CHAPTER 1

FUNDAMENTALS

INTRODUCTION

Communications in general, and especially in systems, covers a broad spectrum, from a simple single-channel voice circuit, to the fastest growing field of electronics—satellite communications. This training manual will provide you with knowledge applicable to questions and situations that arise on the job. Chapter 1 is a refresher course in basic communications systems and terminology. Chapters 2 and 3 will lead you through many of the systems and equipments in use today. Chapter 4 will discuss the Link-11 system, chapter 5 will cover the Link-11 Fault Isolation, chapter 6 will discuss Link 4-A, chapter 7 will introduce you to the new technology in data communications and the Link-16 system, and chapter 8 will discuss local-area networks.

The Electronics Technician rating is extremely diverse. Many ETs never get the opportunity to work in the communications field. Those who do are often locked into one particular system for many years. This assignment pattern sometimes causes ETs to feel overwhelmed or lost in their career. The massive amount of information ETs can be questioned on and expected to know can be frustrating. But the goal **YOU** and every ET must have is to become as knowledgeable as possible to be better. prepared for all future challenges.

After completing this chapter, you should be able to:

- **Identify the basic principles of rf communications**
- **Recognize the basic equipment used for rf communications**
- **Determine the frequency spectrum allocated to rf communications**

RADIO COMMUNICATIONS

Navy ships, planes, and shore bases operate as a team working together to accomplish a specific task. Radio equipment is used to coordinate the activities of the many fleet units by linking them with each other and with shore stations.

Radio can be defined as the transmission and reception of electronic impulses or signals through space by means of electromagnetic waves. Usually, the term is used in referring to the transmission of intelligence code and sound signals, although television and radar also depend on electromagnetic waves.

At one time, the term *radio communications* brought to mind telegraphy (CW), voice (AM), and possibly teletype communications. Today's radio communications has become a highly sophisticated field of electronics. You, the technician, need to become familiar with the diverse systems in use today.

The primary means of communicating between ships and between ships and stations is known as *telecommunications.* Telecommunications refers to communications over a distance and includes any transmission, emission, or reception of signals, writing, images, and sounds. Intelligence produced by visual or oral means or by wire, radio, or other electromagnetic systems is also included. Electrical, visual, and sound telecommunications are all used by the Navy. In this volume we will discuss electrical types of telecommunications.

COMMUNICATIONS SYSTEMS

A communications system consists of two or more units, each having its own separate identity, arranged and interconnected to perform a circuit operation that cannot be performed by one of the individual units alone. Navy communications systems vary from simple to very complex, depending upon the circuit operations involved. Each system requires the integrated use of various types of equipment, so flexibility is of the utmost importance. This flexibility is provided through a complex arrangement of interconnections that allow the physically separated sets, groups, and units to be selectively switched (patched) into the different circuit configurations.

Most shipboard communication equipments do not operate independently. A particular piece of electronic gear may be designated "primary" and still be used in many different system operations. You need to understand all the associated equipment in a system to identify problems correctly and to make repairs promptly. Thorough knowledge of system operations will enable you to say with complete confidence, this communications suite is operational.

SAFETY

Hazards encountered in servicing electronic equipment and the precautions to be taken against them are covered thoroughly in *Electronics Technician Volume 1, Safety,* NAVEDTRA 12411, and the *General Handbook* (NAVSHIPS 0967-000-0100) of the EIMB series.

Safety is everyone's responsibility. Observance of safety precautions will keep your equipment operating, help your career in the Navy, and possibly determine whether or not you survive. Always follow the appropriate safety precautions!

> **Note:** Equipment that we cover in this and other chapters is intended to be merely representative of equipment that you may encounter on board your command. We will not attempt to include all the possible equipment or equipment configurations.

BASIC SYSTEM REQUIREMENTS

Radio equipment can be divided into three broad categories: transmitting equipment, receiving equipment, and terminal equipment. Transmitting equipment generates, amplifies, and modulates a transmitted signal. Receiving equipment receives a radio wave, then amplifies and demodulates it to extract the original intelligence. Terminal equipment is used primarily to convert the audio signals of encoded or data transmission into the original intelligence.

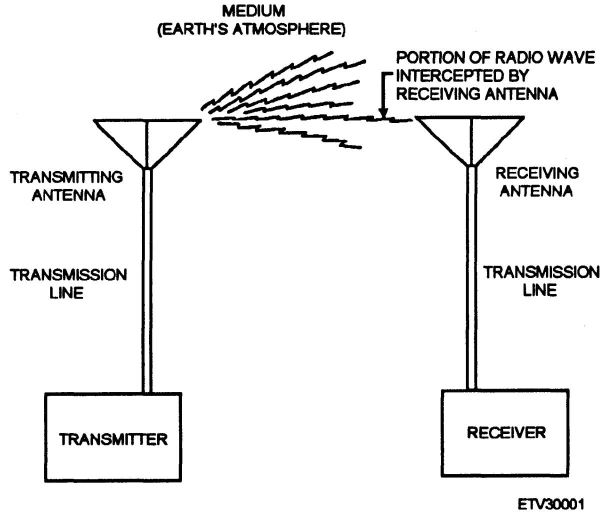

Figure 1-1.—Basic radio communication system.

A basic radio communications system may consist of only a transmitter and a receiver, connected by the medium through which the electromagnetic waves travel (see figure 1-1). The transmitting equipment creates a radio-frequency (rf) carrier and modulates it with audio intelligence to produce an rf signal. This rf signal is amplified and fed to the transmitting antenna, which converts it to electromagnetic energy for propagation.

The receiving antenna converts the portion of the electromagnetic wave it receives into a flow of alternating rf currents. The receiver then converts these currents into the intelligence that was contained in the transmission.

Terminal equipment is used primarily where coded transmissions are employed, to convert the modulated signal into the original intelligence. Systems you will encounter in the fleet use terminal equipment, such as AN/UCC-l, AN/URA-17, and CV-2460.

THE FREQUENCY SPECTRUM

Figure 1-2 shows the overall electromagnetic frequency spectrum as defined by the International Telecommunications Union. Pay particular attention to the part used for communications. Rapid growth in the quantity and complexity of communications equipment and increased worldwide international requirements for radio frequencies have placed large demands upon the rf spectrum. These demands include military and civilian applications, such as communications, location and ranging, identification, standard time, industrial, medical, and other scientific uses.

The military has modified the frequency spectrum for its use as shown in table 1-1. A few general characteristics are described in the following paragraphs.

The extremely-low-frequency (elf), very-low-frequency (vlf), and low-frequency (lf) bands require high power and long antennas for efficient transmission (antenna length varies inversely with the frequency). Transmission of these frequencies is normally limited to shore stations.

The commercial broadcast band extends from about 550 kHz to 1700 kHz. This limits naval use to the

Table 1-1.—Frequency Bands.

FREQUENCY	DESCRIPTION
30-300 GHz	extremely-high-frequency
3-30 GHz	super-high-frequency
300 MHz-3 GHz	ultra-high-frequency
30-300 MHz	very-high-frequency
3-30 MHz	high-frequency
300 kHz-3 MHz	medium-frequency
30-300 kHz	low-frequency
3-30 kHz	very-low-frequency
300 Hz-3 kHz	voice frequency
Up to 300 Hz	extremely-low-frequency

upper and lower ends of the medium frequency (mf) band.

Long-range shipboard communications were conducted exclusively in the high-frequency (hf) band, so a large percentage of shipboard transmitters and receivers are designed to operate in this band. On board your command, you may find satellite communications has pushed hf into aback-up role.

A significant portion of the very-high-frequency (vhf) band is assigned to the commercial television industry. Some naval uses of the vhf band are mobile communications, repeater operation, navigation, amphibious and special operations, short range line-of-sight (LOS) communications, and satellite communications.

The ultra-high-frequency (uhf) band is used extensively by the Navy for LOS and satellite communications. Mobile communications, radar (over 400 MHz), and special operations are some other uses.

The super-high-frequency (shf) band is the workhorse of microwave communications. LOS communi-

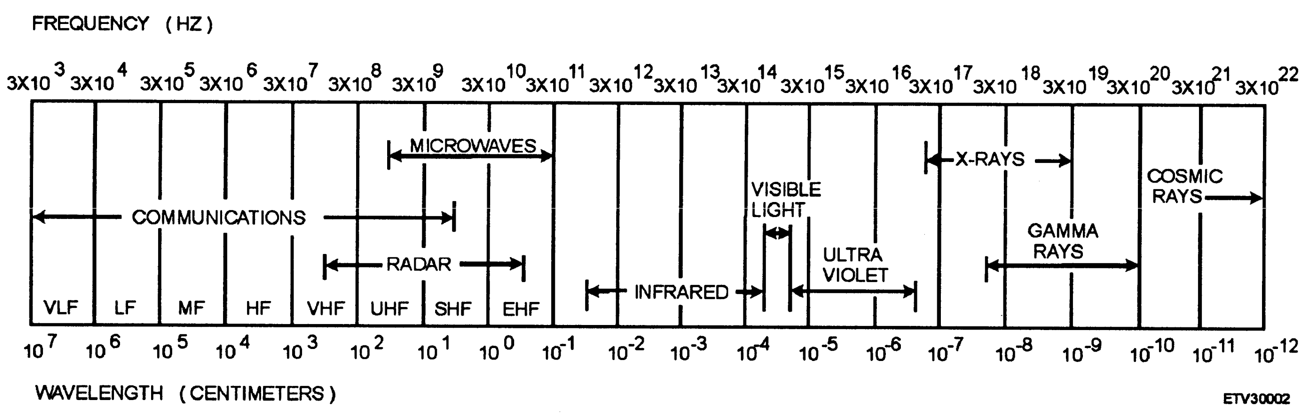

Figure 1-2.—Frequency spectrum.

cations, terrestrial, and satellite relay links, radar, and special operations are some other uses.

Experimental use of the extremely-high-frequency (ehf) band is ending. The Fleet Satellite (FLTSAT) Ehf Package **(FEP)** is attached to two modified uhf FLTSATs. The FEP is currently providing ehf communications capability to Army, Navy, and Air Force ground, airborne, and oceangoing terminals. We will discuss the FEP and its purpose in chapter 3.

Infrared devices and lasers use even higher frequency ranges. Information on equipment using these frequencies can be found in *Electro-Optics,* volume 9, of this training series.

RADIO EMISSIONS

The emission class of an rf transmitter is determined by the type of modulation used. The international designation system for AM and FM emissions is shown in table 1-2. It designates the rf emission by type, mode, and supplemental characteristics.

We will now discuss the basic equipment required for communications.

TRANSMITTERS

For rf communications to take place, a signal has to be generated. Generating the signal is the job of the transmitter. The following paragraphs will very briefly discuss basic transmitters and transmitter fundamentals.

TRANSMITTER FUNDAMENTALS

Equipment used for generating, amplifying, and transmitting an rf carrier is collectively called a radio transmitter. Transmitters may be simple, low-power units, for sending voice messages a short distance or highly sophisticated, using thousands of watts of power for sending many channels of data (voice, teletype, telemetry, t.v., etc.,) over long distances.

Basic transmitters are identified by their method of modulation: continuous wave (CW), amplitude modulation (AM), frequency modulation (FM), or single-sideband (ssb). We will first describe the types of modulation. We will then describe briefly the basic transmitters themselves.

Table 1-2.—Types of Radio Emissions

AØ	FØ	No modulation intended to carry intelligence.
A1	F1	On-off or mark-space keying without the use of a modulating tone.
A2	F2	On-off or mark-space keying of a modulating audio frequency, or of the modulated emission.
A3	F3	Voice-frequency modulating, including simplex AFTS RATT.
A3A		Single-sideband, reduced carrier (SSB).
A3B		Two indpendent sidebands (ISB).
A3H		Single-sideband, full carrier (compatible SSB).
A3J		Single-sideband, suppressed carrier (SSSC).
A4	F4	Facsimile, with modulation of main carrier directly or by a frequency-modulated subcarrier.
A4A		Facsimile using single-sideband, reduced carrier.
A5	F5	Television.
A5C		Television, vestigial sideband.
	F6	Four-frequency diplex telegraphy (RFCS RATT).
A7		Multichannel voice-frequency telegraphy (AFTS MUX).
A7A		Multichannel voice-frequency telegraphy (AFTS MUX) using single-sideband, reduced carrier.
A7B		Multichannel voice-frequency telegraphy (AFTS MUX) using two independent sidebands.
A7J		Multichannel voice-frequency telegraphy (AFTS MUX) using single-sideband, suppressed carrier.
A9	F9	Cases not covered by above (e.g., a combination of telephony and telegraphy).
A9B		Combinations using two independent sidebands.

MODULATION

Modulation is the process of varying some characteristic of a periodic wave with an external signal. The voice frequencies (about 110-3,000 Hz) are contained in the audio frequency spectrum, 10-20,000 Hz. In naval communications the terms *voice communications* and *audio communications* are sometimes used interchangeably. The audio signal is impressed upon the rf carrier because it is impractical to transmit frequencies in the audio range due to their excessive wavelength.

Three characteristics of the carrier wave may be varied, or modulated, at an external signal rate: amplitude, frequency, and phase. The following paragraphs discuss each type of modulation.

Amplitude Modulation (AM)

Amplitude modulations the process of combining audio frequency and radio frequency signals so that the *amplitude* of the radio frequency waves varies at an audio frequency rate.

Frequency Modulation (FM)

Frequency modulation is a process in which the *frequency* of the carrier wave is made to vary. An FM signal should remain constant in amplitude and change only in frequency.

Frequency-Shift Keying (FSK)

Frequency-shift keying is considered a form of FM. It is a digital mode of transmission commonly used in radioteletype applications. In FSK the carrier is present all the time. In a keyed condition, the carrier frequency changes by a predetermined amount called the *mark frequency.* The unkeyed state is called a space.

Phase-Shift Keying (PSK)

Phase-shift keying is similar to FSK except that the phase, not the frequency, is shifted. The primary advantage of PSK is that it can be accomplished in an amplifier stage.

Pulse Modulation

Pulse modulation is accomplished by varying the characteristics of a series of pulses. This can be done by varying the amplitude, duration, frequency, or position of the pulses. It can also be done through coding. Pulse modulation is especially suited for use with communications systems incorporating time-division mutiplexing.

BASIC TRANSMITTERS

Remember, transmitters are generally divided according to their type of modulation. In the discussion below, we describe very briefly how each type operates to help you differentiate between them.

CW Transmitter

A basic CW transmitter is shown in figure 1-3. CW is one of the oldest and least complicated forms of communications. Two advantages of CW are a *narrow bandwidth,* which requires less power out, and *clarity,* even under high noise conditions. The major disadvan-

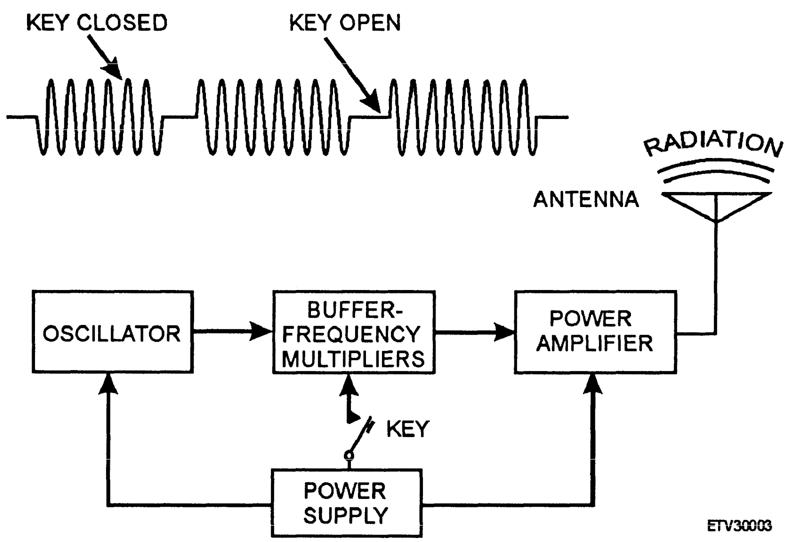

Figure 1-3.—Continuous-wave transmitter.

tage of a CW transmitter is that it must be turned on and off at specific intervals to produce Morse code keying (dots and dashes). This method is very slow by modern day standards. A better method of transmitting is AM.

AM Transmitter

Figure 1-4, a block diagram of an AM transmitter, shows you what a simple AM transmitter looks like. The microphone converts the audio frequency input to electrical energy. The driver and modulator amplify the audio signal to the level required to modulate the carrier fully. The signal is then applied to the power amplifier (pa). The pa combines the rf carrier and the modulating signal to produce the AM signal for transmission.

FM Transmitter

A block diagram of an FM transmitter is shown in figure 1-5. The transmitter oscillator is maintained at a constant frequency by a quartz crystal. This steady signal is passed through an amplifier, which increases the amplitude of the rf subcarrier. The audio signal is applied to this carrier phase-shift network. Here, the frequency of the carrier shifts according to audio signal variations. The FM output of the phase-shift network is fed into a series of frequency multipliers that increase the signal to the desired frequency. The signal is then amplified in the power amplifier and coupled to the antenna.

Two important things to remember are (1) the amount of variation from the carrier frequency depends on the magnitude of the modulating signal and (2) the rate of variations in carrier frequency depends on the frequency of the modulating signal.

The FM transmitter is better than an AM transmitter for communications purposes because FM is less affected by static and other types of interference. An even better transmitter is the single-sideband transmitter, or ssb. Let's look at some of the advantages of ssb transmitters.

SINGLE-SIDEBAND TRANSMITTER

In ssb communications, the carrier is suppressed (eliminated) and the sideband frequencies produced by the carrier are reduced to a minimum. This means no carrier is present in the transmitted signal. It is removed after the signal is modulated and reinserted at the receiver during demodulation. Since there is no carrier, all the energy is concentrated in the sideband(s).

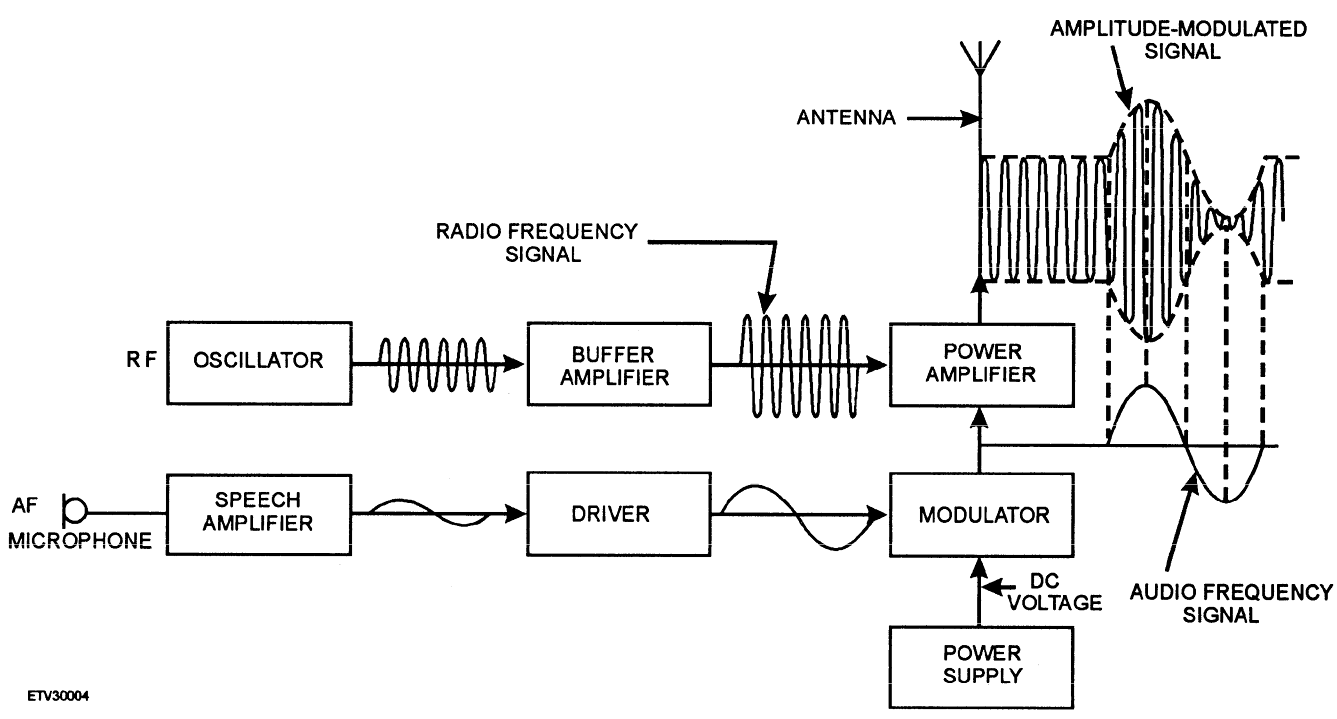

Figure 1-4.—AM transmitter block diagram.

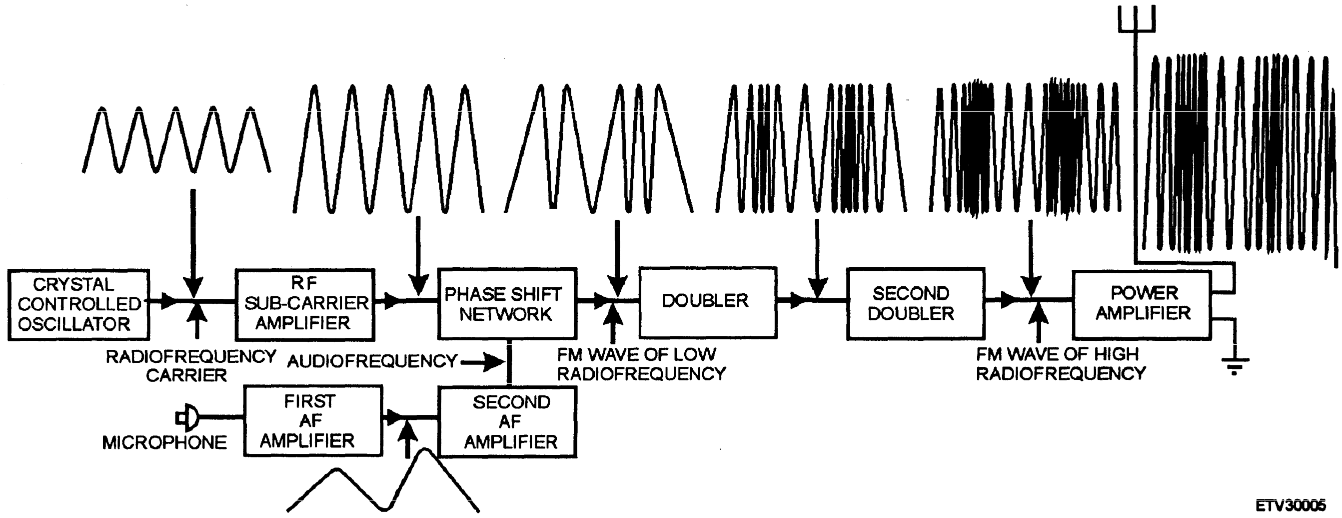

Figure 1-5.—FM transmitter block diagram.

We can make ssb even more efficient by removing one of the sidebands. By filtering out one of the sidebands before it reaches the power amplifier, all the transmitter energy is concentrated into one sideband instead of being split between the carrier and two sidebands. This allows us to use less power for transmission. Other advantages are a narrower receiver bandpass and the ability to place more signals in a small portion of the frequency spectrum. Figure 1-6 is a block diagram of a ssb transmitter.

RECEIVERS

Earlier you were introduced to one link in a communications system, the transmitter. All that is needed to complete the system is a radio receiver. A receiver processes modulated signals and delivers, as an output, a reproduction of the original intelligence. The signal can then be applied to a reproducing device, such as a loudspeaker or a teletypewriter.

RECEIVER FUNCTIONS

To be useful, a receiver must perform certain basic functions. These functions are reception, selection, detection, and reproduction.

Reception

Reception occurs when a transmitted electromagnetic wave passes through the receiver antenna and induces a voltage in the antenna.

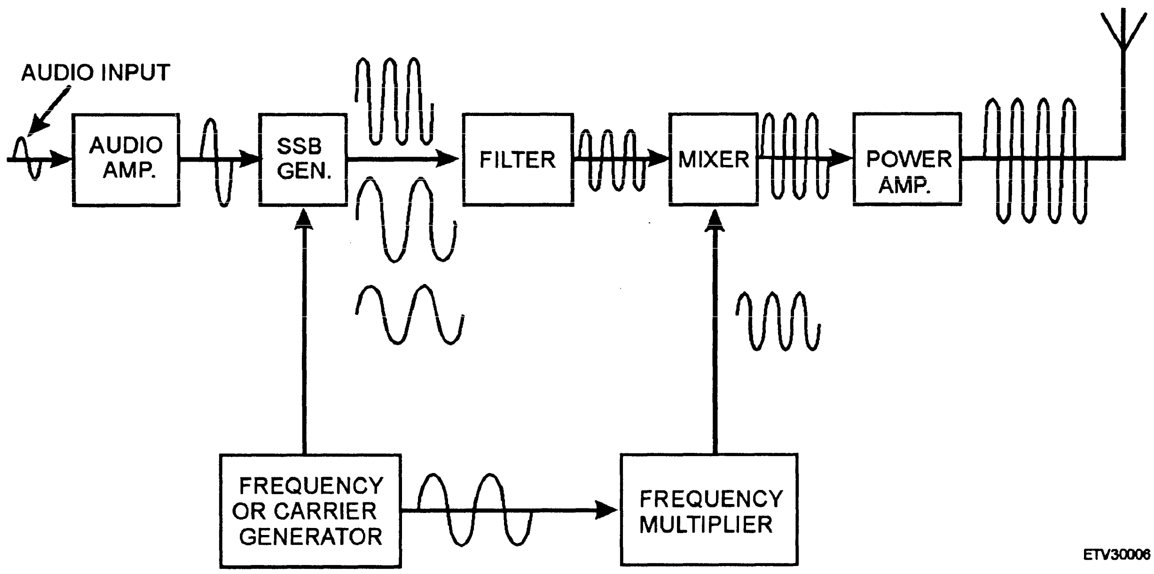

Figure 1-6.—SSB transmitter block diagram.

Selection

Selection is the ability to distinguish a particular station's frequency from all other station frequencies appearing at the antenna.

Detection

Detection is the extraction of the modulation from an rf signal. Circuits that perform this function are called detectors. Different forms of modulation require different detector circuits.

Reproduction

Reproduction is the action of converting the electrical signals to sound waves that can be interpreted by the ear.

RECEIVER CHARACTERISTICS

Understanding receiver characteristics is mandatory in determining operational condition and for comparing receivers. Important receiver characteristics are sensitivity, noise, selectivity, and fidelity.

Sensitivity

Sensitivity is a measure of receiver's ability to reproduce very weak signals. The weaker the signal that can be applied and still produce a certain signal-to-noise (S/N) ratio, the better that receiver's sensitivity rating. Usually, sensitivity is specified as the signal strength in microvolts necessary to cause a S/N ratio of 10 decibels, or 3.16:1.

Noise

All receivers generate noise. Noise is the limiting factor on the minimum usable signal that the receiver can process and still produce a usable output. Expressed in decibels, it is an indication of the degree to which a circuit deviates from the ideal; a noise figure of 0 decibels is ideal.

Selectivity

Selectivity is the ability of a receiver to distinguish between a signal at the desired frequency and signals at adjacent frequencies. The better the receiver's ability to exclude unwanted signals, the better its selectivity. The degree of selectivity is determined by the sharpness of resonance to which the frequency determining components (bandpass filters) have been engineered

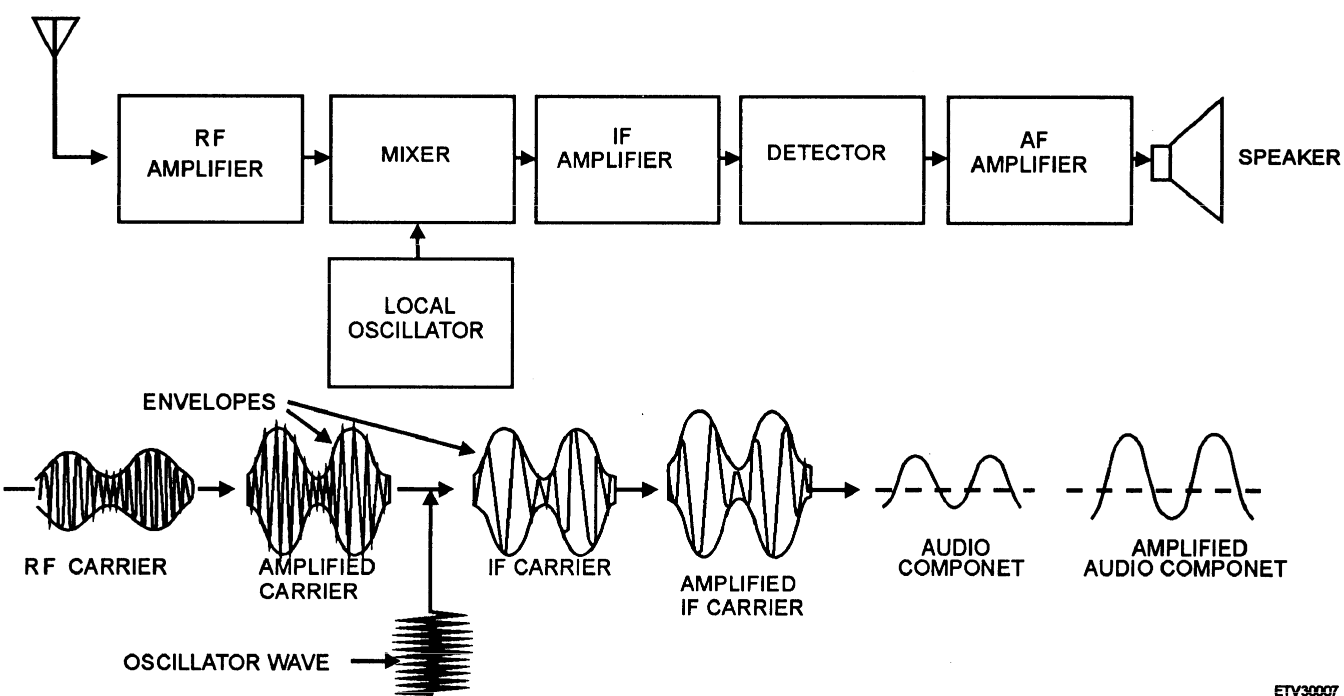

Figure 1-7.—AM superheterodyne receiver and waveforms.

and tuned. Measurement of selectivity is usually done by taking a series of sensitivity readings in which the input signal is stepped along a band of frequencies above and below resonance of the receiver's circuits. As the frequency to which the receiver is tuned is approached, the input level required to maintain a given output will fall. As the tuned frequency is passed, the input level will rise. Input levels are then plotted against frequency. The steepness of the curve at the tuned frequency indicates the selectivity of the receiver.

Fidelity

Fidelity is a receiver's ability to reproduce the input signal accurately. Generally, the broader the bandpass, the greater the fidelity. Measurement is taken by modulating an input frequency with a series of audio frequencies and then plotting the output measurements at each step against the audio input. The curve will show the limits of reproduction.

Good *selectivity* requires a narrow bandpass. Good *fidelity* requires a wider bandpass to amplify the outermost frequencies of the sidebands. Knowing this, you can see that most receivers are a compromise between good selectivity and high fidelity.

AM SUPERHETERODYNE RECEIVER

The superheterodyne receiver was developed to overcome the disadvantages of earlier receivers. A block diagram of a representative superheterodyne receiver is shown in figure 1-7. Superheterodyne receivers may have more than one frequency-converting stage and as many amplifiers as needed to attain the desired power output.

FM SUPERHETERODYNE RECEIVER

Fundamentally, FM and AM receivers function similarly. However, there are important differences in component construction and circuit design because of differences in the modulating techniques. Comparison of block diagrams (figures 1-7 and 1-8) shows that electrically there are two sections of the FM receiver that differ from the AM receiver: the discriminator (detector) and the accompanying limiter.

FM receivers have some advantages over AM receivers. During normal reception, FM signals are static-free, while AM is subject to cracking noise and whistles. Also, FM provides a much more realistic reproduction of sound because of the increased number of sidebands.

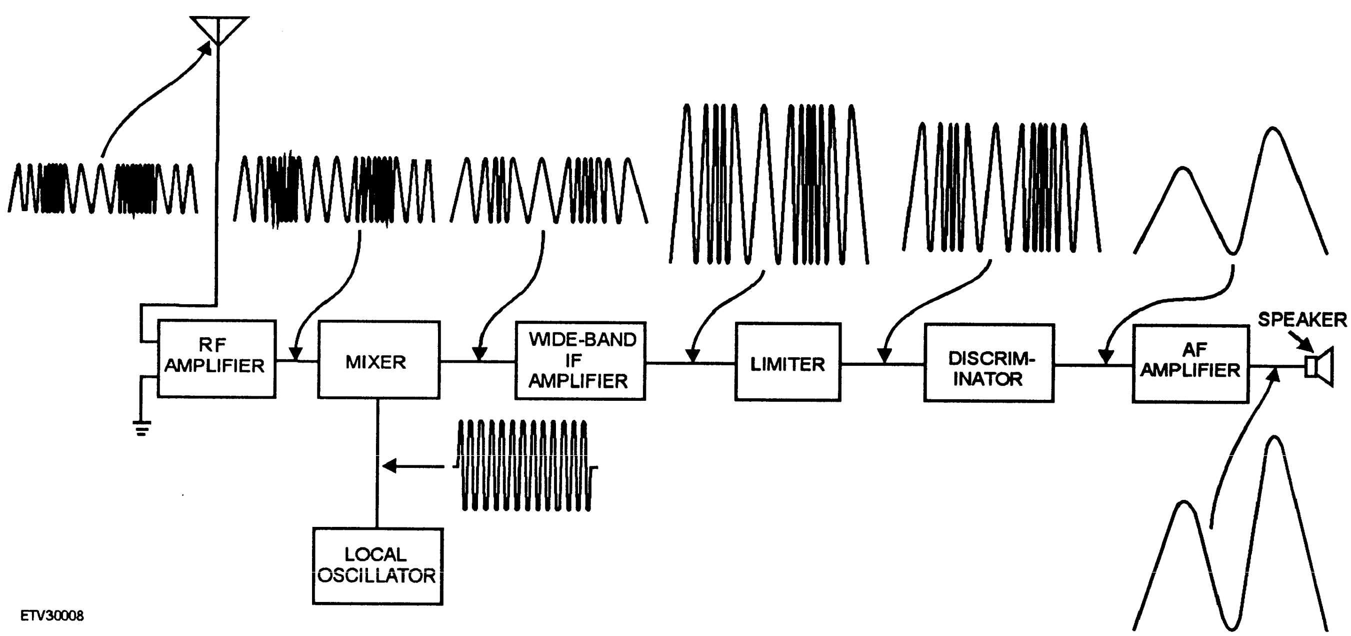

Figure 1-8.—FM superheterodyne receiver and waveforms.

SINGLE-SIDEBAND (SSB)

Figure 1-9 is a block diagram of a basic ssb receiver. Though the ssb receiver is not significantly different from a conventional AM superheterodyne receiver, it must use a special type of detector and a carrier reinsertion oscillator. The oscillators in a ssb receiver must be extremely stable. In some cases, a frequency stability of plus or minus 2 hertz is required. You can see that frequency stability is the most important factor of ssb equipment.

Ssb receivers may use additional circuits that enhance frequency stability, improve image rejection, or provide automatic gain control (age). However, the circuits shown in figure 1-5 will be found in all single-sideband receivers.

AMPLIFICATION

Because the incoming signal may be weak and because a certain minimum voltage level is required for the auxiliary equipment to operate, considerable amplification must take place before the receiver output is used to drive speakers, headphones, or terminal equipment. This is usually called the *gain* of the receiver. Gain is a term used to describe an increase in current, voltage, or power. For example, if the detector, which removes the desired intelligence, requires 1 volt to operate and if the input to the receiver is 1 microvolt, a total amplification of 1 million is required before detection. If the loudspeaker requires 10 volts, another voltage amplification of 10 is necessary between the detector and the loudspeaker.

The gain of an amplifier is expressed in decibels (dB). The decibel is a means of measuring relative levels of current, voltage, or power. Most often it is used to show the *ratio* between input power and output power. This ratio is expressed as gains and losses, where a minus (–) sign placed before dB indicates a loss and a plus (+)(or no sign at all) indicates a gain. The number of decibels change between two power values can be computed by the formula:

$$db = \log_{10} \frac{P1}{P2}$$

The comparison of dB’s to power ratio is shown in table 1-3. You can see instantly the reason behind using the decibel system. It is much easier to say the signal level has increased 40 dB than to say it has increased 10,000 times.

Examining table 1-3 again, you can see that an increase of 3 dB indicates a doubling of power. The reverse is also true. If a signal decreases by 3 dB, half the power is lost. For example, a 100-watt signal *decreased* by *3* dB will equal *50* watts, while the same 100-watt signal *increased* by *3* dB will equal 200 watts. It’s important to understand that **no matter how much power is involved,** a loss or gain of 3 dB always represents a halving or doubling of the output power.

Technically, the dB level of a signal is a logarithmic comparison between the input and output signals. Table 1-4 shows the common logarithms used to calculate dB. Normally the input signal is used as a reference. However, sometimes a standard reference signal is used. The most widely used reference level is a 1 milliwatt signal. Decibels measured in reference to 1 milliwatt are abbreviated dBm. A signal level of 3 dBm is 3 dB above 1 milliwatt and a level of-3dBm is 3 dB below 1 milliwatt. The formula for dBm is a variation of the dB power formula:

$$dbm = 10 \log \frac{actual\ power\ (P2)}{.001\ watt\ (P1)}$$

As a Navy technician, you will use the dBm system of measurement often to perform receiver sensitivity tests. For example, a receiver rated at -110 dBm will detect a signal 110 dB below 1 milliwatt. Suppose the

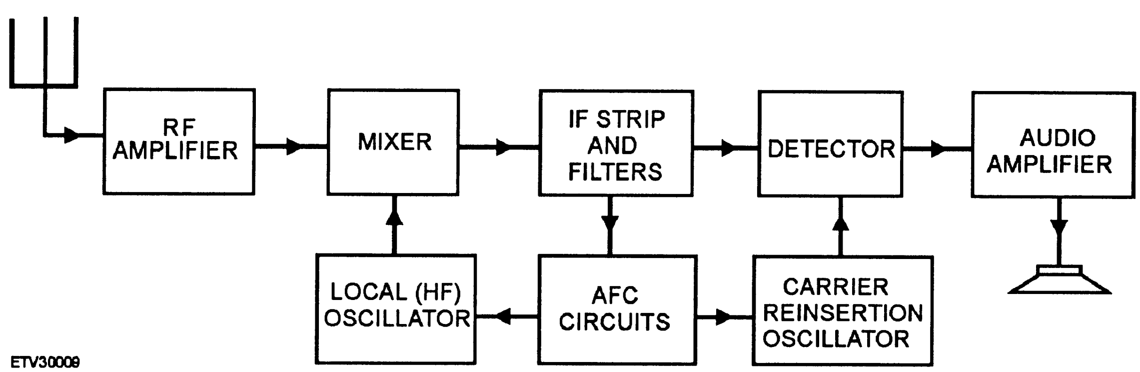

Figure 1-9.—Basic ssb receiver.

Table 1-3.—Decibel to Power Ratio

DB Loss or Gain		Power Ratio Loss or Gain
1	=	1.3
3	=	2.0
5	=	3.2
6	=	4.0
7	=	5.0
10	=	10
20	=	100
30	=	1000
40	=	10,000
50	=	100,000
60	=	1,000,000

Table 1-4.—Logarithms

LOG 1 = 0.0000	LOG 8 = 0.9031
LOG 2 = 0.3010	LOG 9 = 0.9542
LOG 3 = 0.4771	LOG 10 = 1.0000
LOG 4 = 0.6021	LOG 20 = 1.3010
LOG 5 = 0.6990	LOG 30 = 1.4771
LOG 6 = 0.7782	LOG 40 = 1.6021
LOG 7 = 0.8451	LOG 50 = 1.6990
	LOG 60 = 1.7782

receiver's sensitivity drops to -107 dBm. Since a loss of 3 dB reduces the sensitivity by 1/2, the input signal will have to be twice as large to be detected.

TRANSCEIVERS

A transceiver is a unit, usually enclosed in a single case, that combines a transmitter and receiver using a common frequency control. Transceivers are used extensively in two-way radio communications at all frequencies, and in all modes.

The primary advantage of using a transceiver rather than a separate transmitter and receiver is cost. In a transceiver, many of the components can be shared during both transmit and receive operations. Another advantage is that transceivers can be tuned more easily than separate units.

A disadvantage of using a transceiver is that while duplex operation is not possible with most transceivers, communication must sometimes be carried out on two different frequencies. Although this is a problem with most transceivers, some do have provisions for separate transmit and receive operations, allowing them to overcome the problem.

ANCILLARY EQUIPMENT

Now that we have looked at the basic components of a communications system, let's identify some of the ancillary equipment required to make a transmitter and receiver useful.

HANDSET

A handset converts acoustical (sound) energy into electrical energy, which is used to modulate a transmitter. It also converts electrical energy into acoustical energy for the reproduction of the received signal.

To **key** a transmitter, the push-to-talk button is depressed, closing the dc keying circuit, which places the transmitter on the air. The handset is normally connected to a radio set control but can be used locally at the transmitter. Using the "local" option is a good way to determine whether a problem exists in the transmitter or remote equipment.

RADIO SET CONTROL

The radio set control provides the capability to control certain transmitter functions and the receiver output from a remote location. Some control units contain circuits for turning the transmitter on and off, voice modulating the transmission, keying when using CW, controlling receiver output, and muting the receiver when transmitting.

A representative radio set control unit is shown in figure 1-10. As many as four of these units maybe paralleled to a single transmitter/receiver group to provide additional operating positions. This setup is often found aboard ship when a transmitter or receiver is controlled from various locations like the bridge or combat information center.

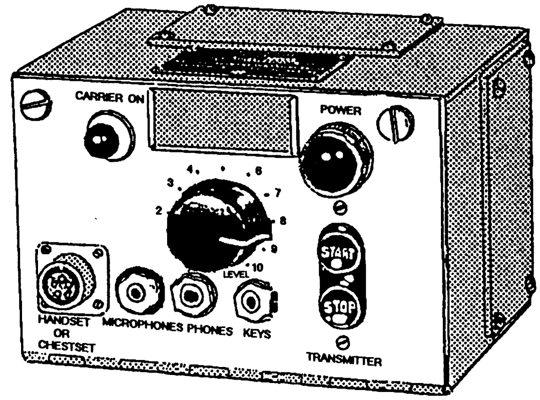

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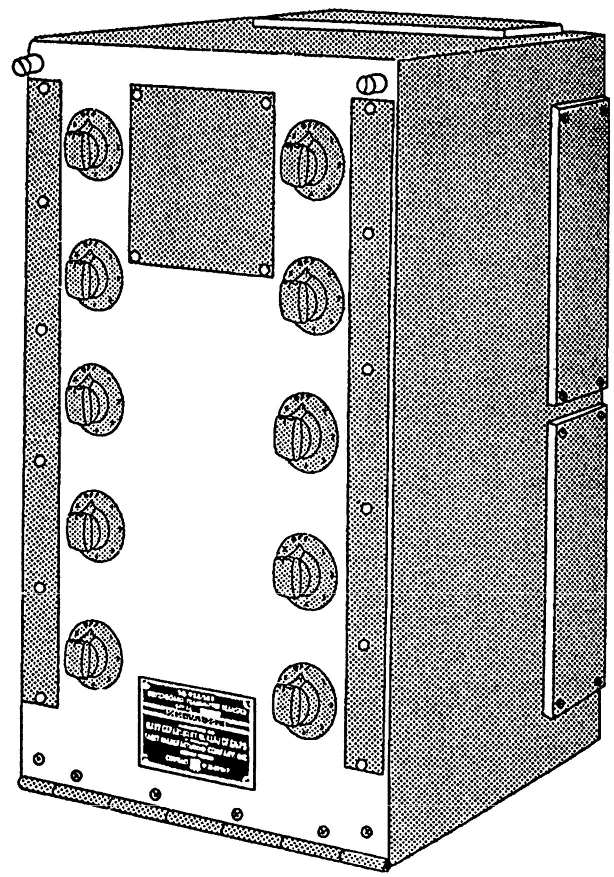
Figure 1-10.—Radio set control



ETV30011

Figure 1-11.—Transmitter Transfer Switchboard (SB-988/SRT).

TRANSMITTER TRANSFER SWITCHBOARD

The transmitter transfer switchboard allows the remote control station functions and signals to be transferred selectively to the transmitters. Figure 1-11 shows a transfer switchboard that allows the functions and controls of anyone, or all, of 10 remote control station functions and signals to be transferred selectively to any one of six transmitters. Each knob corresponds to a remote control station and has 8 operating positions. Positions 1 through 6 correspond to attached transmitters. The seventh position (X) allows for switching of the transmitters to another switchboard. The eighth position (OFF) removes the remote from the system.

RECEIVER TRANSFER SWITCHBOARD

The receiver switchboard allows the audio outputs from the receivers to be transferred to remote control station audio circuits. A representative receiver transfer switchboard is shown in figure 1-12. This switchboard contains 10 seven-position switches. Each switch corresponds to a remote control station and each switch position (1 through 5) represents a receiver. Position X allows the circuits attached to the switch to be transferred to another switchboard.

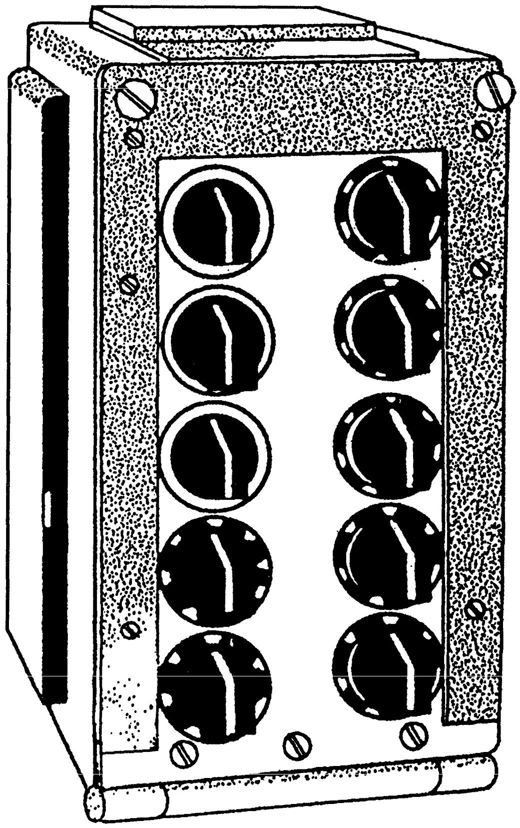


Figure 1-12.—Receiver Transfer Switchboard (SB-973/SRT).

ANTENNAS

An antenna is a conductor or system of conductors that radiates or intercepts energy in the form of electromagnetic waves. An antenna can be simply apiece of wire; but in practice, other considerations make the design of an antenna system complex. The height above ground, conductivity of the earth, antenna shape and dimensions, nearby objects, and operating frequency are just a few of the factors affecting the radiation field pattern.

Information on antenna theory, basic antennas, and wave propagation will be available in *Antennas & Wave Propagation,* volume 7, of this training series. Currently, you can find information in Navy Electricity and Electronics Training Series (NEETS), Module 10, *Introduction to Wave Propagation, Transmission Lines, and Antennas,* NAVEDTRA 172-10-00-83.

SYNCHROS AND SERVOS

In many electromechanical systems, the angular position of a shaft must be transmitted from one location to another without an actual mechanical linkage. You have seen examples of this in mast-mounted rotating directional antennas and the automatic tuning function of receivers and transmitters from remote locations. A widely used method employs ac machines that operate as single-phase transformers. These machines are called *synchros.*

Synchro receivers contain sets of gears that do the actual moving of the device to which the synchro is attached. These receivers are light-duty devices, designed to move small loads or to produce small amounts of torque. When the shaft to be driven at the remote location is connected to an indicating device or some light load, the synchro receiver is capable of developing the necessary torque. But, if the load is a heavy load and more torque is required, torque (power) amplification is required. A control system capable of delivering larger amounts of power or torque is known as a servo mechanism, or *servo.*

You will encounter many systems that use sychros and servos. You can find detailed information about these devices in the *Military Standards Handbook,* MIL-HDBK-225 and NEETS, Module 15, *Synchros, Servos, and Gyros,* NAVEDTRA 172-15-00-85.