What Is Single-Sideband Telephony?

A Few Facts About the New 'Phone Technique

BY BYRON GOODMAN,* W1DX

• The year 1947 will go down in amateur radio history as one of the big ones, since it was in October of that year that the first amateur 14-Mc. single-sideband suppressed-carrier transmissions were made. But most hams would rather make history than read about it, so this article is intended to give you a nodding acquaintance with the principles involved in s.s.s.c. transmission and reception.

The history-making single-sideband suppressed-carrier transmissions of W6YX and WØTQK have aroused considerable interest in the transmission and reception of these signals, and well they might, since it is not at all unlikely that most of us will be using the system within a few years. The name describes the thing of course, but it doesn't tell all. Neither does this article, but it should give you a start toward understanding the stuff.

Everyone knows that a regular a.m. 'phone signal takes up space frequency-wise that can be represented by the sketch in Fig. 1. The carrier frequency, designated by *f*, is a single frequency. The "sidebands" take up room on either side of this frequency, depending upon the audio frequencies present in the modulation. The cross-hatched areas in Fig. 1 represent the frequencies occupied by the sidebands.

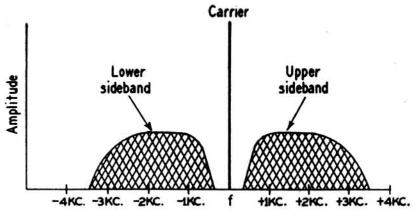

Fig. 1 **— The normal a.m. signal consists of a carrier and a pair of sidebands. The crosshatched areas represent the frequency range of the sidebands.**

At the receiver, the usual practice is to center the carrier in the passband of the receiver, and to use a receiver with a response curve capable of passing both sidebands. This is shown in Fig. 2, where the sketch of Fig. 1 has been superimposed on a typical selectivity curve of a receiver. However, it is not at all necessary to receive *both* sidebands, and this fact has been used by McLaughlin [1] to reduce heterodyne interference. A response curve of a receiver capable of receiving only one sideband is shown in Fig. 2 as a dotted line. Under such conditions, nothing is omitted from the original signal, since one sideband is all that is required. As W1DBM aptly puts it, "both sidebands are saying the same thing." [2]

However, while one sideband can be eliminated without impairing the quality one iota, the *carrier* cannot be eliminated, or even reduced appreciably, if the modulation percentage is high. If, for example, the single-sideband receiver curve of Fig. 2 (the dotted line) were such that it cut into the carrier, the carrier would be reduced in the receiver. This in turn would give a signal that, so far as the detector was concerned, would look like an *overmodulated* signal, since the proper carrier-to-sideband proportions would not have been preserved. On the other hand, the sideband (or sidebands) can be reduced, leaving the carrier the same, with no ill effects other than to reduce the effective modulation percentage that the detector sees. This is the principle of "exalted-carrier" reception.[3]

The point that the carrier must be present in the receiver along with the sideband (or sidebands) before proper detection can take place is an important one to remember in this discussion.

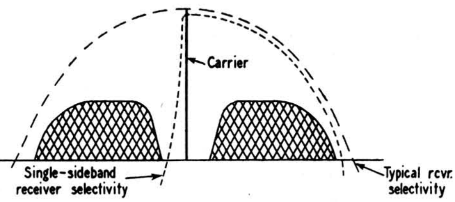

Fig. 2 **— In normal reception, the a.m. signal is centered on the selectivity characteristic of the receiver. However, if the receiver has considerable selectivity, as shown by the dotted line, equally good reception is obtained by passing only one sideband through the receiver.**

Carrier Suppression

There is really no need to transmit the carrier of a 'phone signal, provided the carrier is put back

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[1] McLaughlin, "Exit Heterodyne QRM," *QST*, Oct., 1947.

[2] Rand, "The Q5-er," *QST*, December, 1947.

[3] Crosby, "Exalted-Carrier Amplitude- and Phase-Modulation Reception," *Proc. I.R.E.*, Sept., 1945.

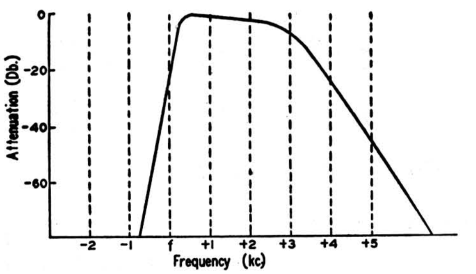

Fig. 3 — **The filter required for sideband elimination requires very rapid attenuation in a range of about 1000 cycles. The characteristic shown above would be suitable for such work — the normal carrier frequency would be placed at *f*.**

on the signal before audio detection takes place. Methods have been known for years for "suppressing" the carrier, and their effectiveness has been proven by a good record of commercial use. The two common types of modulators that suppress the carrier during modulation are the "balanced" modulator (using tubes) and the "ring" modulator (using diode rectifiers in a bridge or lattice arrangement). Both of these take the modulation frequencies and the carrier frequency and give an output that consists only of the sidebands (along with a few combinations of carrier *harmonics* that have to be filtered out). Of course the carrier suppression isn't perfect, but suppressions on the order of 40 to 60 db. are not difficult to obtain, and careful balancing has brought the figure up to 100 db.

But neither Johnny Q. Ham nor anyone else is going to get very far with a system that only suppresses the carrier. While it is easy to transmit, it is practically impossible to receive. The mathematics of the thing shows that the carrier has to be reinserted with the same *phase* relation to the sidebands that the original carrier had. This means, therefore, that it would have to have exactly the same *frequency and phase* relationship as the original carrier, and no frequency drift could be tolerated, since any at all would cause a phase change. So that's out the window.

However, the same mathematics shows that if *one* sideband is received, the carrier can be reinserted in *any* phase, and in practice the frequency can be off by 10 or 20 cycles without impairing the quality too much. That's more like it. While 10 or 20 cycles seems like incredible stability for a receiver, it isn't outside the realm of possibility at all and, in fact, receiver stability has been sneaking up on us over the years without our realizing it. But more of that later.

Sideband Suppression

There are two classical methods of eliminating one sideband. One is a brute-force method that consists simply of lopping off one sideband by using a very selective filter. This is the method used by the commercials. Another more delicate and subtle system requires an elaborate arrangement incorporating 90-degree phase shifts of carrier and audio signals. It has been used,[4] but it isn't easy.

You can't just dismiss that filter with a sentence or two. In the first place, it has to have a characteristic similar to that shown in Fig. 3, and filters like that aren't easy to come by. The frequency *f* represents the carrier frequency at which the filter is used, and the important thing about the filter is the slope of the curve between "+0.5 kc." and "–0.5 kc." Notice that within this 1-kc. range the attenuation goes from 0 to about 50 db. The slope on the other side of the filter is unimportant, just so long as it permits the sideband to pass without excess attenuation. Filters with a characteristic like that of Fig. 3 are not easy to obtain, and the filter is usually designed for a low frequency, since the selectivity in cycles decreases as the frequency *f* is increased. The filter characteristic shown in the McLaughlin article[1] would be satisfactory, and this was obtained at 50 kc. Fifty or 75 kc. probably represents the upper frequency limit for effective sideband filters, unless one resorts to crystal lattice-type filters, infinite-rejection circuits and other complex dodges.

Frequency Changing

Our s.s.s.c. transmitter now begins to take shape. It will start off with a modulator that suppresses the carrier, and then we'll go through a filter that will lop off one sideband, after which we'll have to get the signal to the operating frequency and out on the air. Fig. 4 shows the signal as far as we've gone.

As mentioned earlier, this filtering of the sideband would be done at some low frequency, and we have the problem of getting to the operating frequency. We can't do it by frequency multiplication, any more than we can in conventional a.m. *after* modulation. So the next big point we run across is that you *heterodyne* the signal when you change frequency in s.s.s.c. work. This is old

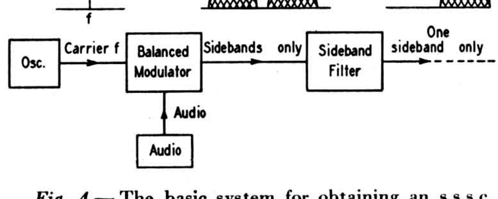

Fig. 4 — **The basic system for obtaining an s.s.s.c. signal. The carrier and audio frequencies are fed into a balanced modulator, where the sidebands are generated minus the carrier. The signal is then passed through a filter that removes one sideband.**

[4] Honnell, "Single-Sideband Generator," *Electronics*, Nov., 1945.

stuff, of course — we do it all the time in receivers and converters. So, if our output from the sideband filter is on 50 kc. and we are headed for 14,250 kc., we would feed the single sideband into a mixer with an oscillator running at, say, 600 kc. This would give beats of 550 and 650 kc. To use only one, we would run the output of the mixer through a 550-kc. filter (a stage of i.f. amplification). Then to get to 14,250, we would beat this signal against a 13,700-kc. oscillator and run the output through enough selective stages to wipe out the undesired 13,150-kc. signal. All this is shown in Fig. 5. To make the job of the filters a little easier, balanced modulators can be used for the mixers, so that the local-oscillator signal is eliminated in the output. In Fig. 5, the local-oscillator signal is shown in the output of each mixer, as would be the case in conventional mixer circuits.

It is also apparent from Fig. 5 that it is only necessary to change the frequency of the last local oscillator in order to change the output frequency. Thus a basic s.s.s.c. exciter and modulator would consist of the stages shown in Figs. 4 and 5. The frequencies wouldn't be the same, necessarily, but the principles involved would be. The entire unit would use receiving tubes and, for the most part, receiver components.

Amplification

It has been pointed out that frequency changing involves the use of heterodyning instead of multiplication in s.s.s.c. technique. We also have to forget about our cherished Class C amplifiers, because the s.s.s.c. must be amplified in a Class A or Class B stage; i.e., an amplifier that reproduces the input signal without distortion. But our receiver techniques are generally Class A, and Class B amplifiers are no strangers to the 'phone man who has been using one for a modulator for the past 14 years. We don't even have to worry about too-careful adjustment of these Class B amplifiers. They are more tolerant with no carrier, unlike the critical "linear" amplifiers everyone shies away from. And, unlike audio Class B amplifiers, they don't have to be push-pull.

So there you have the fundamentals at the transmitter end: carrier suppression in a balanced modulator, sideband rejection in a sharp filter, frequency changing by heterodyning, and amplification in Class A or Class B amplifiers.

Reception

The receiver end is a lead-pipe cinch. All you have to do is tune in the signal and put back the carrier in the right place! Fortunately, any communications receiver is set up to do this, although the technique seems a little strange at first. The first thing you do is turn off the a.v.c., although you can leave it on while you tune in the sideband if you want. You tune in the sideband, as indicated by maximum strength in the 'speaker (or maximum *swing* of the S-meter, if the a.v.c. is on). With a.v.c. off, switch on the b.f.o. and adjust its control, *not* the main tuning control, until the signal clears up and begins to sound like something human. As you vary the b.f.o., you will get various types of inverted speech and deep and falsetto voices, but when you hit it right the speech will sound as natural as any other signal. It may be necessary to back off the manual gain quite a bit, particularly if you have a weak b.f.o. in the receiver. In any event, it's a good idea to run with reduced i.f. gain, because you have no a.v.c. to hold the gain down in the receiver, and you can't afford to have any stage in the receiver overloaded, since the linearity will be destroyed.

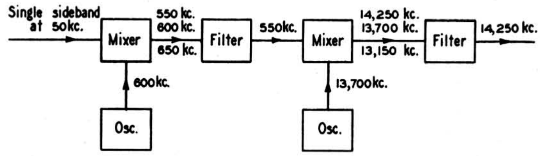

Fig. 5 **— Frequency changing in an s.s.s.c. system is done by heterodyning the sideband to a new frequency and filtering out the undesired beat products. The diagram above shows how a single sideband might be taken from 50 kc. to an operating frequency of 14,250 kc.**

The Advantages of S.S.S.C.

What does all this get you? Some of the benefits won't show up until a number of stations are using the system, but here are a few of the obvious advantages: Transmitting only one sideband, the receiver bandwidth has to be only half as great, for the same fidelity, as it does for double-sideband reception. This gives an immediate 3-db. improvement in signal-to-noise, since reducing the bandwidth by a factor of 2 decreases the noise by the same amount. The power required at the transmitter end for equivalent double- and single-sideband signals at the receiver is considerably less in the case of s.s.s.c. transmission. There is no carrier power to be supplied, and all of the power goes into the one signal-generating sideband. For example, a kilowatt 'phone using double sidebands and the usual carrier requires that a kilowatt of power be supplied to the r.f. amplifier plus the power consumed by the 500-watt modulator. The same signal is obtained at the receiver in the s.s.s.c. system by furnishing power to the final amplifier equal to what would be drawn by a Class B modulator capable of delivering 250 watts of audio. The saving in transmitter input is plenty! When you aren't talking you have no output signal, so there is no good reason why you can't carry on excellent duplex work right on your own frequency! With

(*Continued on page 126*)

Single-Sideband 'Phone

(*Continued from page 15*)

no heterodynes between carriers, there is no heterodyne interference, the big bugaboo of 'phone as practised today. This fact, coupled with the obvious one that your signal occupies only half the spectrum space it does with conventional a.m., will make room for many more 'phone signals in the same number of kilocycles. With selective receivers that pass only one sideband, the number of clear channels is exactly doubled, but there is still another advantage. Suppose the interfering station is only 500 cycles removed; i.e., the two carriers, if they were transmitted, would be separated by that amount. And suppose that the same relative sideband (upper and lower) had been suppressed in each case. The unwanted signal would ride through the receiver along with the desired one, but it would be completely unintelligible. It would only manifest itself as monkey chatter in the background, there would be no interfering heterodyne, and one signal could probably be copied through the other. You know what two equal-strength signals 500 cycles apart can do with conventional a.m. — now you can see why we're so enthusiastic about the possibilities of s.s.s.c.

With only a single sideband transmitted, you can expect less trouble with selective fading, the kind caused by the sidebands coming in with the wrong relative phase to each other and the carrier.

We promised to mention receiver stability. You will recall that the carrier has to be reinserted with an error of less than about 20 cycles for full naturalness, but the requirement is only about 50 cycles for intelligibility. For many years this seemed like an insurmountable obstacle in the way of amateur s.s.s.c., but it is no longer so. Our present receivers, after they are warmed up, are capable of such stability over the period of a transmission, as has been demonstrated by the satisfactory reception of W6YX and WØTQK by many stations. By using crystal-controlled high-frequency oscillators, we should have no trouble with s.s.s.c., even on 29 Mc. This improved stability of receivers has been sneaking up on us over the years, and it only took the transmissions of W6YX and WØTQK to show that amateur s.s.s.c. is here and practical!

Single-Sideband Tests

(*Continued from page 18*)

in the conventional W6YX transmitter is perhaps a little higher than in normal rigs because of the overmodulation splatter-suppressor circuit employed, which permits overmodulation during occasional peaks.[1])

Since October 9th, we have worked the following

(*Continued on page 128*)

[1] Villard, jr., O. G., "Overmodulation Splatter Suppression," June 1947 *QST*