SECTION III
OPERATION

3-1. INTRODUCTION

3-2. This section contains information on front and rear panel features, self check procedures, condition codes (H-codes), and operation using the remote HP-IB interface. Also covered are the principles of operation for all measurements, plus master-slave operation.

3-3. If any of the self check procedures fail acceptable limits as specified in the checks, then adjustment or repair may be necessary.

3-4. Operating instructions for the Model 4943A are covered in this manual only to the extent needed for service. For specific operating procedures, see the 4943A Operating Instructions booklet, HP P/N 04943-90001.

3-5. SELF CHECK

3-6. The self check procedures should be performed periodically by the instrument user to verify performance. The self check procedures should be used for incoming inspection to verify a customer complaint and to determine if any other problems exist. The self check procedures should also be performed prior to the performance checks. The performance checks then verify that the instrument meets published specifications. Failure of the instrument to pass any self check procedure indicates a malfunction that can possibly affect other measurements.

3-7. CONDITION CODES

3-8. Under certain conditions, the 4943A will abort or fail to achieve its normal display. The display will then show a "condition code" or "error code". All these codes contain an "H" prefix followed by two numerals (such as H-08). The self check procedures in Figure 3-2 contain a list of the codes possible when self check fails. Table 3-1 lists the codes possible during normal operation.

CONTROLS, CONNECTORS, AND INDICATORS

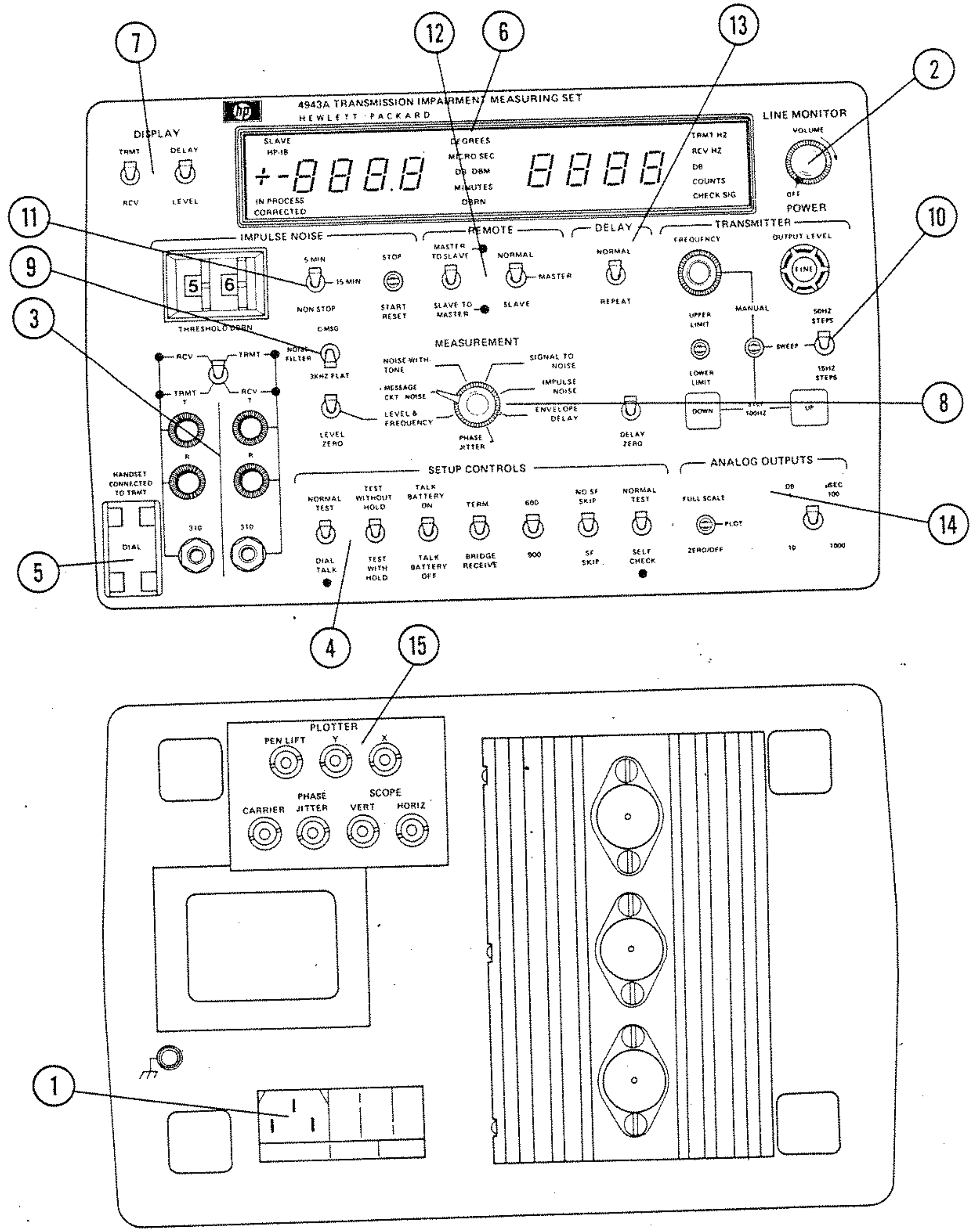


Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (1 of 5)

CONTROLS, CONNECTORS, AND INDICATORS

(1) **Power Cord Module.** Accepts power cord supplied with instrument. Contains line fuse and PC board for selecting line voltage (see Section II of the 4943A Operating and Service Manual). WARNING: ALWAYS CONNECT POWER CORD TO A PROPERLY GROUNDED 3-WIRE POWER OUTLET.

(2) **LINE MONITOR Volume/POWER Off Control.** Switches instrument ac operating power ON and OFF and controls volume of LINE MONITOR speaker. The DISPLAY TRMT – RCV switch determines whether the transmitted or received signal is being monitored. The speaker is located on the right-hand side panel.

(3) **RCV-TRMT Jacks.** A two position toggle switch is used to reverse connections of the left and right jack fields. When switch is in up position, the left jacks are connected for RCV (receive) and the right jacks for TRMT (transmit). When switch is down, connections are reversed. Dot lamps indicate functions of respective jack fields. Connections can be made either to the 310 jacks, or to the TIP and RING binding posts, which are multipled.

(4) SETUP CONTROLS.

NORMAL TEST -- DIAL/TALK Switch. In NORMAL TEST position the selected TRMT jack is connected to the test set's transmitter circuitry, but not to the DIAL connectors. In DIAL/TALK position the TRMT jack is connected to the DIAL connectors, but not to the transmitter circuitry.

TEST WITHOUT HOLD – TEST WITH HOLD Switch. In TEST WITHOUT HOLD position the test set holding circuits are disconnected from the RCV-TRMT jacks. In TEST WITH HOLD position the holding circuits are connected across TIP and RING of both jack fields to hold 2-wire wet (DDD) circuits while testing.

TALK BATTERY ON – TALK BATTERY OFF Switch. In TALK BATTERY ON position the test set provides the necessary talk battery to the DIAL terminals to talk on dry circuits with a lineman's handset. In TALK BATTERY OFF position, talk battery must be supplied by the circuit under test if talking is desired.

TERM – BRIDGE RECEIVE Switch. In TERM position the test set provides a termination on both the RCV AND TRMT circuits. The desired terminating impedance must be selected with the 600-900 switch. In BRIDGE-RECEIVE position the receiving test set is bridged across the circuit under test, which must be terminated with other equipment. NOTE: When using BRIDGE RECEIVE it is still necessary to select the proper impedance of the line under test with the 600-900 switch in order to normalize the measurements.

600-900 Switch. The 600 Ω or 900Ω termination must be selected to match the characteristic impedance of the line under test. When operating in TERM mode, both the TRMT and RCV circuits are terminated in the selected impedance. When operating in BRIDGE RECEIVE mode, the TRMT circuit is still terminated in the selected impedance and the RCV circuit is bridged by more than 45 kΩ. The selection also normalizes level measurements for the respective impedances.

Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (2 of 5)

CONTROLS, CONNECTORS, AND INDICATORS

NO SF SKIP – SF SKIP Switch. In NO SF SKIP position the test set will transmit all selected frequencies. In SF SKIP position the test set will not transmit any frequencies between 2450 Hz and 2750 Hz. This feature prevents the circuit under test from being disconnected by SF signaling units on the dial-up network.

NORMAL TEST – SELF CHECK Switch. In NORMAL TEST position the test set performs normal testing. In SELF CHECK position proper operation of the test set can be verified by performing the procedures given in the SELF CHECK section of this manual.

(5) **DIAL Connectors.** Provides connections for a lineman's handset (butt-in). The terminals are connected to the selected TRMT jack when the DIAL/TALK mode is selected.

(6) **Digital Displays.** Two digital displays provide quantitative information and measurement units for all measurements. Ranging is automatic, and polarity and decimal points are automatically displayed when appropriate. Up to two parameters can be displayed simultaneously. The displays also indicate underrange and overrange conditions. Display of only a (–) sign indicates underrange. Display of only a (+) sign indicates overrange.

(7) **DISPLAY Switches.**

TRMT – RCV Switch. Selects either the transmitted or received information to be displayed.

LEVEL – DELAY Switch. Used in ENVELOPE DELAY measurements to display either level (DBM) or delay (MICRO SEC) information.

(8) **MEASUREMENT Switch.** Programs the test set to perform the selected measurement. For a detailed procedure describing the use of each MEASUREMENT switch position, see the appropriate section of this manual.

LEVEL ZERO Switch. Used in LEVEL & FREQUENCY mode to establish a zero dB reference. All subsequent measurements will be made in dB relative to this reference. If this switch is not operated, measurements will be in absolute dBm. NOTE: If LEVEL ZERO switch has been actuated and it is desired to make an absolute dBm measurement, momentarily rotate MEASUREMENT switch to another position, then back to LEVEL & FREQUENCY again.

DELAY ZERO Switch. Used in ENVELOPE DELAY mode to establish a zero microsecond delay reference. All subsequent envelope delay measurements will be relative to this reference.

(9) **NOISE FILTER Switch.** Used in NOISE measurements to select desired weighting filter (C-MSG or 3KHZ FLAT).

(10) **TRANSMITTER Controls.**

MANUAL – SWEEP – STEP 100 HZ Switch. In MANUAL position frequency is continuously variable from 200 Hz to 3950 Hz by adjusting FREQUENCY control. In SWEEP position frequency automatically steps up and down in 50 Hz or 15 Hz steps selected by 50 HZ STEPS – 15 HZ STEPS switch. Upper and lower sweep limits are set by tuning to desired frequency in MANUAL or STEP 100 HZ and momentarily activating UPPER LIMIT – LOWER LIMIT switch.

OUTPUT LEVEL Control. Varies transmitter output level continuously from –39 dBm to +10 dBm. Output level is displayed on left display.

Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (3 of 5)

CONTROLS, CONNECTORS, AND INDICATORS

(11) **IMPULSE NOISE Controls.**

THRESHOLD DBRN Switches. Sets the desired threshold above which impulse noise peaks will be totalized on the display. The threshold is adjustable from 30 to 109 dBrn.

5 MIN – 15 MIN – NONSTOP Count Time Switch. Selects length of time for which impulse noise is counted. Counting is stopped automatically when either the 5 MIN or 15 MIN positions are selected. Counting must be stopped manually with the STOP – START/RESET switch when the NONSTOP position is selected.

STOP – START/RESET Switch. Impulse noise counting is stopped and total is held on display when switch is momentarily held in STOP position. All previous counts are reset to zero on display and new counting interval is initiated when switch is momentarily held in START/RESET position.

(12) **REMOTE Switches.**

MASTER TO SLAVE – SLAVE TO MASTER Switch. Selects transmission path to be tested. Selecting the MASTER TO SLAVE position will cause the circuit connected to the TRMT jack at the MASTER unit to be tested. Selecting the SLAVE TO MASTER position will cause the circuit connected to the RCV jack at the MASTER unit to be tested. The dot lamp associated with the respective position indicates that the MASTER unit has achieved control of the SLAVE unit. The lamp should light within 10 seconds after the NORMAL – MASTER – SLAVE switches are properly positioned on both the MASTER and SLAVE units.

NORMAL – MASTER – SLAVE Switch. In NORMAL position all controls are under manual front panel control. The test set can be operated manually with other compatible test sets. In MASTER position the unit is in remote control of the SLAVE unit for all MEASUREMENT functions. In SLAVE position the unit is remotely controlled by the MASTER unit for all MEASUREMENT functions.

(13) **DELAY Switch.** Used in ENVELOPE DELAY mode to determine whether the test set is to measure envelope delay (NORM), or to retransmit the envelope delay signal from the far-end of the circuit (REPEAT). This control is not used during MASTER-SLAVE operation.

(14) **ANALOG OUTPUTS Controls.**

FULL SCALE – PLOT – ZERO/OFF Switch. In FULL SCALE position, full scale voltage (+10V) is applied to X and Y output jacks for use in calibrating upper right corner of X-Y Recorder plot. In PLOT position, voltages proportional to frequency or time and measured signal are sent to X and Y output jacks respectively. In ZERO/OFF position 0 volts is applied to both X and Y outputs for use in calibrating lower left corner of X-Y Recorder plot or for deactivating analog output signals.

DB USEC Switch. Selects sensitivity for Y Axis scale. In upper position each internally generated graticule line represents 1 dB in LEVEL & FREQUENCY and 100 uS in ENVELOPE DELAY. In lower position, each graticule line represents 10 dB and 1000 uS respectively.

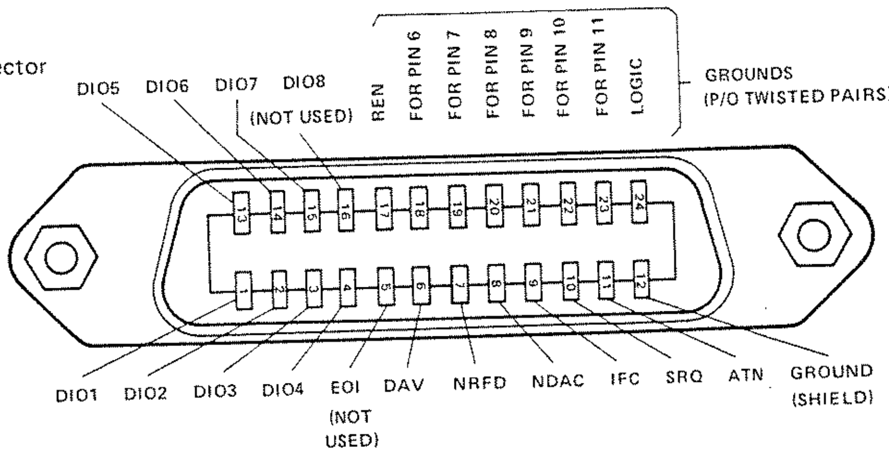
(15) **ANALOG OUTPUT Connectors.** Used to connect analog output circuitry to an oscilloscope or strip chart recorder. Refer to 4943A Operating and Service Manual for complete description and connection instructions.

(15) **Option 010 only:** Due to rear panel space restrictions, the BNC connectors are replaced by a 14-pin connector for Analog Outputs, in addition to the added 24-pin connector for Hewlett-Packard Interface Bus (HP-IB).

Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (4 of 5)

CONTROLS, CONNECTORS, AND INDICATORS

(15) HP-IB Connector (Continued)



LOGIC LEVELS

HP-IB logic levels are low true and TTL compatible (LO = 0.0 to +0.4 Vdc, HI = +2.5 to +5.0 Vdc).

Example: SRQ is LO active.
NRFD is HI active.

Input Signals:

Each input line is terminated with 3000 ohms to +5V and 6200 ohms to ground (one TTL load).

Output Signals:

Each output can drive 15 HP-IB loads. The output is an open-collector driver capable of sinking 48 mA at 0.4V output.

SIGNALS

NRFD
Ready For Data. Indicates 4943A will accept data when NRFD is HIGH.

NDAC
Data Accepted. Indicates 4943A has accepted data. Returns to LOW when 4943A is finished processing data.

DAV
Data Valid. Indicates valid output data is available from 4943A if addressed to talk. Input data is available if 4943A is addressed to listen and ATN is HIGH. Address is valid if ATN is LOW.

ATN
Attention. A LOW state indicates commands are present on the DIO lines. A HIGH state indicates data is present on the DIO lines.

DIO1 thru DIO8
Data Input-Output lines. Message bytes are carried on the DIO signal lines in a bit-parallel byte-serial form, asynchronously and generally in a bidirectional manner. DIO8 not used in 4943A.

REN
Remote Enable. Used by the controller to cause the 4943A to be placed in the remote mode.

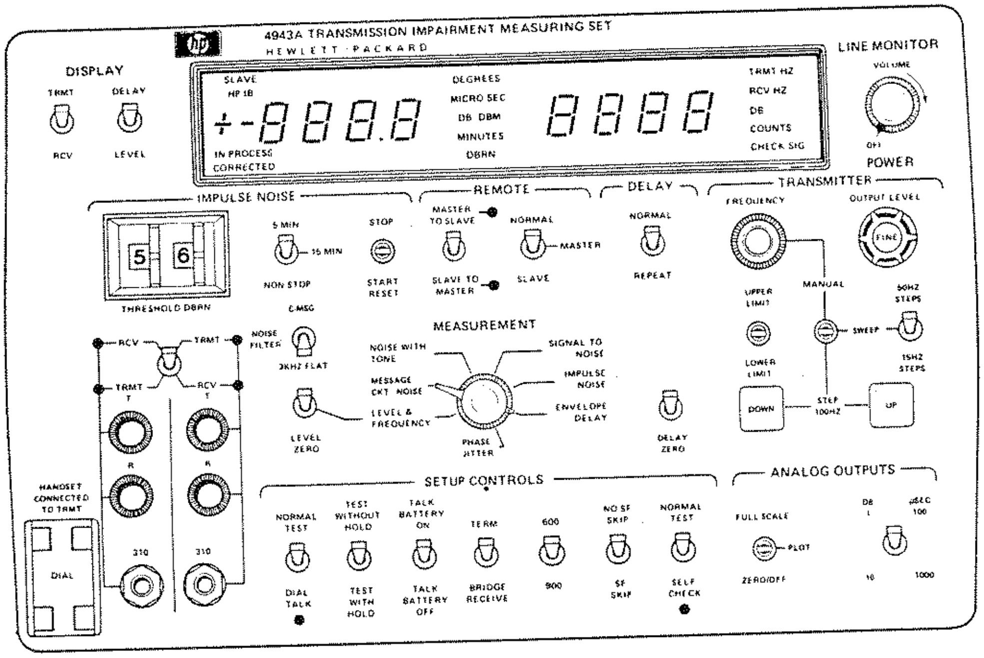
SRQ
Service Request. Indicates the 4943A wants the attention of the controller.

IFC
Interface Clear. Used by the controller to terminate all activity on the bus.

EOI
Not used in 4943A.

Figure 3-1. Front and Rear Panel Controls, Connectors, and Indicators (5 of 5)

SELF CHECK PROCEDURES



NOTE

The SELF CHECK routine automatically makes an operational check of the test set, including its ability to operate in MASTER and SLAVE modes. The test set will automatically step through the SELF CHECK routine and should produce indications at each step as indicated below. At the end of the SELF CHECK routine, the display will indicate PASS if all checks are within specifications. If any steps fail to pass, the display will indicate failure codes at the end of the routine for those steps that fail to pass. A list of SELF CHECK failure codes, and their meanings are given at the end of this procedure.

The SELF CHECK procedure should be performed periodically to verify performance of the test set. SELF CHECK is recommended before transporting the test set to a remote testing site; or whenever there is any doubt about transmission measurement results.

1. PRELIMINARY SETUP
   a. Disconnect test set from on-line testing.
   b. Switch POWER ON.
   c. Loop TRMT jack to RCV jack. Operate RCV/TRMT jack field switch and observe that corresponding dot lamps light.
   d. Set all SETUP CONTROLS Switches to "up" positions.
   e. Set NORMAL TEST – SELF CHECK Switch to SELF CHECK.

Figure 3-2. Self Check Procedures (1 of 3)

SELF CHECK PROCEDURES

2. STEP 1: DISPLAY AND ANNUNCIATOR CHECKS
   a. Observe that left display indicates +888.8 and that right display indicates 8888. Observe that all numerical segments are present and evenly illuminated.
   b. Observe that all display annunciators (except the minus sign) are on and evenly illuminated.
   c. Observe that MASTER TO SLAVE and SLAVE TO MASTER dot lights are on.

   NOTE

   It is not necessary to observe the following test routine unless it is desired to analyze a specific problem with the test set. SELF CHECK status will be displayed at the end of the routine.

3. STEPS 2-4: LEVEL & FREQUENCY CHECKS
   a. Left display should indicate +0.0 DBM (±0.3 dBm). Right display should indicate 1004 RCV HZ (±2 Hz).
   b. Left display should indicate +0.0 DB (±0.3 dB). Right display should indicate 204 RCV HZ (±2 Hz).
   c. Left display should indicate +0.0 DB (±0.3 dB). Right display should indicate 3904 RCV HZ (±2 Hz).

4. STEPS 5-7: C-MESSAGE FILTER CHECKS
   a. Left display should indicate +0.0 DB (±0.3 dB). Right display should indicate 1004 RCV HZ (±2 Hz).
   b. Left display should indicate +16.0 DB (±1.0 dB). Right display should indicate 304 RCV HZ (±2 Hz).
   c. Left display should indicate +2.5 DB (±1.0 dB). Right display should indicate 3004 RCV HZ (±2 Hz).

5. STEPS 8-10: 3 KHZ FLAT FILTER CHECKS
   a. Left display should indicate +0.0 DB (±0.3 dB). Right display should indicate 1004 RCV HZ (±2 Hz).
   b. Left display should indicate +0.0 DB (±0.5 dB). Right display should indicate 304 RCV HZ (±2 Hz).
   c. Left display should indicate +3.0 DB (±2.0 dB). Right display should indicate 3004 RCV HZ (±2 Hz).

6. STEP 11: NOISE-WITH-TONE NOTCH CHECK
   a. Left display should indicate greater than +50 DBM. Right display should indicate 1004 RCV HZ (±2 Hz).

7. STEP 12: IMPULSE NOISE CHECK
   a. Right display should indicate 70 COUNTS (±4 Counts).

8. STEP 13: ENVELOPE DELAY CHECK
   a. Left display should reset to 0 MICROSECONDS, then indicate 3000 MICROSECONDS (±10μS). Right display should indicate 1804 RCV HZ (±2 Hz).

9. STEPS 14-15: PHASE JITTER CHECKS
   a. Left display should read +0.0 DEGREES (±0.2 Deg.). Right display should indicate 1004 RCV HZ (±2 Hz).
   b. Left display should read +11.5 DEGREES (±0.7 Deg.). Right display should indicate 1004 RCV HZ (±2 Hz).

10. STEP 16: SELF CHECK STATUS DISPLAY
    a. If all SELF CHECK tests are within specifications, the display will indicate PASS until the NORMAL TEST-SELF CHECK switch is returned to the NORMAL TEST position. The test set has passed, in addition to the above visible tests, an ENVELOPE DELAY response time test, an IMPULSE NOISE time base generator test, and a complete check of the modem used for MASTER-SLAVE operation.
    b. If the instrument fails to pass any of the above tests, failure codes will be displayed indicating the tests that have failed. These codes will be displayed sequentially until the NORMAL TEST-SELF CHECK switch is returned to the NORMAL TEST position. The table at right shows interpretations of the SELF CHECK failure codes that can be displayed.

Figure 3-2. Self Check Procedures (2 of 3)

SELF CHECK PROCEDURES

11. SELF CHECK – MODEM ONLY.

If a quick SELF CHECK of only the modem is desired, the following procedure can be used:

a. Perform PRELIMINARY SETUP procedures (a) through (d).

b. Switch to SELF CHECK. Depress and hold DELAY ZERO Switch until left display indicates "PASS", then release.

c. If modem passes SELF CHECK, display will immediately indicate PASS. Refer to failure codes, at right, if failure code is displayed.

SELF CHECK FAILURE CODES

CODE	MESSAGE
H16	Test signal not looped around.
H20	Level out of tolerance at 204 Hz (STEP 3).
H21	Level out of tolerance at 1004 Hz (STEP 2).
H22	Level out of tolerance at 3904 Hz (STEP 4).
H30	C-Message Filter out of tolerance at 304 Hz (STEP 6).
H31	C-Message Filter out of tolerance at 1004 Hz (STEP 5).
H32	C-Message Filter out of tolerance at 3004 Hz (STEP 7).
H33	Noise-With-Tone notch filter out of tolerance (STEP 11).
H34	Impulse Noise counts out of tolerance (STEP 12).
H35	3KHZ FLAT Filter out of tolerance at 304 Hz (STEP 9).
H36	3KHZ FLAT Filter out of tolerance at 1004 Hz (STEP 8).
H37	3KHZ FLAT Filter out of tolerance at 3004 Hz (STEP 10).
H38	Impulse Noise time base generator out of tolerance (STEP 12).
H40	Frequency out of tolerance at 1004 Hz (STEP 2).
H41	Frequency out of tolerance at 204 Hz (STEP 3).
H42	Frequency out of tolerance at 3904 Hz (STEP 4).
H50	Residual Phase Jitter out of tolerance (STEP 14).
H51	Phase Jitter out of tolerance (STEP 15).
H70	Envelope Delay response time out of tolerance (STEP 13).
H71	Envelope Delay accuracy out of tolerance (STEP 13).
H72	Envelope Delay 83-1/3 modulation missing (STEP 13).
H80 H81 H82 H83 H84	Test set modem does not pass SELF CHECK (NOTE: Failure of the modem affects only MASTER – SLAVE operation. Normal operation is not affected.)

Figure 3-2. Self Check Procedures (3 of 3)

Table 3-1. Condition Codes (1 of 2)

Under certain conditions, the 4943A will abort or fail to achieve its normal display and indicate a "condition code" in the display. Following is a list of condition codes that can occur, their messages, probable causes, and recommended remedial actions to clear the condition. (Also refer to SELF CHECK procedure for listing of SELF CHECK failure codes).

CONDITION CODE	MESSAGE	PROBABLE CAUSES	RECOMMENDED ACTIONS
H-00	Front panel controls changed while MASTER attempting to achieve control over SLAVE.	1. Operator error.	1. Do not touch controls until dot light illuminates.
H-01	No data carrier received from SLAVE.	1. SLAVE OUTPUT LEVEL set too low 2. Excessive circuit loss. 3. 4943A problem.	1. Check SLAVE OUTPUT LEVEL. 2. Check that MASTER receives at least −40 dBm. 3. Perform SELF CHECK on MASTER and SLAVE units. Return test set for repair if necessary.
H-02, H-11	No data information received from SLAVE.	1. Excessive noise on circuit. 2. 4943A problem.	1. Check circuit noise and impulse noise. 2. Perform SELF CHECK on SLAVE unit. Return test set for repair if necessary.
H-03, H-04	Data errors.	1. Excessive noise on circuit. 2. 4943A problem.	1. Check circuit noise and impulse noise. 2. Perform SELF CHECK on MASTER unit. Return test set for repair if necessary.
H-05	Inappropriate response to MASTER-SLAVE commands.	1. 4943A problem. 2. Distortion on circuit due to high level or circuit malfunction.	1. Perform SELF CHECK on MASTER and SLAVE units. Return test set for repair if necessary. 2. Check MASTER and SLAVE OUTPUT LEVELS.
H-06	SLAVE not responding to MASTER command.	1. MASTER OUTPUT LEVEL set too low. 2. Excessive circuit loss. 3. Excessive noise on circuit. 4. 4943A problem.	1. Check MASTER OUTPUT LEVEL. 2. Check that SLAVE receives at least −40 dBm. 3. Check circuit noise and impulse noise. 4. Perform SELF CHECK on MASTER and SLAVE units. Return test set for repair if necessary.

Table 3-1. Condition Codes (2 of 2)

CONDITION CODE	MESSAGE	PROBABLE CAUSES	RECOMMENDED ACTIONS
H-07	Incompatible SLAVE measurement.	1. SLAVE is being requested to make a measurement it is not capable of making.	1. SLAVE must be compatible with MASTER (or it aborts to LINE LOOP BACK mode for measurements not available in SLAVE unit).
H-08	Invalid command.	1. 4943A problem.	1. Perform SELF CHECK on MASTER unit. Return test set for repair if necessary.
H-09	No data received when expected.	1. Circuit dropout. 2. SLAVE OUTPUT CONTROL moved during data transmission. 3. 4943A problem.	1. Check circuit; re-run test. 2. Do not touch SLAVE OUTPUT Control while measurement in progress. 3. Perform SELF CHECK on MASTER and SLAVE units. Return test set for repair if necessary.
H-10	SLAVE Underrange; test Level or Noise below range capability.	1. Receive LEVEL less than −70 dBm. 2. Receive NOISE less than +20 dBrn.	1. Normal condition; no action necessary.
H-11 See H-02			
H-12	IMPULSE NOISE	1. IMPULSE NOISE exceeded 9999 COUNTS.	1. User shorter counting interval.
H-13	MASTER lost control of SLAVE.	1. SLAVE REMOTE Switch changed to NORMAL or MASTER during data transmission.	1. Do not touch SLAVE REMOTE Switch while measurement in progress.
H-14	Signal dropout >1 Sec. during IMPULSE NOISE measurement.	1. Circuit dropped out carrier.	1. Initiate new test.
H-15	PHASE JITTER overrange.	1. PHASE JITTER greater than 40 DEGREES.	1. Normal condition; no action necessary.
H-16	Improper test signal.	1. Operator error.	1. Check for proper MEASUREMENT Switch position at sending test set.

3-9. OPERATION USING HP-IB (Option 010)

3-10. The HP-IB option adds remote programming and data output capability to the 4943A. The HP-IB interface is Hewlett-Packard's implementation of the IEEE Standard 488-1975.

3-11. RELATED DOCUMENTATION

3-12. A separate publication is available which details the use of the 9825A controller with the 4943A. This operating note, HP P/N 04943-90026, is titled "Operating Your HP Model 4943A Transmission Impairment Measuring Set with the HP Model 9825A Controller". Included in the note is a sample master-slave program, plus an optional HP-IB verification program. If the user is contemplating the use of a 9825A with the 4943A, then this note would be helpful.

3-13. PROGRAMMING DATA

3-14. Table 3-2 through 3-6 provide the user with the needed reference data for remotely operating the Model 4943A. Table 3-2 lists the program code set, giving the codes necessary to implement the programmable measurement functions. Table 3-3 gives the status byte format as output by the 4943A. Table 3-4 lists the allowable HP-IB bus messages. Table 3-5 is a list of the recommended timing delays needed after various actions are implemented. Finally, the format of the 4943A output data character string is given in Table 3-6. This table shows the content of the data word as the 4943A sends it to the controller. This format differs from measurement to measurement.

3-15. PROGRAMMABILITY

3-16. Most front panel controls are remotely programmable via HP-IB. The exceptions are:

a. POWER switch.

b. SETUP CONTROLS

c. TRANSMITTER OUTPUT LEVEL.

d. IMPULSE NOISE THRESHOLD thumbwheel switches.

e. LINE MONITOR VOLUME

f. ANALOG OUTPUTS.

g. RCV-TRMT switch.

These controls must be set manually by the operator before proceeding with the use of remote HP-IB operation.

3-17. TIMING CONSIDERATIONS

3-18. The Model 4943A does not respond instantly to measurement commands. Nor does the telephone circuit under test settle immediately. Timing considerations therefore play an important role when writing software. Table 3-5 lists the timing delays necessary for the 4943A. Timing delays necessary for the circuit under test will need to be determined by observation or experiment.

3-19. PARTIAL CHANGE OF MEASUREMENT PARAMETERS

3-20. When a partial change of measurement parameters is needed, only the changed parameter need be attended to. In effect, the 4943A "remembers" all previous instructions except the changed portion of the instruction. For instance, once a measurement is set up (like Level & Frequency), the transmitter frequency may be changed independently. The other parameters, such as setting the measurement or display, are left unchanged.

3-21. DETECTING INVALID MEASUREMENT DATA

3-22. After entering any measurement data, the data should be checked for validity before use. Four checks can be made of the data. First, determine if an H-code has been entered. Secondly, determine if an underrange condition exists. Thirdly, determine if an overrange exists. Finally, check if a frequency error has occurred. For instance, if a measurement instruction specifies an 804 Hz transmit frequency by a slave unit, did the master receive it?

3-23. An H-code appears as the numbers 9900 to 9916 in the left display data. An underrange is indicated by −9999 in the left display data; an overrange by 9999.

Table 3-2. HP-IB Program Code Set (1 of 2)

CHARACTER (ASCII CODE)	FUNCTION	OCTAL CODE	DECIMAL CODE
R	Remote (Master-Slave) Identifier	122	82
0	Normal	060	48
1	Master & Master-to-Slave	061	49
2	Master & Slave-to-Master	062	50
3	Slave	063	51
M	Measurement Identifier	115	77
1	Level & Frequency	061	49
2	Message Circuit Noise	062	50
3	Noise-with-Tone	063	51
4	Signal + Noise to Noise Ratio	064	52
5	Impulse Noise	065	53
6	Envelope Delay (Display ED & Frequency)	066	54
7	Phase Jitter or Nonlinear Distortion	067	55
W	Noise Filter Identifier	127	87
0	C-Message Filter	060	48
1	3 KHz Flat Filter	061	49
N	NLD Control Identifier	116	78
0	Normal Test	060	48
1	Check Signal	061	49
D	Display Identifier	104	68
0	Display Transmitter	060	48
1	Display Receiver	061	49
2	Display Delay (use with M6)	062	50
3	Display Level (use with M6)	063	51
F	Frequency Identifier	106	70
(x)xxx	Any Frequency between 204 Hz and 3904 Hz	—	—
Z	Zero Identifier	132	90
0	Level Zero	060	48
1	Delay Zero	061	49
P	Impulse Noise Period Identifier	120	80
0	5 Minutes	060	48
1	15 Minutes	061	49
2	Non-Stop	062	50
I	Impulse Noise Identifier	111	73
0	Stop	060	48
1	Start/Reset	061	49
L	Delay Identifier	114	76
0	Envelope Delay Normal Set	060	48
1	Envelope Delay Repeat Set	061	49
O	Output Identifier	117	79
0	Output measurement data when addressed	060	48
1	Pull Service Request to output data	061	49

Table 3-2. HP-IB Program Code Set (2 of 2)

CHARACTER (ASCII CODE)	FUNCTION	OCTAL CODE	DECIMAL CODE
S	Sweep Identifier	123	83
0	Set Upper Limit	060	48
1	Set Lower Limit	061	49
2	Stop Sweep	062	50
3	Start Sweep	063	51
4	50 Hz Step	064	52
5	15 Hz Step	065	53
C	Self Check Identifier	103	67
0	Stop	060	48
1	Start	061	49
E	Execute Identifier Note: "E" must be last character in each program code set. Example: cmd 7, "?U*", "M1E"	105	69
Factory Preset Address: Talk = J, Listen = *			

Table 3-3. Status Byte

BIT	7	6	5	4	3	2	1	Ø (LSB)
	Ø	SERVICE REQUEST	Ø	DATA READY	Ø	Ø	Ø	Ø

- Bits Ø thru 3, 5, and 7 are always logical zero.
- Bits 4 and 6 are logical 1 when the 4943A or 4944A is ready to output data, or when the 4943A or 4944A pulls service request.

Table 3-4. Allowable HP-IB Bus Messages

OPERATION	DESCRIPTION	9825A EXAMPLE
Data	Initiate a measurement. Read measurement data from instrument.	28: wrt 710,"R1M1E" 30: red 710,A,B
Clear (DCL)	Returns 4943A or 4944A to following setup: Normal Level & Frequency 1004 Hz Display Level Master-to-Slave No Self Check Non-Stop C-Message-Filter NLD Normal Test	34: clr 7
Remote	Enables remote operation of devices on bus. Enables remote operation of only 4943A or 4944A on bus.	37: rem 7 40: rem 710
Local (GTL)	Returns the 4943A or 4944A to local control when addressed.	43: lcl 710
Clear Lockout/ Set Local	Sets local mode on all bus devices.	47: lcl 7 or Press RESET key
Abort (IFC)	Clears all bus operations. Unaddresses all talkers and listeners.	50: cli 7 or Press RESET key
Checking Status Byte for Service Request (SRQ)	Determine if service has been requested by any device. Variable S will contain the byte. Bit 7 contains the status bit.	53: rds(7)→S 54: if bit(7,S)=1;ret
Serial Polling of 4943A or 4944A	Enter status byte from 4943A or 4944A and check for presence of service request. Variable Q will contain the decimal equivalent of the byte. The decimal equivalent is "80" for 4943A and 4944A when service requested.	58: rds(710)→Q 59: if Q=80;gto +10

Table 3-5. Timing Considerations

ACTION	RECOMMENDED MAXIMUM DELAYS *Note 1*	9825A EXAMPLE
Address TIMS to "listen" to remote enable	1/2 second	65: rem 7 66: wrt 710 67: wait 500 or 70: rem 710 71: wait 500
Set measurement, normal mode.	2 seconds, except NLD, use 20 seconds	74: wrt 710,"R0M1D1F100400E" 75: wait 2000
Set measurement, master-slave mode, master-to-slave	10 seconds, except NLD, use 40 seconds	78: wrt 710,"R1M1D1F100400E" 79: wait 10000
Set measurement, master-slave mode, slave-to-master	10 seconds, except NLD, use 40 seconds	82: wrt 710,"R2M1D1F100400E" 83: wait 10000
Level zero, normal mode	1/4 second	86: wrt 710,"Z0E" 87: wait 250
Level zero, master-slave mode	2 seconds	90: wrt 710,"Z0E" 91: wait 2000
Delay zero, normal mode	1/2 second	94: wrt 710,"Z1E" 95: wait 500
Delay zero, master-slave mode	1/2 second	99: wrt 710,"Z1E" 100: wait 500
NLD check signal, normal mode	20 seconds	101: wrt 710,"N1E" 102: wait 20000
Change transmit frequency	2 seconds	103: fmt 1,"F",f10.0,"E" 104: for N=204 to 3804 by 200 105: wrt 710.1,N 106: wait 2000 107: next N
Start self check	100 seconds for standard 4943A 120 seconds for 4943A – opt 012 or 4944A	110: wrt 710,"C1E" 111: wait 30000 112: wait 30000 113: wait 30000 114: wait 10000 115: red 710,A
Issue bus commands Local, Clear, and Abort	2 seconds	119: cli 7 120: wait 2000

NOTE: 1. The delay values recommended are usually needed to allow TIMS to settle, and to prevent erroneous data entry. The delays presented are therefore typical maximum values. The user is encouraged to try shorter delay times when system efficiency is needed.

Table 3-6. HP-IB Output Data Format (1 of 2)

		MEASURED VALUE, LEFT DISPLAY (DB or DBM)							MEASURED VALUE, RIGHT DISPLAY (RCV HZ or TRMT HZ)					
CHARACTER NUMBER	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	SIGN	D	D	DP	D	SP	,	SP	F	F	F	F	CR	LF

(a) LEVEL & FREQUENCY MEASUREMENT

				MEASURED VALUE (DBRN)										
CHARACTER NUMBER	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	SIGN	SP	SP	D	D	SP	,	SP	SP	SP	SP	SP	CR	LF

(b) MESSAGE CIRCUIT NOISE MEASUREMENT

				MEASURED VALUE (DBRN or DB)					MEASURED VALUE (RCV HZ or TRMT HZ)					
CHARACTER NUMBER	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	SIGN	SP	SP	D	D	SP	,	SP	F	F	F	F	CR	LF

(c) NOISE-WITH-TONE AND SIGNAL-TO-NOISE MEASUREMENT

				TIME (DURING MEASUREMENT) (MINUTES)					MEASURED VALUE (COUNTS					
CHARACTER NUMBER	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	SIGN	SP	SP	SP	SP	SP	,	SP	F	F	F	F	CR	LF

(d) IMPULSE NOISE MEASUREMENT

		MEASURED VALUE (MICRO SEC)							MEASURED VALUE (RCV HZ or TRMT HZ)					
CHARACTER NUMBER	0	1	2	3	4	5	6	7	8	9	10	11	12	13
	SIGN	D	D	D	D	SP	,	SP	F	F	F	F	CR	LF

(e) ENVELOPE DELAY MEASUREMENT, DELAY DISPLAY

Table 3-6. HP-IB Output Data Format (2 of 2)

	MEASURED VALUE (DEGREES)							MEASURED VALUE (RCV HZ or TRMT HZ)					
0	1	2	3	4	5	6	7	8	9	10	11	12	13
SIGN	D	D	DP	D	SP	,	SP	F	F	F	F	CR	LF

(f) PHASE JITTER MEASUREMENT (STANDARD 4943A ONLY)

MEASURED VALUE (DB)			2ND ORDER STATUS					MEASURED VALUE (DB)			3RD ORDER STATUS			
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
D	D	DP	P	S	SP	,	SP	F	F	DP	P	T	CR	LF

(g) NONLINEAR DISTORTION MEASUREMENT (4944A OR 4943A – OPT 012)

	ERROR CODE DATA												
0	1	2	3	4	5	6	7	8	9	10	11	12	13
SIGN	9	9	X	X	SP	,	SP	9	9	9	9	CR	LF

(h) ERROR CODES

	OUT OF RANGE DATA												
0	1	2	3	4	5	6	7	8	9	10	11	12	13
SIGN	9	9	9	9	SP	,	SP	9	9	9	9	CR	LF

(i) OUT OF RANGE

NOTES:

- (SP) IS AN ASCII SPACE.
- (CR) IS AN ASCII CARRIAGE RETURN.
- (LF) IS AN ASCII LINE FEED.
- (,) IS AN ASCII COMMA USED TO SEPARATE CHARACTER GROUPS.
- (DP) IS A DECIMAL POINT.

"SIGN" IS A SPACE (+) OR MINUS (–).

"D" IS LEFT DISPLAY DATA.

"F" IS RIGHT DISPLAY DATA.

"P" IS A NUMERICAL CODE 0 TO 7:

0		4 TONE CORRECTED
1		4 TONE NOT CORRECTED
2		2 TONE CORRECTED
3		2 TONE NOT CORRECTED
4	INPROCESS	4 TONE CORRECTED
5	INPROCESS	4 TONE NOT CORRECTED
6	INPROCESS	2 TONE CORRECTED
7	INPROCESS	2 TONE NOT CORRECTED

"S" IS A NUMERICAL CODE 0 TO 2:

0 2ND DISTORTION READING
1 2ND DISTORTION UNDERRANGE
2 NOISE READING
3 NOISE UNDERRANGE

"T" IS NUMERICAL CODE 0 TO 2:

0 3RD DISTORTION READING
1 3RD DISTORTION UNDERRANGE
2 NOISE READING
3 NOISE UNDERRANGE

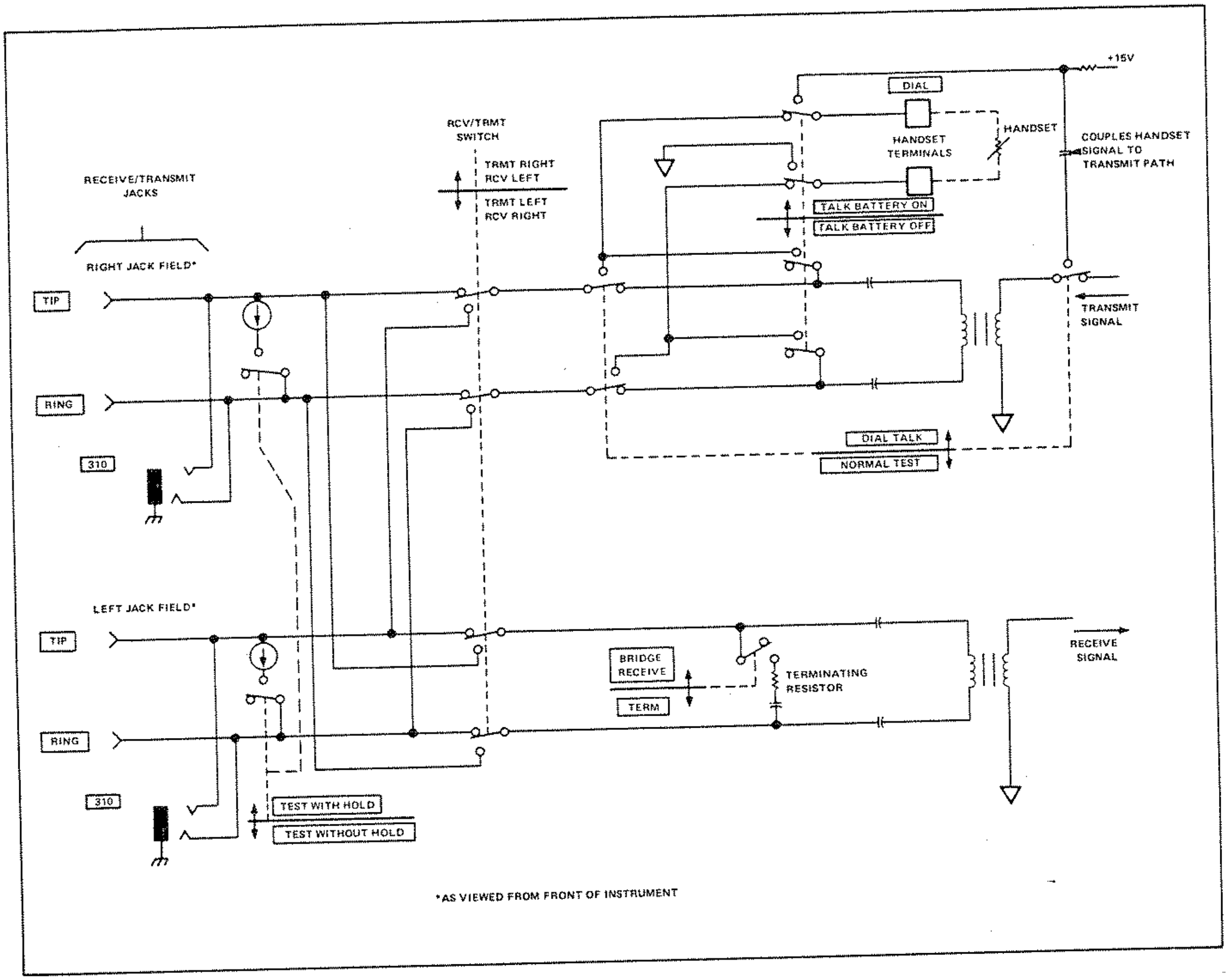


Figure 3-3. Input Switching

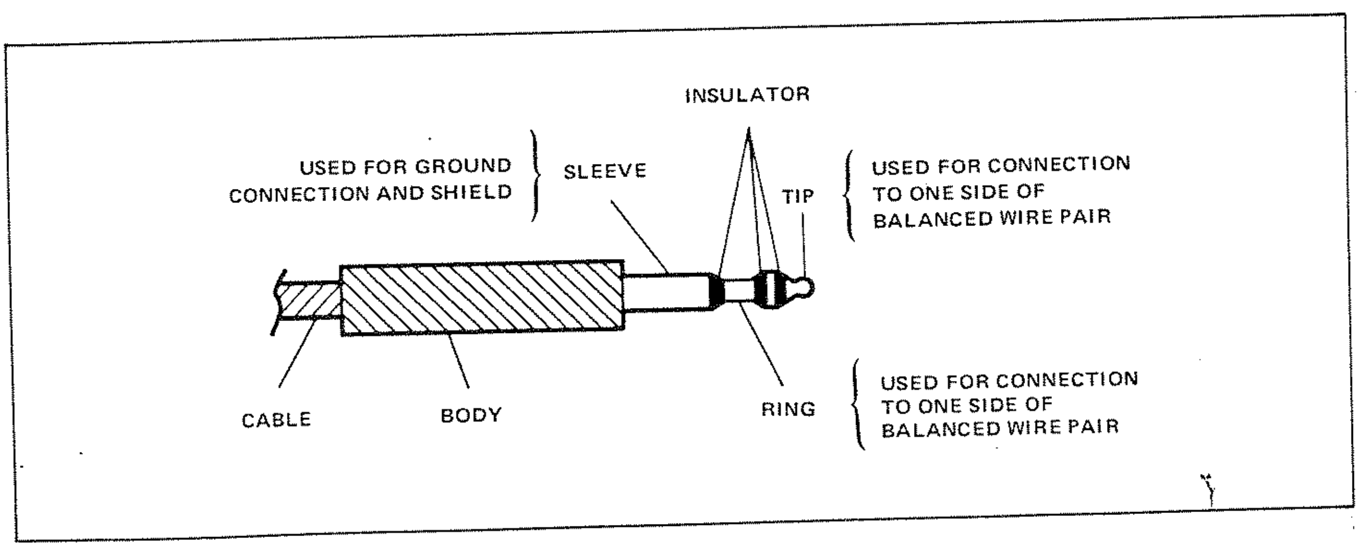


Figure 3-4. Western Electric 310 Plug

3-24. MEASUREMENT PRINCIPLES

3-25. The following text describes the principles of all measurements made by the Model 4943A. Block diagrams and functional descriptions are provided to explain input-output switching and the different measurements.

3-26. INPUT-OUTPUT SWITCHING

3-27. The receive/transmit jacks provide for interconnection of the 4943A to the telephone circuit under test. See Figure 3-3. The RCV/TRMT switch provides for selection of either the transmit or receive function for the left jack field, and simultaneously selects the opposite for the right jack field. Both the left and right jack felds provide parallel (multipled) connection jacks: standard five-way binding posts on top and Western Electric 310 type jacks on the bottom. Either the binding posts or the 310 jacks may be used; both of them should not be used at the same time. Figure 3-4 shows the construction of the 310 plug.

3-28. The TEST WITH HOLD/TEST WITHOUT HOLD setup switch allows the application of a 23 mA current source to the left and right jack field TIP and RING connectors. This provides for the latching of telephone switching equipment required in certain applications (functions as a holding coil).

3-29. The input and output impedance of the 4943A is selectable at either 600 or 900 ohms (not shown in Figure 3-3), which are standard telephone circuit values. The impedance of the 4943A must be selected to match the circuit under test, or erroneous measurement values will be obtained.

3-30. The receive input may be terminated or bridged across the circuit under test. The terminated mode provides a resistive termination on the receive circuit to provide proper loading. When a termination is provided by some other device, then it is not necessary (nor desirable) to provide a termination. In this case the receive input is used in the bridged mode, which provides a high impedance receive input (greater than 50k-ohms).

3-31. The 4943A input and output circuits are balanced to match standard telephone circuits. A balanced circuit is one that is electrically symmetrical; the two sides of the circuit have equal series resistance, series inductance, shunt capacitance, and leakage to ground. Only instruments with balanced inputs will operate properly when connected to a balanced circuit.

3-32. To allow dialing, talking, and listening over the circuit under test, handset terminals (DIAL) are provided for the connection of a lineman's handset. In addition, a +15V source (talk battery) is selectable for series application to the handset terminals. This allows the handset to become an ac signal source for application to the circuit under test.

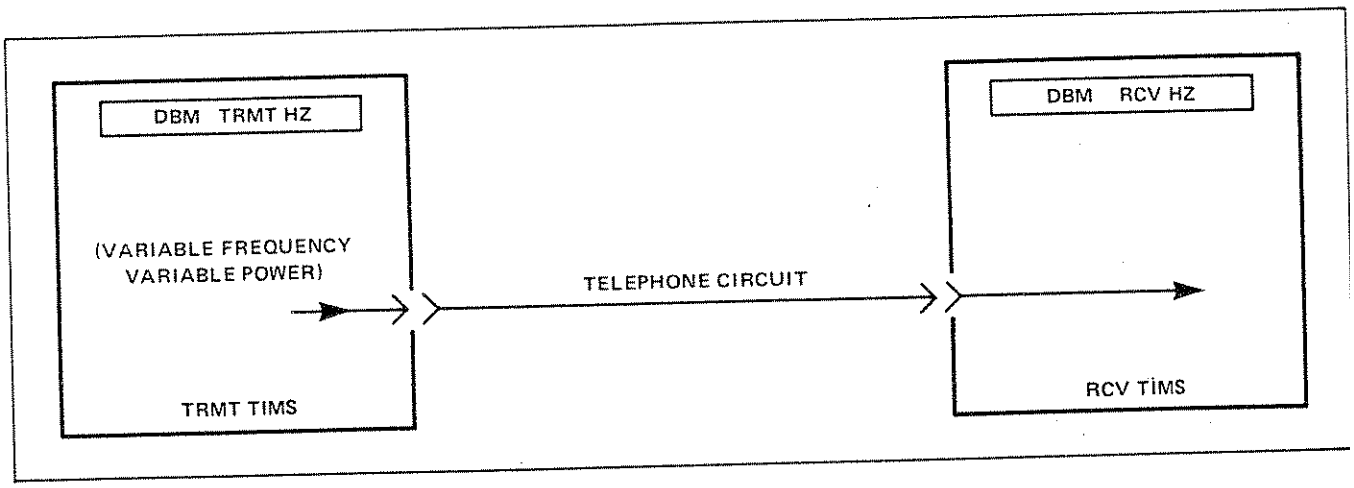


Figure 3-5. Level and Frequency Measurement

3-33. LEVEL AND FREQUENCY MEASUREMENTS

3-34. The level and frequency mode allows measurement of 1000 Hz loss (or gain) and attenuation distortion. These measurements define the amplitude-versus-frequency response of a telephone circuit. Figure 3-5 illustrates the basic setup for these measurements.

3-35. 1000 Hz LOSS. The 1000 Hz loss measurement determines the point-to-point loss (or gain) of a 1000 Hz test frequency transmitted over a telephone circuit. To make this measurement, a 1004 Hz test frequency is transmitted at one end of the circuit, and its power (in dBm) is measured at the other end. The transmitted power is compared with the received power to determine 1000 Hz loss.

3-36. The transmitted frequency is actually 1004 Hz (not 1000 Hz) to prevent measurement errors which would occur over certain telephone circuits. The 4943A offsets all stepped transmitter frequencies by 4 Hz.

3-37. ATTENUATION DISTORTION. The attenuation distortion measurement determines the amplitude-versus-frequency characteristics of a telephone circuit; using a single frequency measurement technique. To make this measurement, a 1004 Hz test frequency is transmitted. At the receiving end, the received power is recorded to obtain a 1004 Hz reference level. The transmitted frequency is then varied over the full transmitter range (while maintaining a constant transmitted level), and the received power is noted in each case. The received powers may then be compared to the 1004 Hz received reference power to obtain the frequency attenuation characteristics of the circuit in dBm.

3-38. To directly obtain the loss deviations relative to 1004 Hz, the LEVEL ZERO switch is depressed during reception of the 1004 Hz reference signal. This action stores the received power in dBm and simultaneously displays this level as 0 dB. Level readings taken at other frequencies will then be displayed in units of dB as compared to the 1004 Hz reference. This eliminates the need to subtract the 1004 Hz reference level from other levels at other frequencies to obtain dB readings.

3-39. According to telephone industry convention, attenuation distortion is defined as a change in loss of a telephone circuit, compared to the loss of a nominal 1000 Hz signal on that circuit. For example, a circuit with 6 dB more loss at 2800 Hz would have an attenuation distortion of +6 dB.

3-40. The SF (single-frequency) SKIP setup switch is provided to automatically prevent the test set from transmitting frequencies within the range of 2450 Hz to 2750 Hz. This feature is used in attenuation distortion and envelope delay to prevent the dropping out of the telephone circuit connection.

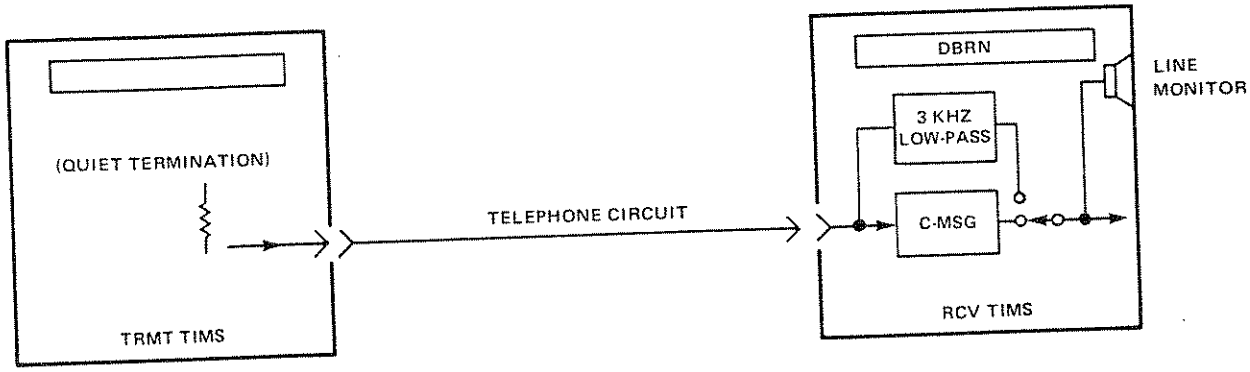


Figure 3-6. Message Circuit Noise Measurement

3-41. MESSAGE CIRCUIT NOISE MEASUREMENT

3-42. The message circuit noise mode allows measurement of the electrical noise on a telephone circuit. Figure 3-6 illustrates the basic setup for this measurement.

3-43. The message circuit noise mode measures the noise on a telephone circuit, which has a quiet termination on one end (supplied by transmitting TIMS) and a weighted measuring device on the other end (receiving TIMS). The quiet termination is a simple resistive termination on the wire pair.

3-44. At the measurement end of the telephone circuit, TIMS includes a frequency weighting (shaped) filter, either C-message or 3 kHz flat (see Figures 3-7 and 3-8). The C-message filter allows measurement of only those noise signals that are of annoyance to the "typical" subscriber of standard telephone service. The 3 kHz flat filter has a response that provides much less attenuation to the low frequencies (60 Hz to 500 Hz) as compared to the C-message filter. By comparing a 3 kHz flat noise measurement to a C-message noise measurement, the relative influence of low frequency noise (60 Hz commercial power, etc.) can be determined.

3-45. Received noise levels are displayed in units of dBrn, or dB with respect to reference noise (1000 Hz tone at −90 dBm). For example, a noise reading of 20 dBrn has an RMS power of −70 dBm (20-90 = −70). With the C-message filter, displayed readings are in units of dBrnC, or noise level in dBrn with a C-message weighted measuring device.

3-46. In addition to measuring noise on a telephone line, the 4943A may be used to listen to that noise. The line monitor speaker provides an amplified reproduction of the signal present at the filter output.

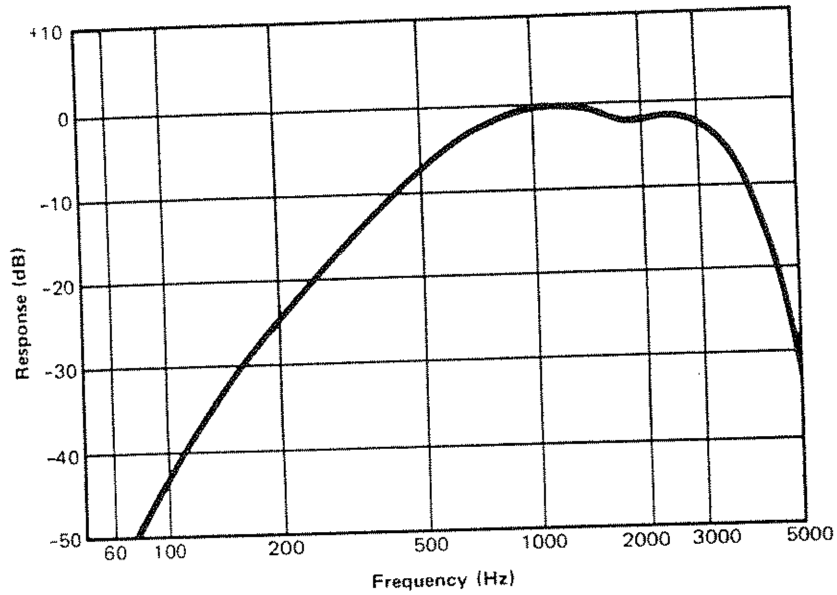


Figure 3-7. C-Message Weighting Characteristic

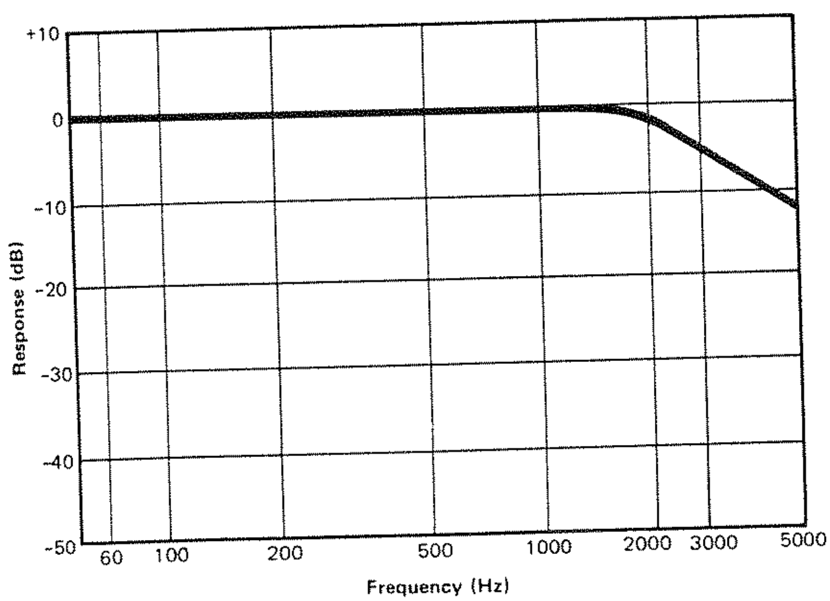


Figure 3-8. 3 kHz Flat Weighting Characteristic

3-47. NOISE-WITH-TONE MEASUREMENT

3-48. The noise-with-tone mode allows measurement of telephone circuit noise in the presence of a transmitted test frequency.

3-49. To make this measurement, a 1004 Hz test frequency is transmitted. At the receiving TIMS, the 1004 Hz signal is selectively attenuated by 50 dB using a notch filter (all frequencies between 995 Hz and 1025 Hz are attenuated by at least 50 dB). The remaining received signal (noise) is passed through a C-message filter for measurement. The received noise level is displayed in units of dBrn. Figure 3-9 illustrates the combination of the C-message weighting and notch filter characteristics.

3-50. SIGNAL-TO-NOISE MEASUREMENT

3-51. The signal-to-noise mode allows measurement of the ratio of received signal-plus-noise power to noise power (S + N/N).

3-52. To make this measurement, a 1004 Hz test frequency is transmitted over the telephone circuit. At the receiving TIMS, the 1004 Hz signal is selectively attenuated by 50 dB using the notch filter. The remaining received signal (noise) is then compared with the original signal-plus-noise signal. The computed signal-to-noise ratio is then displayed in units of dB. Figure 3-10 illustrates this measurement.

3-53. IMPULSE NOISE MEASUREMENT

3-54. This measurement mode allows a count of the impulse noise spikes over a selected time interval.

3-55. Impulse noise is that component of the received noise signal which is much greater in amplitude than the normal peaks of the message circuit noise. It occurs as short duration spikes and/or bursts of energy. Waveform (b) in Figure 3-11 illustrates a received test signal that includes interfering impulse noise spikes.

3-56. The impulse noise measurement allows determination of impulse noise count on a telephone circuit, given a selected amplitude threshold level and a selected measurement period. The 4943A is internally programmed to register a maximum of 7 counts per second. This arrangement agrees with the Bell Telephone System measurement standard.

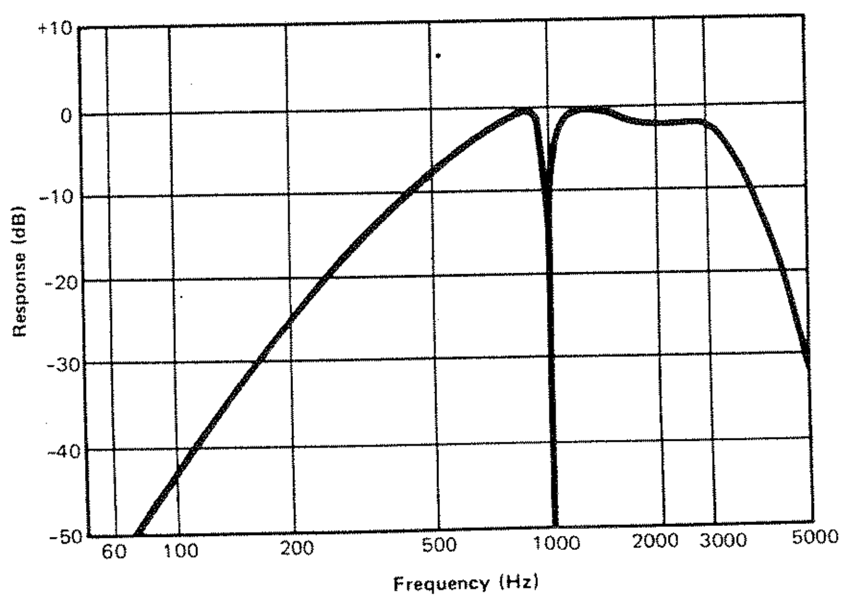
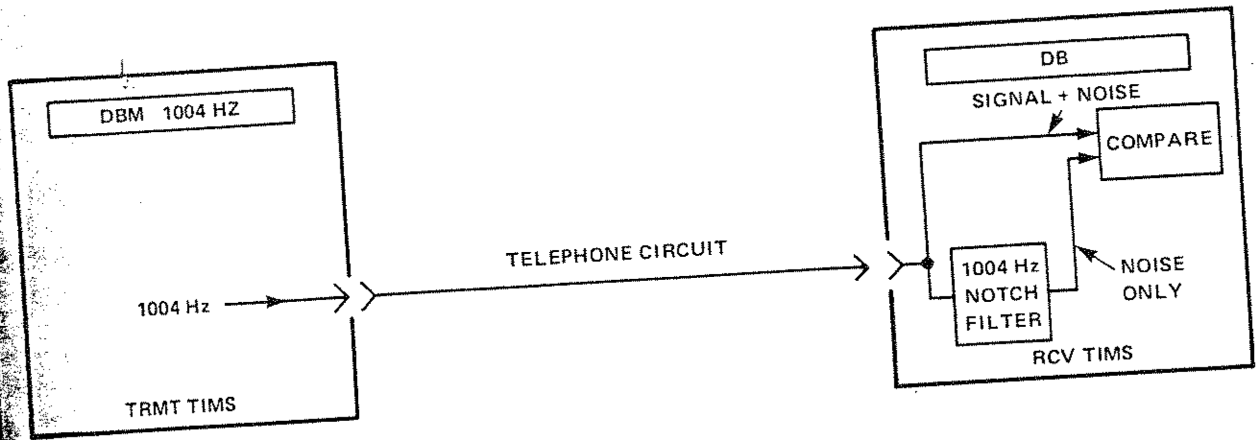


Figure 3-9. C-Message Weighting with Notch



$$\text{S-T-N RATIO} = 10 \log \frac{P_{SIGNAL} + P_{NOISE}}{P_{NOISE}}$$

Figure 3-10. Signal-to-Noise Measurement

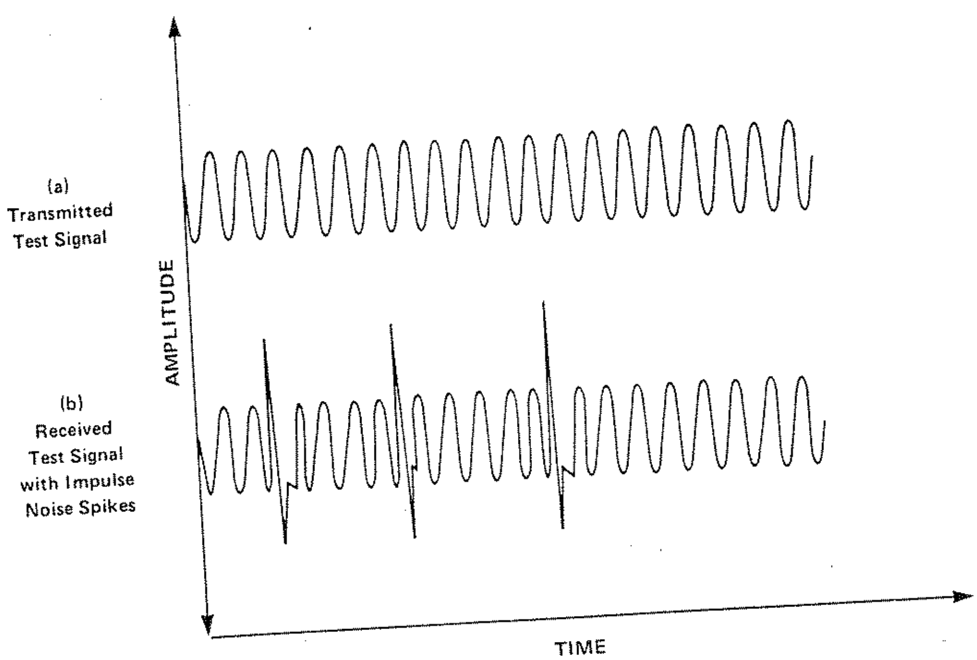


Figure 3-11. Impulse Noise Waveforms

3-57. ENVELOPE DELAY MEASUREMENT

3-58. The envelope delay mode allows measurement of the phase-versus-frequency characteristics of a telephone circuit.

3-59. An ideal circuit which has a linear phase shift characteristic will produce a straight line slope. This slope represents a linear relationship between a change in frequency and a corresponding change in phase as shown in Figure 3-12a. The practical circuit, however, is never ideal and will produce a nonlinear phase shift characteristic (phase distortion) as shown in Figure 3-12b.

3-60. Conventional measurement techniques make it difficult to measure the absolute phase characteristic of a transmission system, since a phase reference is difficult to establish at the receiving end of the circuit. It is possible, however, to measure relative phase shift at the receiving end using the envelope delay measurement technique. This technique makes it possible to measure the envelope delay distortion of a telephone circuit, which provides a relative measure of the phase linearity (or non-linearity) of the circuit.

3-61. RELATING PHASE SHIFT TO ENVELOPE DELAY. Amplitude modulating a low frequency sine wave (f_m) onto a carrier frequency (f_c) produces an amplitude modulated (AM) signal as shown by waveforms (a), (b), and (c) in Figure 3-13. The envelope of the AM signal is the outline (or shape) of the peak excursions of the modulatec signal as shown in waveform (d) of Figure 3-13 The AM process produces a signal whose spectrur consists of the carrier frequency plus an uppe sideband ($f_c + f_m$) and a lower sideband ($f_c - f_m$ Figure 3-14 illustrates this relationship. Since th upper sideband is of a higher frequency than th carrier, it undergoes a greater phase shift than th carrier; since the lower sideband is of a low frequency, it undergoes less phase shift.

3-62. If the AM signal is passed through a circ having a phase shift characteristic which increa linearly with frequency (Figure 3-12a), envelope of the AM signal experiences a shift time (or delay) as shown in waveforms (d) and of Figure 3-13. This occurs because the lo sideband experiences less phase shift than carrier, while the upper sideband encounters m The net result of these phase shifts is that modulation envelope is shifted in phase (or layed) when traveling over a transmission mediu

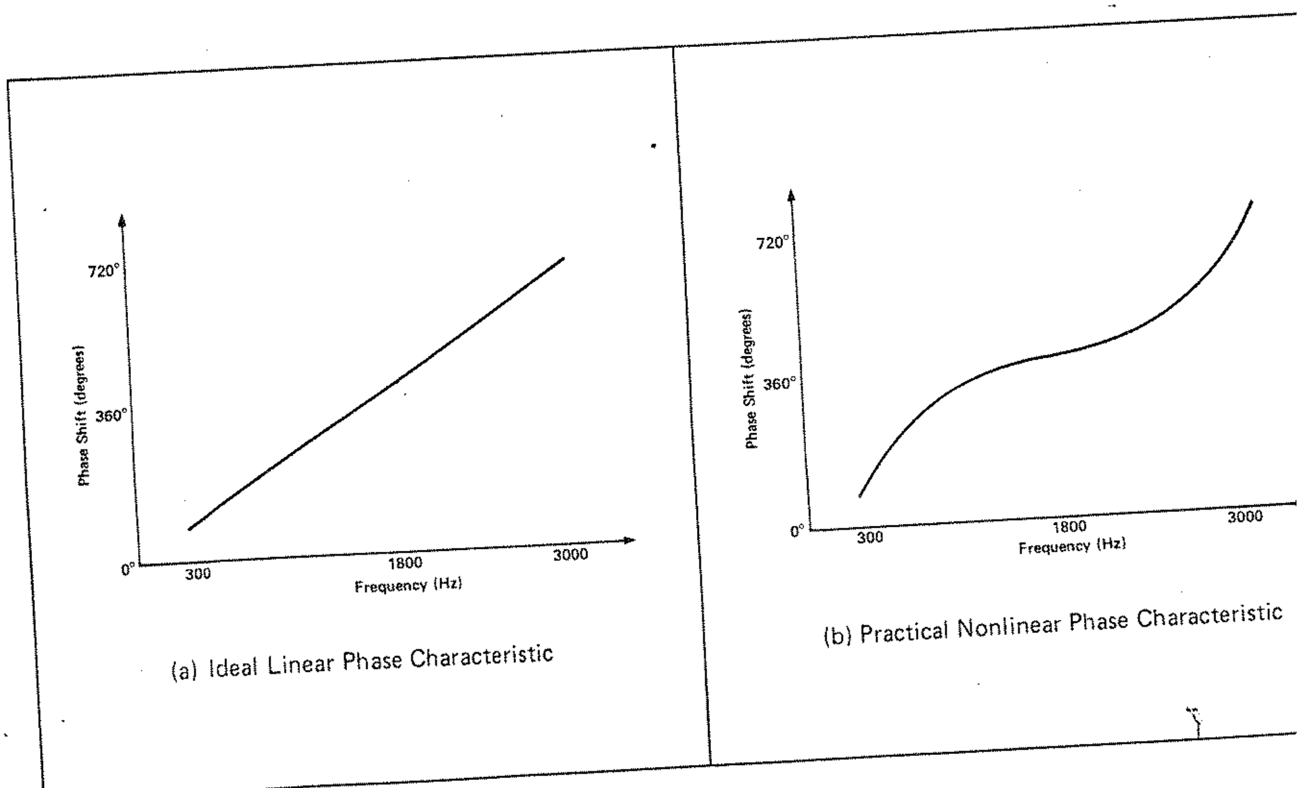


Figure 3-12. Phase-versus-Frequency Relationships

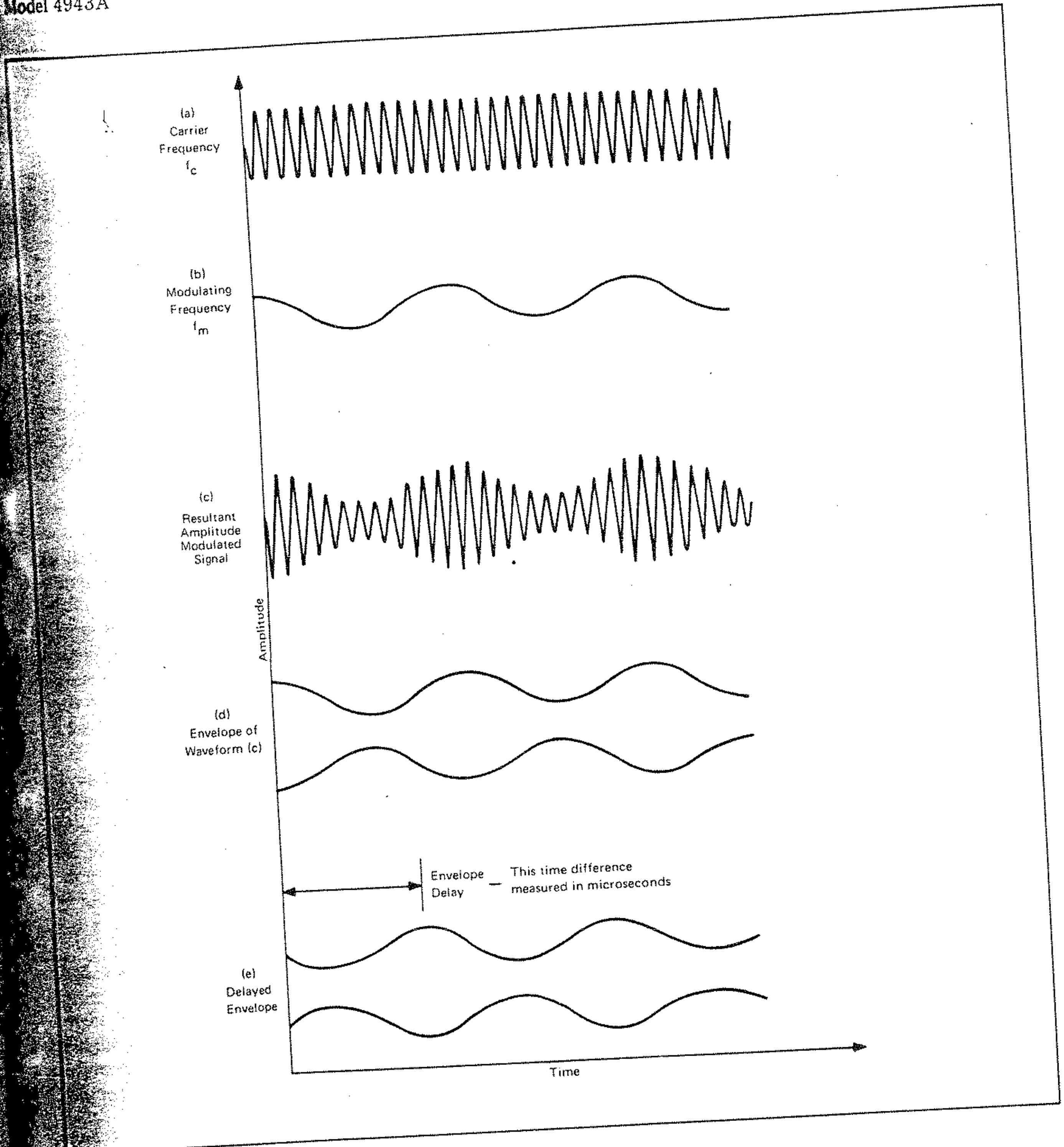


Figure 3-13. Envelope Delay Waveforms

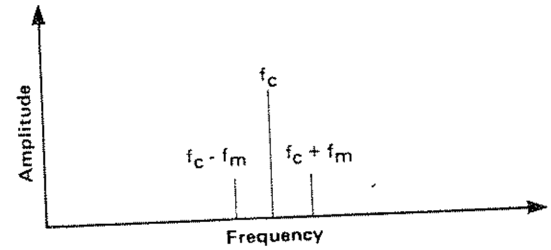


Figure 3-14. AM Signal Frequency Spectrum

3-63. The amount of envelope delay is related to the difference in phase between the two sidebands. If the phase-versus-frequency characteristic of the transmission medium is linear, then any carrier frequency used (with a fixed modulation frequency) will produce a constant envelope delay value. Plots (a) and (b) in Figure 3-15 illustrate this. However, if the phase-versus-frequency characteristic is nonlinear, then different carrier frequencies will produce different envelope delay values. Plots (c) and (d) in Figure 3-15 illustrate this. *When different values of envelope delay occur, the difference between delay values at two different carrier frequencies is termed "envelope delay distortion".*

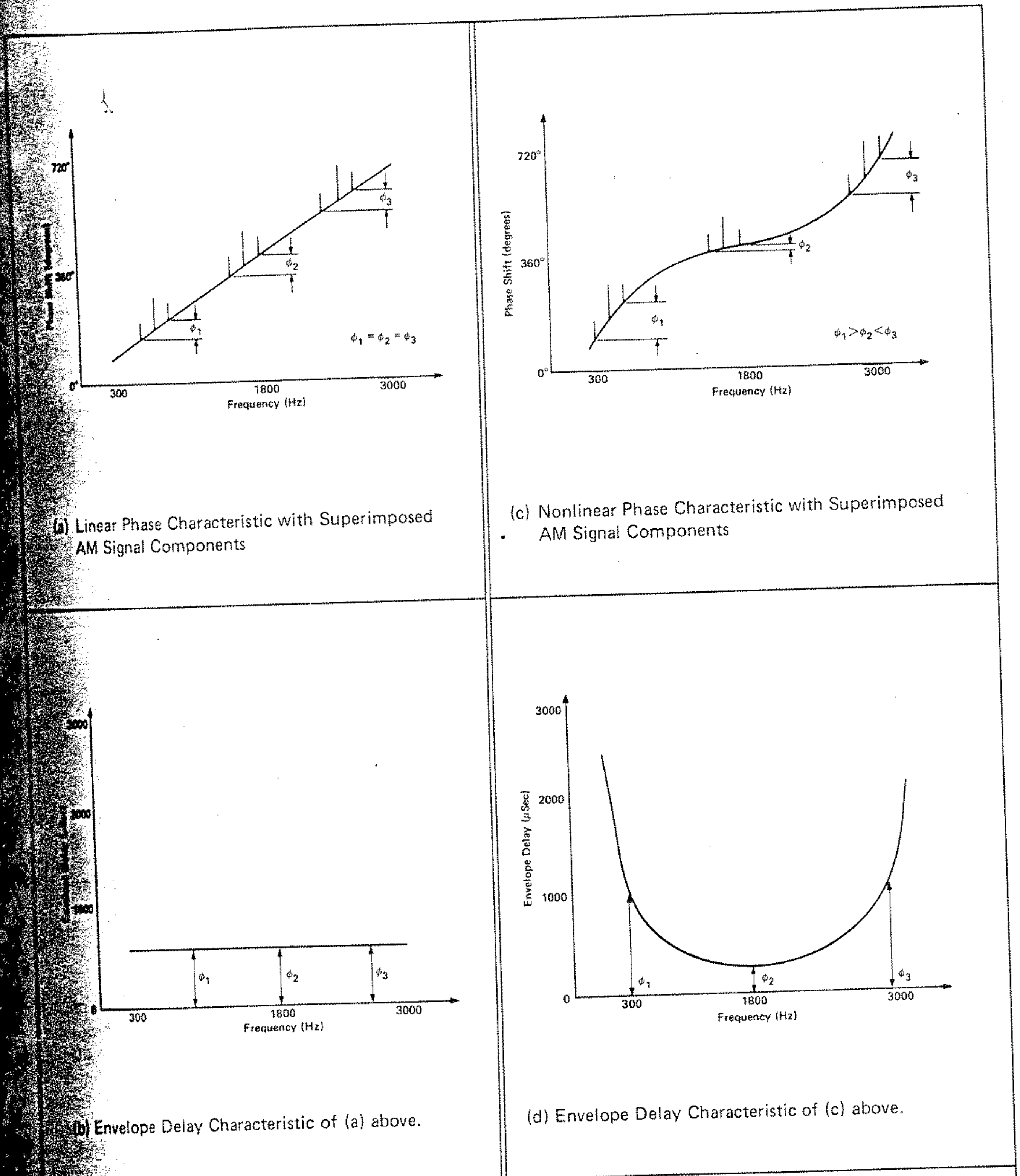
3-64. ENVELOPE DELAY MEASUREMENT TECHNIQUE. To make this measurement, two test sets are used in the configuration shown in Figure 3-16. The normal set transmits a test signal over the circuit under test to the repeat set. The repeat set responds by transmitting envelope delay information back to the normal set over the return reference circuit. The normal set compares its received signal with its transmitted signal to determine envelope delay distortion values.

3-65. The normal set transmits an amplitude modulated test signal consisting of a variable frequency carrier (204 to 3904 Hz) and a fixed modulation frequency (83-1/3 Hz). The carrier frequency is varied over the band of interest, usually in 100 Hz steps. The test signal travels the circuit under test and is received by the repeat set. The receiver of the repeat set amplitude demodulates the incoming test signal to produce the AM envelope. Changing the carrier frequency as mentioned above will result in a change in the delay of the 83-1/3 Hz envelope at the repeat set, if envelope delay distortion exists. The envelope delay values received at the repeat set must now b transmitted back to the normal set fo measurement.

3-66. In the repeat set, the demodulated AM sign is used to amplitude modulate the fixed frequen carrier that is transmitted back to the normal s carrier that is transmitted back to the normal s The repeat set carrier oscillator remains fixed one frequency during the envelope del measurement. The carrier frequency is usua selected at midband (nominally 1804 Hz) becau envelope delay characteristics are fairly consta and attenuation distortion characteristics are fai flat. Since a constant return frequency is used the repeat set, there will be no envelope de distortion encountered by the return refere signal (although there will be a fixed envel delay). Therefore, the envelope delay va received at the normal set will represent envelope delay value received at the repeat set, p the constant envelope delay of the return refere circuit.

3-67. The receiver of the normal set t amplitude demodulates the incoming re reference signal. The phase of the incoming re reference envelope is then compared with original 83-1/3 Hz oscillator signal to deter the difference in phase (envelope delay) betw the two signals.

3-68. To measure the change in envelope d from the normal set to the repeat set (w change in carrier frequency), a DELAY Z control is used to "zero out" the fixed env delay of the entire measurement loop. The zero control sets the phase difference (or env delay) between the 83-1/3 Hz oscillator an return reference envelope to zero. This zero usually done at a normal set transmit frequen



(a) Linear Phase Characteristic with Superimposed AM Signal Components

(c) Nonlinear Phase Characteristic with Superimposed AM Signal Components

(b) Envelope Delay Characteristic of (a) above.

(d) Envelope Delay Characteristic of (c) above.

NOTE: The symbol phi (ϕ) represents the difference in phase between the upper and lower sidebands of the AM signal superimposed on the phase characteristic plots.

Figure 3-15. Relating Phase Shift to Envelope Delay

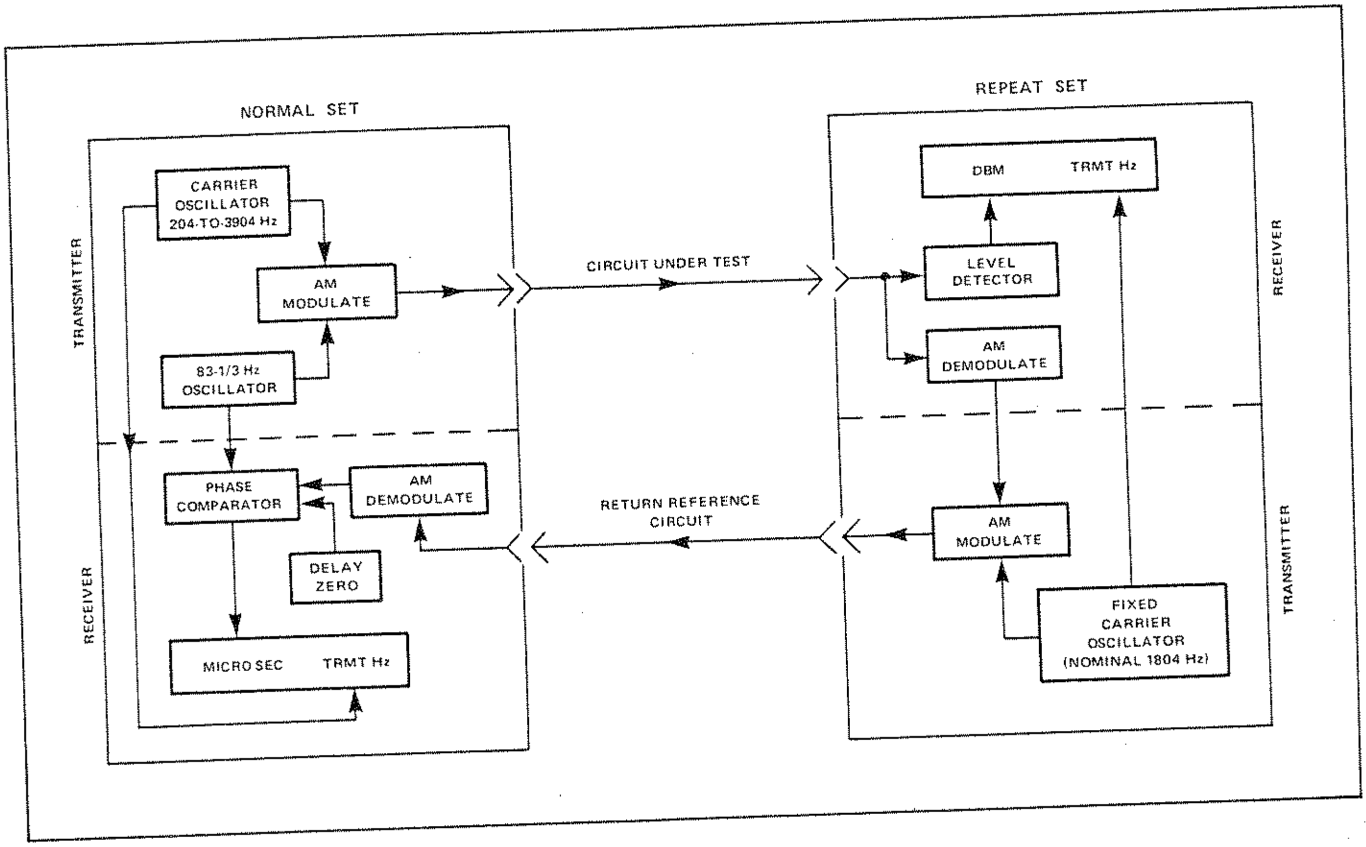


Figure 3-16. Envelope Delay Measurement

1804 Hz. All future envelope delay measurements will then be referenced to the 1804 Hz carrier frequency of the normal set. By changing the normal set carrier frequency from the delay zero reference value, the only changing envelope delay (envelope delay distortion), occurring in the measurement loop, is that incurred by the test signal on the circuit under test.

3-69. RETURN REFERENCE OR FORWARD REFERENCE OPERATION

3-70. The envelope delay measurement may be performed using th e 4943A in either the forward or return measurement mode. *The terms "forward" and "return" refer to the direction of the "reference carrier signal", with respect to the normal test set.* Figure 3-16 in the previous text illustrated the return reference arrangement in detail. It is possible, however, to make the measurement with the normal set generating the reference carrier signal. In both cases, the normal set makes the actual measurement while the repeat set transfers the incoming 83-1/3 Hz modulation onto its transmitted carrier.

3-71. The advantage of using both techniques is in getting all measurement data at one end of the telephone circuit. Figure 3-17 shows how this is done.

3-72. In Figure 3-17a, the variable frequency carrier is sent by the normal set to the repeat set. In (b), the variable frequency carrier is sent by the repeat set. In both cases, the repeat set functions as a repeater for the 83-1/3 Hz modulation. In both cases the normal set measures the change in envelope delay (in microseconds). Therefore envelope delay distortion can be measured in either case.

3-73. The normal set is in essence detecting the changing envelope delay where the carrier is changing. In Figure 3-17a, the normal set measures the distortion in the forward direction. In (b), the normal set measures in the return direction.

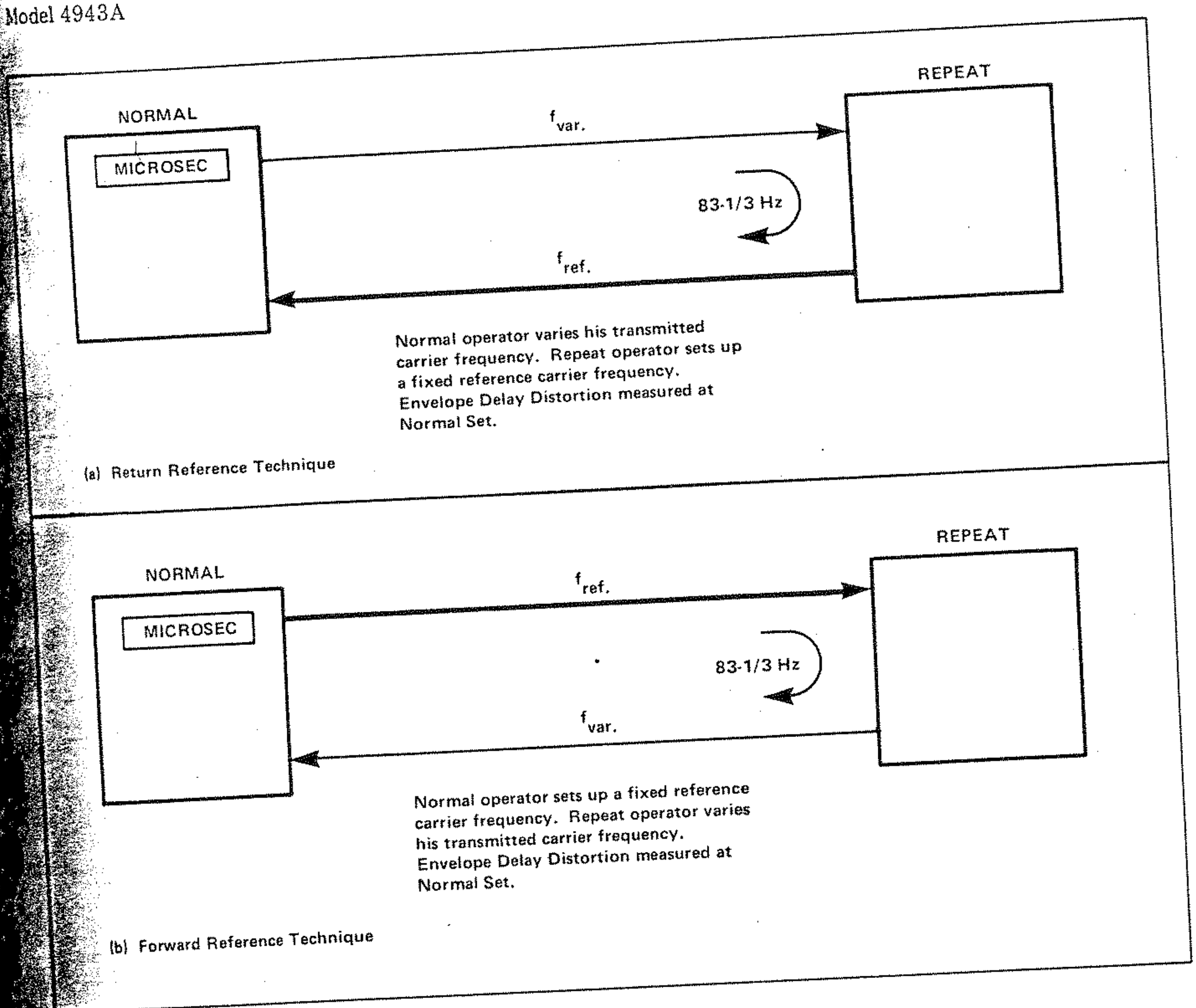


Figure 3-17. Return and Forward Reference

3-74. PHASE JITTER MEASUREMENT

3-75. The phase jitter mode allows measurement of the peak-to-peak phase deviation on a telephone circuit. Phase jitter is the undesired component of a received signal which appears as phase (or frequency) modulation. Figure 3-18 illustrates the effect of phase jitter on a reference test signal.

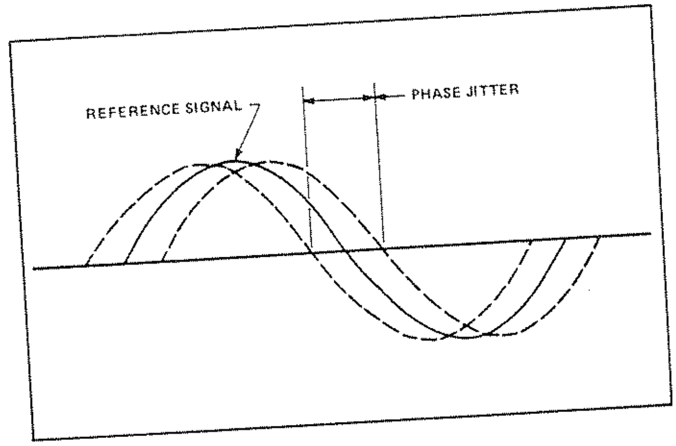


Figure 3-18. Effect of Jitter on Test Signal

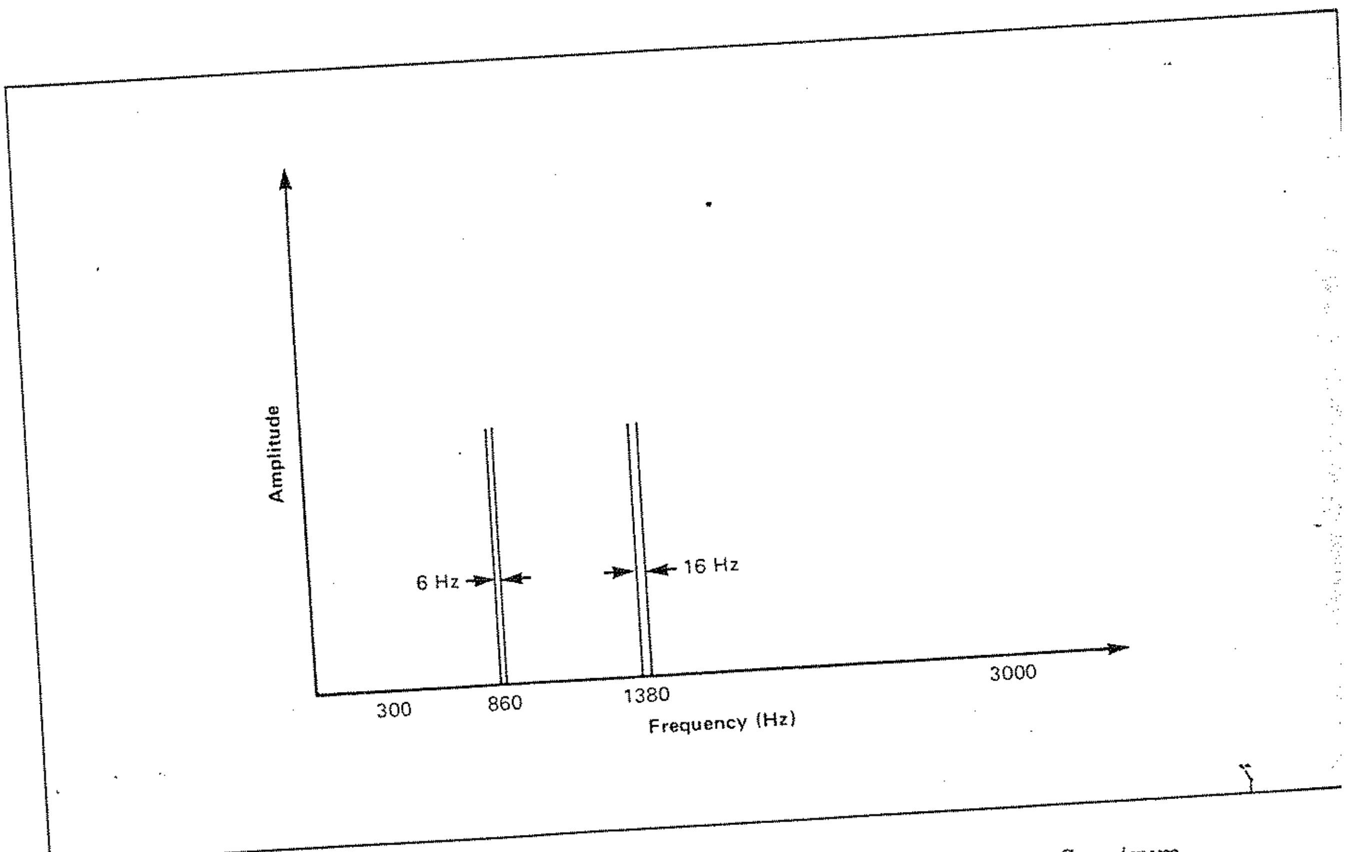


Figure 3-19. Nonlinear Distortion Transmit Signal Frequency Spectrum

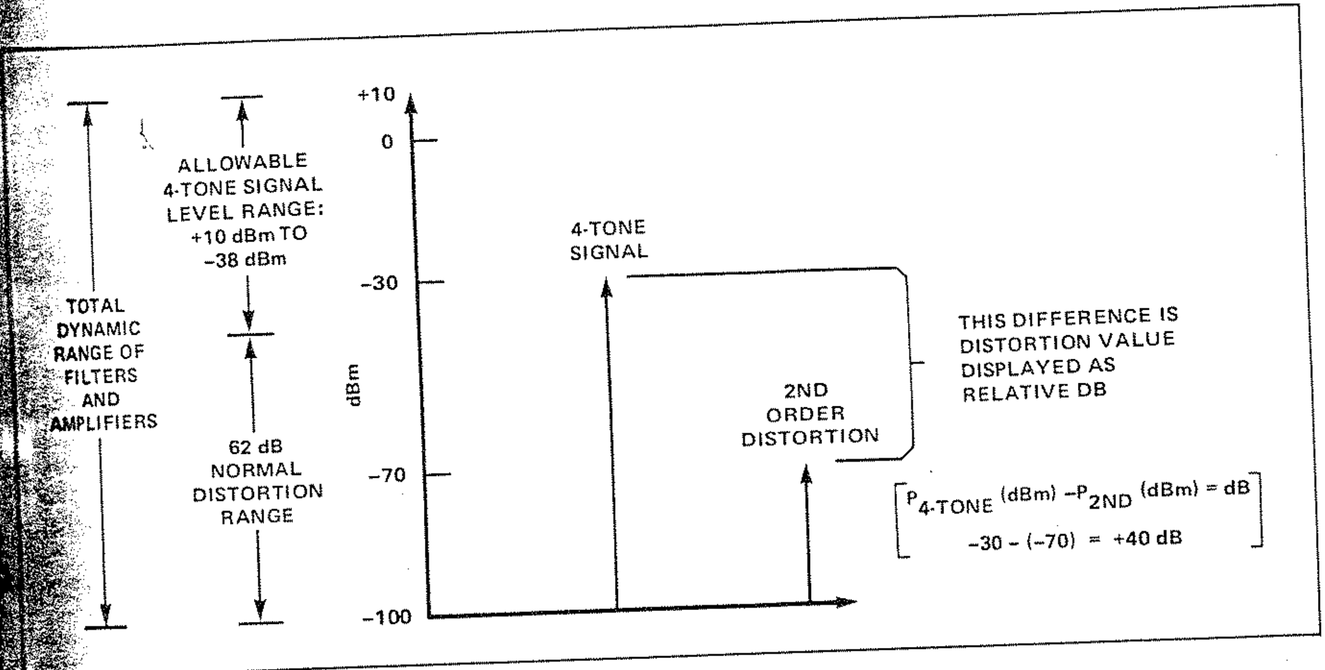


Figure 3-20. Nonlinear Distortion Levels

3-76. NONLINEAR DISTORTION MEASUREMENT (OPTION 012)

3-77. The nonlinear distortion (NLD) mode allows measurement of the second and third order intermodulation distortion products of two test frequency pairs transmitted over a telephone circuit.* Figure 3-19 illustrates the spectrum of the transmitted nonlinear distortion test signal.

3-78. Nonlinear distortion is the generation of new signal components not present in the original transmitted signal. This usually happens when a circuit's loss is nonlinear with respect to input level.

3-79. With a single frequency (f_1) applied to the input of a nonlinear device, the nonlinear distortion appears as harmonics of the input frequency, such as $2f_1$, $3f_1$, $4f_1$, etc. This type of distortion is termed "harmonic distortion". With a multiple frequency signal (f_1 and f_2) applied to the device input, the nonlinear distortion appears as harmonics of the individual input frequencies plus intermodulation products of the input frequencies. This type of distortion is termed "intermodulation distortion", and is the type measured by TIMS. Bell Telephone Laboratory studies have shown that it is valid to measure the power sum of the distortion products $f_1 + f_2$ (2240 Hz) and $f_2 - f_1$ (520 Hz) as representative of the second order distortion, while $2f_2 - f_1$ (1900 Hz) may be measured as representative of the third order distortion; which is the technique utilized by TIMS.

3-80. The check signal provision is included in TIMS to permit correction of error caused by the presence of high background noise. When the NLD toggle switch is momentarily thrown to the CHECK position, the second tone pair shown in Figure 3-19 (as centered at 1380 Hz) is suppressed, and the lower tone pair is doubled in power. This allows the circuit to be checked with a test signal of the same power. Without the two tone pairs being generated, the intermodulation process (as measured by TIMS) does not occur. The receiving TIMS looks for the second and third order products, but since these are not present, the measured received signals consist of noise. The second and third order products as measured with the two tone pairs may then be corrected accordingly to achieve accurate values.

3-81. The objective is in obtaining the amplitude relationship between second order products (or third) and the fundamental frequencies. Figure 3-20 attempts to show this relationship, plus show the acceptable signal levels. The measured 4-tone signal power and distortion power will both

*This non-linear distortion analyzer circuit is licensed under Hekimian Laboratories, Inc. U.S. Patent No. 3,862,380.

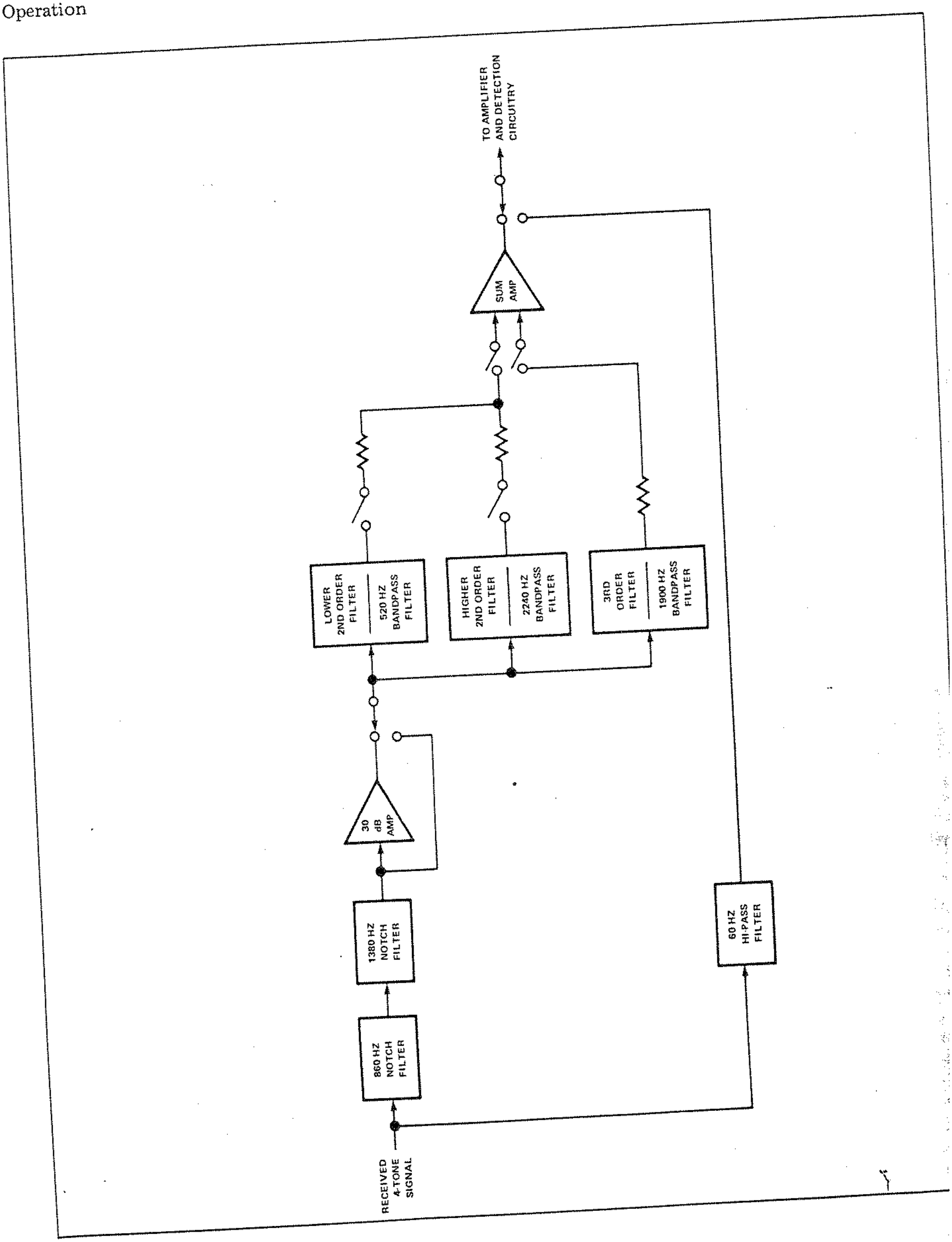


Figure 3-21. Nonlinear Distortion Measurement Technique

normally have a negative sign (–dBm). However, when their difference is computed, a positive value results [–30 – (–70) = +40 dB]. Less distortion gives a larger number of dB spread, more gives a smaller number.

3-82. MEASUREMENT TECHNIQUE. The basic measurement technique is shown in Figure 3-21. The first measurement is of the total 4-tone signal, including distortion. All the distortion filters are bypassed through the 60 Hz high-pass filter. The two second order products are then selected for comparison with the 4-tone signal. These two measured values are in absolute dBm, and as yet undisplayed. They are compared to find the relative dB value for display. Finally, the third order product is measured for similar comparison and display.

3-83. When the NLD CHECK switch is depressed, no distortion products are produced. So what passes through the second and third order filters is noise. Various decision-action paths are taken, according to how much noise power is found. Table 3-7 attempts to organize the complex set of results.

3-84. If the noise levels are at least 10 dB below the distortion, the distortion values are accepted as-is. If the noise is from 10 dB below to 2 dB below, the measured distortion values receive a correction factor. If the noise is from 2 dB below to any value over, then the measured distortion is considered to be noise.

Table 3-7. Nonlinear Distortion Correction Process

NOISE LEVELS RELATIVE TO DISTORTION LEVELS	DECISION MADE BY TIMS	DISPLAY INDICATION*
10 dB below or lower	Measured 4 tone distortion values are valid without correction.	No change in displayed data from 4 tone to 2 tone test. No flashing "2" or "3". No minus signs.
10 dB below up to 2dB below	Measured distortion values need be corrected. **NOISE LEVEL BELOW DISTORTION : CORRECTION FACTOR TO DISTORTION** <1.9 dB : noise decision below 1.9 to 2.6 dB : 4 dB added 2.6 to 3.7 dB : 3 dB added 3.7 to 5.3 dB : 2 dB added 5.3 to 9.6 dB : 1 dB added >9.6 dB : 0 dB added	Display data changes from 4 tone to 2 tone values according to table at left (changes from intermediate to corrected values).
2 dB below to above distortion	Measured 4 tone distortion values are considered to be noise.	"2" and "3" displays continue flashing after "CORRECTED" annunciator comes on.

*A minus sign (–) after either "2" or "3" display indicates a noise or distortion underrange. A flashing "2" or "3" with minus sign is a noise underrange. A solid "2" or "3" with minus sign is a distortion underrange.

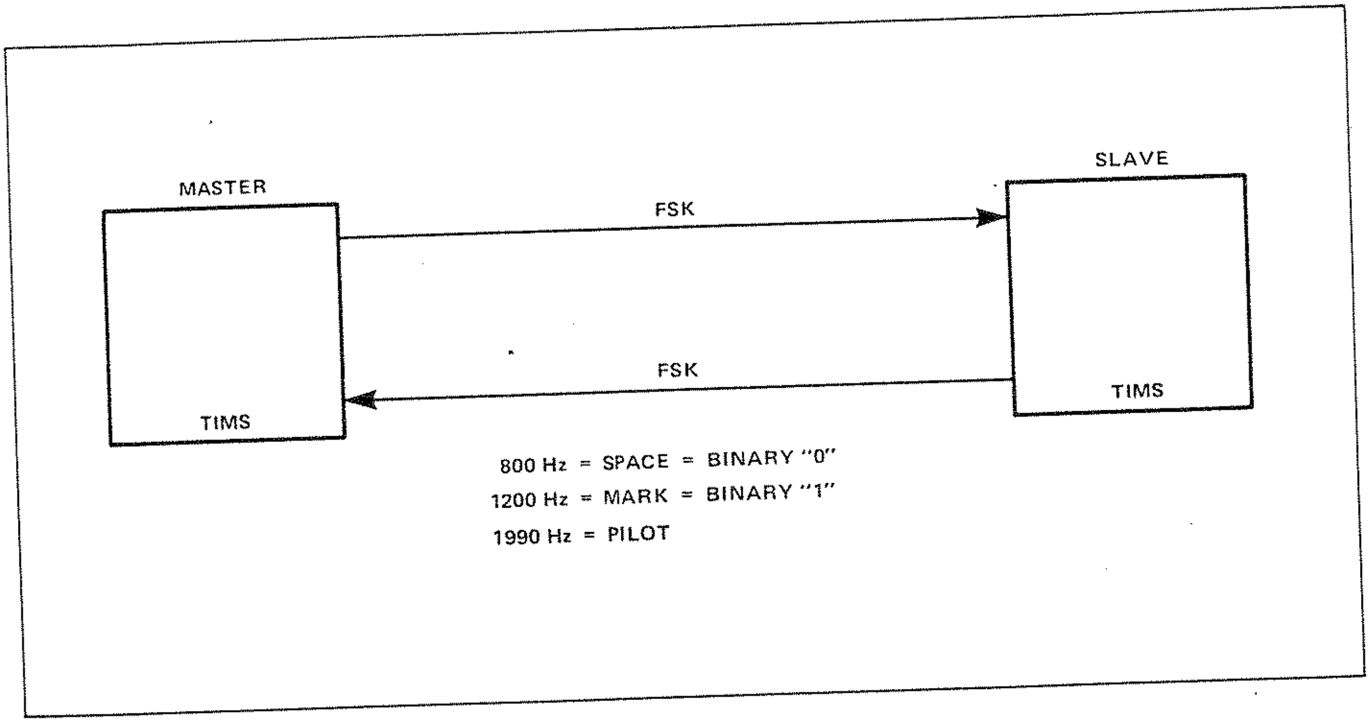


Figure 3-22. FSK Communication

3-85. MASTER-SLAVE OPERATION

3-86. The master-slave feature of the Model 4943A allows remote control of the slave unit by the master unit. The front panel NORMAL-MASTER-SLAVE switch selects the mode of operation for a particular unit. When set to NORMAL, the test set is manually controlled. When set to MASTER, the test set controls the operation of itself and the slave. When set to SLAVE, the front panel controls are disabled except for the TRANSMITTER OUTPUT LEVEL control, the IMPULSE NOISE THRESHOLD switch, and the SETUP CONTROLS.

3-87. HANDSHAKE ROUTINE. The master unit links up with the slave unit by performing a "handshake" routine. The two units "shake hands" or "talk" to each other over the telephone circuit, using frequency shift keying (FSK). The FSK scheme employed is an 800-1200 Hz shift (see Figure 3-22). The 1200 Hz signal represents a mark (binary 1) while the 800 Hz signal represents a space (binary 0). A 1990 Hz signal accompanies the FSK signal and serves as its pilot. This pilot serves to "alert" the receiving unit that FSK is arriving. The FSK pilot is used to confirm the presence of FSK data, and therefore helps prevent the erroneous reception of noise as data bits.

3-88. The master unit begins the routine by sending a group of data bits (a command) to the slave. These bits represent the measurement mode and direction of test (i.e., Level & Frequency, MASTER-TO-SLAVE). After the group of bits are received by the slave, the slave sends the same bit group back to the master. The master compares its originally transmitted message with its received message to check for proper reception.

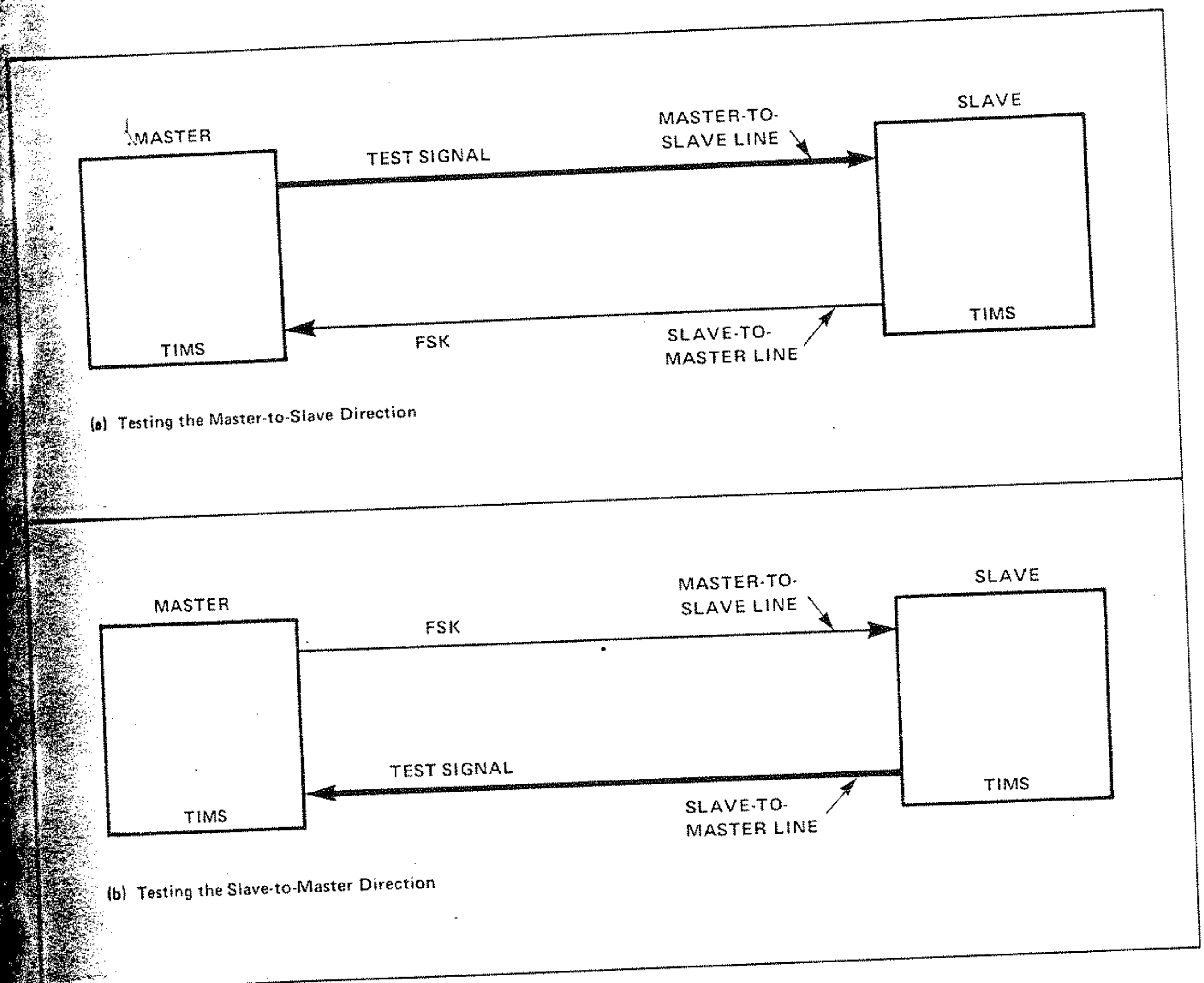


Figure 3-23. Direction of Test

3-89. DIRECTION OF TEST. There are two transmission paths between the master and slave units as shown in Figure 3-23. To test the path from master to slave, the REMOTE switch is set to the MASTER TO SLAVE position. The master then "tells" the slave that it will be receiving a test signal. The slave in turn will "talk" to the master to "tell" it the measured test values at the slave. The master will then display the test values measured by the slave.

3-90. Testing the opposite direction is accomplished by positioning the REMOTE switch to SLAVE TO MASTER. The master sends instructions to the slave unit on the master-to-slave path and measures the test signal sent from the slave.

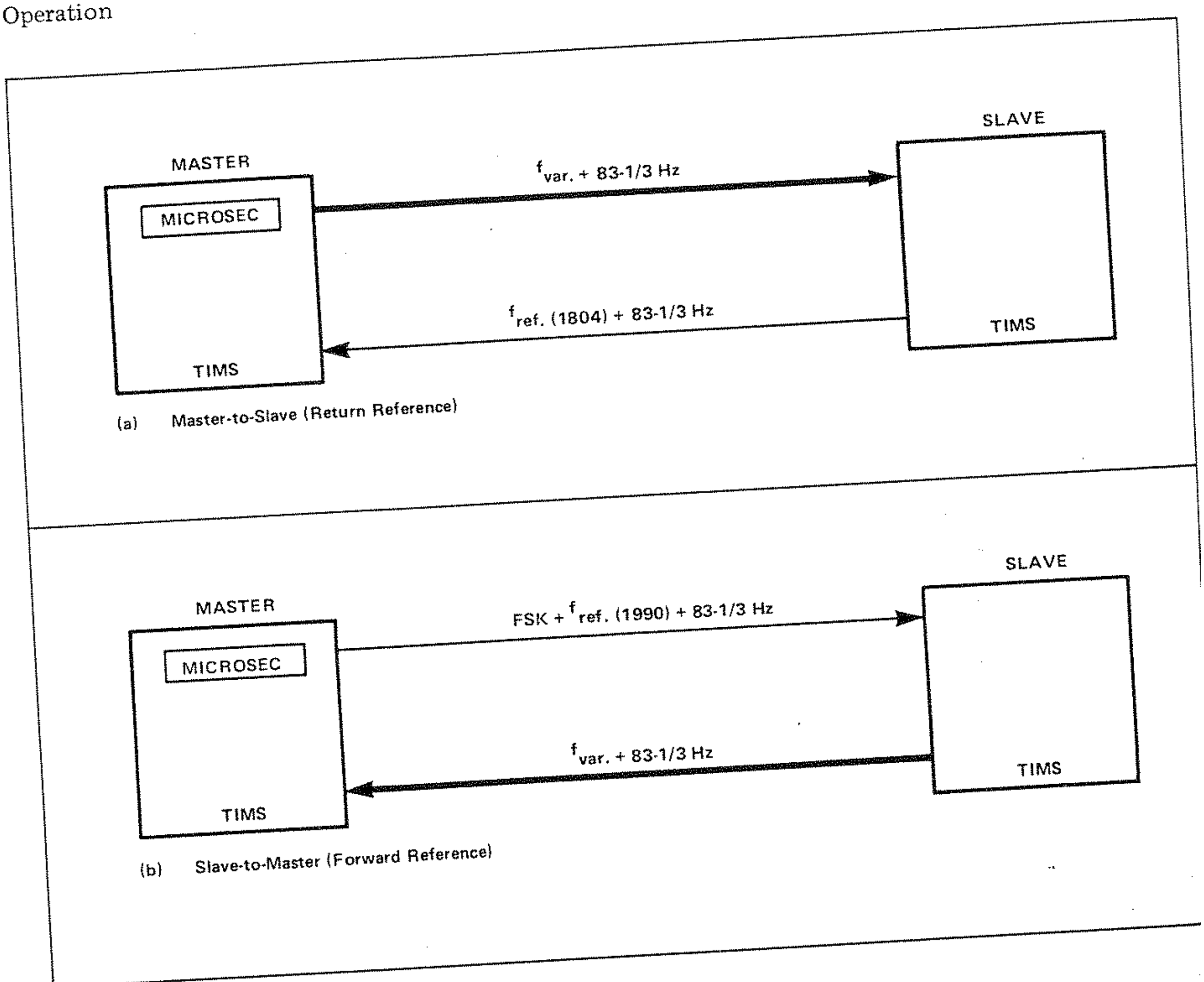


Figure 3-24. Envelope Delay Using Master-Slave

3-91. ENVELOPE DELAY OPERATION. Envelope delay distortion is measured using master-slave operation as shown in Figure 3-24. To begin the measurement, the two units perform the "handshake" routine as described previously. The master unit initially "tells" the slave unit to act as a repeat set. The master then sends down the variable frequency carrier with its 83-1/3 Hz modulation. The slave in turn repeats the 83-1/3 Hz modulation onto a fixed reference frequency of 1804 Hz. Envelope delay is then measured at the master unit.

3-92. To measure in the slave-to-master direction, the master unit sends a composite signal made up of:

FSK . . . . 800 ←→ 1200 Hz

$f_{reference}$ (FSK PILOT). . . . . 1990 Hz

Modulation. . . . . 83-1/3 H

The FSK component is "telling" the slave uni send back a particular carrier frequency. presence of the 1990 Hz signal serves purposes. First, it serves to "alert" the slave FSK is arriving. Secondly, it serves as the f frequency carrier. The slave in turn repeats 83-1/3 Hz onto its variable frequency carrier.

3-93. LINE LOOP BACK

3-94. In this application, the Model 4943A serves as an audio frequency repeater. What comes in goes back out. The test set is selective in that the frequency range passed is between 200 and 3904 Hz. The transmitted output level is selected by the test set operator within the normal range of the instrument.

3-95. This mode of operation is not front panel selectable. But rather, is automatically activated under certain conditions. These conditions occur during the master-slave mode, when incompatible measurements are attempted between differently configured instruments. For instance, this happens if the master unit is attempting a phase jitter measurement, and the slave is a 4943A-Option 012 (with NLD instead of phase jitter).

3-96. The slave would alert the master that it is not capable of making the phase jitter measurement. The slave would then configure itself into the loop back mode.