the MARK is denoted by transmitting a signal on one discrete frequency and the SPACE is denoted by the absence of the signal. The emission designator is A1, A2, or F2, depending upon the particular mode variation being used. This radioteletype mode is rarely used by the Navy/Marine Corps.

The following types of emission designators are representative of those in use by the U.S. Navy and U.S. Marine Corps. In the standard four part emission designator, the first number indicates the "necessary bandwidth" required by the emission. The "necessary bandwidth" calculations for the older type emission designators (.6F1, 1.08F1, 1.7F1, 2.04A2, 2.85F1, 4F4) are based on formulas found in the Radio Regulations, Atlantic City, 1947. The "necessary bandwidths" resulting from calculations using applicable formulas in the current authority, Appendix 5, Radio Regulations, Geneva, 1959 (upon which most of the designators listed in Table 1-4 are based) differ slightly from the 1947 values. Furthermore, the 1959 bandwidth formulas are themselves now under study by the International Radio Consultative Committee (CCIR) of the ITU, and will probably be revised at a future international conference. Therefore, in the interest of continuity and clarity, the following steps have been taken:

1. The older designators involving primarily older equipment have been retained. The bandwidth stated in each case is slightly greater than that derived from the more recent formulas.

2. New designator "necessary bandwidths" have been calculated from the most nearly applicable formula in Appendix 5, Radio Regulations, Geneva, 1959.

The listing in Table 1-4 is not all inclusive. For example, the emission designators for various types of tone generated CW (AN/URC-32, AN/TRC-75, AN/PRC-47) have been omitted. In addition, for the sake of brevity, all possible variations of multiplexed emissions have not been listed. Although the offset of the CW tone from the suppressed carrier (dial) frequency may vary, the old 0.1A1 designator coupled with an assigned frequency is sufficient to permit netting. Care must be taken when incrementally tuned SSB receiving equipment is used on a CW net in common with transmitting equipment which employs a keyed carrier frequency for CW operation.

Notice that some necessary bandwidths have been specified to more significant numbers than others. This was done merely to provide a numerical difference between 60-wpm and 100-wpm teletype designators which, otherwise, would be identical if "rounding off" rules were followed. For example, 1A7J could be used to indicate either 100-wpm or 60-wpm single channel SSB AFTS RATT, depending on local operating procedures or practices.

Any emission may be used on an assigned frequency, providing the bandwidth does not exceed that authorized and the modulation type, transmission type, and supplementary characteristics are the same. One exception to this rule is the current CNO authorization for USN activities and forces to utilize emissions not exceeding 1.24A7J on all frequencies assigned with 1.24F1 emission.

It is also important that the radiated emission should be centered on the assigned frequency. In the event equipment limitations preclude centering, the emission bandwidth must be confined within the authorized bandwidth of the assigned frequency and should be centered as nearly as possible.

Based on the expanded list of emission designators, the following are samples of OPORD or OPLAN use of a hypothetical frequency assigned by CNO to a command.

CNO assignment:
3010.5 (3009) kHz, 1.24F1, 3A3J, 3A7J

Possible OPORD authorizations:

a. 3010.5 (3009) Hz, 3A3J-Telephony (SSB)
b. 3010.5 Hz 1.24F1-100 wpm RFCS RATT
c. 3010.5 (3009.9) Hz, 0.3A7J-100 wpm SSB AFTS RATT (if transmitters have 0.1 Hz incremental tuning capability)
d. 3010.6 (3010) Hz, 0.3A7J-100 wpm SSB AFTS RATT interim assignment (if transmitters have only 1 Hz incremental tuning capability)
e1. 3011 (3009) Hz, 1A7J-100 wpm SSB AFTS RATT (interim assignment due 1-kHz tuning)
e2. 3011 Hz 1A7B-100 wpm ISB AFTS RATT (interim assignment due 1-kHz tuning)
e3. 3011 Hz 1.24F1-100 wpm RFCS RATT (if required to net with SSB and ISB RATT equipment).

These assignments illustrate five possible channel or net uses of an available frequency. All of them cannot be used simultaneously in the same area. When all HF equipment is capable of 0.1-kHz incremental tuning, the illustrated "interim" assignments, in which the emission is not centered on the "assigned" frequency should be deleted.

As a matter related to spectrum conservation, it would be interesting to ascertain the operational flexibility that might be realized with the 0.3A7J emission. Providing adequate measures are taken in respect to equipment separation, power output, transmitter frequency accuracy, and receiver bandwidth, and if used only where operational needs dictate, it would appear that three 100-wpm RATT nets could be accommodated in an authorized 3-kHz bandwidth (e.g., 3009.6(3009), 3010.6(3010), 3011.6 (3011)).

The assignments listed as e1, e2, and e3 could have been on 3010 kHz, but in order to be as consistent as possible with the instructions in paragraphs 106d and 606d, JANAP 195, the 3001-kHz assignment is preferred. In cases involving single sideband (SSB) emissions, the suppressed carrier frequency is listed in parentheses, following the assigned frequency. This technique merely provides a reference point in that the suppressed carrier frequency is usually the frequency appearing on the transmitter dials. (EIB 711)

b. TUNING IN A SINGLE CHANNEL RFCS RATT SIGNAL

Many good RATT signals are so degraded at the receiver that they become either unreadable or take too many hits to be of much use. This is often the result of improper tuning of the receiver. The intent of this article, therefore, is to provide some understanding of the required tuning procedures for proper reception of RATT signals.

Single channel teletype transmissions in the MF and HF bands use a radio frequency carrier shift (RFCS) of 850 Hz, or ± 425 Hz with respect to the

TABLE 1-4. EXAMPLES OF RATT EMISSIONS

Designator	Type of Emission	Sample Equipment	Remarks
0.1A1	CW Manual Morse Telegraphy	TBK	
0.28A7J	60 wpm Single Chan SSB AFTS RATT	AN/SGC-1 w/AN/WRT-2 (HF)	Note 1
0.3A7J	100 wpm Single Chan SSB	AN/SGC-1 w/AN/WRT-2 (HF)	Note 1
0.6F1	60 wpm Single Chan RFCS RATT	TAD-7, AN/WRT-1 (LF/MF)	Note 2
0.98A7J	60 wpm Single Chan SSB AFTS RATT	AN/URC-32, AN/FRT-39, AN/TRC-75 (HF)	Note 3
0.98A7B	60 wpm Single Chan ISB AFTS RATT	AN/WRT-2 (HF)	Note 4
1A7J	100 wpm Single Chan SSB AFTS RATT	AN/URC-32, AN/FRT-39, AN/TRC-75	Note 3
1A7B	100 wpm Single Chan ISB AFTS RATT	AN/WRT-2 (HF)	Note 4
1.08F1	60 wpm Single Chan RFCS RATT	AN/SRT-15, TBK (HF)	
1.24F1	100 wpm Single Chan RFCS RATT	AN/SRT-15, TBK (HF)	
1.5A7	60 wpm Single Chan DSB AFTS RATT	AN/SGC-1 w/TED (UHF)	
1.6A7	100 wpm Single Chan DSB AFTS RATT	AN/SGC-1 w/TED (UHF)	
1.7A7J	100 wpm 8 Chan SSB AFTS RATT*	AN/UCC-1 w/FRT-72 (LF)	Note 5
1.7F1	60 wpm 4 Chan Time Div RFCS RATT	AN/UGC-1 w/AN/SRT-15 (HF)	
2.04A2	1020 Hz AFT Beacon	AN/WRT-1 TED (MF/UHF)	Homer Beacon
2.85F1	100 wpm 4 Chan Time Div RFCS RATT	AN/UGC-1 w/AN/SRT-15 (HF)	
3A3J	Telephony (SSB)	AN/URC-32, AN/WRT-2 (HF)	
3A7J	100 wpm 16 Chan SSB AFTS RATT*	AN/UCC-1 w/AN/WRT-2 (HF)	Note 6
4F4	Facsimile	(HF)	
6A3	Telephony (DSB AM)	AN/SRT-15 (HF)	
10A3	Telephony (DSB AM Broadcast quality)	(MF)	
16F3	Telephony (FM Narrow Band)	(VHF) AN/VRC-46	
30F3	Telephony (FM)	AN/PRC-25, AN/VRC-12 (VHF)	
36F3	Telephony (FM)	AN/PRC-10 (VHF)	
80F9	Multiplexed telephony (FM)	AN/TCC-1 () w/AN/VRC-12 (VHF)	
120F9	Multiplex telephony (FM)	AN/TCC-3 w/AN/GRC-10 (VHF)	

*Based on measured data in the absence of precise mathematical formulas.

Note 1. The AN/SGC-1 produces 700-Hz and 500-Hz mark/space tones. Therfore, these emissions would be centered 600 Hz from the suppressed carrier in the chosen sideband with a plus-minus 100-Hz shift.

Note 2. This designator is retained to normally indicate a plus-minus radio frequency carrier shift of 85 Hz (total 170-Hz shift) for mark/space signals.

Note 3. The AN/URC-32 and AN/TRC-75 type equipment produce 2425-Hz and 1575-Hz mark/space tones. Therefore, the emission is centered 2 kHz above or below the suppressed carrier (dial) frequency, with a plus-minus 425-Hz shift for mark/space signals. Suppressed carrier (dial) frequency should be 2 kHz above or below the assigned frequency. Wherever appearing, the AN/FRT-39 type equipment is assumed to include ancillary equipment such as the TH-39/UGT.

Note 4. The AN/WRT-2 type equipment produces 425-Hz tones in the USB and LSB to indicate a mark or a space signal. Therefore, the emission is centered on the suppressed carrier (dial) frequency with a plus-minus 425-Hz shift for mark/space signals. Note that suppressed carrier frequency is the assigned frequency.

Note 5. This designator covers the use of the eight pairs of tones centered on 1615-Hz and below.

Note 6. If all channels are not keyed, the necessary bandwidth for this mode will actually be dependent upon how many and which specific channels are used. In the interests of simplicity, it is recommended that only the 3A7J designator be used to indicate HF-SSB AFTS multichannel emission.

assigned frequency. If the assigned frequency were 8694 kHz, this would be the center frequency to be radiated from the transmitter. Two signals would be transmitted alternately, and neither of the signals would be 8694 kHz. The teletype mark signal would be transmitted 425 Hz above the center frequency of 8694, and the space signal would be transmitted 425 Hz below the center frequency. This means that the transmitter would develop a mark signal of 8694.425 kHz and a space frequency of 8693.575 kHz. Only these two frequencies need be received, and the receiver should be set to receive them in the center of its reception "window" or passband.

Receivers used for reception of RFCS RATT signals vary in their details, but in general the receiver should be tuned in the following manner:

1. First set the receiver passband to a fairly narrow value, on the order of 1 kHz. Tune the receiver to the frequency of the desired RATT signal by observing the receiver INPUT or CARRIER LEVEL meter. Ignore the received pitch at this point, or better yet, turn the BFO off until the signal is tuned so as to center in the receiver passband. Then lock the main tuning dial if possible.

2. Turn on the receiver BFO and set its frequency 2.0 kHz BELOW the center of the receiver passband (2550 Hz for receivers used with older, unmodified TTY Terminal Units). This value is used because single-channel TTY converters use a passband centered at 2000 Hz in present units, or 2550 Hz for older units. Some receivers have an "FSK" mode in which the BFO is automatically set to the proper value by the mode switch. Other receivers are merely aligned so that the "zero beat" position of the BFO falls in the center of its travel; for these receivers, the proper BFO setting for RFCS operating must be found using step 3. Once the proper point on the BFO control is found, it is a good idea to mark it as the "FSK" setting.

3. Place the receiver BANDPASS control in the 2 kHz position (note that RFCS RATT emission is 1.24F1). With sufficient receiver output to drive the TTY converter, slowly and carefully tune the BFO (called "FREQUENCY VERNIER" in some receivers) until the two horizontal lines on the TTY converter oscilloscope are equal distances above and below the center reference line on the CRT graticule. When this condition exists, the receiver is properly tuned, with the received signal in the center of the receiver passband as well as in the center of the TTY converter passband. The common failing is to leave the receiver BFO at its center or zero beat position and tune the main dial so that the RATT signal is 2.0 kHz off frequency with respect to the center of the receiver passband. The fallacy of this procedure should be obvious if you think about it.

4. If the TTY printer now "prints inverted," the order of sidebands has been inverted in the receiver. This happens in some receivers on some of their bands. When this is the case, there are two alternatives available: either repeat steps 2 and 3, resetting the BFO ABOVE the center frequency rather than below, or else operate the TTY converter NORMAL/INVERT switch to the INVERT position. (EIB 713)

A field change has been developed for converting TTY terminal units to a center frequency of 2000 Hz instead of 2550 Hz so that those receivers that now cannot be offset by 2550 Hz in a stabilized mode can be operated with a stabilized 2.0 kHz offset. TTY terminal units so converted will copy 2425 Hz as a mark and 1575 Hz as a space, which are the values currently used by the AN/URC-32, the AN/ARC-94, and some others.

In order to produce reliable copy of RFCS RATT signals, a receiver should be operated in a tuning mode that provides best stability and accuracy. By using TTY terminal units centered on 2.0 kHz, the associated receiver can be operated at stabilized increments of frequency. For use with unmodified older TTY terminal units, some receivers such as those of the AN/WRC-1, AN/URC-32, and AN/URC-35 employ BFO (carrier) injection only at the dial frequency and therefore the tuning cannot be offset by the required 2550 Hz while the receiver is in a stabilized mode. For operation of the R-1051/URR receiver (Part of the AN/WRC-1) with 2550 Hz terminal units, the following procedure will be helpful:

1. The receiver "window" or reception passband is offset 1.5 kHz from the BFO (and the dial reading) by selecting the SSB mode. For single-channel RFCS, the mark/space relationships are correct when upper sideband is selected.

2. Switch the main tuning to VERNIER and set it for 3 kHz BELOW the assigned frequency. The R-1051/URR receiver frequency control is independent of the transmitter, which is set 2.0 kHz below the assigned frequency channel for RFCS operation.

3. Tune the incremental tuning to approximately 450 Hz and adjust as previously described for a appearance on the TTY converter scope.

This method of receiver tuning is preferable to the use of the CW mode because of the higher stability of VERNIER tuning and the better selectivity of the SSB mode. Using the receiver in this manner also provides better CW reception than that of the CW mode for the same reasons. The R-1051/URR bandwidth is 7 kHz in the CW and the AM modes, and 3.2 kHz in the SSB mode. The narrower selectivity in the SSB mode provides approximately a 2-to-one improvement in signal-to-noise ratio.

Because the AN/URC-32 uses only one stabilized oscillator for both transmitting and receiving, it cannot be used in the transceive mode with a 2550 Hz TTY converter. (EIB 644, NCB 112)

c. AFCS RATT NETS

AFCS terminal units of the AN/SGC-1 series and the newer CV-2460/SGC are reliable and "nettable" items of the ship's TTY system. They are versatile equipments ideal for ORESTES nets within a task group or task unit. For this reason, shipboard operators and technicians should understand their use and features in order to get the most from them. There is no better way to learn the capability of an equipment than by actual operation. This can be done easily by operators who want to become proficient, using an authorized UHF drill frequency.

The AN/SGC-1 and the CV-2460/SGC series AFTS terminal units are DC-to-audio converters in the transmit mode. They receive DC from a teletype loop and convert it into audio frequencies for modulation of a radio transmitter (note: the transmitter must be in the VOICE mode, not MCW mode). For narrow audio frequency shift the high audio tone is 700 Hz and the low tone is 500 Hz. For wide shift (CV-2460/SGC only) the high tone is 2425 Hz and the low tone is 1575 Hz. Normally the high tone indicates a mark and the low tone indicates a space, but this relationship can be reversed at will.

In the receive mode the equipments are audio-to-DC converters. Audio from a receiver is fed into the terminal unit. The signal could have been transmitted either as AFTS or RFCS, as long as the receiver converts it to the proper tones.

Each terminal unit has a mode selector switch which can place it in constant XMIT or constant RCVE, or an AUTO position which permits it to switch to receive whenever a signal arrives from the receiver or go to transmit, keying and modulating the transmitter, whenever the local TTY keyboard is operated. This is ideal for net operation. The CV-2460/SGC has full duplex capability, permitting simultaneous use of transmit and receive functions.

The AFTS terminal units interface with other equipments via three basic inputs/outputs other than the AC power connection:

1. A DC circuit which is looped through the TTY patch panel.
2. An audio input into which a receiver feeds tones.
3. A keying and modulation output by which the terminal unit controls a transmitter.

The equipment is very simple to use, and will function effectively provided that compatibility is maintained with the other parts of the system. The first point of concern is adjustment of the receiver that is used to receive the radio signals. If the output of the receiver is noisy when no actual signal is being received, the noise will trigger the terminal unit into a RCVE condition and it will not go automatically into the XMIT condition when the local teletype keyboard is operated. The noise output of the receiver must be kept low or squelched off during the time no signal is being received. Ideally, the no-signal noise level should be about -30 dB when the receiver output is set to supply audio tones at 0 dB. Noise from the receiver must not be allowed to trigger the terminal unit into a RCVE contition when no tones are being received. The second point is based on the transmitter modulation level that has been set on the ship. If all radiophone remotes are set to furnish -10 dB modulation level into the transmitter speech amplifiers, and the audio output of the AFTS terminal unit is set to furnish 0 dB, overmodulation will occur which will cause distortion and interference. If the output of the terminal unit is set for less than the standard RPU modulation output, undermodulation will occur which will decrease the reliable communication range between ships. If the transmitter has a clipper-filter in its speech amplifier, this circuit should be turned off for tone operation; AGC (or AVC) circuits should be left on. The audio input and output levels from the TTY terminal unit should be set to furnish the same levels into the audio distribution system that the remote phone units furnish. Refer to Transmit-Receive Panels and Remote Control Units under Subsection 1-9.

Don't overlook the "spread" between mark and space frequencies; 700 Hz and 500 Hz for narrow shift AFTS gives a spread of 200 Hz. The normal spread for single channel RFCS in the low frequency bands is 170 Hz. Either terminal unit can be used to copy narrow-shift RFCS of the type used on low frequencies when the associated receiver is set up properly. Just tune up the receiver to the desired signal as previously described in Tuning in A Single Channel RFCS RATT Signal, except that the receiver BFO is offset by -600 Hz rather than 2000 Hz (or 2550 Hz). The audio output from the receiver will be near enough to 700 Hz for mark and 500 Hz for space that the terminal unit can copy it. The CV-2460/SGC provides the additional capability of being able to copy wide shift RFCS single-channel circuits.

Either AFTS terminal unit can also serve as a part of single-channel UHF-to-HF relay circuits. It converts the AFTS signals received on UHF into a keyed DC loop current, and the loop current in turn operates the wide-shift RFCS circuits of the HF transmitter. Care must be exercised if the terminal unit and the HF transmitter have separate loop power supplies. The two power supplies must not be patched together. If such a risk exists, one solution is to wire the terminal unit to a miscellaneous jack on the TTY patch panel rather than to a looping jack. It can then be patched into either loop as required.

When the receiver input levels and the modulation output levels are properly set, and the mark and space frequencies are correct, the AN/SGC-1 and CV-2460/SGC series terminal units will provide reliable and versatile communications. (EIB 737, 741)

d. ORESTES NET

Many of the difficulties encountered on TF/TG ORESTES nets can be attributed to off-frequency situations between ships on the net. From measurements taken on an AN/URA-17 converter, it was determined that a frequency error in excess of 300 Hz introduces distortion to a received signal. A frequency error at 500 Hz makes most received signals unreadable because of excess distortion. Since these frequency errors can be shared by transmitter and receivers, a limit of 150 Hz of tuning error is established for either transmitter or receiver.

ORESTES nets with ASW aircraft or with Marine Corps units have additional requirements for transmitter accuracy because of compatibility considerations. The mark-space frequency accuracy for working with ASW aircraft is ±20 Hz at the assigned frequency. For operation with Marine Corps units, this accuracy requirement is increased to ±15 Hz.

It is imperative that absolute frequency control be practiced by operator/maintenance personnel. Many of the equipments in the Fleet today, although design for systhesized operation, have been long neglected. Since equipments can be operated in the continuous mode, it is common practice to operate in this manner. We pay for this malpractice by accepting poor copy and inordinate delays in passing traffic on nets using this method of communications.

A large percentage of ships have AN/URQ-9/10 frequency standards aboard but improperly utilized. The following equipments are designed for almost absolute highly specialized, highly accurate, frequency control, and indeed are capable of highly accurate control if operated and maintained properly.

AN/WRT-2	AN/WRR-2
AN/URC-32, 35	AN/URT-23
R-1051/URR	AN/WRC-1

Unless these equipments are operated in their stable (synthesized) modes, their dial accuracy may be so far in error (up to 7 Hz) that netting of crypto-covered teletype nets is often impossible. (EIB 714)

e. MULTI-CHANNEL TERMINAL EQUIPMENT

Multiplexing is the term used to define the art of combining more than one channel into one composite channel or trunk so that more than one message at a time can be sent on one transmitter. Multiplexing is usually shortened to the term "MUX" by radiomen. The multi-channel broadcast is a good example of "MUXING" and "DEMUXING." The ship utilizes equipment at the receiver end of the broadcast to "DEMUX" the signal into the individual channels.

Multi-channel broadcasts and ship/shore terminations utilize frequency-multiplexing, whereby each channel of the composite tone package of the broadcast or termination is assigned an audio frequency. The lowest audio frequency used is 425 Hz and the highest frequency used is 2975 Hz. The audio tones for the channels are 170 Hz apart and hence, there are tones at 425, 595, 765, 935, 1105, 1275, and so forth. There are 16 tones between 425 and 2975 Hz that are used. This gives a capability of 16 separate channels of intelligence under conditions.

In order to give ships more reliability in receiving a multi-channel broadcast, the shore station "twins" two channels and keys them with the same channel intelligence. Channels are keyed with the same intelligence to overcome "selective fading" and to give the receiving station two chances of getting the signals at one time. The twinning process uses frequencies separated by 1360 Hz to overcome the possibility of selective fading causing hits on the circuits. Intelligence from one channel is used to key 425 Hz and 1785 Hz channels or tones simultaneously. The ship receives both of these tones and converts them to DC to operate a teletype machine from the best of the two signals. The unit that combines the two signals is called a combiner unit, not similar to the comparator unit in an AN/URA-8. The theory is that if one tone (425 Hz for instance) fades out for an instant, the other tone (1785 Hz) might be loud and clear. Other tones are twined for other teletype channels, such as 595 Hz and 1955, 765 Hz and 2125 Hz, and so forth. This limits the 16 tones in most MUX/DEMUX equipments to eight channels of intelligence, but gives better reliability by overcoming some of the effects of selective fading. Utilizing two frequencies in this manner is referred to as frequency diversity.

Another form of frequency diversity is available to the ships in both ship/shore terminations and broadcast reception. On the broadcast, there are many frequencies (transmitters) on the air with the same composite package of tones for the ships to receive. The ship can tune receivers to two of these frequencies and feed both sets of audio tones in the DEMUX equipment (AN/UCC-1). This gives the equipment two separate audio inputs (from two different transmitters on two different frequencies) to help maintain a good solid signal into the AN/UCC-1. Frequencies should be selected which are as close together as possible, such as an 8 Hz and a 12-Hz frequency or a 12-Hz and a 17-Hz frequency. Frequencies that are wide spread (such as 4 Hz and 17 Hz) should not be used for normal operation of the DEMUX equipment. There may be a sufficient time delay, between the signals from these two transmitters in reaching the ship that added distortion may be added to the circuit within the combine units of the AN/UCC-1.

Only the lower frequency audio tones are transmitted on the low frequency portion of multi-channel broadcasts, because of limitations of antenna bandwidth and the bandwidth of the transmitter itself. These tones are from 425 Hz to 1615 Hz. There is no tone diversity (frequency diversity within the tone package) available. This is not a great hindrance, however, in that selective fading is not normally encountered on low frequency transmission paths.

Ship/shore termination equipment utilizes the same equipment as the multi-channel broadcast, except that the shipboard equipment has a send capability as well as a receive capability. The same operation exists on a multi-channel (VFTG) ship-shore termination as with multi-channel broadcast. There is one slight difference, and this is an asset in circuit reliability. The shipboard operator controls the frequency of the shore transmitters by requesting the two frequencies at which the shore transmitters shall be operated. The operator can choose two frequencies that are very close together and, hence, will assure the same propagation path from the shore transmitter to the ship. This condition gives very good frequency diversity and the ship should experience extremely good reception.

Reception on the ship of any tone diversity tone package can be good without utilizing the tone diversity. If one of the audio tone channels is bad in the AN/UCC-1 equipment, the output signal of the two audio channels involved may be so highly distorted that it cannot be copied. In this case, when one intelligence channel is unreadable or highly garbled, and the other channels of the ship/shore termination or the multi-channel broadcast are good, some remedial action can be taken. A technician on the ship can "untwin" the channels concerned and the operator can try the individual channels and sometimes copy the signal "fiver" on one channel.

MUX and DEMUX theories are not difficult and, if the shipboard operator becomes familiar with the concept of sending more than one intelligence at a time, he can isolate troubles and get good reception in most cases. (EIB 716)

f. SHIP/SHORE MULTIPLEX TERMINATIONS

Ship/shore multiplex terminations were measured aboard the USS ELDORADO. The parameters examined and recorded were: frequency of the carrier, tone frequencies, relative carrier output (when present), and bias distortion.

Continuous samples were taken during the course of the exercise. Almost without exception, it was found that the shore stations were on the correct frequency and well within tolerance. Numerous readings were measured on 45 different A2/A3 frequencies. Of these, only four frequencies can be transmitted from shipboard transmitters in a fully synthesized mode. In order to transmit in a synthesized mode, the carrier frequency must be in an even increment of 1 kHz. Of those measured, none were within tolerance. The average error was 152 Hz. This indicates that the equipments either cannot be operated properly, or that operations are choosing the wrong mode of operation.

The solution is obvious. Maintenance personnel must restore the equipment to designed operating standards, and operators must choose the correct mode. Present instructions (COMFIRST-FLTNOTE 2400 of 31 October) dictate that all A2 and A3 transmissions will be made in a synthesized mode.

Figure 1-9 indicates that only 30% of the transmissions showed proper selection of carrier. Some of these were too far out of tolerance to permit synthesized reception of signals. The remaining 70% indicate either personnel error or equipment malfunction. Figure 1-10 indicates equipment accuracy. Transmitter and receiver frequencies which differ by more than five hertz result in degraded copy. Beyond ten hertz differences, the termination is useless. Note that 40% of the transmission were beyond limits and required AFC controlled receivers which require that a pilot carrier be transmitted in addition to the tones. This results in improper mode of transmission, and also utilizes power which could otherwise be conveying intelligence.

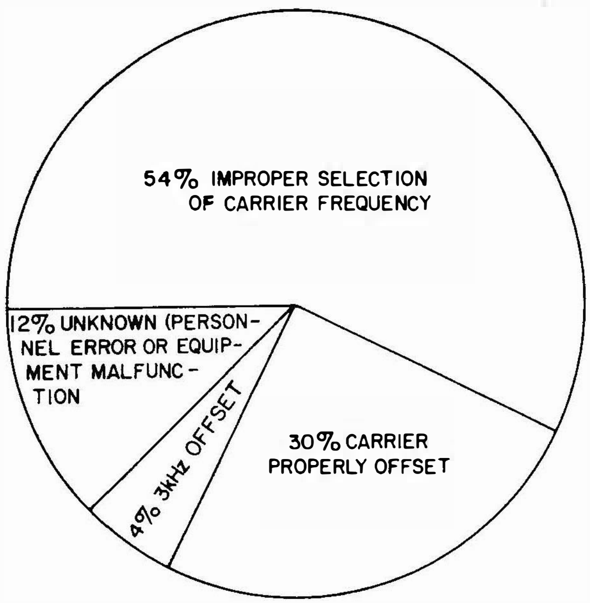

Figure 1-9. Selection of Proper Carrier Frequency Variable Frequency Tone Group (VFTG)

g. TONES AND VFTG CIRCUITS

The tones generated by an AN/UCC-1 VFTG send terminal, or the AN/FGC-60 equivalent shore send terminal, cover the audio frequency range of 382.5 Hz to 3017.5 Hz. Normally, two tones are utilized for each intelligence channel to give close frequency diversity, thereby decreasing the effects of selective fading. The AN/UCC-1 then, normally has an 8-channel intelligence capability with 16 tones. The pairs of audio tones used on a given intelligence channel are separated by 1360 Hz.

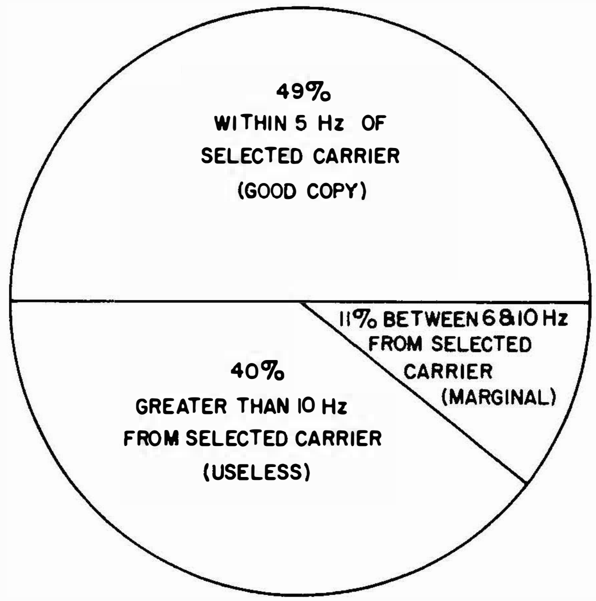

Figure 1-10. Frequency Accuracy of Transmitters (VFTG Terminations)

Because of limitations on crypto equipments, traffic handling capability, teletype machines, and personnel, a ship normally utilizes only four intelligence channels (eight tones). The remaining tones for the unused channels of the AN/UCC-1 serve no useful purpose.

The blocking mode of operation (sometimes called "idling") can often be employed in multichannel operation over VFTG circuits to overcome slow fading, weak signals, or noise which may not permit operations in the twining mode. Blocking is accomplished by inserting dummy plugs into the tone equipment jacks or grounding the output of each separate transmit channel as required. By holding transmission an given channels, the transmitted power used in these channels is concentrated in the channels still in use. The number of channels blocked depends upon the conditions of the frequency or frequencies in use at the time.

CAUTION

When blocking or idling is employed, be sure to readjust the input levels to the transmitter to maintain peak output power. The transmitter output is directly related to the audio input power.

During periods of marginal communications, tones should be blocked to obtain the following advantages:

1. Slightly more power "per tone channel" can be transmitted without overloading the transmitter.

This is only a very slight increase in power and care must be given to ensure that the transmitter is not overdriven to the point that distortion takes place. Readjust levels at the AN/UCC-1 and check transmitter to ensure it is not being over modulated.

2. With fewer tones being transmitted the chances of shipboard generated radio frequency interference are decreased. Also, the chances of intermodulation distortion are decreased tremendously as far as the number of byproducts mathematically available are concerned.

3. Decreased bandwidth also lessens the chances of interference on other ships using adjacent channel operation. By blocking the higher audio frequencies from the tone package, a "guard band" is placed between this tone package and the next higher channel frequency. This causes less interference throughout the fleet.

If the front end (on the receiving end of the circuit) is driven into the non-linear area of conduction, the fewer tones in the tone package will result in fewer by-products being generated within the receiver.

Tone blocking should be practiced until it becomes normal operation. It makes good common sense to only transmit the tones that are used to convey intelligence and to block the unused tones.

It must be remembered that channels 1, 2, 3, and 4 are not the only channels that can be used for terminations. In some cases, it may be advantageous to utilize channels 5, 6, 7 and 8. Any combination of channels may be used. Untwineing can also increase the number of channels available for ships that only have a four-channel capability. Initiative and a desire to communicate should be the guiding doctrine in the use of VFTG MUX equipment. (E1B 718)

h. TUNING MUX (MULTI-CHANNEL) CIRCUITS

Multi-channel circuits permit more than one channel of intelligence to be transmitted and received over one frequency. Only one transmitter and one receiver are necessary at each end. In ship/shore terminations, one additional transmitter and receiver are used to give better reliability, although one receiver will operate the circuit. In broadcasts, the shore station runs many frequencies in order to provide reception to ships all over the area of responsibility for that particular shore station.

The single channel radio teletype signal has a shift of 850 hertz and can be readily tuned in on practically any receiver with just a little care. If the audio from the receiver enters the teletype converter at slightly different frequencies than those for which the converter is designed, the circuit will probably operate QRK 5 anyway. In multi-channel (MUX) operation, the shift on each channel is only 85 hertz-one tenth the shift that single channel radio teletype circuits use. These circuits are much more critical and difficult to tune. The result of a frequency error on multiplex is ten times more critical than would be indicated by the difference in the amount of shift. As an example, a frequency error of 500 hertz on FSK will introduce approximately 5% distortion to the copied signal; a frequency error of only 5 hertz in MUX operation will introduce this same 5% distortion.

The package of tones that originates in the MUX unit ashore has 425 hertz as the lowest frequency tone, and tones are present every 170 hertz up the audio frequency spectrum, with a tone of 2975 Hz as the highest frequency audio tone. There are 16 tones for the 8 or 16 channels of intelligence that are normally transmitted on MUX circuits. These tones are transmitted as audio modulation to a single sideband suppressed carrier transmitter and are radiated as the upper sideband of the transmitter. Assume that the assigned frequency for radiation of MUX is 4905 kHz; the frequency is cleared for a three kHz bandwidth so the tone must straddle the center frequency or assigned frequency (4905 kHz) in this case). The tones occupy roughly 3000 Hz (3kHz) of the spectrum. In order to straddle the assigned frequency with these tones, the suppressed carrier on the transmitter must be placed 1.5 kHz below the assigned frequency. In the assumed case, the frequency assigned is 4905 kHz and the suppressed carrier is placed 1.5 kHz below that, or at 4903.5 kHz. When this suppressed carrier is modulated by the 425 hertz (lowest frequency of the MUX tone), the two frequencies are added, and that 425 hertz tone is radiated at a radio frequency of 4903.925 kHz (4903.5 plus 0.425). The highest frequency audio tone is 2975 Hz or 2.975 kHz and, when it is modulated in the transmitter, its output frequency becomes 4903.5 plus 2.975 or an RF frequency of 4906.475 kHz. The audio tones for the other channels are in between these two RF frequencies.

With suppressed carrier single sideband type of transmission, the receiver picks up the individual channel frequencies in one package, but has no carrier frequency in the package to use as a reference. The "carrier" frequency is actually generated and injected into the package of tones within the receiver on board ship. Tuning the receiver produces this injected carrier into the tone package and then the tone are detected (demodulated) and appear as audio. This is fed to the AN/UCC-1 equipment for conversion into teletype signals.

With the receiver on the correct frequency, listen to the audio and make sure that the frequency is clear, with little or no noise for interference. Try several antennas and patch cords to obtain the strongest and clearest reception possible. If the receiver has an antenna tuning device, be sure and peak this for maximum received signal. If the signal is extremely strong, decrease the amount of radio frequency gain so that the AGC action of the receiver will not distort the audio output to the receiver. Adjust the audio level out of the receiver to the correct level for the input of the device used to convert the audio tones to teletype signals. Normally, this will be an AN/UCC-1 equipment. Adjust the level out of the receiver after the patches have been made to feed the signals into the AN/UCC-1.

Keep a second receiver tuned in to another frequency on either broadcast or ship termination type circuits to give an instant back-up if one frequency fails or a transmitter goes off the air at the shore station. Keep an audio monitor on the two frequencies to make sure that they are both of traffic quality at all times. If one frequency goes bad, QSY the receiver to a new frequency before the other frequency also goes bad. If two signals are found of the same quality, the AN/UCC-1 equipment can be set up for receiving and comparing both of these frequencies in frequency diversity. In order to use this mode of operation, the AN/UCC-1 must be set up in accordance with the technical manual and, additionally, both frequencies must either be broadcast from the same transmitting location or locations that are the same distance from the ship.

Not all receivers on board ship will operate efficiently on MUX signals, as the receivers tend to drift in frequency. They will drift only a few cycles, but that may be enough to highly distort a circuit. The receivers commonly used now for MUX signals are the R-1051/URR, AN/WRR-2, and the AN/SRR-19. The AN/WRR-2 receiver cannot be used on frequencies where the carrier must be injected at half kHz points, unless Field Change I has been applied. The other receivers on board ship, such as the R-390/URR, are not suitable for MUX operation unless in an emergency.

The signal pulses on diversity channels (twinned pairs) must arrive simultaneously at the terminal equipment in order that the channels (4 on Quad Diversity) may be used in diversity operation. Errors in arrival time (1 to 5 milliseconds delay distortion) were introduced by the shore transmitting stations during operation BASE LINE II. Because of this delay, compensation at the receive MUX terminal should be made while receiving the desired station. The procedures in the AN/UCC-1 Technical Manual require that the transmit station send reversal type signals during alignment of the equipment with the test set provided. This procedure is not always possible, especially on broadcast circuits; however, the adjustment can be made while traffic is being passed by measuring delay between channels with a dual trace oscilloscope.

The signal pulses arriving at the KW-37 broadcast channel must arrive simultaneously with each of the pulses on the associated KG-14 channels for proper operation. The KG-14 has a variable delay switch which can be used to compensate for known delay differentials. The alternate procedure is to compensate for all delays at the MUX receiving terminal. It is not feasible for a shore broadcast station to transmit reversal type signals to permit adjusting channel delay with the test set provided with the AN/UCC-1 equipments. The adjustment or measurement of delay distortion must therefore be made while traffic is being passed by measuring delay between channels with a dual trace oscilloscope.

The difference is delay distortion between twinned broadcast channels and associated KW-37 and KG-14 broadcast channels should be fairly constant throughout each broadcast area. These delays will very likely be different between one broadcast area and another until broadcast stations develop procedures and equipment capability to standardize on synchronization. (EIB 719)

i. UHF/HF RELAY

The communications duties of destroyers include providing the carriers with UHF/HF relay, not only during HERO and RADHAZ conditions but for sustained periods of time. In the past, only the destroyers homeported in WESTPAC together with a few ships deployed to WESTPAC had worked out the details of VOX relay, and these "old reliables" were perpetually asked by the carriers to perform relay duties. So many of the new arrivals lacked the ability to conduct a successful relay that the Fleet Commander called for command attention and insisted on performance. Henceforth each destroyer must not only demonstrate a relay capability commensurate with its existing transmitter installation but a proficiency in relay as well. Carriers have been asked to rotate the relay assignment among the destroyers attached and to report inabilities on the part of any of them. The carriers are beginning to realize that a 2100 ton class destroyer is incapable of providing the same degree of relay services as the DLG class because of the obvious disparity of equipment. However, this does not exonerate the 2100 ton class destroyer from demonstrating a proficiency in each of the modes if her communications installation includes the proper types, not numbers, of equipment.

Relay capability in each of the following modes should be established:

Single channel VOX relay Consists of converting UHF AM voice or tone-mode teletype signal to HF using the C-4621/SR retransmission unit.

Double channel simultaneous VOX relay Consists of converting two UHF AM or tone-mode (AFSK) teletype signals to an HF SSB voice or tone-mode teletype signal using the C-4621/SR unit.

Single channel VOX relay on single sideband Consists of converting an UHF AM voice or tone-mode teletype signal to an HF SSB voice or tone-mode teletype signal using the C-4621/SR unit.

Independent sideband two channel VOX relay Consists of converting two UHF signals, one voice and the other tone-mode teletype to one HF upper sideband voice and lower sideband tone-mode teletype using the C-4621/SR unit.

Composite (2 or 3 channel) MUX relay Consists of converting a UHF composite MUX signal to an HF composite MUX signal on a sideband using the C-4621/SR.

Single channel frequency shift teletype relay Consists of converting an UHF tone-mode teletype signal to a HF frequency shift signal using the AN/SGC-1A.

Diversity frequency shift teletype relay Consists of converting a single UHF tone-mode teletype signal to one HF frequency teletype and one MF frequency shift teletype signals using the AN/SGC-1A.

A MUX relay in frequency shift mode is difficult to manage because of the slow response of the mechanical relay in the AN/SGC-1A. An electronic relay replacement to remedy this deficiency is being considered at this time.

The most common error is the mistaken belief that the VOX (C-4621/SR) can drive a frequency shift keyer. The VOX unit can handle only audio signals and drive a modulator. However, the AN/SGC-1A teletype tone modulator can convert the tone-mode teletype audio signal into the mark and space bits to key the DC loop of a frequency shift keyer. Upon learning that the AN/SGC-1A is necessary to convert a tone-mode teletype to frequency shift, many ships find that they are unable to isolate the AN/SGC-1A in the teletype DC loop board. Both the frequency shift keyer in the transmitter and the tone modulator have their own DC loops, and