THE MIX-SELECTION 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-SELECTION 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!

—Lighthouse Larry

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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 "sidelbands" usually associated with your 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 sidelines 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 SS in the balance of this discussion): (1) the filter system, and (2) the phasing system.

In both systems, SS 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 spur of a signal which 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 more exacting, since all desired signals in the set of side bands must be passed, yet the signals appearing at other frequencies should be attenuated at least 30 db (801 to 1 in power) or more. The required order of filter selectivity is most easily achieved at frequencies below 500 kilocycles. Thus, multiple-tube type SS modulators/transmitters now on the air have the SS generating circuit operating on 450 kilocycles, utilizing either a mechanical filter or various types of filter fabricated from quartz crystals.

In the filter system, SS signal is generated at any desired output frequency, but it is inconvenient to change the frequencies. However, it is easy to change the amplitudes in this type of system.

In the phasing system, an SS signal is generated at a number of channels frequencies and select one by bandswitching with either system.

A further limitation in obtaining an SS output is on several amateur bands in both filter and phasing systems is that harmonics of the SS 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 SS signal.

We now have inductors, first components that are not readily available for a filter-type SS generator designed to operate directly on an amateur band; second, that the phasing systems can be used at any desired narrow band of frequencies, but does not lend itself to conventional inductors and transformers; that harmonics of the SS generator signal cannot be used and that all modulation techniques for single-sideband and adjacent-frequency SS generator problem, for that matter, is to employ the same general system used in suppressed-carrier transmitters. That process is to heterodyne an SS generator signal, which may be outside the allowed 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 one way 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 output 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 output 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, frequency selective non-linear circuits must be used to prevent these spurious signals from appearing in the transmitted signal.

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 1000 kilocycles away from the desired signal frequency will be attenuated more than 50 db. Any 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 any 20 per cent range or they may appear along with the output signal to an appreciable extent.

Since it has already been pointed out that point 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. Really, the best way to avoid spurious signals resulting from harmonics of the input signals is to place both at least two high-Q tuned circuits in the mixer circuit.

Since the phasing-type SS generator operating frequency is not only considerably raised, the signal may have to be changed in frequency then the amateur band on which output is desired. In this case, it is not strictly followed, since an SS generator signal frequency is in steps of 28.8 to 180 kilocycles usually chosen for 14-, 31- and 80-cycle transmitters.
Since the heterodyning signals mentioned for permit operation on only two bands, the practice followed in many filter-type SSB exciters is to again heterodyne the 3.6-4.0 megacycle SSB signal described in lines 5 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. 3. This variable SSB signal frequency, its spur signals and harmonics must now be considered as an input signal to the second mixer, as pointed out on line 8. If an output signal from the second mixer in the 1.4-2.0 megacycle range is again desired, a fixed frequency signal of either 2.0 or 3.0 megacycles also should be used as mix input to the 3.6-4.0 megacycle SSB generator. A 2.0-megacycle signal would be a poor choice, since it falls within the foreground danger zone, but line 9 on the chart shows that the 3.8-4.0 megacycle input signal is satisfactory.

The following diagram illustrates the basic principles involved in the design of a double-conversion SSB exciter. A high- selectivity tuned circuit 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 foreground danger zone. This also happens with the second harmonic of a 3.5 megacycle mixing signal shown in line 10. One spurous signal can be avoided by choosing 11.1 megacycles, on line 11, for a mixing signal frequency instead. As for 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 14.2-15.5 megacycle second 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 foreground 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 will fall 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 34.1-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.

**“HI 4- 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 that is 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 foreground danger zones of any desired operating band should be shown. The widely-used 3.8-4.0 megacycle band is the best, since its harmonic frequency is good, but has certain disadvantages. Line 15 on the chart shows that the third harmonic, at 7 megacycles, falls within the danger zone when a mixer output signal in the 3.8-4.0 megacycle band is desired. Again, suitable mixer design is necessary to reduce the severity of this spurious signal.

(Continued on page 4)
A variable frequency oscillator must be used with this fixed SSR 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 (1.0–1.2 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 7.2–7.5-megacycle mixer output signal on line 20, the VFO tuning range of 1.2–1.3 megacycles may be used. However, the VFO third harmonic of the 7.2–7.5-megacycle signal may not have sufficient signal strength to pass through the feedthrough danger zone. A trap circuit in the mixer output to attenuate this unwanted harmonic will result in one type of commercial SSR 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 38.3–39.0-megacycle mixer sum output signals (12.15–14.15 and 19.2–20.0 megacycles, respectively) shown on lines 21 and 22 present no special problems. Of, VFO signals in the 30.25–30.45 and 21.3–21.5 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 33.

Methods of obtaining a 50-megacycle SSR output signal are shown on chart lines 24 and 25. A variable frequency SSR exciter having output on the 21–28-megacycle band may be led into a second mixer stage from which the 50-megacycle signal is obtained. On line 24, a signal on 28.75 megacycles, and the SSR exciter signal on 21.25–21.45 megacycles is mixed to obtain a 50.5–50.75-megacycle mixer output signal. On line 25, an SSR exciter output signal in the 35.8–39.5-megacycle range is mixed with a 21.25–21.45 megacycle signal to obtain a 50.5–50.75-megacycle output signal. In both cases, the semi-spurious frequency signal difficulties may be experienced with this combination. All of these possible semi-spurious frequency signals interfering transmitter should in itself be free of spurious signal, or the subscriber is encouraged to screen the output signal with the aid of a suitable half-wave trap circuit in the output stage of the second mixer stage.

DO IT YOURSELF SUGGESTIONS

The third harmonic of the SSR generator in the 4-megacycle range, shown on line 15 at 17 megacycles, may be utilized for the 3.8–4 megacycles range, and the 6.1–6.5-megacycle amateur bands by selecting the lower SSR generator frequency bands by selecting the lower frequency bands. A good example is shown on line 30, 8.5 megacycles, which has only the fourth harmonic falling in the upper range of the 4-megacycle danger zone. This particular frequency permits a commercial VFO tuning range of 12.75–13.25 (line 16) and 14.2–14.34 megacycles (line 32) mixer output signals. The 6.1–6.5-megacycle VFO tuning range on line 28 falls within the danger zone, so the 11.8–12.1-megacycle range on line 29 is better.

Look what happens when a low-frequency VFO tuning range (0.7–0.8 megacycles on line 25) is used for a mixer output signal in the 7.3–7.5-megacycle range. The VFO eighth and ninth harmonics both lie in the mixer output range, requiring equal mixer design to avoid almost certain trouble from spurious signals. Placing the VFO frequency range in the 1.2–1.3-megacycle range, as shown on line 31, avoids this problem. The two VFO tuning ranges required for sum mixer output signals in the 21.25–21.45 megacycles range on lines 21 and 24. Output in the 30-megacycle band may be obtained with double conversion signal combinations similar to those shown on lines 24 and 25.

Most SSR generator signal frequencies below 5 megacycles will have harmonics falling within several frequency danger zones. But, by giving 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 6.3 megacycles (line 35) establishes the same VFO tuning range of 8.8–8.9 megacycles to be used for mixer output signals on 1.8–2.0 megacycles (line 36) and 14.2–14.34 megacycles (line 42). An alternate tuning range of 9.0–9.1 megacycles for 1.8–2.0 megacycle output is shown on line 37.

When choosing for a mixer output signal on 3.8–4.0 megacycles, VFO tuning ranges of either 2.2–2.4 (frequency ranges of 10.9–11.2 megacycles (line 29) present no significant problems. Careful alignment of the high "Q" tuned circuits following the mixer is necessary to keep the second harmonic of the VFO tuning range, or VFO output, as far away from the desired VFO tuning range as possible. Combining the 6.2-megacycle SSR generator signal with either a 1.9–2.1-megacycle VFO tuning range (11.8–12.0 megacycle) or a 12.2–12.5-megacycle (line 41) VFO signal, however, as a 1.9–2.1-megacycle VFO is tuned through its range, the sixth harmonic signal will cross the SSR generator signal, and the seventh harmonic will cross the mixer output signal. Obviously, this combination is an excellent spurious output signal or "hissing" generator, so use 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 13.05–13.25 (line 43) and 22.2–22.4 (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 SSR generator signal on 21 megacycles, when operating the exciter on the 28.5-megacycle band.
Here’s an idea which will be of interest to many persons wishing to study for their amateur radio license—also radio clubs which are conducting or are planning to conduct an amateur license-training course. The Radio-Electronics Television Manufacturers Association has recently packaged a unique amateur radio study course, complete with code instruction on five 13-inch-diameter long-playing records, a handy book of theory tracings and supplementary aids, plus a copy of the ARRL License Manual. The complete course is available for $15, postage paid, from their office, Suite 800, Wyatt Building, Washington 3, D. C.

Most of you are radio amateurs—devoted to amateurism—a term which has many explanations. An excellent statement on this subject—one which really highlights the unofficial view—was recently published in a French amateur radio magazine. Our English translation, which follows, has not been edited in order to preserve the original editorial’s flavor and meaning:

The permanent secretary of the Academy of Sciences has affirmed that "The Amateur has a fundamental and indispensable role in all activities." From our point of view in radio, electronic theory has no meaning unless applied electronics follows. The experiments tried and the experi- ences considered exist only with the view of immediate application. The results, obtained ought in effect, to be put at the service of humanity as soon as possible.

Whether he be aware of it or not, the individual lives by means of a continuous exchange of services with this large family of humanity. If he attempts to isolate himself, he will never, under the weight of work or leisure, without giving anything in exchange, become a parasite.

The spontaneous and the OM par excellence sometimes in case of emergency should not make asforget his permanent and private status. This renders in all of his activities in the external to make them issues, that the does not expect a flood of brilliant results of him, but rather the genre of his joining the exchange, is intellectual, daily experience.

It is in this manner that techniques are perfected and the frontier of the unknown is always being pushed. The amateur, through observation, is the one to note the necessity to hide in one’s station and never communicate one’s small, simple, but essential results of facts. It is only in order to improve one’s self the light of that friendly cooperation which makes amateurism so charming.

Thus, your work, experiments, and research should be made public at meetings, replications, or at annual and international conferences. It is necessary to know the results obtained, even if they are not brilliant. Another OM will know perhaps how to use them in a better manner. Do not be too personally ashamed and look at the results objectively.;

Whether you like the leisure frequencies or CQ/C/EHF, remain contactable: assume that you are young or not young and now or a trace of trouble, would becoming a reality.

Third, avoid contacts, if possible. It is only under these conditions that Amateurism will develop.

J. Auber, F.,
Radio REF Aug./Sept., 1956

That closing date (January 3, 1957) for nominations for the 1956 Edison Radio Amateur Award is approach- ing fast, so now is the time to name your candidates! The judges can consider only those candidates nomi- nated by letter from you.

Many public service activities qualify a person for Award recognition. Check the partial list below, then write a nominating letter and mail it to the Edison Radio Amateur Award Committee, General Electric Company, Schenectady 5, N. Y.

Here are typical activities that prospective candi- dates you know may have performed:

• Inauguration ceremonies work in a business, such as road, railroad, electric, or appliance.

• Relaying messages from remote points for the benefit of isolated services and citizens.

• Civil-defense or organization work.

• Designing motorcars or other equipment or encouraging amateur activities and interests. Helping amateurs or others with their specialized problems through profes-

• Publishing a book or other literature that contributes to amateur or general scientific knowl-

• Helping physically handicapped amateurs or others.

• Designing and constructing radio equipment for use by persons in remote parts of the earth, who do not have access to regular commercial communications channels.

• Weather reporting, radio assistance to ships or local traffic and police authorities; co-operation in forest-fire prevention and control.

P.E. Award rules were published on page 1 of September, 1956 QST and QG magazines, or, drop me a line asking for a copy.

WHAT’S AVAILABLE FREE—some back issues of G.E. HAM NEWS 1953 and later—USA PACK-

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• G.E. HAM NEWS Second Class. Volume containing all issues from 1951 through 1955, plus a handy cross index, $2.00, postpaid.

Has your amateur radio club heard it yet? I mean the tape recording of the 1953 Edison Radio Amateur Award presentation ceremony which I will loan to your club secretary or program chairman upon request. Personal stories, good humor, but please write at least a month in advance of the date on which you wish to have it. There are only so many recorded for other groups—and my thanks for the splendid co- operations received from all clubs who have thus far requested the program.

—Lighthorse Larry
WHAT ABOUT MIXER CIRCUITS?

Mixers (modulators) can have single or complex, single-ended or push-pull (balanced) output, operate at low or high levels, and employ double or multiple tubes. A single-ended mixer (the circuit used in most UHF television tuners and the balanced diode mixer (two of them are used in the SEB, 3j) are more footproof than multielement tube mixers, but no power gain can be obtained, and the grid 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 detection 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 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 unbalance 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 adapted 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 maximum power output from a low-level mixer stage can be brought up to a respectable level in one stage with a 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 very low harmonic generation properties, but off-axis mixers will not, whether balanced or otherwise.

The overall 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 tube 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 selectivity of cascaded tuned circuits at the mixer output frequency.