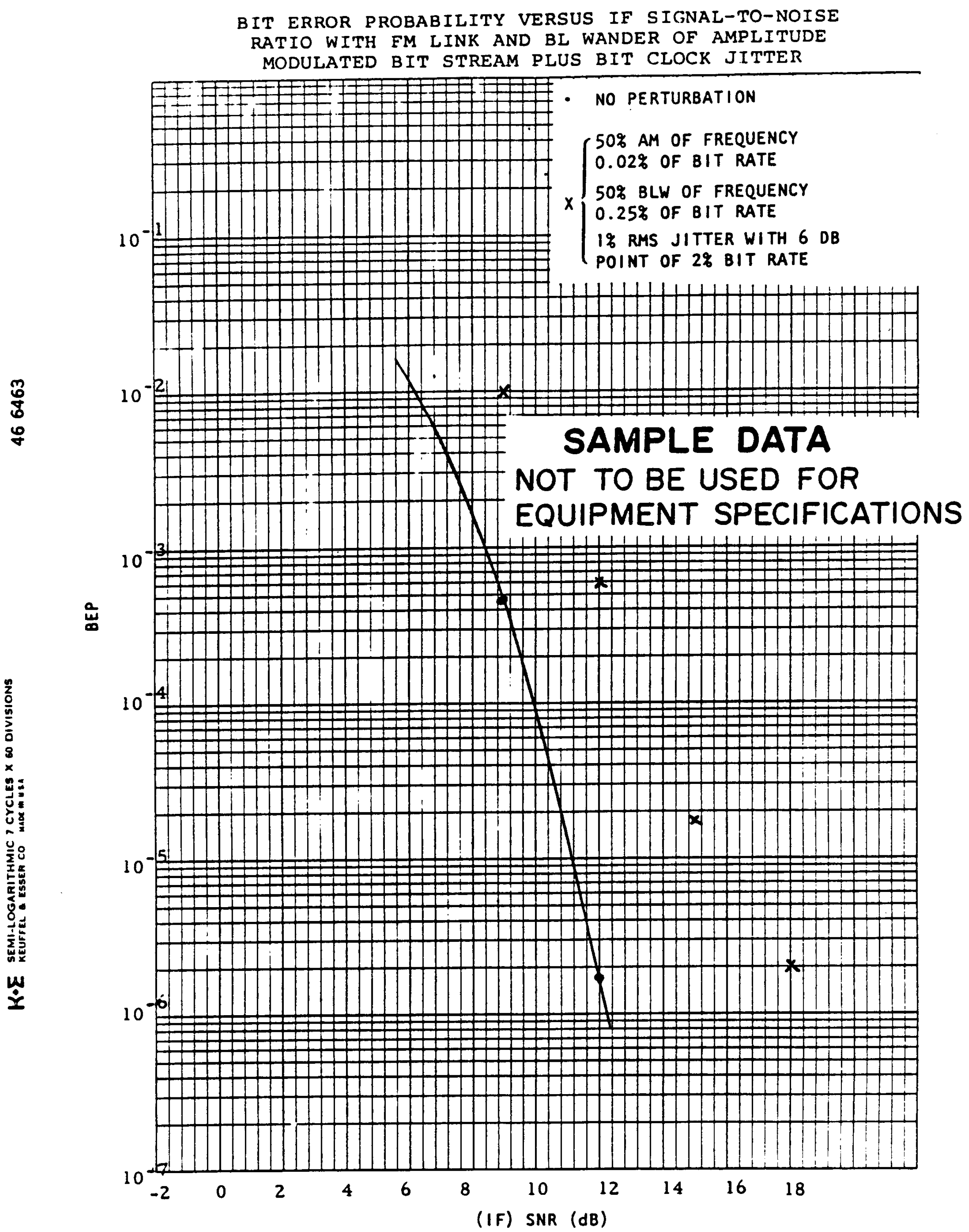


Figure 4.1.6-10 Sample Plot Presentation of Data Sheet 4.1.6.4.

DATA Sheet 4.1.6.1 BEP TEST WITH BIT STREAM AM

Test: 4.1.6 Bit Stream Base-Line Wander and AM Test

Manufacturer ____________ Model ____________ Serial No. ____________

Tested by ____________, ____________

Date ____________

Bit Synchronizer Input Signal Conditions								
PCM Signal				FM Link Settings			AM	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq. % Bit Rate

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)

Sig. Gen. Mfg. ____________

Model ______ Serial No. ____

Rcvr. Mfg. ____________

Model ______ Serial No. ____

Carrier Freq. ____________

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3			5
6			5
9			6
12			8
15			8

DATA Sheet 4.1.6.2 BEP TEST WITH BASE-LINE WANDER ADDED TO BIT STREAM

Test: 4.1.6 Bit Stream Base-Line Wander and AM Test

Manufacturer ____________ Model ____________ Serial No. ____________

Tested by ____________, ____________

Date ____________

Bit Synchronizer Input Signal Conditions								
PCM Signal				FM Link Settings			BLW	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq. % Bit Rate

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)

Sig. Gen. Mfg. ____________

Model ______ Serial No. ____

Rcvr. Mfg. ____________

Model ______ Serial No. ____

Carrier Freq. ____________

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3			5
6			5
9			6
12			8
15			8
18			8

DATA SHEET 4.1.6.3 BEP TEST WITH BASE-LINE WANDER ADDED TO AM BIT STREAM

Test: 4.1.6 Bit Stream Base-Line Wander and AM Test

Manufacturer ____________ Model ____________ Serial No. ____________

Tested by ____________, ____________ ____________

Date ____________

Bit Synchronizer Input Signal Conditions										
PCM Signal				FM Link Settings			BLW		AM	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq % Bit Rate	%	Freq. % Bit Rate

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)

Sig. Gen. Mfg. ____________
Model ______ Serial No. ____
Rcvr. Mfg. ____________
Model ______ Serial No. ____
Carrier Freq. ____________

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3			5
6			5
9			6
12			8
15			8

\TA SHEET 4.1.6.4 BEP TEST WITH AM PLUS BASE-LINE WANDER PLUS JITTER

Test: 4.1.6 Bit Stream Base-Line Wander and AM Test

Manufacturer ____________ Model ____________ Serial No. ____________

Tested by ____________, ____________

Date ____________

Bit Synchronizer Input Signal Conditions										
PCM Signal				FM Link Settings			BLW		AM	
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz	%	Freq % Bit Rate	%	Freq. % Bit Rate

Bit Synchronizer Settings			Jitter	Jitter
Detector Type	Loop BW (% Bit Rate)	Tracking Range (%Bit Rate)	6 dB Point (%Bit Rate)	% (rms) Bit Rate

Sig. Gen. Mfg. ____________

Model ______ Serial No. ____

Rcvr. Mfg. ____________

Model ______ Serial No. ____

Carrier Freq. ____________

IF SNR	BEP		Measurement Interval (Period 10^N bits)
dB	Perturbed	Not Perturbed	N
3			5
6			5
9			6
12			8
15			8

4.2 Part II. PCM/FM Testing

Part II modifies the procedures of Part I and is to be used to determine if a selected bit synchronizer has the required characteristics essential for PCM/FM telemetry applications.

4.2.1 Test Setup Calibration for Predetection SNR

4.2.1.1 Purpose - The SNR is an important parameter in many of the performance tests conducted on PCM bit synchronizers. Calibration of the test setup is necessary for obtaining an accurate SNR to allow evaluation of performance in satisfying specifications or for comparing competing designs.

4.2.1.2 Test Equipment:

4.2.1.2.1 For procedure using test setup shown in figure 4.0.2-1:

- BER test setup or PCM test set
- Voltage controlled oscillator
- Noise source
- Band-pass filter
- Amplifier
- Discriminator
- True rms voltmeter

4.2.1.2.2 For procedure using test setup shown in figure 4.0.2-2:

- BER test setup or PCM test set
- RF signal generator
- Receiver
- True rms voltmeter

4.2.1.3 Test Method:

4.2.1.3.1 Procedure 1 (using setup in figure 4.0-2-1.):

4.2.1.3.1.1 Setup - Connect the test equipment as shown in figure 4.0.2-1.

NOTE

Refer to subparagraphs .4.0.1 and 4.0.2 for standard test conditions.

4.2.1.3.1.2 Set output attenuation on the noise source to –40 dB and set the variable output level control to its minimum value.

4.2.1.3.1.3 Set the output of the voltage controlled oscillator (VCO) to a convenient level in the range of O.lV to 0.3V rms as read on the true rms voltmeter.

4.2.1.3.1.4 Set the output attenuator on the noise source to 5 dB and adjust the variable level control so that the reading on the true rms voltmeter increases 3 dB. If the input circuits of the discriminator are linear in the range selected, the signal power from the VCO is equal to the noise power.

4.2.1.3.1.5 Check results against the following chart to test for linearity.

Noise Source Attenuator	Output Power	dB Increase on True RMS Voltmeter (relative to S)
40 dB	S	--
5	2S	3
2	3S	4.8
0	4S	6

4.2.1.3.1.6 If the results do not check, reduce the output of the VCO and repeat. Having found a linear range, SNR in the band-pass filter (BPF) output can be varied in 1-dB steps by the noise source output attenuator. For example, when the noise source output attenuator is set for 18 dB, SNR is 13 dB, etc.

BPF Output SNR (dB)=noise generator output attenuator (dB)–5 dB.

4.2.1.3.2 Procedure 2 (using setup in figure 4.0.2-2):

4.2.1.3.2.1 Setup - Connect the test equipment as shown in figure 4.0.2-2.

NOTE

Refer to subparagraphs: 4.0.1 and 4.0.2 for standard test conditions.

NOTE

Here the noise source is the RF section of the receiver which has a fixed noise level. Therefore, it is convenient to use the output attenuator on the RF signal generator.

4.2.1.3.2.2 Turn the output attenuator to –130 dBm or less.

4.2.1.3.2.3 Disable the receiver AGC and substitute a bias which provides linearity over the range N to 4N.

4.2.1.3.2.4 Increase the signal generator output power (P_S) until the true rms voltmeter reading increases 3 dB. Call this P_{si}. If the receiver IF is operating in a linear range, P_{si}=N.

4.2.1.3.2.5 Test for linearity by checking results against the following chart.

P_S	Output Power	dB Increase (relative to N)
0 (or –130 dBm)	N	--
P_{si}	2N	3
$2P_{si}$ (P_{si}+3 dB)	3N	4.8
$3P_{si}$ (P_{si}+4.8 dB)	4N	6

4.2.1.3.2.6 If the results do not coincide, reduce the IF gain (by adjusting AGC bias) until a check is obtained. Restore AGC. The SNR in the linear IF can be varied by setting the output attenuator of the signal generator (assuming that its calibration is maintained).

4.2.1.3.2.7 Express the performance of the bit synchronizer in terms of the SNR in a predetection bandwidth equal to the bit rate (f_b). Let the noise bandwidth of the IF be B_n (approximately equal to the 3-dB bandwidth). Let the SNR in B_n be $(SNR)B_n$. Then,

$$(SNR)_{f_b}=\frac{B_n}{f_b}(SNR)_{B_n}$$

or, in dB,

$$(SNR)_{f_b}\ dB=(SNR)_{B_n}dB+10\log_{10}\frac{B_n}{f}$$

4.2.2 Frequency Modulation (FM) Sensitivity of the RF Signal Generator

4.2.2.1 Purpose - This test determines the modulation sensitivity of the signal generator, whether it is at RF or IF. The modulation sensitivity is required so that the correct carrier deviation is utilized during the performance tests.

4.2.2.2 Test Equipment:

Signal generator (RF or IF)
Low frequency signal generator
True rms voltmeter
Spectrum analyzer (or internal receiver spectrum analyzer)

4.2.2.3 Test Method:

4.2.2.3.1 Setup - Connect the test equipment as shown in figure 4.2.2-1.

NOTE

Refer to subparagraphs 4.0.1 and 4.0.2 for standard test conditions.

4.2.2.3.2 Frequency modulate the carrier with a sinusoid of frequency (f_m) about half of the desired peak deviation.

4.2.2.3.3 Increase amplitude of the sinusoid until the first carrier disappearance (as viewed on the receiver spectrum display) occurs.

4.2.2.3.4 The peak carrier deviation is then fd=2.4fm.

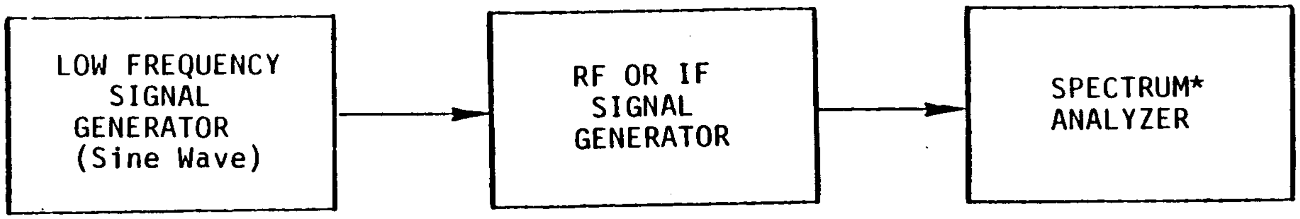
4.2.2.3.5 Read the rms value of the sinusoid. Call this V_{rms}.

4.2.2.3.6 The modulation sensitivity is:

$$S_m = \frac{2.4 f_m}{2V_{rms}} \quad \text{Hz/volt}$$

4.2.2.3.7 Example: If it is desired to modulate the carrier $0.7f_b$ peak-to-peak, where f_b=bit rate; the peak-to-peak voltage (v) of the bit stream is then:

$$v = \frac{0.7 f_b}{S_m} \quad \text{volts}$$



**Spectrum analyzer may be either internal or external to the receiver used in the test.*

Figure 4.2.2-1 Test Setup for Frequency Modulation Sensitivity Calibration.

4.2.3 Bit Synchronizer Tests

4.2.3.1 Purpose - These tests determine the performance of the bit synchronizer under test when the input noise is obtained at the output of an FM receiver.

4.2.3.2 Test Equipment:

Test equipment required is described in subparagraph 4.2.1.2 plus any additional equipment required by the specific test being conducted.

NOTE

Refer to subparagraphs 4.0.1 and 4.0.2 for standard test conditions.

4.2.3.3 Procedure - Repeat the tests described in Part I vs. predetection SNR expressed in a bandwidth equal to the bit rate.

4.2.3.4 Data Reduction - Record data on Data Sheet 4.2.3.1. An example of Data Sheet 4.2.3.1 use is shown in figure 4.2.3-1 and a corresponding sample data plot is shown in figure 4.2.3-2.

DATA SHEET 4.2.3.1 BIT SYNCHRONIZER TESTS

Test: 4.2.3 Bit Synchronizer Tests

Manufacturer ______________ ... No. ______________

Tested by ______________ ______________

Date ______________

Bit Synchronizer Input Signal Conditions						
PCM Signal				FM Link Settings		
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz
100	∞	NRZ	PR	70	180	70

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)
FS	0.1	-

Sig. Gen. Mfg. DCS

Model GOV-4 Serial No. 74386

Rcvr. Mfg. EMR

Model 4142 Serial No. 219

Carrier Freq. 450 KHz

IF SNR	Bit Error Probability			Measurement Interval (Period 10^n Bits)
(dB)	Total (1's + 0's)	1's	0's	N
0	1.8×10^{-1}			5
+3	6.6×10^{-2}			5
+6	1.1×10^{-2}			5
+9	4.3×10^{-4}			6
+12	9×10^{-7}			8

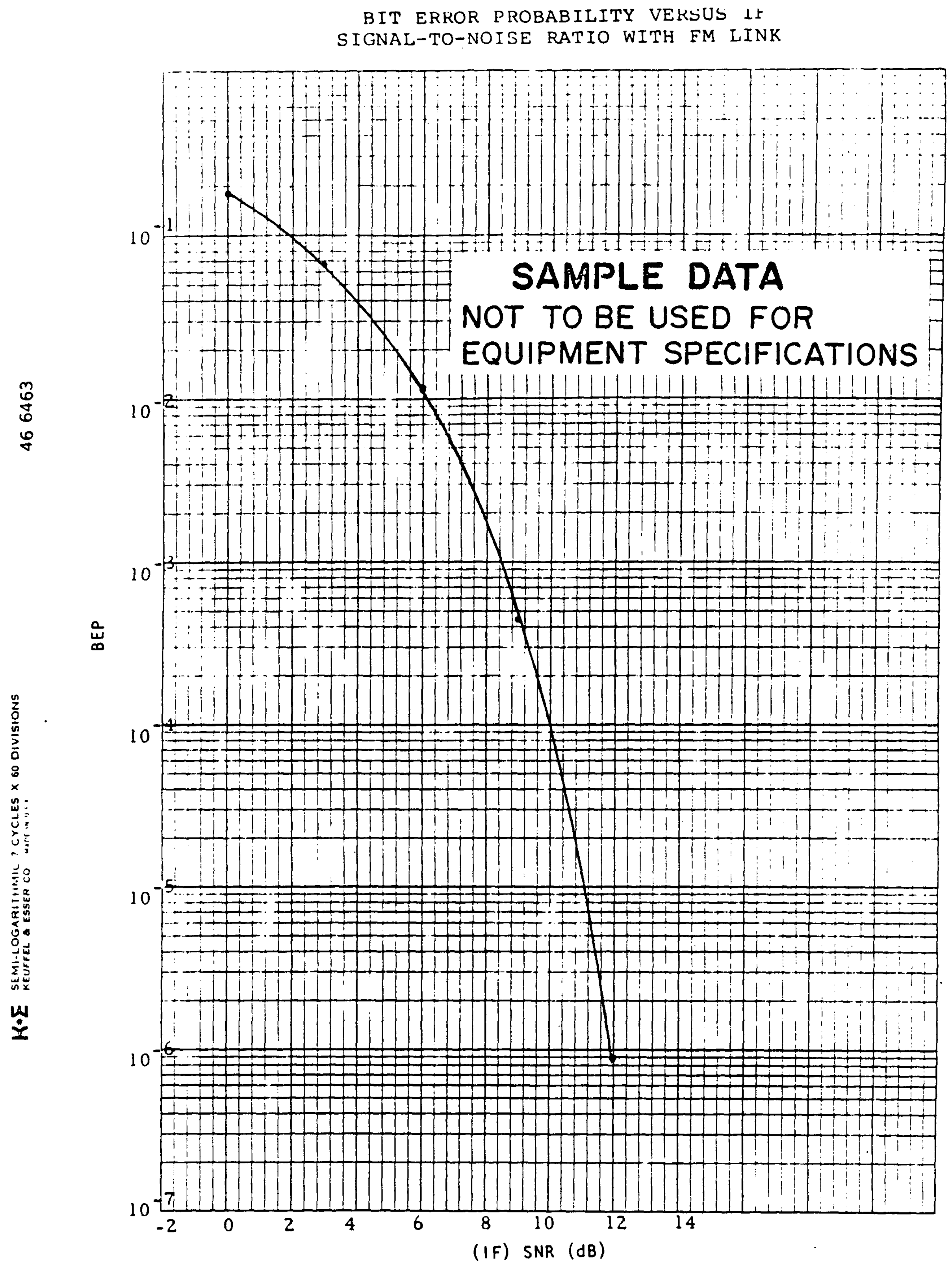


Figure 4.2.3-2 Sample Plot Presentation of Data Sheet 4.2.3.1.

DATA SHEET 4.2.3.1 BIT SYNCHRONIZER TESTS

Test: 4.2.3 Bit Synchronizer Tests

Manufacturer ______________ Model ______________ Serial No. ________________

Tested by __________________, ____

Date ___________________

Bit Synchronizer Input Signal Conditions						
PCM Signal				FM Link Settings		
Bit Rate kB/s	Premodulation Filter Bandwidth kHz	Code	Word Pattern	Carrier Deviation Peak-to-Peak, kHz	IF Bandwidth kHz	Post Detection Filter Bandwidth kHz

Bit Synchronizer Settings		
Detector Type	Loop B.W. (% Bit Rate)	Tracking Range (% Bit Rate)

Sig. Gen. Mfg. ______________

Model _______ Serial No. ____

Rcvr. Mfg. ________________

Model _______ Serial No. ____

Carrier Freq. ______________

IF SNR	Bit Error Probability			Measurement Interval (Period 10^n Bits)
(dB)	Total (1's + 0's)	1's	0's	N
0				5
+3				5
+6				5
+9				6
+12				8

This page intentionally left blank

CHAPTER 5

FM DISCRIMINATORS

5.0 General

5.0.1 The FM discriminator evaluation is the acquisition and distribution of performance information that will be useful to groups engaged in telemetry activities. To this end, uniformity of test procedures used is important for obtaining valid comparisons of performance and periodic checks on installed equipment or testing of new equipment.

5.0.2 Performance tests are recommended for all IRIG subcarrier channels intended for use with the discriminators. Care should be taken to establish known environmental conditions such as temperature and humidity to minimize the uncertainty in performance. In addition, the equipment should be energized from a regulated line. Particular care should be taken in the test setup design to avoid the error-producing effects of ground-loop currents.

5.0.3 Definition of Terms

5.0.3.1 Band Pass Input Filter (BPIF) - The channel selection filter centered at the channel center frequency and with a 3-dB bandwidth corresponding to the channel bandwidth.

5.0.3.2 Center Frequency (f_c) - The center frequency for a given channel as defined in IRIG Standard 106-XX, Telemetry Standards, Appendix A, paragraph 5.4.

5.0.3.3 Deviation Ratio - The deviation ratio of a channel is defined as the ratio of one half the defined deviation bandwidth to the cutoff frequency of the discriminator low pass output filter.

5.0.3.4 Lower Band Edge (LBE) Frequency - The frequency which corresponds to the lower deviation limit defined in table 3-1, IRIG-106-XX, for a given channel.

5.0.3.5 Low Pass Output Filter (LPOF) - The output filter contained in or plugged into the discriminator with its cutoff frequency (3-dB point) defined as the maximum data frequency.

5.0.3.6 Modulation Index - In angle modulation with a sinusoidal modulating wave, the ratio of the peak frequency deviation to the frequency of the modulating wave:

$$m = \Delta f / f_{max'}$$

where Δf = the maximum frequency difference between the modulated carrier and the unmodulated carrier.
fmax = the maximum modulating frequency.

5.0.3.7 Upper Band Edge Frequency (UBE) - The frequency which corresponds to the upper deviation limit defined in IRIG-106-XX, subparagraph 7.2.25.

5.0.4 Standard Test Conditions - To ensure uniformity of testing, the following standard test conditions and preliminary adjustments should be completed before individual tests are conducted.

5.0.4.1 Input Signal Level - The standard input signal level for the specified procedures is 0.3 Vrms, except as modified in a specific procedure.

5.0.4.2 Output Load - The load placed on the discriminator shall be the maximum load specified.

5.0.4.3 Warm-up

5.0.4.3.1 The discriminator under test shall be allowed to warm up prior to the start of a test according to the performance specification.

5.0.4.3.2 Test equipment used in test procedures shall be allowed to warm up so that drifts and other variations caused by the test equipment shall be minimized. Generally, a 30 minute warm-up period is recommended.

5.0.4.4 Output Voltage - The output voltage shall be adjusted prior to the start of a test to conform to the following requirements:

5.0.4.4.1 With the input signal set to the center frequency of the desired channel and unmodulated, the output voltage shall be 0±10 mV dc.

5.0.4.4.2 With the upper (lower) band edge frequency applied to the discriminator input, the output voltage shall be +10(-10) Vdc or the maximum specified for operation within ±10 mV dc.

5.0.4.5 Tolerances - The measurements which are identified in the following test methods should be made with sufficient precision to satisfy the intended purpose. It is recommended that the maximum tolerance used conform to the following:

Frequency	±0.1% or 1 Hz whichever is smaller
Voltage	±1.0 mV
dB	±0.1 dB.

5.0.4.6 An oscilloscope is connected to the discriminator output in most tests. It is used to observe glitches and to identify anomalous behavior which may not be detected by other instrumentation.

5.1 Deviation Sensitivity and Static Linearity

5.1.1 Purpose - This test determines the deviation sensitivity and static linearity of an FM discriminator.

5.1.2 Test Equipment

Signal generator
Frequency counter
Digital voltmeter (dc)

5.1.3 Test Method

5.1.3.1 Setup - Connect the test equipment as shown in figure 5.1.1.

5.1.3.2 Conditions

5.1.3.2.1 Set the discriminator low pass output filter to cut off frequency of interest.

5.1.3.2.2 Maximize output load according to specification.

5.1.3.3 Procedure

5.1.3.3.1 Set the signal generator frequency to center frequency and adjust output voltage to zero.

5.1.3.3.2 Set the input frequency to LBU and adjust output voltage to specified maximum output level.

5.1.3.3.3 Repeat steps 5.1.3.3.1 and 5.1.3.3.2 as necessary to achieve desired accuracy.

5.1.3.3.4 The test may be performed with either 5 or 11 data points. Generally the 11-step data collection is used for acceptance testing, and the 5-step data collection is used for rapid revalidation of discriminator performance.

5.1.3.3.5 Eleven Point Test - Record the input frequency and output voltage for frequencies equivalent to the LBE deviation limit frequency $f_c - 0.8(\Delta f)$, $f_c - 0.6(\Delta f)$, $f_c - 0.4(\Delta f)$, $f_c - 0.2(\Delta f)$, f_c, $f_c + 0.2(\Delta f)$, $f_c + 0.4(\Delta f)$, $f_c + 0.6(\Delta f)$, $f_c + 0.8(\Delta f)$ and UBE deviation limit frequency on data sheet 5.1.1, where $\Delta f = f_c - LBE = UBE - f_c$.

5.1.3.3.6 Five Point Test - Record the input frequency and output voltage for frequencies equivalent to the LBE deviation limit, $f_c - 0.5(\Delta f)$, $f_{c'}$ $f_c + 0.5(\Delta f)$, UBE deviation limit on data sheet 5.1.2.

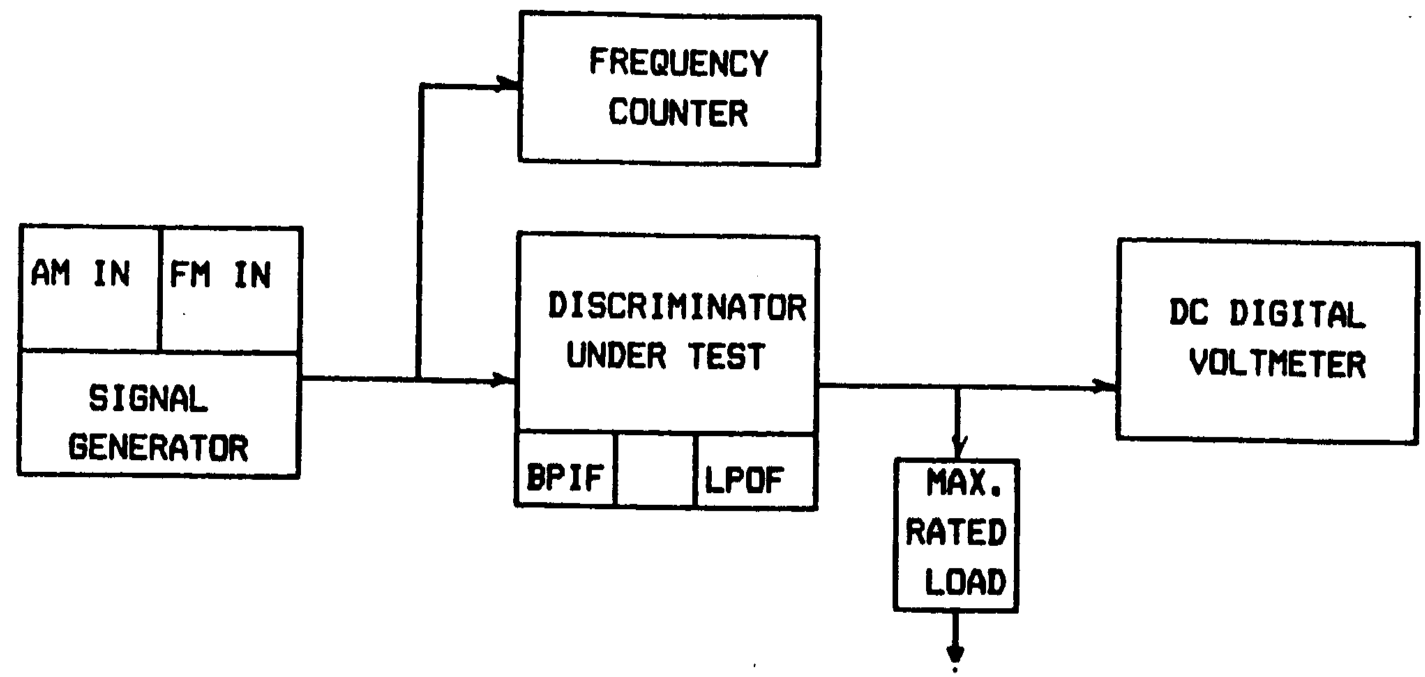


Figure 5.1.1 Test Setup for Deviation Sensitivity and Static Linearity.

FM DISCRIMINATORS

DATA SHEET 5.1.1

TEST Deviation Sensitivity and Static Linearity (11 Point)

MANUFACTURER ______________________ MODEL ____________________________

SERIAL NO. _________________________ IRIG CHANNEL ____________________

CHANNEL SELECTOR SERIAL NO. _________ LOW PASS OUTPUT FILTER S/N _______

CENTER FREQUENCY ________________ kHz UPPER BAND EDGE ______________ kHz

LOWER BAND EDGE _________________ kHz LOW PASS FILTER CUTOFF ________ kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other ________________

TEST PERSONNEL __________________ DATE ____________ LOCATION ___________

Calculate: Δf = Center Freq - Lower Band Edge Freq = ___________kHz
= Upper Band Edge Freq - Center Freq = ___________kHz

i	Equation	Frequency Calculated (kHz)
1	$f_c - \Delta f$	______
2	$f_c - 0.8\ \Delta f$	______
3	$f_c - 0.6\ \Delta f$	______
4	$f_c - 0.4\ \Delta f$	______
5	$f_c - 0.2\ \Delta f$	______
6	f_c	______
7	$f_c + 0.2\ \Delta f$	______
8	$f_c + 0.4\ \Delta f$	______
9	$f_c + 0.6\ \Delta f$	______
10	$f_c + 0.8\ \Delta f$	______
11	$f_c + \Delta f$	______

Record the actual input frequency and output voltage in the table below and calculate the remaining information:

i	Input Frequency (kHz)	Output Voltage (Vdc)	$\Delta f_i = f_i - f_c$	$(\Delta f_i)^2$	$\Delta f_i \times V_i$
1	______	______	______	______	______
2	______	______	______	______	______
3	______	______	______	______	______
4	______	______	______	______	______
5	______	______	______	______	______
6	f_c	______	______	______	______
7	______	______	______	______	______
8	______	______	______	______	______
9	______	______	______	______	______
10	______	______	______	______	______
11	______	______	______	______	______
	Add columns:	ΣV_i = ______	$\Sigma \Delta f_i$ = ______	$\Sigma(\Delta f_i)^2$ = ______	$\Sigma \Delta f_i \times V_i$ = ______
			$(\Sigma \Delta f_i)^2$ = ______		

DATA SHEET 5.1.1 (Continued)

DEVIATION SENSITIVITY=

$$b = \frac{11\left(\sum_{i=1}^{11} \Delta f_i \times V_i\right) - \left(\sum_{i=1}^{11} V_i\right)\left(\sum_{i=1}^{11} \Delta f_i\right)}{11\left(\sum_{i=1}^{11} (\Delta f_i)^2\right) - \left(\sum_{i=1}^{11} \Delta f_i\right)^2} = \_\_\_\_\_\_ \text{volts/kHz,}$$

and

ZERO OFFSET=

$$a = \left(\sum_{i=1}^{11} V_i - b \times \sum_{i=1}^{11} \Delta f_i\right)/11 = \_\_\_\_\_\_ \text{volts.}$$

Calculate the following:

i	Δf_i	$a + b\ \Delta f_i$	V_i	DEVIATION FROM LINEAR FIT $(a + b\ \Delta f_i) - V_i$
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				

FM DISCRIMINATORS

DATA SHEET 5.1.2

TEST Deviation Sensitivity and Static Linearity (5 Point)

MANUFACTURER__________ MODEL__________

SERIAL NO.__________ IRIG CHANNEL __________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N __________

CENTER FREQUENCY__________kHz UPPER BAND EDGE__________kHz

LOWER BAND EDGE__________kHz LOW PASS FILTER CUTOFF__________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________

TEST PERSONNEL__________ DATE__________ LOCATION__________

Calculate: Δf = Center Freq - Lower Band Edge Freq = ______kHz
= Upper Band Edge Freq- Center Freq = ______kHz

i	Equation	Frequency Calculated (kHz)
1	$f_c - \Delta f$	______
2	$f_c - 0.5\ \Delta f$	______
3	f_c	______
4	$f_c + 0.5\ \Delta f$	______
5	$f_c + \Delta f$	______

Record the actual input frequency and output voltage in the table below and calculate the remaining information:

i	Input Frequency (kHz)	Output Voltage (Vdc)	$\Delta f_i = f_i - f_c$	$(\Delta f_i)^2$	$\Delta f_i \times V_i$
1	______	______	______	______	______
2	______	______	______	______	______
3	f_c______	______	______	______	______
4	______	______	______	______	______
5	______	______	______	______	______
	Add columns:	$\Sigma V_i =$ ______	$\Sigma \Delta f_i =$ ______	$\Sigma (\Delta f_i)^2 =$ ______	$\Sigma \Delta f_i \times V_i =$ ______
			$(\Sigma \Delta f_i)^2$ ______		

DATA SHEET 5.1.2 (Continued)

DEVIATION SENSITIVITY=

$$b = \frac{5\left(\sum_{i=1}^{5} \Delta f_i \times V_i\right) - \left(\sum_{i=1}^{5} V_i\right)\left(\sum_{i=1}^{5} \Delta f_i\right)}{5\left(\sum_{i=1}^{5} (\Delta f_i)^2\right) - \left(\sum_{i=1}^{5} \Delta f_i\right)^2} = \_\_\_\_\_\_ \text{ volts/kHz,}$$

and

$$\text{ZERO OFFSET} = a = \left(\sum_{i=1}^{5} V_i - b \times \sum_{i=1}^{5} \Delta f_i\right)/5 = \_\_\_\_\_\_\_\_\_\_\_\_ \text{volts.}$$

Calculate the following:

i	Δf_i	$a + b \Delta f_i$	V_i	DEVIATION FROM LINEAR FIT $(a + b \Delta f_i) - V_i$
1				
2				
3				
4				
5				

5.1.4 Data Reduction

5.1.4.1 Eleven Point Test. The best fit straight line is of the form

$$a + b\,(f - f_c) = V$$

where a is the center frequency output voltage offset in volts, and b is the deviation sensitivity in volts per kilohertz. The coefficients a and b are obtained from the equations

$$b = \frac{11\left(\sum_{i=1}^{11} \Delta f_i \times V_i\right) - \left(\sum_{i=1}^{11} V_i\right)\left(\sum_{i=1}^{11} \Delta f_i\right)}{11\left(\sum_{i=1}^{11} (\Delta f_i)^2\right) - \left(\sum_{i=1}^{11} \Delta f_i\right)^2}$$

and

$$a = \left(\sum_{i=1}^{11} V_i - b \times \sum_{i=1}^{11} \Delta f_i\right)/11$$

Where

Δf_i is the ith frequency difference $(f_i - f_c)$
V_i is the ith output voltage

The deviation sensitivity (b) and offset (a) should be compared to the specific value. The difference between actual output voltage, V_i, and that calculated from the best fit curve defined by the coefficients a and be should be compared to the static linearity specification (see data sheet 5.1.1 sample).

5.1.4.2 Five Point Test - The equations for determining a and b are

$$b = \frac{5\left(\sum_{i=1}^{5} \Delta f_i \times V_i\right) - \left(\sum_{i=1}^{5} V_i\right)\left(\sum_{i=1}^{5} \Delta f_i\right)}{5\left(\sum_{i=1}^{5} (\Delta f_i)^2\right) - \left(\sum_{i=1}^{5} \Delta f_i\right)^2}$$

and

$$a = \left(\sum_{i=1}^{5} V_i - b \times \sum_{i=1}^{5} \Delta f_i\right)/5$$

Where a, b, Δf_i and V_i are defined in subparagraph 5.1.4.1. The deviation sensitivity (b), offset (a) and the deviation from best fit straight line should be compared to the specification as in subparagraph 5.1.4.1 (see data sheet sample 5.1.2).

FM DISCRIMINATORS

DATA SHEET 5.1.1 (Sample)

TEST Deviation Sensitivity and Static Linearity (11 Point)

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL

CHANNEL SELECTOR SERIAL NO. LOW PASS OUTPUT FILTER S/N

CENTER FREQUENCY 70. kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF 2.1 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other

TEST PERSONNEL DATE LOCATION

Calculate: Δf = Center Freq - Lower Band Edge Freq = 10.5 kHz
= Upper Band Edge Freq- Center Freq = 10.5 kHz

i	Equation	Frequency Calculated (kHz)
1	$f_c - \Delta f$	59.5
2	$f_c - 0.8\ \Delta f$	61.1
3	$f_c - 0.6\ \Delta f$	63.7
4	$f_c - 0.4\ \Delta f$	65.8
5	$f_c - 0.2\ \Delta f$	67.9
6	f_c	70.0
7	$f_c + 0.2\ \Delta f$	72.1
8	$f_c + 0.4\ \Delta f$	74.2
9	$f_c + 0.6\ \Delta f$	76.3
10	$f_c + 0.8\ \Delta f$	78.4
11	$f_c + \Delta f$	80.5

Record the actual input frequency and output voltage in the table below and calculate the remaining information:

i	Input Frequency (kHz)	Output Voltage (Vdc)	$\Delta f_i = f_i - f_c$	$(\Delta f_i)^2$	$\Delta f_i \times V_i$
1	59.500	-10.012	-10.5	110.25	105.126
2	61.600	-8.010	-8.4	70.56	67.284
3	63.700	-6.009	-6.3	39.69	37.8567
4	65.800	-4.007	-4.2	17.64	16.8294
5	67.900	-2.006	-2.1	4.41	4.2126
6	f_c 70.000	-0.006	0	0.00	0.000
7	72.100	+1.995	2.1	4.41	4.1895
8	74.200	+3.996	4.2	17.64	16.7832
9	76.300	+5.997	6.3	39.69	37.7811
10	78.400	+7.998	8.4	70.65	67.1832
11	80.500	+9.997	10.5	110.25	104.9685
	Add columns:	$\Sigma V_i = -0.063$	$\Sigma \Delta f_i = 0$	$\Sigma(\Delta f_i)^2 =$ 485.1	$\Sigma \Delta f_i \times V_i =$ 470.6142
			$(\Sigma \Delta f_i)^2 = 0$		

DATA SHEET 5.1.1 (Sample) (Continued)

DEVIATION SENSITIVITY=

$$b = \frac{11\left(\sum_{i=1}^{11} \Delta f_i \times V_i\right) - \left(\sum_{i=1}^{11} V_i\right)\left(\sum_{i=1}^{11} \Delta f_i\right)}{11\left(\sum_{i=1}^{11} (\Delta f_i)^2\right) - \left(\sum_{i=1}^{11} \Delta f_i\right)^2} = \underline{0.95282}\ \text{volts/kHz},$$

and

ZERO OFFSET=

$$a = \left(\sum_{i=1}^{11} V_i - b \times \sum_{i=1}^{11} \Delta f_i\right)/11 = \underline{-0.00573}\ \text{volts.}$$

Calculate the following:

i	Δf_i	$a + b\ \Delta f_i$	V_i	DEVIATION FROM LINEAR FIT $(a + b\ \Delta f_i) - V_i$
1	-10.5	-10.010	-10.012	0.002
2	-8.4	-8.009	-8.010	0.001
3	-6.3	-6.008	-6.009	0.001
4	-4.2	-4.008	-4.007	-0.001
5	-2.1	-2.007	-2.006	-0.001
6	0	-0.006	-0.006	0
7	2.1	1.995	1.995	0
8	4.2	3.996	3.996	0
9	6.3	5.997	5.997	0
10	8.4	7.998	7.998	0
11	10.5	9.999	9.997	0.002

FM DISCRIMINATORS

DATA SHEET 5.1.2 (Sample)

TEST Deviation Sensitivity and Static Linearity (5 Point)

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ______

CHANNEL SELECTOR SERIAL NO. ______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY 80 kHz UPPER BAND EDGE 84 kHz

LOWER BAND EDGE 76. kHz LOW PASS FILTER CUTOFF 1 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ______

TEST PERSONNEL ______ DATE ______ LOCATION ______

Calculate: Δf = Center Freq - Lower Band Edge Freq = 4 kHz
= Upper Band Edge Freq- Center Freq = 4 kHz

i	Equation	Frequency Calculated (kHz)
1	$f_c - \Delta f$	76
2	$f_c - 0.5\ \Delta f$	78
3	f_c	80
4	$f_c + 0.5\ \Delta f$	82
5	$f_c + \Delta f$	84

Record the actual input frequency and output voltage in the table below and calculate the remaining information:

i	Input Frequency (kHz)	Output Voltage (Vdc)	$\Delta f_i = f_i - f_c$	$(\Delta f_i)^2$	$\Delta f_i \times V_i$
1	76	8.953	-4	16.	-35.812
2	78	4.476	-2	4.	-8.952
3	f_c 80	0.001	0	0.0	0.000
4	82	-4.475	2	4.0	-8.950
5	84	-8.951	4	16.0	-35.804
	Add columns:	$\Sigma V_i =$	$\Sigma \Delta f_i =$	$\Sigma (\Delta f_i)^2 =$	$\Sigma\ \Delta f_i \times V_i =$
		0.004	0	40	-89.518
			$(\Sigma\ \Delta f_i)^2 =$		
			0		

DATA SHEET 5.1.2 (Sample) (Continued)

DEVIATION SENSITIVITY=

$$b = \frac{5\left(\sum_{i=1}^{5} \Delta f_i \times V_i\right) - \left(\sum_{i=1}^{5} V_i\right)\left(\sum_{i=1}^{5} \Delta f_i\right)}{5\left(\sum_{i=1}^{5} (\Delta f_i)^2\right) - \left(\sum_{i=1}^{5} \Delta f_i\right)^2} = \underline{-2.238} \text{ volt/kHz,}$$

and

$$\text{ZERO OFFSET} = a = \left(\sum_{i=1}^{5} V_i - b \times \sum_{i=1}^{5} \Delta f_i\right)/5 = \underline{0.001} \text{ volts.}$$

Calculate the following:

i	Δf_i	$a + b\ \Delta f_i$	V_i	DEVIATION FROM LINEAR FIT $(a + b\ \Delta f_i) - V_i$
1	-4	8.953	8.953	0
2	-2	4.477	4.476	0.001
3	0	0.001	0.001	0
4	2	-4.475	-4.475	0
5	4	-8.951	-8.951	0

5.2 Zero and Band Edge Stability Test

5.2.1 Purpose - This test determines the zero and band edge stability of an FM discriminator over a one-hour period.

5.2.2 Test Equipment

Signal generator with frequency stability of $+10^{-6}$/day
Frequency counter
Digital voltmeter (dc)
Oscilloscope

5.2.3 Test Method

5.2.3.1 Setup - Connect the test equipment as shown in figure 5.2.1.

5.2.3.2 Conditions

5.2.3.2.1 Warm up all equipment according to specifications.

5.2.3.2.2 Set discriminator low pass output filter to cutoff frequency of interest.

5.2.3.2.3 Maximize output load according to specification.

5.2.3.3 Procedures

5.2.3.3.1 Adjust signal generator output level and discriminator balance and output levels in accordance with paragraph 5.0 of General Procedures.

5.2.3.3.2 Apply LBE frequency to discriminator and record time, input frequency, and output voltage on data sheet 5.2.1. Repeat procedure for center and UBE frequencies.

5.2.3.3.3 Repeat step 5.2.3.3.2 approximately one hour later, using the same frequencies recorded earlier without adjusting discriminator balance and output voltage levels.

5.2.4 Data Reduction - Compare change in discriminator output voltages obtained at center and band edge frequencies with specifications. Subtract voltage readings of second test from first test and record in AV column on data sheet. Calculate percentage change and record in percentage change column (see data sheet 5.2.1 sample).

NOTE

If uniform change in discriminator output voltage is noted between groups of data and this change can be corrected by resetting zero output at center frequency within drift specification, then discriminator is operating normally.

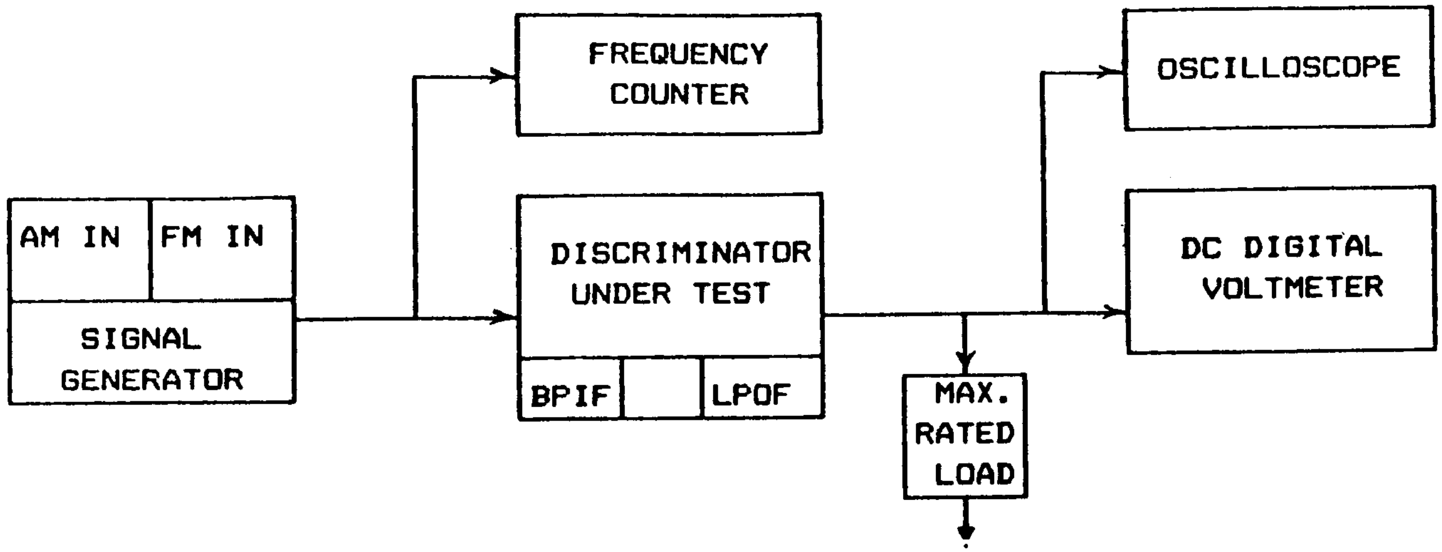


Figure 5.2.1 Test Setup for Zero and Band Edge Stability.

FM DISCRIMINATORS

DATA SHEET 5.2.1

TEST Zero and Band Edge Stability Test

MANUFACTURER____________________ MODEL____________________

SERIAL NO.____________________ IRIG CHANNEL ____________________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY______________kHz UPPER BAND EDGE______________kHz

LOWER BAND EDGE______________kHz LOW PASS FILTER CUTOFF__________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other______________

TEST PERSONNEL______________ DATE__________ LOCATION______________

Time:__________

Input Frequency	Frequency (kHz)	Output Voltage (Vdc)
Lower Band Edge	________	________(L)
Center Freq.	________	________
Upper Band Edge	________	________(U)

Time:__________

Input Frequency	Frequency (kHz)	Output Voltage (Vdc)	Δ V
Lower Band Edge	________	________	________
Center Freq.	________	________	________
Upper Band Edge	________	________	________

Percent Change	(Δ V x 100/(U-L))
Lower Band Edge	________
Center Freq.	________
Upper Band Edge	________

FM DISCRIMINATORS

DATA SHEET 5.2.1 (Sample)

TEST Zero and Band Edge Stability Test

MANUFACTURER XYZ MODEL DEF

SERIAL NO. 70 IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 70.0 kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF 2.1 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

Time: 1300

Input Frequency	Frequency (kHz)	Output Voltage (Vdc)
Lower Band Edge	59.500	-10.009 (L)
Center Freq.	70.000	-0.008
Upper Band Edge	80.500	-9.990 (U)

Time: 1400

Input Frequency	Frequency (kHz)	Output Voltage (Vdc)	ΔV
Lower Band Edge	59.500	-10.010	0.001
Center Freq.	70.000	-0.008	0
Upper Band Edge	80.500	+9.989	0.001

Percent Change	(ΔV x 100/(U -L))
Lower Band Edge	0.005%
Center Freq.	0
Upper Band Edge	0.005%

5.3 Static Noise

5.3.1 Purpose - This test measures the amount of static noise at the FM discriminator output.

5.3.2 Test Equipment

Frequency counter
Signal generator
Oscilloscope
True rms voltmeter
Digital voltmeter (dc)

5.3.3 Test Method

5.3.3.1 Setup - Connect the test equipment as shown in figure 5.3.1.

5.3.3.2 Conditions

5.3.3.2.1 Warm up all equipment according to specifications.

5.3.3.2.2 Maximize output load according to specification.

5.3.3.3 Procedure

NOTE

Incidental phase or frequency modulation in signal generator will affect test results. Generator used should contribute less than 10 percent to parameter being measured.

5.3.3.3.1 Place a low pass output filter in test discriminator to reflect the deviation ratio at which the discriminator will typically be used.

5.3.3.3.2 Adjust signal generator output level and discriminator balance and output levels in accordance with paragraph 5.0 of General Procedures.

5.3.3.3.3 Adjust signal generator to LBE frequency, measure discriminator dc and rms output voltages and record on data sheet 5.3.1.

5.3.3.3.4 Repeat step 5.3.3.3.3 for center frequency and UBE frequency.

5.3.3.3.5 Repeat steps 5.3.3.3.3 and 5.3.3.3.4 for other deviation ratios as needed.

5.3.4 Data Reduction - Compare data obtained with specifications. Calculate percent noise by dividing rms voltages by peak-to-peak dc voltage and multiply by 100 (see data sheet 5.3.1 sample).

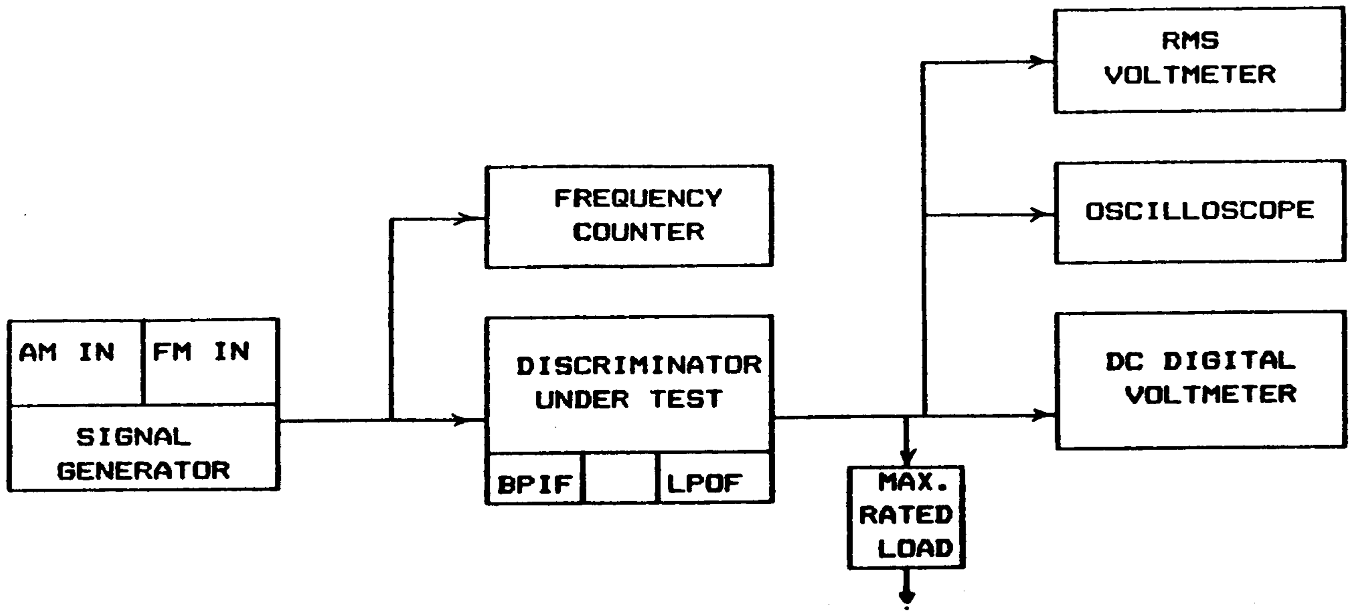


Figure 5.3.1 Test Setup for Static Noise.

FM DISCRIMINATORS

DATA SHEET 5.3.1

TEST Static Noise Test

MANUFACTURER__________ MODEL__________

SERIAL NO.__________ IRIG CHANNEL __________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N __________

CENTER FREQUENCY__________kHz UPPER BAND EDGE__________kHz

LOWER BAND EDGE__________kHz LOW PASS FILTER CUTOFF__________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________

TEST PERSONNEL__________ DATE__________ LOCATION__________

Specifications:

Dev. Ratio	LPOF Freq.	Noise rms	Band Edge Vdc	Filter S/N

Performance data:

Center Frequency=__________kHz

Dev. Ratio	BPIF BW	LPOF	dc Volts	Noise Vrms	% Noise

Lower Band Edge Frequency (LBE) =__________kHz

Dev. Ratio	BPIF BW	LPOF	V_{LBE} Vdc	Noise Vrms	% Noise

Upper Band Edge Frequency (UBE) =__________kHz

Dev. Ratio	BPIF BW	LPOF	V_{UBE} Vdc	Noise Vrms	% Noise

To calculate % Noise use the following:

$$\%\ \text{Noise} = \frac{\text{Noise rms}}{|V_{UBE} - V_{LBE}|} \times 100.$$

FM DISCRIMINATORS

DATA SHEET 5.3.1 (Sample)

TEST Static Noise Test

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 70.0 kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF ____ kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

Specifications:

Dev. Ratio	LPOF Freq.	Noise rms	Band Edge Vdc	Filter S/N
1	10.5 kHz			
2	5.25 kHz			
5	2.1 kHz			

Performance data:

Center Frequency= 70.0 kHz

Dev. Ratio	BPIF BW	LPOF	dc Volts	Noise Vrms	% Noise
1	21 kHz	10.5 kHz	-0.004	0.007	0.035
2	21	5.25	-0.005	0.003	0.015
5	21	2.1	-0.008	0.001	0.005

Lower Band Edge Frequency (LBE) = 59.5 kHz

Dev. Ratio	BPIF BW	LPOF	V_{LBE} Vdc	Noise Vrms	% Noise
1	21 kHz	10.5 kHz	-10.000	0.0093	0.045
2	21	5.25	-10.003	0.004	0.02
5	21	2.1	-10.007	0.002	0.01

Upper Band Edge Frequency (UBE) = 80.5 kHz

Dev. Ratio	BPIF BW	LPOF	V_{UBE} Vdc	Noise Vrms	% Noise
1	21 kHz	10.5 kHz	+9.985	0.006	0.03
2	21	5.25	+9.996	0.004	0.02
5	21	2.1	+9.989	0.002	0.01

To calculate % Noise use the following:

$$\%\ \text{Noise} = \frac{\text{Noise rms}}{|V_{UBE} - V_{LBE}|} \times 100.$$

5.4 Harmonic Distortion

5.4.1 Purpose - This test measures the amount of harmonic distortion present at the discriminator output.

NOTE

This test does not discriminate between distortion introduced in the signal source and distortion introduced in the discriminator under test. One method of verifying that the signal source is not introducing appreciable distortion is to perform this test using the same signal source settings and modulating signal but using a wideband discriminator with excellent linearity. If the distortion values from this test are significantly lower than with the discriminator under test, the signal source can be eliminated as a source of distortion. If, however, the distortion is sufficiently low with the discriminator under test, there is no need to be concerned about the cause of the distortion.

5.4.2 Test Equipment

Audio oscillator with all harmonics at least 60 dB below amplitude of fundamental output frequency
Signal generator or voltage controlled oscillator which can be frequency modulated
Frequency counter
Distortion analyzer
Spectrum analyzer or wave analyzer
Digital voltmeter

5.4.3 Test Method

5.4.3.1 Setup - Connect the test equipment as shown in figure 5.4.1.

5.4.3.2 Conditions - Set the signal generator to the following (see paragraph 5.0 for general test conditions):

Output frequency - discriminator center frequency
Output amplitude - 0.3 Vrms
Peak deviation - discriminator band edge

The discriminator LPOF should be chosen to reflect a deviation ratio of one, that is, equal to peak deviation of discriminator. The audio oscillator output should be a sine wave at a frequency of 0.1 times the discriminator LPOF cutoff frequency.

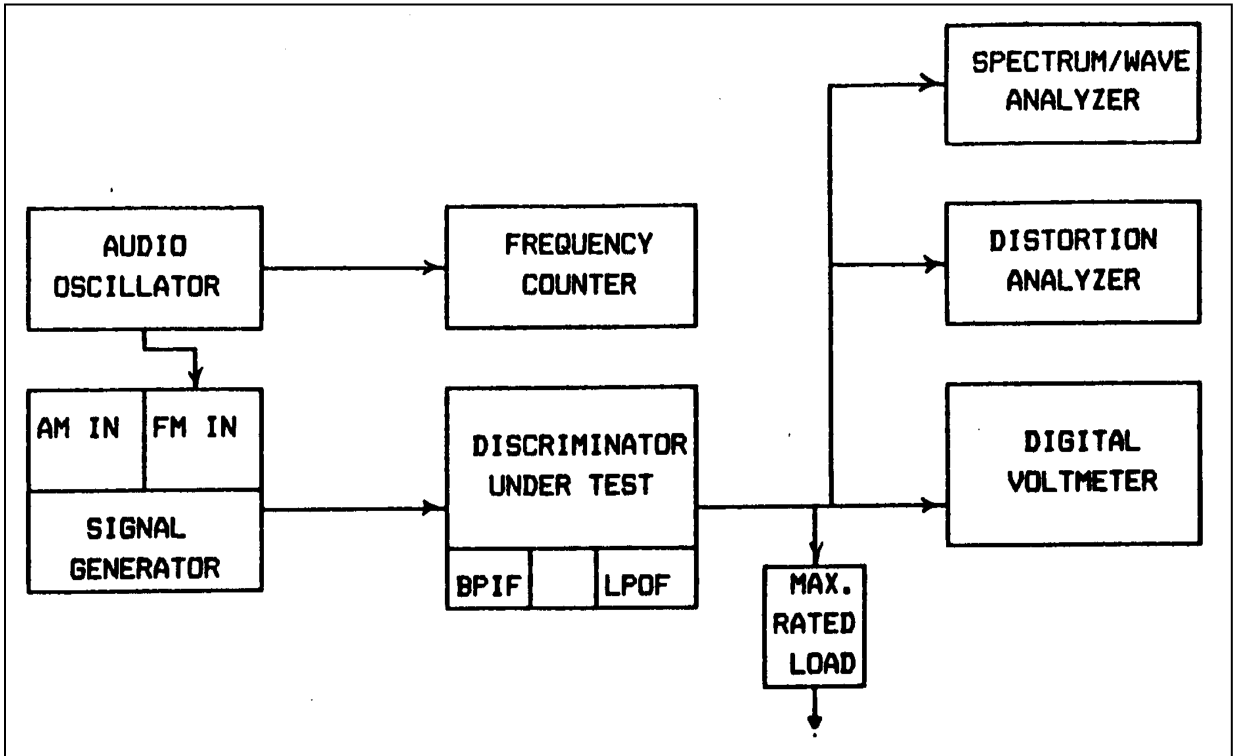


Figure 5.4.1 Test Setup for Harmonic Distortion.

5.4.3.3 Procedure

5.4.3.3.1 Set the unmodulated input signal to the input center frequency and adjust discriminator output voltage to 0 V. Apply modulation to signal generator to produce band edge peak deviation. Adjust output gain to give maximum specified output voltage swing.

5.4.3.3.2 Measure total distortion using distortion analyzer and record on data sheet 5.4.1. Measure output signal amplitude at fundamental and second, third, fourth, and fifth harmonics using spectrum analyzer or wave analyzer and record on data sheet 5.4.1.

5.4.4 Data Reduction - Calculate distortion at second, third, fourth, and fifth harmonics by subtracting amplitude (in dBm) at fundamental from amplitude (in dBm) at each harmonic. Record these values on data sheet 5.4.1. Calculate percent harmonic distortion from

$$\% \text{ harmonic distortion} = (10^{d/20}) \times (100),$$

Where d = harmonic distortion in dB.

(See data sheet 5.4.1 sample.)

FM DISCRIMINATORS

DATA SHEET 5.4.1

TEST Harmonic Distortion

MANUFACTURER__________________________ MODEL______________________________

SERIAL NO.____________________________ IRIG CHANNEL ______________________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY_________________kHz UPPER BAND EDGE________________kHz

LOWER BAND EDGE__________________kHz LOW PASS FILTER CUTOFF________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________________

TEST PERSONNEL__________________ DATE____________ LOCATION________________

Modulating Frequency _______________ Hz

Total Harmonic Distortion _______________ dB _______________ %

Frequency	Output Amplitude	Distortion	
Fundamental	____________ dBm		
Second Harmonic	____________ dBm	_____ dB	_____ %
Third Harmonic	____________ dBm	_____ dB	_____ %
Fourth Harmonic	____________ dBm	_____ dB	_____ %
Fifth Harmonic	____________ dBm	_____ dB	_____ %

FM DISCRIMINATORS

DATA SHEET 5.4.1 (Sample)

TEST Harmonic Distortion

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ______

CHANNEL SELECTOR SERIAL NO. ______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY 70.0 kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF 10.5 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ______

TEST PERSONNEL ______ DATE ______ LOCATION ______

Modulating Frequency			1050	Hz
Total Harmonic Distortion	-44.4	dB	0.6	%

Frequency	Output Amplitude	Distortion	
Fundamental	-3.1 dBm		
Second Harmonic	-51.4 dBm	-48.3 dB	0.38 %
Third Harmonic	-50.9 dBm	-47.8 dB	0.41 %
Fourth Harmonic	- dBm	- dB	0 %
Fifth Harmonic	-55.8 dBm	-52.7 dB	0.23 %

5.5 Line Voltage Sensitivity

5.5.1 Purpose - This test determines the effect of variations in ac line voltage on FM discriminator signal output.

5.5.2 Test Equipment

Frequency counter
Voltmeter (ac)
Variable autotransformer
Oscilloscope
Voltmeter (dc)
Signal generator

5.5.3 Test Method

5.5.3.1 Setup - Connect test equipment as shown in figure 5.5.1.

5.5.3.2 Conditions

5.5.3.2.1 Warm up all equipment according to specifications.

5.5.3.2.2 Maximize output load according to specification.

5.5.3.3 Procedure

5.5.3.3.1 Adjust signal generator output level and discriminator balance and output levels in accordance with paragraph 5.0.

5.5.3.3.2 Set the input frequency to the LBE frequency.

5.5.3.3.3 Record on Data Sheet 5.5.1 Input Frequency, dc output Voltage and ac Line Voltage as ac line voltage is increased in increments of approximately 5 percent of normal operating voltage from minimum operating voltage to maximum operating voltage. Observe output waveform with oscilloscope and note any change on data sheet 5.5.1 as ac line voltage is varied.

Example: If normal operating voltage is 120 Vac and specified operating range is 105 Vac to 135 Vac, data points should be approximately 6 Vac apart.

5.5.3.3.4 Repeat step 5.5.3.3.3 for center frequency and UBE frequency.

5.5.4 Data Reduction - Calculate the line voltage sensitivity as indicated on data sheet 5.5.1 and compare with electrical specifications. The line voltage sensitivity may be calculated for any two data points on the data sheet at any input frequency. The ac maximum and ac minimum are the upper and lower values of ac line voltage that determines the data points. The dc maximum and dc minimum are the corresponding discriminator outputs for the two different ac line voltage values at a given frequency (see data sheet 5.5.1 sample).

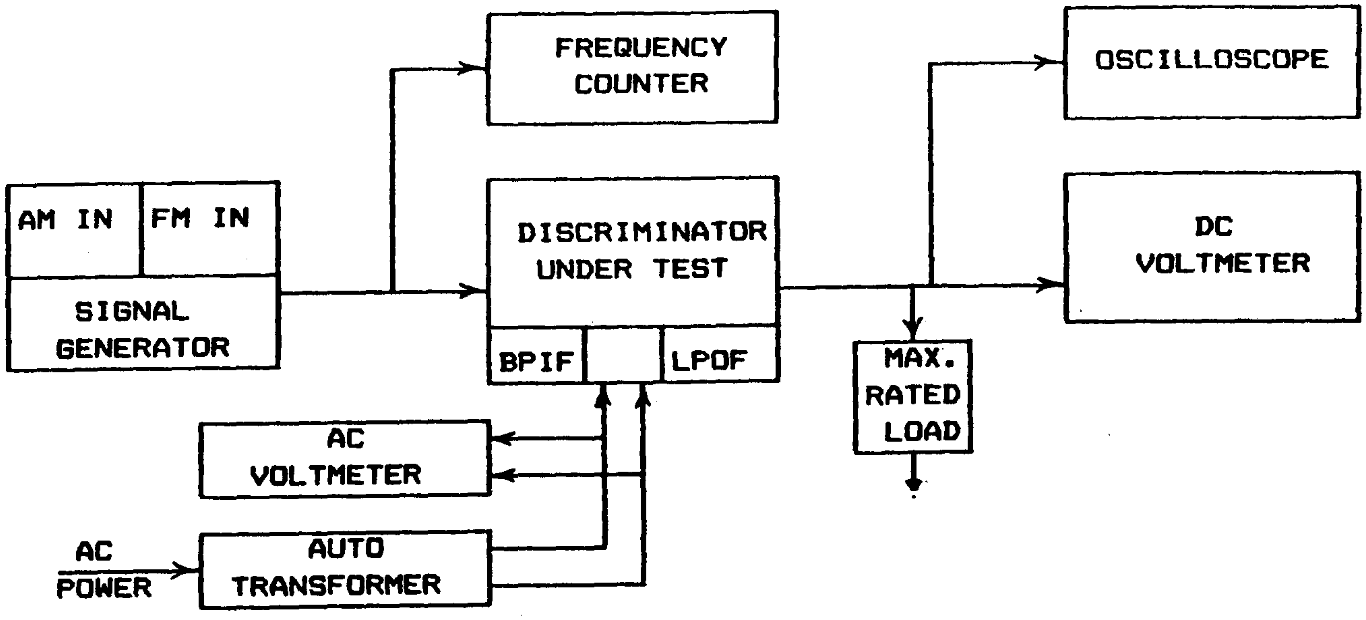


Figure 5.5.1 Test Setup for Line Voltage Sensitivity.

FM DISCRIMINATORS

DATA SHEET 5.5.1

TEST Line Voltage Sensitivity Test

MANUFACTURER________________ MODEL________________

SERIAL NO.________________ IRIG CHANNEL ________________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY____________kHz UPPER BAND EDGE____________kHz

LOWER BAND EDGE____________kHz LOW PASS FILTER CUTOFF________kHz

LOW PASS FILTER TYPE - [ ] CA [ ] CD [ ] Other________________

TEST PERSONNEL________________ DATE____________ LOCATION______________

---

ac Operating Range ____________Vac TO ____________Vac

% Full Bandwidth Tolerance ____________%

	Discriminator Inputs					
	LBE		Center Freq.		UBE	
Specified	________	kHz	______	kHz	________	kHz
Measured	________	kHz	______	kHz	________	kHz

ac Line Voltage	Discriminator Outputs (Vdc)				Comments
Nominal	________	(L)	______	________ (U)	
________	________		______	________	
________	________		______	________	
________	________		______	________	
________	________		______	________	
________	________		______	________	

$$\text{Line Voltage Sensitivity} = \frac{\dfrac{dc_{MAX} - dc_{MIN}}{U-L}}{ac_{max} - ac_{min}} \times 100\% \text{ per Vac}$$

= ________________% per Vac

FM DISCRIMINATORS

DATA SHEET 5.5.1 (Sample)

TEST Line Voltage Sensitivity Test

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 70.0 kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF 2.1 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

ac Operating Range 105 Vac TO 132 Vac
% Full Bandwidth Tolerance 0.5 %

	Discriminator Inputs		
	LBE	Center Freq.	UBE
Specified	59.5 kHz	70.0 kHz	80.5 kHz
Measured	59.5000 kHz	70.000 kHz	80.5000 kHz

ac Line Voltage	Discriminator Outputs (Vdc)			Comments
Nominal	-9.328 (L)	-14 mV	+9.981 (U)	
105	-9.328	-15	+9.982	
112	-9.328	-15	+9.981	
119	-9.326	-15	+9.979	
126	-9.326	-15	+9.979	
132	-9.326	-15	+9.980	

$$\text{Line Voltage Sensitivity} = \frac{\dfrac{dc_{MAX} - dc_{MIN}}{U - L}}{ac_{MAX} - ac_{MIN}} \times 100 \ \% \text{ per Vac}$$

$$= \frac{\dfrac{-9.326 + 9.328}{9.981 + 9.328}}{119 - 105} \times 100 \ \% \text{ per Vac}$$

$$= 7.4 \times 10^{-4} \ \% \text{ per Vac}$$

5.6 Output Impedance and Current

5.6.1 Purpose - This test measures the output resistance and current drive capability of an FM discriminator.

5.6.2 Test Equipment

Signal generator	Frequency counter
Digital voltmeter (dc)	True rms voltmeter
Variable load	Ohmmeter

5.6.3 Test Method

5.6.3.1 Setup - Connect the test equipment as shown in figure 5.6.1.

5.6.3.2 Conditions

5.6.3.2.1 Warm up all equipment according to specifications.

5.6.3.2.2 Set up signal generator in accordance with standard conditions in paragraph 5.0.

5.6.3.3 Procedure

5.6.3.3.1 Set signal generator to center frequency and adjust discriminator to 0 V output.

5.6.3.3.2 Apply UBE frequency to discriminator input and adjust discriminator for maximum output (see subparagraph 5.0.4.4.2).

5.6.3.3.3 Disconnect load and measure and record open circuit output voltage on data sheet 5.6.1 for UBE frequency.

5.6.3.3.4 Connect a resistive decade box set for maximum resistance to the discriminator.

5.6.3.3.5 Decrease resistance until the output voltage is one-half of the open circuit value.

5.6.3.3.6 Disconnect decade box from circuit and measure and record its resistance on data sheet 5.6.1. This resistance will be used to calculate the maximum output current of the discriminator.

5.6.3.3.7 Repeat procedure and record results using LBE frequency.

5.6.3.3.8 Set the signal generator to a frequency equal to the discriminator center frequency plus 1 percent of the UBE frequency minus the center frequency ($f_c+0.01(f_{UBE}-f_c)$) . Repeat steps 5.6.3.3.3 through 5.6.3.3.5. Disconnect decade box from circuit and measure and record its resistance on data sheet 5.6.1. The measured resistance is the dc output resistance.

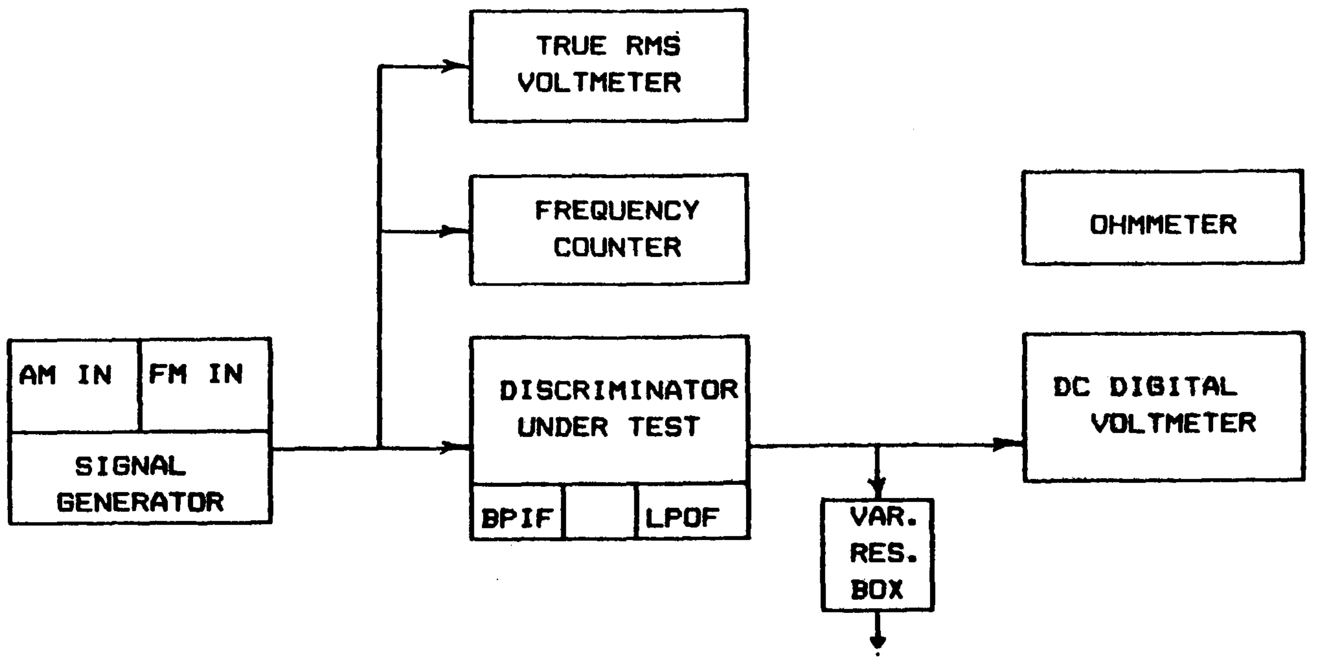


Figure 5.6.1 Test Setup for Output Impedance and Current.

FM DISCRIMINATORS

DATA SHEET 5.6.1

TEST Output Impedance and Current

MANUFACTURER__________ MODEL__________

SERIAL NO.__________ IRIG CHANNEL __________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N __________

CENTER FREQUENCY__________kHz UPPER BAND EDGE__________kHz

LOWER BAND EDGE__________kHz LOW PASS FILTER CUTOFF__________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________

TEST PERSONNEL__________ DATE__________ LOCATION__________

MAXIMUM OUTPUT CURRENT

Upper Band Edge Frequency	__________	kHz
Open Circuit Voltage	__________	Vdc
Resistance	__________	Ohms
Lower Band Edge Frequency	__________	kHz
Open Circuit Voltage	__________	Vdc
Resistance	__________	Ohms

Maximum Current = V/2R =__________mamp.

OUTPUT IMPEDANCE

Center Frequency +0.01 (UBE-f_c)	=	__________	kHz
Open Circuit Voltage	=	__________	Vdc
Resistance	=	__________	Ohms
Center Frequency -0.01 (UBE-f_c)	=	__________	kHz
Open Circuit Voltage	=	__________	Vdc
Resistance	=	__________	Ohms

5.6.3.3.9 Set the signal generator to a frequency equal to the discriminator center frequency minus 1 percent of the UBE frequency minus the center frequency. Repeat steps 5.6.3.3.3 through 5.6.3.3.6.

5.6.4 Data Reduction - Calculate the maximum output current by dividing the open circuit voltage by two times the measured resistance (subparagraph 5.6.3.3.6) (see data sheet 5.6.1 sample).

FM DISCRIMINATORS

DATA SHEET 5.6.1 (Sample)

TEST Output Impedance and Current

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 70.0 kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF ____ kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

MAXIMUM OUTPUT CURRENT

Upper Band Edge Frequency	80.5	kHz
Open Circuit Voltage	+10.083	Vdc
Resistance	34	Ohms
Lower Band Edge Frequency	59.5	kHz
Open Circuit Voltage	-10.084	Vdc
Resistance	34	Ohms

Maximum Current = V/2R = 148.3 mamp.

OUTPUT IMPEDANCE

Center Frequency +0.01 (UBE-f_c) =	70.105	kHz
Open Circuit Voltage =	43	mVdc
Resistance =	0.31	Ohms
Center Frequency -0.01 (UBE-f_c) =	69.895	kHz
Open Circuit Voltage =	-104	mVdc
Resistance =	0.32	Ohms

5.7 Amplitude Modulation Rejection Test

5.7.1 Purpose - This test determines how well a discriminator rejects amplitude modulation which is present on its input signal.

5.7.2 Test Equipment

Signal generator
Square wave generator
Frequency counter
Oscilloscope (dual trace) 2 required
Scope camera or plotter

5.7.3 Test Method

5.7.3.1 Setup - Connect the test equipment as shown in figure 5.7.1.

5.7.3.2 Conditions

5.7.3.2.1 Warm up all equipment according to specifications.

5.7.3.2.2 Set up the discriminator according to the standard conditions in subparagraph 5.0.

5.7.3.2.3 Set up the signal generator according to the standard conditions in subparagraph 5.0.4.1.

5.7.3.3 Procedure

5.7.3.3.1 Set the frequency of the square-wave generator to 5 percent of the LPOF cutoff frequency.

5.7.3.3.2 Adjust the square-wave generator output amplitude and offset to apply a 20-dB step in amplitude at the output of the signal generator. The peak-to-valley voltage relationship of the amplitude modulated subcarrier signal should be a ratio of 10 (voltage peak = 10 x voltage valley).

5.7.3.3.3 Measure and record on data sheet 5.7.1 the peak-to-peak discriminator output voltage. Take a photograph of the oscilloscope trace and attach to the data sheet.

5.7.3.3.4 Repeat steps 5.7.3.3.2 and 5.7.3.3.3 for the UBE frequency.

5.7.3.3.5 Repeat steps 5.7.3.3.2 and 5.7.3.3.3 for the LBE frequency.

5.7.3.3.6 This test may be repeated for other signal levels as required by actual usage.

5.7.4 Data Reduction - Compare the data with the specification. (see data sheet 5.7.1 sample).

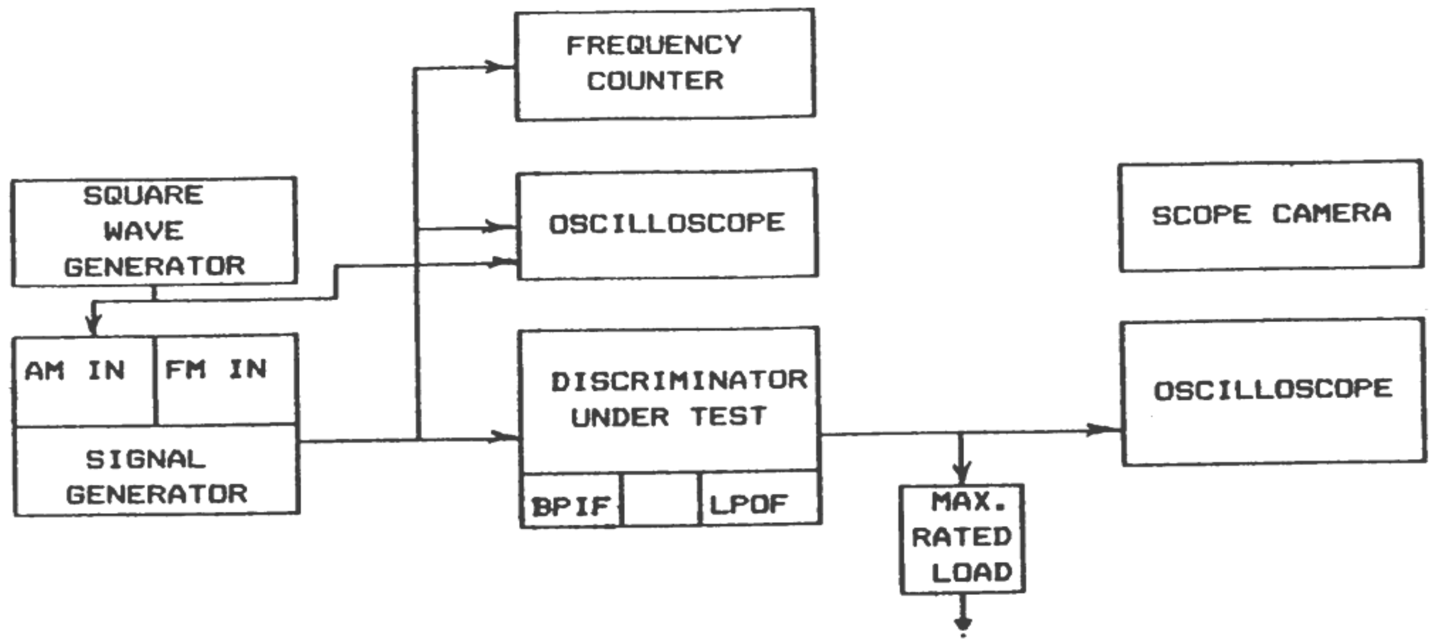


Figure 5.7.1 Test Setup for Amplitude Modulation Rejection.

FM DISCRIMINATORS

DATA SHEET 5.7.1

TEST Amplitude Modulation Rejection

MANUFACTURER____________ MODEL____________

SERIAL NO.____________ IRIG CHANNEL ____________

CHANNEL SELECTOR SERIAL NO.____________ LOW PASS OUTPUT FILTER S/N ____________

CENTER FREQUENCY____________kHz UPPER BAND EDGE____________kHz

LOWER BAND EDGE____________kHz LOW PASS FILTER CUTOFF____________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other____________

TEST PERSONNEL____________ DATE____________ LOCATION____________

V_{MIN} = ____________ V
V_{MAX} = ____________ V (10 x V_{MIN})

Lower Band Edge Frequency = ____________ kHz Output Voltage = ____________ Vdc

	Specification	Measurement
Peak-to Peak Output Voltage (V)	____________	____________

Center Frequency = ____________ kHz Output Voltage = ____________ Vdc

	Specification	Measurement
Peak-to Peak Output Voltage (V)	____________	____________

Upper Band Edge Frequency = ____________ kHz Output Voltage = ____________ Vdc

	Specification	Measurement
Peak-to Peak Output Voltage (V)	____________	____________

Attach Photograph Here	Attach Photograph Here	Attach Photograph Here
Lower Band Edge	Center Frequency	Upper Band Edge

FM DISCRIMINATORS

DATA SHEET 5.7.1 (Sample)

TEST Amplitude Modulation Rejection

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ______

CHANNEL SELECTOR SERIAL NO. ______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY 70. kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF 2.1 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ______

TEST PERSONNEL ______ DATE ______ LOCATION ______

V_{MIN} = 30.0 mV
V_{MAX} = 300. mV (10 x V_{MIN})

Lower Band Edge Frequency = 59.500 kHz Output Voltage = -9.424 Vdc

	Specification	Measurement
Peak-to Peak Output Voltage (V)	______	613 mV

(See attachment 1 for lower band edge.)

Center Frequency = 70.000 kHz Output Voltage = -0.005 Vdc

	Specification	Measurement
Peak-to Peak Output Voltage (V)	200mV	369 mV

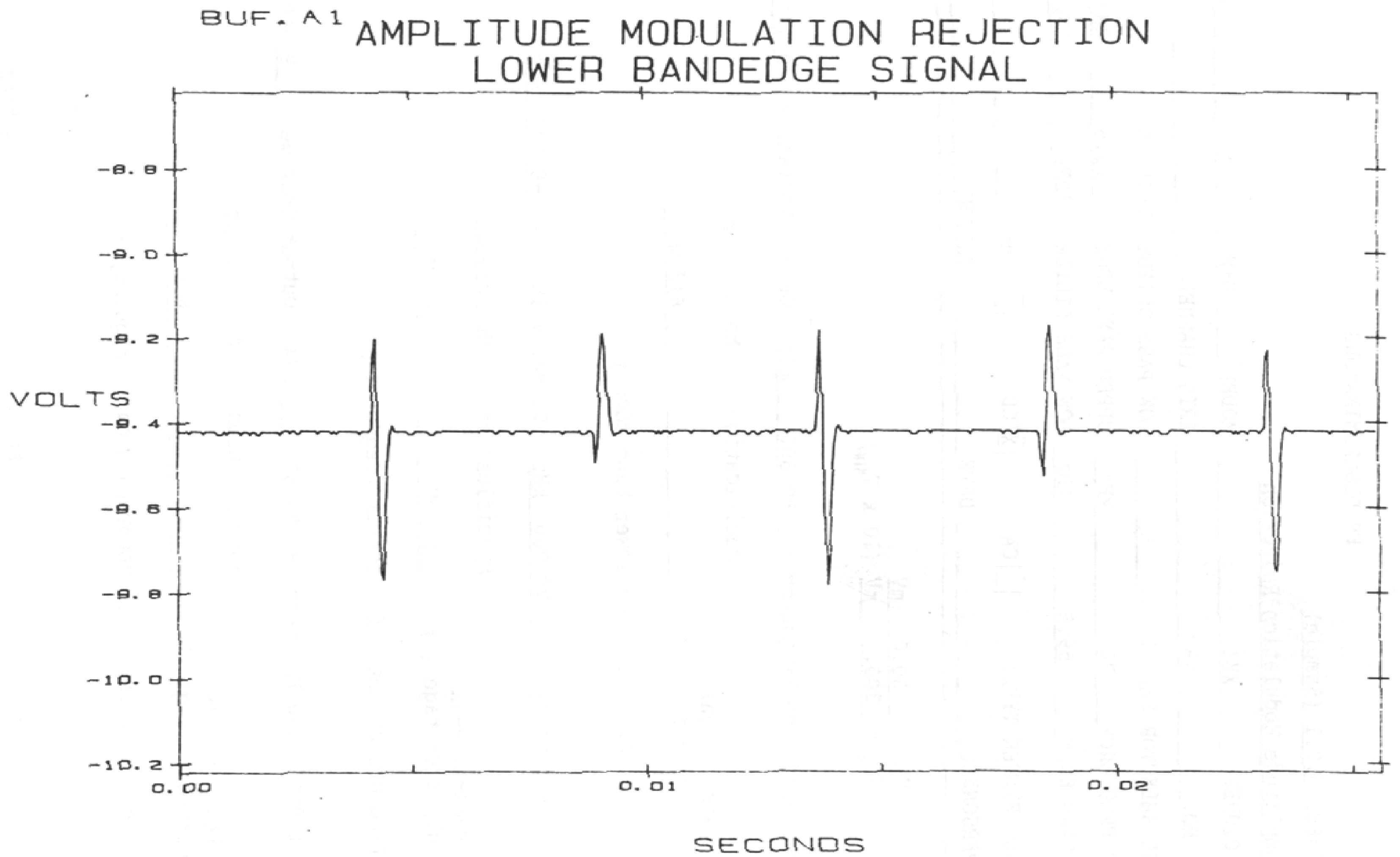
(See attachment 2 for center frequency.)

Upper Band Edge Frequency = 80.500 kHz Output Voltage = 9.660 Vdc

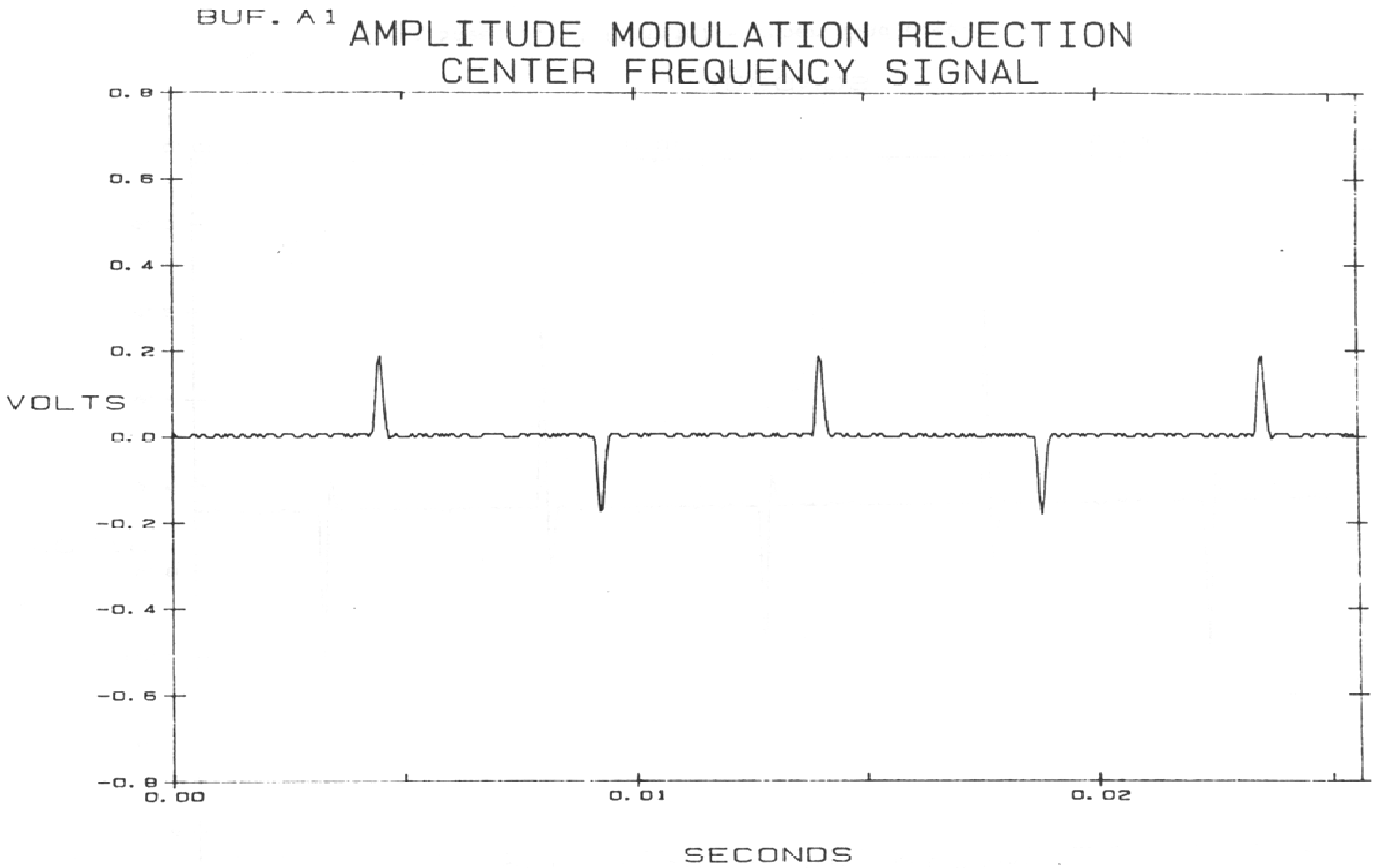
	Specification	Measurement
Peak-to Peak Output Voltage (V)	______	806 mV

(See attachment 3 for upper band edge frequency.)

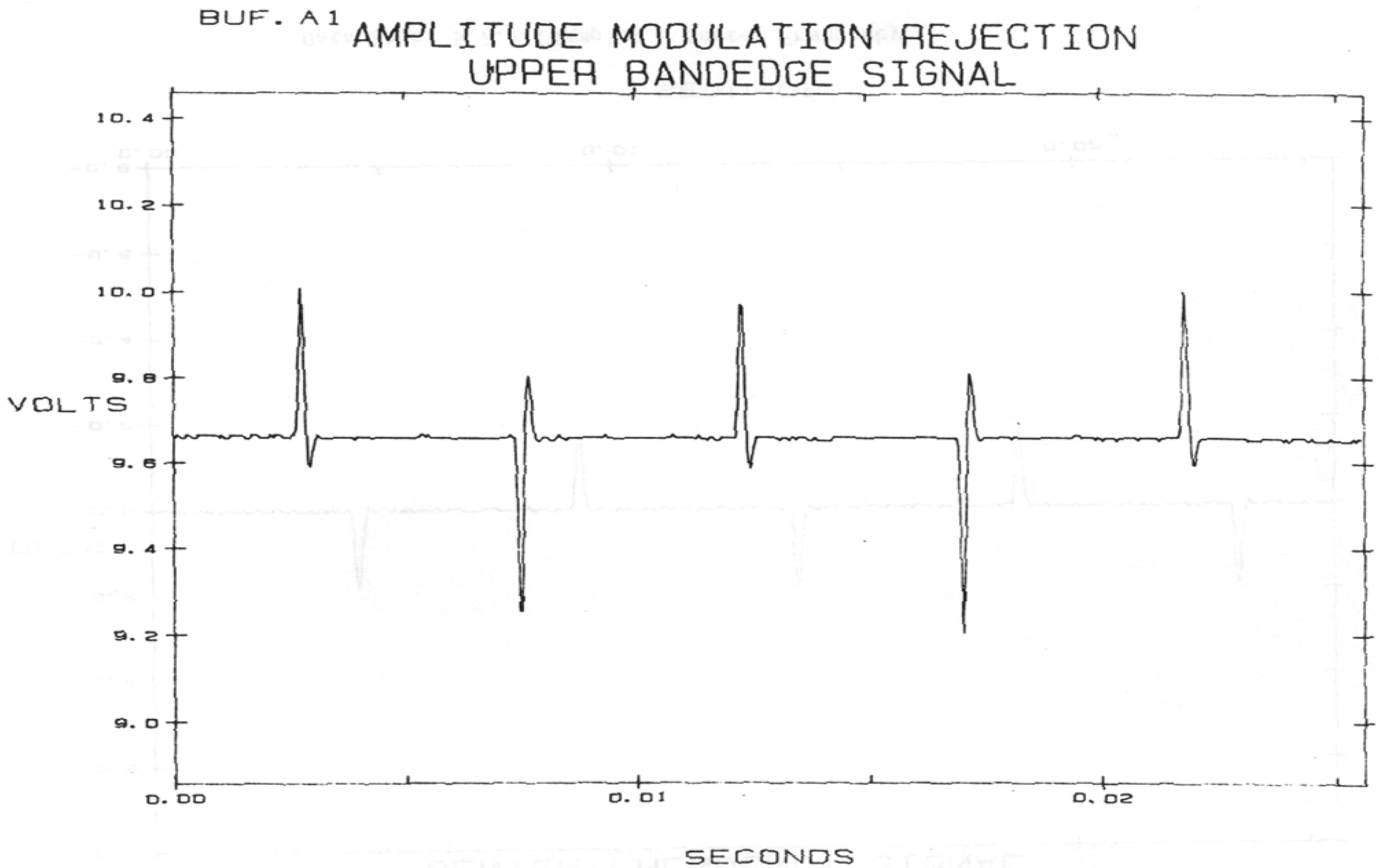
Attach Photograph Here	Attach Photograph Here	Attach Photograph Here
Lower Band Edge	Center Frequency	Upper Band Edge



Data Sheet 5.7.1 (Sample) - Lower Band Edge.



Data Sheet 5.7.1 (Sample) - Center Frequency.



Data Sheet 5.7.1 (Sample) - Upper Band Edge.

5.8 Signal-To-Noise Ratio

5.8.1 Purpose - This test measures output signal-to-noise ratio (SNR) to verify proper performance of the discriminator in the presence of in-band input noise.

5.8.2 Test Equipment

Signal generator or voltage controlled oscillator
Voltmeter (dc)
White gaussian noise generator
Active summing network (see note)
True rms voltmeter
Oscilloscope
Frequency counter
Spectrum analyzer

NOTE

A passive summing network can be used if proper precautions are taken to make sure that the summing network output amplitude of the signal or noise, or both, do not vary if the other input is connected or disconnected.

5.8.3 Test Method

5.8.3.1 Setup - Connect the test equipment as shown in figure 5.8.1.

5.8.3.2 Conditions - See paragraph 5.0 for general test conditions. Adjust the discriminator output to 0 Vdc with an unmodulated signal at the discriminator center frequency applied to the discriminator input. Set the signal generator to the discriminator UBE and adjust the discriminator output to 5 Vdc.
Record on data sheet 5.8.1. Reset the signal generator to the following:

Output frequency = discriminator center frequency
Output amplitude = 0.3 Vrms at output of summing network.

5.8.3.3 Procedure

5.8.3.3.1 Remove the noise from the summing network. Measure the rms signal voltage at the output of the discriminator bandpass filter. Record this value on data sheet 5.8.1. Measure the rms voltage at the discriminator low pass filter output. Record this value on the line labeled maximum SNR under the heading of low pass filter output noise volts.

5.8.3.3.2 Connect the noise generator to the input of the summing network and remove the signal generator. Set the rms voltage of the noise at the output of the discriminator bandpass filter to be 30 dB less than the rms signal voltage measured above. Connect the signal generator to the input of the summing network. Set up the spectrum analyzer to monitor the signal and noise in the discriminator bandpass filter. Note the noise level for future reference. Remove the signal from the summing network. The noise level should not change. If the level changes, a problem exists. Some discriminators have changes in gain when the input signal is too small. Increase the noise level and observe whether the BPIF output level suddenly decreases. If this change occurs, increase the noise level by another 3 to 6 dB and note the level on the rms voltmeter. Reconnect the signal generator and disconnect the noise generator. Set the signal generator to a level 30 dB above the rms value of the noise. Measure the BPIF output voltage and record in place of the value measured in subparagraph 5.8.3.3.1. Reconnect the noise generator and note the noise level on the spectrum analyzer. Disconnect the signal generator. The noise level should not change.

NOTE

If the noise level changes, the test probably cannot be performed. Also check the BPIF output with the signal connected to verify that limiting is not occurring. Limiting or automatic gain control (AGC) will invalidate the results of this test.

Record the rms signal value on data sheet 5.8.1.

5.8.3.3.3 Measure the rms voltage at the output of the discriminator low pass filter and record on data sheet 5.8.1.

5.8.3.3.4 Repeat steps 5.8.3.3.2 and 5.8.3.3.3 with the rms voltage of the noise 20, 15, and 12 dB less than the rms voltage of the signal measured in subparagraph 5.8.3.3.1.

5.8.4 <u>Data Reduction</u>

5.8.4.1 Calculate the SNR at the discriminator low pass filter output from

$$SNR_o = 20\,(\log(\text{signal at UBE/noise at low pass filter output})) - 3\text{ dB}.$$

NOTE

The 3 dB is subtracted to convert peak to rms for sine wave.

Record on data sheet 5.8.1.

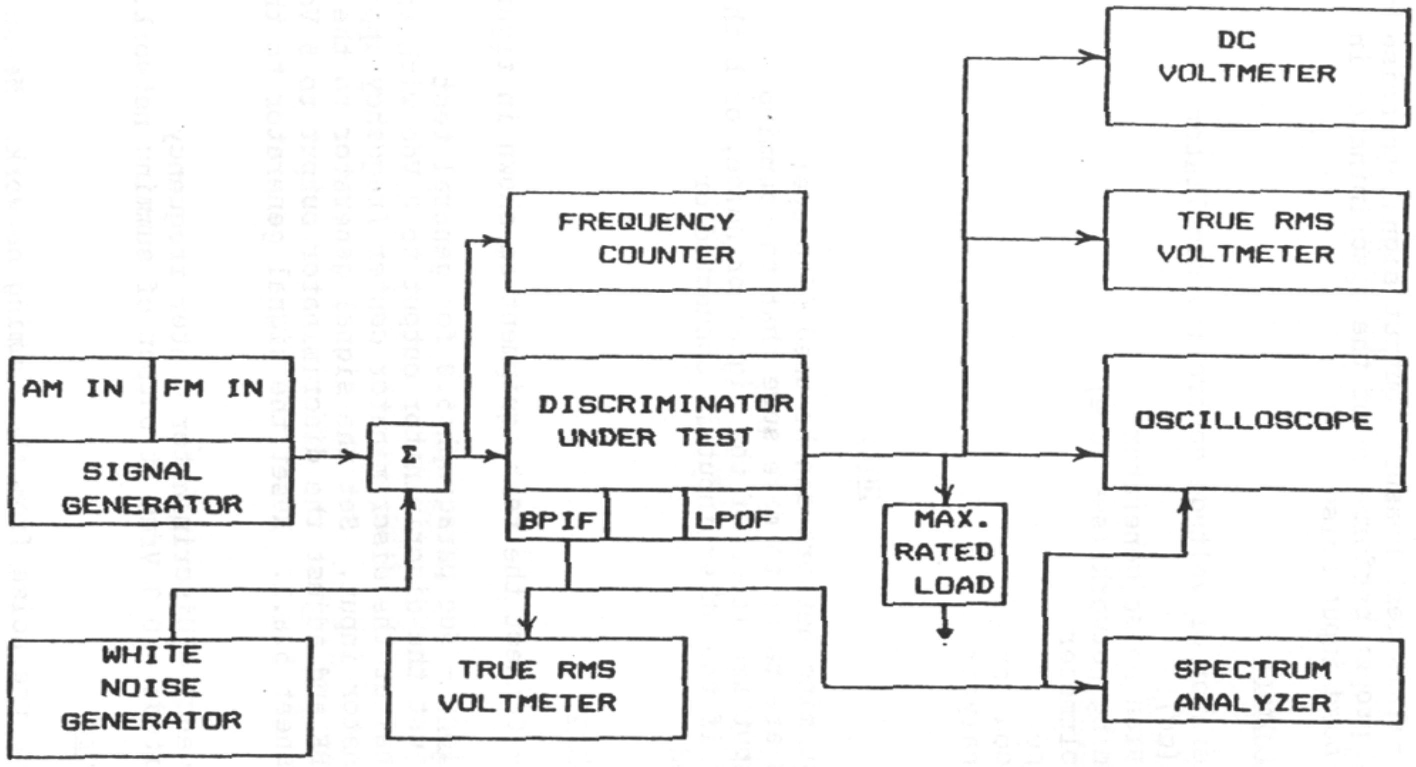


Figure 5.8.1 Test Setup for Signal-to-Noise Ratio.

FM DISCRIMINATORS

DATA SHEET 5.8.1

TEST Signal-to-Noise Ratio

MANUFACTURER__________ MODEL__________

SERIAL NO.__________ IRIG CHANNEL __________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N __________

CENTER FREQUENCY__________kHz UPPER BAND EDGE__________kHz

LOWER BAND EDGE__________kHz LOW PASS FILTER CUTOFF__________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________

TEST PERSONNEL__________ DATE__________ LOCATION__________

Discriminator output voltage with UBE frequency input__________Vdc

Signal at output of discriminator bandpass filter __________Vrms

Low Pass Filter Output

Approximate Input SNR(dB)	Noise Volts	Measured SNR_o	Calculated SNR_T
30			
20			
15			
12			

5.8.4.2 Calculate the expected SNR at the discriminator output from:

$$SNR_T = \frac{3B\rho\,(\Delta f)^2}{2(f_o)^3}$$

$$SNR_T = 30(\log \frac{UBE - f_c}{f_o}) + 4.77 + SNR_i \text{ (dB)}$$

Where B = Discriminator bandpass filter bandwidth = $2\Delta f$
ρ = SNR at bandpass filter output = SNR_i
Δf = Peak deviation
f_o = Low pass filter cutoff frequency
f_c = Discriminator center frequency
UBE = Upper Band Edge Frequency.

Record SNR_i on data sheet 5.8.1 (see data sheet 5.8.1 sample).

NOTE

The first quantity (30 log ( )) in the previous equation takes on the following values for commonly used deviation ratios (peak deviation to low pass filter cutoff frequency):

Deviation Ratio	*30 log ( )*
1	*0*
2	*9.03*
4	*18.06*
5	*20.97*

The SNR values calculated from the above equation assumes that the filters are ideal; therefore, the results are only approximations for real world filters. Measured values will usually be a few dB lower than the calculated values. The low pass filter cutoff frequency is defined to be the frequency at which the output is reduced by 3 dB relative to the amplitude at dc.

FM DISCRIMINATORS

DATA SHEET 5.8.1 (Sample)

TEST Signal-to-Noise Ratio

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL

CHANNEL SELECTOR SERIAL NO. LOW PASS OUTPUT FILTER S/N

CENTER FREQUENCY 70.0 kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF 2.1 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other

TEST PERSONNEL DATE LOCATION

Discriminator output voltage with upper band edge frequency input 5.06 Vdc

Signal at output of discriminator bandpass filter 90.6 mVrms

Low Pass Filter Output

Approximate Input SNR(dB)	Noise Volts	Measured SNR_o	Calculated SNR_T
	0.94mV	71.6dB	-
30	9.3mV	51.7	55.7dB
20	25.8mV	42.9	45.7
15	46 mV	37.8	40.7
12	65 mV	34.8	37.7

5.9 Band Pass Input Filter Shape

5.9.1 Purpose - This test measures the discriminator bandpass filter frequency response. This data can be used to correct the output frequency response for roll-off because of the discriminator bandpass filter.

NOTE

Two test methods are contained in the procedure. The sine-wave method is the preferred method but it will not work if there is limiting or AGC before the bandpass filter output test point. The sine-wave test consists of applying fixed amplitude sine waves of various frequencies to the discriminator input and measuring the amplitude at the bandpass filter output test point. The white-noise test consists of applying a wide band white-noise signal to the discriminator input and measuring the noise spectrum at the discriminator input and measuring the noise spectrum at the bandpass filter test point. This method is immune to AGC action because all input frequencies will be amplified by the same amount; therefore, the output is representative of the bandpass filter frequency response.

5.9.2 Test Equipment

5.9.2.1 Procedure 1 - Sine-Wave Method

Signal generator
True rms voltmeter
Spectrum analyzer with tracking generator - resolution bandwidth <10 percent of specified discriminator bandpass filter bandwidth
Oscilloscope camera (for photographing spectrum analyzer display) or plotter

5.9.2.2 Procedure 2 - White-Noise Method

Spectrum Analyzer - resolution bandwidth <10 percent of specified discriminator bandpass filter bandwidth. Video bandwidth <1 percent of resolution bandwidth
White-noise generator - noise generator with flat output spectral density (±0.5 dB) over frequencies of interest.
True rms voltmeter
Oscilloscope camera for photographing spectrum analyzer display or plotter

5.9.3 Test Method

NOTE

Procedure 1 will not work for discriminators which have AGC or limiting before the bandpass filter test point. This point can be *checked by applying a center frequency sine wave with amplitude of 0.3 Vrms to the discriminator input and measuring the bandpass filter output using the true rms voltmeter. Call this value X dB. Set the input to the following amplitudes and measure the bandpass filter output:*

	Output (dB1
0.3 Vrms	X
0.6 Vrms	X + 6
0.095 Vrms	X – 10
0.03 Vrms	X – 20

If the output values are within ± 0.5 dB of the values in the table, the system is linear and Procedure 1 can be used. If not, either try a different input level or use Procedure 2.

5.9.3.1 Sine-Wave Method (Procedure 1)

5.9.3.1.1 Setup - Connect the test equipment as shown in figure 5.9.1.

5.9.3.1.2 Conditions - see paragraph 5.0 for general test conditions.

5.9.3.1.3 Procedure

5.9.3.1.3.1 Set the signal generator output amplitude to 0.3 Vrms and the frequency to the center frequency of the discriminator under test. Measure the bandpass filter output amplitude using the true rms voltmeter. Record this value on data sheet 5.9.1. Measure and record the bandpass filter output amplitude at the other frequencies shown on data sheet 5.9.1. Keep the input amplitude constant at 0.3 Vrms.

NOTE

Other input amplitudes should be used instead of 0.3 Vrms if they are more typical of actual usage or if the system is not linear for an input voltage of 0.3 Vrms.

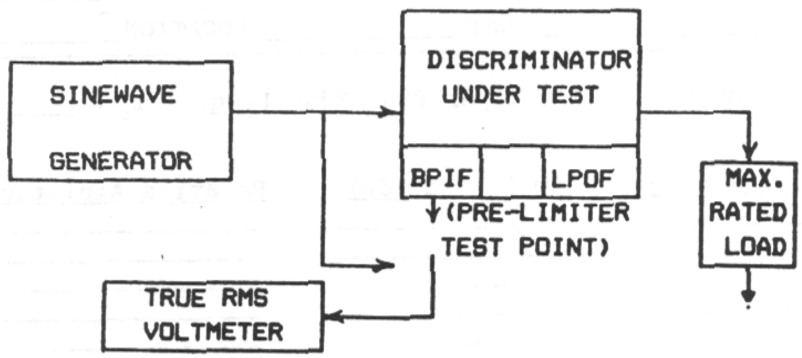


Figure 5.9.1 Test Setup for Bandpass Input Filter Frequency Response.

FM DISCRIMINATORS

DATA SHEET 5.9.1

TEST Bandpass Filter Frequency Response

MANUFACTURER________________ MODEL________________

SERIAL NO.________________ IRIG CHANNEL ________________

CHANNEL SELECTOR SERIAL NO.________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY____________ kHz UPPER BAND EDGE____________ kHz

LOWER BAND EDGE____________ kHz LOW PASS FILTER CUTOFF________ kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other____________

TEST PERSONNEL____________ DATE__________ LOCATION____________

f_c = Center Frequency Δf = Upper Band Edge Freq. - f_c = ________ kHz

	Frequency (kHz)	Amplitude (dB)	Relative Amplitude (dB)
f_c			
$f_c + \Delta f/2$			
$f_c - \Delta f/2$			
$f_c + \Delta f$			
$f_c - \Delta f$			
$f_c + 2\ \Delta f$			
$f_c - 2\ \Delta f$			

EXAMPLE:

Relative Amplitude at $(f_c + \Delta f)$ = Amplitude at $(f_c + \Delta f)$ - Amplitude at f_c

Spectrum Analyzer Settings

Vertical Scale (dB/div)____________ dB
Lower Frequency ____________ kHz
Upper Frequency ____________ kHz
Resolution Bandwidth ____________ Hz
Video Bandwidth ____________ Hz

Attach

Photograph

Here

5.9.3.1.3.2 Set up the equipment as shown in figure 5.9.2. Set the spectrum analyzer tracking generator output to 0.3 Vrms at the discriminator center frequency (fc). Set the sweep limits at fc–2.5 Δf and fc+2.5 Δf (Δf = UBE frequency – fc). Set the spectrum analyzer vertical sensitivity to 2 dB/division. Adjust the center frequency level to be 2 dB below top of display. Photograph the spectrum and attach to data sheet 5.9.1.

5.9.3.2 <u>White-Noise Method - (Procedure 2)</u>

5.9.3.2.1 <u>Setup</u> - Connect the noise generator output to the spectrum analyzer input.

5.9.3.2.2 <u>Conditions</u> - Set the spectrum analyzer resolution bandwidth to a value ≤10 percent of the specified bandpass filter bandwidth of the discriminator under test. Set spectrum analyzer video bandwidth to a value ≤1 percent of resolution bandwidth. Set spectrum analyzer sweep limits to f_c–2.5 Δf and f_c+2.5 Δf respectively (see data sheet 5.9.1). The spectrum analyzer vertical sensitivity should be set to 2 dB/division. Adjust the noise generator output amplitude to 0.5 Vrms. Set the noise generator output frequency response such that the noise is white over the frequency range of interest.

5.9.3.2.3 Verify that the noise spectrum is flat within ±0.5 dB over the frequency range of interest.

5.9.3.2.4 <u>Procedure</u> - Connect the equipment as shown in figure 5.9.3. Measure and photograph the spectrum at the discriminator bandpass filter output. Estimate the values at the frequencies shown on data sheet 5.9.1. Attach the photograph to the data sheet.

5.9.4 <u>Data Reduction</u> - Verify that the values recorded on data sheet 5.9.1 meet the required specification (see data sheet 5.9.1 sample).

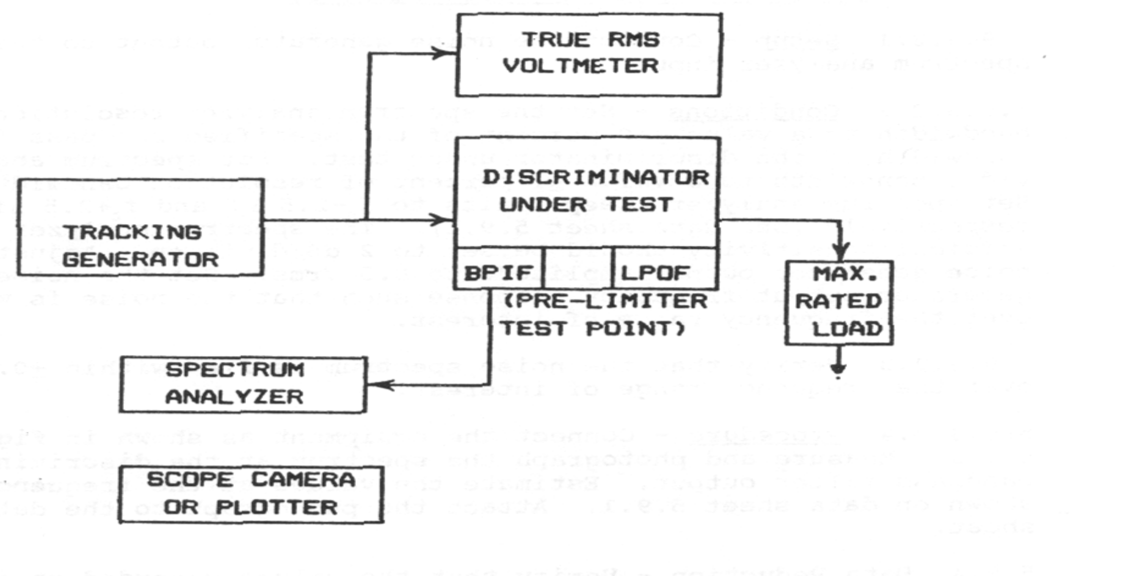


Figure 5.9.2 Test Set-up for Bandpass Input Filter Frequency Response.

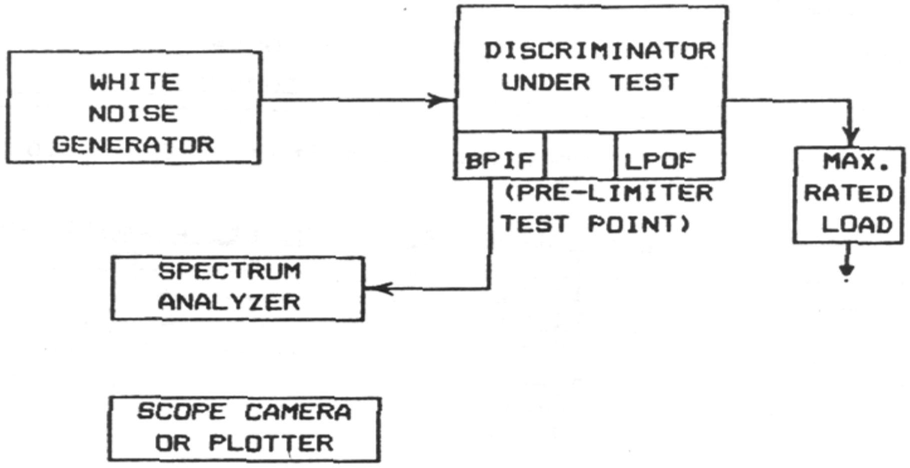


Figure 5.9.3 Test Setup for Bandpass Input Filter Frequency Response.

FM DISCRIMINATORS

DATA SHEET 5.9.1 (Sample)

TEST Bandpass Filter Frequency Response

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 70.0 kHz UPPER BAND EDGE 80.5 kHz

LOWER BAND EDGE 59.5 kHz LOW PASS FILTER CUTOFF 2.1 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

f_c = Center Frequency Δf = Upper Band Edge Freq. - f_c = 10.5 kHz

	Frequency (kHz)	Amplitude (dB)	Relative Amplitude (dB)
f_c	70	14.6	0.00
$f_c + \Delta f/2$	75.25	13.44	-1.14
$f_c - \Delta f/2$	64.75	14.06	-0.54
$f_c + \Delta f$	80.5	10.64	-3.96
$f_c - \Delta f$	59.5	11.6	-3.00
$f_c + 2\Delta f$	91	1.73	-12.87
$f_c - 2\Delta f$	49	2.5	-12.10

EXAMPLE:

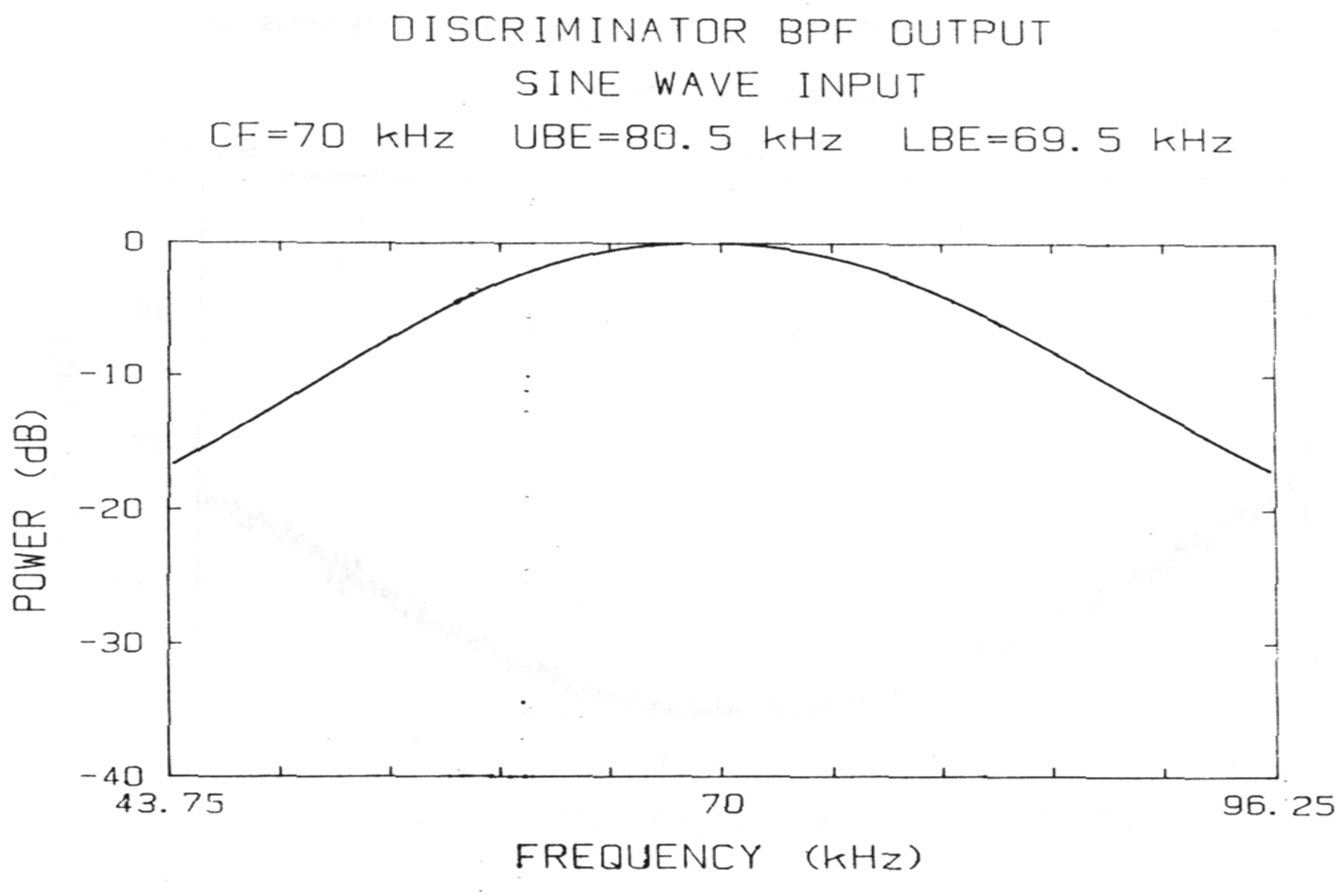
Relative Amplitude at $(f_c + \Delta f)$ = Amplitude at $(f_c + \Delta f)$ - Amplitude at f_c

Spectrum Analyzer Settings

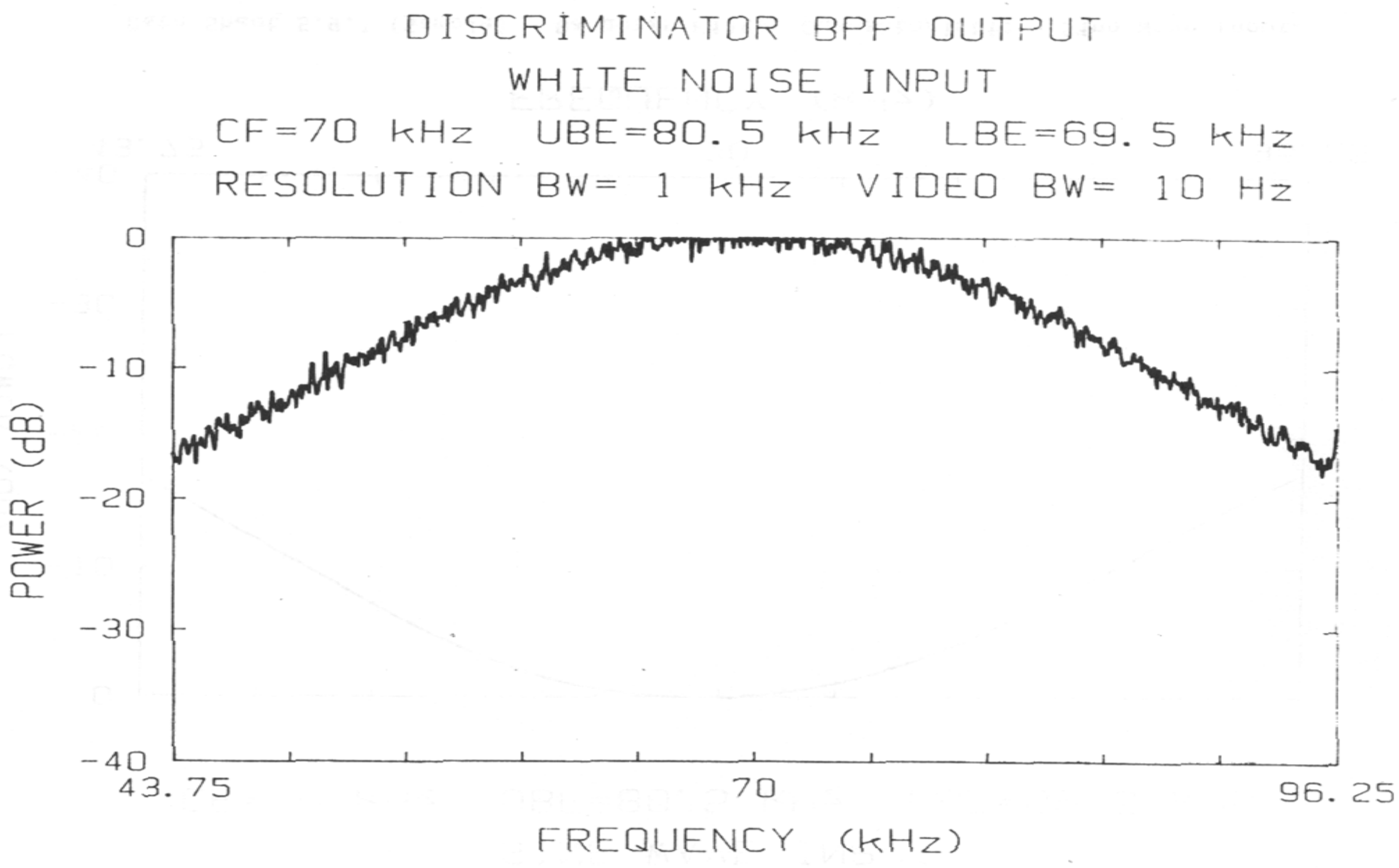
Vertical Scale (dB/div) 10 dB
Lower Frequency 43.75 kHz
Upper Frequency 96.25 kHz
Resolution Bandwidth 1000 Hz
Video Bandwidth 10 Hz

Attach Photograph Here

(See attachments 1 and 2.)



Data Sheet 5.9.1 (Sample) - Bandpass Filter Characteristic - Sine Wave Input.



Data Sheet 5.9.1 (Sample) - Bandpass Filter Characteristic - White Noise Input.

5.10 Out-of-Band Frequency Rejection

5.10.1 Purpose - This test measures the frequency and amplitude of spurious signals at the discriminator output when signals outside the discriminator pass band are applied to the input.

5.10.2 Test Equipment

Signal generator or voltage controlled oscillator which can be frequency modulated
Sine-wave generator with sweep capability
Sine-wave generator
Summing network
X-Y recorder True rms voltmeter
Spectrum analyzer

5.10.3 Test Method

5.10.3.1 Setup - Connect the test equipment as shown in figure 5.10.1.

5.10.3.2 Conditions - See paragraph 5.0 for general test conditions. Set up the spectrum analyzer as follows:

Minimum frequency:	0 Hz
Maximum frequency:	10 times discriminator low pass filter cutoff frequency
Resolution bandwidth:	≤10 percent of discriminator low pass filter cutoff frequency
Vertical sensitivity:	10 dB/division

5.10.3.3 Procedure

5.10.3.3.1 Set the signal generator to the following:

Amplitude at input to discriminator: 0.3 Vrms
Frequency: Discriminator center frequency
Peak deviation: Discriminator band edge
Modulating frequency: One half of discriminator low pass filter cutoff frequency

Measure the discriminator full scale signal output level on the spectrum analyzer. Set this level to be near the top of the display and record on data sheet 5.10.1.

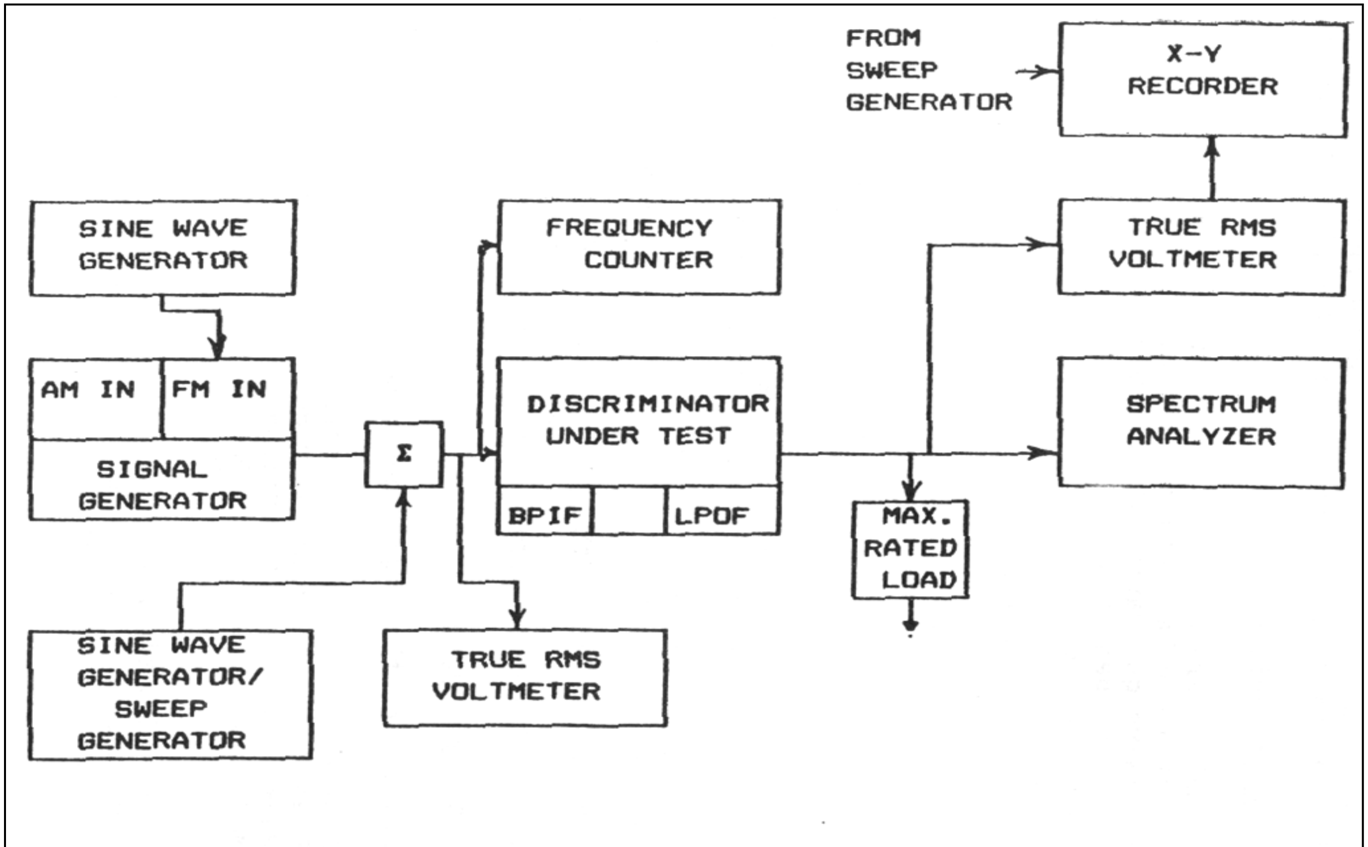


Figure 5.10.1 Test Setup for Out-of-Band Frequency Rejection.

FM DISCRIMINATORS

DATA SHEET 5.10.1

TEST Adjacent Channel or Unwanted Frequency Rejection

MANUFACTURER__________________________ MODEL______________________________

SERIAL NO.____________________________ IRIG CHANNEL ______________________

CHANNEL SELECTOR SERIAL NO.___________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY_________________kHz UPPER BAND EDGE_________________kHz

LOWER BAND EDGE__________________kHz LOW PASS FILTER CUTOFF________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other_________________

TEST PERSONNEL__________________ DATE____________ LOCATION_______________

Full Scale Signal __________dBm

Out-of-Band Frequency At Input	Unwanted Frequency At Discriminator Output		Relative To Full Scale Signal
________kHz	________kHz	______dBm	________dB
________kHz	________kHz	______dBm	________dB
________kHz	________kHz	______dBm	________dB
________kHz	________kHz	______dBm	________dB
________kHz	________kHz	______dBm	________dB
________kHz	________kHz	______dBm	________dB

5.10.3.3.2 Set the sine-wave generator to the following conditions:

Amplitude at input to discriminator: 0.3 Vrms
Frequency: Center frequency of the next adjacent usable channel below discriminator under test
Modulation: Disconnected

Measure the amplitude of any spurious signals in the spectral display and record the frequency and amplitude of these signals on data sheet 5.10.1.

5.10.3.3.3 Repeat step 5.10.3.3.2 with the sine-wave generator set to the following frequencies:

a. The UBE frequency of the adjacent usable channel below discriminator under test.
b. The LBE frequency of the adjacent usable channel above discriminator under test.
c. Center frequency of the adjacent usable channel above discriminator under test.

5.10.3.3.4 Remove the modulation from the signal generator. Set the sine-wave generator to sweep mode and sweep slowly between the following frequencies:

a. The 100 Hz to UBE frequency of the adjacent usable channel below discriminator under test.
b. The LBE frequency of the adjacent usable channel above discriminator under test to 1 MHz.

If any spurious output signals are detected, go to the frequency that caused the problem and record the input frequency, output frequency and level on data sheet 5.10.1. The X-Y recorder can be used to detect spurious signals.

5.10.4 Data Reduction - Subtract the full-scale signal level from each of the out-of-band frequency levels and record under relative column on data sheet 5.10.1 (see data sheet 5.10.1 sample).

FM DISCRIMINATORS

DATA SHEET 5.10.1 (Sample)

TEST Adjacent Channel or Unwanted Frequency Rejection

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ______

CHANNEL SELECTOR SERIAL NO. ______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY 64 kHz UPPER BAND EDGE 68 kHz

LOWER BAND EDGE 60 kHz LOW PASS FILTER CUTOFF 2 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ______

TEST PERSONNEL ______ DATE ______ LOCATION ______

Full Scale Signal -4.3 dBm

Out-of-Band Frequency At Input	Unwanted Frequency At Discriminator Output		Relative To Full Scale Signal
____ kHz	____ kHz	____ dBm	____ dB
____ kHz	____ kHz	____ dBm	____ dB
____ kHz	____ kHz	____ dBm	____ dB
____ kHz	____ kHz	____ dBm	____ dB
____ kHz	____ kHz	____ dBm	____ dB
____ kHz	____ kHz	____ dBm	____ dB

No spurious signals detected.
All spurious signals at least
50 dB below full scale sine wave.

5.11 Pulse Response

5.11.1 Purpose - This test measures the response of the discriminator to an input signal which is modulated by pulses, for example, pulse amplitude modulation (PAM) or pulse code modulation (PCM).

5.11.2 Test Equipment

Signal generator which can be frequency modulated
Square-wave generator
Frequency counter
Oscilloscope
Oscilloscope camera or plotter

5.11.3 Test Method

5.11.3.1 Setup - Connect the test equipment as shown in figure 5.11.1.

5.11.3.2 Conditions - See paragraph 5.0.

5.11.3.3 Procedure

5.11.3.3.1 Frequency modulate the signal generator with a square wave. The square-wave frequency should be equal to 0.1 times the discriminator LPOF cutoff frequency. The peak deviation of the signal generator should be 0.5 times the UBE frequency minus the center frequency of the discriminator. Take a photograph of the oscilloscope display. Measure the rise time, overshoot, and settling time, and record on data sheet 5.11.1.

5.11.3.3.2 Repeat step 5.11.3.3.1 with a peak deviation equal to the UBE frequency minus the center frequency.

5.11.4 Data reduction - Compare the results with the specification (see data sheet 5.11.1 sample).

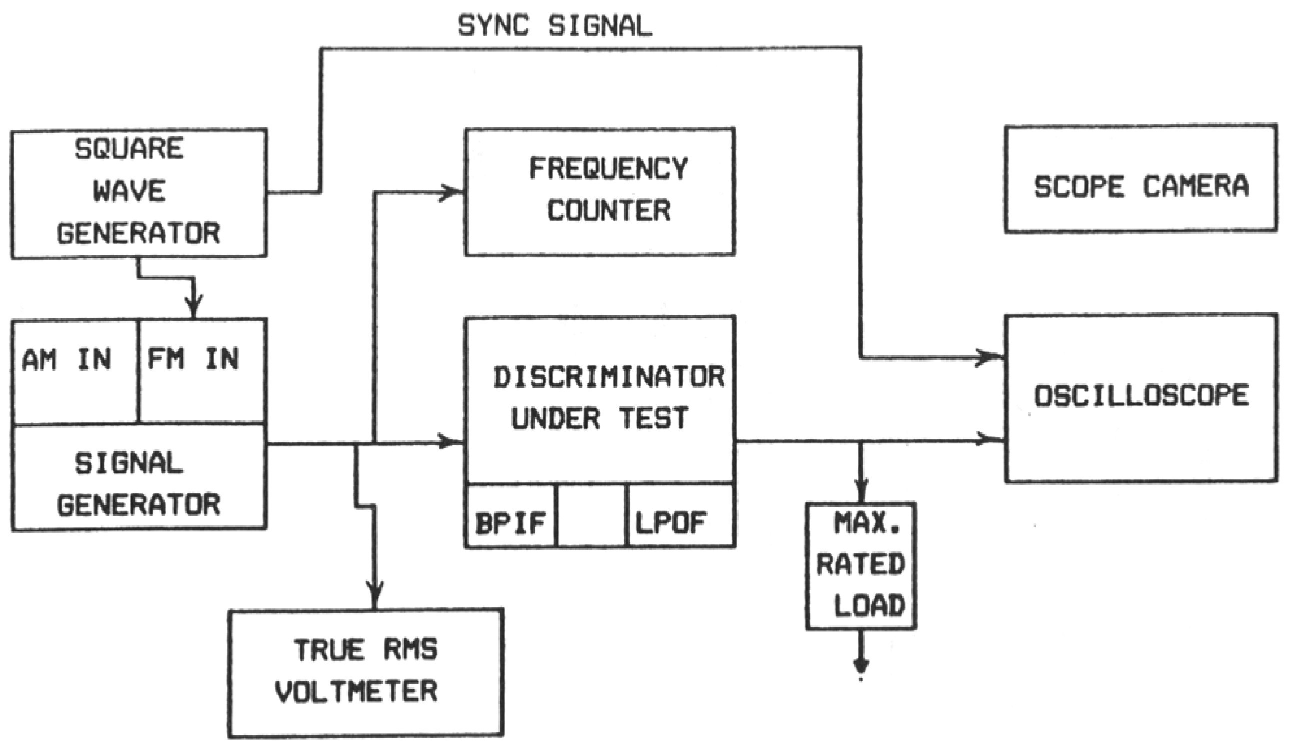


Figure 5.11.1 Test Setup for Pulse Response.

FM DISCRIMINATORS

DATA SHEET 5.11.1

TEST Pulse Response

MANUFACTURER__________ MODEL__________

SERIAL NO.__________ IRIG CHANNEL __________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N __________

CENTER FREQUENCY__________ kHz UPPER BAND EDGE__________ kHz

LOWER BAND EDGE__________ kHz LOW PASS FILTER CUTOFF__________ kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________

TEST PERSONNEL__________ DATE__________ LOCATION__________

Square Wave Frequency	__________ kHz
Peak Deviation	__________ kHz
10 to 90% Rise Time	__________ ms
Overshoot	__________ % of peak-to-peak amplitude
Settling Time to Within 2% of Step	__________ ms
Peak Deviation	__________ kHz
10 to 90% Rise Time	__________ ms
Overshoot	__________ % of peak-to-peak amplitude
Settling Time to Within 2% of Step	__________ ms

ATTACH PHOTO

ATTACH PHOTO

FM DISCRIMINATORS

DATA SHEET 5.11.1 (Sample)

TEST Pulse Response

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ______

CHANNEL SELECTOR SERIAL NO. ______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY 80 kHz UPPER BAND EDGE 84.0 kHz

LOWER BAND EDGE 76.0 kHz LOW PASS FILTER CUTOFF 1.0 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other______

TEST PERSONNEL______ DATE______ LOCATION______

Square Wave Frequency	0.100 kHz
Peak Deviation	4. kHz
10 to 90% Rise Time	0.35 ms
Overshoot	0.8 % of peak-to-peak amplitude
Settling Time to Within 2% of Step	0.600 ms

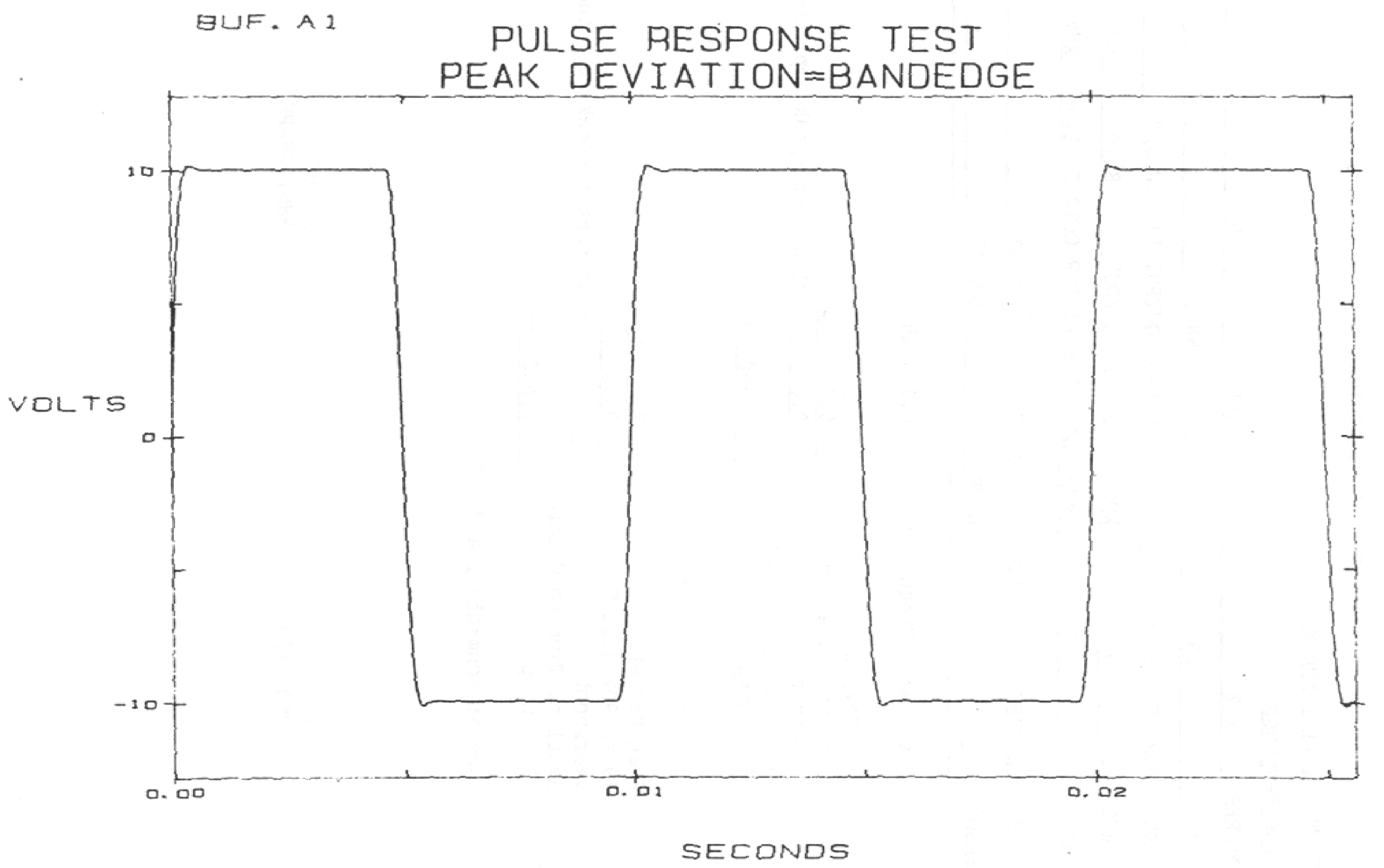
(See attachment 1.)

Peak Deviation	2. kHz
10 to 90% Rise Time	0.35 ms
Overshoot	0.7 % of peak-to-peak amplitude
Settling Time to Within 2% of Step	0.650 ms

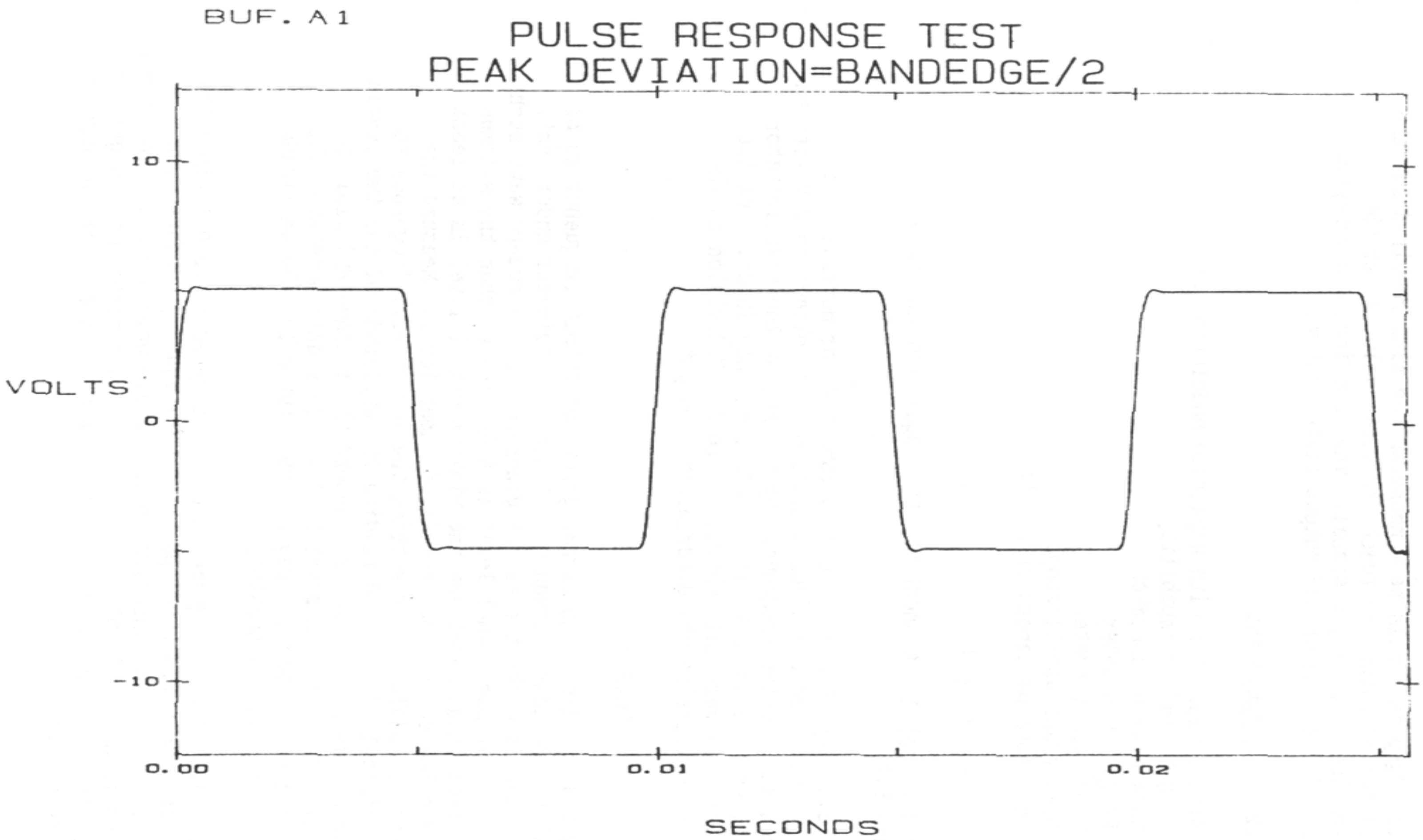
(See attachments 1 and 2.)

ATTACH PHOTOGRAPH

ATTACH PHOTOGRAPH



Data Sheet 5.11.1 (Sample) - Pulse Response Peak Deviation - 4kHz.



Data Sheet 5.11.1 (Sample) - Pulse Response Peak Deviation - 2kHz.

5.12 Acquisition and Settling Time

5.12.1 Purpose -This test measures the time required for the discriminator output to reach its final value after the application of an input signal. The time includes bandpass filter, discriminator and output filter delays.

5.12.2 Test Equipment

Signal generator with amplitude modulation or gate on/off capability
Square-wave generator
Frequency counter
True rms voltmeter
Dual-trace oscilloscope
Oscilloscope camera or plotter

5.12.3 Test Method

5.12.3.1 Setup - Connect the test equipment as shown in figure 5.12.1.

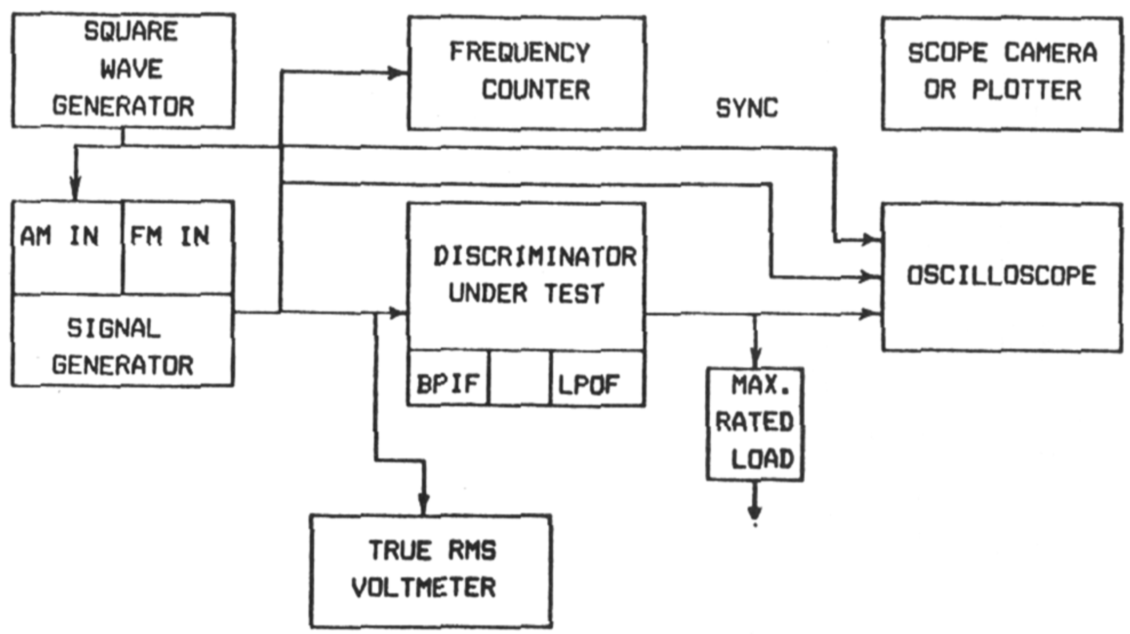


Figure 5.12.1 Test Setup for Acquisition and Settling Time

5.12.3.2 Conditions - See paragraph 5.0 for general test conditions. Set the discriminator output voltage to 0 V with an unmodulated center frequency input. Adjust the discriminator output voltage to +5 V with an UBE frequency input. Set the oscilloscope vertical sensitivity to 0.1 V/division on the channel monitoring the discriminator output.

5.12.3.3 Procedure
5.12.3.3.1 Adjust the signal generator output frequency to be equal to the center frequency of the discriminator under test. Amplitude modulate the signal generator with a square wave such that

the maximum signal level is 6 dB greater than the minimum specified input level and the minimum signal level is at least 20 dB below the minimum specified input level. Measure the amplitude modulation by setting the square wave frequency to approximately 0.1 Hz and reading the amplitude of the two levels using a true rms voltmeter. Record the maximum and minimum signal levels on data sheet 5.12.1. (A signal generator which can be gated on and off may be substituted for the amplitude modulated signal generator).

5.12.3.3.2 Set the square wave frequency equal to 0.1 times the discriminator output low pass filter frequency. Adjust the oscilloscope to synchronize on the square wave signal. Photograph the oscilloscope display. Measure the time between the signal going to the high input level state and the discriminator output Figure 5.12.1 settling to within one vertical division (1 percent of peak-to-peak output voltage swing) of its final value. The square wave frequency and oscilloscope horizontal time base may have to be adjusted to obtain the desired accuracy. A sample oscilloscope display is shown in figure 5.12.2. Record the results on data sheet 5.12.1.

5.12.4 Data Reduction - Compare the results with the specification (see data sheet 5.12.1 sample).

FM DISCRIMINATORS

DATA SHEET 5.12.1

TEST Acquisition and Settling Time

MANUFACTURER________________________ MODEL________________________

SERIAL NO.________________________ IRIG CHANNEL ________________________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY________________kHz UPPER BAND EDGE________________kHz

LOWER BAND EDGE________________kHz LOW PASS FILTER CUTOFF__________kHz

LOW PASS FILTER TYPE: [ ] CA [ ] CD [ ] Other________________

TEST PERSONNEL________________ DATE____________ LOCATION______________

Signal Generator Levels With Amplitude Modulation

Input to discriminator

Maximum_______mVrms

Minimum_______mVrms

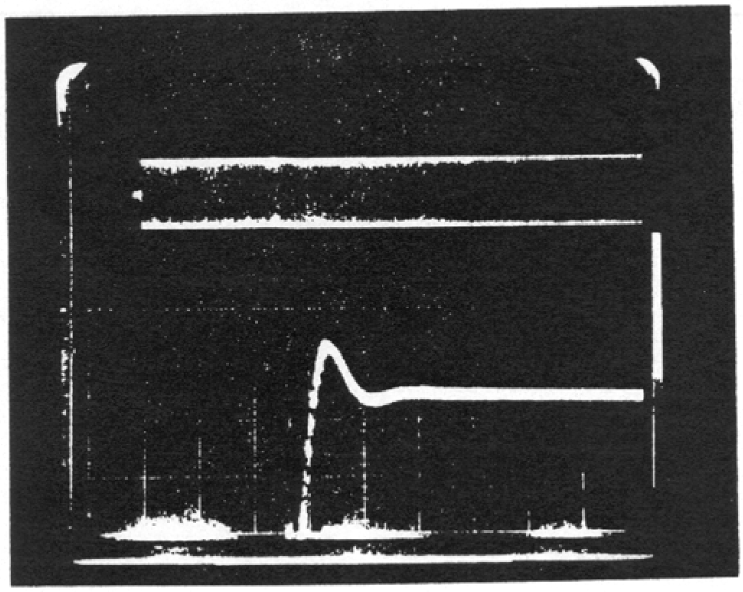


Figure 5.12.2 Photograph of Oscilloscope Display for Acquisition and Settling Time Test.

Center Frequency: 128 kHz
Bandpass Filter Bandwidth: 8 kHz
Low Pass Filter Bandwidth: 4 kHz
Horizontal Sensitivity: 0.1 ms/major division
Settling time to within 1% of full scale: 0.36 ms
Final value: 2 major divisions up from bottom of display

FM DISCRIMINATORS

DATA SHEET 5.12.1 (Sample)

TEST Acquisition and Settling Time

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 64 kHz UPPER BAND EDGE 68 kHz

LOWER BAND EDGE 60 kHz LOW PASS FILTER CUTOFF 2 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

Signal Generator Levels With Amplitude Modulation

Input to discriminator

Maximum 20. mVrms

Minimum 0.2 mVrms

5.13 Data Frequency Response

5.13.1 Purpose - This test measures the data frequency response of an FM discriminator.

5.13.2 Test Equipment

Audio oscillator (sine wave)
Signal generator or voltage controlled oscillator which can be frequency modulated
Frequency counter
Oscilloscope
Voltmeters, rms, 2 required
Spectrum analyzer
Wave analyzer (optional)

5.13.3 Test Method

5.13.3.1 Setup - Connect the test equipment as shown in figure 5.13.1.

5.13.3.2 Conditions - See paragraph 5.0 for general test conditions. The signal generator should be set to the following:

Output frequency = discriminator center frequency
Output amplitude = 0.3 Vrms
The discriminator output should be set to 0V dc with an unmodulated center frequency input.

5.13.3.3 Procedure

5.13.3.3.1 The first step in this procedure will be to set the signal generator peak deviation equal to the (UBE frequency – center frequency) of the discriminator.

NOTE

The Bessel null method is described here. Other methods of setting the peak deviation may be used if desired.

Set the audio oscillator frequency to the desired peak deviation/2.405 (first Bessel carrier null). Decrease the audio oscillator amplitude to a minimum. Slowly increase the amplitude until the first carrier null is observed on the spectrum analyzer.

Measure this amplitude using the rms voltmeter and record on data sheet 5.13.1. Increase the audio oscillator frequency until it is equal to the peak deviation. Measure the difference (in dB) between the modulated carrier amplitude and the amplitudes of the first sideband pair. This difference should be 4.8 dB (sidebands lower than modulated carrier). If both sidebands are not between 4.3 and 5.3 dB lower than the modulated carrier, the frequency response of the signal generator is not adequate for this test, and a different signal generator or voltage controlled oscillator must be used.

5.13.3.3.2 Set the audio oscillator frequency to one-tenth of the discriminator low pass filter cutoff frequency. Adjust the audio oscillator amplitude to be equal to the value determined in step 5.13.3.3.1, that is, the value which results in the desired peak deviation. Measure the discriminator output on the rms voltmeter and record on data sheet 5.13.1.

5.13.3.3.3 Set the audio oscillator to the frequencies listed on data sheet 5.13.1 while maintaining the output amplitude constant. The highest audio oscillator frequency will be equal to four times the discriminator low-pass filter cutoff frequency. Measure and record the discriminator output on data sheet 5.13.1 for each frequency.

5.13.4 Data Reduction - Subtract the discriminator output amplitude (in dB) at one-tenth the low-pass filter cutoff frequency from the amplitude at each of the other frequencies. Record on data sheet 3.1 (see data sheet 5.13.1 sample).

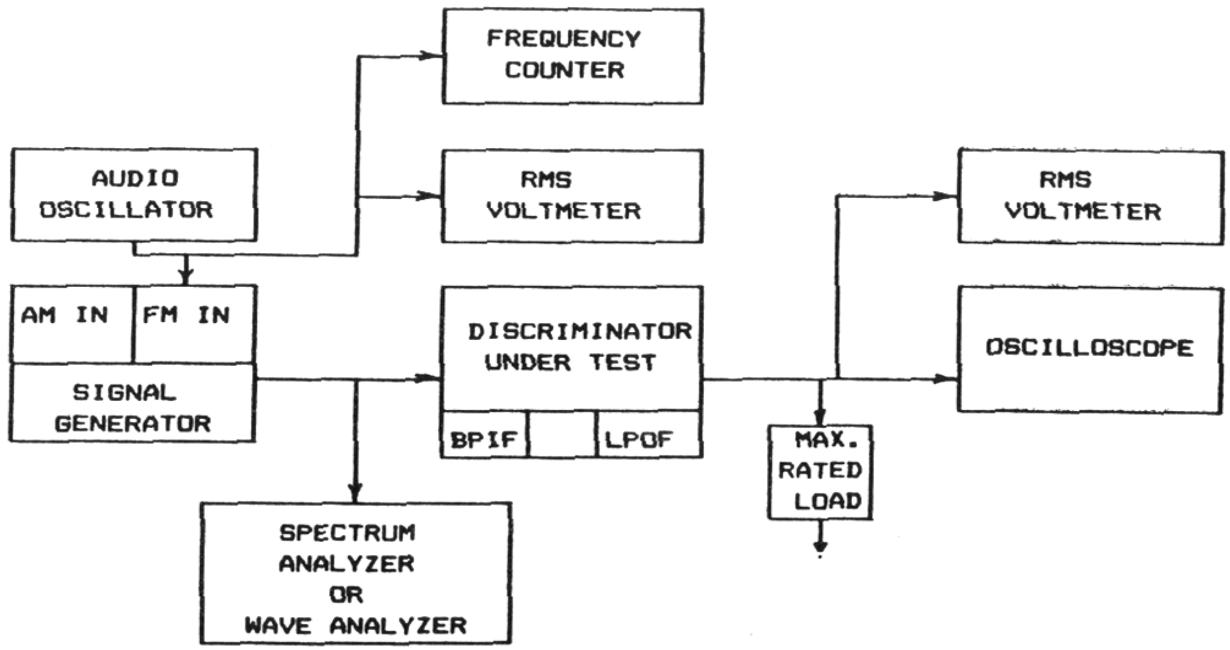


Figure 5.13.1 Test Setup for Data Frequency Response.

FM DISCRIMINATORS

DATA SHEET 5.13.1

TEST Data Frequency Response

MANUFACTURER____________ MODEL____________

SERIAL NO.____________ IRIG CHANNEL ____________

CHANNEL SELECTOR SERIAL NO.______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY__________ kHz UPPER BAND EDGE__________ kHz

LOWER BAND EDGE__________ kHz LOW PASS FILTER CUTOFF______ kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________

TEST PERSONNEL__________ DATE________ LOCATION__________

Rms voltage at FM input of the signal generator ______Vrms

% of LPOF Cutoff Frequency	Frequency(Hz)	Discriminator Output Amplitude (dBm)	Discriminator Relative Amplitude (dB)
10			0
40			
70			
100			
200			
300			
400			

FM DISCRIMINATORS

DATA SHEET 5.13.1 (Sample)

TEST Data Frequency Response

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 64 kHz UPPER BAND EDGE 68 kHz

LOWER BAND EDGE 60 kHz LOW PASS FILTER CUTOFF 2.0 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

Rms voltage at FM input of the signal generator 0.641 Vrms

% of LPOF Cutoff Frequency	Frequency (Hz)	Discriminator Output Amplitude (dBm)	Discriminator Relative Amplitude (dB)
10	200	29.05	0
40	800	28.50	-0.55
70	1400	27.28	-1.77
100	2000	25.3	-3.75
200	4000	11.72	-17.33
300	6000	-6.89	-35.94
400	8000	-23.09	-52.14

5.14 Tape Speed Compensation

5.14.1 Purpose - This test measures the performance of the tape speed compensation (TSC) circuitry in an FM demodulation system.

NOTE

A reference discriminator and associated delay line are needed to perform this test.

5.14.2 Test Equipment

Two stable signal generators with FM inputs
Reference discriminator and delay line
Baseband spectrum analyzer X-Y recorder
Baseband frequency sweep generator
Oscilloscope (preferably with dual trace)

5.14.3 Test Method

5.14.3.1 Setup - Connect the test equipment as shown in figure 5.14.1.

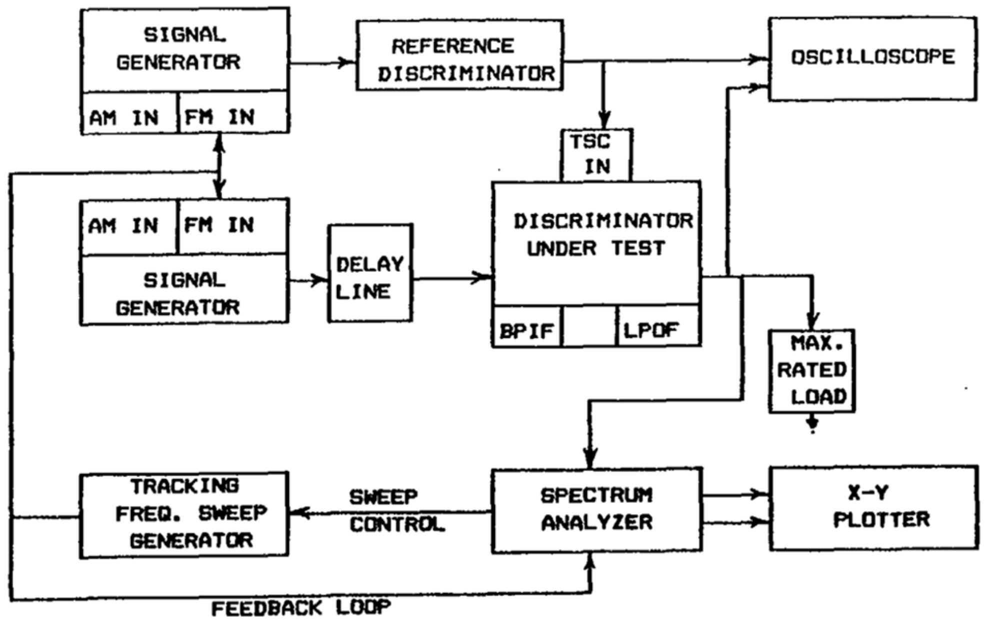


Figure 5.14.1 Test Setup for Tape Speed Compensation Test

5.14.3.2 Conditions - Disconnect the baseband frequency sweep generator from the inputs of the signal generators. Set the output frequency of the signal generator driving the reference discriminator to the center frequency of the reference discriminator and the output frequency of the signal generator driving the discriminator under test to the center frequency of the discriminator under test. While monitoring the outputs of the discriminators, vary the output of each signal generator ±3 percent of the center frequency and note the positions of the trace on the oscilloscope. Set the signal generators back to the respective center frequencies and reconnect the baseband frequency sweep generator. Adjust the output level so that the peaks of the output signals from the discriminators are at the trace positions noted earlier. A voltage divider may be needed on the FM input of the most sensitive of the two signal generators to create an equal, percent deviation sensitivity on both signal generators. The spectrum analyzer should be set up to the following conditions:

Start Frequency:	Between 0 Hertz and discriminator low pass filter cutoff frequency/100
Stop Frequency:	Discriminator low-pass filter cutoff frequency.
Resolution bandwidth:	Less than or equal to stop frequency/100
Vertical scale:	10 dB/division
Sweep rate:	If the baseband frequency sweep generator cannot track the sweep of the spectrum analyzer, set the sweep period to 100 times that of the baseband frequency sweep generator

Set up the baseband frequency sweep generator to the same start and stop frequencies as the spectrum analyzer.

5.14.3.3 Procedure

5.14.3.3.1 Disconnect the TSC input from the discriminator under test. With the equipment under operation, set the trace on the spectrum analyzer to the reference level of the log scale while measuring the power spectrum of the output of the test discriminator. (If the frequency sweep generator is tracking the spectrum analyzer, this trace will be a continuous line. If the sweep rates are not tracking and are set up in a 1 to 100 ratio as described in subparagraph 5.14.3.2, the trace will be about 100 evenly spaced discrete frequency peaks.)

5.14.3.3.2 Reconnect the TSC input to the discriminator under test and record the spectrum on the X Y recorder This trace will be the level attenuation versus tape speed variation frequency for the TSC.

5.14.4 Data Reduction - Note the dB level below the reference level at 10 evenly spaced points along the curve positioned to pick up both the best and worst case frequencies in the discriminator's bandwidth. Record the approximate frequency and amplitude levels an data sheet 5.14.1 (see data sheet 5.14.1 sample).

5.14.5 Measurement Variation - The baseband frequency sweep generator and spectrum analyzer may be replaced with a baseband frequency response level measuring set for this test.

FM DISCRIMINATORS

DATA SHEET 5.14.1

TEST Tape Speed Compensation

MANUFACTURER________________________ MODEL____________________________

SERIAL NO.__________________________ IRIG CHANNEL ______________________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY________________kHz UPPER BAND EDGE______________kHz

LOWER BAND EDGE_________________kHz LOW PASS FILTER CUTOFF________kHz

LOW PASS FILTER TYPE: [ ] CA [ ] CD [ ] Other________________

TEST PERSONNEL________________ DATE____________ LOCATION______________

Reference Oscillator Frequency______________kHz

Reference Discriminator Model______________ Serial No.________________

Delay Line Model ___________________________ Serial No.________________

Frequency (Hz)	TSC Improvement (dB)
______________	____________________
______________	____________________
______________	____________________
______________	____________________
______________	____________________
______________	____________________
______________	____________________
______________	____________________
______________	____________________
______________	____________________

FM DISCRIMINATORS

DATA SHEET 5.14.1 (Sample)

TEST Tape Speed Compensation

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ______

CHANNEL SELECTOR SERIAL NO. ______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY 70 kHz UPPER BAND EDGE 75.25 kHz

LOWER BAND EDGE 64.75 kHz LOW PASS FILTER CUTOFF 1.05 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ______

TEST PERSONNEL ______ DATE ______ LOCATION ______

Reference Oscillator Frequency 100 kHz

Reference Discriminator Model ______ Serial No. ______

Delay Line Model ______ Serial No. ______

Frequency (Hz)	TSC Improvement (dB)
100	31
200	24
300	20
400	18
500	16
600	14
700	13
800	12
900	11
1000	10

5.15 Discriminator Phase Response

5.15.1 Purpose - This test determines phase response characteristics of a discriminator including bandpass input and LPOF. This test should be of value where phase distortion or nonlinearity is the cause of data quality or phase-related processing problems.

5.15.2 Test Equipment

5.15.2.1 For Procedure 1 - Incremental Method

Audio oscillator
Oscilloscope with dual trace or phase meter
Voltage-controlled signal generator without filter
Frequency counter

5.15.2.2 For Procedure 2 - Quick-Look Spectral Method

White noise generator
Voltage-controlled signal generator without filter
Dual-channel spectrum analyzer with transfer function and display and plotting capability

5.15.3 Test Method

5.15.3.1 Procedure 1 - Incremental Method

This method involves measuring delay through the discriminator as a function of intelligence frequency. The delay may be measured using either an oscilloscope or a phase meter.

5.15.3.1.1 Setup 1

Connect equipment as shown in figure 5.15.1.

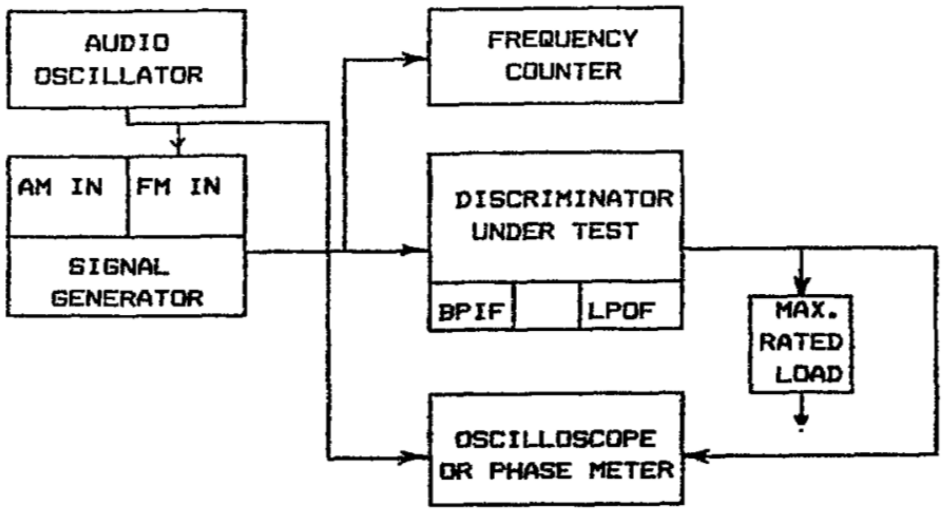


Figure 5.15.1 Test Setup for Discriminator Phase Response

5.15.3.1.2 Condition 1

Both procedures 1 and 2 depend on negligible relative contribution to phase nonlinearity by the signal generator. This condition is ensured only through use of a small, central, highly linear portion of the signal generator range, and both procedures are, therefore, less valid for large percentage deviation cases. The discriminator should already be set for 0 V out at center frequency and a nominal band edge voltage appropriate for the unit under test.

5.15.3.1.3 Procedure 1

5.15.3.1.3.1 Set the audio oscillator frequency equal to the discriminator UBE frequency minus the center frequency. Set the audio oscillator amplitude to produce a band-edge-to-band-edge deviation of the signal generator. This procedure produces a signal with a modulation index equal to one. The two traces on the oscilloscope are the audio oscillator output and the discriminator output. The delay of the discriminator output relative to the audio oscillator output is the quantity being measured.

5.15.3.1.3.2 Measure the time difference between the zero crossings of the two traces and record on data sheet 5.15.1 (see data sheet 5.15.1 sample). Repeat for other modulation frequencies as desired. (Modulation frequencies of 0.25, 0.5, 0.75, and 1 times the peak deviation provide a reasonable data base for most applications.) This test may be repeated for other peak deviations as desired.

5.15.3.2 Quick-look Spectral Method (Procedure-2)

This method involves using a dual-channel spectrum analyzer/display to observe the phase response curve given a white noise driven signal generator as input to the discriminator.

5.15.3.2.1 Setup 2 - Connect equipment as shown in figure 5.15.2.

5.15.3.2.2 Condition 2

This method uses a dual channel spectrum analyzer with phase response plotting capability. Resolution/accuracy of phase measurement will depend on dynamic range, numerical cursor readout availability, and other features of a given analyzer. The discriminator should already be set for 0 V output at center frequency and a nominal band edge voltage appropriate for the unit under test.

5.15.3.2.3 Procedure 2

Use one channel of the dual-channel analyzer on the input to the signal generator and the second channel on the discriminator output. Select the phase portion of transfer function or cross-spectral mode of the analyzer. Adjust analyzer gain and white-noise amplitude to avoid overrange or saturation. If necessary to avoid saturation, low-pass filter the white noise prior to the signal generator. Any prefiltering of the signal generator input must be wider than the LPOF in use and have linear phase characteristics. Select a frequency analysis range greater than that of the discriminator LPOF in use. Observe and hard copy the phase versus frequency plot and attach to data sheet 5.15.2.

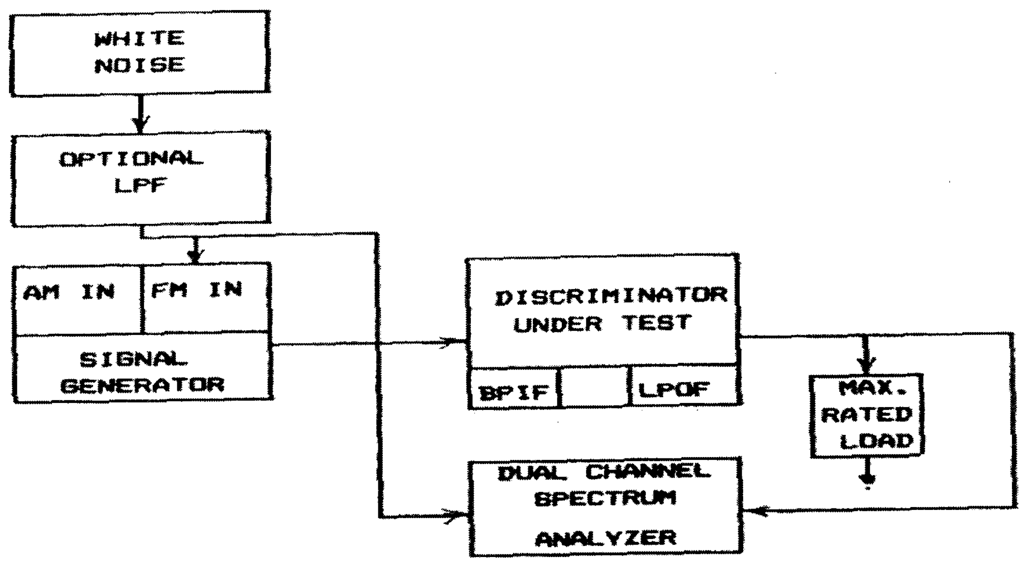


Figure 5.15.2 Test Setup for Discriminator Phase Response (Procedure 2).

FM DISCRIMINATORS

DATA SHEET 5.15.1

TEST Discriminator Phase Response (Procedure 1)

MANUFACTURER____________ MODEL____________

SERIAL NO.____________ IRIG CHANNEL ____________

CHANNEL SELECTOR SERIAL NO.________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY____________ kHz UPPER BAND EDGE____________ kHz

LOWER BAND EDGE____________ kHz LOW PASS FILTER CUTOFF________ kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other____________

TEST PERSONNEL____________ DATE________ LOCATION____________

Frequency at Signal Generator Input = f_i	Modulation Index (Peak Dev./ f_i)	Delay (D) Measured with Oscilloscope	Relative Phase Angle (Degrees) (=360xDxf_i)
	1.0		

FM DISCRIMINATORS

DATA SHEET 5.15.1 (Sample)

TEST Discriminator Phase Response (Procedure 1)

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 128 kHz UPPER BAND EDGE 132 kHz

LOWER BAND EDGE 124 kHz LOW PASS FILTER CUTOFF 4 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

Frequency at Signal Generator Input = f_i	Modulation Index (Peak Dev./ f_i)	Delay (D) Measured with Oscilloscope	Relative Phase Angle (Degrees) (=360xDxf_i)
4 kHz	1.0	207 us	298.1
3	1.33	207	223.6
2	2	207	149.
1	4	207	74.5
2	1	207	149.

FM DISCRIMINATORS

DATA SHEET 5.15.2

TEST Discriminator Phase Response (Procedure 2)

MANUFACTURER____________________ MODEL____________________

SERIAL NO.____________________ IRIG CHANNEL ____________________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N ________

CENTER FREQUENCY________________kHz UPPER BAND EDGE________________kHz

LOWER BAND EDGE________________kHz LOW PASS FILTER CUTOFF________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other________________

TEST PERSONNEL________________ DATE__________ LOCATION____________

Signal Generator____________________ Spectrum Analyzer____________________

White Noise Generator____________________

Attach spectral plots with full annotation.

NOTE

Procedure 2 does not involve incremental point collection but provides an immediate response curve picture. The technique used is the same as plotting the transfer function or phase characteristic, or both, of a filter. In this case, the signal generator discriminator combination is the "filter" under test.

5.15.4 Data Reduction

5.15.4.1 Procedure 1 (see data sheet 5.15.1)

The data in tabular form consists of an independent variable (frequency) and a dependent variable (delay). These variables should be plotted on a large enough scale to show phase nonlinearity (non-constant delay) to the degree required. Delay may be converted to phase angle and entered on the last data sheet column. Convert delay to angle by multiplying the delay value by the frequency of the audio oscillator sine wave times 3600 (see data sheet 5.15.1 sample) .

5.15.4.2 Procedure 2 - The analyzer provides the phase versus frequency plot directly. These graphics should be attached to data sheet 5.15.2 (see data sheet 5.15.2 sample).

FM DISCRIMINATORS

DATA SHEET 5.15.2 (Sample)

TEST Discriminator Phase Response (Procedure 2)

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL 10

CHANNEL SELECTOR SERIAL NO. ______ LOW PASS OUTPUT FILTER S/N ______

CENTER FREQUENCY 5.400 kHz UPPER BAND EDGE 5.805 kHz

LOWER BAND EDGE 4.995 kHz LOW PASS FILTER CUTOFF 0.081 kHz

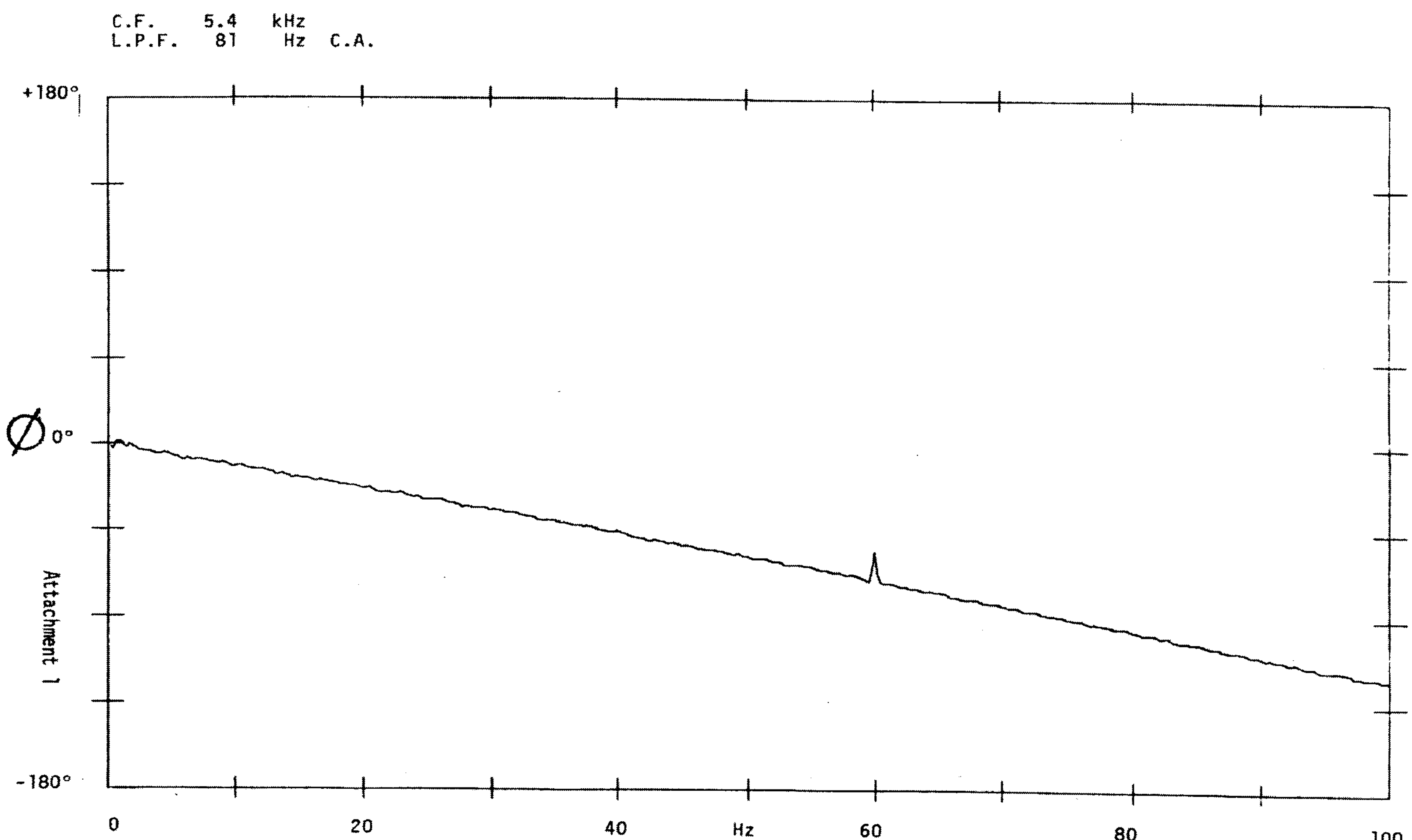
LOW PASS FILTER TYPE: [X] CA [X] CD [ ] Other ______

TEST PERSONNEL ______ DATE ______ LOCATION ______

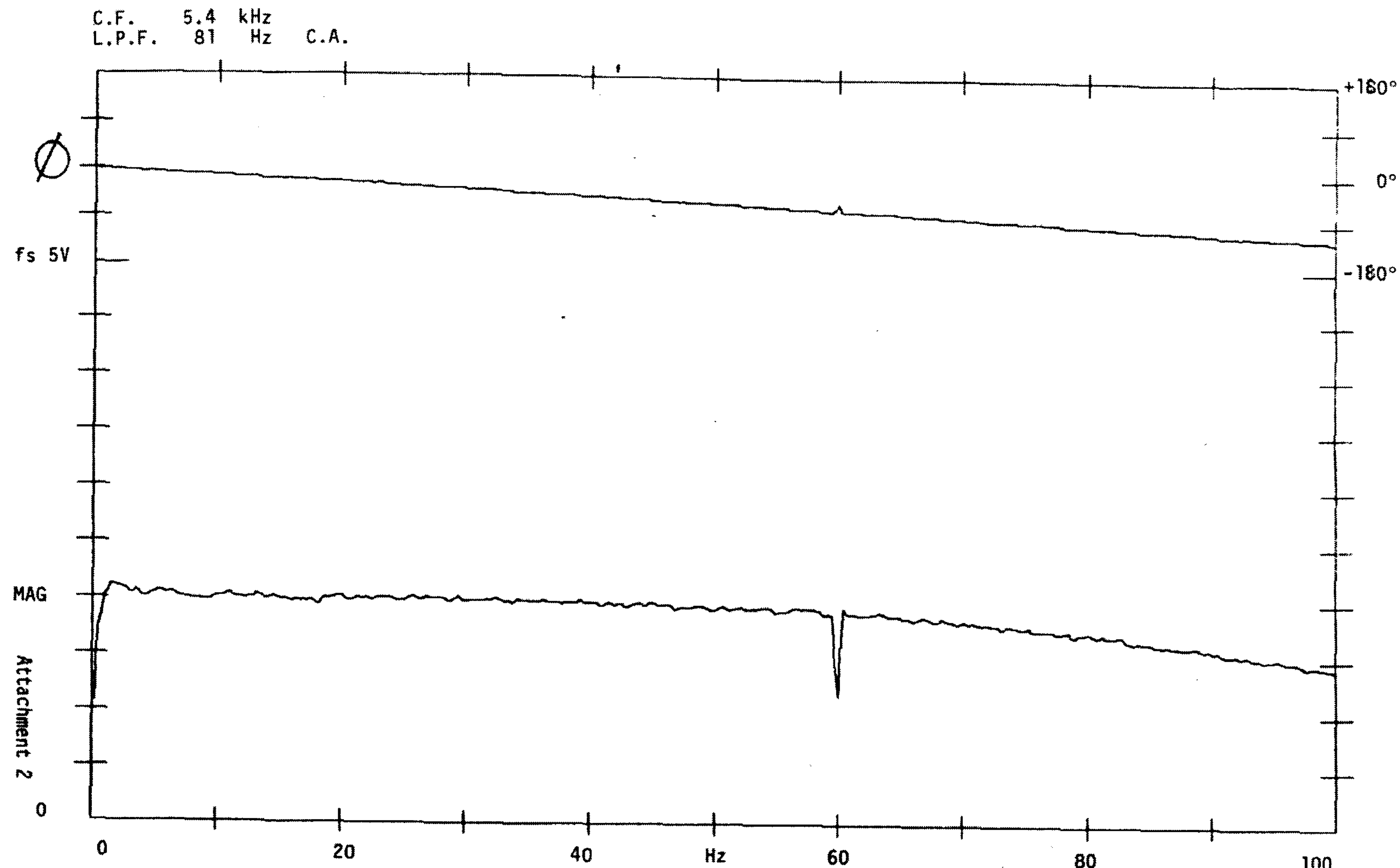
Signal Generator LMN Spectrum Analyzer OPH

White Noise Generator RST

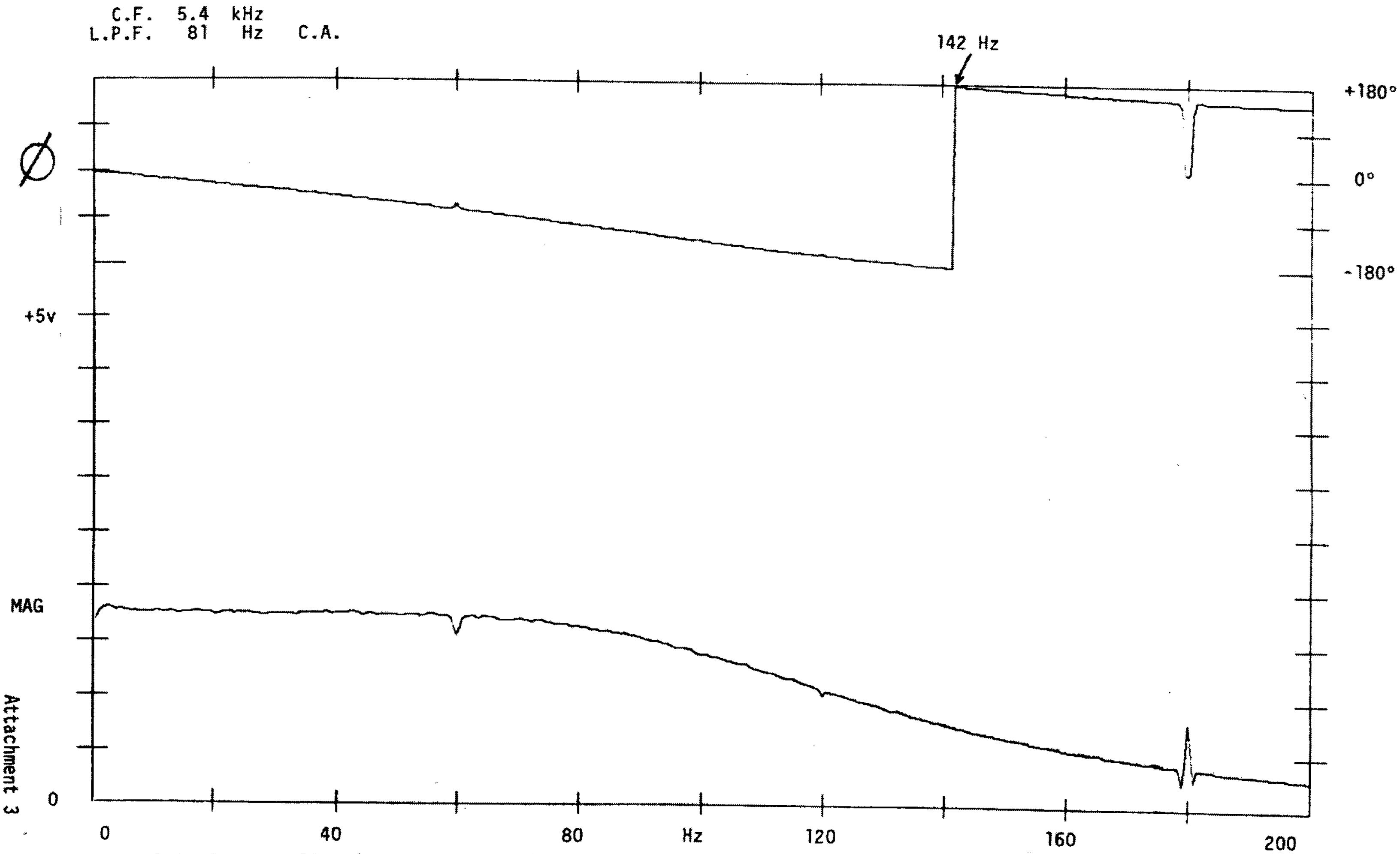
(See attachments 1 through 6.)



Data Sheet 5.15.2 (Sample Number 1) (60Hz Noise) - Constant Amplitude Phase Response.

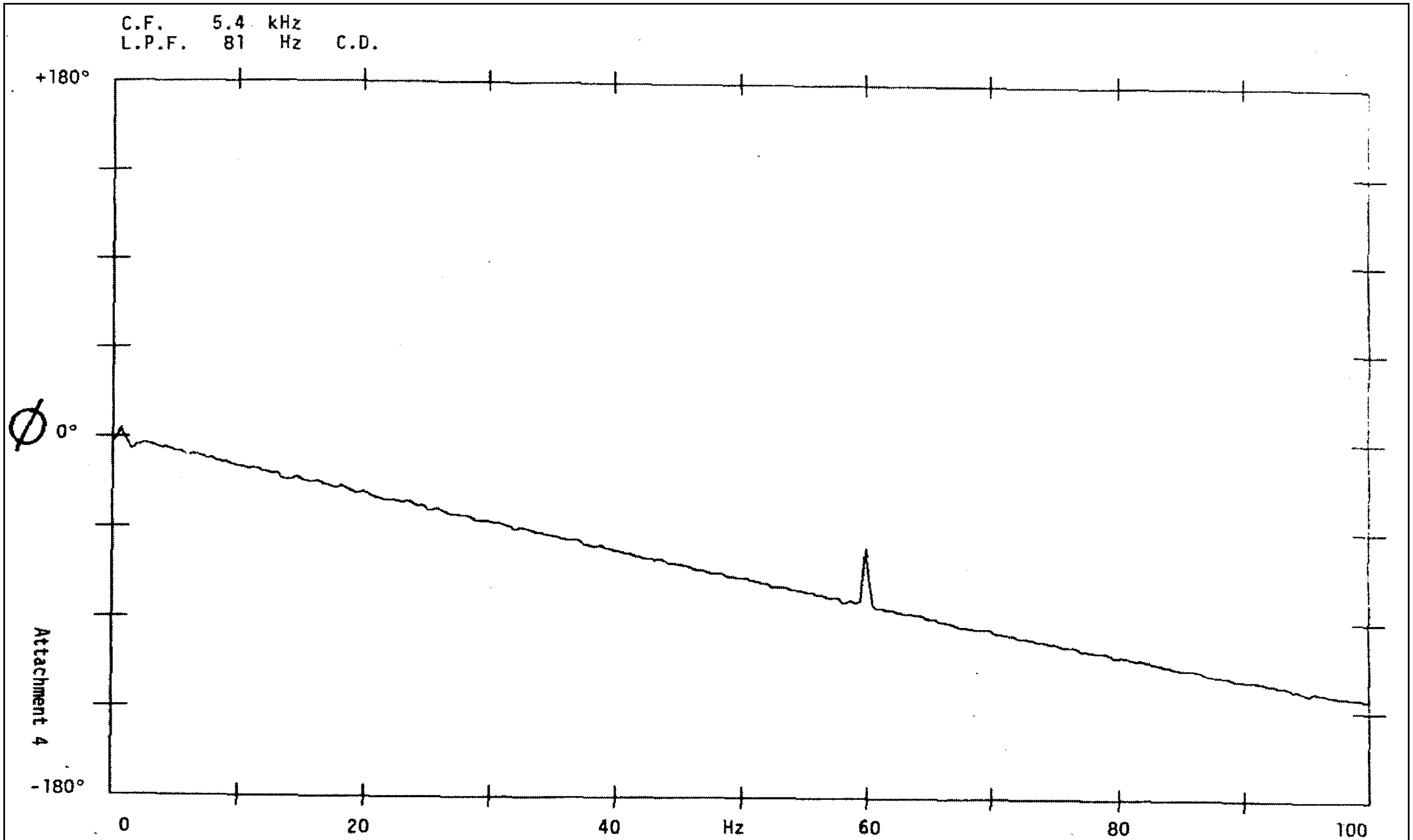


Data Sheet 5.15.2 (Sample Number 2) - Constant Amplitude Phase and Amplitude Response.

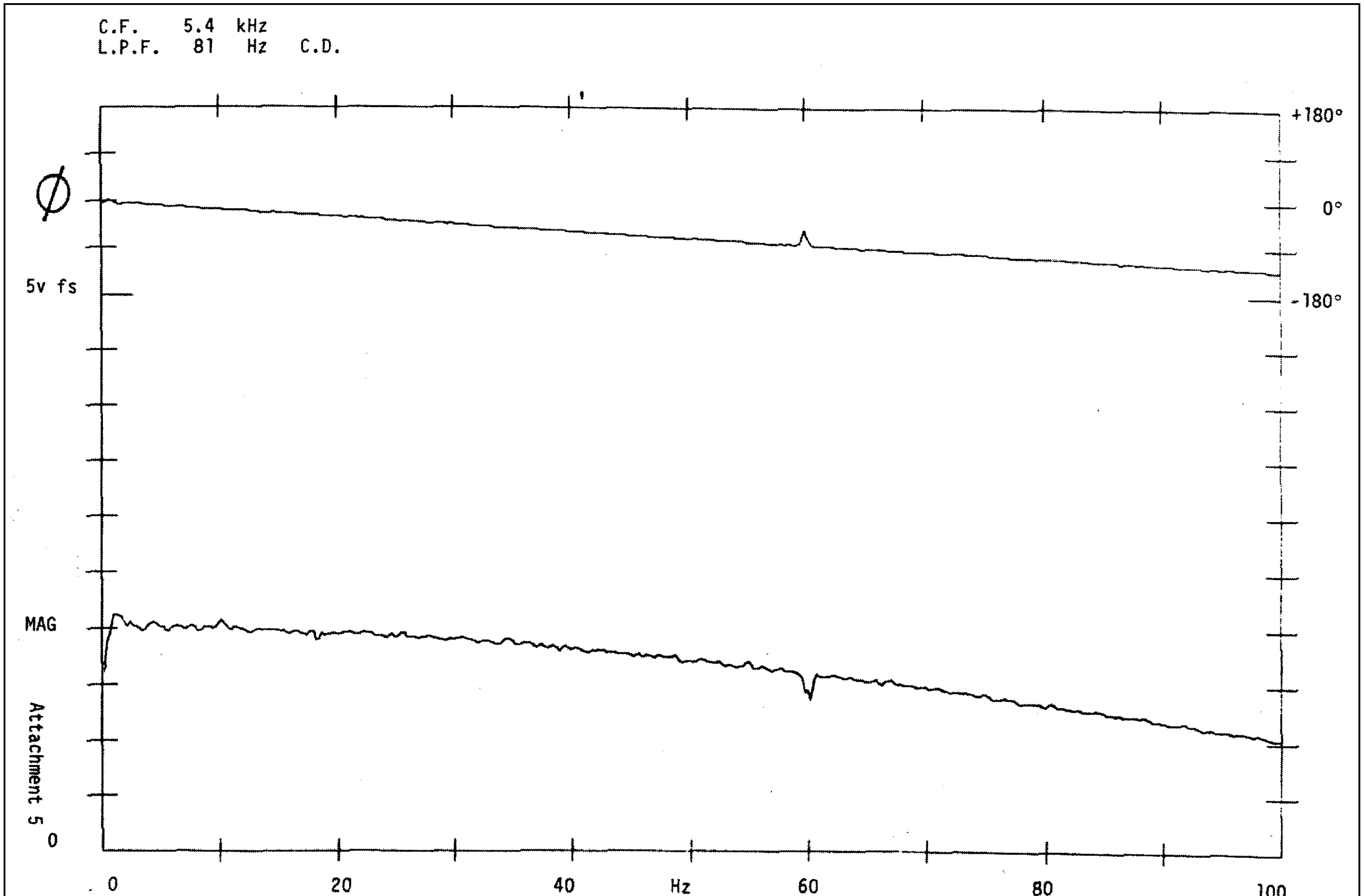


Data Sheet 5.15.2 (Sample Number 3) - Phase and Amplitude Response (Wider Frequency Scale).

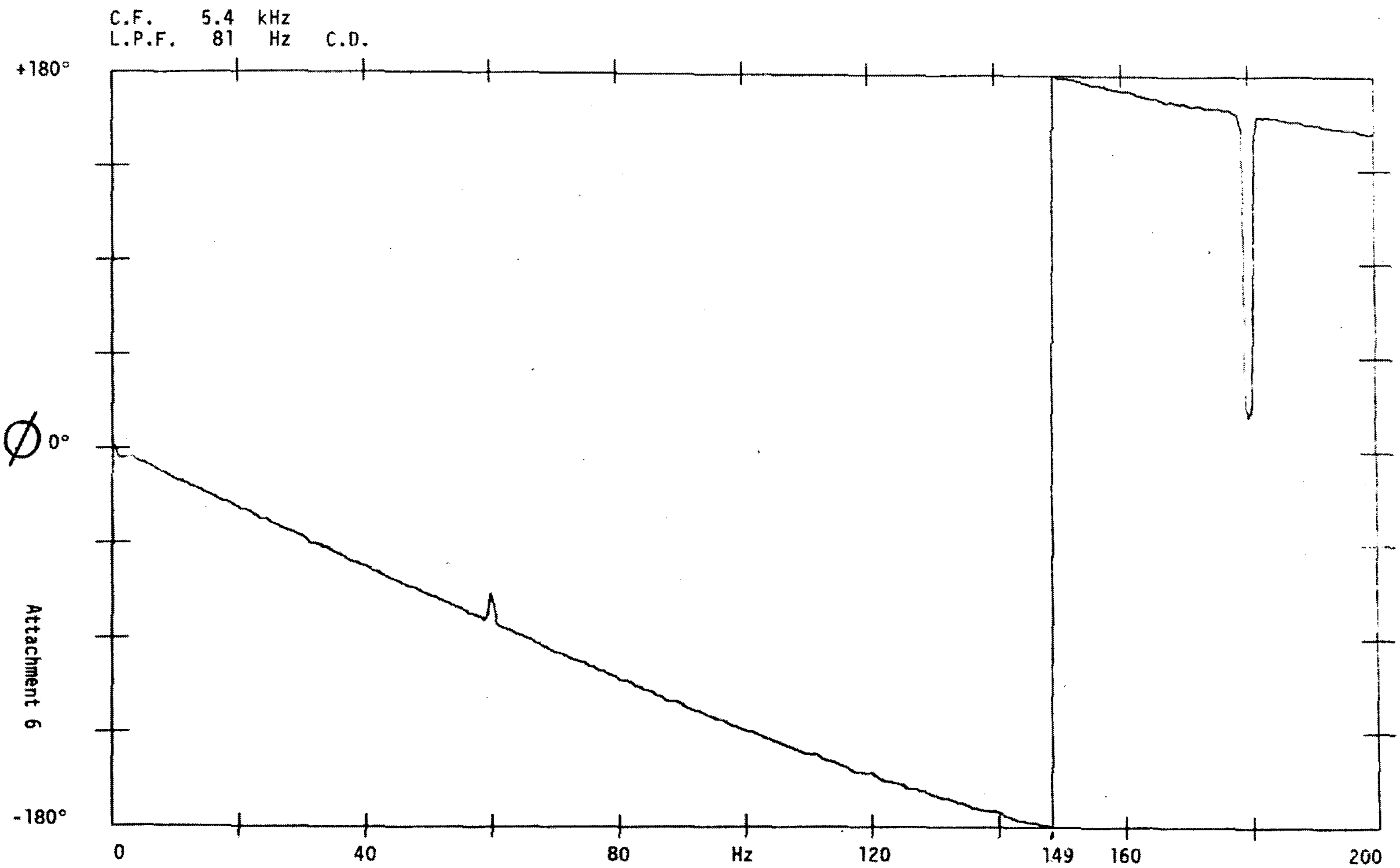
Attachment 3



Data Sheet 5.15.2 (Sample Number 4) - Constant Delay Phase Response.



Data Sheet 5.15.2 (Sample Number 5) - Phase and Amplitude Response.



Data Sheet 5.15.2 (Sample Number 6) - Phase Response (Wide Frequency Scale).

5.16 Two Tone Intermodulation Test

5.16.1 Purpose - This test permits the measurement of distortion produced in a subcarrier discriminator independent of the harmonic distortion present in the modulation source or produced in the FM modulated signal generator. The results of this test will indicate the effects of significant phase nonlinearities of the channel selectors (BPIF) which are generally the cause of increased distortion with higher modulation frequencies.

5.16.2 Test Equipment

- Audio oscillator (modulation sources) (2)
- Signal generators (2)
- Double balanced mixer
- Spectrum (or wave) analyzer
- Oscilloscope

5.16.3 Test Method

5.16.3.1 Setup - Connect the test equipment as shown in figure 5.16.1.

5.16.3.2 Conditions

5.16.3.2.1 Warm up all equipment according to specifications.

5.16.3.2.2 Maximize output load according to specifications.

5.16.3.3 Procedure

5.16.3.3.1 Install LPOF in discriminator to reflect a deviation ratio of one or less if available. Cutoff frequency of LPOF is equal to the peak deviation of the subcarrier channel under test.

5.16.3.3.2 Calibrate the discriminator/oscilloscope setup at the subcarrier channel deviation limits, adjust the center frequency of the signal generators and the level of the modulation sources to produce an indication on the oscilloscope that has an envelope shaped like a sine overlaying a minus sine wave. In addition, the crests of the signal observed should extend to the subcarrier channel edges. Under this condition, the input signal is being equally deviated by each of the modulating signals and the peak deviation of the composite modulation is the rated deviation of the channel. For this initial setup, modulation frequencies (f_1 and f_2) of 20 and 25 percent of the LPOF frequencies are recommended.

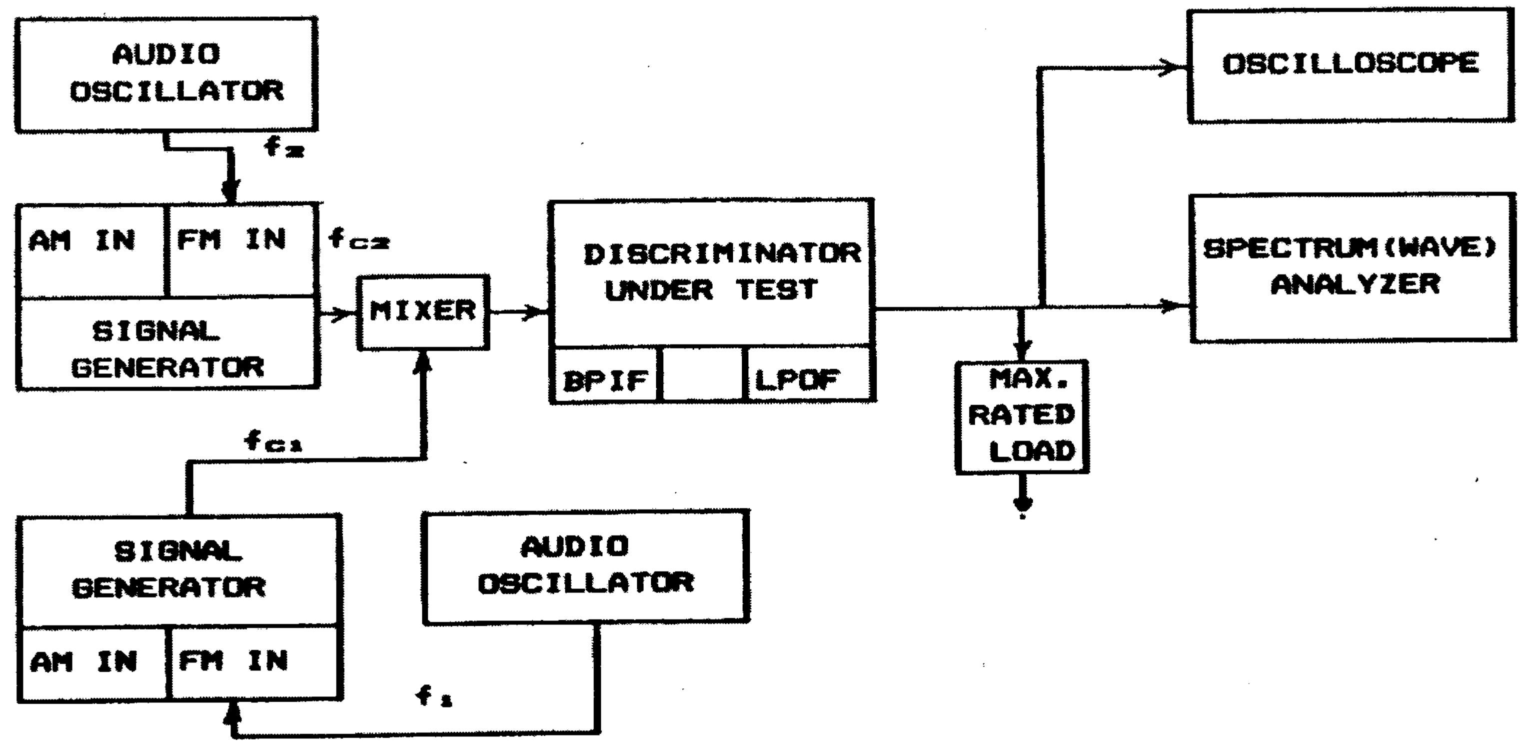


Figure 5.16.1 Test Setup for Two Tone Intermodulation Test.

NOTE

The center frequencies of the signal generators (f_{c1} and f_{c2}) shall be set such that their difference ($f_{c1}–f_{c2}$) is equal to the discriminator center frequency.

The output of the double balanced mixer shall be set to 0.3 Vrms.

An alternate modulated signal source is a single FM signal generator modulated by the composite of the two tones (f, and f2) that have been linearly summed. This approach may be limited by the intermodulation products in the input signal to the discriminator.

5.16.3.3.3 Adjust the spectrum (wave) analyzer to individually measure the level of the two modulation frequencies. Record these levels on data sheet 5.16.1.

5.16.3.3.4 Measure and record the level of the intermodulation (IM) component located at the difference frequency ($f_2–f_1$).

5.16.3.3.5 Measure and record any IM components located at $2f_l–f_2$ and $2f_2–f_l$.

5.16.3.3.6 Increase the modulation frequencies to 80 and 90 percent of the LPOF frequencies and repeat steps 5.16.3.3.3 through 5.16.3.3.5.

5.16.4 <u>Data Reduction</u> - Express the IM in percentage or in dB with respect to the desired modulation levels (see data sheet 5.16.1 sample).

NOTE

The IM to modulation ratio of the difference frequency product ($f_2–f_1$) normally varies as the square of the modulation levels, whereas the $2f_1–f_2$ and $2f_2–f_l$ components normally vary as the cube of the modulation levels. Other modulation levels may be tried, if desired, to determine if the discriminator under test follows these rules.

FM DISCRIMINATORS

DATA SHEET 5.16.1

TEST Two Tone Intermodulation Test

MANUFACTURER__________ MODEL__________

SERIAL NO.__________ IRIG CHANNEL __________

CHANNEL SELECTOR SERIAL NO.__________ LOW PASS OUTPUT FILTER S/N __________

CENTER FREQUENCY__________kHz UPPER BAND EDGE__________kHz

LOWER BAND EDGE__________kHz LOW PASS FILTER CUTOFF__________kHz

LOW PASS FILTER TYPE: ☐ CA ☐ CD ☐ Other__________

TEST PERSONNEL__________ DATE__________ LOCATION__________

Low Frequency Test

f_1 = 20% of LPOF Frequency = ________ Amplitude of f_1 = ________V,dB*

f_2 = 25% of LPOF Frequency = ________ Amplitude of f_2 = ________V,dB*

Amplitude of $f_2 - f_1$ Freq. Component = ________V,dB*

Amplitude of $2f_1 - f_2$ Freq. Component = ________V,dB*

Amplitude of $2f_2 - f_1$ Freq. Component = ________V,dB*

High Frequency Test

f_1 = 80% of LPOF Frequency = ________ Amplitude of f_1 = ________V,dB*

f_2 = 90% of LPOF Frequency = ________ Amplitude of f_2 = ________V,dB*

Amplitude of $f_2 - f_1$ Freq. Component = ________V,dB*

Amplitude of $2f_1 - f_2$ Freq. Component = ________V,dB*

Amplitude of $2f_2 - f_1$ Freq. Component = ________V,dB*

* Strike out unused units (either V or dB).

(See attachments 1 and 2.)

FM DISCRIMINATORS

DATA SHEET 5.16.1 (Sample)

TEST Two Tone Intermodulation Test

MANUFACTURER XYZ MODEL DEF

SERIAL NO. ABC IRIG CHANNEL ____

CHANNEL SELECTOR SERIAL NO. ____ LOW PASS OUTPUT FILTER S/N ____

CENTER FREQUENCY 64 kHz UPPER BAND EDGE 68 kHz

LOWER BAND EDGE 60 kHz LOW PASS FILTER CUTOFF 4 kHz

LOW PASS FILTER TYPE: [ ] CA [X] CD [ ] Other ____

TEST PERSONNEL ____ DATE ____ LOCATION ____

Low Frequency Test

f_1 = 20% of LPOF Frequency = 800 Hz Amplitude of f_1 = -9.1 ~~V~~, dB*

f_2 = 25% of LPOF Frequency = 1000 Hz Amplitude of f_2 = -9.1 ~~V~~, dB*

Amplitude of $f_2 - f_1$ Freq. Component = ____ ~~V~~, dB*

Amplitude of $2f_1 - f_2$ Freq. Component = ____ ~~V~~, dB*

Amplitude of $2f_2 - f_1$ Freq. Component = -60.6 ~~V~~, dB*

f_2+f_1 -60.6 dB

High Frequency Test

f_1 = 80% of LPOF Frequency = 3200 Hz Amplitude of f_1 = -9.6 ~~V~~, dB*

f_2 = 90% of LPOF Frequency = 3600 Hz Amplitude of f_2 = -9.7 ~~V~~, dB*

Amplitude of $f_2 - f_1$ Freq. Component = -62.9 ~~V~~, dB*

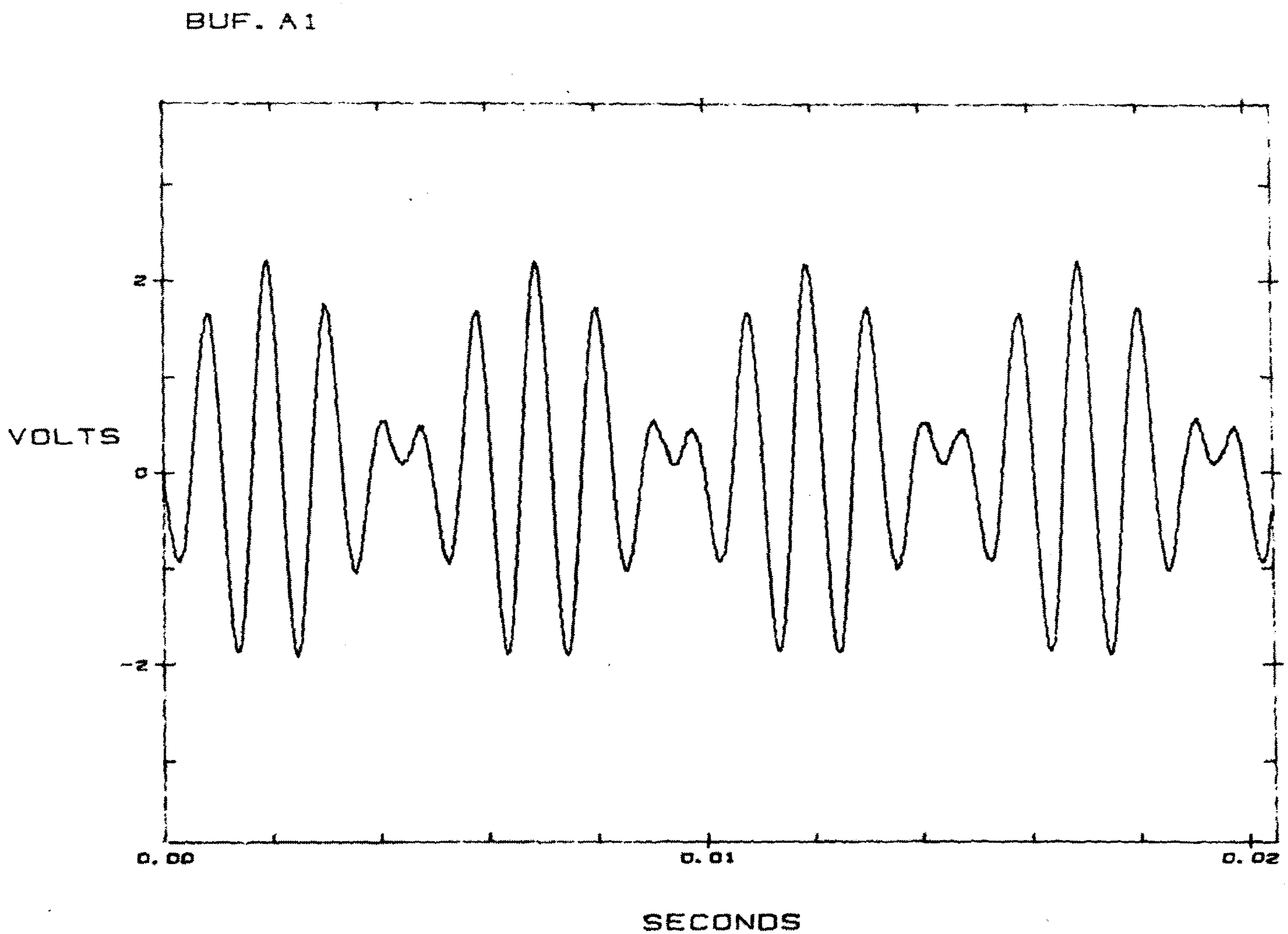
Amplitude of $2f_1 - f_2$ Freq. Component = -42.1 ~~V~~, dB*

Amplitude of $2f_2 - f_1$ Freq. Component = -46.1 ~~V~~, dB*

f_2+f_1 -49.1 dB

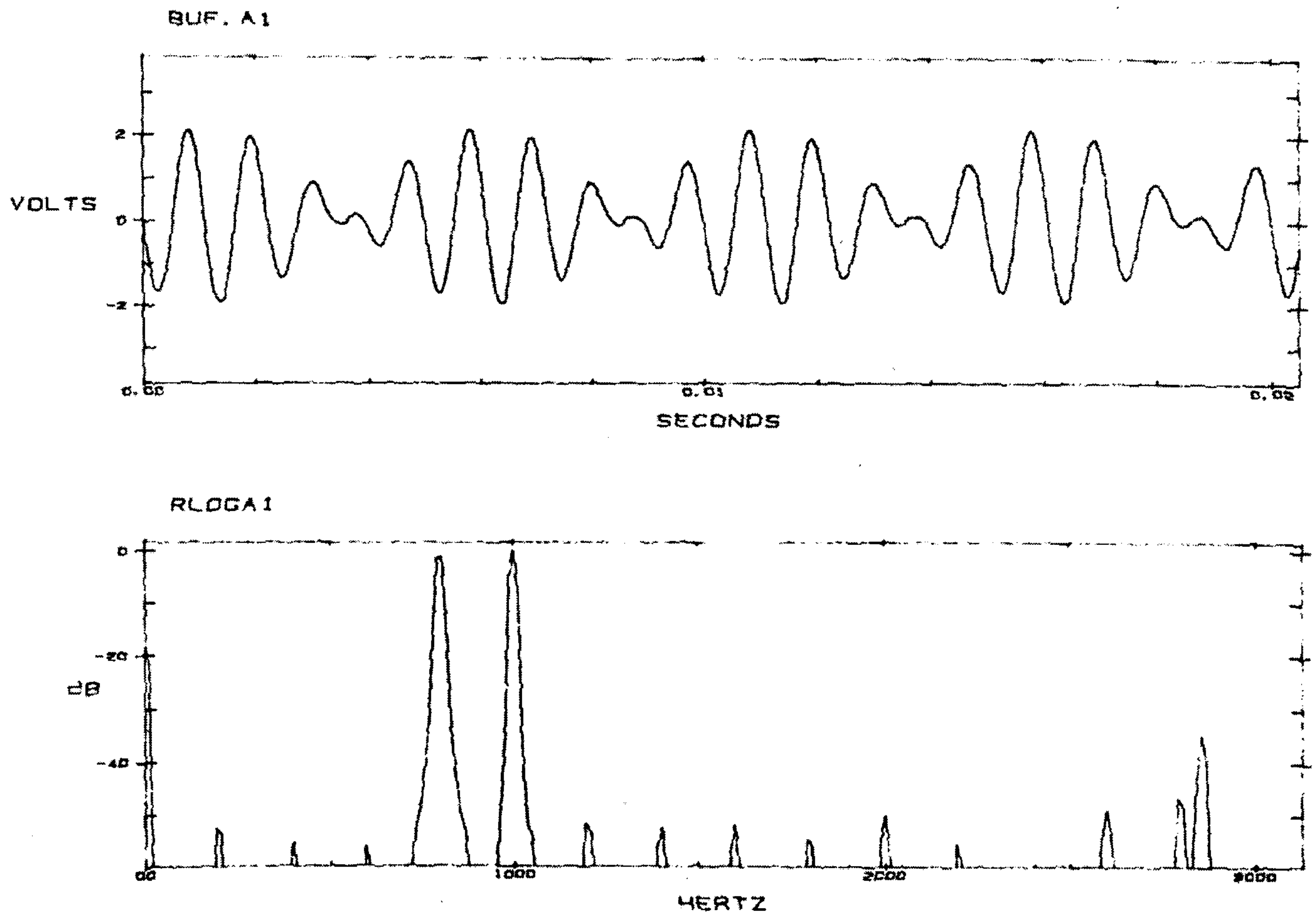
* Strike out unused units (either V or dB).

(See attachments 1 and 2.)



Attachment 1

Data Sheet 5.16.1 (Sample) - Discriminator LPF Output Two Tone Test.



Data Sheet 5.16.1 (Sample) - Discriminator LPF Output Two Tone Test.

Attachment 2

Appendix IV-A

THE SPECTRUM OF AN NRZ-PN SEQUENCE

NOTE

Appendix IV-A addresses material contained in chapter 2 of this volume.

The spectrum of an NRZ-PN sequence consists of a Fourier series of sinusoids with a fundamental frequency equal to the sequence repetition rate with power values inscribed within the random PCM NRZ power spectrum depicted in figure IV-A.l. The fraction of the total power in each component near 0 frequency is approximately 2/m where m is the number of bits in the sequence. Thus, when m is large, such as $2x10^3$, the spectrum is nearly continuous and has the same shape as random NRZ. Similarly, for a split-phase PN sequence, the Fourier component frequencies are multiples of the sequence rate with power value inscribed within the random split-phase spectrum shown in figure IV-A.1.

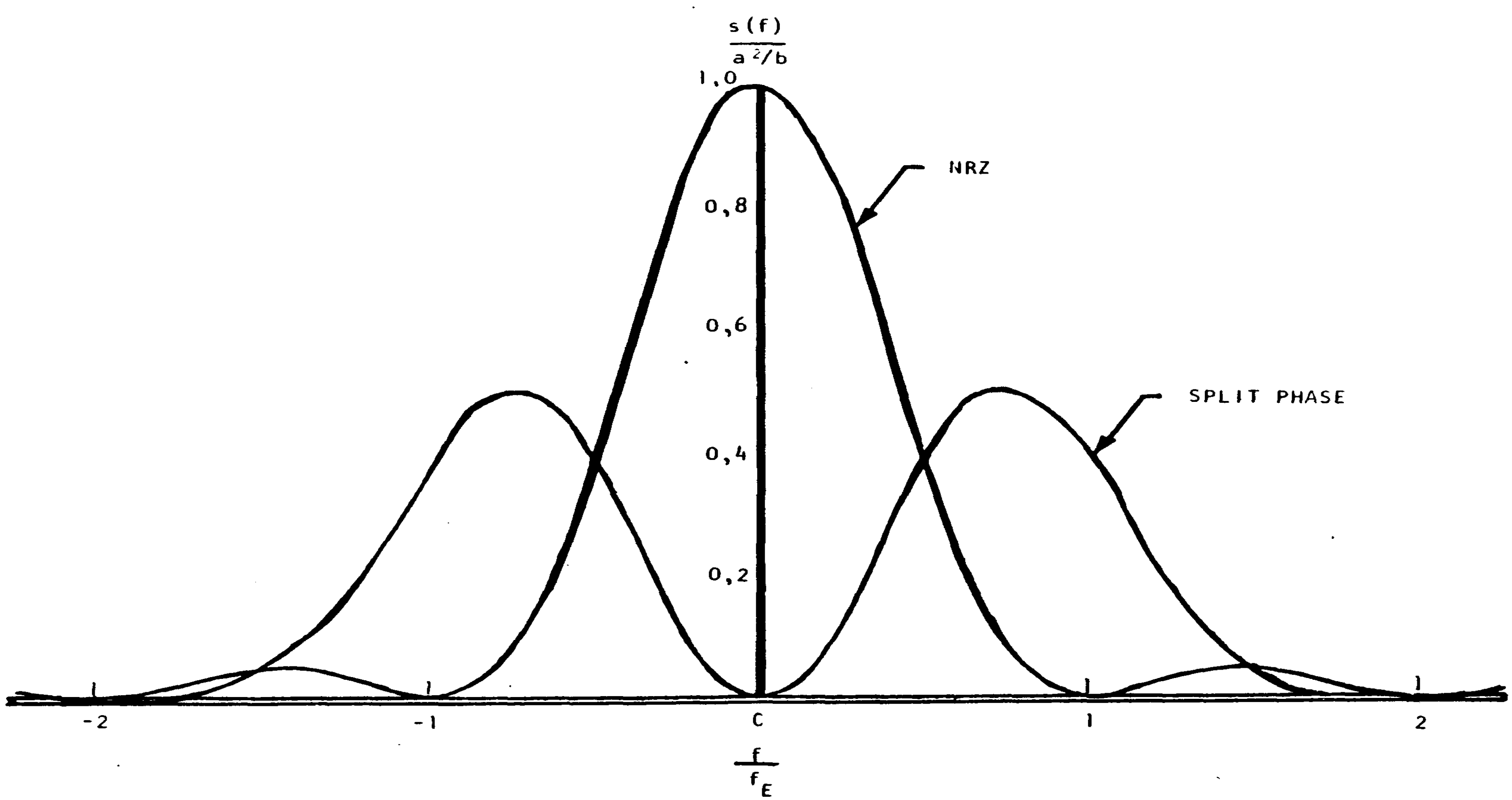


Figure IV-A.1 Random PCM Power Spectra.

Appendix IV-B

CALCULATION OF BIT ERROR MEASUREMENT INTERVALS

NOTE

Appendix IV-B addresses material contained in chapter 4 of this volume.

1.0 General

This appendix describes the selection of measurement intervals and provides samples of experimental data and data plots. The description of interval selection is presented as a theoretical treatment of the calculation of bit error measurement interval. The sample experimental data and data plots are presented for illustration purposes only and are not to be used for equipment specifications. Sample data and data plots are provided for each of the tests indicated in the standard test procedures in chapter 4.

1.1 <u>Measurement Intervals:</u>

1.1.1 Select measurement intervals which will provide statistically significant data with measurement repeatability equivalent to ±0.2-dB SNR variation. Measurements over intervals longer than the equivalent of 10^7 bit periods will require appropriate averaging of repeated measurements or the use of an external counter and timing arrangement. Some combinations of bit rate and SNR may require lengthy measurement intervals to obtain statistically significant data. The usefulness of such performance measurements will be dependent upon such things as the application in which the bit synchronizer is to be used and the purpose for which the measurements are made.

1.1.2 The measurement interval required for specified BEP measurement repeatability is a function of the BEP. However, the BEP can be expressed as a function of the signal energy per bit-to-noise power spectral density and this relationship can be used to derive a specified probability of a certain repeatability. The expression for the measurement interval (in bit periods) required to achieve a 0.95 probability of a ±0.2-dB repeatability is derived in this appendix. The derivation also shows the substitution required for other probabilities.

1.1.3 The BEP for unfiltered NRZ-L with additive gaussian noise and an optimum bit detector has been derived by Lindsey (see reference 1) to be:

$$BEP = \frac{1}{2} erfc\left(\sqrt{R}\right) = \frac{1}{\sqrt{\pi}} \int_{\sqrt{R}}^{\infty} e^{-t^2} dt$$

Where R=ratio of signal energy per bit to single-sided noise power spectral density in watts/Hz.

1.1.4 Hoel (see reference 2) states the following corollary: "The proportion of success x/n will be approximately normally distributed with mean P and standard deviation $\sqrt{Pq/n}$ if n is sufficiently large. Where P=BEP, q=l-P, x is the number of bit errors in the interval, and n is the number of bits in the measurement interval for this appendix." Hoel also states that it is a good approximation when np> 5.

1.1.5 A normally distributed variable has a 0.95 probability of being within 1.96 standard deviations (σ) of this mean. Therefore, if the change in BEP, caused by a 0.2-dB change in R is known and this change is forced to be larger than or equal to (1.96σ), the probability of being within 0.2 dB of the actual BEP will be 0.95. Since the slope $\left(\frac{dBEP}{dR} = \frac{e^{-R}}{\sqrt{\pi}}\right)$ of the BEP (linear) vs. R (dB) decreases for increasing R, it is necessary only to consider the case of R+0.2 dB.

1.1.6 Therefore, the measurement interval required (in number of bit periods) can be derived as follows:

$$1.96\,\sigma \le (\Delta P)\quad \sigma = \sqrt{\frac{P(1-P)}{n}} = \sqrt{\frac{P}{n}}\sqrt{1-P} \approx \sqrt{\frac{P}{n}} \quad for\ P << 1$$

$$1.96\sqrt{\frac{P}{n}} \le (\Delta P)$$

$$(\Delta P) \ge 1.96\sqrt{\frac{P}{n}}$$

$$(\Delta P)^2 \ge 3.84\left(\frac{P}{n}\right)$$

$$n \ge \frac{3.84P}{(\Delta P)^2}$$

$$n \ge \frac{3.84P}{\left(\frac{\Delta P}{P}\right)^2 P}$$

1.1.7 The BEPs calculated from BEP= ½ erfc ($\sqrt{R}$) are:

erfc ($\sqrt{R}$) determined from NBS table (see reference 3).

R	BEP	n Min	Expected Number of Bit Errors in n
3.0	2.29 x 10^{-2}	1.5 x 10^{4}	350
3.2	2.05 x 10^{-2}		
6.0	2.39 x 10^{-3}	4.6 x 10^{4}	110
6.2	1.94 x 10^{-3}		
9.0	3.37 x 10^{-5}	1.1 x 10^{6}	38
9.2	2.27 x 10^{-5}		
12.0	9.0 x 10^{-9}	1.5 x 10^{9}	13.5
12.2	4.17 x 10^{-9}		
15.0	9.1 x 10^{16}`		
15.2	2.02 x 10^{-16}		

1.1.8 The measurement interval required for other probabilities within 0.2 dB can be calculated by replacing 1.96 by the K listed in the following chart.

Probability	K
0.90	1.64
0.95	1.96
0.99	2.58
0.999	3.30

1.1.9 The measurement intervals calculated for the theoretically optimum case will be longer than those required for the practical case with a physically realizable bit synchronizer. A longer measurement interval results in increased statistical accuracy.

REFERENCES

1. Lindsey, W.C., "Bit Synchronization System Performance Characterization, Modeling, and Tradeoff Study," Technical Publication TP-73-18, Pacific Missile Test Center, Point Mugu, California, 4 September 1973.

2. Hoel, Paul G., "Introduction to Mathematical Statistics," 4th edition, John Wiley and Sons, Inc., New York, 1971, pp 82-83.

3. National Bureau of Standards, "Tables of the Error Function and its Derivative," Applied Mathematics Series 41, 2nd edition, U.S. Government Printing Office, Washington, D.C., 1954.

This page intentionally left blank

Appendix IV-C

DEFINITIONS AND SUGGESTED CIRCUITS FOR BIT SYNCHRONIZER TESTING

NOTE

Appendix IV-C addresses material contained in chapter 4 of this volume.

1.0 General

This appendix provides the definitions used for bit slippage probability (BSP) and acquisition testing and contains the suggested schematics for external delay and gate for procedure 2 (subparagraph 4.1.4.3.2) of the acquisition test.

1.1 Definitions

1.1.1 Reference Clock - The reference clock is the clock of the test set PCM generator suitably delayed for phase coincidence with the bit synchronizer output clock when in stable locked condition.

1.1.2 Bit Slippage - Bit slippage is the gain or loss of one or more bits by the bit synchronizer.

1.1.3 Bit Acquisition - Bit acquisition has occurred when the BEP drops from approximately 0.5 to the BEP characteristic of the input SNR. In practice, there may be base-line offset due to logic, FM receiver mistuning, etc., which requires time to be balanced out by the bit synchronizer and detector. Thus, it is necessary to specify offset conditions in connection with this test.

1.2 Auxiliary Circuits for Acquisition Test

1.2.1 Figure IV-C.1 gives circuits for the PCM delay and PCM gate included in figure 4.1.4-2.

1.2.2 Figure IV-C.2 illustrates the use of procedure 2 for acquisition time and consists of two photographs showing oscilloscope traces of eight acquisition tries for two different BEPs. Time to acquire can be easily determined by the photographic method with BEP as large as 0.4, as illustrated. Use of a storage scope would be faster because the times could be read directly and logged for each try.

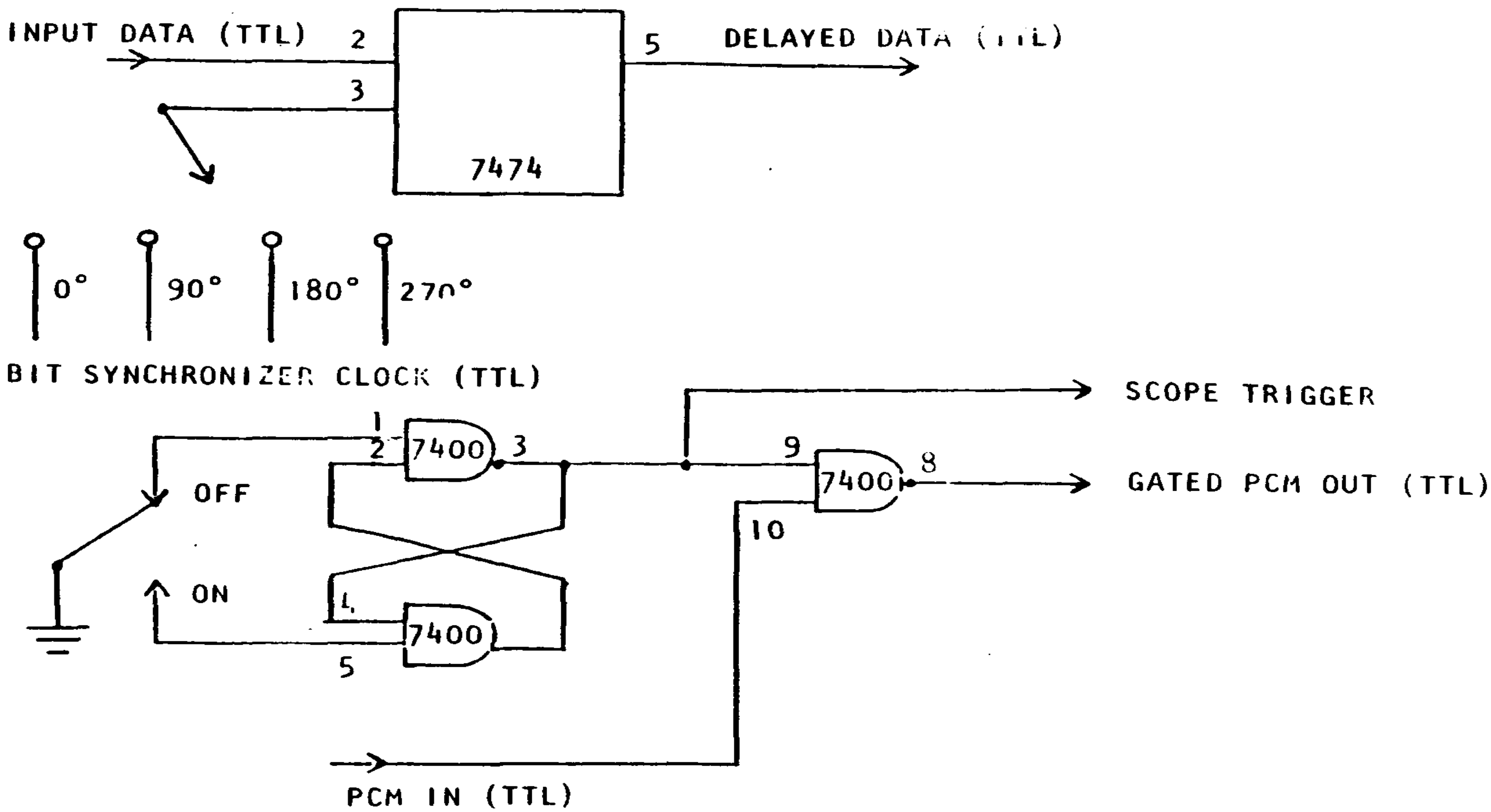
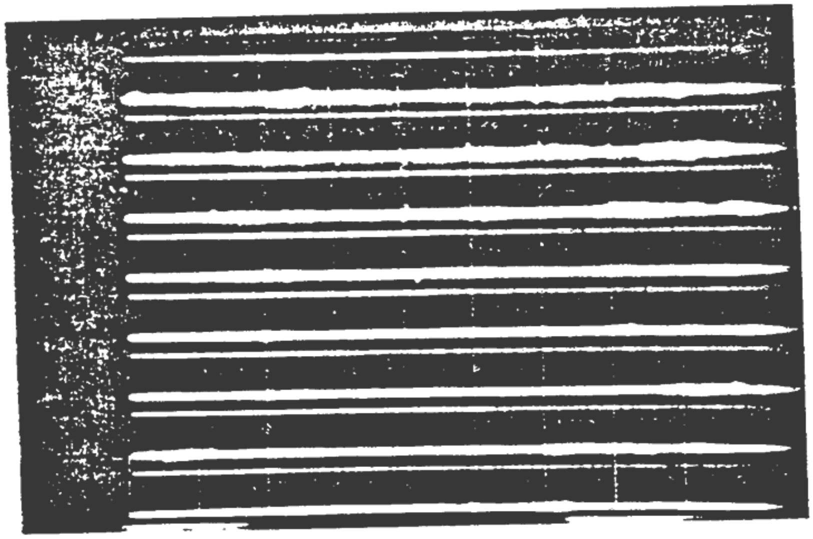
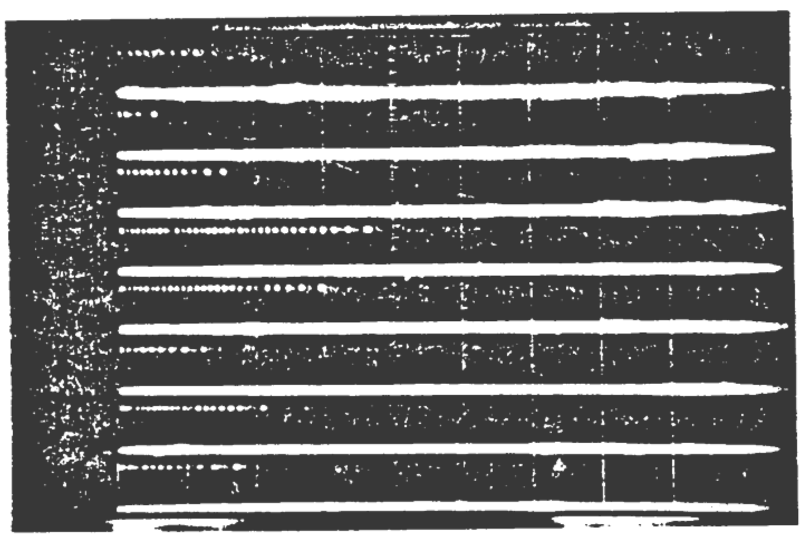


Figure IV-C.1 PCM Data Delay and PCM Gate.



$P_e = 4 \times 10^{-2}$

10 ms/div



$P_e = 6 \times 10^{-6}$

5 ms/div

Figure IV-C.2 Illustrations of Procedure 2 of the Acquisition Test

1.3 Suggested Circuits for Amplitude Modulator and Noise Shaper

1.3.1 Amplitude Modulator

Figure IV-C.3 is a suggested schematic for the amplitude modulator. This circuit, with some minor changes, was taken from the Motorola application sheets. Approximate voltage ranges for the two inputs are given. This circuit will work satisfactorily to at least 10^6 bits/sec.

1.3.2 Noise Shaper

Figure IV-C.4 is a suggested schematic for shaping the noise for the jitter test, subparagraph 4.1.5.3.11.

1.3.3 IF Bandwidth and Carrier Modulation for Base-Line Wander Plus Jitter Test

When base-line wander and AM are applied simultaneously to the bit stream, an IF bandwidth wider than the optimum for unperturbed bit streams is required. As an example, for 50-percent AM and 50-percent base-line wander, the IF bandwidth should be about $4f_b$ and the carrier modulation should be about $0.5f_b$ at the lowest point of the AM, i.e., with no AM it should be f_b (where f_b is the bit rate). For more details, see reference below.

REFERENCE

Nichols, M. H., Consultant, "Bit Synchronizer and Signal Conditioner Test Procedures Using Bit Streams with Clock Flutter, Zero Wander and Amplitude Modulation," TOR-0076 (6550-38)-6, The Aerospace Corporation, Los Angeles, California, 1 April 1976.

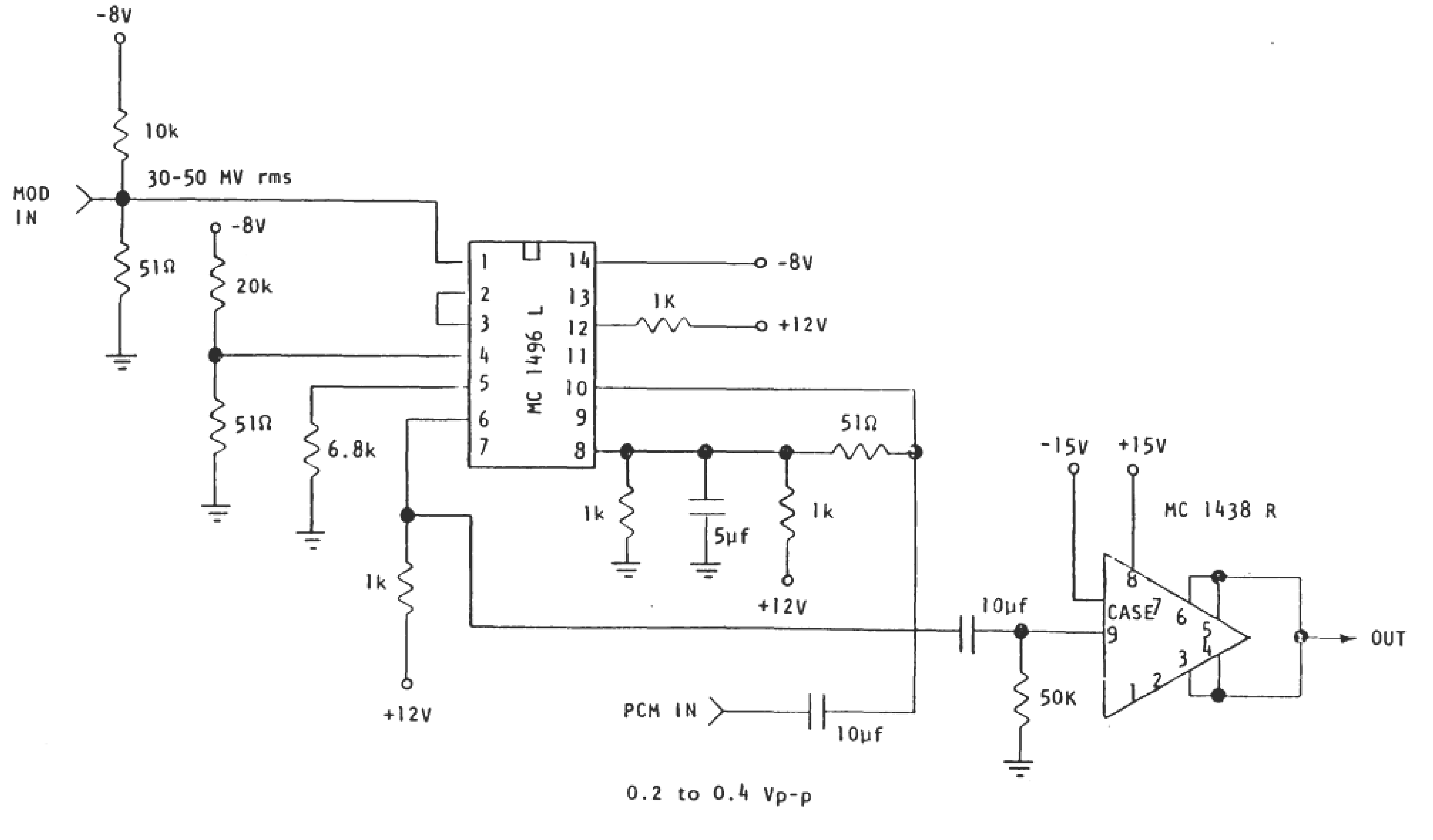


Figure IV-C-3 Suggested Circuit for Amplitude Modulator.

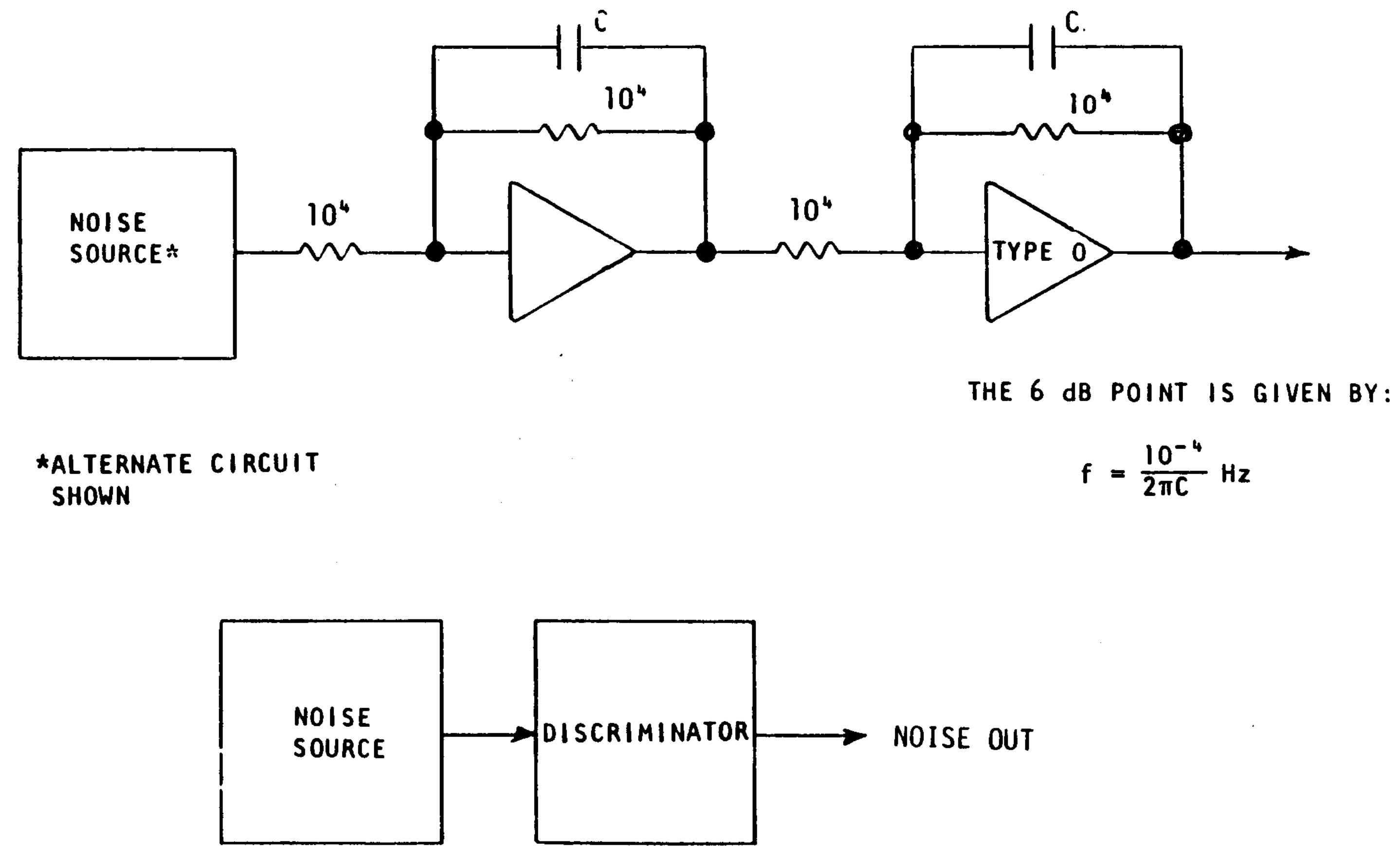


Figure IV-C.4 Jitter Noise Shaping Circuit.

**** END OF DOCUMENT ****