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Single-Sideband:

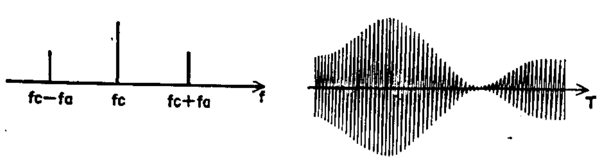
Is It Really Better Than Amplitude Modulation?

A Word of Warning

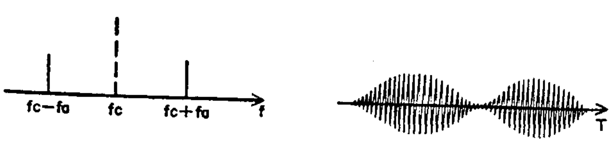
Before going any further it is only fair to warn the reader of the intent of this article. What I shall attempt to show is that AM as a basic modulation process is every bit as good as single-sideband. Furthermore, the performance advantages claimed for SSB come about not due to any fundamental fault of AM but rather due to the faulty use we are making of this modulation process. Assuming that there are still a few readers left we shall continue.

What is AM?

This question on the surface may seem to be a very simple one to answer but there are some points involved which are not too obvious. For example if we have a modulating frequency f_a and a carrier frequency f_c, conventional AM may be represented as shown in *fig. 1 (a)* by a carrier and a pair of sidebands each of



(a) This is AM as we now know it.



(b) This is AM as it should be.

Fig. 1. Two Types of AM Signals.

½ the carrier amplitude. Now as is well known, the carrier wave conveys no intelligence and its removal from the AM signal would not affect the information bearing components or sidebands. Thus if we remove the carrier from the conventional AM signal of *fig. 1 (a)* we shall have the suppressed-carrier, double-sideband AM signal of *fig. 1 (b)*. Note that the sideband (intelligence) powers in (a) and (b) are the same but that the total signal power in (b) is considerably less than in (a). Although the signal shown in 1 (b) does not look like an AM signal it is simply a conventional AM signal with the carrier removed. As we shall see the carrier component of an AM signal need not and should not be transmitted. Once we realize that the carrier component of an AM signal is not basic to the modulation process, it becomes clear that the signal of *fig. 1 (b)* represents "amplitude modulation" just as much as that of *fig. 1 (a)* and that 1 (b) represents the more efficient way of getting the message across.

Questions immediately arise as to how we are to generate and receive double-sideband suppressed-carrier (DSB) AM signals and some of the possibilities will be discussed later in this article.

The 9db. SSB Power Advantage— It Doesn't Really Exist

We are now in a position to examine the signal-to-noise properties of a DSB AM system as compared to an SSB system with the aid of *fig. 2*. Note that the sideband amplitude for the SSB signal is E volts while the sidebands in the DSB signal are each E$\sqrt{2}$ volts in amplitude. This makes the *average signal power* in the two cases the same. If we assume a noise power P_N to exist in the small bandwidth required to receive the various sidebands the

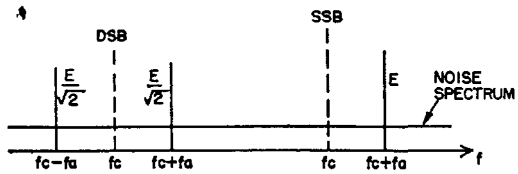


Fig. 2. DSB and SSB Signals in Noise

signal-to-noise ratio (on a power basis) will be for SSB.

$$\left(\frac{S}{N}\right)SSB = \frac{E^2}{P_N}$$

Now in the DSB case if we demodulate each of the sidebands properly and combine them, the signal components will add voltage-wise and the two noise components will add on a power basis. Thus we will have a signal voltage of $\sqrt{2}E$ and a total noise power of $2P_N$. The signal-to-noise ratio for the DSB signal will then be (again on a power basis)

$$\left(\frac{S}{N}\right)DSB = \frac{2E^2}{2P_N} = \frac{E^2}{P_N}$$

which is the same as for SSB. Thus we have one important result: when both are properly received, DSB and SSB require the same average signal power for a given signal-to-noise ratio at the receiver. The 9 db figure we hear quoted so often somes from a comparison based on *peak* power with full carrier assumed in the AM signal.

The Bandwidth Saving of SSB— It Won't Reduce Interference

This last statement must have convinced even the most broad-minded reader that the author has gone non-linear, but bear with me a while longer. In a given bandwidth it is quite true that twice as many SSB clear channels may be assigned as DSB clear channels which would initially lead one to believe that universal use of SSB would result in less interference than universal use of DSB. This sort of argument is misleading because we do not use the amateur bands on a channel assignment basis. Within the band edges we operate wherever and whenever we wish. So we must discard the "double the number of channels" picture and start with a new and more meaningful approach.

The correct approach to the interference problem on the amateur bands involves the mathematical theory of probability. Probability theory enters the picture because within the band edges signals appear at random frequencies and at any receiver location with random signal strengths. Thus if we consider this "jumble" of signals on the bands as constituting the intereference, we are interested in how the *average* interference level would be affected if all signals were DSB or SSB. This idea of judging performance on an *average* basis is very important and to illustrate my point let me give an example which has nothing to do with SSB or DSB.

We all know that at times we can do very well with low power and a poor antenna. In spite of this we don't laugh at the fellow who goes to a kilowatt and puts up a rhombic. Why? Well, because we know that *on the average* the KW and rhombic will give better performance than our 6L6-rain gutter combination. In other words we don't judge the performance of a new antenna or a new transmitter on the basis of the one or two hours of operation but rather we compare the *average* performance of the new system over a considerable period of time before we come to any conclusion as to whether or not we have made an improvement. This idea of judging performance on an *average* basis is so simple that it is almost obvious but don't let this fool you. This way of looking at the situation makes a lot of sense—keep it in mind.

Now let's get back to the SSB-DSB interference question. With the "jumble of signals" picture in mind (if someone questions this concept let him tune some of the crowded phone bands on a busy weekend) what would be the effect on the average interference level if every signal were SSB instead of DSB? Put another way, if each operator instead of splitting his radiated power equally between two sidebands (DSB) confined all his power to one sideband (SSB), would the average interference level in the band be reduced? The answer is *no,* the average interference level would remain unchanged! In other words *on the average* the amount of interference which we would get in our receivers would be the same if everyone were transmitting SSB or if everyone were transmitting DSB. The reduced bandwidth of SSB will not reduce interference. (Heterodyne interference which is such a serious problem now would be eliminated in either the SSB or DSB case since both are suppressed carrier systems.)

DSB Reception—Several Possibilities

Let's go back a bit and review what has been said so far. To begin with we have shown that if the carrier component of a conventional AM signal is removed we have a more basic form of the AM signal which we have called DSB. Secondly when DSB and SSB were compared on an average power basis the 9 db power advantage of SSB vanished. Finally we showed that due to the random frequency location of signals within a band the reduced transmission bandwidth of SSB did not result in reduced interference. So far SSB and DSB performance has been very much the same. The big advantage of DSB over SSB will show up at the transmitter but first let us consider the reception of DSB.

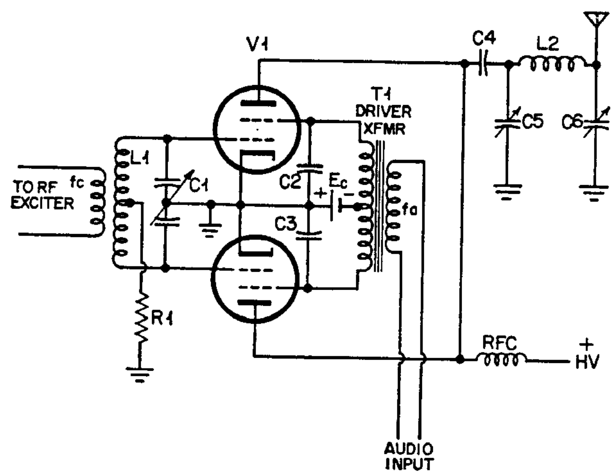
An ideal DSB receiver demodulates both sidebands and combines them so that all the transmitted power is used. To get the two sidebands to add in-phase however requires the receiver local oscillator to be phase-locked to the carrier which isn't transmitted. This sounds difficult if not impossible but such is not the case. Phase control under such conditions can (and has) been very simply obtained since carrier frequency and phase can easily be established from the received sidebands. Let's forget about the "ideal" DSB receiver for the moment and consider a more familiar reception method which although it does not give the best results its use will prove entirely satisfactory.

If one thinks of the DSB signal as two SSB signals back-to-back the use of SSB receiving techniques immediately suggest itself. Of course if we receive only one sideband we are apparently losing 3 db since one-half the transmitted power lies in the other or unused sideband. This other sideband is not being wasted, however, since it is available for use by the receiver when needed. In other words we may switch from one sideband to the other as the interference situation at the receiver changes, always picking the sideband with the lesser interference. The ability of the receiver operator to choose between two sidebands and pick the one with a minimum of interference buys back a good part of the 3 db loss, so much in fact that the difference on the average is not worth considering. Thus even if a non-ideal reception method such as SSB is employed, DSB transmissions can be received thru interference just as effectively as SSB transmissions. It is quite true that the upper and lower sidebands of an AM signal contain the same information but this isn't bad and if properly used, this feature (redundancy, as the communications engineer would call it) will pay handsome dividends. As a matter of fact in modern communications systems we sometimes go to a lot of trouble to put in redundancy by repeating the message in one form or another. This causes the transmitted signal to occupy more bandwidth but this repetition gives the receiver a much better chance of getting the message thru in spite of interference. The point to be made here is that AM has an inherent "diversity" advantage over SSB; let's not complain about it but rather we should try to make more good use of it.

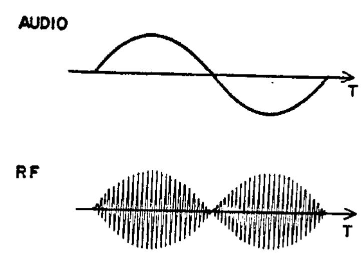
DSB transmissions may be received on a standard AM receiver by the same methods which permit such a receiver to detect SSB signals. The process requires some skill but it certainly can be done. A better solution involves the use of SSB adapters of the types Norgaard and others have proposed. These units simplify reception considerably and they make sideband switching a quick and simple matter. The best solution is of course a receiver or adapter designed specifically for DSB but this matter is beyond the scope of our present discussion.

DSB Transmitters—The Payoff

The DSB transmitter is far simpler to build and operate than a SSB transmitter. The DSB transmitter is simpler even than a conventional AM transmitter. Special tricks or gimmicks? No, just the proper combination of some old and well known techniques. No linear amplifiers, no filters, no phasing network, no frequency translators; you can do it yourself. How is all this possible? Well, it's mostly due to the simple fact that we no longer have to generate a carrier. To see how all these nice things come about take a look at *fig. 3*.



(a) DSB Transmitter, Basic Circuit



(b) DSB Waveforms

Fig. 3. DSB Transmitter Circuit and Waveforms

The final tubes V_1 and V_2 are beam tetrodes and are operated as screen-modulated class-C amplifiers. The plates are paralleled and are connected to the antenna load by means of a pi matching network. The control grids are driven push-pull from a normal r-f exciter at the operating frequency. The screen grids are by-passed to r.f. by C_2 and C_3 and are connected to the audio transformer T1. (A normal driver transformer will handle more audio power than will ever normally be required for amateur service.) The center-tap of T1 is either grounded or connected to a negative bias supply depending on the tube type and plate voltage used. Blocking capacitor C_4 is used to isolate DC from the pi coupler as is usual. Now for the operation.

With no audio both tubes are nearly cut-off by virtue of the fact that the screens are either grounded or biased negatively, thus no output. If we assume a sinusoidal audio tone as the modulating signal as shown in (b), one screen is driven positive during the first half-cycle and the other is driven negative. The tube with the positive screen conducts and r.f. is supplied to the load by that tube. During the next half of the audio cycle the other tube supplies the power and the first tube rests. Note that only one tube is working at any one time, except when there is no audio then both tubes loaf. *Fig. 3* (b) shows the audio and r-f waveforms. Only one audio cycle is shown. Note further that the r.f. during the first half of the audio cycle is phased 180° to the r.f. during the second half of the audio cycle. This is typical of a suppressed-carrier AM signal. Suppose we add a carrier wave to the r-f wave of 3 (b). If the carrier wave has the same phase as the r.f. in the first audio half-cycle and an amplitude equal to the maximum amplitude of 3 (b) the two voltages will add during the first audio half-cycle and subtract during the second half resulting in the old 100% modulation picture. So the circuit of 3 (a) produces AM without carrier or a DSB signal.

A word or two about circuit efficiency is now in order. Since we are screen modulating, the efficiency will vary from zero at no audio drive to normal class-C efficiency at audio peaks. If an analysis is made the efficiency based on average r-f power out to DC power in will be

$$\frac{\pi}{4}\eta_M \times 100\%$$

for sine-wave audio where η_M is the efficiency at the audio peaks which runs about 0.8. The overall efficiency is theoretically about 60% with 50% the value usually obtained in practice. This may not sound too impressive but let's look a bit further. Note that the efficiency expression involves $\pi/4$ and the normal class-C efficiency as a product. In a normal AM transmitter $\pi/4$ is the theoretical efficiency of the class-B modulators and η_M of course is the efficiency of the class-C final. Thus the circuit of *fig. 3* (a) will produce r-f sidebands with the same efficiency as a conventional high-level modulated AM transmitter. The reason 3 (a) is so much simpler than a normal AM rig is that in 3 (a) we aren't bothering to generate the carrier.

The peak power outputs which can be obtained from a given pair of tubes in this service may be estimated by taking the carrier output given in the handbook for *one* tube in class-C telephony service and multiplying by four. *You can do at least this good and probably better.* For example, if a pair of 6146 tubes is to be used we find in the handbook that *one* tube will give 52 watts of carrier output in class-C telephony service at 600 plate volts and 150 screen volts. If we set the high voltage at 1200 volts and run the screens to 300 volts on audio peaks we will get 4 × 52 or 208 peak watts output. This you know you can do because the voltages and powers quoted are those which exist in Class-C telephony service during modulation peaks.

Without getting into too much circuit detail or DSB-linear amplifier power comparisons this much is clear: the class-C amplifier with its ability to put out large amounts of peak power is ideally suited for voice service in the circuit of *fig. 3* (a). The average voice sideband power produced by a pair of tubes in DSB service will easily match the average voice sideband power produced by the same tubes in SSB linear amplifier service.

The above power discussion actually underplays an important advantage of DSB over SSB. In DSB or standard AM systems voice clipping and filtering, if properly done, can increase significantly the average sideband power output of a given transmitter. Such tricks cannot be used in SSB since a flat-topped wave is deadly to an SSB system. (Such a waveform results in a very high peak-to-average power ratio for the SSB signal.) Do not confuse peak clipping with the peak limiting or audio AGC tricks that are sometimes used in SSB designs. These are defensive measures which in effect permit the audio *peaks* to fully load but not overload the linear RF amplifier. The average power gain of DSB using a good clipper-filter over SSB can be considerable but for the moment I'm willing to settle for a draw.

A few final comments: The r-f excitation in DSB service is not at all critical. Adjust for normal phone drive and you've got it made. That is one reason why screen modulation of tetrodes is to be preferred over control-grid modulation of triodes. You can use triodes but you have to watch the ratio of audio voltage to r-f voltage. With the Tetrodes you just read the grid mils. The r-f exciter of course is normal—use the one you've got. One more thing—we said that only one tube works at a time. This is true except that the "off" tube acts as a neutralizing capacitor for the "on" tube. The circuit is self neutralizing since the grid-plate capacitance of the "off" tube is in just the right spot for grid neutralization.

Concluding Remarks

I would not like to oversell DSB; it won't perform miracles. However, when compared with SSB we may draw the following conclusions:

1. SSB has no power advantage.
2. SSB will not reduce interference.
3. SSB is much harder to generate.

That's the end of my story, which is a good thing because I can see them coming for me now. ■