SSB Topics

FREQUENCY CONVERSION FOR SSB — MIXERS, MODULATORS and FILTERS — INPUT IMPEDANCES FOR G-G LINEARS

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

SINGLE-SIDEBAND is one of the most efficient methods of voice communication by radio. It provides for more effective use of available frequencies and of potential transmitter capability.

By eliminating one sideband it is possible to reduce the transmitted bandwidth, so that it is no greater than that of the applied audio or speech frequency signals. This enables the equipment designer to control the bandwidth by restricting the audio frequencies to those required for transmission of maximum intelligence. Further, it is possible for an increased number of stations to operate in a given band of frequencies.

In the transmitted SSB signal the radio frequency power is directly proportional to the original audio frequency power—and with the carrier suppressed, there is essentially *no* RF output when there is *no* audio input. By suppressing the carrier and one side-band, the entire power capability of the final amplifier can be utilised to radiate the remaining sideband, which contains all the required voice intelligence to be transmitted. This means that the typical AM transmitter final amplifier—modified for linear operation—can provide *four times the effective power output* when driven by a single-sideband exciter.

Single-sideband not only offers spectrum and power economy, but also is less susceptible to the annoying effects of selective fading and interference than amplitude modulation. The elimination of the transmitted carrier and the improved performance of SSB during unfavourable propagation conditions produce the principal advantages of the SSB method of communication.

Frequency Conversion Problems

The design of a band-switching single-sideband exciter, in which the SSB signal is generated at a low frequency, requires the use of multiple-frequency conversion systems to obtain output on the higher-frequency bands. This heterodyning process combines the original SSB signal with a second signal of a different freqnency, to produce two new additional signals whose frequencies are the sum and the difference of the two original signal frequencies, respectively. The circuit which performs the heterodyning function is called a *converter, mixer* or *modulator.* The heterodyne process is often described as: *convert, mix, beat, heterodyne* or *modulate.* It should be recognized that all of these imposing terms mean exactly the same thing. Fig. 1 shows a basic block diagram of a mixer stage fed by two signal generating stages to produce the desired output frequency.

The actual output of each mixing stage contains the two input signals, all harmonics of the two input signals and, in addition, all possible combinations of the sum and difference frequencies of all the harmonics! (The desired output frequency is normally either the sum or difference frequency of the sideband generator frequency and the conversion injection frequency.) *All products except the one desired output signal frequency* are considered spurious signals and adequate precautionary measures must be included to prevent radiation of these spurious signals from the transmitter output.

The stages following the mixer circuit should include at least two high-selectivity tuned circuits at the desired output frequency, as a means of obtaining adequate spurious signal suppression. Cascading a number of tuned circuits—ganged and tracked together—would be an excellent arrangement. Such a method is often found in commercially designed equipment. With a Q of 100 in each tuned circuit, attenuation of 50 dB (100,000 to 1 in power), or more, will be obtained for spurious signals which are within plus or minus 10 per cent of the mixer output signal frequency. In practice, the two input signal frequencies and their harmonics should not

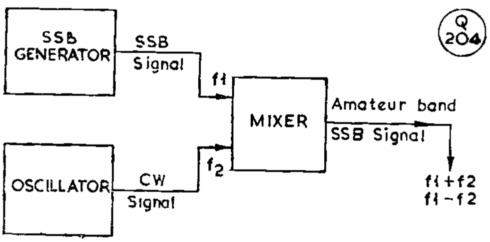

Fig. 1. A mixer stage fed by two signal generating stages. The SSB signal, F1, and the RF carrier, F2, are heterodyned to produce two new beats, the sum and difference of F1 with F2. Careful selection of the two signal frequencies is necessary to eliminate the possibility of spurious beats appearing with the wanted signal.

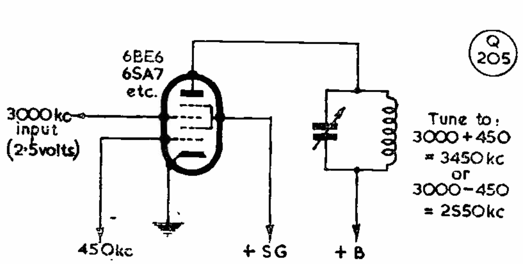

Fig. 2. Pentagrid mixer suitable for SSB frequency conversion. A 450 kc SSB signal is fed to grid 1, and the conversion frequency RF signal to grid 3. The plate circuit is tuned to the sum or difference of the two input frequencies; in this example, the output could be either 3,450 or 2,550 kc.

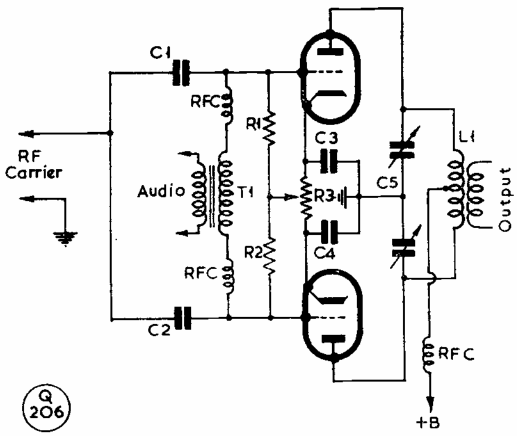

Fig. 3. Typical push-pull balanced modulator. The RF drive is introduced in parallel in both valves and the audio modulating frequency in push-pull. The carrier is suppressed in the push-pull tuned output circuit, with only the two sideband frequencies remaining — thus, a double-sideband suppressed-carrier signal. In practice, C5 is tuned to the RF input signal and the cathode bias potentiometer R3 adjusted for maximum carrier suppression.

Table of Values

Fig. 3. Push-Pull Balanced Modulator

C1, C2	= 100 μμF	R3	= 1,000 ohm potentiometer for carrier balancing
C3, C4	= .01 μF	RFC	= RF chokes
C5	= 150 μμF, variable, split-stator	T1	= Audio transformer, plate to grid
L1	= Plate coil tuned to carrier frequency		
R1, R2	= 15,000 ohms		

appear within this 20 per cent range, or they may also appear in the output.

There are a number of different types of mixer circuits, most of which will generate harmonics of both input signal frequencies, even though the harmonic content of the input signals is very low. These harmonics should not appear within 10 per cent of the desired mixer output frequency. The *ideal* way of avoiding spurious frequencies resulting from harmonics of the input signal is to place both the mixer input frequencies higher than the output signal frequency. This is often impossible — for example, when heterodyning the output of a 400 to 500 kc filter-type generator to a higher frequency.

In a phasing-type or HF crystal filter-type SSB generator the operating frequency is not restricted. Therefore, the signal may be placed higher in frequency than the amateur band on which output is desired. For design convenience, this may not be always followed—as in the case of the popular 9-mc phasing generator, which is used for operation in the 14, 21 and 28 mc bands.

The *General Electric Ham News,* Volume 11, No. 6, for Nov.-Dec., 1956, includes a "mix-selector" chart, which is helpful in determining spurious products for various different mixing frequencies.

About Mixers

In single-sideband applications the mixer is often referred to as a "modulator." Its circuitry can be simple or complex, single-ended (as used in a receiving converter circuit) or push-pull (commonly called a balanced modulator) and may use either diodes or multi-element valves. The single or balanced diode mixers are more foolproof than the average multi-element valve mixers. However, the diode is likely to have high harmonic output and will provide no power gain.

The use of pentode or other multi-element valves designed for mixer service in receivers usually results in less harmonic generation than in a diode circuit. In order to avoid distortion of the output signal it is necessary carefully to control the operating conditions. The conventional mixer circuits for these valves feed each mixer input signal to a separate grid. A tuned circuit resonant at the desired output frequency is connected to the plate of the valve.

A pentagrid mixer circuit using a receiving type mixer valve is shown in Fig. 2. The output signal from the 450 kc SSB generator is fed into the No. 1 injection grid and the conversion frequency is fed into the No. 3 grid. Although this is the reverse of the normal grid connections, it has been found to produce an improvement of 10 dB in distortion. The SSB signal is fed to the mixer at a low level to avoid distortion. The conversion frequency is fed at about 20 dB higher level. This results in very low harmonic generation of the SSB signal in the mixer valve.

(Over

Table of Values

Fig. 4. The Push-Push Method of Balancing

C1	= 150 μμF, variable, split-stator	C5	= 0.001 μF
C2, C3	= .01 μF	R1	= 1,000 ohm carrier balancing potentiometer
C4	= 150 μμF, variable	T1	= Audio transformer, plate to grid.
L1	= Grid coil, centre-tapped. Tuned to carrier frequency	RFC	= RF choke
L2	= Plate coil tuned to carrier frequency		

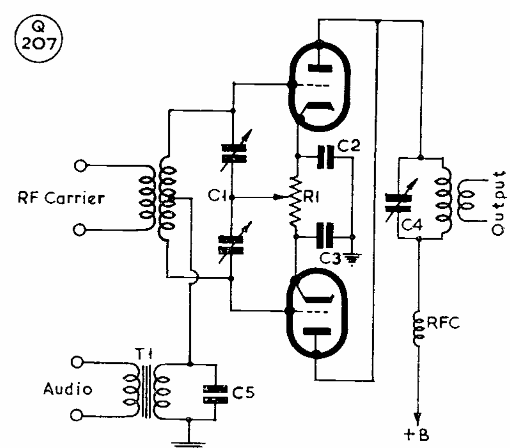

Fig. 4. The push-push balanced modulator with grid and plate circuits resonated for the RF carrier frequency. Both the RF excitation and the audio are in push-pull, with the output in parallel. C1, C4 are tuned to the carrier frequency, and R1 set for minimum carrier output. As in the case of Fig. 3, a DSB signal appears in the tank circuit.

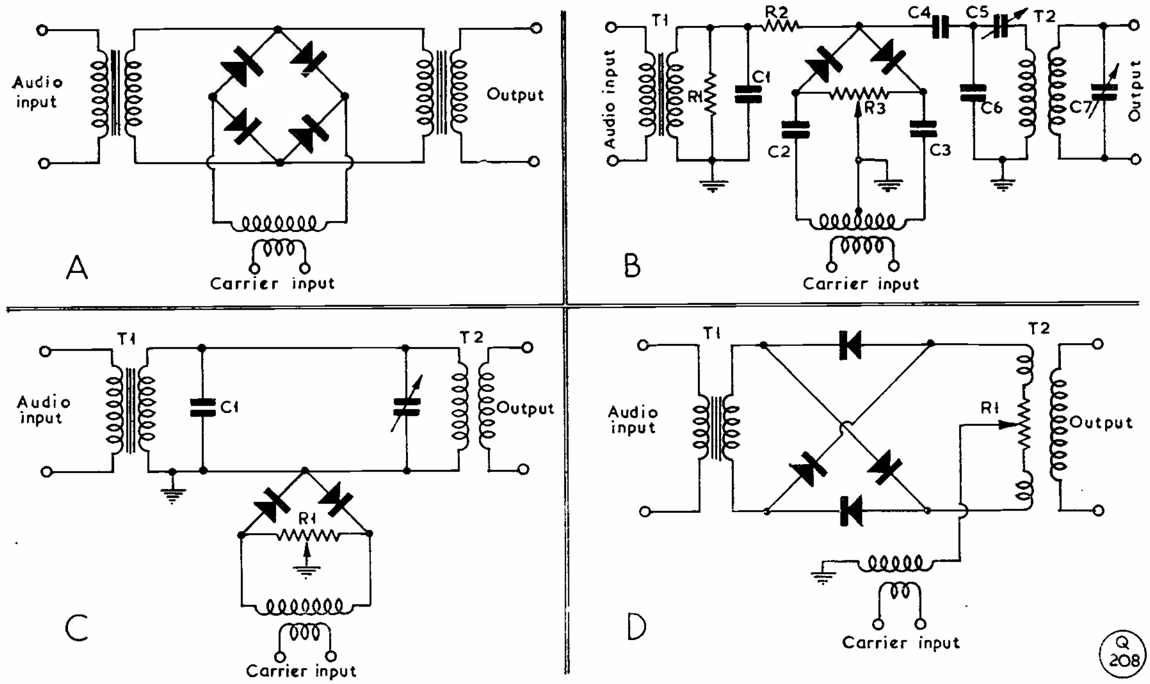

Fig. 5. Rectifier type balanced modulator circuits. The individual rectifier may be germanium crystal diodes, copper oxide rectifiers or silicon diodes. Each rectifier is selected to match closely the characteristics of the other three. In (A) is a shunt-type balanced modulator, a bridge arrangement as used in many commercial applications. The circuit at (B) is a practical adaptation of (A), the values specified being for a 450 kc carrier frequency; this type of balanced modulator can be used to feed a crystal lattice filter. (C) is a series-type balanced modulator, and (D) is a ring modulator, with input and output impedances of approximately 500 ohms; this circuit is more suitable for frequencies of 50 kc and below.

The balanced modulator mixer stage offers the main advantage of cancelling the fundamental and certain harmonics of at least one of the input signals. It is usually possible to balance this circuit for maximum attenuation of the fundamental of either input signal, but not both simultaneously. The circuitry for a balanced modulator may appear in several different forms. In the push-pull arrangement shown in Fig. 3, the conversion signal is fed to the valve grids in parallel and the audio in push-pull, with the plates of the valves connected in push-pull. The circuit illustrated in Fig. 4 is called the push-push balanced modulator. In this case the RF drive and the audio are applied in push-pull and the output circuit is in parallel. Both circuits will operate with equal effectiveness to balance-out the RF carrier. Under perfect balance conditions, there will be *no* output with *no* audio signal input.

In the diode-type balanced modulator circuits shown in Fig. 5, the diode rectifiers are connected so that no RF can pass from the carrier signal source to the output circuit through the two possible paths. If the diodes have equal forward resistances, no RF will get through to the output. The circuit is unbalanced with application of an audio signal and some RF will appear in the output circuit. As is the case for all balanced modulator circuits, with an RF carrier and audio signal inputs, the output is a double-sideband suppressed-carrier signal.

Table of Values

Fig. 5(B). Shunt type balanced modulator

C1, C2, C3	= 330 $\mu\mu$F mica or ceramic	R3	= 1,000 ohm carrier balancing pot.
C4, C6	= .001 μF	T1	= Plate to 500 ohm transformer
C5, C7	= To tune primary and secondary of T2 to carrier freq.	T2	= IF xformer, with series-tuned primary
R1, R2	= 1,000 ohms		

Fig. 5(C). Series type balanced modulator

C1	= 0.003 μF	T1	= Plate to grid audio transformer
R1	= 1,000 ohm carrier balancing pot.	T2	= IF transf. tuned to carrier freq.

Fig. 5(D). The Ring Modulator

R1	= 250 ohms	T2	= Tuned to carrier frequency.
T1	= Plate to 500 ohm audio transformer		

When using diodes minimum distortion is obtained when the RF carrier voltage is at least 5 to 10 times that of the peak audio voltage. It is suggested that several volts of RF and a fraction of a volt of AF be used in the average operating circuit. The forward resistances of the diodes may be measured with an ohmmeter, to assure as close a match as possible.

A balanced modulator of particular interest which does not use push-pull circuitry is that in the Collins KWS-1 SSB transmitter. This circuit, given in Fig. 6, is very similar to one of the popular product de-modulator circuits, also developed by Collins for use in their SSB receivers. The rather complex tuned plate section is required due to the high ratio of VFO input voltage to SSB signal voltage. The purpose of the tuned plate circuit is to reject a strong undesired frequency component in the mixer output, which results from the high-level VFO signal. The principle involved is called "selective feedback rejection."

The tuned plate circuit consists of C4, C5 and L1, with C4 and L1 tuned to resonance at the desired output frequency in the 3 to 4 mc range. Condensers C1, C2 and C3 form a capacitive voltage divider, with the values of C2 and C3 chosen to determine the amount of feedback for the undesired VFO component. The variable condenser, C1, is adjusted to null out the particular frequency to be rejected. Heterodyne action in the valve and selective feedback rejection in the tuned plate circuit produce excellent selective bandpass and stability characteristics for the 3 to 4 mc range.

This circuit may also be used for mixing an audio signal with that of an RF carrier. The audio would be fed to pin No. 7 in place of the indicated 250 kc SSB signal, and with proper adjustments, the output would consist of a double-sideband suppressed-carrier signal.

For a complete discussion on the various forms of balanced modulators the reader is referred to the following amateur publications: *Single Sideband for the Radio Amateur*,* published by ARRL; and the two *CQ Magazine* publications: *Single Sideband Techniques*, by Brown and the *New Sideband Handbook*,* by Stoner.

* Obtainable from Publications Dept., *Short Wave Magazine*, Ltd.

HF Crystal Filter Circuits

By using a high-frequency crystal filter for sideband selection in an SSB receiver or transmitter, one or more frequency conversions may be eliminated. Elimination of the additional mixing stages offers the advantage of circuit simplification and improved performance, as previously discussed. A well designed and properly aligned HF filter will provide the selectivity and stability required in SSB equipment. It is for these reasons that the HF filter has become so popular among the Sideband group and is destined to become a "standard" in SSB generating systems.

A mobile single-sideband transceiver, designed around a high-frequency surplus-crystal filter, was described in *QST* for June 1959. The author, W3TLN, makes good use of surplus FT-243 HF crystals in the filter circuit, in a similar manner to that described in "SSB Topics" for April 1959. While the complete transceiver by W3TLN is of interest to those contemplating the design and construction of such a unit, the discussion following will be limited to the subject at hand HF filter applications and associated circuitry.

The diagram shown in Fig. 7 indicates one of the possible ways to use the HF filter in an SSB generator. While 8·55 mc surplus crystals are used in this filter, W3TLN points out that the same results can be anticipated with crystals in the 5 to 8·5 mc range.

A conventional Pierce oscillator circuit is used for the 8553 kc carrier crystal. The condenser in parallel with this crystal is used to lower the frequency for proper placement on the filter slope. The balanced modulator is similar to the one used by Collins in their KWS-1 and KWM-1. The author suggests that other modulator circuits could be used if preferred.

The filter input is terminated and isolated from the non-linear impedances of the balanced modulator by a resistive isolating pad. The filter output is terminated in a resistor of 510 ohms, which was determined to give the flattest passband with the crystals used. The crystal filter is of the back-to-back

Table of Values

Fig. 6. Collins balanced modulator circuit

C1, C4	8-50 μμF midget variable	C7, C8	.001 μF
C2	270 μμF mica or ceramic	L1	Tuned to 80 m. with C4 and C5
		R1	47,000 ohms
C3	430 μμF mica or ceramic	R2	47 ohms
		R3	220 ohms
C5	20 μμF mica or ceramic	R4	100,000 ohms
		R5	10,000 ohms
C6	.01 μF	RFC	2.5 mHy RF choke

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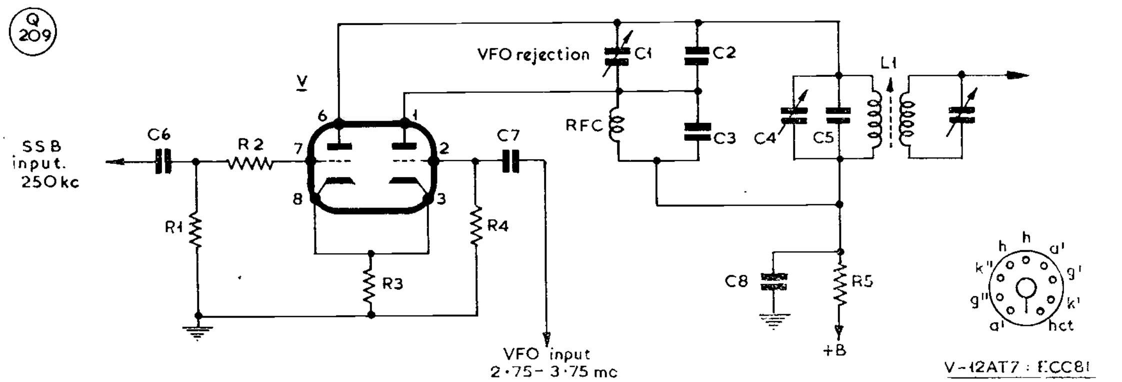

Fig. 6. An unusual balance modulator arrangement, of the type found in the Collins KWS-1 SSB transmitter. The sideband signal at 250 kc is taken from the output of a mechanical filter and mixed with the 2,750-3,750 kc VFO signal to produce output in the 80-metre band. The tank circuit C4-L1 is tuned for 80 metres. The RF voltage on pin 7 is about 0.1v. and at pin 2 it is 1.5v. The principle known as selective feedback rejection is used to "null out" the strong VFO component in the output, this being performed by C1.

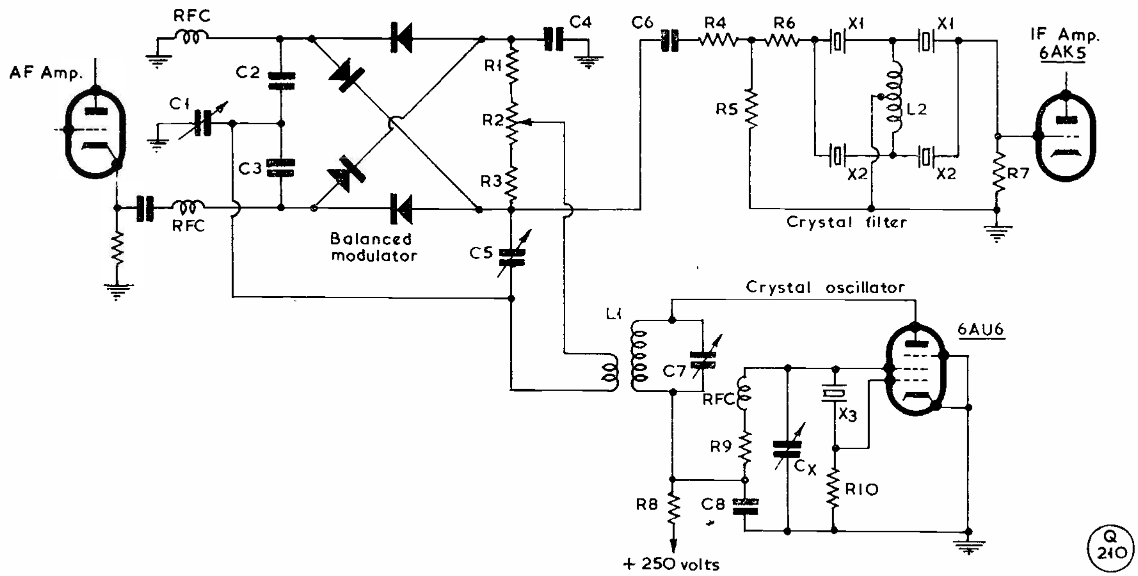

Fig. 7. Portion of an SSB generator using an HF crystal filter. In this circuit, the carrier CO is on 8553 kc. Cx is used to tune the crystal frequency lower if required ; carrier suppression is by a ring-type balanced modulator, the adjustment for exact null being on C1, C5, R2. The filter is terminated with the correct value resistors to give the flattest pass-band.

half-lattice configuration, using crystal pairs with 1·5 kc frequency separation. A bifilar winding on a toroidal ferrite core is used to couple the two filter sections together.

Further experimentation by G2MA has produced the interesting filter circuit shown in Fig. 8. Two half-lattice filters are again connected in the back-to-back circuit, with 1·9 kc separation for the two crystal pairs. This filter was measured and gave a bandwidth of 2·2 kc at the 6 dB points and had a shape factor of 2·2, which is ideal for SSB.

It will be noted that the input and output circuits are terminated in resistors and tuned circuits. The two tuned circuits are adjusted for maximum signal output and the series condensers, C3 and C4 are included to permit optimum impedance matching. G2MA points out that if the tuned circuits and the impedance matching condensers are omitted, the values of the terminating resistors, R1 and R2, must be determined experimentally. This may vary with different crystals and different frequency spacings. A value of about 430 ohms is suggested as a starting point.

G2MA has also done some experimentation with four pairs of HF crystals in a filter. Although the exact frequency matching was quite tricky, the filter produced "skirts" which were nearly vertical ! It should be noted that the performance of the 1·5 kc separation G2MA filter described in this column for June 1959 was incorrectly stated. The shape factor should have been 2·3 and *not* 60:1 as the "gremlin" indicated—that is, the bandwidth at the 60 dB down points was 2·3 times the width at the 6 dB points.

Impedances in Grounded-Grid Linears

Impedance matching in grounded-grid linear amplifiers seems to be a problem confronting a

Table of Values

Fig. 7. Using an HF crystal filter

C1, C5, C7	= 3-25 $\mu\mu$F midget variable	R5	= 220 ohms
C2, C3, C8	= 0.001 μF	R6	= 330 ohms
C4, C6	= 200 $\mu\mu$F	R7	= 510 ohms
Cx	= 3-12 $\mu\mu$F midget variable	R8	= 1,000 ohms
L1	= Tuned to resonate at 8.5 mc with C7	R9	= 10,000 ohms
R1, R3	= 470 ohms	R10	= 350,000 ohms
R2	= 100 ohm potentiometer	RFC	= 100 μHy RF choke
R4	= 1,200 ohms	X1	= 8550 kc, FT-243 crystal
		X2	= 8551.5 kc, FT-243
		X3	= 8553 kc, FT-243
		L2	= 50 μHy bifilar wound on toroidal ferrite core

number of readers. As the majority of queries concern tetrodes and pentodes connected for high-μ triode operation—that is, with all grids operating at the same DC and signal voltages—this discussion will be limited to that mode of operation.

In a grounded-grid amplifier there are the same number of impedances to be matched as in a conventional grounded-cathode amplifier. Impedance matching becomes more important in the g-g stage when considering that the input and output impedances appear in shunt to the driver stage. This is shown in Fig. 9A. These two impedances will react upon each other—that is, a variation in one will effect the other. The actual circuit with impedances indicated is shown in Fig. 9B.

The plate load impedance is computed in the normal manner, the same as for any conventional linear amplifier. The input impedance is an entirely different problem. The actual computation is quite complicated for the average amateur and requires valve data which is normally not published by the valve manufacturers.

Fortunately, a simple method for approximating the imput impedance of g-g valves connected as high-μ triodes has been described by W6GEG, in *CQ Magazine* for January, 1956. The opposite of impedance — conductance — is first computed. If the plate resistance, Rp, is much greater than the load impedance, ZL, and the μ of the valve remains much greater than unity, the input conductance can be shown as:

$$gi = \frac{\mu}{Rp} = gm$$

This represents the valve's conductance in g-g. As impedance is the reciprocal of conductance, the input impedance may be determined by dividing the gm into 1. Valve transconductance can be obtained from manufacturers' data, which can in turn be divided into 1 to determine the input impedance in ohms.

Three well-known SSB personalities — W2CFT, left; G6LX/DJØBM, centre; and DL4WX at right. This photograph was taken at the station of DL4WX.

As an example, the 813, with a transconductance of 3750, has an approximate input impedance of 267 ohms. In this case, the driver stage output circuit must provide for a proper match to 267 ohms for maximum transfer of power.

Another point to remember in determining input impedances for g-g stages is, that for valves operated in parallel, the total input impedance for the amplifier is the impedance of one valve divided by the total number of valves in parallel. Therefore, in the case of the 813 stated above, two valves in parallel would present an input impedance of 133·5 ohms to the driver.

Table 1 lists some of the valves found to perform well with both grid and screen grid grounded. The transconductance was extracted from manufacturers' data sheets and input impedance was calculated from the formula :

$$Zg = \frac{1}{gm}$$

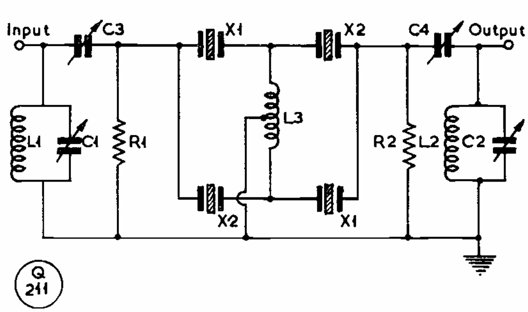

Fig. 8. HF crystal filter circuit suggested by G2MA. Two half-lattice filters are connected back-to-back, with correct impedance matching. The frequency separation of the crystals is 1.9 kc (X1, 8,600 kc ; X2, 8601.9 kc). The filters are coupled by a 25-turn bifilar coil L3, using a Mullard FX-1299 ferrite toroid core. The inductance is not critical. The tuned circuits are resonant at the filter frequency, and C3, C4 are 3-30 $\mu\mu$F miniatures for impedance matching. R1, R2 are 1,000 ohms each, non-inductive.

News and Views

It has recently been learned that the U.S. firm, The Brush Development Company, manufacturer of numerous piezo-electric crystal devices, is developing a mechanical filter utilizing piezo-electric material. The design frequency of the first filters will be in the IF range. The early indications are that the price will be about $7 (U.S.).

Also, an electronic firm in Japan is reported to be ready to start production on a mechanical filter. While no details are available at the time of writing, it can be safely assumed that the price will be reasonable !

One of the new SSB transmitter/exciter units manufactured in the States is using sub-assemblies prefabricated in Japan.

In Conclusion

When you receive this issue of SHORT WAVE MAGAZINE, your conductor will be on holiday in the States. It is hoped that many of the manufacturers of sideband equipment can be visited and through " SSB Topics " descriptions of U.S. activities and current developments in the field of sideband presented.

Many thanks to our readers for their contributions and helpful suggestions. Don't forget to send your reports on activities, experiments and sideband circuitry, as well as photographs of yourself and station, to this feature. (*Over*

Table 1

Valve Type	Transconductance (gm)	Input Impedance (ohms)
6AG7	11,000	90
6V6	3,750	266
6L6	5,200	192
802	2,250	444
837	3,400	294
6146	7,000	143
4E27	2,800	357
4E27A	2,150	466
4-125A	2,450	408
813	3,750	267
803	4,000	250
4-250A	4,000	250
1625	6,000	167
EL-34	11,000	90
EL-38	11,000	90
4X150A	12,000	80

"SSB Topics" will appear again in the December issue, for which all correspondence should be received by October 23. 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.

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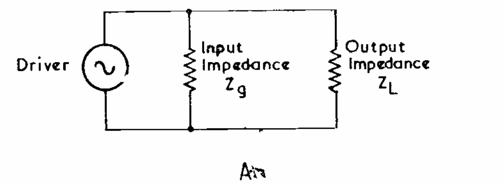


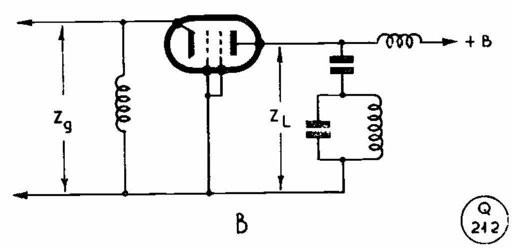


Fig. 9 (A). Input and output impedances of a grounded grid linear amplifier appear in shunt to the driver. Any change in one has a reaction on the other; this can demand high drive. Fig. 9 (B) shows the circuit for a grounded-grid, grounded-screen amplifier. Many pentodes or tetrodes may be used in this configuration with good results; in the case of a pentode with separate suppressor, this should be tied to the other two grids.

MARCONI TROPOSPHERIC SCATTER LINK FOR WEST INDIES

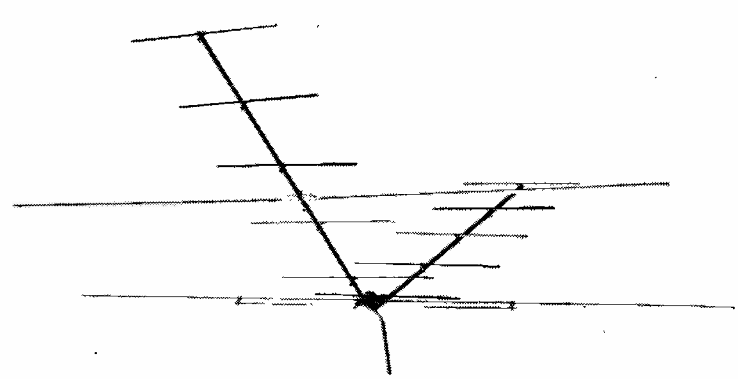
Cables & Wireless Ltd. have placed an order with Marconi's Wireless Telegraph Co. Ltd. for a quadruple diversity UHF tropospheric scatter link between the West Indies islands of Trinidad and Barbados. Duplicated VHF multi-channel links to carry the signals between the tropospheric scatter terminals and the operating centres are also to be installed. The Trinidad scatter site will be established at a point along the Blanchisseuse Road, some ten miles from the Cable & Wireless station at Port-of-Spain. In Barbados the scatter station will be at Mount Misery with a two-way multi-channel VHF link connection to the Cable & Wireless radio receiving station at Carrington.

The system will carry six telephone speech channels initially, one of which will be used for telegraphy, embodying three 100-baud FM/VF channels. One FM/VF channel will be in two-channel (50 baud) time-division multiplex. Automatic error correction is to be provided by the incorporation of the new Marconi Autoplex equipment.

Each of the tropospheric scatter sites will have two Marconi Type HS315 1 kW UHF transmitters with associated drive equipments, Type HD313. Each transmitter feeds into a 30ft. dish aerial to give an effective radiated power of some 4 megawatts in the direction of maximum intensity. Operation is in the band 680-970 mc, with a frequency spacing between transmitters of 4 mc. Since the system is quadruple diversity, two transmitters operate at each terminal, with their dishes set up about 100ft. apart. The path distance is about 210 miles.

TAKING CARE AT UHF

In a further comment on the hazards of exposure to UHF radiation, G2TA (Bushey, Herts.) says that it has now been found that there is danger to the eyes at frequencies between 1,000 and 3,000 mc if the gear is capable of producing a field of the order of 0·1 watt per sq. cm. In other words, don't peer down a waveguide with the transmitter on.



The Labgear type C.30 aerial assembly is a special three-channel model designed to cater for one Band I and one Band III transmission originating from one direction, and an additional Band III service from a completely different direction.