costs on machines and equipment.

Some products that have been sources of radiofrequency interference in the past have been redesigned and rebuilt to eliminate the trouble. Among these products are some makes of freezers, fluorescent lamps, induction heaters, diathermy machines, electric typewriters, electric office machines, portable electric tools, and tape recorders.

Manufacturers and operators of induction heaters and diathermy machines faced a difficult problem. Their equipments use radiofrequency energy to operate. Those built to early designs generated the required amount of energy but little or no concern was given to where it fell in the wavebands.

Since it was difficult and expensive to make these types of equipments RFI-free, they continued to interfere with all the services that used the wavebands in which the interference fell.

Eventually industry and Government together solved the problem by restricting generation of the required radiofrequency energy to particular wavebands. The bands, on which unlimited radiation is permitted, are set aside for the exclusive use of industrial, scientific, and medical equipment.

When new uses of radiofrequency energy are planned, consideration should first be given to restricting the energy to the specified wavebands so that filtering and shielding will not be necessary.

Principles of Single Sideband (SSB)

Single sideband (SSB) is not a new term in the history of communications. Single sideband has been known since 1915, when it was conceived by a mathematician named Carson, and it was observed in related work by an engineer named Arnold. Since then, in the course by the development of radio, single sideband, which is a mode of emission, has been periodically "discovered" anew.

Today's developments in radio have given a new impetus to the advantages of applying SSB to Fleet communications.

The following is a brief indoctrination on the technique of single sideband suppressed-carrier.

Carrier. In conventional voice communications, the carrier provides a path for transporting the desired voice intelligence to the receiver and for reconverting it into usable, audible intelligence. The carrier is an oscillating wave of energy that has a frequency corresponding to the transmitting frequency used by the ship or station.

Modulation. The technique by which voice intelligence is superimposed on the carrier is called modulation. Without modulation, the carrier or continuous wave (CW) signal occupies no bandwidth in frequency spectrum. It can be visualized as an infinitely thin line drawn at a specific frequency when a plot of frequency along a horizontal axis is one dimension and height of the carrier is merely a measure of its amplitude or signal strength (figure 1).

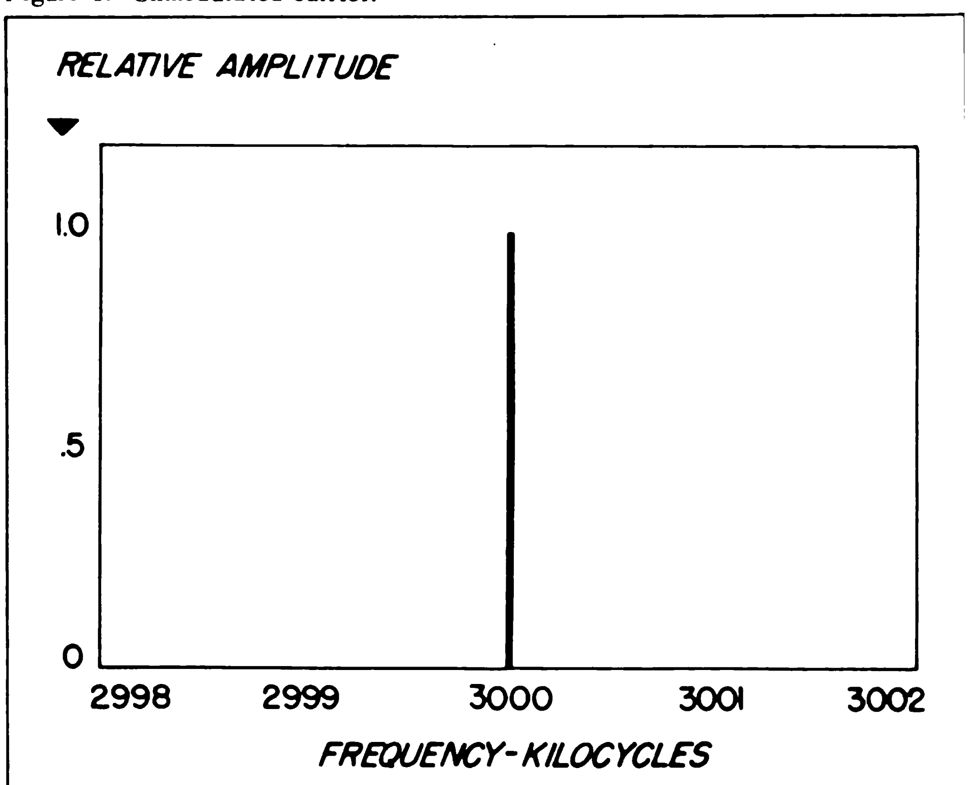
When single tone or voice modulation is placed on the carrier, turmoil begins. The carrier will be present at its original frequency. However, other radiofrequency signals also are present at the output of the transmitter when viewed on an oscilloscope.

The span of the radiofrequencies that appear by the side of the carrier depends on the audio modulation frequency fed into the transmitter by either a controlled audio source or voice.

If the audiofrequency fed into the transmitter is 1000 cycles a second, the two additional signals present at the transmitter output would be exactly 1000 cycles on each side of the carrier frequency (figure 2). If the audio tone fed into the transmitter is 300 or 3000 cycles, the two additional signals would move closer to, or farther away from, the carrier, respectively.

Thus, for each single audiofrequency fed into the microphone of an amplitude-modulated transmitter, two sideband signals are present at the output of the transmitter.

Figure 1. Unmodulated carrier.



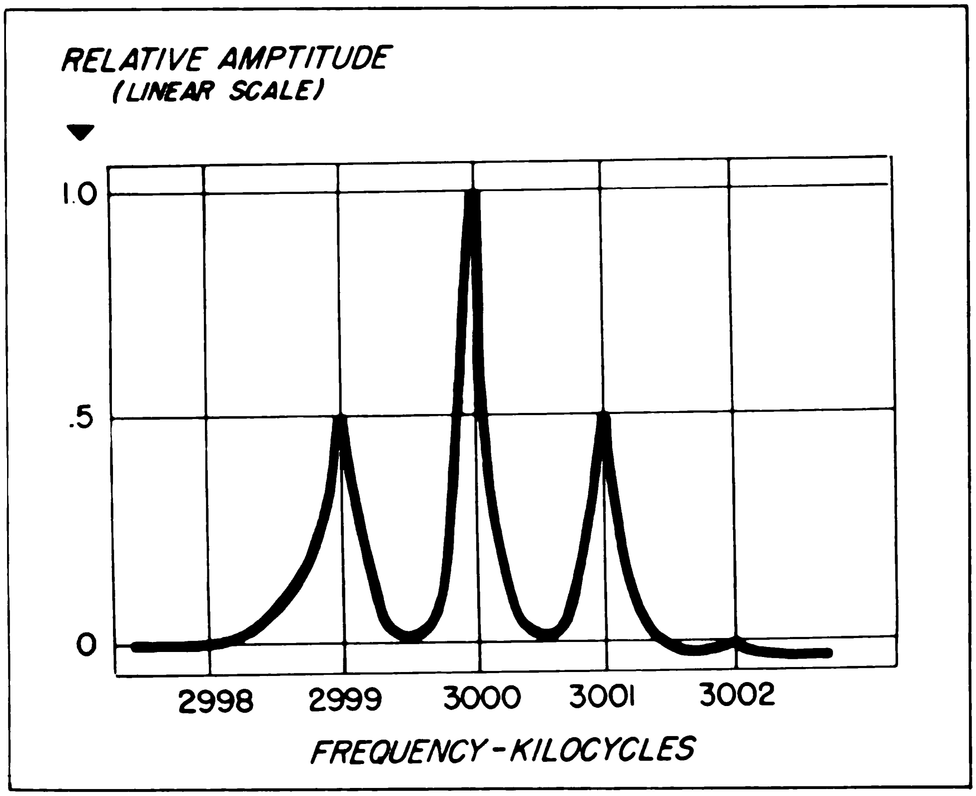


Figure 2. An upper and lower carrier of 1000 kilocycles appears on either side of the DSB carrier at 3000 kilocycles.

Since each sideband is carrying the same intelligence, naturally, this appears to be an uneconomical means of transmission.

Sidebands. Modulation of the carrier produces a complex signal consisting of three individual waves: The original carrier, plus the two identical sidebands that carry the same intelligence described. This type of modulation is known as "amplitude modulation" (AM), or, as is usually indicated in frequency plans, "A3" or "voice."

Because of the wide interest now developing in SSB, amplitude modulation is sometimes referred to as double sideband (DSB), to distinguish it from single sideband.

Bandwidth. The amount of radio spectrum required to transmit the desired intelligence is called "bandwidth." For conventional DSB voice transmission, a bandwidth of 6 to 7 kilocycles, plus separation on either side to prevent interference between adjacent channels, is normally required.

Detection. When the DSB signal appears at the second detector of the communication receivers, the carrier frequency is heterodyned with the two sidebands. The two separate but identical audio signals are recovered and combined into the audio system of the receiver. In principle, these two sidebands add in phase to produce usable audio intelligence at the speaker or headphones.

Suppressed-Carrier. The carrier may be eliminated by using a balanced modulator in one of the early radiofrequency stages of the transmitter so that the sidebands are produced but no pilot carrier will be present. This aspect is sometimes the most difficult or troublesome in understanding single sideband suppressed-carrier.

There is no carrier output under modulation conditions in a properly designed suppressed-carrier system. That is, when speech is fed into the transmitter, the carrier itself does not appear. What is heard or seen on a scope is radiofrequency energy appearing at the transmitter output as sideband energy or "talk power."

Single Sideband. If one of the two sidebands is "filtered" or "phased out" before it reaches the transmitter power amplifier, the same intelligence can be transmitted on the remaining single sideband. All the power then is transmitted on one sideband, rather than being divided between the carrier and both sidebands as in DSB.

This higher transmission efficiency amounts to a power gain of 4 to 6 decibels for the wanted single sideband. Equally important, the bandwidth required for SSB voice circuit is approximately half that needed for DSB (figure 3).

Receiving SSB. SSB demands a receiver with rigid frequency stability because the reception of SSB signals is not as simple as that of DSB or AM signals. The receiving station has the problem of furnishing an artificial carrier, since the SSB signal no longer has a carrier against which the sideband signals can be heterodyned in the receiver to de-modulate the sideband and produce useful audio signals.

Normally, the artificial carrier is furnished by the beat-frequency oscillator in the receiver. This is not to be confused with many commercial single sideband transmitters that transmit a residual (not totally suppressed) carrier signal, so that either the proper carrier reinsertion frequency may be detected or automatic frequency control equipment may be used. Such is the type in the Navy's fixed shore installations.

It is necessary that the SSB transmitter have the same high order of stability as the receiver. The transmitter and receiver must not drift apart more than 50 cycles for quality voice reception. Therefore, frequency stability of the receiving and transmitting equipment for SSB suppressed-carrier must be very rigid, and an artificial "local" carrier is necessary.

SSB Advantages. It has been pointed out that in DSB there are two sidebands which are heterodyned with the carrier in the receiver to produce a single audio signal that carries voice intelligence heard in a speaker or headset. If these sidebands are not received in proper phase (usually because of multipath skywave propagation conditions), the signal heard is fuzzy, distorted, and possibly quite loud.

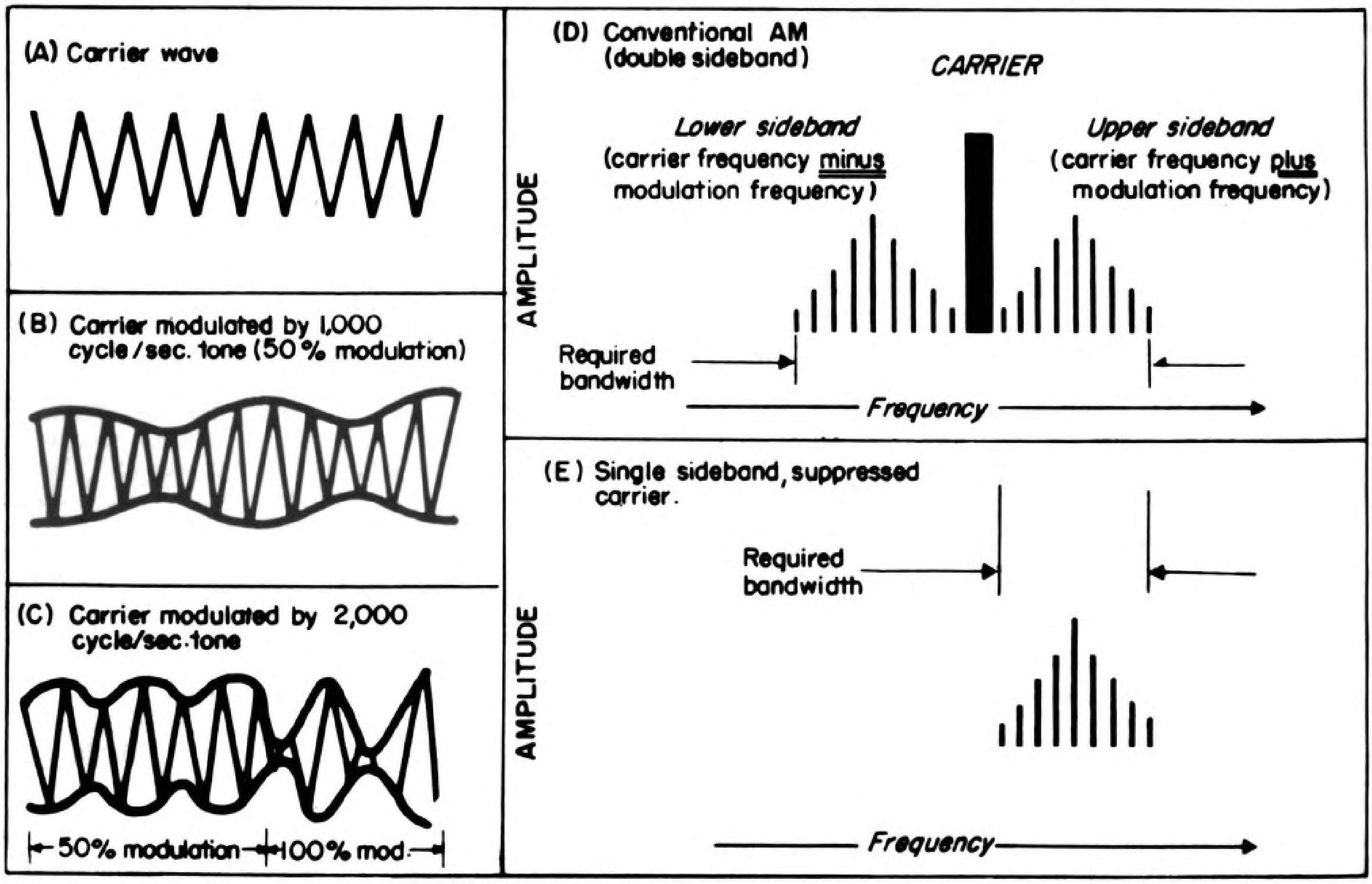


Figure 3. Comparison of DSB and SSB bandwidths.

Undoubtedly, the cause of the report "loud but distorted" is that one sideband has received a slight phase shift because of the multipath transmission. As a result, the other sideband is nearly cancelled, and there is distortion and loss of intelligibility.

Fading or slight phase shift of the carrier can produce similar results. However, with the suppressed-carrier type of SSB, these problems reportedly do not exist.

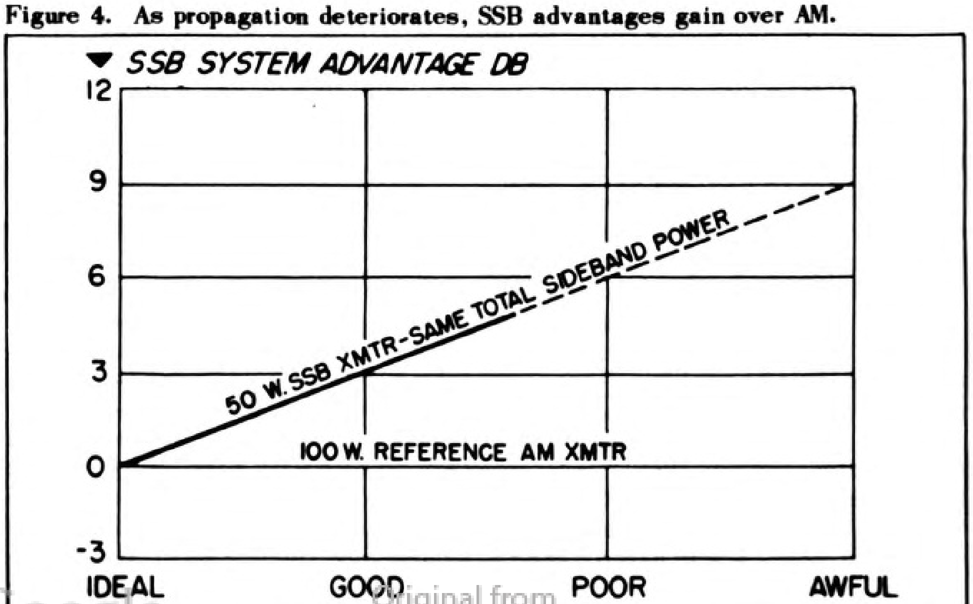
Other advantages of suppressed-carrier SSB include--

1. *Increase in Effective Power.* In a conventional DSB system, approximately two-thirds of the power of the transmitting goes into the carrier, and the remaining third is divided equally between the two sidebands. However, with the suppressed-carrier SSB system, all power goes into the single sideband which carries the useful voice intelligence.

Although there is still disagreement as to the amount of power gain in the SSB system, it has generally been accepted that, under normal operating conditions with moderate signal-to-noise ratio, the gain is between 6 and 9 decibels of improvement over an equivalent DSB transmitter. The SSB transmitter provides 6 decibels of gain, and 3 decibels of gain is derived from the narrow band single sideband receiver used at the receiver location.

The relative advantages of SSB and DSB depend on propagation conditions. As conditions deteriorate, the SSB advantage in voice communication grows (figure 4).

Figure 4. As propagation deteriorates, SSB advantages gain over AM.



2. *Provision of Double Number of Channels.* In the simplest system of SSB suppressed-carrier, the number of channels on the same frequency in the radio spectrum is doubled. The two channels are referred to as "upper" and "lower" sideband. Because there are so few frequencies free for new assignments in the spectrum, particularly in the 2 to 30 megacycle range, doubling the number of channels that can be used for transmission is an important advantage in Fleet communications.

3. *Reduction in Interference.* In normal voice DSB communication systems, the carrier of the transmitting station remains on the air until the transmitter is turned off. If an additional station transmits while the carrier of the other station is on, squeals and howls result. These are caused by the heterodyne of two or more signals transmitting at the same time.

In SSB, with voice break-in, as soon as the individual stops speaking into the microphone, "talk power" in the sideband leaves the air, and the receiver is automatically re-energized. A ship may enter the network as soon as the "talk power" leaves the air.

Even though two stations may transmit at the same time, a receiving station can read through the interfering station the same way we are able to listen to more than one conversation at the same time around a conference table.

4. *Netting SSB.* The highly stable transmitters and receivers being developed make it possible to have the extremely accurate frequency reference needed. Suppressed-carrier SSB demands a stable frequency of roughly 100 times the accuracy required for conventional DSB and more than that existing in the Fleet today.

The Bureau of Ships expects to provide transmitters and receivers that will have an accuracy of one part in 100,000,000 or better, for a 24-hour period.

Compatibility. The problem of compatibility arises because a "pure" single sideband transmitter cannot satisfactorily work with the DSB equipment now in use. Fortunately, SSB equipment can be designed so that the carrier can be eliminated or inserted by the use of suitable switching. The low-level modulation is then amplified and transmitted as a conventional DSB signal.

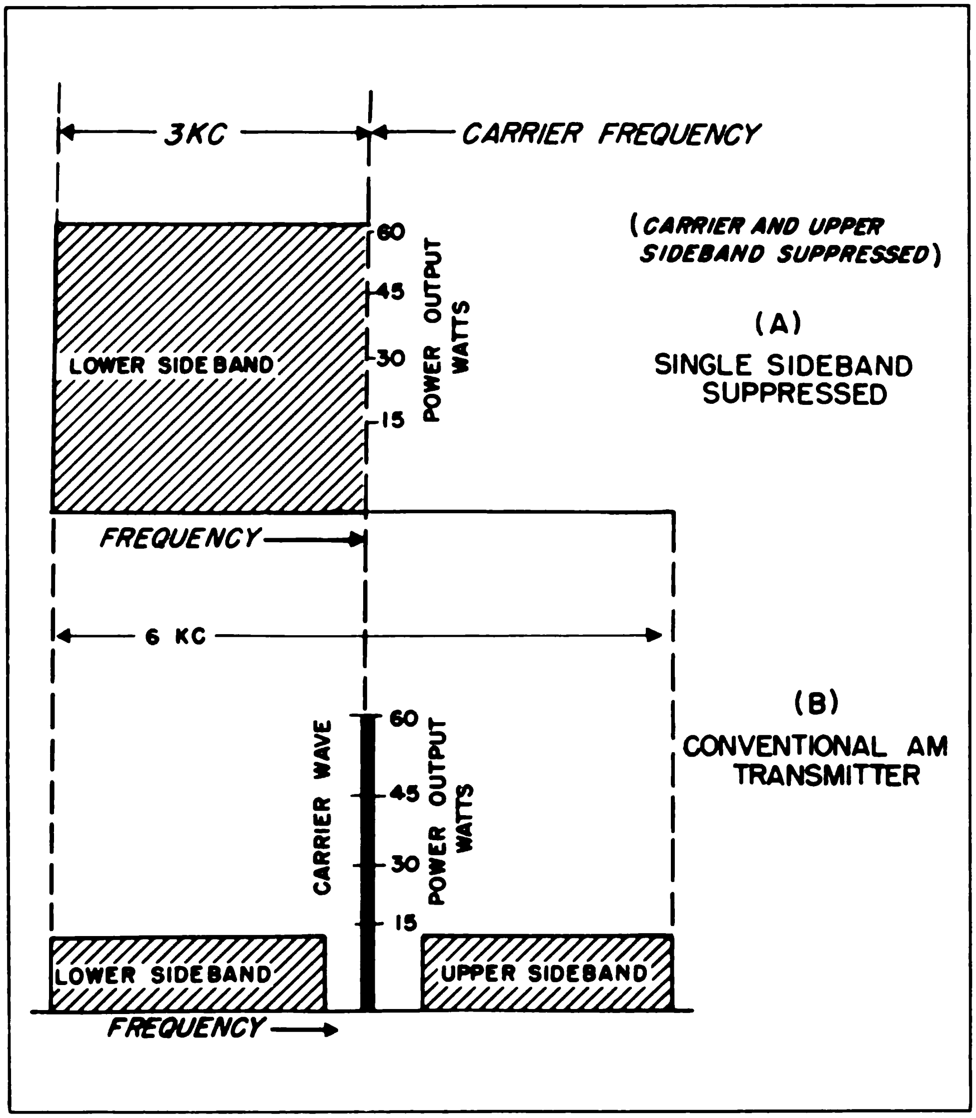


Figure 5. Comparative frequency--power spectra.

It would not be economical to carry both DSB and SSB, especially in aircraft. For this reason, SSB equipment, whether demonstration, interim, or final, will have the flexibility to work either SSB or DSB.

Application to Fleet. A great simplification of transmitter design for single sideband application has resulted with recently developed techniques. Such equipments now practical are--

- Extremely accurate and relatively small crystal-controlled oscillators for frequency reference.
- Filters for eliminating the unwanted sideband.
- Highly stable, easily driven linear amplifiers with new types of power tetrodes.

The power tetrode, with its simple gain, greatly reduces the number of stages of amplification required and minimizes circuit complexity, which can be further translated into reduction in size and weight of equipment, greater reliability, and higher power with correspondingly lower over-all cost.

Much more will be heard about single sideband now that installations can be of economical size and can be completely different from the large shore station fixed-service SSB installations that are now in service in the naval communication system.--*Excerpts from Naval Communications Bulletin, July 1956.*

