SPECIAL REPORT ON VHF SSB
Presenting a 2-part series on VHF Sideband Equipment

PART I... In this Issue:

A COMPLETE 20-WATT, 144-MC. SSB EXCITER

By David W. Bray, KE1MG

PART II... In the September-October, 1962 Issue:

A 144-MC. DIRECT SSB GENERATOR & HETERODYNING SSB SIGNALS TO 144 MC.

By James V. O'Mara, W2NZ

Interest in SSB on the VHF amateurs bands — principally 50 and 144 megacycles — is growing rapidly. This two-part series in GE HAM NEWS has been prepared by two long-time experimenters with VHF SSB techniques — and proven in hundreds of tests over a rugged 40-odd mile path between their stations. There's a wealth of good ideas in their circuits, choices of frequency conversion, and construction techniques. You'll find it's easy to modify or add to your present equipment and try VHF Single Sideband!

INTRODUCTION — It is not necessary to extol the advantages of single or double sideband on the high frequency amateur radio bands, but on the VHF bands where there is no QRM, just steady receiver noise, many people do not realize the advantages of single or double sideband. These advantages can largely be summed up as follows:

1. In order to achieve high power output with an amplitude modulated signal, a large audio amplifier of at least one-half the total input power to the transmitter is required. For one kilowatt transmitter the audio power output is extremely difficult and costly to achieve. However, a single sideband exciter of only 6 watts output is capable of driving a pair of 500-watt class B pentode tubes in a linear amplifier to full 1200 watt peak effective output. If this same amplifier was used to amplify an amplitude modulated signal one finds that its efficiency is so poor that an amplifier which is capable of putting out 800 watts of SSB RF power delivers approximately 200 watts. Thus single and double sideband provide a simple means of producing a high power RF signal.

2. By theory and experimentation it has been shown that CW has a 17 db. advantage over amplitude modulation. That is, a transmitter capable of transmitting one kilowatt input fully amplitude modulated on the high frequency spectrum range as a 20-watt transmitter which is operated on CW. This is all well and good if you want to use CW. However, it has also been shown that a single sideband emission is nearly as effective as CW. Actual tests on the 144-megacycle band have shown that, even though not exactly predicted by theory, a single sideband signal can be copied with the same ease as CW when the distance between stations is such that the signal strength of the received signal is very weak. Under these same conditions an amplitude modulated signal is indistinguishable. Therefore, single or double sideband do provide two very obvious advantages in the VHF bands: (1) equipment simplicity, and (2) taking power.

This article describes a 144-megacycle exciter which is capable of operating single sideband, double sideband, amplitude modulation and CW. It has a power output of approximately 6 watts which is adequate for local use or to drive a pentode-type kilowatt linear amplifier to full rated output. It also includes a tunable crystal oscillator with good stability and a voice operated control system. The exciter is a double type single sideband generator which provides good carrier suppression and unwanted sideband rejection.

CIRCUIT DESCRIPTION — The Exciter consists of four basic circuits: (1) a phasing type single sideband generator, (2) a 30 megacycle oscillator, (3) a tunable crystal oscillator, and (4) a RF mixer and amplifier. Each of the separate circuits which make up the Exciter are discussed in detail, and all references are made to the schematic diagram, Figure 1.
The carrier generator is a transistor oscillator (V1) operating on 25 megacycles. This oscillator is very stable. It uses the screen grid of a 6AS6 dual- triode RF pentode as the plate of the oscillator, and the suppressor grid as the control grid. The suppressor grid is connected to the screen grid and the screen grid is grounded. The screen grid is connected to the plate grid of the 6AS6 tube, and the plate grid is connected to the plate of the 6AS6 tube. The plate of the 6AS6 tube is connected to the plate of the oscillator, and the plate of the oscillator is connected to the plate of the RF amplifier. The RF amplifier is connected to the RF phase shift network.

The balanced modulator consists of a pair of 6SL7 triode tubes (V6 and V7). Each of the balanced modulators suppresses the carrier and produces a double sideband suppressed carrier signal. The carrier signal is disconnected from the output of the RF amplifier. The output of the RF amplifier is fed to the 6SL7 tubes, and the output of the 6SL7 tubes is fed to the 6SL7 tubes. The output of the 6SL7 tubes is fed to the 6SL7 tubes.

VARIABLE CRYSTAL OSCILLATOR -- A stable but tunable oscillator can be achieved by placing a variable capacitor (C0) in series with the crystal. As the value of the inductor is changed, the frequency of oscillation will change proportionally. However, since variable inductors are difficult to tune and particularly in a linear manner -- the inductance compensating capacitor between the crystal and the capacitor. A modified Pierce oscillator is achieved by placing a variable capacitor in series with the crystal and a temperature compensating capacitor between the crystal and the capacitor. The feedback circuit is then provided by the variable capacitor and the zero temperature coefficient trimmer capacitor (C1).

An ideal crystal frequency for 144 megacycles band operation is 5056 kilocycles, since no harmonics fall in the broadcast band. A variable capacitor and crystal will pull very nicely at 100 megacycles. An ideal crystal is 11.3 megacycles. Mixing the desired frequency shifts the carrier frequency by 2 megacycles. The 2 megacycles shift provides a phase shift of the audio input. This results in a double sideband suppressed carrier signal.

AUGMENTOR AND PHASE SHIFTER -- The major problem with the phasing type single sideband generator is the problem of providing a precise 90 degrees phase shift for each balanced modulator. This 90 degrees phase shift is achieved by using a carefully selected crystal oscillator. In order to obtain this precise phase shift, a complex network must be used. Usually this network is made up of resistances and capacitances values that are not readily available. However, a special phase shift network was used which contained 4 microhenries of standard and capacitor values, with 5 percent tolerance. All other values were hand selected so that the suppression provided by this network is as good as possible, and the actual components used should be close to the specified values.

The audio amplifier itself is straightforward. It consists of three triode type tubes: a 12AX7 and two 12AT7's. The 12AX7 (V17) functions as a normal two-stage triode amplifier. The output of the audio section feeds the first section of the 12AT7 (V18) which is transformer coupled to the audio phase shift network and the VOX amplifier. The 600-ohm winding of T4 feeds the phase shift network and the 3000-ohm winding drives the VOX amplifier.

The output of the phase shift network is a push-pull signal and is fed to an amplifier consisting of a 12AT7 (V19) connected in push-pull with a balancing potentiometer (R1) in the cathodes, and the plate of each connected to a separate output transformer (T2 and T3). The 600-ohm windings of each drive the 6Q70 double balanced modulator tubes.

In order to choose the desired sideband, the output of T2 and T3 are connected to a 4-pole, 2-position tap switch (S3) as shown in Fig. 7. The lower sideband is chosen if transformer leads 1 and 2 from T2 are connected to modulator 600-ohm transformer leads 3 and 4 from T3 are connected to modular grid 3 and 3, respectively. To obtain lower sideband leads 1 and 3 are interchanged. To obtain double sideband the actual components used in parallel in T2 lead 3 is opened.
The mixer is stable since the cathode is grounded. Bias is provided by self-bias operation of the control grid, and the single anode signal is fed to a completely separate element of the tube. By tuning the plate of the tube to 144 megacycles and coupling it through a double tuned circuit into the following amplifier stage, a very clean 144-megacycle output signal is produced from this mixer.

**VHF Amplifier** — The first amplifier stage is a 6AG6 VHF pentode (V5) operated as a class A amplifier. Double-tuned circuits are used from the mixer into its control grid, and into the following stage. The 566W, even though operated in class A, provides ample drive for the 6500 twin pentode (V4) output stage, operated class AB1 with a fixed bias of 2.0 volts. The 6500 is operated push-pull and requires no neutralization because of its internal neutralization circuit. The output of the push-pull tank is link coupled to the IF output connector. The 6500 operating in class AB1 provides about 6 watts CW output.

To measure the RF output of the exciter, the diode CR1 and RF choke RFC1 are mounted in a coaxial cable RF connector, and then plugged into a “Test” connector in the output cable line, as shown in the rear and top views. A DC connection then runs to the meter control switch 3. The voice output control circuit is complete without the voice control circuitry. In this exciter a familiar type voice control circuit is used. The output of the audio amplifier from the 3220 ohm tap of the audio transformer is fed to one half of the 12AT7 triode (V3B). The output of the 800 ohm tap or load impedance of the receiver is fed to the other half of the 12AT7 triode (V3A). The output of V3A from the audio channel is then rectified by diode CR3, and used to charge a 4.5 µF capacitor with an adjustable discharge resistor of 2.2 megohms. This operates a control circuit.

**FOOTNOTES**

In television discussion of the use of klystrons operated in the extra high frequency bands only are to be found in the literature in connection with the development of radar during World War II. Reference should be made to the following articles on the subject: Newkirk, “A High Frequency Oscillator,” Proc. I.R.E., May 1942, pages 445-452. 


BOTTOM VIEW of the exciter showing the locations of small parts and wiring. Sheet aluminum shields are fitted around the sideband generator and VHF RF sections of the exciter. Note the group of feedthrough capacitors and small RF chokes in the power lead filter compartment at the lower left.

MAIN CHASSIS — The main chassis has four shielded areas. These consist of the single sideband generator, the RF assembly, the control section and the power plug section. Construction of the single sideband generator is seen in the bottom view. The output from the single sideband double balanced modulators (V₀ and V₁) passes through a feed-through terminal in the shield directly to the suppression grid pin of the RF mixer tube (V₂). The assembly of the 144-megacycle amplifier stages (V₀ and V₁) is detailed in the sketch of Fig. 5, in addition to the bottom view. The control section in the middle of the main chassis contains the two relays, R₁ and R₂. plus the pilot light, control switchen, key jack, and audio transformers. The power plug section compartment is filled with small RF choke (RFC) and 100-pf. ceramic feedthrough bypass capacitors mounted in the partition. Those filters keep RF energy from leaking out of the exciter through the power leads.

The variable crystal oscillator will only be as stable as the frequency of the crystals. Because the crystal is operated in a parallel mode in which it is pulled from its normal operating frequency, it is more temperature sensitive than a normal crystal. Therefore, the crystal and its holder are fitted into the exciter so that they cannot be mounted in an assembly as shown in the top view and preferably connected to the front panel by a metal strap in contact with the crystals to maintain the temperature of the front panel.

This assembly is a simple aluminum frame which is bonded to the crystal holders thereby providing thermal contact to the crystal. The crystal holders and their mounting frame and the aluminum frame reflect the radiant heat from the nearby tubes. Isolation around the crystal prevents additional heating. A metal strap which touches the metal portion of the crystal holder also helps keep the crystal at nearly constant temperature.

An alternate solution is to purchase a crystal oven and operate the crystal in this oven in place of the crystal sockets shown. Two crystal sockets are shown, but only one of the sockets, the one to the right facing the front panel, is connected. The other socket is a dummy in which to store the space crystal at the same temperature. To change to the second crystal, simply reverse them in their sockets.

OPERATION AND ADJUSTMENT — Before applying power to the exciter, all tubes should be pulled out of their sockets. Since some stages are only biased by grid currents, if the oscillator or amplifier are not operating properly some of the stages could be drawing excessive current. Place the tubes in their sockets one at a time as the adjustment proceeds.

First adjust the transistor oscillator by removing the 3,000-ohm resistor across the inductor (L₁), removing the crystal and shorting out the socket. Set the variable capacitor (C₁a) to approximately one-half of maximum capacity; and, with a grid dip meter tune the inductance to the 30-megacycle crystal frequency. Reconnect the 3,000-ohm resistor and place the crystal in its socket. Connect a vacuum tube voltmeter to the control grid of the 6C68 buffer and tune the variable capacitor (C₃b) for maximum output voltage. If the first step is to adjust the plate coil (L₆) of the 6C68 buffer by setting it at some point which is not the grid dip meter; it can then be peeked later. If the grid dip coil (L₆C₇) is adjusted, it should be tuned until the megacycle oscillator stage is peaked. At this point, the VHF RF preamp can then be finished after the variable crystal oscillator and output of the RF stages have been adjusted.

The final single sideband adjustments are made after 144-megacycle output is obtained by listening to the signal on a receiver covering the 144-megacycle band.

RF ADJUSTMENTS — Adjustment starts with the variable crystal oscillator (V₀₂). Insert the oscillator tube and the first doubler (V₂), then connect a high impedance voltmeter — preferably a vacuum tube voltmeter — on the grid of the first doubler. Switch the oscillator to crystal position, turn the tuning capacitor (C₇a) to maximum capacity and adjust the feedback capacitor (C₈) for maximum negative voltage on the first doubler grid. Then switch the VXO into the variable position. Tune the inductance (L₄) to minimum value and the negative temperature coefficient capacitor (C₉) to approximately one-half its maximum value. With the VTVM on the grid of the first doubler, tune C₈a across the band and determine if the oscillator is operating over its whole range. If not, adjust either L₄ or C₉ or both, until the oscillator delivers equal voltage at the grid of V₂. Now adjust L₈ to that in the crystal position across the band. Adjustment of the oscillator’s tuning range is made by listening on the 144 megacycle receiver after the remainder of the RF section is operating. Next, switch the VXO to crystal position, turn C₉ to minimum capacity, and place the second doubler tube (V₂) in its socket. Connect the VTVM to the grid of the mixer stage (V₀₂) and adjust L₈ for maximum negative voltage. If the signal is not obtained, adjust L₈ and L₉ until a signal is obtained on the mixer grid. Then peak L₈, L₉, and L₁₀. The VTVM on the grid of the mixer stage will probably affect the settings of L₈ and L₉, but this will be0
inert carrier by turning the carrier balance controls off center (they prob-
ably will be off balance anyway) and with an insulated tool, adjust L1 by
spreading or compressing the center tapping a maximum of 0.025".
The maximum negative voltage on the grid of the 680 is 5.0 volts. This
must also be adjusted the signal at L1 may be suppressed. The quiescent
elements of L1, L2, and L3 can be made. After the above the couplings in the
modulator and the coupling between L1, and L2 are then the 0.014 150 volts at
a maximum of 5 V to 60 V at the end of the 6300.

**VFO FREQUENCY ADJUSTMENT** — Most 6300-

kilocycle crystals will have a pull of 250 ± 200 cycles at 144 megacycles.
However, if L4 is set for maximum pull, the frequency will not be very stable. Therefore, it is
recommended that a pull of about 100 kilocycle be used. To make this
adjustment, set the VFO to crystal position and L5 to 0.01 micromhos for
maximum frequency. This will result in the highest frequency
of the 144 Mc signal being at the 0.014 150. Next, switch the oscillator to VFO position and
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NEW G-E COMPACTRENS SIMPLIFY TV

Radio amateurs have a dramatic demonstration of how General Electric's new line of compact receiver tubes can simplify electronic equipment in the industry toward "compactron- ing" television receivers.

The tube complements in these new TV sets are ordered about one third through substituting multifunction compactors for conventional receiving tubes in most circuits. Amateurs can expect the same degree of simplification in amateur radio equipment using compactors.

In the latest line of General Electric television receivers, an average of 7 to 8 compactors per chassis replaces 11 to 13 conventional tubes used in previous models. A total of 19 compactors replaces 20 tubes in the three basic chassis which go into all 22-inch table and console TV's; in the 18-inch "Designers" series, the 18-inch portable "Century" and "Celebrity" models, and the new lightweight, 22-pound 16-inch "Eскорт" model.

The photo below shows 8 compactors and 1 standard tube (left) taken over the complement of the basic chassis of the 18-inch "escort" portable TV. At the right are the 18 conventional tubes which composed the tube complement in a typical TV basic chassis of several years ago.

Making the comparison is Christopher O. McCool, Home Electronics Products Design Engineering Manager of G-E's Receiving Tube Department, who spearheaded the compacton development program. Neither the power rectifier nor tuner tubes are included in the example.

The multi-function compacton types have many applications in equipment having a number of circuit functions like the TV receivers described above. Amateur received back-hatch excitors and transceivers can be simplified with multi-function compactons in the small signal circuits. And, horizontal sweep type power compactons are available for...

G-E COMPACTRENS IN HAM GEAR

General Electric's new compacton multi-function receiving tubes are appearing in the latest amateur radio equipment now coming on the market. One of the first such applications is the new Hammarlund HF-50 solenoid transmitter. In the HF-50 trいろide compacton (each section similar to those in a 3AX7-A triode tube) is used as the input and amplifier, audio modulator for the balanced modulator, and the carrier oscillator. One section of each performs a separate function.

This is a good example of how G-E's compacton technology can simplify electronic equipment through combining functions usually performed by two or three conventional tubes, into one compact envelope. A list of compacton types was published on page 6 of the January-February, 1962 issue (Vol. 17, No. 1) of G-E HAM NEWS. A supplement to this list containing a number of new types will be published in the September-October, 1963 issue.

The HF-50 transmitter, incidentally, covers several 1-megacycle segments which include the 3.5, 7, 14, 21 and 28-megacycle amateur bands. It will run up to 130 watts P.E.P. input, and has all of the latest features.

G-E VHF FM GEAR AT K7USA

The VHF FM stations on the 50 and 144-megacycle bands at K7USA the amateur radio station at the Century 21 exhibition in Seattle have been furnished by General Electric's Communication Products Department located in Lynchburg Va.

The 80-watt deck-type base stations, the same as supplied to hundreds of commercial VHF communications users, operate on the national amateur FM calling frequencies of 52.525 and 146-146.245 megacycles. In addition, frequencies of 146.580, 146.560 and 147.000 megacycles are available for casual operation to keep the calling frequencies clear.

If you are planning to attend the Century 21 exhibition in Seattle this summer, and have VHF FM mobile equipment in your car, be sure to take along crystals which cover the above channels so that you can contact K7USA to perform the tasks to which conventional sweep tubes are usually assigned in amateur radio.

G-E HAM NEWS plans to publish articles on "compactorized" equipment for the home constructor in coming issues. Watch for them!

Available FREE from your G-E Tube Distributor

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