Single-Sideband Operating Tests

Some Results — and Suggestions for Improving Reception

BY O. G. VILLARD, JR.,* W6QYT

> **• On the evening of September 21, 1947, the 75-meter 'phone band was the scene of a contact that well may have signaled the beginning of a revolution in amateur radiotelephony, for this was the first amateur work with single-sideband suppressed-carrier transmission. Since then the transmissions of W6YX have given many the opportunity to try out the technique of receiving single-sideband signals — signals that sound like nothing human when detected by ordinary methods.**
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> **This article summarizes the reactions of those operators who have contacted W6YX, offers explanations, and suggests improved methods for receiving s.s.s.c. transmissions. W6YX will continue to be on the 14-Mc. band as regularly as possible, so keep an ear out for the transmissions.**
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> **In s.s.s.c. lies the certainty of doubling the effective width of the 'phone bands — and the possibility that the actual improvement in utilization may be much more than 2 to 1. If you operate 'phone, better begin now to find out what single-sideband is all about.**

The following notes are based on our own listening experience, plus reports received in over-the-air contacts. There is little that is quantitative in all this, but to the extent that the impressions of careful observers may be relied on, it should be of interest.

Relative Power

For equivalent sideband power, single-sideband-suppressed-carrier apparently gives a louder-sounding signal than conventional double-sideband transmission. One would suspect this to be in part attributable to the increase in receiver sensitivity when the b.f.o. is switched on (caused by curvature of the second-detector characteristic — a well-known effect) but the significant thing is the fact that the "louder-sounding" signal gets through the QRM better. One possible explanation is that in many communications receivers sideband clipping begins at audio frequencies as low as 2000 cycles per second. Thus a conventional signal of average width would be somewhat clipped whereas the s.s.s.c. signal might not be clipped at all.

The double-sideband transmitter at W6YX has a 7000-cycle total radiated bandwidth, whereas the s.s.s.c. transmitter has a 2500-cycle total radiated bandwidth. Both rigs use sharp cut-off low-pass filters. The matter of bandwidth is one point which obscures the comparison at W6YX, of course, since the audio-frequency response of the s.s.s.c. rig is 300–2500 cycles whereas that of the double-sideband rig is 100–3500 cycles. Thus the speech sounds "crisper" on the s.s.s.c. rig. We hope to arrange matters so that both rigs have the same speech bandwidth, and will make further tests.

However, taking everything into account, the results with s.s.s.c. still are surprisingly good. Once the knack of tuning the signal in is learned, most amateurs prefer the single- to the double-sideband transmission.

Tricks in Demodulating the Signal

Roughly one-fourth of the operators with whom we tried out s.s.s.c. reported themselves unable to receive it clearly at all. The most common complaint was that no matter *how* the local oscillator was tuned, the signal never did become clear and distortion-free. It is believed that a certain percentage of receivers have local or beat oscillators which have appreciable frequency or amplitude modulation because of hum voltages. On such a receiver a c.w. signal simply doesn't sound p.d.c. This effect is often missed in practice, because a small amount of hum may go unnoticed in c.w. work. But any hum modulation on the reinserted carrier of an s.s.s.c. signal plays absolute hob with the speech quality. We have one receiver on the campus which has this defect, and s.s.s.c. heard on it sounds appalling. The hum completely garbles the voice, apparently because each individual speech-frequency component acquires the hum modulation.

It is very desirable to use the minimum r.f. gain setting when the b.f.o. is used for demodulation. This assures a strong reinserted carrier in relation to the signal. The a.v.c. should also be disabled, because in many receivers a change in a.v.c. voltage, such as might be caused by a burst of incoming speech, can shift the receiver local oscillator a few cycles, thus detuning the reinserted carrier from the correct frequency at a syllabic rate.

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The most desirable arrangement is to use a separate signal-frequency oscillator. This allows the receiver to be tuned without upsetting the frequency of the reinserted carrier. It is then easy to adjust the receiver to accept the band occupied by the signal, with the aid of a variable-selectivity crystal filter. Maximizing the audio output, by varying the tuning alone, assures correct setting of the receiver passband. Selectivity may then be increased until sideband clipping is evident. Some of the oscillators that have been successfully used to demodulate the s.s.s.c. signal include the BC-221- or LM8-type frequency meter, several varieties of VFO, and even a regenerative preselector set into weak oscillation! The harmonics of a separate oscillator can of course be used.

The strength of the locally-injected carrier is not especially critical. Too little voltage causes the speech to sound distorted. Too much causes the receiver to block up or become microphonic. However, the receiver a.v.c. may be switched on when a separate oscillator is used, and this will prevent blocking although the available gain may thereby be reduced. For greatest flexibility, the oscillator injection should probably be adjustable. Incidentally, some receivers, particularly the HQ-120, seem not to have very much b.f.o. voltage injected into the i.f. amplifier. Greater coupling here might help.

Stability Considerations

Virtually all receivers will drift while warming up after being thrown from "stand-by" to "on." It is therefore desirable to leave the receiver on during transmission and reception, if the b.f.o. is used for demodulation. A continuously-operating separate oscillator renders this procedure unnecessary. Moreover, receivers without voltage regulation of the local oscillator will shift frequency enough, when the line voltage changes by a minute amount, to throw the reinserted carrier off frequency when the b.f.o. is used for demodulation. One amateur had to retune every time his wife switched a light on and off upstairs! Sets like the AR-88 and the new HRO do have voltage regulation of the local oscillator, and are noticeably more stable with respect to line-voltage changes.

We have found that unless the receiver *or* the external oscillator is phenomenally stable, it will be necessary to retune from time to time to keep the reinserted carrier on the "nose" anyway. (The Collins 75A receiver seems to get away from this problem very nicely.) Even with an ECO — unless it is voltage-regulated and very, very stable — there will be appreciable drift, requiring occasional retuning. However, tests with two crystals of the same frequency — one in a variable air-gap holder — have shown that it is possible to maintain absolute zero beat even on 10 meters with 80-meter crystals, for considerable periods of time. Exact zero beat may be found by varying the capacitance across the crystal holder for a vernier effect — most variable gaps give too coarse an adjustment. A set-up like this is reminiscent of a loran receiver, in which the pips remain at the same place on the screen for minutes at a time. Thus if two hams wanted to work regular skeds, they could use two crystals on the same frequency — one at the transmitter, and a variable one for carrier reinsertion at the receiver.

Suppression of Carrier

At first it was thought that radiation of a pilot carrier would be desirable. However, unless you are going to pick up this carrier, amplify and reinsert it, it does more harm than good, because if a b.f.o. or separate oscillator is used for carrier reinsertion, it will be found that a strong beat is set up between the pilot carrier and this oscillator when the reinserted carrier is not quite at the correct frequency, but yet not far enough off to affect the intelligibility seriously were the pilot carrier absent. By far the best results are obtained when the "pilot carrier" is completely suppressed.

Using Receiver B.F.O.

It seems to be true that when the receiver b.f.o. is used for carrier reinsertion, using extra crystal selectivity complicates the tuning procedure. This, in all likelihood, is because the incoming s.s.s.c. signal often ends up somewhere outside the receiver passband, if the b.f.o. is not set correctly, and is hence chopped off when the bandwidth is narrowed. It is not easy (as is most desirable) to get the signal properly centered in the receiver passband, and *then* to set the b.f.o. to the correct frequency! The whole process is greatly simplified when a separate oscillator is used. However, our signals have been received successfully by means of the b.f.o. on virtually every type of receiver, including the BC-312-type surplus set.

Appearance on Panadapter

Several amateurs have looked at the s.s.s.c. signals on the Hallicrafters panoramic adapter, and have reported that the s.s.s.c. signals are about ⅔ as broad as our conventional signal, whereas they should be only about one-third as broad. This is probably attributable to the poor resolution of the panoramic adapter, although on this point we haven't much experience as we haven't tried an adapter ourselves. At any rate the panoramic adapter owners unanimously conceded that the s.s.s.c. was *somewhat* narrower!

Performance with DX

We have had only three real DX contacts, not having tried for these especially, but the performance on these was what one would expect. In all cases they got us O.K. Actually, the 20-

meter band QRM between here and the East Coast is probably a tougher test than a DX contact. We would like to try a contact with a European during which the characteristic flutter fade was bad, however; it might be instructive to see how s.s.s.c. compares with double-sideband under those conditions. The ZS we worked had a good receiver and had no difficulty copying us. There seems to be some evidence, however, that if the signal is marginal the receiving operator tends to lose contact entirely unless his locally-reinserted carrier is right on the nose. Under those conditions the loss in intelligibility which comes when the local carrier is slightly off tune cannot be tolerated. However, when signals are strong, slight detuning — plus or minus 10 or 20 cycles or so — does not hurt as it is still possible to understand what is being said.

In general, the presence of strong heterodyne QRM makes finding the correct frequency for the local carrier considerably more difficult. For example, there is an almost irresistible temptation to zero-beat the local oscillator with one of the interfering carriers, and not to set it at the correct frequency for demodulation of the s.s.s.c. signal. This is purely a habit pattern of long standing which has to be consciously broken! Again, use of a separate carrier oscillator aids in reading through QRM, because the receiver may be readily detuned slightly to one side of the s.s.s.c. signal to avoid interference. However, it is worth pointing out that the crystal rejection notch can be used equally well when either the b.f.o. or a separate oscillator is employed for demodulation.

Some Misleading Impressions

Some amateurs, on hearing s.s.s.c. for the first time, will report the signal to be exceptionally "sharp." There seems to be a tendency to confuse the exactness with which the local carrier must be reinserted, with the "sharpness" of the signal. Some report, for example, that the signal is "broad" with the b.f.o. turned off, but "extremely sharp" with the b.f.o. on. Fig. 1 may explain this effect to some extent. Without the b.f.o. the receiver output will be the envelope of the s.s.s.c. signal, reduced in strength because of the detuning, and with the relative amplitude of its frequency components somewhat altered. In general, the audio output will be in the range 300–2500 cycles. (Not exactly, of course, as the envelope of an s.s.s.c. signal does not contain the same frequency components as the signal itself. But for a complex wave such as speech, it sounds roughly the same.) Now with the b.f.o. on, and centered, say, at the middle of the passband, the output of the receiver second detector in the example in Fig. 1 will be a band of frequencies in the range 4000–6500 c.p.s. These frequencies will tend to be rejected if the receiver has poor audio fidelity, and in any case the ear is not as sensitive to them. Consequently the receiver output sounds weaker by comparison, and one gains the impression that the selectivity has been increased, as far as the s.s.s.c. signal is concerned, when the b.f.o. is turned on. It should be emphasized that reports on the sharpness — i.e. bandwidth — of the signal are best made with the aid of the crystal filter which, in its sharpest position, effectively turns the receiver into a manually-operated spectrum analyzer.

Miscellaneous Data on S.S.S.C. Tests

The first QSO was with W6VQD, Winfield G. Wagener, September 21, 1947, at 9:30 P.M. PST on 3970 kc. Win reported the signal Q5 S8 through heavy 75-meter QRM on his BC-348-Q receiver. He used the crystal filter and reported the quality good and the voice recognizable. The transmitter power was about 20 watts peak into a haywire antenna. W6ZTE is the campus station of the Stanford Radio Club; W6YX, the other transmitter, is located near the Ryan High Voltage Laboratory which is about one mile from the center of the campus. W6ZTE is located in the Electronics Research Building (part of Electrical Engineering Department) on the campus.

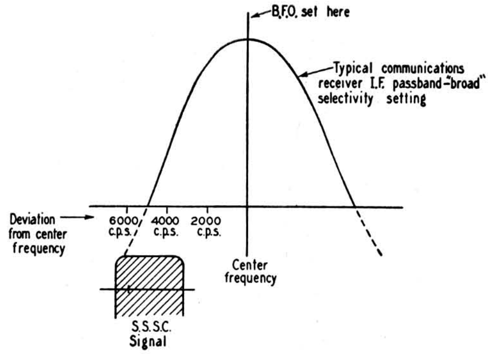

Fig. 1 — **Why the detuned single-sideband signal sounds weaker with the b.f.o. on. Without the b.f.o., the rectified components of the detuned signal are more or less in the original audio range, but when the b.f.o. is switched on the signal components all beat with the b.f.o. to produce components of high audio frequency. These higher frequencies are amplified less in the audio system, and in addition do not seem as loud to the ear. The over-all effect is that the detuned signal tends to be suppressed.**

The higher-power rig was then built and was first tested over the air in a QSO with WØNWF on 20 meters on October 9, 1947. Peak envelope power output was gradually raised over a period of time to the present 400-watt (approximate) level. This is comparable to the 350 watts of peak sideband power provided by the regular W6YX transmitter running 1-kw. input, assuming an efficiency of 70 per cent. (*Average* sideband power

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Single-Sideband 'Phone

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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

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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

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

DX on s.s.s.c. (no special effort made at DX work):

October 9th —	VK4KS	Fragmentary contact. VK4KS in contest.
October 25th —	KH6MQ/J9	Kwajalein, Marshall Islands. Got us distinctly through bad QRM.
	ZS6GF	Pretoria, South Africa. Had 40-minute solid QSO. Reported s.s.s.c. easily readable but hard to tune. Had AR-88 receiver.

On November 3, 1947, worked WØTQK at 8:55 P.M. PST, for the first two-way single-sideband QSO. Our first contact with WØTQK was on October 21st, and he had built up his entire rig in the meantime! On November 8th, worked WØTQK for first duplex s.s.s.c. QSO; very nearly solid circuit for one-and-one-half hours.

Thanks are due the following members of the Stanford Radio Club for their assistance in connection with the single-sideband tests: Dave Thompson, W6VQB, Rob Beaudette, W7FXI, and Chet Carr, W6NVH.

Single-Sideband Transmitter

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In all cases where the receiving station has been able to tune in the s.s.s.c. signal correctly, the results have been very gratifying. The most apparent effect is the terrific reduction in QRM compared to double-sideband transmission.

When one tunes in a single-sideband signal, it sounds like — and is! — a sideband that has lost its carrier. No amount of tuning will restore its readability. The essential thing to remember is that this very narrow band of frequencies being transmitted must be centered in the passband of the receiver i.f. amplifier. This is most easily done by using sharp i.f. selectivity, crystal in first or second position, and tuning for maximum signal. Once centered in the i.f. channel, the receiver is set up for c.w. reception, audio gain on full and r.f. gain reduced, and the b.f.o. set to the frequency of the missing carrier. In order to set the b.f.o. a very careful adjustment is required, since the exact frequency may be passed over during periods of no modulation. If the oscillator is set on the wrong side, the speech will appear inverted and unreadable. As most receivers will drift during stand-by, the high-frequency oscillator (main tuning) should be corrected since most of the drift is in this oscillator. Changing the b.f.o. will set the signal out of the i.f. passband. If sufficient selectivity is available in the i.f. amplifier, it can easily be seen that two stations can use the same carrier frequency with no interference. A recent test with a dual-conversion amateur receiver showed that no retuning was necessary over a period of more than half an hour. S.s.s.c. communication places a severe stability requirement

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