SSB—Introducing a Series

On Single Sideband Equipment Operation and Maintenance

This is the first of a series of articles that are intended to give fairly complete and detailed information on single sideband (SSB) communications.

The Navy's first single sideband installation was placed in operation on the Washington to San Francisco point-to-point circuit in 1945. This is a double sideband suppressed carrier system in which one sideband originally carried a two-tone frequency diversity telegraph system in which 6 teletype channels were derived from 24 telegraph carrier channels. Conversion to a 16 teletype channel system in the same spectrum will be made on all major circuits within the next year.

The other single sideband equipment is used for overseas telephone service, order wire, and facsimile. A 50-kilowatt power amplifier for the standard 2-kilowatt transmitter is used on the longer point-to-point circuits. Single sideband in this form has been and will continue to be the basic Navy communications system for point-to-point circuits.

The articles now to be published are taken, substantially verbatim, from a training course written by Collins Radio Company based on its own design objectives. As Collins' articles contain technical material of great value in the operation and maintenance of SSB communications equipment, a training manual with practically the same material is being prepared. Pending the issue of such a manual, commanding officers and other executives will, without doubt, wish to bring this series to the attention of those persons in their commands whose work will benefit from the information.

Service personnel may request extra copies of the Bureau of Ships Journal from the Bureau. Also, copies of the Journal are for sale to the general public by the Government Printing Office—see the inside of the front cover for more details.

Introduction

The need for single-sideband communications systems has arisen because present day radio communications require extended range, faster, more reliable communications, spectrum conservation, and smaller, lighter-weight equipment.

The quantity of commercial and military traffic is so great in the high-frequency (2 to 30 megacycles) spectrum that it has become necessary to restrict the use of this spectrum to those services that cannot be accommodated by other means.

Landlines, microwave links, and UHF scatter propagation are used to relieve the load from the high-frequency spectrum. In many instances, these provide better and more reliable service.

There are, however, many communication services that need the propagation characteristics obtainable only in the high-frequency range. Among these are ship-to-shore communications, air-to-ground communications, and the many military and naval systems that require independence, mobility, and flexibility. Since the high-frequency spectrum space is limited, it is essential that the best possible use be made of the space available.

Therefore, communication systems must operate on a minimum bandwidth, the guard bands between channels must be minimized to allow for frequency drift and poor selectivity, and spurious radiation must be kept to a very low value to avoid interference between the services. In addition, a more reliable signal is desirable if not essential.

Single sideband communication systems in their present state of development provide these assets.

What SSB Means

A single-sideband signal is an audio signal converted to a radiofrequency, with or without inversion.

For instance, an intelligible voice signal contains audio frequencies over the range of 300 to 3000 cycles per second (c.p.s.). If this audio signal is converted to a radiofrequency by mixing it with a 15-megacycle RF frequency, the resultant sum frequencies cover the range of 15,000,300 to 15,003,000 c.p.s.

Such a signal is an SSB signal without inversion and is referred to as an upper sideband, because it occupies the spectrum space above the RF conversion frequency. Note that the 15-megacycle carrier is not included in the range of the SSB signal.

The above example does not indicate the presence of a difference frequency. However, when the voice signal is mixed with the RF frequency, a difference frequency does develop that covers the range from 14,999,700 to 14,997,000 c.p.s. This signal is also an SSB signal but it is an SSB signal with inversion. This SSB signal is referred to as a lower sideband signal because it occupies the spectrum space below the RF conversion frequency.

Figure 1 illustrates the position of the SSB signal in the RF spectrum.

From the above description of the SSB signal, it is apparent that only one sideband signal need be transmitted to convey the intelligence. Since two sideband signals are obtained from the mixing process, one sideband must be removed before transmission. To receive the SSB signal, it is necessary to convert the SSB signal to the original audio signal. The conversion requires identical transmitter and receiver conversion frequencies.

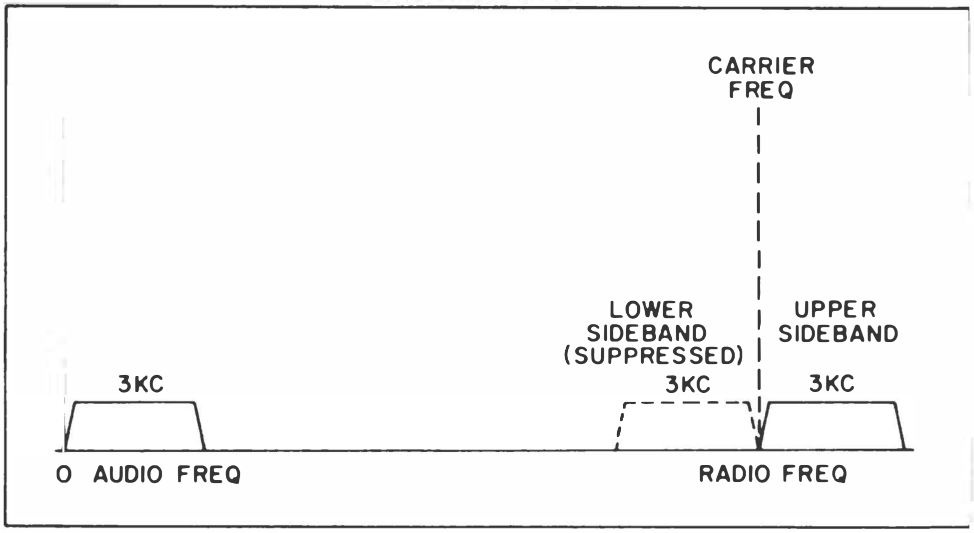


Figure 1. Location of SSB signal in radiofrequency spectrum.

In the past, a low-power, pilot carrier was transmitted for automatic frequency control (afc) purposes to provide the conversion. However, because of present day frequency stabilities (1 c.p.s. at 10 mc. in ground and 10 c.p.s. at 10 mc. in mobile equipment), the need for afc and pilot carriers is eliminated.

Several methods of sideband communication are in use or under development.

- The "single-sideband" method as the term is used in this series of articles refers to the method that is, perhaps, more accurately termed "single-sideband, suppressed carrier." In this method, only one sideband is transmitted and the carrier is suppressed to the point of nonexistence. To demodulate the single-sideband signal requires conversion of the signal with a locally generated signal close to the proper frequency but with no phase relationship.
- In the "single-sideband, pilot carrier" system only one sideband is transmitted, but a low-level carrier of sufficient amplitude for reception is also transmitted. To demodulate this signal, the pilot carrier is separated from the sideband in the receiver, then amplified and used as the conversion frequency to demodulate the sideband signal.
- In another method, the pilot carrier is used for automatic frequency control of the receiver.
- In the "double-sideband" (DSB) system, both the upper and lower sidebands of the signal are transmitted with the carrier suppressed to the point of nonexistence. To demodulate the double sideband requires insertion of a locally generated carrier of both the proper frequency and the proper phase. This system depends on an automatic frequency and phase control, derived from the double-sideband signal, for control of the locally generated carrier.
- In the "single-sideband, controlled carrier" system only one sideband is transmitted, but a carrier that varies inversely with the signal level is also transmitted. In this method there is an appreciable average carrier level for automatic-frequency-control, yet the sideband power is not reduced below the full transmitter rating.

Historical Development

Although SSB transmission has only received publicity in the last few years, the knowledge of the sideband and the development and use of SSB techniques have progressed over the last 40 years.

The acoustical phenomenon of combining two waves to produce sum and difference waves carried over into electric-wave modulation. The presence of the upper and lower sidebands in addition to the carrier frequency was tacitly assumed to exist but was not concretely visualized in the earliest modulated transmissions.

Recognition that one sideband contained all the signal elements necessary to reproduce the original signal came in 1915. It was then that at the Navy Radio Station, Arlington, Va. an antenna was tuned to pass one sideband well, even though the other was attenuated.

From 1915 until 1923, the physical reality of sidebands was vigorously argued with the opponents contending that sidebands were mathematical fiction. However, the first trans-Atlantic radiotelephone demonstration in 1923 provided a concrete answer.

In the trans-Atlantic system, an SSB signal with a pilot carrier was used. Single sideband was used because of the limited power capacity of the equipment and the narrow resonance bands of efficient antennas at the low frequency used (57 kilocycles). By 1927 trans-Atlantic SSB radiotelephony was open for public service. Also, SSB techniques were used in various telephony applications and multiplexing systems.

Only recently have equipment developments made possible the full exploitation of the advantages of SSB communication. These developments have led to the more general acceptance of SSB communication systems.

There are now available several radio amateur and commercial SSB radio sets, fixed-station SSB exciters up to 50-kilowatt linear power amplifiers, and airborne transceivers capable of reliable communications with unlimited range. Some of these equipments, especially the military equipments, are provided with automatic frequency selection and automatic tuning to further enhance their value as reliable, easily operated systems.

Transmitting System Units

Figure 2 shows the basic units of an SSB system in their functional relationship for an SSB transmitter.

The audio amplifier is of conventional design. Audio filtering is not required because the highly selective filtering that takes place in the SSB generator attenuates the unnecessary frequencies below 300 c.p.s. and above 3000 c.p.s.

A voice signal is used only as a convenience for explanation. The input signal may be any desired intelligence signal and may cover all or any part of the frequency ange between 100 and 6000 c.p.s.

The upper limit of the input audio ;ignal is determined by the channel ›andwidth and the upper cutoff fre- ղuency of the filter in the SSB ;enerator. The lower limit of the nput audio signal is determined by he lower cutoff frequency of the ilter in the SSB generator.

The SSB generator produces the ;SB signal at an IF frequency. The nost familiar way to produce the ;SB signal is to generate a double- ;ideband (DSB) signal and then ›ass this signal through a highly ;elective filter to reject one of the ;idebands. The SSB signal is gen- ›rated at a fixed IF frequency be- ause highly selective circuits are equired.

elective Filters

The highly selective filter re- ղuirements for the filter method of ;SB generation are met by either ;rystal or mechanical filters. Both ›f these filters have been improved n performance and reduced in size ınd cost to make their application ›ractical.

The generated SSB signal at a ixed IF frequency then passes hrough mixers and amplifiers where t is converted up in frequency to he transmitted RF frequency. Two- ;tage conversion is shown with the ;econd conversion frequency being ı multiple of the first conversion requency.

The frequency conversions re- ղuired to produce the RF frequency ›roduce sum and difference fre- ղuencies as well as higher order nixing products inherent in mixing :ircuits. However, the undesired lifference frequency or the unde- ;ired sum frequency, along with he higher order mixing products, s attenuated by interstage tuned :ircuits.

:xciter

The SSB exciter drives a linear ›ower amplifier to produce the high ›ower RF signal. A linear power ımplifier is required for SSB trans- nission, because it is essential hat the plate output RF signal be ı replica of the grid input signal.

Any nonlinear operation of the ›ower amplifier will result in in- ermodulation (mixing) between the requencies of the input signal. This mixing will produce not only undesirable distortion within the desired channel but will also produce intermodulation outputs in adjacent channels.

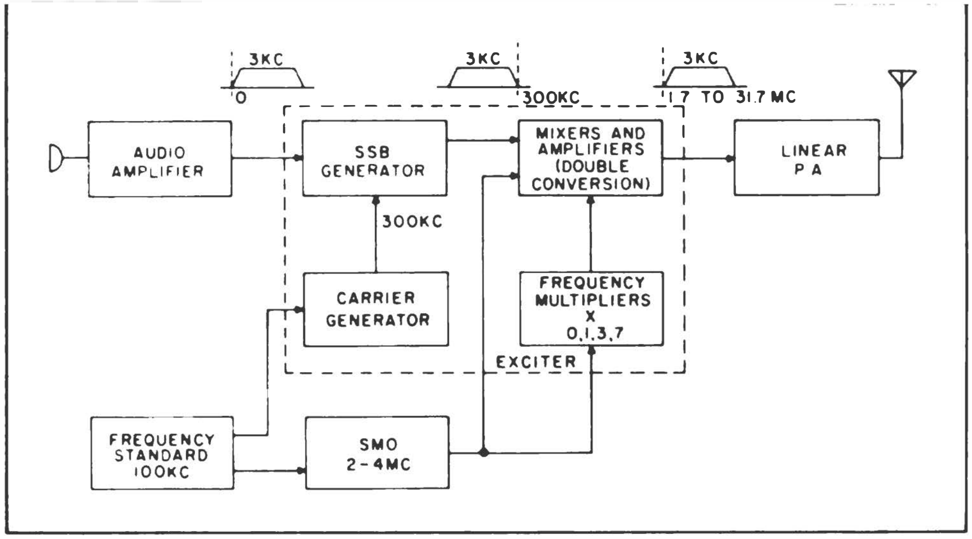


Figure 2. Functional units of an SSB transmitting system. Note: Signal inversion, due to subtractive mixing in first stage of SSB exciter, makes it necessary to use the lower sideband output, from the SSB generator, to produce the final upper sideband signal.

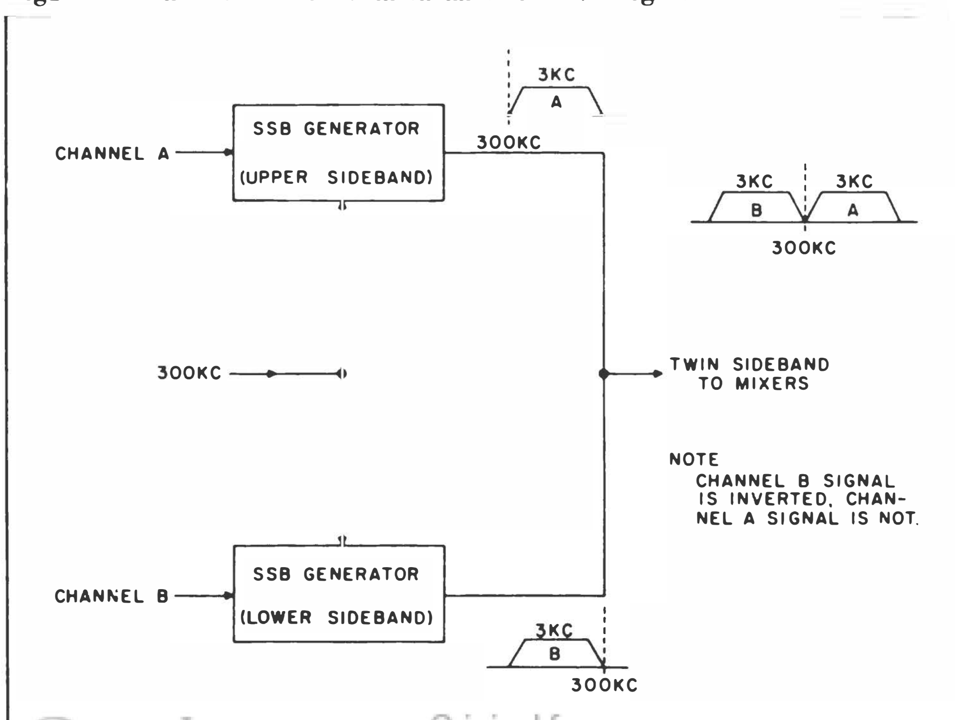
Distortion in the linear power amplifier is kept low by the design choice of power amplifier tubes, their operating conditions, and use of RF feedback circuits.

The low distortion obtainable in modern linear power amplifiers is not necessary to the SSB system nor is it needed for good voice transmission, but it is essential to minimize the guard band between channels and thereby makes possible the full use of the spectrum space.

Stabilized Master Oscillator (SMO)

Because an SSB system without a pilot carrier must have an extremely stable frequency system, the frequency standard and stabilized master oscillator (smo) are extremely important. The standard frequency is obtained from a crystal

Figure 3. Generation of the twin-channel sideband signal.



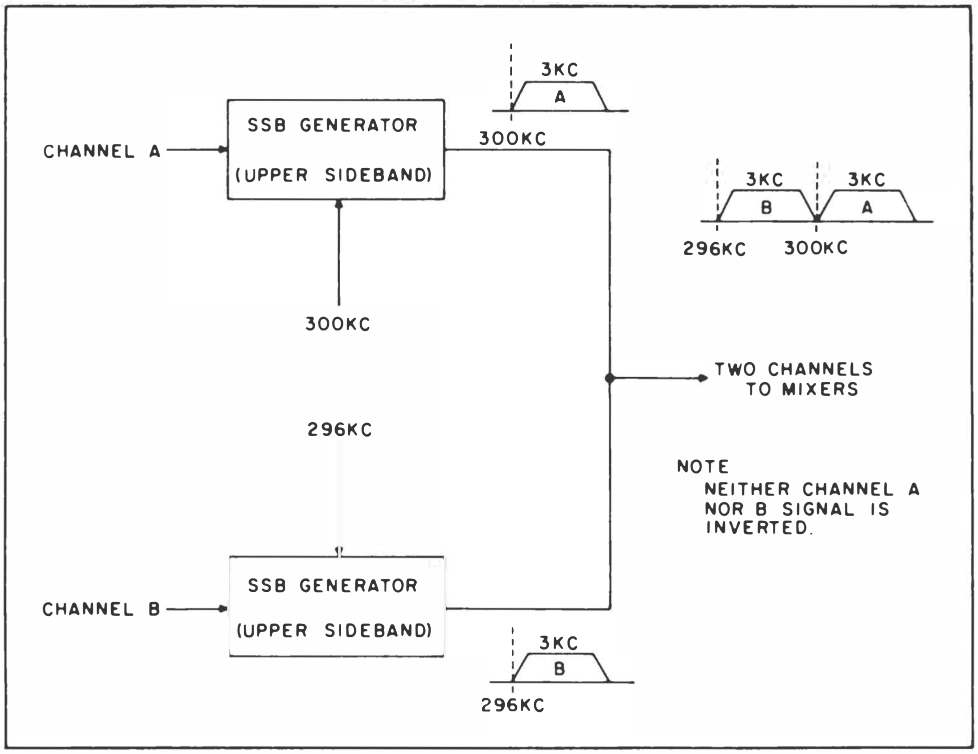


Figure 4. Generation of two-channel SSB signal.

oscillator with the crystal housed in an oven. Since the stability of the crystal frequency depends directly on the stability of the oven temperature, stable thermal control of the oven is necessary.

This control is obtained by using heat-sensitive semiconductors in a bridge network. Any variation in the oven temperature, then, is indicated and corrected by an unbalance in the control bridge. This system will limit changes in oven temperature to 0.001° C.

Such oven stability will provide a standard frequency which will vary no more than 1 c.p.s. in 10 megacycles per day when used in fixed-station equipment and no more than 10 c.p.s. in 10 megacycles per day when used in mobile station equipment.

The carrier generator provides the IF carrier used to produce the fixed IF SSB signal, and the SMO provides the necessary conversion frequencies to produce the RF SSB signal. The frequencies developed in these units are derived from or phase locked to the single standard frequency so that the stability of the standard frequency prevails throughout the SSB system.

Choice of the fixed IF frequency and the conversion frequencies to obtain the RF frequency is an extremely important design consideration.

Optimum operating frequencies of the various circuits must be considered as well as the control of undesirable mixing products. The frequency scheme shown in figure 2 is the result of extensive study and experimental verification. It produces a minimum spurious output in the high-frequency range (2 to 32 megacycles).

The use of harmonically related conversion frequencies in the mixer makes it possible for the frequency range to be covered with a single 2- to 4-megacycle oscillator, a very

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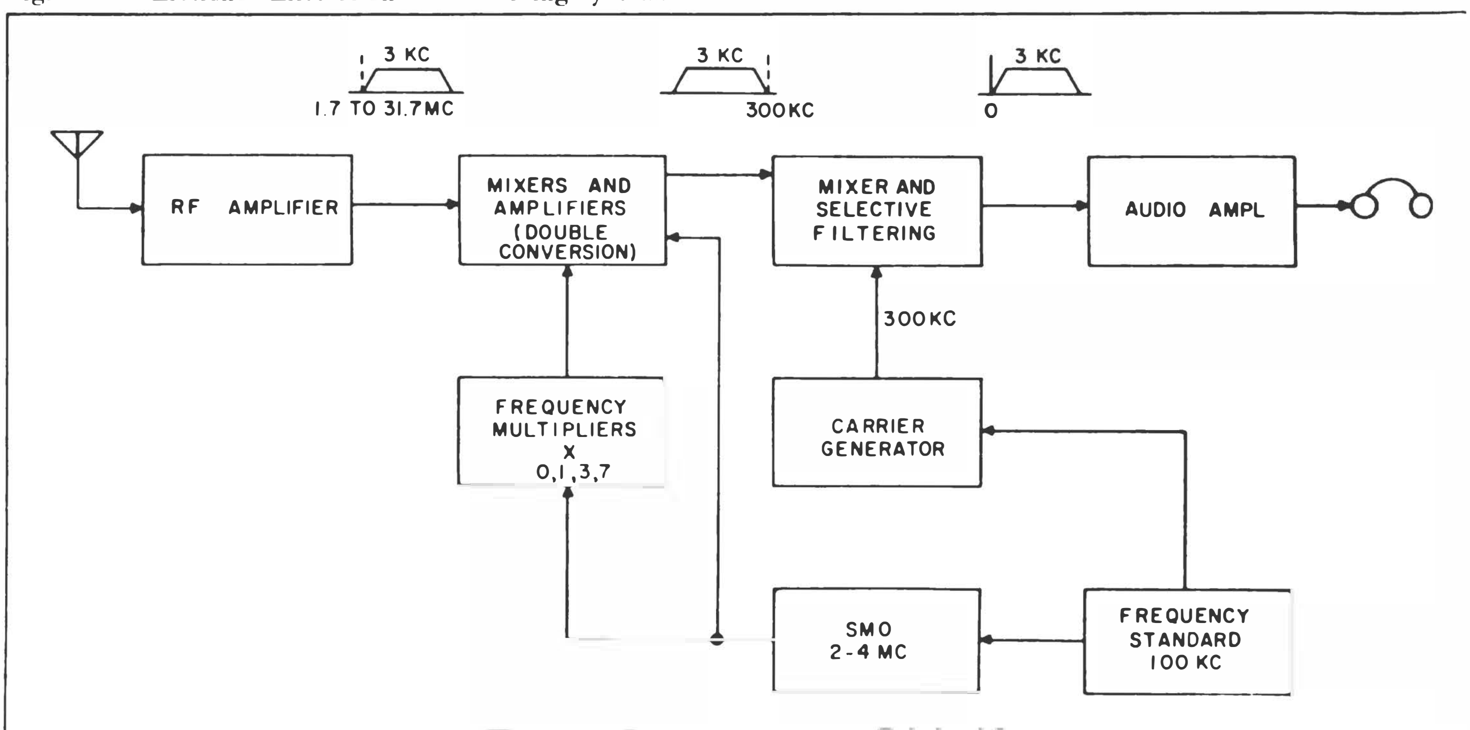
Figure 5. Functional units of an SSB receiving system.



an attempt to parallel vacuum tube and transistor circuits. It is impossible, in a given circuit, to replace a tube with a transistor or a transistor with a tube without first modifying the circuit.

Transistors, when properly treated, have exceptionally long life. The most common transistor failures are caused by applying too much heat to the transistor leads and by subjecting them to improper voltages.

Most transistors are provided with long flexible leads so that they can be soldered directly into a circuit. The solder connections should be made quickly, and it is good practice to grasp the lead with long-nose pliers positioned between the transistor body and the lead end, thus providing a heat sink.

Transistors may be mounted in any position, but are critical with respect to physical location in a circuit. They should not be mounted where the ambient temperature will affect operation, such as near power resistors or tubes.

As the operating temperature of a transistor is increased, its amplification and life are decreased. Increased temperature also tends to increase the noise level of the transistor. In some cases in which transistors are operated near their maximum ratings a permanent heat sink is necessary.

Often, if a transistor is subjected to the wrong voltage polarity, it is permanently damaged. Inserting a transistor incorrectly into a socket is the same as applying the wrong bias polarity. Technicians should learn to identify transistor terminals. Figure 6 which shows the basing arrangement of four common designs is intended to help with this problem.

Transistors are frequently damaged by transient surges. When any component in transistor equipment is removed or installed, the power should be turned off. The same rule applies when batteries in transistorized portable devices are being replaced.

When the difficulty has been localized in a piece of transistorized equipment, it is wise to check first the components of the associated circuit before plugging in a new transistor. Blindly substituting transistors can be costly.

If the trouble is thought to be caused by a transistor, a good idea is to replace it with one of the same type. The only sure way of checking a transistor is to substitute another one of the same type in the circuit. Transistor testers are not always reliable.

After inserting a new transistor the associated circuit may have to be "peaked" for optimum operation.

(The foregoing article was adapted from one in the April issue of Sylvania News.)

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practical range for obtaining high oscillator stability. Use of the 300-kilocycle fixed IF frequency is the optimum operating frequency for the mechanical filter required in the SSB generator.

Adding Channels

The foregoing discussion may give the impression that only single channel communication is possible with an SSB system. Quite the opposite is true.

To add additional channels to the SSB system requires only additional circuits in the SSB generator. One method is to use the upper sideband of one signal and the lower sideband of the other signal. Figure 3 shows the circuit for producing these two channels and the location of each channel with respect to the carrier frequency.

It should be noted that with this method a twin sideband is transmitted, and that the signal in the lower sideband is inverted.

Another method of adding channels is shown in figure 4. Different fixed IF frequencies, one raised 4 kilocycles from the original, are injected into separate SSB generators, and the upper sideband is filtered from each output. This method produces two channels both in the upper sideband.

As additional channels are added to the system, less transmitter power output is available for each channel.

The SSB transmitter is designed for linear operation from the audio input amplifier through the output power amplifier. That is, the transmitter faithfully transmits the original input intelligence with negligible distortion.

This distortion-free system is ideally suited for the transmission of time division multiplex and "Kineplex" signals, because the original pulses are transmitted without distortion of their wave shape.

Receiving System Units

To receive the SSB signal requires a heterodyning system that will convert the RF signal down to its original position in the audio spectrum.

The basic functional units of such a receiver are shown in figure 5. It can be seen that the SSB receiver is almost identical with a conventional heterodyne receiver except for the detection circuit. The RF signal is amplified and converted down in frequency to a fixed IF frequency. Then a final fixed IF injection frequency is required to bring the signal down to its original position in the audio spectrum.

Many of the units of an SSB receiver are identical with units of the SSB transmitter, as can be seen by comparing figures 2 and 5.

The frequency standard, carrier generator, and smo are identical. The double conversion mixer and amplifier unit of the receiver can be made identical to the double conversion mixer and amplifier unit of the transmitter. Because of this similarity, transceivers can be constructed with much of the circuitry used for both receiving and transmitting by merely adding switching to reverse the direction of signal flow.

Equipment size, weight, cost, and power consumption are substantially reduced by the use of dual purpose units and the addition of switching to reverse the direction of the signal.

The second article in the SSB series will compare the SSB system with the AM and FM systems.