CHAPTER 4

DEMODULATORS, REKEYERS, AND DEMULTIPLEXERS

As explained in chapter 1, teletype signals have to be routed from a receiver to additional equipment for further processing. The more complex the signal, the more processing stages will be required, i.e., a two-channel teletype signal, in addition to being demodulated, has to be separated into individual channels for print-out. Common demodulators, rekeyers, and demultiplexers that are used throughout the Naval Security Group will be explained in this chapter.

DEMODULATORS

Modulation is applied to a signal to make it compatible for transmission over the air. Once the signal is received, the modulation, having served its purpose, must be removed or changed before the signal can be further processed. This is accomplished by the use of a demodulator. The type of demodulator to be employed will depend upon the type of modulation used to transmit the signal. The first type of demodulator to be discussed will be the AN/FRA-86 Frequency Shift Converter.

AN/FRA-86 FREQUENCY SHIFT CONVERTER

The AN/FRA-86 Frequency Shift Converter (figure 4-1) is widely used to demodulate the frequency shift keyed carrier methods known as FREQUENCY SHIFT KEY (FSK) and DOUBLE FREQUENCY SHIFT KEY (DFSK). Frequency Shift Key (FSK) is a special type of frequency modulation whereby the frequency of the transmitted RF carrier is shifted between two distinct frequency values (MARK/SPACE), determined by one sending device. Double Frequency Shift Key (DFSK) is also a special type of frequency modulation. In this case, the frequency of the transmitted RF carrier is shifted between four distinct frequency values and combined into two canals of information, representing two independent sending devices. The AN/FRA-86 will also detect and indicate, by means of a cathode ray tube (CRT), the frequency drift of a received signal. This allows the operator to visually monitor and, when necessary, retune the signal.

The AN/FRA-86 Frequency Shift Converter consists of two rack-mounted units: FREQUENCY SHIFT CONVERTER unit and INDICATOR unit.

Frequency Shift Converter Unit

The frequency shift converter unit contains twin circuits which perform all of the selection, demodulation, and conversion functions of the AN/FRA-86. The twin circuits allow for two independent receiver inputs, if desired.

Indicator Unit

The indicator unit contains the CRT which, as noted above, enables the operator to visually monitor the incoming signals from each receiver. One presentation available on the CRT (figure 4-2) corresponds to the incoming AF signal and displays the frequency levels of the FSK and DFSK signal being received. Another presentation (figure 4-3) displays the Keyed Direct Current (KDC) output of each information canal. The indicator unit also

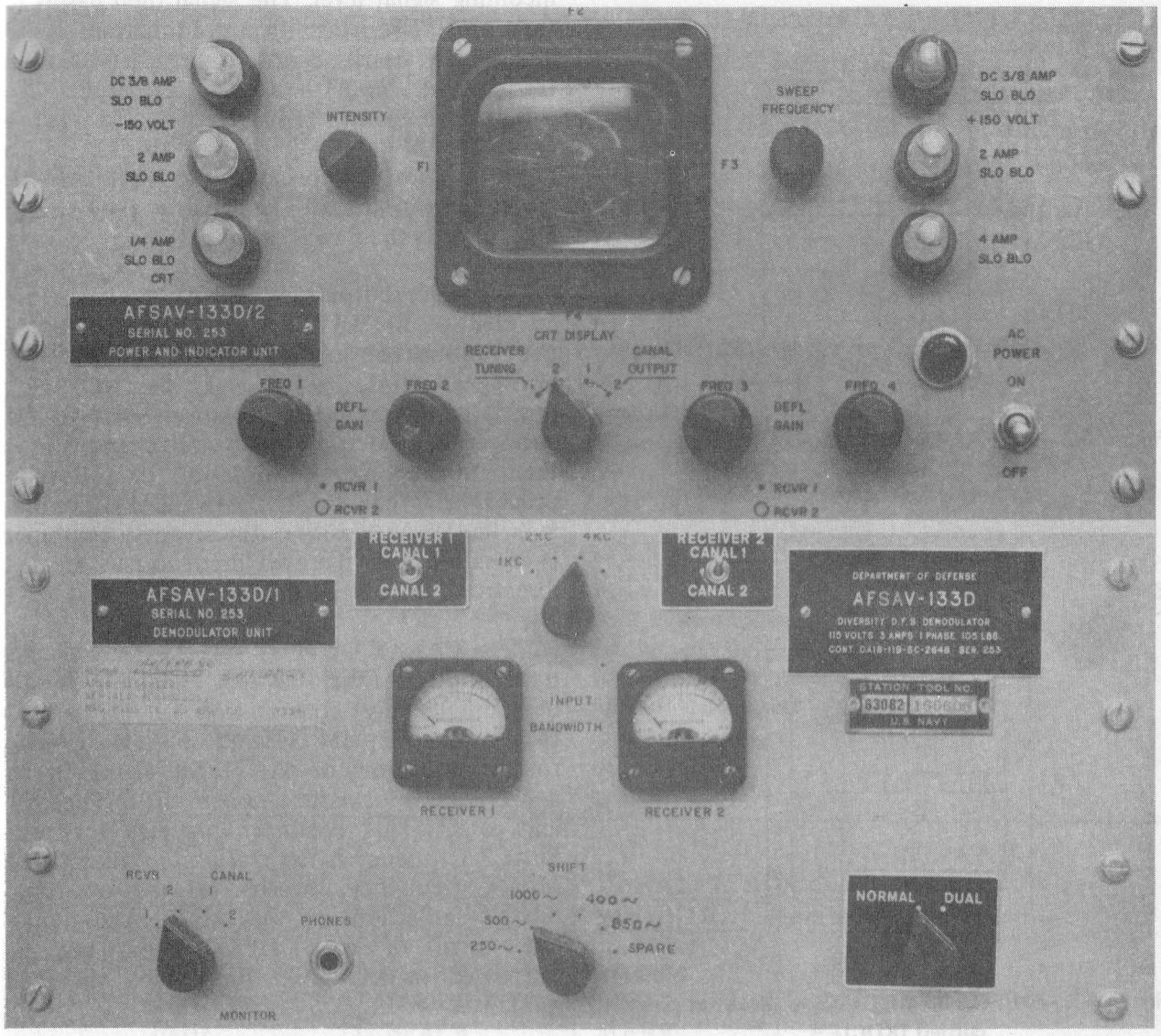

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Figure 4-1.—AN/FRA-86 frequency shift converter.

contains the power supplies for all voltages used in the AN/FRA-86.

Input

The AN/FRA-86 will accept two input signals, either in the form of audio frequency (AF), FSK, or DFSK, or a combination of both types. The input frequency range is from 4 to 7 kHz, with a center frequency of 5.5 kHz.

Outputs

The AN/FRA-86 is designed to provide a total of six signal outputs. The types of outputs are as follows:

KEYED DIRECT CURRENT (KDC)—1 KDC output for each canal.

KEYED TONE (KT)—1 KT output for each canal.

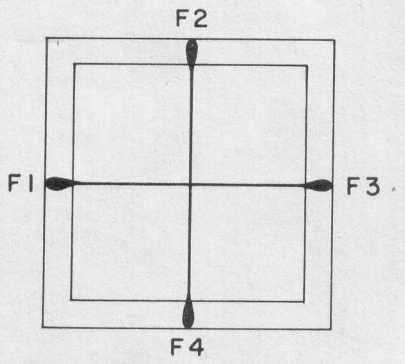

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Figure 4-2.—AN/FRA-86 CRT display of frequency levels.

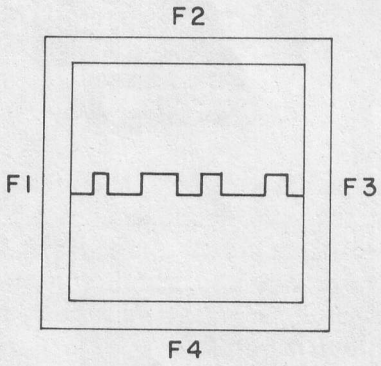

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Figure 4-3.—AN/FRA-86 CRT display of keyed direct current (KDC).

LIMITER (AF output)—1 limiter output for each AF input.

Theory of Operation

As shown in figure 4-4, the incoming audio frequency signals are fed to two separate, but functionally identical, circuits. Within each circuit, the AF signal first passes through a BANDPASS FILTER where unwanted frequencies are eliminated. Immediately following the BANDPASS FILTER, an INPUT LEVEL METER is used to monitor the incoming signal level. The signal then passes to the LIMITER stage whose function is to maintain a nearly constant output level even though the input level may fluctuate. The output of the limiter is fed to a DISCRIMINATOR network. The DISCRIMINATOR responds to each of the frequencies of the DFSK signal as they appear and converts them to KDC pulses.

The four outputs of the discriminator are coupled to the DIVERSITY COMBINER and the indicator (CRT) unit. When the NORMAL/DUAL switch is in the NORMAL position, the diversity combiner selects the stronger of the two input signals and allows them to pass to the outputs for follow-on processing. When the NORMAL/DUAL switch is in the DUAL position, the diversity combiner is bypassed and the two input signals are fed directly to the output stages.

The CANAL OUTPUT stage, by means of a patching network which enables it to demodulate any combination of marks and spaces, i.e., F1=MM, F2=MS, F3=SM, F4=SS, routes each arm of the DFSK signal to its appropriate information canal in the form of KT and KDC. This condition assumes that the SPACE frequency is lower than the transmitted MARK frequency. Because of the two-canal output limitation of the AN/FRA-86, only one canal of each DFSK signal can be outputted at any given time when the dual mode is used.

Cathode Ray Tube (CRT) Presentations

A knowledge of the various conditions in which FSK and DFSK signals may appear is necessary to determine an existing signal condition and the proper tuning of a FSK or DFSK signal with a known signal condition. In order to best understand and interpret the various keying conditions, refer to table 4-1 and compare the four frequencies of a DFSK signal to the four outputs of the discriminator stage of the AN/FRA-86.

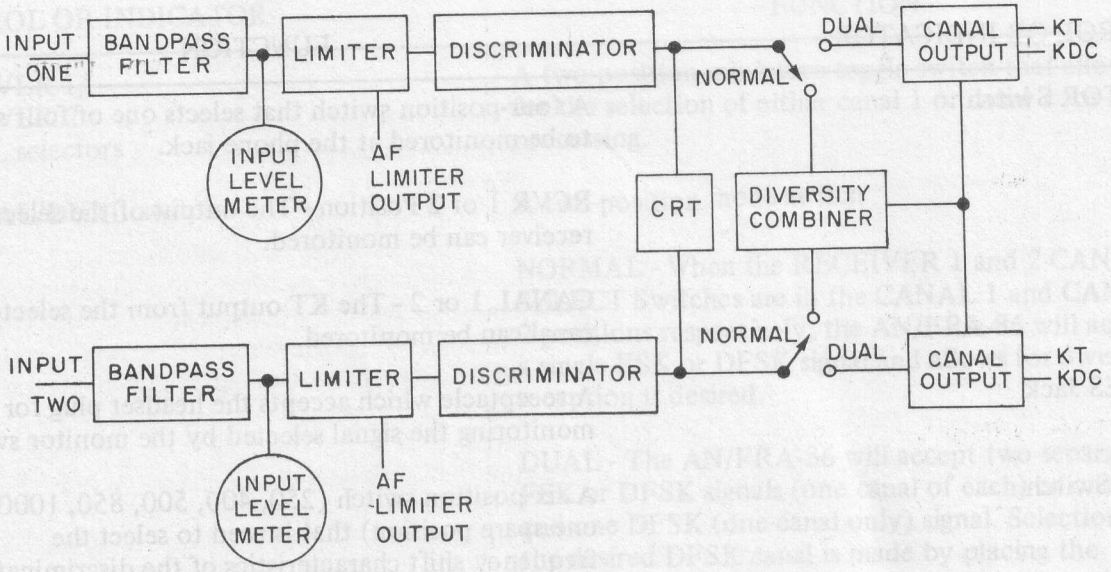

Figure 4-4.—AN/FRA-86 block diagram.

Table 4-1.—DFSK Signal Keying Condition

(1000Hz Shift)

R-390A INPUT FREQUENCY	CANAL "A" CONDITION	CANAL "B" CONDITION	DISCRIMINATOR OUTPUT FREQUENCY
4kHz	MARK	MARK	F1
5kHz	MARK	SPACE	F2
6kHz	SPACE	MARK	F3
7kHz	SPACE	SPACE	F4

Controls and Functions

The AN/FRA-86 FREQUENCY SHIFT CONVERTER is used to receive various types of Frequency Shift Key signals. It is important for the operator to know the controls and their functions in order to properly tune and determine existing signal conditions. The CONVERTER unit controls and indicators are listed in Table 4-2 and the INDICATOR unit controls and indicators are listed in Table 4-3. (Refer to figure 4-1 while studying these tables.)

As explained in the discussion of DFSK modulation, when the MARK or SPACE elements in a CANAL change, a corresponding change is made in the DFSK frequency level keyed. These changes will appear on the CRT. For example, a DFSK signal with both canals actively transmitting (MARK/SPACE transitions occurring) would appear on the CRT as a "cross". If canal A stops transmitting and holds on its MARK frequency, only the frequencies

Table 4-2.—AN/FRA-86 Converter Unit Operating Controls, Indicators and Functions

CONTROL OR INDICATOR	FUNCTION
MONITOR Switch	A four-position switch that selects one of four signals to be monitored at the phone jack. RCVR 1 or 2 Position - The output of the selected receiver can be monitored. CANAL 1 or 2 - The KT output from the selected canal can be monitored.
PHONES Jack	A receptacle which accepts the headset plug for monitoring the signal selected by the monitor switch.
SHIFT Switch	A six-position switch (250, 400, 500, 850, 1000, and one spare position) that is used to select the frequency shift characteristics of the discriminator. A DFSK signal with a frequency excursion of 1500Hz would require a setting of 500. A FSK signal shifting 500Hz would also require a setting of 500.
RECEIVER 1/ RECEIVER 2 level meters	VU (volume unit) meters used to indicate the level of the output signals from receiver No. 1 or receiver No. 2.
INPUT BANDWIDTH Switch	A four-position switch (1, 2, 4, and one spare position) used to select a pair of bandpass filters through which the receiver input signals must pass. For FSK signals, set this switch to match the frequency shift/excursion of the incoming signal. For DFSK signals, set this switch at four (4) times the frequency shift of the incoming signal. 1 KC - The selected bandpass filters enable only frequencies that are within 500Hz of the center frequency to pass. 2 KC - The selected bandpass filters enable only frequencies that are within 1kHz of the center frequency to pass. 4 KC - The selected bandpass filters enable only frequencies that are within 2kHz of the center frequency to pass. SPARE - Normally not used, however, an additional setting may be installed.

Table 4-2.—AN/FRA-86 Converter Unit Operating Controls, Indicators and Functions—Continued

CONTROL OR INDICATOR	FUNCTION
RECEIVER 1/ RECEIVER 2 CANAL selectors	A two-position miniature toggle switch that allows for the selection of either canal 1 or canal 2 for processing.
NORMAL/DUAL switch	A two-position mode switch NORMAL - When the RECEIVER 1 and 2 CANAL SELECT Switches are in the CANAL 1 and CANAL 2 positions respectively, the AN/FRA-86 will accept a single FSK or DFSK signal and allows for diversity reception if desired. DUAL - The AN/FRA-86 will accept two separate FSK or DFSK signals (one canal of each) or one FSK and one DFSK (one canal only) signal. Selection of the desired DFSK canal is made by placing the RECEIVER 1 or 2 CANAL selector switch in the CANAL 1 or CANAL 2 position.

Table 4-3.—AN/FRA-86 Indicator Unit Operating Controls, Indicators and Functions

CONTROL OR INDICATOR	FUNCTION
AC POWER switch	A two-position switch (ON-OFF) used to supply power to both units.
AC POWER indicator	A red lamp which lights when a.c. power is applied to the power supply and is extinguished when the power is disconnected from the power supply.
CRT DISPLAY	A four-position switch used to select one of the four outputs for display on the CRT screen. RECEIVER 1 TUNING - The output frequencies F1, F2, F3, and F4 of receiver No. 1 are displayed on the CRT screen. RECEIVER 2 TUNING - the output frequencies F1, F2, F3, and F4 of receiver No. 2 are displayed on the CRT screen. CANAL 1 OUTPUT - The KDC output of canal No. 1 is displayed on CRT screen. CANAL 2 OUTPUT - The KDC output of canal No. 2 is displayed on CRT screen.

Table 4-3.—AN/FRA-86 Indicator Unit Operating Controls, Indicators and Functions—Continued

CONTROL OR INDICATOR	FUNCTION
DEFL GAIN (Deflection Gain)	Four sets of two-knob controls which control the amplitude of the F1, F2, F3, and F4 images on the CRT screen when the CRT DISPLAY switch is in the RECEIVER 1 TUNING or RECEIVER 2 TUNING position. The outer (smaller) knobs control the amplitude of receiver number 1 and the inner (larger) knobs control the amplitude of receiver No. 2. F1, F2, F3, and F4 correspond to the four frequencies of a DFSK signal; an FSK signal will use only F2 and F3.
INTENSITY	Controls the brightness of the image on the CRT screen. KEEP IT AS LOW AS POSSIBLE FOR EYE COMFORT AND TO PREVENT BURNING OF THE SCOPE FACE.
SWEEP FREQUENCY	Controls the sweep duration when the CRT DISPLAY switch is in the CANAL 1 or 2 OUTPUT position. It controls how fast the MARK/SPACE format of the signal is displayed on the CRT DISPLAY screen. You can slow down or speed up this presentation by adjusting the SWEEP FREQUENCY control.

F1 (MM) and F2 (MS) will appear on the CRT. (Refer to figure 4-5 through 4-9 for DFSK CRT displays.)

When the input signal is an FSK signal, properly tuned, the higher frequency will correspond to F2 (M) and the lower frequency to F3 (S). (Refer to figure 4-10.)

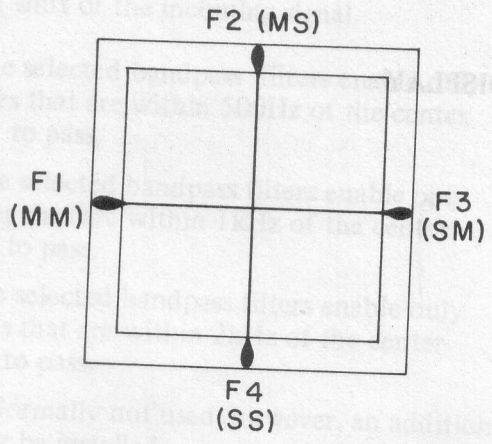

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Figure 4-5.—DFSK signal condition with both canals active.

Operating Procedures

The operating procedures for the AN/FRA-86 FREQUENCY SHIFT CONVERTER include: Preliminary Operating Procedures; Calibration Procedures; NORMAL mode Operating Procedures; DUAL mode Operating Procedures, and Signal Re-tuning Procedures. The R-390A/URR receiver with a modified BFO microdial is used to supply inputs to the AN/FRA-86; therefore, it is imperative that an operator know the operating and calibrating procedures of the R-390A/URR

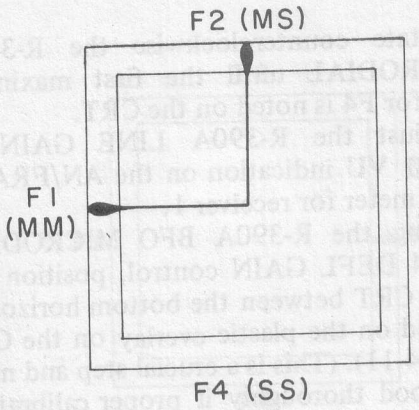

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Figure 4-6.—DFSK signal condition.

Canal A—Holding on a Mark Frequency
Canal B—Transmitting

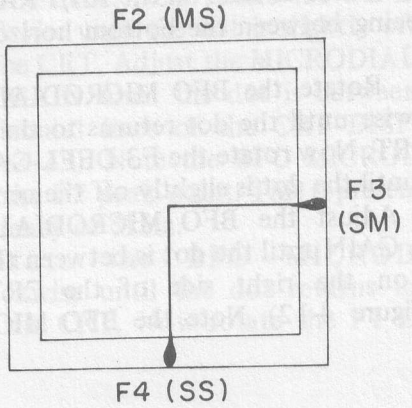

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Figure 4-7.—DFSK signal condition.

Canal A—Holding on a Space Frequency
Canal B—Transmitting

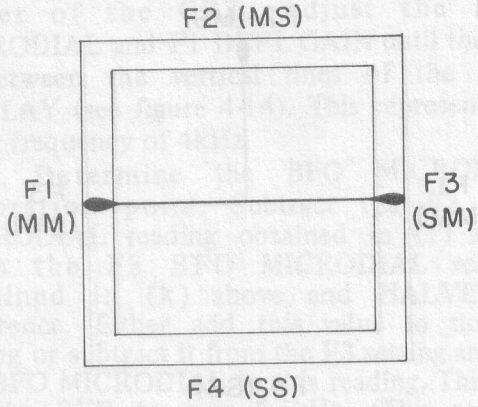

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Figure 4-8.—DFSK signal condition.

Canal A—Transmitting
Canal B—Holding on a Mark Frequency

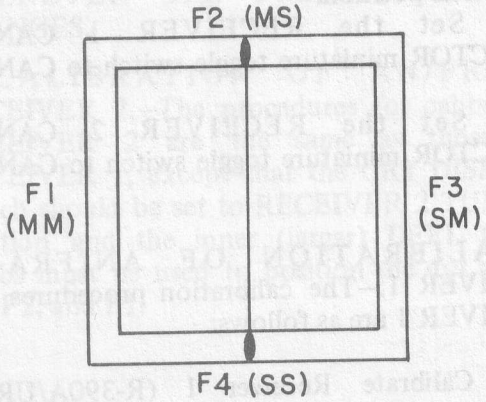

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Figure 4-9.—DFSK signal condition.

Canal A—Transmitting
Canal B—Holding on a Space Frequency

when operating the AN/FRA-86 FREQUENCY SHIFT CONVERTER.

PRELIMINARY OPERATING PROCEDURES.—The preliminary AN/FRA-86 operating procedure steps are listed below:

a. Turn the AC POWER switch to ON. The red a.c. power indicator lamp should light up, indicating that power has been applied to the AN/FRA-86. Allow a minimum warmup interval of 15 minutes before continuing.

b. Rotate all the DEFL GAIN controls full counterclockwise.

c. Set the CRT DISPLAY switch to the RECEIVER TUNING 1 position.

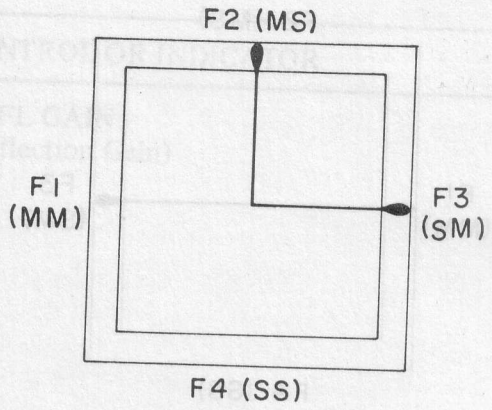

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Figure 4-10.—FSK signal condition transmitting.

d. Rotate the INTENSITY control clockwise until a clear round dot appears in the center of the CRT screen.

e. Set the NORMAL /DUAL switch to the NORMAL position.

f. Set the RECEIVER 1 CANAL SELECTOR miniature toggle switch to CANAL 1.

g. Set the RECEIVER 2 CANAL SELECTOR miniature toggle switch to CANAL 2.

CALIBRATION OF AN/FRA-86 RECEIVER 1.—The calibration procedures for RECEIVER 1 are as follows:

a. Calibrate Receiver 1 (R-390A/URR) using normal R-390A calibration procedures.

b. Set the R-390A BANDWIDTH KC selector to 8.

c. Set the INPUT BANDWIDTH switch on the AN/FRA-86 to 4 KC.

d. Set the AN/FRA-86 SHIFT switch to the frequency shift of the signal to be copied.

e. Rotate the BFO MICRODIAL on the R-390A in a clockwise direction while observing the AN/FRA-86 INPUT LEVEL meter. Continue turning the MICRODIAL until the meter peaks and starts dropping.

f. Rotate clockwise the outer (smaller) DEFL GAIN control for F4 until the dot is slightly off the center of the CRT.

g. Set the R-390A LINE GAIN control to maximum.

h. Rotate counterclockwise the R-390A BFO MICRODIAL until the first maximum deflection for F4 is noted on the CRT.

i. Adjust the R-390A LINE GAIN to provide a $\emptyset$ VU indication on the AN/FRA-86 input level meter for receiver 1.

j. Using the R-390A BFO MICRODIAL and the F4 DEFL GAIN control, position the dot on the CRT between the bottom horizontal lines printed on the plastic overlay on the CRT (see figure 4-11). (This is a crucial step and must be understood thoroughly if proper calibration is to be accomplished.) The dot can be moved by either the BFO MICRODIAL or the F4 DEFL GAIN; however, the object is to position the dot so that it is at its maximum peaking point. In other words, PEAK it with the BFO MICRODIAL and POSITION it with the DEFL GAIN. When the dot is peaked, the input frequency from the R-390A is exactly 7kHz and is represented as such on the AN/FRA-86 by the dot being between the bottom horizontal lines.

k. Rotate the BFO MICRODIAL counterclockwise until the dot returns to the center of the CRT. Now rotate the F3 DEFL GAIN clockwise until the dot is slightly off the center of the CRT. Adjust the BFO MICRODIAL and F3 DEFL GAIN until the dot is between the vertical lines on the right side of the CRT display (see figure 4-12). Note the BFO MICRODIAL

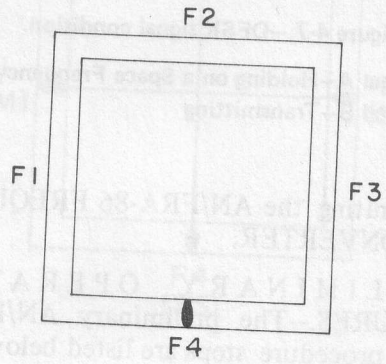

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Figure 4-11.—F4 Peaked.

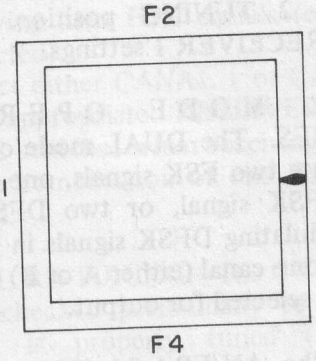

Figure 4-12.–F3 Peaked.

reading at the F3 peak. This represents an input frequency of 6 kHz.

l. Rotate the BFO MICRODIAL counterclockwise until the dot returns to the center of the CRT. Now rotate the F2 DEFL GAIN clockwise until the dot is slightly off the center of the CRT. Adjust the MICRODIAL and F2 DEFL GAIN until the dot is between the upper horizontal lines of the CRT DISPLAY (see figure 4-13). Note the BFO MICRODIAL reading at the F2 peak point. This represents an input frequency of 5kHz.

m. Rotate the BFO MICRODIAL counterclockwise until the dot returns to the center of the CRT. Now rotate the F1 DEFL GAIN clockwise until the dot is slightly off the center of the CRT. Adjust the BFO MICRODIAL and F1 DEFL GAIN until the dot is between the vertical lines of the CRT DISPLAY (see figure 4-14). This represents an input frequency of 4kHz.

n. Determine the BFO MICRODIAL calibration point. Subtract the F2 BFO MICRODIAL reading obtained in (1) above from the F3 BFO MICRODIAL reading obtained in (k) above and HALVE the difference. Either add this value to the F2 setting or subtract it from the F3 setting and set the BFO MICRODIAL to this reading. This will set the BFO to true 5.5kHz. (This reading should be recorded for each individual BFO calibrated.)

NOTE: THE CALIBRATED POSITION PEAKS AT F1, F2, F3, and F4 WILL CHANGE WHEN THE SHIFT SWITCH IS SET TO A POSITION OTHER THAN THAT OF ITS CALIBRATED POSITION; THEREFORE, THE AN/FRA-86 SHOULD BE CALIBRATED WHENEVER THE FREQUENCY SHIFT CHANGES.

CALIBRATION OF AN/FRA-86 RECEIVER 2.–The procedures for calibrating RECEIVER 2 are the same as those for RECEIVER 1, except that the CRT DISPLAY switch should be set to RECEIVER 2 TUNING position and the inner (larger) DEFL GAIN knobs must be used to position the dot at F4, F3, F2, and F1.

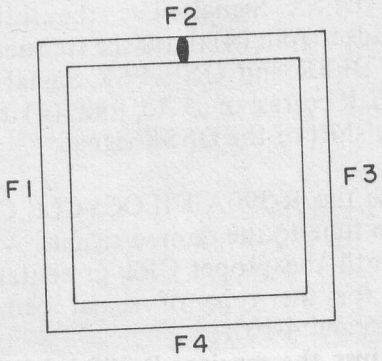

Figure 4-13.–F2 Peaked.

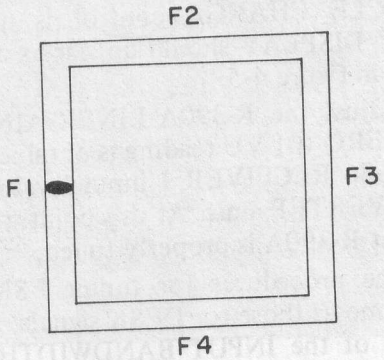

Figure 4-14.–F1 Peaked.

NORMAL MODE OPERATING PROCEDURES.–The following procedures are based on a 3000Hz DFSK signal input with both canals active:

a. Set the AN/FRA-86 NORMAL/DUAL switch to NORMAL.

b. Set the SHIFT switch to the position which corresponds to the shift between adjacent frequencies of the DFSK signal to be demodulated-in this case, 1000 Hz.

c. Set the INPUT BANDWIDTH switch to 4 KC (for DFSK signals, a bandwidth setting equal to four times the shift between adjacent frequencies is required). Under NO circumstances should a bandwidth setting be used that is as narrow as, or more narrow than, the input signal's total excursion. If possible, the R-390A BANDWIDTH setting should be the same as that of the AN/FRA-86 INPUT BANDWIDTH setting.

d. Set the AN/FRA-86 CRT DISPLAY switch to the RECEIVER 1 TUNING position.

e. Set the AN/FRA-86 RECEIVER 1 CANAL selector to CANAL 1, and RECEIVER 2 CANAL selector to CANAL 2.

f. Set the R-390A FUNCTION switch to the AGC position.

g. Using the R-390A KILOCYCLE CHANGE control, tune to the desired signal. Adjust the KILOCYCLE CHANGE control until dots/rays appear at F1, F2, F3, and F4 on the CRT DISPLAY tube. All four dots/rays should appear to reach their peak simultaneously. To accomplish this, slow movement of the KILOCYCLE CHANGE control is necessary. The CRT DISPLAY should appear as a "cross" as shown in figure 4-5.

h. Adjust the R-390A LINE GAIN control until a ZERO (Ø) VU reading is obtained on the AN/FRA-86 RECEIVER 1 input level meter on the CONVERTER unit. At this point, the signal in the first R-390A is properly tuned.

i. The procedures for tuning FSK signals are the same as those for DFSK signals, with the exception of the INPUT BANDWIDTH setting and the CRT DISPLAY presentation. A properly tuned FSK signal should appear as depicted in figure 4-10.

j. The procedure for tuning the second R-390A is the same as that for the first; however, set the CRT DISPLAY switch to the RECEIVER 2 TUNING position. DO NOT disturb the RECEIVER 1 settings.

DUAL MODE OPERATING PROCEDURES.–The DUAL mode can be used to demodulate two FSK signals, one FSK signal and one DFSK signal, or two DFSK signals. When demodulating DFSK signals in the DUAL mode, only one canal (either A or B) of a DFSK signal can be selected for output.

a. Set the AN/FRA-86 NORMAL/DUAL switch to DUAL.

b. Set the AN/FRA-86 SHIFT switch as follows:

TWO FSK Signals–If the frequency shifts are not the same, set the SHIFT switch to match the lower of the two shifts.

TWO DFSK Signals–The frequency shift of the two signals must be equal.

ONE FSK and ONE DFSK Signal–Set the SHIFT switch to the frequency shift of the DFSK signal. The frequency shift of the FSK signal must be either equal to or twice the shift of the DFSK signal.

c. Set the INPUT BANDWIDTH switch as follows:

TWO FSK Signals–Use the setting that corresponds to the highest frequency excursion (shift) of the two signals.

TWO DFSK Signals–Use the setting that corresponds to four (4) times the frequency shift.

ONE DFSK and ONE FSK Signal–Use the setting that corresponds to four (4) times the frequency shift of the DFSK signal.

d. Use the R-390A KILOCYCLE CHANGE control to tune to the desired signals. Adjust the control until the proper CRT presentations are obtained for the type of signal being tuned (figures 4-5 and 4-10).

e. Adjust the receiver R-390A LINE GAIN control until a ZERO (Ø) VU reading is obtained on the input level meter on the CONVERTER unit.

f. Set the AN/FRA-86 RECEIVER 1 and RECEIVER 2 CANAL selector switches to the the appropriate position to obtain proper output when receiving two FSK signals (either canal may be selected).

g. Select either CANAL 1 or CANAL 2 by using the appropriate RECEIVER 1/2 and CANAL 1/2 switches when receiving two DFSK signals or a combination of one FSK and one DFSK signal.

SIGNAL RE-TUNING.—The CRT DISPLAY should be checked periodically to ensure that the signal is properly tuned (RECEIVER TUNING 1/2). Whenever the legs of the dots/rays fail to lie just outside of the inner screen rectangle, the receiver must be re-tuned. Use the KILOCYCLE CHANGE control to re-tune the signal. DO NOT ADJUST THE BFO MICRODIAL SETTING OR ADJUST THE DOTS/RAYS BY MEANS OF THE DEFL GAIN CONTROLS.

CV-1627/URR TWO-CHANNEL REKEYER

The CV-1627/URR (AFSAV 39-C) two-channel rekeyer (figure 4-15) is used to convert Keyed Tone (KT) signals received from the AN/FRA-86, or similar terminal equipment, into d.c. pulses to operate teleprinters for one or two independent single-channel teletype systems. The input is Keyed Tone with a minimum element length of 5 MS.

Controls and Functions

The operator controls and functions explained in Table 4-4 below, can be found on the front panel on the CV/1627/URR (see figure 4-15).

Operating Procedures

The following operating procedures are based on a single-channel teletype signal:

a. Place the POWER ON-OFF switch in the ON position. The POWER INDICATOR lamp should glow.

b. Place the CHANNEL 1 NORMAL-REVERSE switch in the NORMAL position.

c. Patch the channel 1 signal from AN/FRA-86 Keyed Tone output to the channel 1 input of the CV-1627/URR.

d. Place the PRINTER CURRENT meter switch in the Channel 1 position.

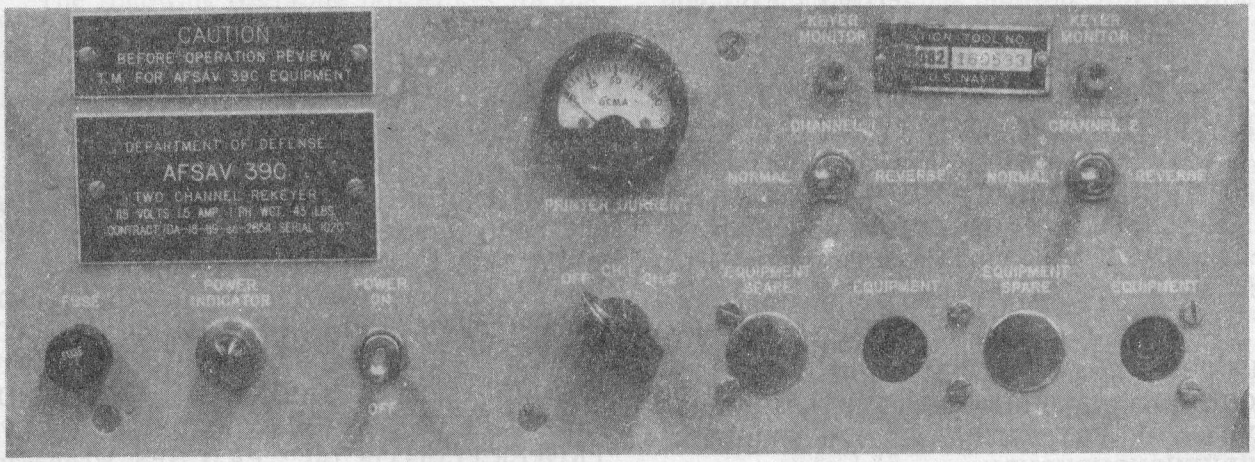

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Figure 4-15.—CV-1627/URR two-channel rekeyer.