SSB Topics

HF CRYSTAL FILTERS — FEATURES OF THE HT-32 TRANSMITTER — NOTES AND NEWS

Conducted by **J. C. MILLER, DJ0BX (W9NTV)**

THE development of new spectrum-saving techniques, especially those which will compress more and more intelligence into narrower bandwidth transmissions, has been stimulated by the ever-increasing number of uses and users of the available communications frequencies. Government and commercial communications services have been hard-pressed in an effort to obtain adequate channels for their requirements. New countries have demanded space in the already overcrowded spectrum. Interference between services has become a major problem. No one familiar with the field of communication can deny that immediate action is necessary to develop systems which will increase the usability of the available communications channels. Many believe that single-sideband techniques, with the prime advantage of reduced spectrum occupancy, may provide an answer.

And how does this affect the radio amateur? Our family is also growing. In fact, the amateur fraternity has increased by leaps and bounds during the last ten years, creating unprecedented activity on the amateur bands. The surging interest in radio-telephone communication has produced interference levels of fantastic proportions. We are not only bothered with conflicting speech signals, but have the piercing shrieks of heterodynes added to the general snarl of QRM. As if this were not enough of a problem, we find that we must share certain of our frequencies with other services—not to mention the numerous intruders who frequently slide into our bands to add to the confusion.

We amateurs must therefore also be interested in a system which will increase the usability of our frequencies. Let's imagine that a dream condition exists—one in which all AM phone transmissions were reduced to half their normal bandwidth and no carriers were radiated. We would immediately enjoy better communication, with double the number of phone channels per band and the complete absence of heterodynes! A system is available to all of us which could begin to make this dream come true. It will reduce the interference, increase the effective width of our band assignments and increase the reliability of our contacts. What is this system? Single-sideband, *of course!*

Some Thoughts on Switching Sidebands

In the U.S. 75-metre phone band — where the sideband population is extremely heavy — the QRM problem is somewhat eased by an interesting method: The ability to select either upper or lower sideband at will. It has become common practice for all stations engaged in a net to transmit on the same (suppressed) carrier frequency using the same side-band. As the net becomes overcrowded, or if several of the stations wish to carry on a personal chat without taking the other net operators' time, they switch to the other sideband and continue with their QSO. When they have finished their discussion, they flip back to the original sideband and rejoin the net.

With two nets operating on the same virtual frequency—one on the upper and one on the lower sideband—the unwanted sideband suppression of all transmitters must be quite good. Under these operating conditions, a station with poor suppression receives prompt advice of the fact! Of course, the receiving equipment must also have good sideband rejection and sideband selectability.

Why Not Use Both Sidebands?

When your conductor is not operating on one of the sideband frequencies, he enjoys a second hobby—that of experimenting with a "high-fidelity" audio reproducing system. With the advent of stereophonic recordings, interest and equipment expanded to include two complete audio channels — from the record pickup to the loudspeakers. From time to time it was jokingly mentioned that the next step in these experiments should be to convert the sideband transmitter to permit stereophonic transmission, with one audio channel on each sideband. (No, the writer *does not* advocate stereophony on the amateur bands!)

It seems that others have had the same idea of

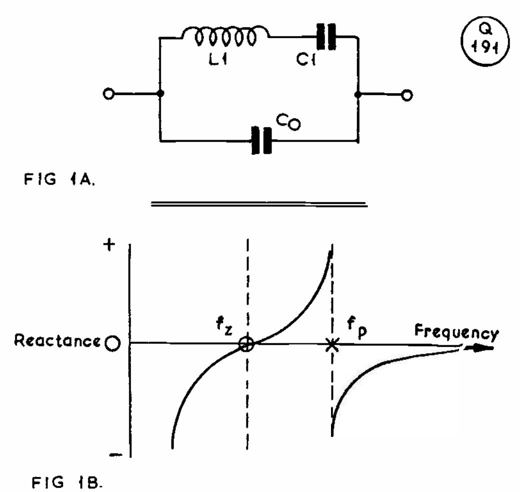
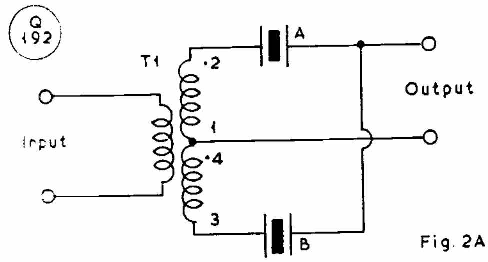


Fig. 1. At (A) is the equivalent electrical circuit of a crystal. The effective mass and "stiffness" of the crystal is represented by L1 and C1; Co is the shunt capacity of the holder. At (B) is shown the reactance characteristic of a crystal. C1, L1 are in series resonance at Fz; C1, L1, Co are in parallel resonance at Fp. These two resonances are very close together.



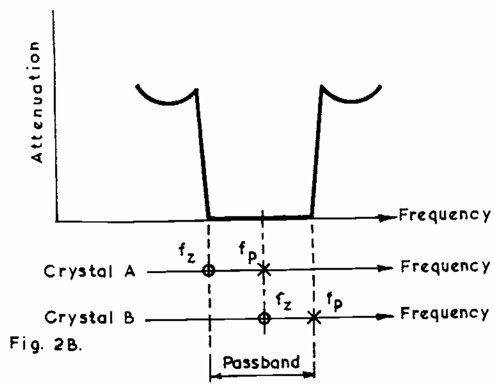


Fig. 2. (A) is the popular half-lattice crystal filter. Crystals A and B are selected so that the parallel-resonant frequency of one is the same as the series-resonant frequency of the other. Optimum results are obtained with very tight coupling between the two halves of the secondary of T1.
(B) Theoretical attenuation characteristic of a half-lattice crystal filter. The pair of crystals produce a flat pass-band between the lower series-resonant frequency and the higher parallel-resonant frequency.

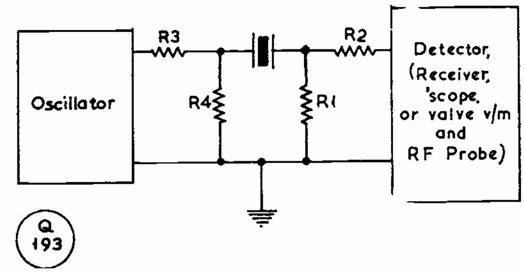


Fig. 3. Suggested test circuit for measuring the series- and parallel-resonant frequencies of a crystal. Erroneous results will be given if the test circuit adds capacity in shunt across the crystal; for this reason, the crystal holders should be soldered directly in circuit for the test. R1, 250 ohms, is used to eliminate input capacity of the measuring detector; R2, of 1,000-2,000 ohms, isolates the crystal from the detector. When the oscillator is tuned from lower to higher frequency a sharp rise in output will indicate the series-resonant frequency Fz; this will be followed by a dip at the parallel-resonant frequency Fp. Resistors R3, R4 are each 50 ohms.

utilizing the SSB technique for stereo transmissions. An experimental broadcasting system that provides stereophonic sound through a single receiver and dual loudspeakers on the medium-wave broadcast band was recently demonstrated by the Radio Corporation of America. In this system, the two separate sound channels making up the stereo programme were fed to an SSB transmitter with each stereo channel carried by one of the sidebands. Full carrier was also transmitted.

In the special AM-stereo receiver common RF, mixer and IF amplifier stages are used. Following the common IF amplifiers, the composite signal is applied to two separate sideband "selectors," detectors, audio amplifiers and loudspeakers. While the actual method of sideband selection is not known, it is believed that the receiver used in the demonstration employed the new RCA mechanical filters. This method of transmission can be received on a conventional AM receiver without the stereo effect.

All SSB operators are invited to write in for this feature, with a note of bands worked on SSB, equipment used and results to date, expressed as two-way SSB contacts by countries worked.

The special stereo receiver will, of course, receive non-stereo broadcasts, reproducing them through a choice of either speaker, or both, without the stereophonic effect.

High-Frequency Crystal Filters

This is a subject in which many of our readers have indicated a great deal of interest. Eliminating the need for multiple-frequency conversion, the high-frequency filter is already finding applications in SSB receivers and generators. A number of new transmitting and receiving techniques using filters in the 4-to-10 mc range have appeared in the amateur literature. One of the commercial manufacturers of amateur sideband exciters uses a crystal filter with a design frequency of 5 mc. Filters in the 9 mc region are available from a few of the crystal companies—priced at from £9 - £18. With prices in this range, thoughts turn to war-surplus stocks for material and the work bench for experimentation.

An excellent article describing high-frequency crystal filter design techniques appeared in *Proceedings of the IRE*, February, 1958, by D. I. Kosowsky. The author deals with crystal-lattice theory in a fairly simple manner, with adequate formulæ and design information to provide those interested with sufficient data to develop several types of filters.

A method of designing and constructing crystal filters, using surplus FT-243 crystals in the HF range, appeared in the January 1959 issue of *QST*. In this article, W3TLN reviews a few of the fundamental concepts of crystal lattice design that appeared in the Kosowsky treatment, with an interesting description of his experiments with filters for amateur applications. As little information has been made available to the amateur on this subject, the following review of the mentioned articles should be of interest to those who contemplate the design and construction of amateur filters.

The approximate equivalent electrical circuit of a crystal is shown in Figure 1A. This circuit has a series-resonant frequency or "zero" of impedance

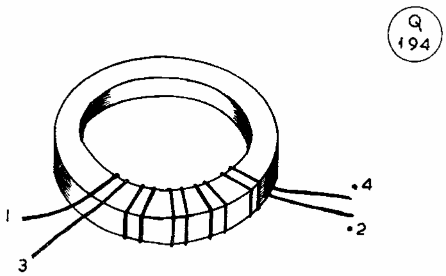


Fig. 4. Ferrite toroidal core with bifilar winding. Use of a ferrite material designed for the operating frequency will produce the best results. (Lower frequency ferrites can be used for experimental purposes, but the efficiency will be lower.) The winding numbers correspond to Figs. 2 and 5; for the secondary centre-tap, ends 1, 4 are connected together. If a toriod is not available, a pot-core or a rod of ferrite is suggested as an experimental substitute.

and a parallel-resonant frequency or "pole" of impedance. This is shown in graphical form in Figure 1B, where the reactance of the equivalent circuit is plotted for all frequencies between zero and infinity. The symbols for the zeroes and poles are also shown. These symbols are convenient in network design, particularly where one is dealing with a circuit containing several poles and zeroes. The object is to juggle circuit values so that some of the zeroes each cancel out a pole.

The simple half-lattice filter is shown in Figure 2A. The impedances of the two crystals must be approximately equal for the lattice to present a high insertion loss between its input and output, and for the voltage at the common output connection to equal that at the coil centre-tap. If the crystal holders have the same capacity, the only problem is to construct a coil which will have exactly the same voltage from terminals 1 and 2 as that from 3 and 4.

In half-lattice design, crystals A and B are different in frequency. If we analyze this condition, using poles and zeroes, we find: At the zero point of crystal A the impedance balance of A and B is upset and a voltage appears between the common output connection and the coil centre-tap. At the pole frequency of crystal A this also occurs. The same statements hold for crystal B, except the unbalance is in the opposite direction. At this point it is clear that the pass-band of the filter is as wide as the spacing of all poles and zeroes. Referring back to Figure 1B, the way in which the impedance change around the zero differs from that around a pole may be seen, which will suggest how the crystals can be arranged to produce a flat pass band. In Figure 2B, the desired arrangement—a flat pass band from the zero of crystal A to the pole of B—is obtained by arranging the series-resonant frequency of crystal B to coincide with the parallel-resonant frequency of crystal A.

We are now ready to determine the pole-zero spacing for our FT-243 surplus crystals. To measure the series- and parallel-resonant frequencies, the test arrangement shown in Fig. 3 is suggested by W3TLN. The oscillator or signal generator can be almost any kind that might be available, as long as it covers the frequencies of the crystals to be measured and has a slow tuning rate. The series- and parallel-resonant frequencies are, of course, at the peak and null of the signal across R1. The actual frequency difference may be read from a calibrated oscillator or good communications receiver dial.

In actual crystal measurements, two 5645 kc crystals showed a pole-to-zero spacing of 2·2 kc on one and 2·4 kc on the other. Their series-resonant frequencies were about 560 cycles apart. The upper frequency crystal was moved to a frequency 1500 cycles above the lower by using an ammonium bifluoride etching bath. The crystals were tried in the circuit of Figure 2A, using a $\frac{3}{4}$-inch ferrite toroid, with the secondaries wound bifilar for the push-pull coil, T1. This coil, shown in Fig. 4, must have very tight coupling between its two secondaries and a high enough inductance to avoid resonance with the crystal shunt capacitance near the pass band. In this coil 25 bifilar turns, or 50 turns total, were used to provide an inductance of 50 microhenrys for each half of the secondary coil. The exact inductance is not critical; however, the tight coupling is very important.

In the initial test of this filter, the input was fed from a low impedance and the output fed to a valve grid. Satisfactory flat pass band characteristics were not obtained until the filter was terminated in a proper resistance; 1500-ohm termination gave the best results.

The half lattice sections can be cascaded to give better rejection off the skirts. For example, crystals of the same frequency can be paralleled on the half-lattice arms, or two sections can be used with an isolating valve placed between them. A more interesting method of using two half-lattice filters is to connect them back-to-back, as shown in Fig. 5. In this connection, spurious off-frequency responses are reduced, as there is little chance of the spurious responses of crystals A and B lining up with those of A^1 and B^1. The coil L1 is wound bifilar as before, and the terminating resistors are chosen experimentally to provide the best pass band. The crystal

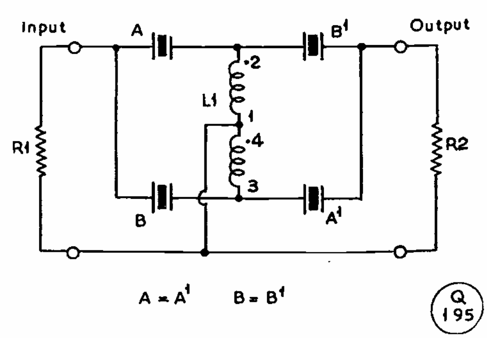


Fig. 5. Two half-lattice filters cascaded in a back-to-back connection. The attenuation curve of this filter shows better selectivity and fewer spurious responses than the simpler single half-lattice, but the pass-band is the same for both. Terminating resistors R1 and R2 are non-inductive types and the exact value must be determined by experiment to produce the best pass-band. Crystals A-A^1 are on the same frequency, with B-B^1 on another equal frequency.

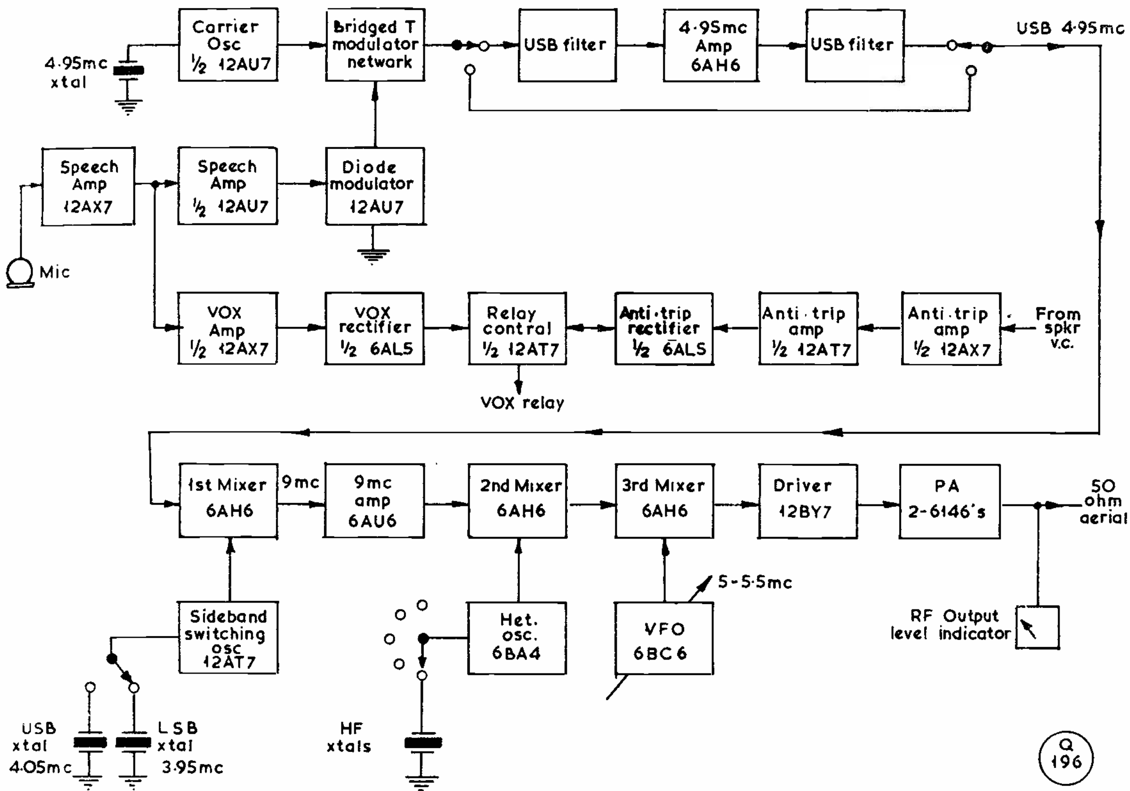


Fig. 6. Simplified block diagram of the Hallicrafters Model HT-32 transmitter-exciter. This equipment will operate in the 80, 40, 20, 15 and 10 metre bands, on either SSB, DSB or CW. An HF crystal sideband filter of unusual design, working on 4.95 mc, is a feature of the HT-32.

(*Note : In this diagram, the LSB crystal frequency should be marked as 13.95 mc.*)

frequencies should be matched as closely as possible. With four 7300 kc crystals (the pairs separated 1500 cycles) in the back-to-back circuit, W3TLN measured the attenuation outside the pass band as better than 60 dB. The bass band was approximately 2.5 kc, which is adequate for phone use.

It is hoped that this simpler technique for connecting half-lattice filters in cascade will provide many of our readers with the information required to continue with the experiments. It is believed that there are many interesting applications for high-frequency crystal filters in sideband work. FT-243 crystals are readily available in the 5 to 9 mc range, at very reasonable prices. It is suggested that you obtain a handful and give these ideas a try. And don't forget to advise " SSB Topics " of the results of your efforts!

21 mc Operation with the " W2EWL Special "

The very popular " Cheap and Easy Sideband " SSB transmitter, a simple BC-458 Command Transmitter conversion described in *QST* for March, 1956, and May, 1958, may be easily and inexpensively modified for operation on 21 mc.

The original 1626 VFO valve is replaced with a 12SN7GT dual triode. One half of this valve is used as a VFO, calling only for valve socket re-wiring—no other changes are required in the original oscillator circuit. The second triode section is used as a frequency doubler. Any conventional triode doubler circuit will be satisfactory.

The oscillator is tuned between 6200 and 6225 kc to produce doubler output between 12,400 and 12,450 kc. When mixed with the 9 mc SSB signal, the transmitter output will cover the 21,400 to 21,450 kc SSB portion of the 15-metre band.

The HT-32 Transmitter

A number of requests for information regarding this well-known Hallicrafters Sideband transmitter have been received. As several new techniques of interest to the sideband group are used in this equipment, such as a high-frequency crystal filter and bridged-tee sideband modulator, a few of the details are being discussed this month.

A block diagram of the H.T.-32 appears in Fig. 6. The basic SSB signal is generated in a 4·95 mc crystal oscillator and is fed directly to the bridged-T balanced modulator. The modulating signal passes through several stages of amplification and appears across the diode modulator which is part of the grounding leg of the balanced modulator network.

The 4·95 mc double-sideband suppressed-carrier signal from the balanced modulator is then passed through two crystal filters where the lower sideband is suppressed. The circuit by-passing the filters is switched in when AM or CW is desired. The upper sideband is fed to the first mixer where it is combined with either 4·05 mc or 13·95 mc from the sideband selecting oscillator. The resultant 9 mc signal is either maintained or inverted through the selectable sideband principle. The 9 mc signal is fed straight through to the third mixer for 80-metre operation, or is heterodyned to an appropriate frequency in the second mixer. This frequency is one which will combine with the 5 mc VFO to give the proper output frequency, *e.g.* for 40-metre operation the 9 mc signal is heterodyned to 12·5 mc by beating against a 21·5 mc crystal; 20-metre operation is essentially the same as on 80 except that "sum" mixing is used in place of "difference" mixing at the third mixer; on 15 metres the 9 mc signal is heterodyned to 16 mc by beating against a 25 mc crystal. As the VFO covers only 500 kc, it is necessary to use four crystals to accommodate the ten-metre band. The crystal frequencies for this purpose are 32, 32·5, 33 and 33·5 mc. Following the third mixer, the on-frequency SSB signal is amplified by the driver stage and fed to the parallel 6146 linear amplifier. The output stage uses a pi-network coupling circuit with only one control—that is, the plate tuning control. The familiar pi-network loading control is taken care of by the band switch, which selects the required value of fixed capacity to give proper matching to the RF amplifier when a 50-ohm load is used. An RF output meter is connected across the line, serving as a resonance indicator for the driver and amplifier tuning controls as well as a voice level monitoring meter. This circuit was described in "SSB Topics" for December, 1958.

The VOX circuit obtains audio ahead of the audio level gain control, amplifies it, rectifies it and applies the voltage to the relay control tube. The anti-trip signal is obtained from the receiver output transformer. The audio is amplified through two stages, rectified and applied to the VOX diode rectifier as a bias voltage.

The HT-32 crystal filter is of interest, primarily because of the unusual circuit arrangement; this is shown in Fig. 7 and has appeared in several of the manufacturer's advertisements. It will immediately be seen that this very simple circuit consists of only two crystals and one coil. While specific information is not available, the manufacturer has advised that the circuit is actually as simple as shown, but that the crystals must be carefully selected in production.

The filters are assymmetrical, cutting off sharply on the carrier side (4·95 mc) and rolling off gradually on the other. The stated audio pass band is 3 dB down at 500 and 3500 cycles, which might be an indication of the filter pass-band.

Based on a quick analysis, it would appear that the coil must be very high-Q and resonant with the capacitance of crystal X1, its holder and its circuit

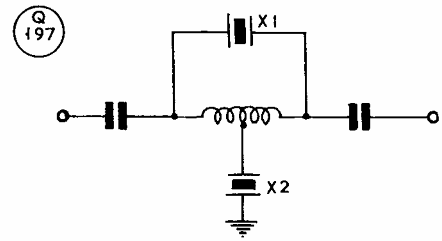


Fig. 7. The HF crystal-filter circuit in the Hallicrafters HT-32, actual values for which have not yet been released. It can be assumed that the assymmetrical curve of this filter is determined by crystal X2 on the sharp cut-off side, and by X1 on the other side. Two of these filters are used in the HT-32 to select the upper sideband.

strays, at the pass-band frequency. The two crystals are probably normal for a half-lattice filter, with X1 the roll-off frequency and X2 the sharp cut-off or carrier side of the filter. The filter terminal impedances are high, estimated at about 50,000 ohms. Your conductor would appreciate hearing from any of our readers who may have further information or ideas pertaining to this interesting filter circuit.

News and Views

A good tip on a method to improve the activity of those sluggish FT-241A low-frequency crystals has been passed on by G2DAF. He has found that a commercial product named "Silver Dip," designed for cleaning household silver-plated tableware, will clean the silver-plated crystals and noticeably increase their activity. The process is simple—just dip the crystal into the solution, wash thoroughly in hot water and dry.

A note from G2CWL advises that he is enjoying his first taste of sideband activity. After 178 QSO's with W3HQO, AM to sideband, he was finally persuaded to take the plunge. One day recently he appeared on schedule with SSB instead of AM, which was a real surprise for W3HQO!

An excellent addition for your sideband library has been made available in the form of a new SSB handbook. This book presents the subject in an easy-to-read manner, covering the theory, operation and construction of sideband gear quite thoroughly. It is called the *New Sideband Handbook*, written by W6TNS, and published by *CQ's* proprietors. The book is available from SHORT WAVE MAGAZINE, Publications Dept., at 25s. 6d. post free.

In Conclusion

The next "SSB Topics" will appear in the June issue, for which all correspondence should be received by April 30. Address "SSB Topics," c/o Editor, SHORT WAVE MAGAZINE, 55 Victoria Street, London, S.W.1, or direct to your conductor at Mauerkircher Strasse 160, Munich 27, Germany. Remember to send in your contribution—we want the news, views, ideas, results and suggestions of *all* the Sideband fraternity, together with notes of SSB contacts of particular interest, on any band, and photographs to illustrate this feature.

Until June, all the best and Good Sidebanding!
Vy 73 de Jim, DJØBX.