A New Approach to Single Sideband

Generating S.S.S.C. by the "Phasing" Method

BY DONALD E. NORGAARD,* W2KUJ

• Here is an outline, with some practical pointers, of a method for generating a single-sideband suppressed-carrier signal without the need for a sharp filter and multiple heterodyning. The complete practicability of the system has been proved by almost two years of laboratory and on-the-air testing by the author. It is a significant step in taking s.s.s.c. out of the luxury class and placing it within the reach of every amateur.

THE *QST* article [1] describing a single-sideband exciter operating on the principle of filtering out the undesired sideband undoubtedly has left many an amateur wondering if all single-sideband equipment is necessarily complicated. The filter principle is effective, of course, but it leads to over-all complexity of a transmitter and requires very careful design, construction and adjustment. In fact, to set up such a transmitter and make it work properly is a task that requires considerable technical skill and meticulous attention to detail. The few who have done this job well deserve to be complimented.

On the other hand, the advantages of s.s.s.c. over a.m. are too great to be passed over by any amateur looking for something better in 'phone technique. Some of these advantages have been described in previous articles in *QST*, and Table I shows a comparison of some of the features. These points were discussed in detail last month.[2]

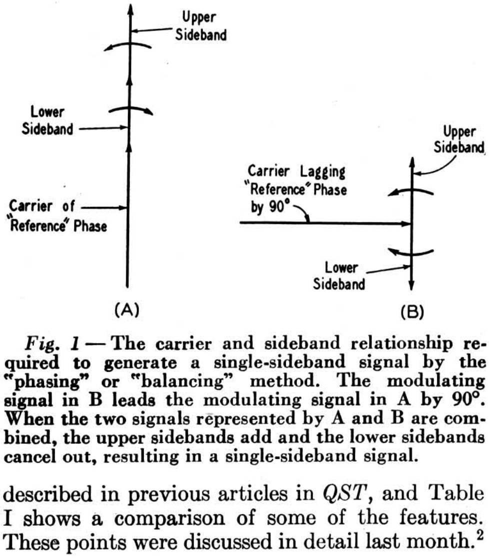

Fig. 1 — The carrier and sideband relationship required to generate a single-sideband signal by the "phasing" or "balancing" method. The modulating signal in B leads the modulating signal in A by 90°. When the two signals represented by A and B are combined, the upper sidebands add and the lower sidebands cancel out, resulting in a single-sideband signal.

S.S.S.C. by "Phasing"

Fortunately for the rest of us, another method of generating single-sideband signals has been developed to a degree that many of the problems associated with the filter method are eliminated, and better performance can be obtained at much lower cost. Fundamentally, the method consists of removing one of the sidebands by means of a balancing process rather than by filtering.

The principle employed may be explained by reference to Figs. 1-A and 1-B, which are vector diagrams showing the relationship between carrier and sidebands produced in amplitude modulation. In Fig. 1-A a carrier is shown in "reference" phase, and the positions of the sideband vectors indicate that peak-envelope conditions exist at the instant shown. In Fig. 1-B a carrier of the same frequency but 90° away from that of Fig. 1-A is shown. The two sideband vectors in Fig. 1-B indicate that the envelope has a value (at the instant shown) equal to the carrier; that is, the modulating signal is 90° away from that which gave the conditions shown in Fig. 1-A.[3]

If the conditions shown in Fig. 1-A exist at the output of one modulating device at the same instant that the conditions indicated in Fig. 1-B exist at the output of another modulating device, and if the sideband frequencies and magnitudes are the same, the simple sum of Figs. 1-A and 1-B will consist of carrier and upper sideband only. It can be seen that the lower-sideband vectors are equal in magnitude and opposite in direction, and hence would cancel one another. How can this result be obtained in practice?

The vector diagram of Fig. 1-A might be said to represent the output of a modulated amplifier where a carrier of reference phase is modulated by a tone of reference phase. Thus, Fig. 1-B would represent the output of a second modulated amplifier where a carrier of the same frequency but 90° displaced from reference phase is modulated by a tone that is also 90° displaced from its reference phase. To make the whole thing work, the frequencies of all corresponding signals

---

* Research Laboratory, General Electric Co., Schenectady, N. Y.

[1] A. H. Nichols, "A Single-Sideband Transmitter for Amateur Operation," *QST*, January, 1948.

[2] D. E. Norgaard, "What About Single Sideband?" *QST*, May, 1948.

[3] For interpretation of these vector diagrams, see *QST* for May, 1948, page 14.

represented in the two vector diagrams must be exactly the same. This would suggest an arrangement such as Fig. 2, which would operate satisfactorily if the 90° phase-shift devices held amplitudes and phases of the respective signals to agree with the requirements indicated in Figs. 1-A and 1-B. The carrier phase-shifter is easy to build, since the carrier frequency is constant, but the modulating signal phase-shifter might not be, since it must work over a wide range of frequencies. To build such a phase-shifter has been so difficult a problem that people have been forced into the alternative measure of using filters to attenuate an undesired sideband. The arrangement of Fig. 2 works in principle but not in practice, for any wide range of modulating frequencies.

It so happens that two phase-shift networks having a *differential* phase shift of 90° can be inserted between the source of modulating signals and the modulating devices to generate sets of sidebands which can be combined to cancel one of the sidebands as indicated earlier. This leads to an arrangement such as that shown in Fig. 3, where the symbols "α" and "β" indicate the two networks that have a *difference* in phase shift of 90° over any desired range of modulating signal frequency. The principle of Fig. 3 has been found to be practical for several important reasons:

1) A carrier of any desired frequency can be used. This means that heterodyning the output to a higher frequency is not at all necessary as is the case when a filter is used to eliminate one sideband.

2) Conventional parts may be used in any and all of the circuits. There is no "problem of the filter." The cost, therefore, is low.

3) Any desired range of modulating frequencies may be employed. There is no theoretical limit to how low or how high these frequencies may be, but, of course, there are practical limits. The phase-shift networks to be described will cover a frequency range of 7 octaves, far more than is necessary for speech. This range may be extended by appropriate extension of the network design.

TABLE I

A Comparison of A.M. and S.S.S.C.

	Amplitude Modulation		*S.S.S.C.*	
	Transmitter (*% of Peak*)	*Receiver* (*% of Peak*)	*Transmitter* (*% of Peak*)	*Receiver* (*% of Peak*)
Peak Power Output	100	100	100	100
Carrier Power Output	25	25	0	supplied by receiver
Carrier Voltage	50	50	0	
Total Peak Sideband Power	12.5	12.5	100	100
Bandwidth (% of audio spectrum)	200	200	100	100
"Communication Efficiency" *	12.5	—	100	—
Practical "Communication Efficiency" **	10 (max.)	—	70	—
System Gain* (Decibels)	0 (reference)		plus 9	

* Based on output power.

** Based on input power.

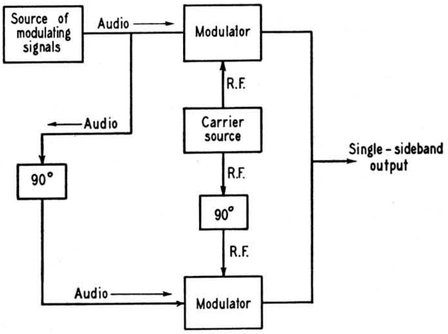

Fig. 2 — **A block diagram showing the circuits required to generate a single sideband by the method of Fig. 1. This is an impractical method because there is no known means for obtaining the 90° audio shift over a wide range of frequencies.**

4) Modulation may be accomplished at any chosen power level. In the interest of efficiency, it is generally wise to carry out this portion of the process at receiver-tube level, using linear amplifiers to build up the power.

5) Simple switching may be provided so that amplitude-modulation, phase-modulation or single-sideband signals may be generated.

The only critical portions of the arrangement of Fig. 3 are the phase-shift networks. Enough design work has been done on these so that simple and practical equipment can be built. Adjustment procedures are straightforward and simple, too. Fig. 4 is a circuit diagram of a complete α or β phase-shift network, the difference between the two networks being in the constants R_1, C_1, R_2, C_2, etc. Values for these constants are given in Table II. It should be pointed out that the plate and cathode resistors for each tube section must be carefully matched to within 1% of one another, and that the plate power supply have very low internal impedance. An electronically-regulated supply is perhaps the most practical means of satisfying this latter requirement.

The characteristics of the phase-shift networks are shown in Fig. 5. It can be seen that the differential phase shift averages 90° over a fre-

TABLE II

Values for Use with Fig. 4

Symbol	*α Network*	*β Network*	*Remarks*
R_1	51,000 ohms	0.10 megohm	Adjust *RC* product to 12.30 microsec. for α, 51.20 microsec. for β. Tolerance: ± ½%.
C_1	241 μμfd.	512 μμfd.	
R_2	0.10 megohm	0.56 megohm	Adjust *RC* product to 148.5 microsec. for α, 420.0 microsec. for β. Tolerance: ± ½%.
C_2	1485 μμfd.	750 μμfd.	
R_3	0.56 megohm	0.56 megohm	Adjust *RC* product to 1230 microsec. for α, 5120 microsec. for β, Tolerance: ± ½%.
C_3	2200 μμfd.	9140 μμfd.	
R_{10}	2.2 megohm	2.2 megohm	Input circuit may be omitted if driving circuit supplies grid return.
C_{10}	0.05 μfd.	0.05 μfd.	
$R_{11a,\,b}$	1000 ohms	1000 ohms	Resistors *a* and *b* in each section should be matched to within ± ½%.
$R_{12a,\,b}$	2000 ohms	2000 ohms	
$R_{13a,\,b}$	3000 ohms	3000 ohms	
$R_{14a,\,b}$	4000 ohms	4000 ohms	10% tolerance suitable.

B + = 300 volts. All resistors are ½-watt composition. For sake of stability R_1, R_2, R_3, R_{11}, R_{12}, R_{13} and R_{14} should be high-quality resistors. Continental "Nobleloy" Type X-½ resistors are recommended. C_1, C_2 and C_3 should be made up of fixed mica and compression padders in parallel to permit adjustment of *RC* products to agree with close tolerances in "Remarks" column.

Tubes used: two 6SL7GT double triodes for each network.

Maximum signal input: 2 volts peak-to-peak.

Insertion loss: approx. 8 db. for each network.

quency range of at least 7 octaves, or from 60 to 7000 c.p.s., for the constants given. Of course, the ideal differential phase shift is exactly 90°, and the excursions of the actual phase-shift curve are ±2° from this value. The ratio of undesired sideband to desired sideband is dependent upon this deviation, the most unfavorable points being at the peaks and valleys of the differential-phase-shift curve. The ratio

$$\frac{\textit{undesired sideband}}{\textit{desired sideband}} = \tan\left(\frac{\delta}{2}\right),$$

and for $\delta = 2°$,

$$= \tan\left(\frac{2°}{2}\right) = 0.0174, \text{ or } -35 \text{ db.}$$

The symbol δ represents the deviation of the actual performance from the ideal 90°, and, in the above example, δ was taken at its maximum value. The average attenuation of the undesired sideband is more than 40 db. over the band of modulating frequencies between 60 and 7000 c.p.s. There is little to be gained by improvement of this ratio, since subsequent amplifier distortions can introduce the unwanted sideband in sufficient amounts to mask any improvement gained by idealizing the phase-shift network characteristics.

A Practical Exciter Circuit

While the block diagram of Fig. 3 is useful in explaining the principle of generating single-sideband signals, it does not represent a complete single-sideband exciter with enough gadgets to satisfy a person with a practical turn of mind. There is little to be gained by using single sideband unless the carrier is attenuated, but Figs. 1-A, 1-B, and 3 do not indicate this. Therefore, Fig. 6 is offered as a workable system that provides for carrier attenuation, amplitude modulation, phase modulation, single sideband, operation on 75- or 20-meter 'phone, and QSY within these bands. If multiband operation is not desired and if QSY [4] is not deemed necessary, modulation can be accomplished at the operating frequency by appropriate simplification of the arrangement of Fig. 6.

It is not the purpose of this article to give specific circuit-design data for a complete single-sideband exciter; rather, the purpose is to point out the over-all features that *must* be observed in order to satisfy the requirements of this system of generating single-sideband signals. For instance, the design of the bandpass circuits indicated in Fig. 6 is beyond the scope of this article. The advantage of using such an arrangement designed to cover the amateur band in use is that no tuning adjustments whatsoever need be made when it is desired to QSY. With ordinary circuits, best operation usually demands retuning when large percentage changes in frequency are made. However, ordinary tuned circuits can be substituted for the bandpass transformers, as in any transmitter.

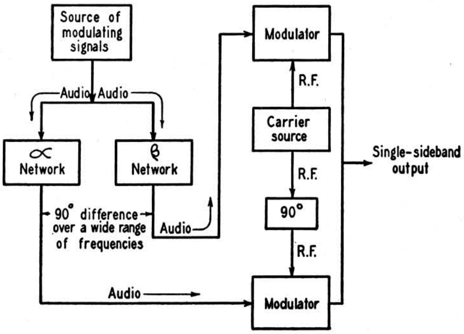

Fig. 3 — The system outlined in Fig. 2 becomes practical by using two audio channels (α and β networks) with a constant phase *difference* of 90°.

A conservative output rating for an 807 output stage would be 30 watts peak, under drive conditions where the grid takes no current (Class AB_1). This will compare in sideband power to an a.m. signal of 60 watts carrier output. If suitable bias

---

[4] By "QSY" is meant any change in frequency, whether obtained in discreet steps (by switching crystals, for example) or continuously-variable frequency control by means of a VFO.

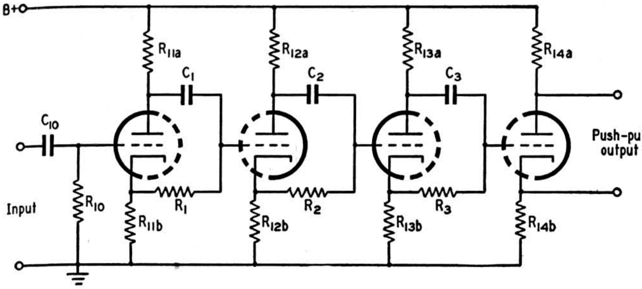

Fig. 4 — A typical 3-element ∝ or β phase-shift network. Values are given in detail in Table II.

and drive are supplied to the 807, a conservative 50 watts peak output may be obtained. This, of course, is the power equivalent of 100 watts carrier output of an a.m. signal. In either case, the output power is sufficient to drive additional amplifiers of fairly-sizable ratings or to use directly as a low-power single-sideband 'phone transmitter. In comparison, only 15 watts [5] of carrier output can be obtained when using a.m., or 40 watts [5] with phase modulation.

It is usually practical to build the voice-frequency equipment (the a.f. amplifiers and the phase-shift networks) on one panel, and the modulators, converter (if used), and amplifiers including the 807 output stage on another. The dashed line in Fig. 6 indicates such a division and gives us a chance to consider these portions separately. The functional block diagram (Fig. 6) might appear formidable at first glance, but the whole arrangement lends itself to rather simple circuit design. Separate consideration of the two portions of Fig. 6 should not be taken to indicate independence of one from the other. It is well to keep in mind that in this system the audio-frequency circuits and the radio-frequency circuits must work hand-in-hand in order to generate single-sideband signals of superior quality.

Notes on the Audio System

The audio-amplifier and phase-shift circuits are straightforward. The important consideration is that the phase-shift and amplitude relationships determined by the phase-shift circuits must be preserved over the entire voice range in succeeding parts of the system. Fortunately, there is nothing difficult about it, once the objectives are clearly in mind. These objectives are:

1) Low harmonic distortion and noise.
2) Vanishingly small discrepancies in phase-shift and amplitude response.
3) Ease of control and adjustment.
4) Simplicity and low cost.
5) Stability of characteristics.

Most microphones in current amateur use require low-level amplification (the usual microphone preamplifier) to bring their output signals up to, say, a level of one or two volts. This is the job required of the audio amplifier ahead of the ∝ and β phase-shift networks. (See Fig. 6.)

This is as good a time as any to mention the desirability of including in the "preamp" a bandpass or low-pass audio filter to pass the important speech band out to 3000 cycles or so, to conserve space on the bands. The operation of the rest of the circuits in the system in no way requires this, but good sportsmanship in the use of our bands does. It is good practice to eliminate unnecessary low frequencies, too, concentrating on the portion of the audio spectrum between 200 and 3000 c.p.s. for maximum intelligibility. Numerous articles [6] have been written on the subject, and suitable bandpass-filter designs are available for this purpose. Why do anything about it at all, if the system as such does not require it? The answer has two important aspects — important to *you* as an occupant of the bands we share:

1) Intelligible speech does not require transmission of frequencies higher than 3000 c.p.s. To do so adds practically nothing to intelligibility but does increase the space in the band required for transmission. It boils down to the fact that we want the "other fellow" to use as little of our bands as possible, and the Golden Rule certainly does apply in this matter. In addition, regardless of how "high fidelity"-minded one may be,

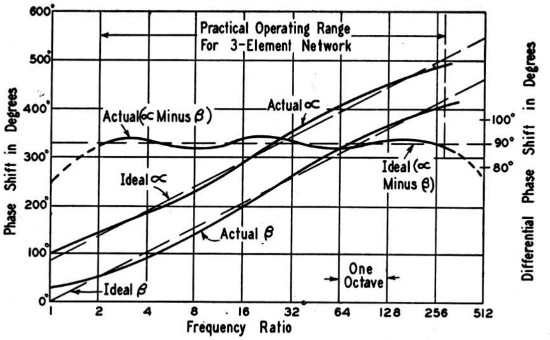

Fig. 5 — This plot shows how the 90° difference between the ∝ and β networks is maintained over a wide frequency range. The scale for the phase difference is given on the right-hand side of the graph.

---

[5] RCA ratings for this class of service.

[6] W. W. Smith, "Premodulation Speech Clipping and Filtering," *QST*, February, 1946; J. W. Smith and N. H. Hale, "Let's Not Overmodulate," *QST*, November, 1946; W. W. Smith, "More on Speech Clipping," *QST*, March, 1947; Galin, "Audio Filters for the Speech Amplifier," *QST*, November, 1947.

crowded bands force the operator who listens to the transmission to restrict his receiver bandwidth so much that he receives only what is necessary, if even that much. Not only is "high fidelity" wasted, but also its use is downright selfish.

2) Elimination of frequencies below 200 c.p.s. removes a large percentage of the high-energy speech components that do not contribute to intelligibility. Such elimination permits the transmitter to concentrate its efforts on only the *essential* portions of speech power. In practice, this means something like 3 to 6 db. in system effectiveness. Remember how we gained 9 db. by eliminating the carrier (corresponding to zero modulation frequency) and one sideband,[2] on the basis that these components were not essential? Two or three dollars spent on a suitable audio filter (and that's all one should cost) can give a transmitter a communication effectiveness equivalent to doubling or quadrupling its output power. It's worth it!

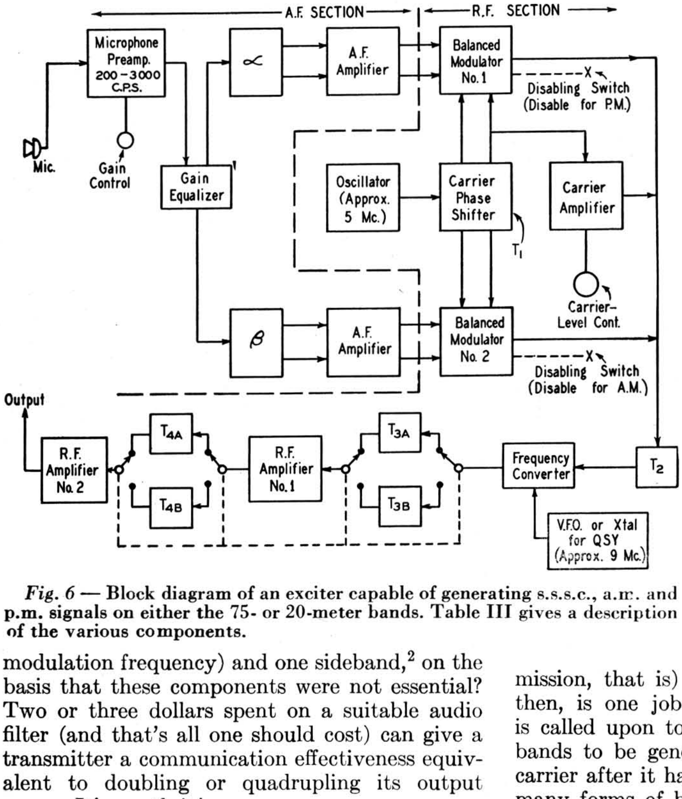

Fig. 6 — **Block diagram of an exciter capable of generating s.s.s.c., a.m. and p.m. signals on either the 75- or 20-meter bands. Table III gives a description of the various components.**

Notes on the R.F. System

Considerable flexibility is possible in the design of the radio-frequency portion of the block diagram in Fig. 6. The objectives in this portion of the single-sideband system are:

1) Very high order of frequency stability.

2) Provision for 90° r.f. phase shift in the excitation for the two balanced modulators.

3) Ease and stability of adjustment.

4) Absence of r.f. feed-back.

5) Low distortion in modulation and subsequent amplification.

6) Provision for adjustable carrier level; generation of a.m., p.m., and single-sideband signals; output-level control.

7) (optional features) Operation on 75- or 20-meter bands; easy QSY within each band; choice of sideband transmitted.

Obviously, a number of methods exist for accomplishing these objectives. Many of the possible methods that may occur to the designer will satisfy the requirements quite well; some will not. Others, while technically adequate, may be difficult to adjust or may be impractical in some other way. Since the handling of radio frequencies is concerned in this portion, good mechanical layout and construction is of considerable importance. Also, since stability of adjustment is one of the principal objectives, it is a good idea to provide some sort of locking arrangement for the balance controls to prevent accidental shifting of their positions.

Balanced Modulators

Fig. 6 indicates the use of two balanced modulators. The balanced modulator is not a new idea — in fact it is one of the oldest modulation schemes in existence — but such a thing is not often employed in amateur practice. A little explanation might be helpful in understanding why and how balanced modulators are used.

In amplitude modulation the maximum strength of any sideband that can be produced is one-half the strength of the carrier.[2] Since the carrier must be present in order to be modulated, but is not needed afterward (in single-sideband transmission, that is) it can be balanced out. This, then, is one job that the balanced modulator is called upon to do — namely, to permit sidebands to be generated, but to balance out the carrier after it has served its purpose. There are many forms of balanced modulators; some balance out one or the other of the two signals supplied; others can balance out both input signals. But none of them can balance out *one* sideband and not the other. Nature itself seems to be quite positive about that. But while balanced modulators may be new to amateur radio, there is nothing difficult about their construction and adjustment.

Since the signal that is to be balanced out is an alternating-current wave, it is necessary in the process to take account of phase relationships as well as magnitudes. Unless the two signals which are to be balanced have a phase difference of exactly 180°, perfect balance cannot be obtained by any amount of adjustment of amplitudes alone. This, incidentally, may explain why trouble is sometimes encountered in neutralizing an amplifier, since the same principle is involved. In the case of the balanced modulator, the perfection of balance required is usually quite high, and some means for satisfying the conditions necessary for balance must be provided. Very few arrangements automatically provide the conditions necessary for perfect balance and frequently those that do are limited to operation at low frequencies, where circuit strays have negligible effect. It has been found practical to "grab the bull by the horns" and use some arrangement where separate phase- and amplitude-balance adjustments are provided, rather than to hope for a fortuitous set of conditions that might permit balance.

The circuit shown in Fig. 7 illustrates this philosophy. Fundamentally, only one of the tubes need be supplied with modulating signal, two tubes being necessary only to allow balance of the undesired component (the carrier) in the output. If, however, each tube is made to generate sidebands as well as to balance the carrier from the other, the ratio of residual unbalanced carrier signal to desired output is made smaller at low cost. Likewise, even small amounts of the modulation defect known as carrier shift are effectively reduced. The carrier signals at points *A* and *B* in Fig. 7 are made as nearly equal in magnitude and opposite in phase as is feasible using circuit components of ordinary commercial tolerances. The *RC* circuit between point *A* and grid No. 1 of the first modulator tube (a 6SA7 converter tube in this example) may be designed to provide about 20° phase shift at the operating frequency, by suitable choice of R_a and C_a. The *RC* circuit in the other grid can be designed to produce variable phase shift from 10° to 30°, by adjustment of the trimmer capacity, C_b. This permits a phase correction of $\pm 10°$ — usually sufficient to insure perfect phase balance of the signals applied to the tubes. No attempt is made to equalize the magnitudes of the signals in the grid circuits because it is almost too much to expect that a perfectly-balanced pair of tubes could be found in order to take advantage of balanced amplitudes. Instead, the function of amplitude balance is accomplished by means of a bias adjustment on one of the tubes of the pair, so that the carrier signals are balanced out in the plate circuit of the tubes. That, incidentally, is what must happen anyway, regardless of the method used. The picture is completed by applying push-pull modulating signals to the No. 3 grids so that the sidebands produced by the separate modulation processes in each tube add together in the common plate circuit. The audio-frequency component balances out in the plate and screen circuits, this being a case of a balanced modulator that balances against each of the input signals. However, slight unbalance of the audio-frequency signals does absolutely no harm in the particular application of this circuit, so no provision is made for balance adjustment at low audio frequencies.

TABLE III

Explanation of Fig. 6

Microphone preamplifier	Sufficient gain to bring microphone output to a voltage level of approx. 2 volts, peak-to-peak.
α, β	Phase-shift networks in accordance with Fig. 4. Two 6SL7GT tubes.
A.F. amplifier	Push-pull self-balancing amplifier with good phase and amplitude characteristics. Maximum output required approx. 2 volts, peak-to-peak.
Balanced Modulators 1 and 2	Two 6SA7 tubes (in each). See Fig. 7 for details.
Carrier phase-shifter, T_1	5-Mc. double-tuned transformer with push-pull output from each winding at low impedance. Output on each line 2 volts, peak-to-peak.
Carrier amplifier	6SJ7 tube.
T_2	5-Mc. double-tuned transformer.
Disabling switches	Bias controls for No. 3 grids of modulators. Can be ganged to permit s.s.s.c.–a.m.–p.m.
Carrier-level control	Bias control on grid No. 1 of carrier amplifier. Minus 10 volts to minus 3 volts range.
T_{3a}, T_{4a}	Bandpass double-tuned transformers to cover 75-meter 'phone band.
T_{3b}, T_{4b}	Bandpass double-tuned transformers to cover 20-meter 'phone band.
Frequency converter	6SA7 converter tube.
R.F. amplifier No. 1	6AK6 miniature beam tube. Operates as Class A amplifier.
R.F. amplifier No. 2	807 beam-power output tube. Can be operated as Class A or B amplifier.

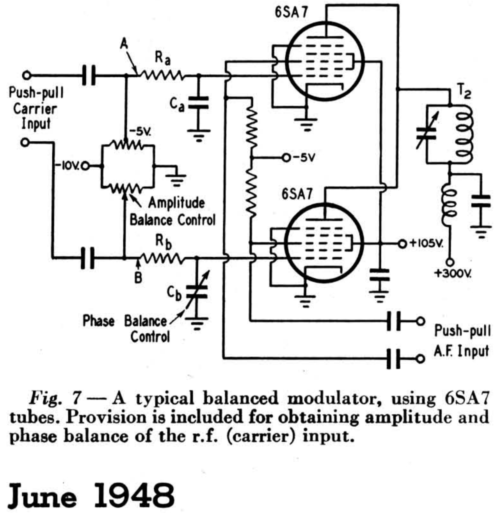

***Fig. 7* — A typical balanced modulator, using 6SA7 tubes. Provision is included for obtaining amplitude and phase balance of the r.f. (carrier) input.**

In any balanced modulator the efficiency is necessarily low, since at least one of the input signals is dissipated in the modulating elements or associated circuits. In the case of a balanced modulator that suppresses the carrier, the efficiency cannot possibly be greater than 50%. The efficiency obtained in practice is more like 5% to 10%. Where two balanced modulators are used (as in Fig. 6) the efficiency is still lower, since the unwanted sideband is dissipated. This situation leads to the choice of generating a single-sideband signal at very low power level where the inescapably low efficiency in the generation of the signal wastes no large amounts of power.

Good operating characteristics are obtained with 6SA7 tubes in this application when the No. 1 and No. 3 grids are supplied with maximum signals of about 1 to 2 volts peak-to-peak, at a bias of about 5 volts, negative. Other voltages are the same as recommended for converter service.

As in the case of the audio system, the radio-frequency circuits can employ receiving tubes of extremely modest ratings up to the point in the system where the signal levels reach the power-tube class. For instance, the r.f. portion of Fig. 6 up to the grid circuit of the output stage would somewhat resemble in over-all magnitude and construction the i.f. portion of an average communication receiver. The versatility of Fig. 6 should make it attractive, although some of this versatility is obtained at the expense of circuit complication not fundamentally a part of single-sideband operation. This is apparent when comparing Fig. 6 with Fig. 3.

Suppressed Carrier

The block diagram (Fig. 6) includes a carrier amplifier and carrier-level control for several good reasons. A really obvious one is that a.m. and p.m. signals *must* have a carrier, but the balanced modulators provide sidebands without carrier to the remainder of the system. In the case of a.m. or p.m. operation, the carrier amplifier supplies carrier of "reference" level to "hang the sidebands on." Although previous articles in *QST* [1,2,7,8] have emphasized that a carrier is "excess baggage" in single-sideband systems, it is good practice to transmit a small amount of carrier with the sideband to act as a pilot to aid the receiver in supplying carrier of the correct frequency. This has long been commercial practice and does not interfere in any measurable way with the effective power gain that single-sideband operation offers. In fact, the practical difficulty of taming at least three oscillators (one or more in the transmitter; two in the receiver) so that their combined relative frequency error is not more than about 50 cycles essentially demands that some automatic means be employed to aid in the task. Receivers can be built (and rather simply, too) with a carrier-locking arrangement that requires only a small amount of transmitted carrier to keep the locally-generated carrier absolutely synchronized with that from the transmitter. It has been found that a carrier level 20 db. below reference level (that's 26 db. below the peak output of the transmitter) is sufficient to accomplish this function very satisfactorily. If, for example, the peak power output of a single-sideband transmitter is 100 watts, only ¼ watt of carrier output is needed to overcome this stability problem. Indeed, very little "steam" is wasted in blowing this whistle!

Transmission of this amount of carrier does not interfere with using the b.f.o. in conventional receivers to supply the carrier, since the b.f.o. must be set so closely to this carrier frequency that no audible beat can be heard. In other words, completely-suppressed-carrier operation merely "implies" a carrier frequency, while 20-db.-attenuated-carrier "suggests" the carrier frequency and is a practical necessity for really satisfactory single-sideband operation.

Performance

A transmitter employing the principles presented in this article has been operated on the 14-Mc. 'phone band since February, 1948, with excellent results. Interesting comparisons have been made on many occasions between phase modulation, amplitude modulation and single-sideband — all at the same peak power. Almost universally, the reports of readability and QRM reduction indicate that single sideband really is worth something after all. Many interesting QSOs have been held under conditions that would make communication utterly impossible with amplitude modulation or phase modulation. The receiver employed is one that was converted for single-sideband operation, this playing no small part in the success of many of the contacts. The principle upon which the receiver operates will be described in a subsequent article.

Do we go to single-sideband? The equipment is simple enough; the rest is up to you.

About the Author

• Donald E. Norgaard, W2KUJ, ex-W5ABB-W5ARL, received his first ham ticket in 1931, culminating an interest first stirred up in 1928. An E.E. graduate of Rice Institute, he holds amateur Class A, radiotelegraph second-class, New York State professional engineer, and private aircraft pilot licenses. Although his present work as a research associate at the General Electric Co. keeps him quite busy, Don finds time to engage in amateur experimental work and rag-chewing on the 20-meter 'phone band — that is when he's not flying his Luscombe.

---

[7] B. Goodman, "What is Single-Sideband Telephony?" *QST*, January, 1948.

[8] O. G. Villard, jr., "Single-Sideband Operating Tests," *QST*, January, 1948.