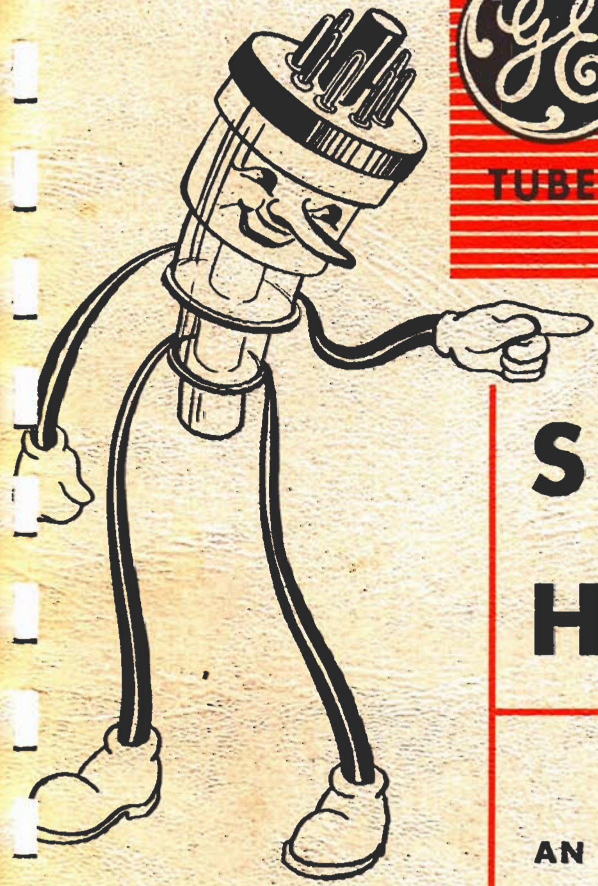
—Lighthouse Larry

TUBES

HAM NEWS



SIDEBAND HANDBOOK

First Edition

AN EDUCATIONAL PUBLICATION
OF
RECEIVING TUBE DEPARTMENT

GENERAL ELECTRIC
Owensboro, Kentucky

PRICE: $2.00 in U.S.A.
$2.50 Elsewhere

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INTRODUCTION

Interest by radio amateurs in single sideband and other suppressed-carrier transmission and reception techniques for voice communication has grown by leaps and bounds since some pioneering experiments were conducted by radio amateurs back in the 1940's.

And a large part of this pioneering happened right at *General Electric,* where scientists (who also were radio amateurs) at *General Electric's* world-famous Research Laboratory developed wide-band audio frequency phase-shift networks.

These patented networks made possible the generation of a single sideband, suppressed-carrier signal at high radio frequencies. They simplified the design of single sideband transmitters by eliminating additional circuits required to convert the SSB signal usually generated in a low frequency filter up to the operating frequency.

From this key research, the design and construction of simple phasing type projects which have been described in *G-E HAM NEWS* followed. These articles include the famous "SSB, Jr." 5-watt SSB transmitter; the "Signal Slicer" receiving adapter; and similar circuits. Our records show that thousands of radio amateurs constructed their first SSB equipment from the original *G-E HAM NEWS* designs.

And, again in the 1950's, pioneering work by radio amateurs at *General Electric* resulted in still more simplification of suppressed-carrier transmitters by using the double sideband techniques evolved from synchronous communications studies made by *General Electric.*

All of this wealth of background material from *G-E HAM NEWS* has been reprinted in this first edition of *Lighthouse Larry's Sideband Handbook.* In addition, later information on many of the articles on sideband has been compiled and follows the reprints of the original articles.

We've also included some key articles on subjects related to sideband in this handbook, such as linear amplifiers, RF and audio accessories, and power supplies. Especially noteworthy is the original *G-E HAM NEWS* articles on Dynamic Power Supply Regulation which prompted more radio amateurs to use high-capacitance filter.

We dedicate this book to the radio amateurs who have pioneered and furthered suppressed-carrier communications techniques. And, at *G-E HAM NEWS,* we're proud of our small part in making sideband in amateur radio a success.

73,

—*Lighthouse Larry*

ARTICLES

CHAPTER VII AUDIO ACCESSORIES FOR SIDEBAND

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TUBES

HAM NEWS

presents **HOW-TO-DO-IT IDEAS**
from the 999 radio amateurs at
GENERAL ELECTRIC

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CHAPTER I—
HETRODYNING AND MIXING

What About Mixed Circuits? From November-December, 1956

Mixers (modulators) can have simple or complex, single-ended or push-pull (balanced) circuitry, operate at low or high level, and employ diodes or multi-element tubes. A single-ended diode mixer (the circuit used in most UHF television tuners) and the balanced diode mixer (two of them are used in the SSB, Jr.) are more foolproof than multi-element tube mixers, but no power gain can be obtained, and the diode mixer is likely to have high harmonic output. This is the price of simplicity plus low distortion in the output signal.

Although a triode tube may be used as a mixer, both input signals must be applied to the control grid, or to the control grid and cathode, respectively. Even though generation of harmonics in a triode mixer is apt to be lower than in a diode circuit, the operating conditions must be carefully controlled to avoid distortion of the output signal. This applies equally to pentodes and the multi-grid tubes designed especially for mixer service in superheterodyne radio receivers. Mixer circuits for these tubes usually feed each mixer input signal into a separate grid, where the signals are combined in the tube's electron stream. A circuit tuned to the desired output signal frequency is connected to the tube's plate. Each of the mixer tube's input signal grids should operate in the Class A region for lowest harmonic output, since the amplitude of input signal harmonics *generated* in the mixer depends on the operating point and amplitude of the input signals. Even though a pentagrid mixer stage requires critical adjustment for minimum distortion, it will have a lower harmonic output when properly adjusted than the other types of mixers.

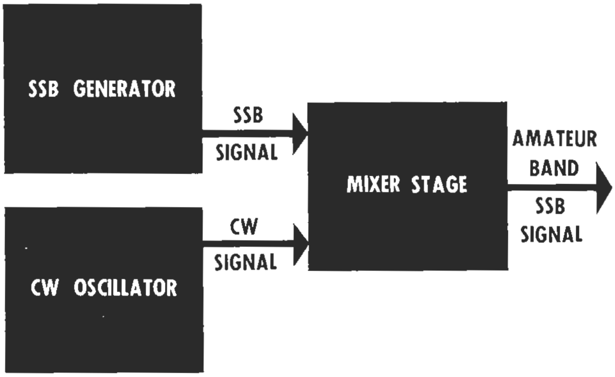
Since normal Class A amplifier efficiency is only 25—30 per cent, and that of a Class A mixer is even lower, much of a properly operated mixer tube's input power is dissipated instead of appearing as output power. For this reason, a high-level mixer tube will have much lower power output than the same tube in a linear amplifier. Even the minute power output from a low-level mixer stage can be brought up to a respectable level in one high gain linear amplifier stage.

Even though single-ended mixer circuits are widely used, the balanced mixer circuit offers the inherent advantage of cancelling the fundamental and certain harmonics of at least one, and possibly both, input signals. Usually this type of mixer can be precisely balanced for maximum attenuation of the fundamental or a particular harmonic of either input signal, but not all simultaneously. In general, a properly operated balanced mixer using pentagrid tubes will have low harmonic generation properties, but other mixers will not, whether balanced or otherwise.

The actual circuitry for a pentagrid balanced mixer may have both pairs of input signal grids connected to separate push-pull tank circuits, with the tube plates connected in parallel to a single-ended tuned circuit, or one pair of grids may be connected in push-pull, the other pair of signal grids in parallel, and the plates connected to a push-pull tank circuit. The mixer input signal on which cancellation is desired should be applied to the signal grids through the push-pull tank circuit. However, under certain conditions, it is possible to cancel out the desired output signal!

Any balanced mixer may become unbalanced due to component aging and operating voltage changes, so a mixer balancing adjustment should be provided in the circuit. Finally, the pentagrid tube balanced mixer circuit may help reduce those spurious signals which cannot be readily attenuated with special trap circuits, or by depending on the skirt selectivity of cascaded tuned circuits at the mixer output frequency.

THE MIX-SELECTOR CHART



Watch your signals when designing that new multi-band SSB exciter or heterodyne-type VFO for your present CW or AM transmitter. Our MIX-SELECTOR chart explains why signal frequencies employed in heterodyning must be carefully selected to avoid the transmission of spurious signals along with your desired signal. Examine our typical signal combination examples—then try working out your own ideas on logarithmic graph paper!

Single Sideband Background

The rapidly increasing interest in single-sideband transmission and reception on the amateur bands focuses attention on the basic differences between single-sideband suppressed carrier transmitters and the old more conventional RF system used in CW and AM transmitters. A simplified block diagram of the usual AM or CW rig, Fig. 1, shows the RF tube lineup starting with an oscillator, often followed by buffer or harmonic amplifiers which then drive one or more amplifier stages at the output frequency. Modulation usually is applied to the final RF amplifier stage in one of several ways which differ mainly in the amount of audio power required for the modulation process.

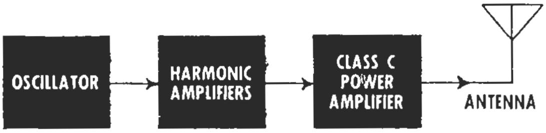


Fig. 1. Block diagram of a typical multi-stage transmitter to which a CW or AM system may be connected.

GENERATING SINGLE SIDEBAND SIGNALS

What are the "sidebands" usually associated with voice modulation of a transmitter? Basically, they are groups of radio frequencies which result from mixing (or modulating) a fixed radio frequency signal with one or more audio signal frequencies. These signals add to and subtract from the fixed frequency to form the above-mentioned groups of closely related radio frequency signals both lower and higher than the fixed frequency. The number of individual signals present in both sets of sidebands at any one time depends upon the number of individual signal frequencies present in the modulating signal.

Probing the mysteries of present-day single-sideband techniques brings forth a multitude of other terms such as: sideband filter, phase-shift network, balanced modulator—etc. Understanding single sideband is further complicated by mention of two systems of generating a single-sideband-suppressed-carrier signal (which we will call SSB in the balance of this discussion): (1) the filter system, and (2) the phasing system.

In both systems, SSB signals are derived from amplitude-modulated signals. In the filter system, an amplitude-modulated signal is passed through a filter which attenuates one of the two sets of sidebands characteristic of amplitude modulation. The phasing system consists of two amplitude-modulated systems combined in such a manner that one set of sidebands is reinforced while the other is cancelled. In either system, it is customary to balance out the so-called carrier from a signal that would otherwise be a completely standard amplitude-modulated signal. When properly adjusted, both systems will deliver the same type of output signal.

Obviously, the filter requirements in that system are quite strict, since all desired signals in one set of side frequencies must be passed, yet the signals appearing in the unwanted set of side frequencies should be attenuated at least 30 db (1000 to 1 in power) or more. The required order of filter selectivity is most easily achieved at frequencies below 500 kilocycles. Thus, many filter-type SSB amateur transmitters now on the air have the SSB generator circuits operating on 450 kilocycles, using either a mechanical filter, or a lattice-type filter made from quartz crystals.

In the phasing system, the signal can be generated at any desired output frequency, but it is inconvenient to change frequency easily. In fact, it is difficult—that is, cumbersome and expensive—to generate an SSB signal at a number of chosen frequencies and select one by bandswitching with either system.

A further limitation in obtaining an SSB output signal on several amateur bands in both filter and phasing systems is that harmonics of the SSB generator cannot be used. The reason is that frequency multiplication depends upon non-linear operation of the multiplier stage, and such operation introduces intolerable distortion to a signal whose character is already established, such as an AM or SSB signal.

We now have indicated, first, that components are not readily available for a filter-type SSB generator designed to operate directly on an amateur band; second, that the phasing system can be used at any desired narrow band of frequencies, but does not lend itself to convenient bandswitching; and third, that harmonics of the SSB generator signal cannot be used.

The really practical solution to the band-changing and adjustable-frequency SSB generator problem, for the home constructor, is to employ the same principle used in superheterodyne receivers. That process is to heterodyne an SSB generator signal, which may be outside the amateur bands, to the desired amateur frequency. The block diagram on page 1 shows the two signal generating stages connected to a mixer stage.

FREQUENCY CONVERSION

Frequency conversion, also known as heterodyning, is simply a process of combining two signals of different frequency to form two new additional signals having frequencies which are, respectively, the sum and the difference of the two original signal frequencies. The circuit in which heterodyning takes place is usually called a mixer, converter or modulator. (They are essentially the same thing.)

There are many types of mixer circuits, but most will generate harmonics of both frequencies being applied to them even though the harmonic content of the input signals is very low. Thus, many signal frequencies can be present in the output of a mixer stage—the two input signals, their sum and difference signals, and the harmonics of both input signals.

All signals except the one desired output signal frequency must be considered as spurious signals. Therefore adequate precautionary measures must be taken to prevent these spurious signals from appearing in the transmitter output.

An important step to ensure adequate suppression of spurious signals is to have at least two high-selectivity tuned circuits resonant at the desired output frequency in the stages following the mixer circuit. If each of these tuned circuits has a "Q" of 100, spurious signals which are 10 per cent lower or higher in frequency than the mixer output signal will be attenuated more than 50 db (100,000 to 1 in power). Spurious signals within 10 per cent of the output signal frequency will be attenuated much less. Practically speaking, neither of the mixer input signal frequencies nor their harmonics should fall within this 20-percent range or they may appear along with the output signal to an appreciable extent.

Since it already has been pointed out that most mixer circuits will generate harmonics of the input signals, these harmonic frequencies also should not fall within 10 per cent of the desired mixer output signal frequency. Ideally, the best way to avoid spurious signals resulting from harmonics of the input signals is to place both mixer input signal frequencies higher than the output signal frequency. This cannot always be done, especially when converting the output from a filter-type SSB generator, which usually operates below 500 kilocycles, to the assigned amateur frequencies.

Since the phasing-type SSB generator operating frequency is not similarly restricted, the signal may be placed higher in frequency than the amateur band on which output is desired. In practice, this is not strictly followed, since an SSB generator signal frequency in the 3.8- to 10-megacycle range is usually chosen for 14-, 21- and 28-megacycle transmitters.

USING THE MIX-SELECTOR CHART

We hope the old saying, "One picture is worth ten thousand words," applies equally to the MIX-SELECTOR chart on pages 4 and 5. However, a brief line-by-line explanation will be given to clarify these typical examples of signal frequencies used in heterodyne-type SSB exciters.

The "LEGEND" on page 5 pictures the marks used for identifying mixer input and output signals as follows: Fixed frequency input signals are shown as narrow vertical black lines. Second, variable frequency mixer input signals are shown as black blocks whose width is indicative of the frequency range covered. Each fundamental frequency signal is identified with a figure "1," and the harmonics by numbers representing their order. The height of the lines and blocks decreases as the harmonic order increases to illustrate the decreasing relative importance of the higher order harmonics as spurious signals.

Frequencies from 1.5 to 60 megacycles are numbered on line 1 and indicated by vertical lines running down the chart. This frequency span covers most amateur bands on which SSB techniques presently are employed. The U.S. amateur radiotelephone segments in each amateur band are identified by the solid black blocks on line 2, which then are carried down the chart in grey shaded bands.

The FEEDTHRU DANGER ZONE, previously described under FREQUENCY CONVERSION, is marked by the pink areas beginning at line 3 and running down on either side of each amateur 'phone band segment. The left margin of each pink area is considered to be 10 per cent lower in frequency than each 'phone band lower edge, and the right pink margin represents a frequency 10 per cent higher than the upper limit of the same 'phone segment. Of course these danger zones apply only to the amateur band on which the desired mixer output signal is shown, for each horizontal listing on the chart.

FILTER-TYPE SSB GENERATOR FREQUENCIES

Line 4 shows the harmonic signals of a 0.45-megacycle filter-type SSB generator, beginning at 1.8 megacycles with its fourth harmonic. The 0.45-megacycle signal frequency must be heterodyned to the amateur bands to be useful. Suppose it is desired to operate in the 1.8–2.0 megacycle band with a 0.45-megacycle filter-type SSB generator signal. A difference frequency mixer output signal can be obtained by operating the other mixer input signal range at 2.25–2.45 megacycles, as shown by the solid black block marked "1" on line 5. Notice that the SSB generator fourth harmonic signal at 1.8 megacycles is within the feedthrough danger zone and may appear in the mixer output. The strength of this spurious signal will depend upon the type of mixer circuit used. It is clear that a mixer having extremely low harmonic output is necessary to avoid troublesome effects caused by the fourth harmonic generated within the mixer. The high selectivity tuned circuits which should follow the mixer stage for the purpose of attenuating the 2.25–2.45-megacycle signal also will attenuate the higher order harmonics shown by the other black blocks marked "2," "3," "4" and "5" on line 5.

When a mixer output signal in the 3.8–4.0-megacycle range is desired, a heterodyning signal either lower (3.35–3.55 megacycles) or higher (4.25–4.45 megacycles) may be used, as shown in lines 6 and 7, respectively. Note that both heterodyning signal ranges (the black blocks marked "1" on lines 6 and 7) fall partly within the feedthrough danger zone of 3.4–4.4 megacycles. Attenuating these adjustable frequency signals with a trap circuit is more difficult than trapping out a fixed frequency, since one tuning adjustment of the trap probably will not be effective over the entire range. In this case a balanced mixer which cancels the variable frequency mixing signal would be desirable.

Since the heterodyning signals mentioned thus far permit operation on only two bands, the practice followed in many filter-type SSB exciters is to again heterodyne the 3.8–4.0-megacycle SSB signal described in lines 6 and 7 to the other amateur bands in a second mixer stage. A block diagram of a typical double conversion SSB exciter is shown in Fig. 2. This variable SSB signal frequency, its spurious signals and harmonics must now be considered as an input signal to the second mixer, as plotted on line 8. If an output signal from the second mixer in the 1.8–2.0-megacycle range is again desired, a fixed frequency signal of either 2.0 or 5.8 megacycles also should be used to mix with the 3.8–4.0-megacycle SSB generator signal. A 2.0-megacycle signal would be a poor choice, since it falls within the feedthrough danger zone, but line 9 on the chart shows that the 5.8-megacycle input signal is satisfactory.

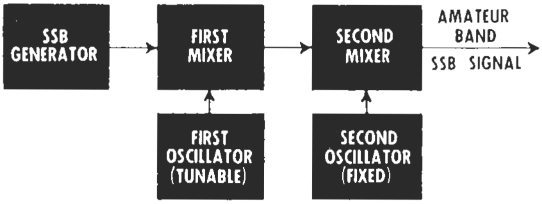


Fig. 2. Block diagram of a double-conversion SSB exciter. High-selectivity tuned circuits should immediately follow both first and second mixer stages to avoid transmitting spurious signals from either mixer.

For a second mixer output signal on 7.2–7.3 megacycles, the second harmonic signal of the SSB generator, 7.6–8.0 megacycles, falls within the feedthrough danger zone. This also happens with the second harmonic of a 3.3-megacycle mixing signal shown in line 10. One spurious signal can be avoided by choosing 11.1 megacycles, on line 11, for a mixing signal frequency instead. As before, a mixer which does not generate harmonics is necessary. On line 12, the fourth harmonic of the SSB generator signal falls within the danger zone for 14.2–14.3-megacycle second mixer output, but the 10.3-megacycle mixing signal should not prove troublesome.

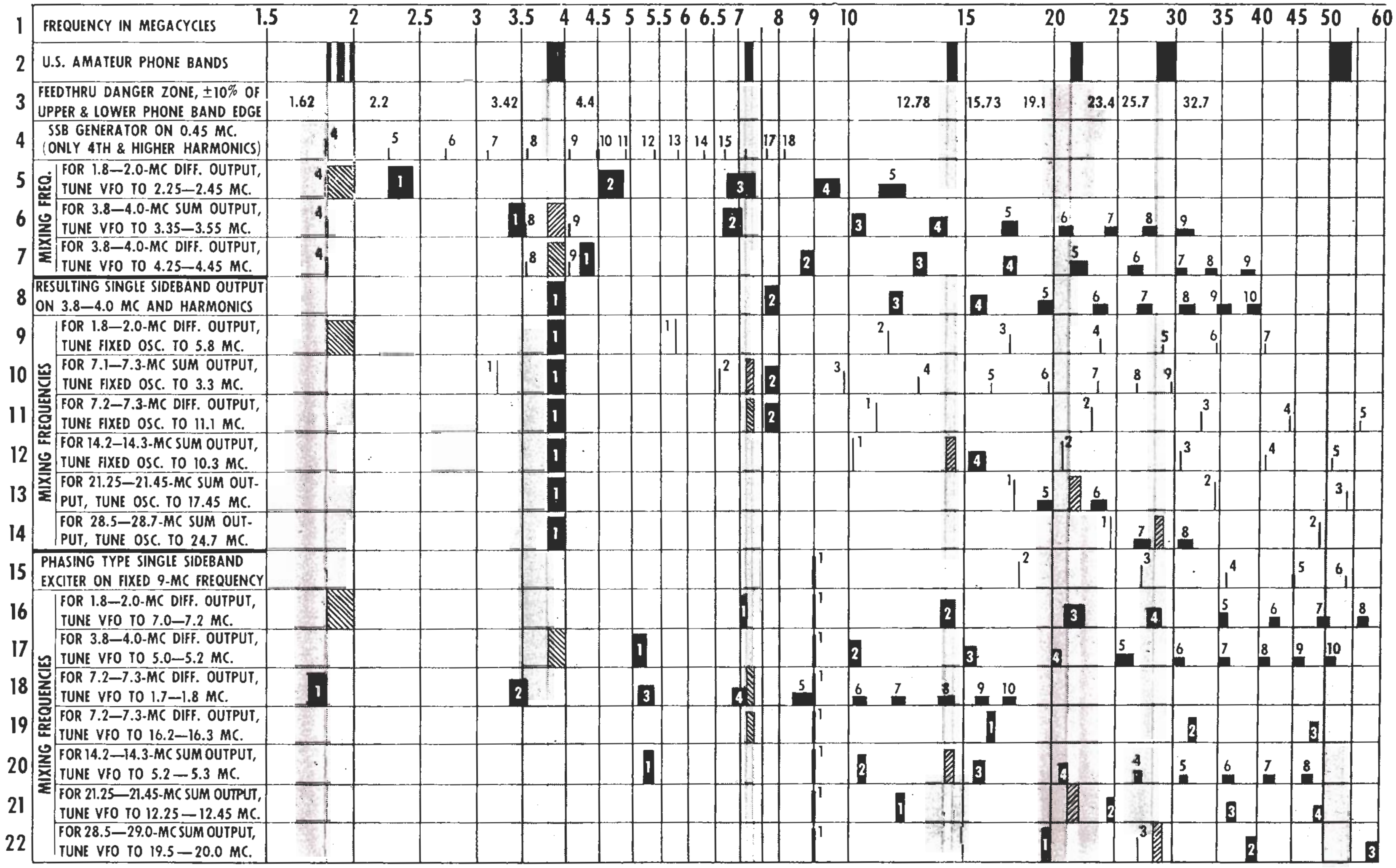
As indicated on line 13, the fifth and sixth harmonics of the SSB generator signal will fall within the feedthrough danger zone when a second mixer output signal on 21.25–21.45 megacycles is desired. However, the 17.45-megacycle mixing signal required for this output signal frequency is well outside the danger zone. Again, when an SSB signal at 28.5 megacycles is required, as shown on line 14, the seventh and eighth harmonics of the SSB generator signal may appear in the second mixer output. The 24.7-megacycle mixing signal appears to be a safe choice. All the foregoing examples indicate that a mixer which has very low harmonic output, plus a balanced type in some cases, should be chosen.

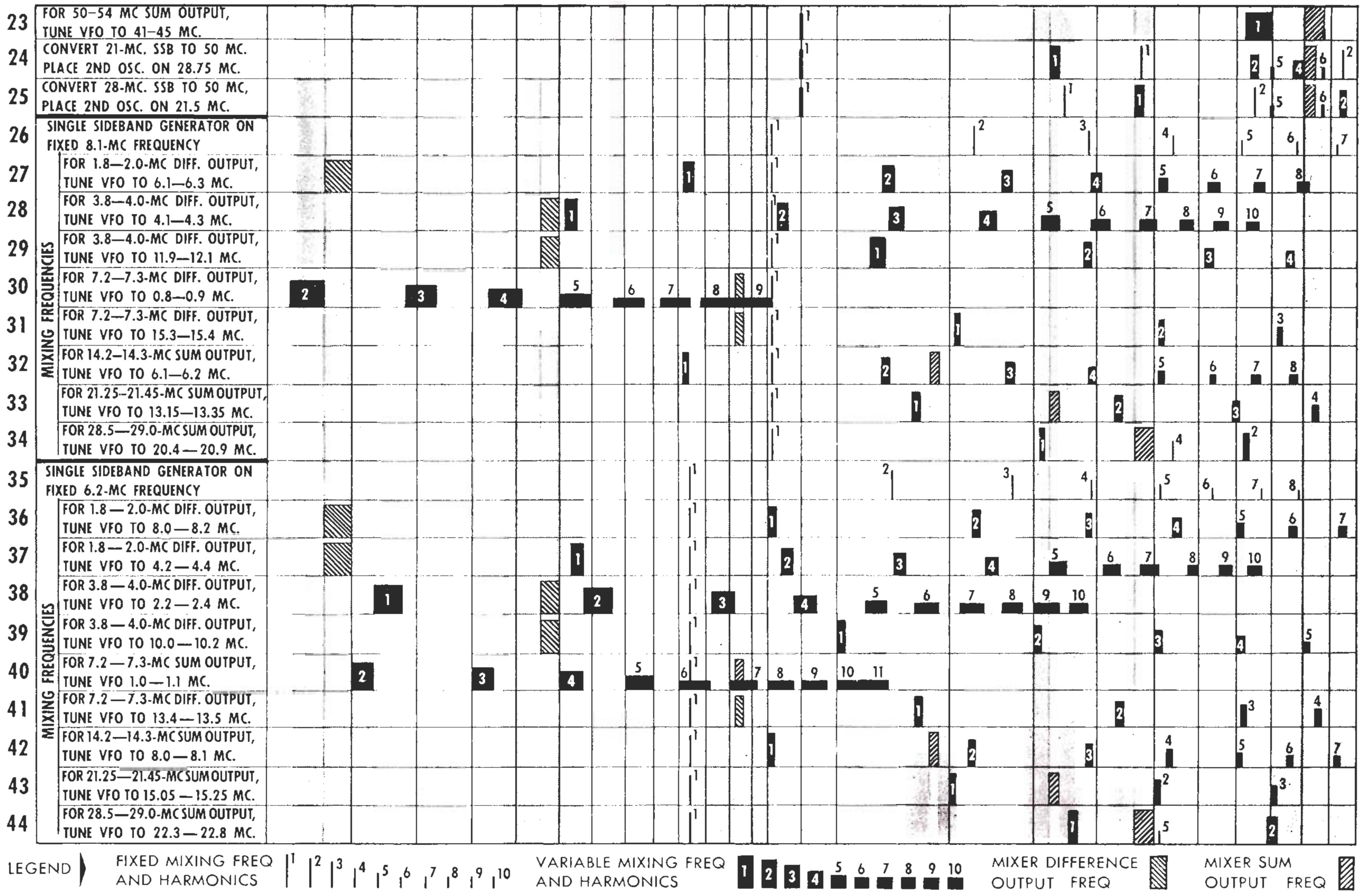
THE 9-MEGACYCLE PHASING-TYPE SSB GENERATOR

A common practice when designing a phasing-type all-band SSB exciter is to choose an SSB generator signal frequency which permits the same mixing signal frequency range to be used for a mixer output signal on either of two bands. But, this is not the primary consideration, since a frequency whose harmonics fall outside the feedthrough danger zones of any desired operating band should be chosen. The widely-used 9-megacycle SSB generator signal frequency is good, but has certain disadvantages. Line 15 on the chart shows that the third harmonic, at 27 megacycles, falls within the danger zone when a mixer output signal in the 28-megacycle band is desired. Again, suitable mixer design is necessary to reduce the severity of this spurious signal.

(Continued on page I-10)

MIX-SELECTOR CHART




23 FOR 50–54 MC SUM OUTPUT, TUNE VFO TO 41–45 MC.
24 CONVERT 21-MC. SSB TO 50 MC. PLACE 2ND OSC. ON 28.75 MC.
25 CONVERT 28-MC. SSB TO 50 MC, PLACE 2ND OSC. ON 21.5 MC.
26 SINGLE SIDEBAND GENERATOR ON FIXED 8.1-MC FREQUENCY
MIXING FREQUENCIES
27 FOR 1.8—2.0-MC DIFF. OUTPUT, TUNE VFO TO 6.1—6.3 MC.
28 FOR 3.8—4.0-MC DIFF. OUTPUT, TUNE VFO TO 4.1—4.3 MC.
29 FOR 3.8—4.0-MC DIFF. OUTPUT, TUNE VFO TO 11.9—12.1 MC.
30 FOR 7.2—7.3-MC DIFF. OUTPUT, TUNE VFO TO 0.8—0.9 MC.
31 FOR 7.2—7.3-MC DIFF. OUTPUT, TUNE VFO TO 15.3—15.4 MC.
32 FOR 14.2—14.3-MC SUM OUTPUT, TUNE VFO TO 6.1—6.2 MC.
33 FOR 21.25–21.45-MC SUM OUTPUT, TUNE VFO TO 13.15—13.35 MC.
34 FOR 28.5—29.0-MC SUM OUTPUT, TUNE VFO TO 20.4—20.9 MC.
35 SINGLE SIDEBAND GENERATOR ON FIXED 6.2-MC FREQUENCY
MIXING FREQUENCIES
36 FOR 1.8—2.0-MC DIFF. OUTPUT, TUNE VFO TO 8.0—8.2 MC.
37 FOR 1.8—2.0-MC DIFF. OUTPUT, TUNE VFO TO 4.2—4.4 MC.
38 FOR 3.8—4.0-MC DIFF. OUTPUT, TUNE VFO TO 2.2—2.4 MC.
39 FOR 3.8—4.0-MC DIFF. OUTPUT, TUNE VFO TO 10.0—10.2 MC.
40 FOR 7.2—7.3-MC SUM OUTPUT, TUNE VFO 1.0—1.1 MC.
41 FOR 7.2—7.3-MC DIFF. OUTPUT, TUNE VFO TO 13.4—13.5 MC.
42 FOR 14.2—14.3-MC SUM OUTPUT, TUNE VFO TO 8.0—8.1 MC.
43 FOR 21.25—21.45-MC SUM OUTPUT, TUNE VFO TO 15.05—15.25 MC.
44 FOR 28.5—29.0-MC SUM OUTPUT, TUNE VFO TO 22.3—22.8 MC.
LEGEND
FIXED MIXING FREQ AND HARMONICS 1 2 3 4 5 6 7 8 9 10
VARIABLE MIXING FREQ AND HARMONICS 1 2 3 4 5 6 7 8 9 10
MIXER DIFFERENCE OUTPUT FREQ
MIXER SUM OUTPUT FREQ

(Continued from page I-7)

A variable frequency oscillator must be used with this fixed SSB generator signal if an adjustable frequency mixer output signal is desired for the amateur bands. The VFO tuning ranges required for mixer output on 1.8—2.0 and 3.8—4.0 megacycles (7.0—7.2 and 5.0—5.2 megacycles, respectively) are shown on lines 16 and 17. These two examples both illustrate the desirable feature of having both mixer input signals higher in frequency than the output signal.

Two possible mixer input signal combinations for 7.2—7.3-megacycle mixer output are shown on lines 18 and 19. Note that the fourth harmonic of the 1.7—1.8-megacycle VFO signal on line 18 falls within the danger zone, so the 16.2—16.3-megacycle VFO range is a better choice. For a 14.2—14.3-megacycle mixer output signal on line 20, the VFO tuning range of 5.2—5.3 megacycles may be used. However, the VFO third harmonic signal at 15.6—15.9 megacycles is within the feedthrough danger zone. A trap circuit in the mixer output to attenuate this spurious signal is included in one type of commercial SSB exciter. Note that lines 17 and 20 are typical examples of getting two-band operation with one VFO signal range.

The mixer input signals required for 21.25—21.45 and 28.5—29.0-megacycle mixer sum output signals (12.25—12.45 and 19.5—20.0 megacycles, respectively) shown on lines 21 and 22 present no special problems. Or, VFO signals in the 30.25—30.45 and 37.5—38.0-megacycle ranges, respectively, may be used for mixer output on these bands if the stability of the higher frequency VFO is adequate. This problem is even greater when a 50-megacycle mixer output signal is desired. A VFO range of 41—45 megacycles is then required, as shown on line 23.

Methods of obtaining a 50-megacycle SSB output signal are shown on chart lines 24 and 25. A variable frequency SSB exciter having output on the 21- or 28-megacycle bands may be fed into a second mixer stage from which the 50-megacycle signal is obtained. On line 24, a signal on 28.75 megacycles, and the SSB exciter signal on 21.25—21.45 megacycles are mixed to obtain a 50.0—50.2-megacycle mixer output signal.

On line 25, an SSB exciter output signal in the 28.5—29.0-megacycle range is mixed with a 21.5-megacycle signal to obtain a 50—50.5-megacycle SSB output signal from the second mixer. Fewer spurious signal difficulties may be experienced with this combination. All signals which are involved in a double-heterodyning transmitter should in themselves be free of spurious signals. If not, a pyramiding of spurious signals is possible at the output of the second conversion stage.

OTHER PHASING SSB GENERATOR FREQUENCIES

The third harmonic of the SSB generator in the 9-megacycle range, shown on line 15 at 27 megacycles, may be shifted so that it falls between the feedthrough danger zones for the 21- and 28-megacycle amateur bands by selecting a lower SSB generator frequency around 8 megacycles. The chart shows a good example on line 26, 8.1 megacycles, which has only the fourth harmonic falling at the upper edge of the 29.7-megacycle danger zone. This particular frequency permits a common VFO tuning range to be used for 1.8—2.0 (line 27) and 14.2—14.3-megacycle (line 32) mixer output signals. Two choices are shown for a 3.8—4.0-megacycle mixer output signal. The 4.1—4.3-megacycle VFO tuning range on line 28 falls within the danger zone, so the 11.9—12.1-megacycle range on line 29 is better.

Look what happens when a low-frequency VFO tuning range (0.7—0.8 megacycles on line 30) is used for a mixer output signal in the 7.2—7.3-megacycle band! The VFO eighth and ninth harmonics both land in the mixer output range, requiring excellent mixer design to avoid almost certain trouble from spurious signals. Placing the VFO range at 15.3—15.4 megacycles, as shown on line 31, avoids this problem. The two VFO tuning ranges required for sum mixer output signals in the 21.25- and 28.5-megacycle bands are illustrated on lines 33 and 34. Output in the 50-megacycle band may be obtained with double conversion signal combinations similar to those shown on lines 24 and 25.

Most SSB generator signal frequencies below 5 megacycles will have harmonics falling within several feedthrough danger zones. But, by going a bit higher in frequency, to the 6.2—6.5-megacycle range, all lower order harmonics except the fifth are in the clear. A frequency of 6.2 megacycles (line 35) enables the same VFO tuning range (8.0—8.2 megacycles) to be used for mixer output signals on 1.8—2.0 megacycles (line 36) and 14.2—14.3 megacycles (line 42). An alternate VFO tuning range (4.0—4.2 megacycles) for 1.8—2.0-megacycle output is shown on line 37.

When shooting for a mixer output signal on 3.8—4.0 megacycles, VFO tuning ranges of either 2.2—2.4 megacycles (line 38) or 10.0—10.2 megacycles (line 39) present no stubborn problems. Careful alignment of the high "Q" tuned circuits following the mixer is necessary to prevent the second harmonic of the 2.2—2.4-megacycle VFO range from feeding through. A 7.2—7.3-megacycle mixer output signal may be obtained by combining the 6.2-megacycle SSB generator signal with either a 1.0—1.1-megacycle (line 40) or a 13.4—13.5-megacycle (line 41) VFO signal. However, as a 1.0—1.1-megacycle VFO is tuned through its range, the sixth harmonic signal will cross the SSB generator signal, and the seventh harmonic will cross the mixer output signal. Obviously, this combination is an excellent spurious output signal or "birdie" generator, so the 13.4—13.5-megacycle VFO signal is preferable.

The sum mixer output signals on both the 21.25- and 28.5-megacycle bands may be obtained with VFO tuning ranges of 15.05—15.25 (line 43) and 22.3—22.8 (line 44) megacycles, respectively. The only special precaution necessary with the signal combinations listed on lines 36 to 44 is a trap circuit to attenuate the fifth harmonic of the SSB generator signal on 31 megacycles, when operating the exciter on the 28.5-megacycle band.

DO IT YOURSELF SUGGESTIONS

Although other SSB generator signal frequencies may be used, choice of one of the following frequency ranges is suggested for the SSB generator when designing an all-band exciter with a minimum of spurious signals resulting from harmonics of the SSB generator signal: 6.2—6.5, 8.1—8.5, 11.7—12.7, 16.5—19.0, 23.5—25.5 and 33—45 megacycles.

What about a system in which the VFO signal is fed into a harmonic amplifier, and the resulting second, third, or fourth harmonic is used as the heterodyning signal in the mixer stage? This can lead to more complications from spurious signals than a double conversion system. In addition, it multiplies any VFO frequency drift by the same factor as the harmonic. Generally speaking, the double conversion system is preferable when a variable frequency mixer input signal higher than 10 megacycles is required to obtain a mixer output signal in the 7-, 21-, 28-, and 50-megacycle bands.

You can figure out your own SSB exciter signal frequency combinations by: (1) plotting the fundamental and harmonics of a tentative SSB generator frequency on graph paper; (2) plotting the VFO tuning ranges for obtaining output on each amateur band; and (3) filling in the harmonics of each VFO tuning range to see whether they fall within the feedthrough danger zone for the band on which the mixer output signal appears. If this happens, the SSB generator frequency may be shifted, then new VFO tuning ranges plotted which will miss the danger zones. Often, an SSB generator signal frequency may be found which permits the same VFO tuning range to be used on two bands. However, if you find a combination which produces a mixer output signal on **four** bands with only two VFO tuning ranges, then you've really hit the jackpot!

GE ELECTRONICS

USING THE G-E 6AR8 SHEET BEAM TUBE

In Balanced Modulator, Synchronous Detector and Burst Gate Applications

DESCRIPTION AND RATING

The G-E 6AR8 sheet beam tube has attracted much attention for balanced modulator applications. It has the ability to perform mixing action of two input signals and cancel them in the output to provide an output signal equal to their sum or difference frequencies. Complete technical information is repeated on these pages, along with typical circuits in which radio amateurs have expressed an interest.

GENERAL

Cathode—Coated Unipotential

Heater Voltage, AC or DC	6.3	Volts
Heater Current	0.3	Amperes

Envelope—T-6½, Glass
Base—E9-1, Small Button 9-Pin
Mounting Position—Any

Direct Interelectrode Capacitances, approximate*

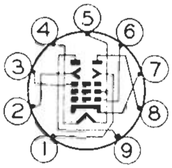
Deflector-Number 1 to All	4.8	μμf
Deflector-Number 2 to All	4.8	μμf
Grid-Number 1 to All Except Plates	7.5	μμf
Plate-Number 1 to All	5.0	μμf
Plate-Number 2 to All	5.0	μμf
Grid-Number 1 to Deflector-Number 1, maximum	0.040	μμf
Grid-Number 1 to Deflector-Number 2, maximum	0.060	μμf
Plate-Number 1 to Plate-Number 2	0.4	μμf
Deflector-Number 1 to Deflector-Number 2	0.38	μμf

MAXIMUM RATINGS

DESIGN-CENTER VALUES

Plate-Number 1 Voltage	300	Volts
Plate-Number 2 Voltage	300	Volts
Accelerator Voltage	300	Volts
Peak Positive Deflector-Number 1 Voltage	150	Volts
Peak Negative Deflector-Number 1 Voltage	150	Volts
Peak Positive Deflector-Number 2 Voltage	150	Volts
Peak Negative Deflector-Number 2 Voltage	150	Volts
Positive DC Grid-Number 1 Voltage	0	Volts
Plate-Number 1 Dissipation	2.0	Watts
Plate-Number 2 Dissipation	2.0	Watts
DC Cathode Current	30	Milliamperes
Grid-Number 1 Circuit Resistance		
With Fixed Bias	0.1	Megohms
With Cathode Bias	0.25	Megohms

BASING DIAGRAM

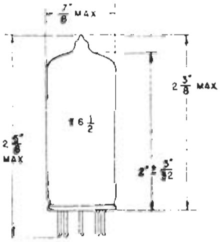


RETMA 9DP
BOTTOM VIEW

TERMINAL CONNECTIONS

Pin 1—Deflector Number 2
Pin 2—Deflector Number 1
Pin 3—Accelerator
Pin 4—Heater
Pin 5—Heater, Internal Shield, and Focus Electrodes†
Pin 6—Grid Number 1 (Control Grid)
Pin 7—Cathode
Pin 8—Plate Number 2
Pin 9—Plate Number 1

PHYSICAL DIMENSIONS



RETMA 6-3

CHARACTERISTICS AND TYPICAL OPERATION

AVERAGE CHARACTERISTICS WITH DEFLECTORS GROUNDED

Plate-Number 1 Voltage	250	Volts
Plate-Number 2, Connected to Plate-Number 1		
Accelerator Voltage	250	Volts
Deflector-Number 1 Voltage	0	Volts
Deflector-Number 2 Voltage	0	Volts
Cathode-Bias Resistor	300	Ohms
Total Plate Current	10	Milliamperes
Accelerator Current	0.4	Milliamperes
Grid-Number 1 Transconductance	4000	Micromhos
Grid-Number 1 Voltage, approximate I_b (total) $= 10$ Microamperes	−14	Volts

AVERAGE DEFLECTOR CHARACTERISTICS

Plate-Number 1 Voltage	250	Volts
Plate-Number 2 Voltage	250	Volts
Accelerator Voltage	250	Volts
Cathode-Bias Resistor	300	Ohms
Deflector Switching Voltage, maximum‡	20	Volts
Deflector-Bias Voltage for Minimum Deflector Switching Voltage‡	−8	Volts
Voltage Difference between Deflectors for $I_{b1}=I_{b2}$, approximate	0	Volts
Plate-Number 1 Current, maximum $E_{d1} = -15$ Volts, $E_{d2} = +15$ Volts	1.0	Milliamperes
Plate-Number 2 Current, maximum $E_{d1} = +15$ Volts, $E_{d2} = -15$ Volts	1.0	Milliamperes
Deflector-Number 1 Current, maximum $E_{d1} = +25$ Volts, $E_{d2} = -25$ Volts	0.5	Milliamperes
Deflector-Number 2 Current, maximum $E_{d1} = -25$ Volts, $E_{d2} = +25$ Volts	0.5	Milliamperes

* Without external shield.

† Pin 5 should be connected directly to ground.

‡ Deflector switching voltage is defined as the total voltage change on either deflector with an equal and opposite change on the other deflector required to switch the plate current from one plate to the other.

Note: The 6AR8 should be so located in the receiver that it is not subjected to stray magnetic fields.

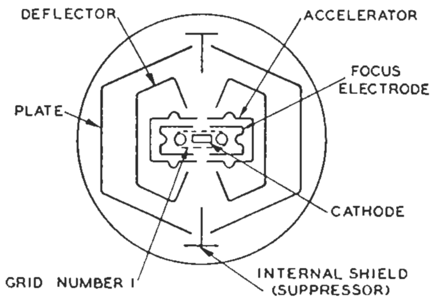


Fig. 1 CROSS-SECTION SCHEMATIC DIAGRAM OF THE 6AR8

OPERATING CONSIDERATIONS FOR THE 6AR8

A cross-section schematic diagram of the construction of the 6AR8 is shown. In this tube, the electrons pass from the cathode to either of the two plates in the form of a planar beam or "sheet." Before the electron stream emerges from the openings in the accelerator structure, it is acted on by the focus electrodes and the control grid. The focus electrode tends to converge the electrons into the required sheet beam, while the conventional grid-number 1 structure which surrounds the cathode serves to control the intensity of the beam.

Between the accelerator and the plates the electron beam passes between the deflector electrodes. Depending on the voltages applied to the deflectors, the beam will be directed entirely to either one or the other of the two plates or proportioned between them. The internal shield, located between the two plates, acts to suppress the interchange of secondary-emission electrons between the plates. The suppressor and the focus electrodes are internally connected to one side of the heater.

In normal operation, positive d-c voltages are applied to the accelerator and plates, and signal voltages are applied to the deflectors and control grid. The frequency of the signal applied to the deflectors determines the rate at which the plate current is switched between the two plates; the grid-number 1 voltage varies the magnitude of the plate current. The interesting tube characteristics which result from the unique construction of the 6AR8 are indicated by the average tube characteristic curves which follow. The tube may be considered as equivalent to a voltage-controlled single-pole double-throw switch through which a current, the magnitude of which is also voltage-controlled, flows.

If both plates and the accelerator are operated at +250 volts and a cathode-bias resistor of 300 ohms is employed, the deflectors require a peak switching voltage of 20 volts (or a peak voltage difference between deflectors of 40 volts) maximum to switch the plate current from one plate to the other. In a practical circuit, however, in which the deflectors are driven in push-pull with the center-tap of the source grounded, a somewhat higher value of deflector drive voltage must be used. The increased drive voltage is required to allow for those tubes in which the switching characteristics are somewhat offset with respect to zero voltage difference between deflectors.

For an accelerator voltage of +250 volts, the minimum deflector switching voltage occurs at a d-c deflector bias of approximately −8 volts; however, the d-c deflector bias is not particularly critical for focus as the deflection sensitivity characteristic exhibits a broad maximum. Care should be exercised, nevertheless, to assure that defocusing effects are not present whenever the tube is operated at conditions other than those recommended.

The circuit diagram for two 6AR8 tubes employed as synchronous detectors[π] in a color television receiver is shown. In this arrangement, positive voltages are applied directly to the accelerator grids and through load resistors R1, R2, R4 and R5 to each of the plates. The chrominance signal is applied to the control grid of each tube. The 3.58-megacycle reference signal is applied in push-pull between the deflectors of each tube. The small coupling capacitor, Cc, between the tuned driving circuits provides the necessary 90-degree phase shift for the I and Q detectors. Also each tube is biased with a cathode resistor, R3 and R6; resistor R6 is variable so that the relative gains of the two demodulators can be adjusted.

In principle, the 6AR8 circuit is a product-demodulator type of synchronous detector; however, because the circuit uses a double-plate sheet-beam tube rather than a dual-control pentode or heptode, certain significant operating features result. First the 6AR8 circuit is capable of delivering relatively large and balanced output voltages which exhibit good linearity. Because output voltages are available of both positive and negative polarities, the need for the incorporation of phase-inverter circuits in the matrix section of the color receiver is completely eliminated. Also, providing the oscillator reference voltage is adequate to switch the plate currents between the two plates, the circuit is insensitive to variations in the amplitude of the oscillator voltage over a wide range. Furthermore, unlike the pentode or heptode synchronous detector circuits in which the third grid is driven positive by the oscillator reference voltage, the deflectors of the 6AR8 require very little excitation power. Consequently, less power is required from the 3.85-megacycle reference oscillator in the sheet-beam tube circuit.

Another feature is that space-charge coupling effects, which are inherently present in dual-control pentodes and heptodes, are unnoticeable in the 6AR8. Also, unlike most dual-control pentodes and heptodes in which the screen current is an appreciable percent of the plate current, the accelerator current of the 6AR8 is less than one-twentieth of its plate current.

[π] R. Adler and C. Heuer, "Color Decoder Simplifications Based on a Beam-Deflection Tube," Trans. IRE, PGBTR-5, Jan. 1954.

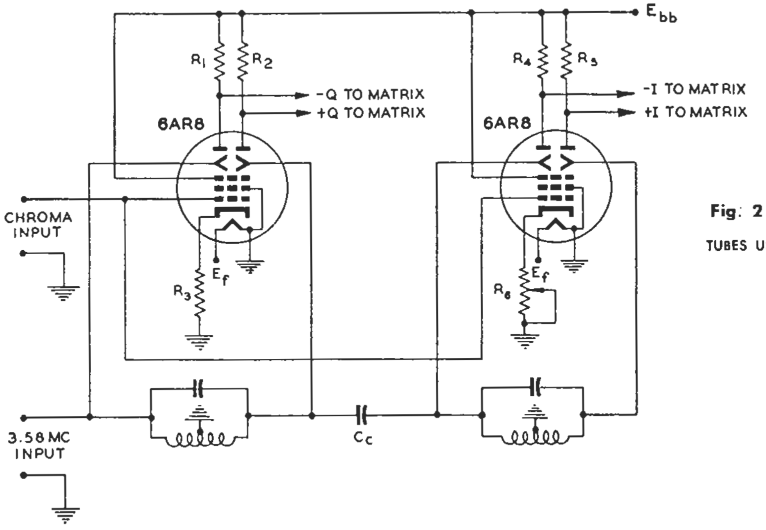


Fig. 2 CIRCUIT DIAGRAM OF TWO 6AR8 TUBES USED AS SYNCHRONOUS DETECTORS

TYPICAL CIRCUITS USING THE G-E 6AR8

The G-E 6AR8 sheet beam tube is, by its very nature, suited for a number of circuit applications in amateur radio single sideband transmitting and receiving equipment. The following circuits illustrate these applications.

Component values as shown will provide normal performance of these circuits in most cases. However, in certain instances, the values of cathode resistances may require lowering to obtain optimum circuit performance. Also, shielding and other r. f. constructional practices, have not been shown.

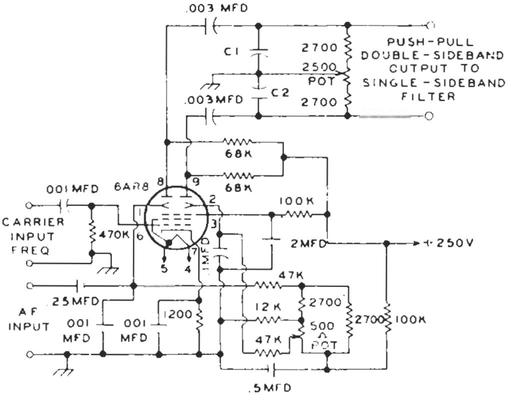


Fig. 3 Suggested circuit for a balanced modulator using the 6AR8 sheet beam tube with the audio signal applied to one beam deflecting plate, and the r.f. signal to be modulated applied to the control grid. All resistances are in ohms, 1/2 watt unless otherwise specified. "K" equals 1,000. Capacitance values are in microfarads (mfd), except where specified. Capacitors C_1 and C_2 should be equal in value, with a total series capacitance of the proper value to resonate the input side of the sideband filter at the operating frequency.

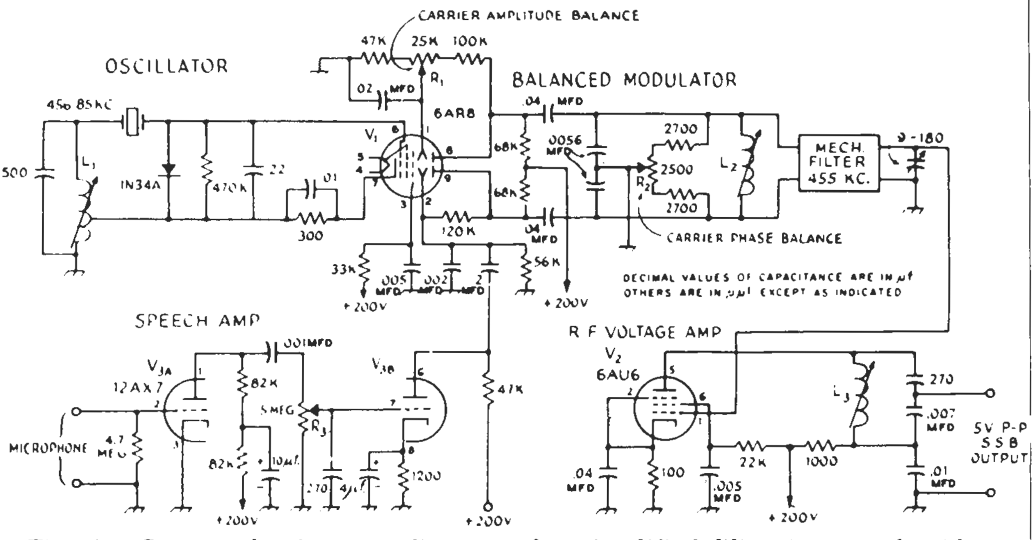


Fig. 4 Suggested schematic diagram of a simplified filter-type single sideband generator operating at 455 kilocycles. The G-E 6AR8 sheet beam tube combines the functions of carrier oscillator, and balanced modulator. The output from the 6AR8 plates is a double sideband, suppressed carrier signal. One sideband is removed after passage through the bandpass filter at the right. All resistances are in ohms, 1/2 watt rating unless specified. Potentiometers R_1, R_2 and R_3 have composition elements. Capacitances are in micro-microfarads, unless value is specified in microfarads (mfd). Capacitors with polarized markings are electrolytic types.

Fig. 5. Suggested schematic diagram of a G-E 6AR8 sheet beam tube operating as a combined tunable oscillator (VFO) and mixer. Circuit values are shown for a tunable oscillator operating at 3.3 to 3.6 megacycles, with a 455-kilocycle SSB signal applied to one beam deflection plate. The sum of the two input frequencies appears in the output circuit, T_1, tuned to the 3.8 to 4.0-megacycle range. The oscillator coil, L_4, has an inductance of 4.7 microhenries. It was wound on a 3/4-inch diameter ceramic coil form, with 21 turns of No. 20 enameled wire spacewound 1 inch long. The cathode tap is 3 turns, and the grid tap 10 turns, from the grounded end.

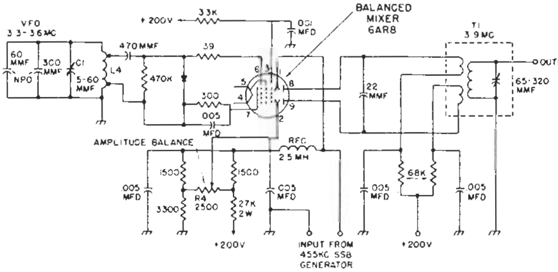
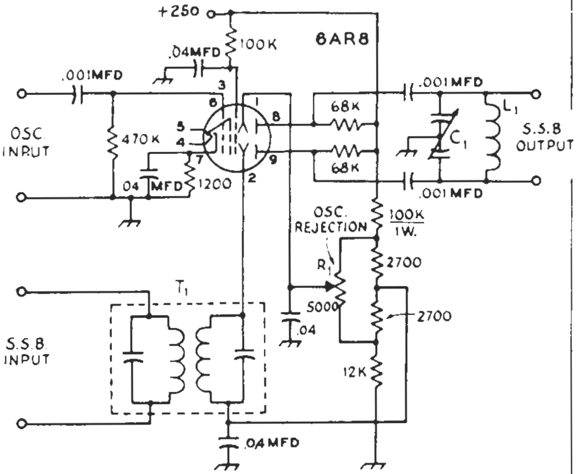


Fig. 6 Suggested schematic diagram for a 6AR8 tube in a balanced mixer circuit. This circuit is suitable for combining two input signals from a SSB generator and tunable oscillator (VFO), and obtaining either the sum or difference signal in the tuned output circuit, C_1--L_1. Conventional tuned circuits may be used here, and in T_1. All resistances are in ohms, 1/2 watt, unless specified. Capacitances are in microfarads (mfd). A linear taper composition potentiometer should be used for R_1.



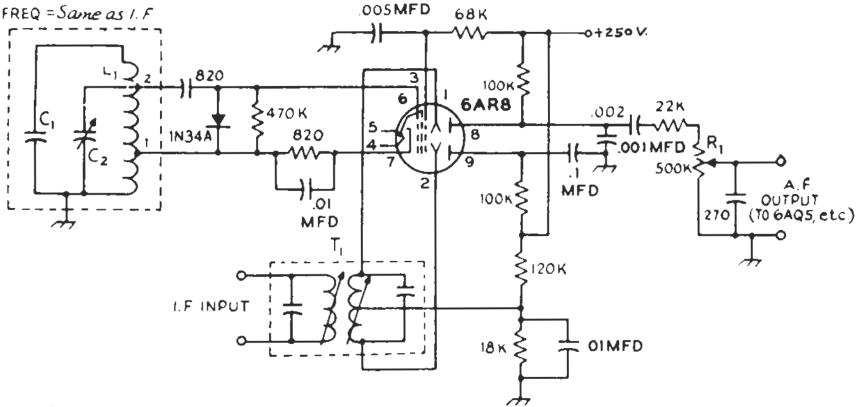


Fig. 7. Suggested circuit for a 1-tube product detector using the G-E 6AR8 sheet beam tube. The circuit contains its own carrier oscillator utilizing the cathode, control grid and number three grid elements. The beam deflecting plates are in the detection circuit, and the audio output signal is taken from the plates. The oscillator tuned circuit should have high capacitance for best stability. Taps 1 and 2 on L_1 should be about 5 and 25 percent, respectively, from the grounded end. Resistances are in ohms, 1/2-watt rating. Capacitances in decimals are in microfarads (mfd); those in whole numbers are in micro-microfarads (mmf).

BALANCED MODULATORS

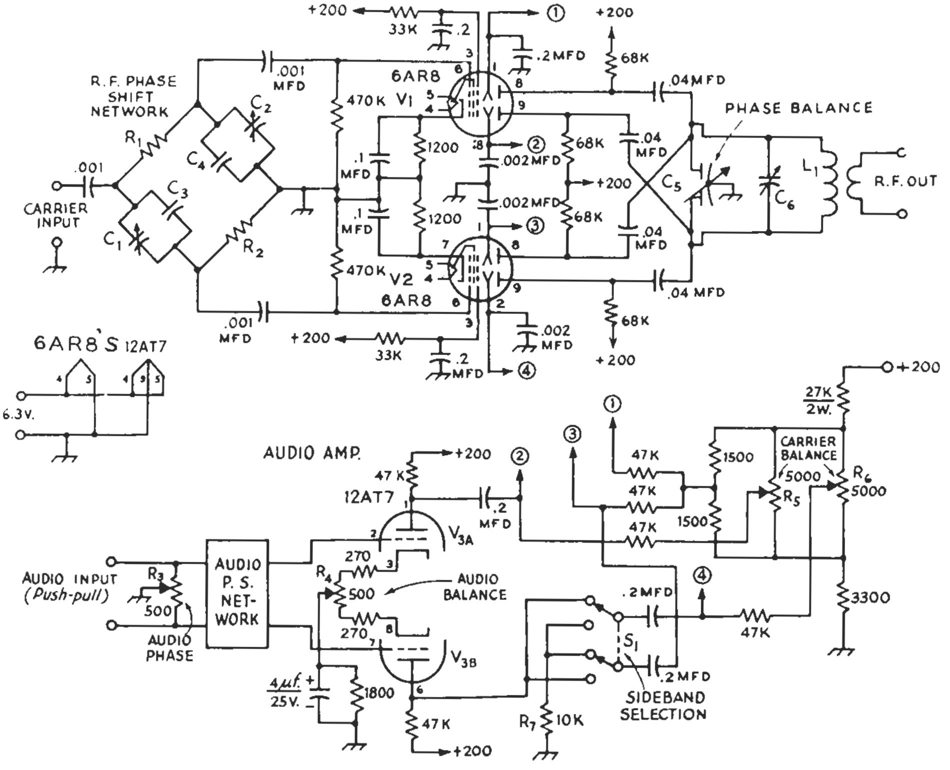


Fig. 8. Suggested schematic diagram for a phasing type SSB generator featuring a double balanced modulator with two 6AR8 sheet beam tubes. This circuit is suitable over the range from intermediate frequencies to approximately 30 megacycles. Capacitances are in micro-microfarads (mmf), except those marked "uf", which are in microfarads (mfd). Resistances are in ohms, 1/2 watt rating unless otherwise specified. Values for capacitors C_1, C_2, C_3, C_4, C_5, and C_6, and coil L_1 will depend on the operating frequency. Values for C_3 and C_4 should be chosen so that their reactance at the operating frequency is equal to the resistance of R_1 and R_2, which should be 100 ohms each, with exact values closely matched.

A SSB exciter construction article with the 6AR8 as a balanced modulator was described in the July, 1956 issue of CQ, on pages 24 to 31. This filter type exciter was designed and constructed by William I. Orr, W6SAI.

Additional material on applications of sheet beam receiving tubes has been published in the March, 1960 issue of QST magazine.

A new article showing the G-E 6AR8 as a balanced modulator in a simple double sideband transmitter, reconstructed from a surplus Command Set transmitter, appears in the May, 1961 issue of CQ magazine, on pages 48 through 51.

A new type of miniature sheet beam tube which has low output capacitances, and thus is capable of operating in balanced modulator circuits well into the VHF region, has just been announced by the General Electric Receiving Tube Department. It is known as the 7763 and will appear in G-E HAM NEWS articles during 1962.