July 5, 1949.

J. D. HOLLAND

CIRCUIT ARRANGEMENT FOR USE WITH WIDELY-SEPARATED FREQUENCY BANDS

2,474,978

Filed Aug. 18, 1945

3 Sheets-Sheet 1

FIG. 1

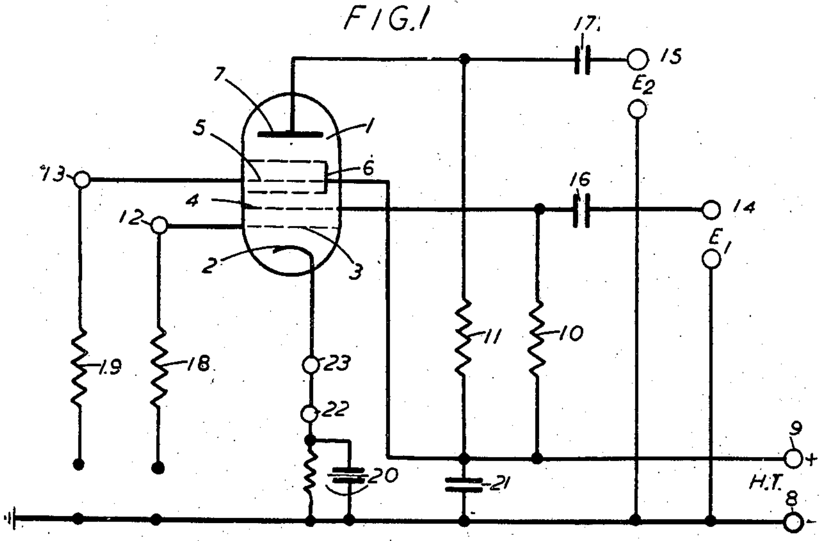
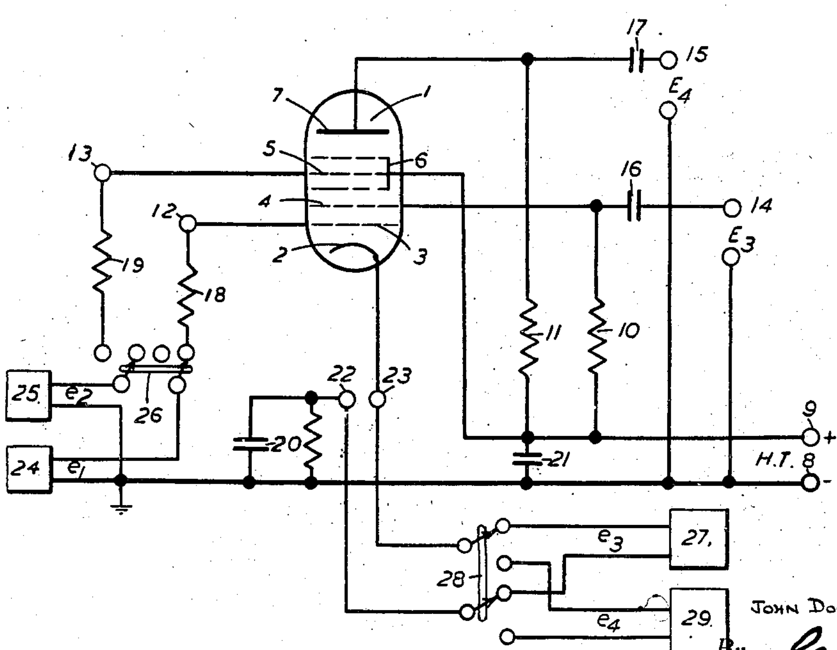


FIG. 2



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July 5, 1949. **J. D. HOLLAND** 2,474,978

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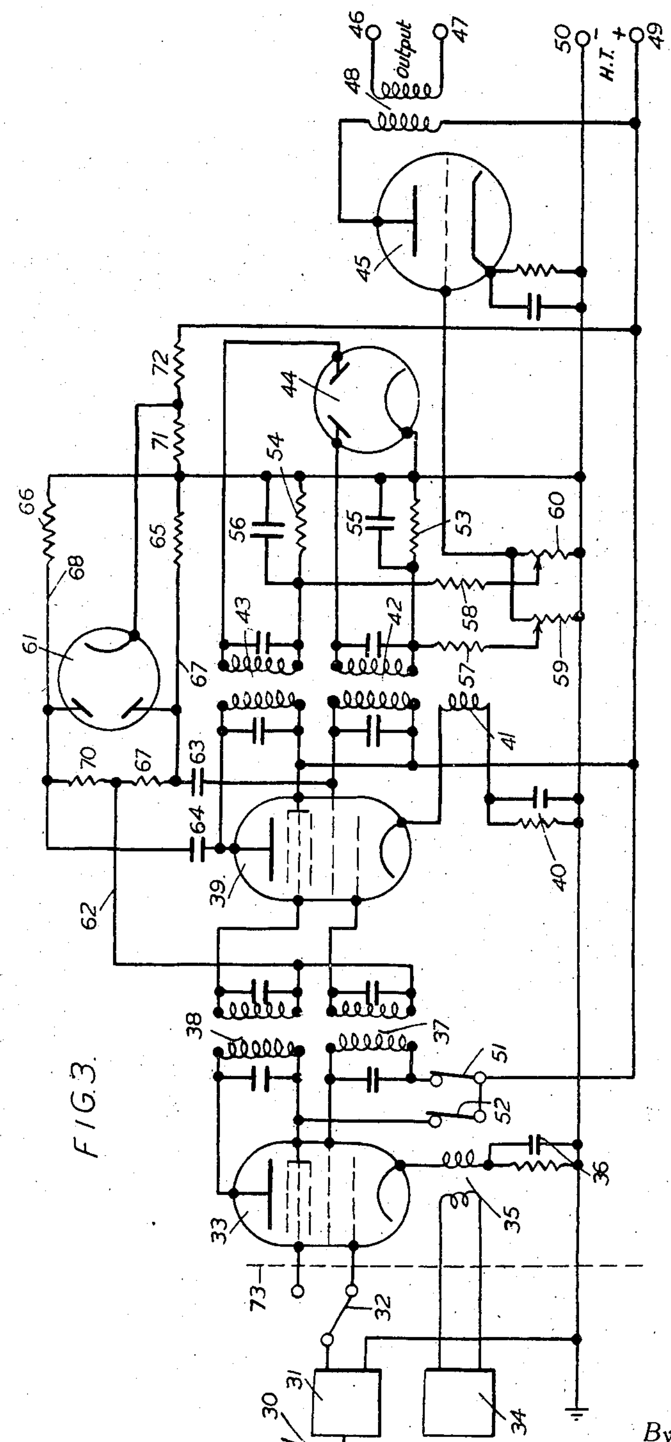

FIG. 3

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FIG. 4

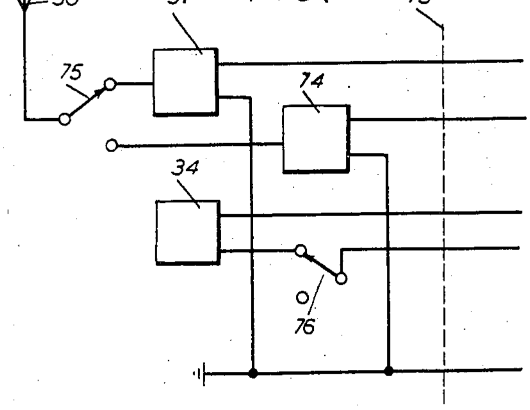


FIG. 5

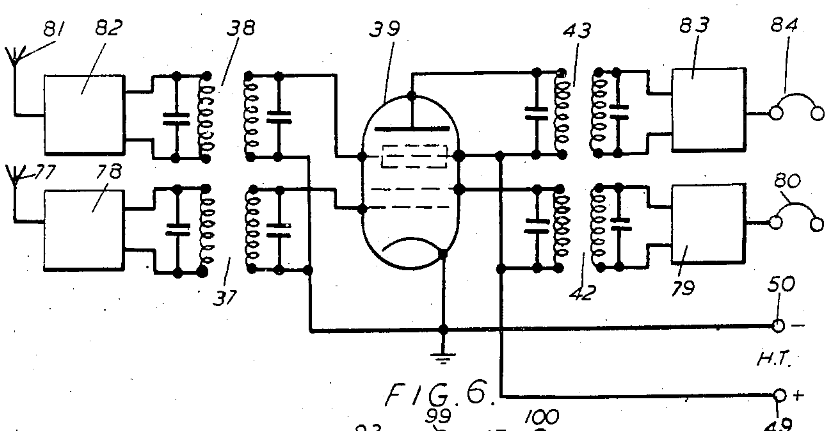
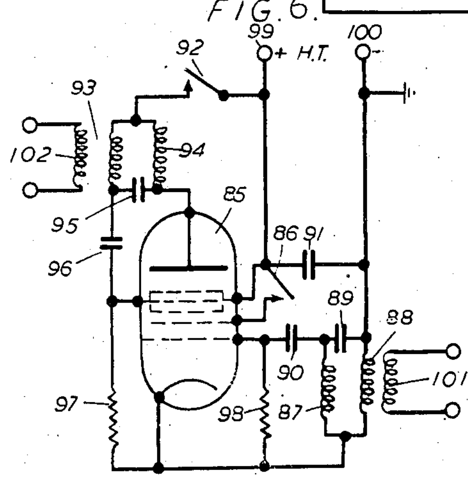


FIG. 6



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Patented July 5, 1949

2,474,978

UNITED STATES PATENT OFFICE

2,474,978

CIRCUIT ARRANGEMENTS FOR USE WITH WIDELY SEPARATED FREQUENCY BANDS

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Application August 18, 1945, Serial No. 611,378
In Great Britain September 1, 1944

4 Claims. (Cl. 250—20)

The present invention relates to thermionic valve circuits and particularly to circuits for translating or generating signals occupying two different bands of frequencies.

It is of course well known to amplify all the channels of a multi-channel system simultaneously in the same amplifiers and to separate the channels afterwards by means of filters. In such a case waves of all frequencies are simultaneously applied to the input electrodes of any valve in the amplifier, and the amplified waves are all simultaneously derived from the output electrodes thereof.

In the case of the present invention, the amplifier or other translating device is provided with a multi-electrode valve having at least three grid electrodes between the cathode and the anode which is treated as two triodes having a common cathode and sharing the same electron stream. One of these component triodes is used to translate or generate waves occupying one band of frequencies, and the other to translate or generate those occupying another band.

In this way the two channels are kept separate, though they are dealt with by the same valve.

It is also well known to employ a pentagrid valve as a frequency changer for a single band of frequencies by using the cathode and the first two grids as a triode oscillator and the third grid and anode with the cathode as a modulator. Thus whereas in this arrangement the valve is employed only to deal with one band of signal frequencies, according to the present invention the two parts of the valve are each employed for separate bands of frequencies.

The several features of the invention are set out as claims 1, 2 and 3 respectively, of the statement of claim.

The invention will be described with reference to the accompanying drawings in which

Figs. 1 and 2 show simplified schematic circuit diagrams of arrangements according to the invention.

Fig. 3 shows a schematic circuit diagram of a two-path radio receiver according to the invention.

Fig. 4 shows a modification of part of Fig. 3.

Fig. 5 shows a radio receiver according to the invention providing two separate signal channels; and

Fig. 6 shows a double oscillator according to the invention.

The type of multi-grid valve shown in the above circuits for the purpose of illustrating the invention is one sometimes called a "pentagrid,"

having five grids interposed between the cathode and the anode. The third and fifth grids are connected together to form a single screen electrode for the fourth grid. For the purpose of the present invention the screen electrode is not essential and can be omitted, the minimum requirement being that there should be at least three grids between the cathode and the anode. There may, of course, be any number of grids in excess of three, the extra grids being suitably polarized.

Fig. 1 shows diagrammatically an arrangement according to the invention. A pentagrid valve 1 comprises a cathode 2, three grids 3, 4 and 5, a screen grid electrode 6 and an anode 7. The electrodes 2, 3 and 4 constitute one triode portion, of which electrode 4 serves as the anode, and electrodes 2, 5 and 7 constitute another triode portion. The cathode 2 is connected to the grounded negative terminal 8 of the high tension supply, the positive terminal 9 of which is connected directly to the screen grid 6 and to electrodes 4 and 7 through impedance elements 10 and 11 respectively. The control grids 3 and 5 are connected to input terminals 12 and 13 respectively, and the anodes 4 and 7 are connected to output terminals 14 and 15 through blocking condensers 16 and 17, respectively. A suitable bias network 20 may be inserted in series with the cathode as shown. A condenser 21 serves as a by-pass condenser shunting the high tension source.

The impedance elements 18 and 19 represent input circuits each carrying a separate channel of signals. The signal input voltages are represented by the symbols e_1 and e_2 in series with the elements 18 and 19. The amplified or otherwise translated signals are obtained at the output terminals 14 and 15 the corresponding output voltages being E_1 and E_2 as indicated.

Let f_1 and f_2 be the signal frequencies corresponding to the input voltages e_1 and e_2, and suppose that the valve 1 is employed as an amplifier. Then when both sets of signals are applied to the respective input grids, the electron stream proceeding from the cathode will contain variations at both frequencies, so that amplified signals at both frequencies will appear at both of the anodes 4 and 7. The impedance elements 10 and 11 accordingly represent any suitable tuned circuits or filters, or the like, adapted to suppress one of the frequencies and to allow the other to pass. In order that this may be achieved without unduly complicating the impedance elements, the two frequencies f_1 and f_2

should preferably be widely separated: for example, one should be not less than about double the other, and preferably also one frequency should not be a harmonic of the other. Where the signals comprise two bands of frequencies, then the lowest frequency of the upper band should preferably be at least double the highest frequency of the lower band.

Furthermore, the two triode portions of the valve 1 will usually have different mutual conductances (the upper portion having generally the higher value) and in order to minimise interference the associated circuits should preferably be arranged so that the gains of the two amplifiers do not differ by more than about 10 decibels. As the output circuit which operates at the lower frequency will usually have a higher dynamic impedance than that operating at the lower frequency, it is desirable to operate the triode portion 2, 3, 4, at the lower frequency so that by associating with it the high impedance output circuit the gains of the two amplifiers will tend to be equalized.

If the two triode portions of the valve 1 are not operated simultaneously, then it is not important that the two frequencies f_1 and f_2 should be very widely separated, or that they should be harmonically unrelated, and a larger difference of gain for the two amplifiers can be allowed, since interference does not arise. In any case however, it is desirable that the valve should be so biassed that neither of the amplifiers are overloaded.

It will be evident that the signals applied at terminals 12 and 13 are independently amplified and are kept to separate circuits throughout. The two corresponding channels may be used simultaneously or separately. The arrangement is equivalent to two separate amplifiers each with its own valve, but the two valves are part of the same pentagrid valve. The valve 1 may also be used as a double frequency changer. In this case the strap between the terminals 22 and 23 shown in the grid connection is removed and these terminals are connected to a suitable local carrier frequency oscillator (not shown). The bias circuit 20 is chosen so that both sections of the valve 1 operate as modulators. Then if f_0 is the local carrier frequency, side bands f_0+f_1 can be obtained from the anode 4 and sidebands f_0+f_2 from the anode 7. The circuit elements 10 and 11 could then comprise band filters each of which is adapted to select a corresponding side band and to supply it to terminal 14 or 15. So long as the frequencies f_1 and f_2 are well separated, the band filters represented by the elements 10 and 11 need not be very selective.

The two channels may be provided with different local carrier frequencies by means of a simple switching arrangement, such as that shown in Fig. 2, in which the elements which are similar to corresponding elements of Fig. 1 are designated by the same numerals.

In Fig. 2, 24 and 25 represent the sources of the voltages e_1 and e_2 at frequencies f_1 and f_2. A switch 26 connects the source 24 to the input terminal 12 in the position shown, and in the other positions it disconnects the source 24 and instead connects the source 25 to the input terminal 13. A carrier frequency source 27 of voltage e_3 and frequency f_3 is connected by the switch 28 when in the position shown to the terminals 22 and 23 in series with the cathode 2. This will produce a side band f_3+f_1 at terminal 14 of voltage E_3. When the switch 28 is operated

to the other position, it substitutes for the source 27 a source 29 of voltage e_4 at frequency f_4. If the two switches 26 and 28 are mechanically connected so as to be operated together, then a side band f_4+f_2 at voltage E_4 will be obtained at terminal 15. Thus by means of the two switches 26 and 28 it is possible to select either one of the sources 24 and 25 and to provide at the same time a corresponding carrier frequency. Moreover, the corresponding side bands are obtained in separate channels.

It will be evident that the arrangement of Fig. 2 can be either a modulator or a demodulator for either channel; and it could be a modulator for one channel and a demodulator for the other.

In the remaining figures of the accompanying drawings three different types of circuit according to the invention are given as illustrations of the general principles described with reference to Figs. 1 and 2. These types are as follows:

(1) A circuit in which the two channels which pass through the multi-grid valve or valves are not intended for use simultaneously, but one channel is used for signals covering one part of a frequency band and the other for those covering another part of the band.

(2) A circuit in which the two channels are completely independent throughout and may be used simultaneously or separately.

(3) A circuit in which the two triode portions of a multi-grid valve are used as oscillators for generating two different frequencies.

Fig. 3 shows a circuit according to the invention suitable for a radio receiver adapted to cover a very wide range of frequencies, for example 15 to 26,000 kilocycles per second (kc. s.). Such a large range cannot be satisfactorily covered by the use of a single intermediate frequency for reasons of selectivity, image suppression, and gain. It is desirable therefore to divide the range into two parts, for example 15 to 500 kc. s. using an intermediate frequency of 40 kc. s. and 500 to 26,000 kc. s. with an intermediate frequency of 560 kc. s. According to the present invention two channels are provided in the receiver, in which intermediate frequencies of 40 and 560 kc. s. are respectively derived and amplified in the two corresponding portions of the valves.

In the radio receiver shown in Fig. 3 the waves are received on an antenna 30 and are passed to the high frequency amplifiers and selective circuits 31 which may be arranged in any convenient way. A switch 32 enables the output of 31 to be applied to the upper or lower input grid of a pentagrid valve 33 arranged similarly to the valve 1 of Fig. 2. A carrier frequency oscillator 34 of adjustable frequency corresponds to the oscillator 27 of Fig. 1 and is connected to the cathode circuit of the valve 33 through a transformer 35. The usual bias network for this cathode is shown at 36.

Two tuned output transformers 37 and 38 couple the two triode portions of the valve 33 to the corresponding triode portions of an amplifying pentagrid valve 39. This amplifying valve has the usual cathode bias network 40, and also a coil 41 connected in series with the cathode; the purpose of this coil will be described later. A pair of tuned output transformers 42 and 43 similar to 37 and 38 couple the two portions of the amplifying pentagrid 39 to two corresponding detector circuits which include the two halves of a double diode 44. The outputs of the two detector circuits (which will be described in detail later), are both applied to a low frequency amplifying valve 45 of any suitable type, which may be a simple triode as shown, or a pentode or pentagrid or other multi-grid valve. The amplified signal output is obtained from the terminals 46 and 47 connected to the anode circuit of the valve by a transformer 48.

It will be seen that the amplifying valve 39 is arranged substantially in the same way as the valve 1 of Fig. 1, the tuned transformers 42 and 43 corresponding respectively to the elements 10 and 11 of this figure. The tuned transformers 37 and 42 operate as band pass filters, and should be designed to pass an intermediate frequency of 40 kc. s. The tuned transformers 38 and 43 should likewise be designed to pass an intermediate frequency of 560 kc. s.

The two anodes of the valve 39 are each connected through the primary winding of the corresponding tuned transformer to the positive terminal 49 of the high tension supply, (the negative terminal 50 of which is connected to ground), and the screen grid is connected directly thereto. The corresponding connections to the valve 33 are similar, except that two normally closed switches 51 and 52 have been interposed as shown, for a purpose to be explained later, in connection with another embodiment of the invention. They are not needed for the embodiment now being described, and could be omitted.

The previously mentioned detector circuits comprise diode load resistances 53 and 54 shunted by condensers 55 and 56 each connected between the lower terminal of the secondary winding of the corresponding tuned transformer 42 or 43, and ground. The upper terminal of each secondary winding is connected to ground through the corresponding half of the double diode 44. The detected voltage obtained across the load resistance 53 or 54 is applied through the fixed resistance 57 or 58 and adjustable potentiometer 59 or 60 to the control grid of the valve 45.

A second double diode 61 is provided to generate an appropriate automatic gain control voltage for the amplifying valve 39. This voltage is applied over the conductor 62 to both the input grids of this valve through the corresponding secondary windings of the transformers 37 and 38. The anodes of the valve 39 are connected through blocking condensers 63 and 64 to the corresponding anodes of the double diode 61. The two diode load resistances are 65 and 66, and the corresponding rectified voltages obtained across these resistances are applied to the conductor 62 through conductors 67 and 68 and resistances 69 and 70. Appropriate smoothing circuits (not shown) may be included in the conductors 67 and 68 according to the usual practice. Two resistances 71 and 72 are connected in series across the high tension supply, and the cathode of the double diode 61 is connected to the junction point of these resistances. This provides a positive bias for the cathode which is the so-called delaying bias which prevents any gain control voltage from being generated until the incoming signal level exceeds some predetermined limit.

The circuit is intended to be employed in the following way. To receive signals in the lower band (15 to 500 kc. s.), the switch 32 is placed in the position shown, and the frequency of the local oscillator 34 is adjusted to obtain the lower intermediate frequency (40 kc. s.) from the lower anode of the frequency changing valve 33. This intermediate frequency is amplified in the lower portion of the amplifying valve 39 and is rectified in the left hand half of the double diode 44. The rectified signals are then applied through the resistance 57 and potentiometer 59 to the low frequency amplifier valve 45 and thence to the output terminals 46 and 47. The potentiometer 59 may be adjusted to give an appropriate output level. At the same time the double diode 61 produces a suitable gain control voltage which is applied to the lower input grid of the amplifying valve 39 through the resistances 69 and conductor 62.

When signals in the higher range are being received, the swtch 32 is set in the upper position, and the frequency of the oscillator is set in order to obtain the higher intermediate frequency (560 kc. s.). This is now generated in the upper portion of the frequency changing valve 33 and amplified in the upper portion of the amplifying valve 39, and is rectified in the right hand half of the double diode 44. The rectified signals are applied through resistance 58 and adjustable potentiometer 59 to the low frequency valve 45. The gain control voltage for the upper portion of the amplifying hexode 39 is generated by the double diode 61 and applied through resistance 70 and conductor 62.

It will thus be seen that the two channels provided by the valves 33 and 39 are never employed simultaneously. For this reason it is immaterial that the upper intermediate ferquency happens to be the 14th harmonic of the lower intermediate frequency. The advantage of the arrangement is that all switching in the intermediate frequency or detecting circuits is avoided, the switches 51 and 52 not being used in this embodiment, as already explained, and being preferably omitted.

The coil 41 shown connected in series with the cathode of the valve 39 may be used to introduce negative feedback for stabilizing the operation of one triode portion of the valve without affecting the other portions. The coil 41 is assumed to be coupled to the transformer 42 so that some of the output energy is fed back to the input of the lower triode. The winding 41 should, of course, be so poled that the energy is fed back in negative phase in order to obtain the desired stabilization. Clearly the coil 41 could alternatively be coupled to the transformer 43 in which case the negative feedback will be applied to the upper triode instead of to the lower triode. In case it is not desired to use any negative feedback at all, the coil 41 may be omitted and replaced by a direct connection.

It will be evident that either or both of the double diodes may be replaced by two separate diodes or by any other suitable rectifying devices or circuits such as dry rectifiers.

Any number of amplifying stages (not shown) may be added either before or after the valve 33, each such stage comprising a multi electrode valve arranged similarly to the valve 39.

By a slight modification of the circuit, Fig. 3 can be put to a different use. In marine work it is sometimes necessary to provide for stand-by reception on a certain narrow range of frequencies, for example 488 to 515 kc. s. The portion of Fig. 3 to the left hand side of the dotted line 73 may then be modified as shown in Fig. 4, in which 30 is the antenna as before and 31 comprises the high frequency amplifier and selective circuits adapted for the range 2,000 to 25,000 kc. s. for example.

The block 74 comprises selective and amplifying circuits for the stand-by range 488 to 515 kc. s.

The carrier frequency oscillator **34** is as before, and is adapted for the range covered by the amplifier **31**. A switch **75** allows the antenna **30** to be connected to either of the elements **31** or **74**, and another switch **76**, which may be coupled to **75** is provided for disconnecting the oscillator **34** when the antenna **30** is connected to the element **74**.

Referring now to Fig. 3, the valve **33** should be biassed in such a manner that the lower triode portion operates as a simple amplifier for the stand-by range 488 to 515 kc. s., while the upper triode acts as a modulator for the high frequency range as before, and the oscillator **34** is set to produce a suitable intermediate frequency such as 1,000 kc. s., to which the transformers **38** and **43** will be tuned. The transformers **37** and **42** will of course be tuned for the stand-by range. Selection by the double diode **44** for both ranges takes place as before.

The advantage of this arrangement is that the operator may set his apparatus to receive on some frequency in the high frequency range, and by simply operating the two switches **75** and **76** (Fig. 4) he may listen in at any time on the stand-by range without upsetting the normal adjustments of the apparatus for the high frequency range. It is to be noted that the switch **76** disconnects the oscillator **34** when the valve **33** is acting as an amplifier for the stand-by range.

It will be seen that the stand-by range is demodulated directly without the introduction of an intermediate frequency, and the two portions of the valve **33** perform different functions.

There are, of course, other ways in which the switching may be carried out. Another method utilizes the switches **51** and **52** included in Fig. 3. In Fig. 4 the switch **75** may be omitted and the antenna **30** may be permanently connected to both of the devices **31** and **74**. Then when it is desired to receive on the high frequency range, the switch **51** (Fig. 3) is opened, thus disabling the lower triode portion of the valve **33**, and the switch **76** (Fig. 4) is left in the position shown. In order to listen in the stand-by range, the switches **52** and **76** are opened, and switch **51** is closed. The upper portion of the valve **33** is now disabled and the oscillator **34** is disconnected. The three switches **51**, **52** and **76** may clearly be mechanically connected so that all the necessary switching is performed simultaneously for each range.

Fig. 5 shows an example of a pentagrid valve arranged according to the invention to produce amplification in each of two entirely separate signal channels which may be used separately or simultaneously. The valve **39** with its tuned transformers **37**, **38**, **42** and **43** is arranged practically in the same way as in Fig. 3 except that the feedback coil **41** and the automatic gain control arrangements are omitted.

The first channel comprises an antenna **77** connected to receiving circuits represented by the block **78** and including ferquency changing means supplying a first intermediate frequency to the tuned transformer **37**. This channel also comprises a detecting circuit **79** connected to the tuned transformer **42** and supplying the detected signals to the receiver **80**. The second channel comprises the antenna **81**, receiving and frequency changing circuits **82** supplying a second intermediate frequency to the tuned transformer **38**, and a detecting circuit **83** connected to the tuned transformer **43** and supplying the detected

signals to the receiver **84**. The two intermediate frequencies (which should preferably be well separated, as already explained) are amplified, by the respective portions of the pentagrid **39** as previously described, and are separately detected and supplied to corresponding receivers. The two signal channels so obtained are thus quite independent of one another.

Additional stages of amplification (not shown) may be provided by other valves arranged in the same way as the valve **39**.

The circuits represented by the blocks **78**, **79**, **82** and **83** are not shown in detail, and they may be provided in any well known way.

In Figs. 3 and 5, the tuned transformers **37**, **38**, **42** and **43** represent only one possible form of selective circuits which may be used for keeping the two channels separate. Various other types of tuned circuits could be used, or wave filters of various configurations. What is required is that the selective circuits used in one channel shall transmit the waves corresponding to that channel and shall exclude those corresponding to the other channel.

Referring again to the valve **39** shown in Fig. 5, which is arranged as a simple amplifier in both channels if the output sides of the tuned transformers **42** and **43** were connected back to the respective input grids of the valve **39** in place of the transformers **37** and **38**, instead of being connected to the circuits **78** and **79**, as shown, then a double oscillator would result giving two different frequencies respectively determined by the tuning of the transformers **42** and **43**.

A similar result would be obtained whatever type of selective circuit were employed, provided, of course, that the poling of the connections is such as to produce positive feedback, and that the gain of each of the triode portions is sufficient.

Fig. 6 shows an example of a double oscillator designed according to this principle. The valve **85** is a pentagrid as before. When the switch **86** is closed, the anode of the lower triode portion is coupled back to the control grid by means of the inductively coupled coils **87** and **88** which are tuned by the condenser **89**, the circuit being completed by the relatively large blocking condenser **90** and by-pass condenser **91**. In a similar way when the switch **92** is closed, the anode of the upper triode portion of the valve is coupled back to the control grid by means of the inductively coupled coils **93** and **94** which are tuned by the condenser **95**, the circuit being completed by the blocking condenser **96**. The upper and lower control grids are connected to the cathode by the high resistances **97** and **98**. The high tension supply is intended to be connected to the terminals **99** and **100** as indicated and the negative terminal **100** may be connected to ground.

Thus so long as the windings **87** and **88** and the windings **93** and **94**, respectively, are poled so that positive feedback is obtained in both cases, then oscillations at one frequency determined by the tuning of the circuit **87**, **88**, **89** will occur when the switch **86** is closed, and may be obtained from a coil **101** coupled to the coils **87** and **88**. Likewise if the switch **92** is closed oscillations at another frequency determined by the tuning of the circuit **93**, **94**, **95** will occur and may be obtained from a coil **102** coupled to the coils **93** and **94**.

The oscillator of Fig. 6 may be conveniently employed in combination with Fig. 3 for the reception of continuous wave telegraphy. The output coils **101** and **102** may be respectively connected to corresponding additional windings (not shown) on the transformers 42 and 43 of Fig. 3. Assuming that the intermediate frequencies corresponding to the two continuous wave channels are 40 k. c. s. and 560 k. c. s. as before, then the lower and upper triodes in Fig. 6 may be tuned to oscillate at 41 and 561 k c. s. for example, giving a beat note of 1000 cycles with the above mentioned intermediate frequencies.

Then the switches 86 and 92 may be mechanically coupled with the switch 31 so that when receiving on the lower channel of Fig. 3 the switch 86 is closed, and when receiving on the other channel the switch 92 is closed. Another switch (not shown) associated with the oscillator 34 may if desired be also mechanically coupled to the switch 31 so that the proper local carrier oscillator frequency is obtained automatically in each case.

It will be evident, of course, that the oscillator of Fig. 6 may be designed to produce any desired pair of frequencies.

What is claimed is:

1. An electric wave translating arrangement for a wide band of frequencies comprising a thermionic valve having a cathode, an anode, and at least three grid electrodes mounted in order therebetween, a source of signals of a wide band of frequencies, a switch connected to said source and having two contacts connected respectively to the first and third of said grid electrodes counting from said cathode, and two selective filter circuits connected respectively to the second of said grid electrodes and to said anode, the filter circuit connected to said second grid electrode being designed to pass the lower frequencies of said band of frequencies and to exclude the higher band, the filter circuit connected to said anode being designed to pass the higher frequencies of said band of frequencies and to exclude the lower band, whereby said switch is positioned to make contact with said first grid contact for said lower frequencies and with said third grid contact for said higher frequencies, said arrangement passing said broad band of frequencies.

2. A translating arrangement according to claim 1, wherein each of said filter circuits comprises a band filter composed of a transformer having tuned primary and secondary windings, each of said filter circuits being designed to exclude frequencies passed by the other of said filters.

3. A translating device according to claim 1, wherein said signal source and said switch are connected in series between said cathode and the one of said grids to which said switch is connected and which further comprises a source of a constant frequency connected in series with said cathode and said signal source for beating said constant frequency with said signals.

4. A translating device according to claim 1, which further comprises a source of operating potential for said tube connected in series with said cathode and both said filter circuits, whereby said tube amplifies said signals.

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