Dec. 27, 1938. W. BIER 2,142,038

BAND PASS FILTER

Filed Aug. 26, 1936 2 Sheets-Sheet 1

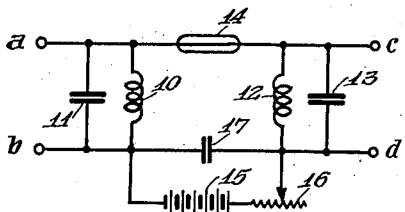

Fig:1

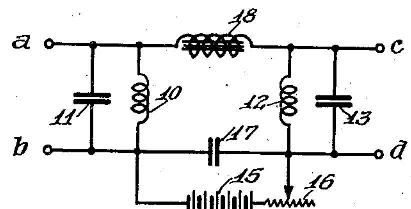

Fig:2

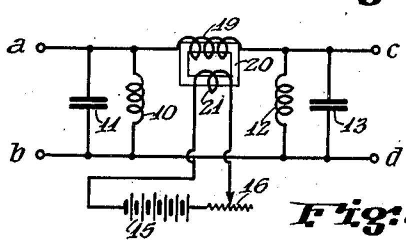

Fig:3

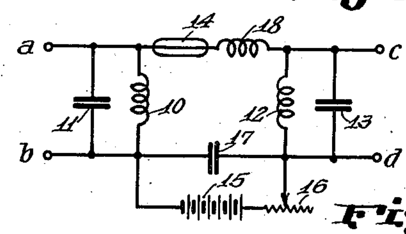

Fig:4

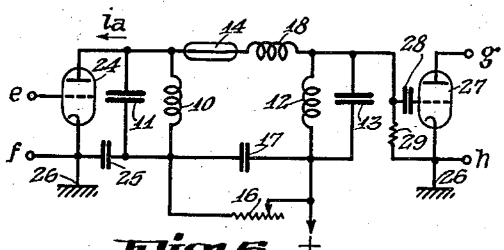

Fig:5

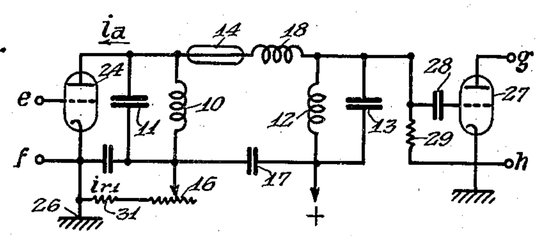

Fig:6

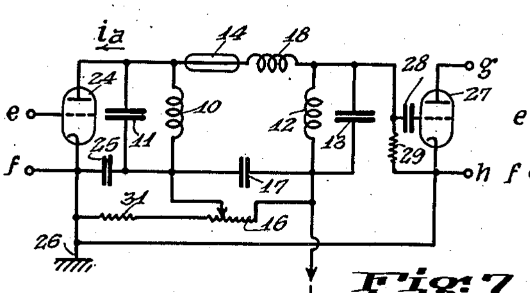

Fig:7

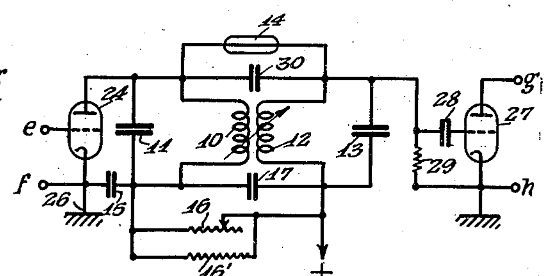

Fig:8

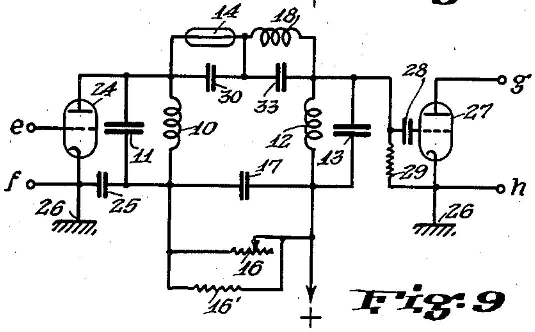

Fig:9

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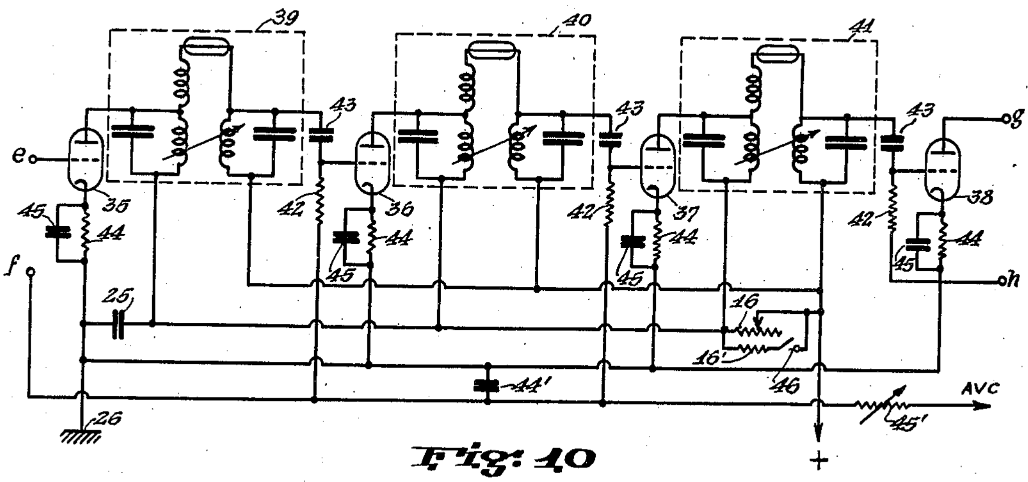

Fig: 10

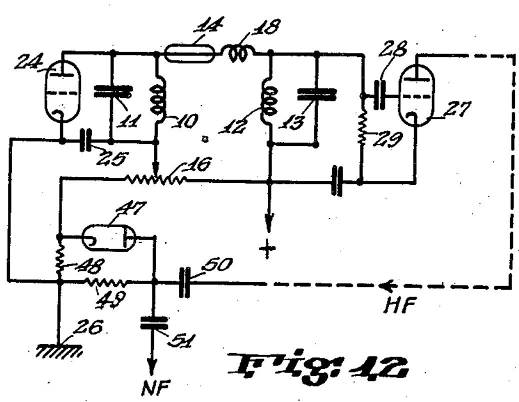

Fig: 12

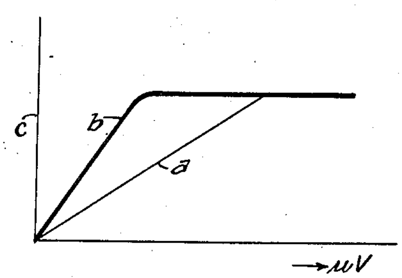

Fig: 11

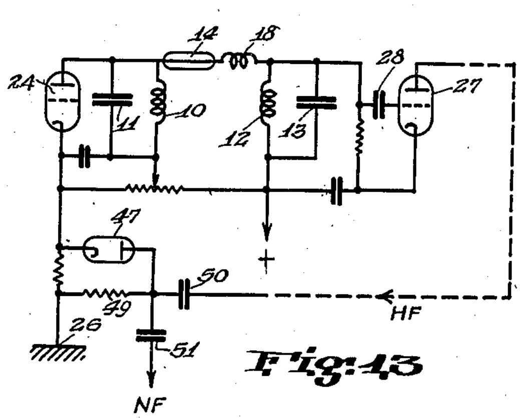

Fig: 13

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UNITED STATES PATENT OFFICE

2,142,038

BAND PASS FILTER

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Application August 26, 1936, Serial No. 97,913
In Germany August 30, 1935

21 Claims. (Cl. 178—44)

The present invention relates to improvements for and methods of operating selective circuits, more particularly circuits for transmitting or receiving modulated carrier signals, and objects of the invention are the provision of a control system for varying the selectivity or band width of a selective circuit or band pass filter by purely electrical means, such as by varying an auxiliary electric current or potential.

Another object of the invention is the provision of a system of automatic selectivity control for broadcast receivers or other receiving apparatus for modulated carrier signals whereby the band width or frequency response characteristic of the system is automatically increased or, in other words, the selectivity decreased as the signal strength increases and vice versa, in such a manner as to provide high selectivity or narrow band width and consequent decrease of background noise and other interference for weak or distant signals, and to provide low selectivity or a broad band width and consequent improved fidelity and quality of reception for strong or local signals.

Further objects and features of the invention will become apparent from the following detailed description of several practical embodiments of the invention and its mode of operation taken in conjunction with the accompanying drawings forming part of this specification and wherein;

Fig. 1 is a diagram showing a simple variable band selector circuit according to the invention;

Figs. 2 to 4 are modifications of a band selector of the type shown by Fig. 1.

Figs. 5 to 9 illustrate a selector circuit of the type shown by the previous figures embodied in an amplifying system.

Fig. 10 illustrates a portion of a multi-stage receiver or amplifier with automatic selectivity or band width control by means of variable band filters serving as a coupling means between successive amplifying stages.

Fig. 11 is a diagram illustrative of the function of one of the features of the circuits shown in Figs. 8, 9 and 10; and

Figs. 12 and 13 illustrate the employment of the inventive circuit in conjunction with a silent tuning system.

Similar reference characters identify similar parts throughout the different views of the drawings.

With the above mentioned objects in view, the invention generally involves the provision of an impedance element forming the coupling link or part thereof between two or more circuits of a selective system or band pass filter, said impedance element being adapted to vary its reactive or nonreactive impedance by the variation of an auxiliary electric current.

Impedance elements suited for this purpose are known in the art in a variety of constructions based on various functions and operating characteristics. Thus, a space discharge tube may be provided for the purpose of this invention which, as is well known, constitutes an impedance element whose impedance value may be varied by adjusting the bias of a gird or an equivalent control element. Another impedance element suited for the purpose of the invention consists in a metal wire arranged within a tube filled with a suitable gaseous atmosphere such as a hydrogen atmosphere in case of an iron wire or nitrogen when using a uranium dioxide conductor. Impedance elements of this type as known in the art have a positive or negative impedance characteristic represented by the impedance as a function of the current passing through the tube. Devices of this type are known in the art as current limiters by reason of the fact that the current passing through such a device remains practically constant over a wide range of the voltage applied to its terminals or, in other words, the internal impedance changes if a varying current is impressed from the outside. Thus for instance, a tube of the uranium oxide-nitrogen type is adapted to vary its impedance (non-reactive impedance) from about 150,000 ohms to about 10,000 ohms by varying the current through the tube from 1 to 10 mA.

Other types of variable impedance which may be used successfully in connection with the invention are the well known cuprous oxide or other dry rectifiers of similar type. Devices of this type present an impedance which may vary from about 200,000 ohms to 6,000 ohms for a biasing potential varying from zero to 20 volts.

Further suited for the invention are iron core inductance coils through which a direct biasing current is passed or which may be provided with a separate biasing or premagnetization winding. There are many other variable impedances which may be employed for carrying out the invention which broadly consists in the provision of an impedance element of the above mentioned character as a coupling link between separate circuits or units of a band selector system.

Referring to Fig. 1 of the drawings, there is shown a simple variable band selector according to the invention. The input signals which may be in the form of a modulated carrier current, such as supplied from an R. F. or I. F. stage of a radio receiver are impressed upon the input terminals *a* and *b* and taken off the output terminals *c* and *d* for utilization in any desired manner after passing through the filter system. The latter may serve as a coupling arrangement between successive stages of a cascade amplifier such as for coupling successive high frequency or intermediate frequency stages in a radio receiver, as will be described in greater detail hereinafter.

The variable band filter shown comprises a pair of tunable circuits each connected between the input and output terminals and comprising inductance coils **10** and **12** shunted by condensers **11** and **13**, respectively. The upper terminals of the circuits **10**, **11** and **12**, **13** are connected through a variable impedance element **14** of the general character described above and in the example shown consisting of an iron-hydrogen or uranium oxide-nitrogen resistor. The lower terminals of the circuits **10**, **11** and **12**, **13** are connected across a suitable current source such as a battery or the like in series with a regulating resistance **16**. In this manner a direct current path is established from the battery **15**, through resistor **16**, inductance **12**, variable coupling element **14**, inductance **10**, and back to battery **15**. By adjusting the resistance **16**, the current through the device **14** is varied causing a variation of its impedance and in turn of the frequency response characteristic or band width of the system which may thus be adjusted to suit any special requirements. Item **17** is a by-pass condenser for the high frequency currents shunting the battery **15**.

The function and operation of a circuit of the type described is as follows: If the current through the device **14** is low; that is, if its impedance is high, the coupling between the resonant circuits **10**, **11** and **12**, **13** is loose resulting in a narrow resonance curve or band width and in turn high selectivity of the system. If, on the other hand, the current of the device **14** is high or its impedance low, the coupling between the circuits **10**, **11** and **12**, **13** becomes closer resulting in a greater or lesser broadening of the resonance curve or band width and in turn decreased selectivity of the system. In this manner any desired selectivity or band width can be obtained by controlling the biasing current for the impedance device **14**.

Referring to Fig. 2, there is shown a similar selective system to Fig. 1 wherein a reactive coupling impedance **18** in the form of an iron core induction coil is substituted for the non-reactive impedance **14** shown in Fig. 1. As is well known, the electrical inductance of such a coil may be varied within substantial limits by varying the biasing current or pre-magnetization of the iron core, in the example shown by adjusting the resistance **16**. As a result, the inductance of the coil **18** is varied between substantial limits, resulting in a variation of the degree of coupling between the circuits **10**, **11** and **12**, **13** and in turn in a substantial modification of the selective or band width characteristics of the system.

The change of selectivity or band width in an arrangement according to Figure 2 is substantially similar as in arrangement of Figure 1, but the resonance curve obtained has a more favorable flat topped shape due to the employment of at least one reactive impedance element in the coupling path, the impedance value of which varies with the frequency of the impressed signals. The output resonant circuit **12**, **13**, the coupling impedance **18** and the condenser **17** are connected in series and form a shunt circuit across the input resonant circuit **10**, **11**. Thus, the energy transferred from the circuit **10**, **11** to the circuit **12**, **13** varies depending both on the magnitude of the impedance **18** or the biasing current therethrough and on the frequency of the impressed signals. If the impedance **18** is high (low biasing current) a substantial signal potential drop will be generated across the same thereby decreasing the potential drop across the circuit **12**, **13** and resulting in a loose coupling between the resonant circuits or narrow band width of the system. This applies to a single signal frequency impressed upon the system. If an extended band of frequencies such as a modulated carrier signal is impressed upon the system, the coupling will be less for the higher and lower frequencies of the band due to the relatively higher drops generated across the impedance **18** by the high frequencies and across the condenser **17** by the lower frequencies of the band, respectively. As a result of this a resonance or selectivity curve of favorable shape with steep ascending and descending branches is obtained. If the impedance **18** is low (large biasing current) conditions are reversed and the coupling becomes tighter resulting in a widening of the band of the band width or frequency response curve without substantially affecting the steepness of the ascending and descending branches.

Fig. 3 shows another modification of a variable band width selector similar to Fig. 2 but differing therefrom in the provision of a coupling inductance coil **19** having a closed iron core **20** and a separate pre-magnetization or biasing winding **21** connected to the battery **15** and regulating resistance **16**. The function of this arrangement is similar to that of Figure 2 as is understood.

Referring to Fig. 4, this illustrates a system comprising the features of both Figs. 1 and 2 by the employment of a reactive and non-reactive coupling impedance **18** and **14**, respectively, connected in series between the circuits **10**, **11** and **12**, **13**. The inductance **18** may be variable or fixed; that is to say, it may be provided with or without an iron core. This circuit combines the advantages of both a non-reactive and a reactive coupling whereby a substantially "flat top" selectivity or resonance characteristic substantially without humps or depressions is obtained by the proper design of the separate circuit elements.

Referring to Fig. 5 there is shown a band pass system of the type according to Fig. 4 embodied in a vacuum tube amplifier. Item **24** represents an input amplifying tube having its grid-cathode path connected across the input terminals *e* and *f* and having its output or anode-cathode path connected across the tuned circuit **10**, **11** with a blocking condenser **25** inserted in the cathode connecting lead. There is further provided an output tube **27** having its grid-cathode path coupled with the tuned circuit **12**, **13** through a coupling condenser **28** and a grid leak resistance **29** and having its output or anode-cathode path connected with the output terminals *g* and *h*. The cathodes of tubes **24** and **27** are connected to ground **26** in accordance with the usual practice. The anode current for the tube **24** is supplied by a suitable high tension source, the positive terminal of which is indicated by the plus symbol.

In the circuit shown, the anode current for the tube **24** supplied from the high tension source is passed through a pair of parallel branches, one of which includes the variable coupling impedance **14** and the other includes the regulating resistance **16**. If R represents the value of the impedance **14** and r the value of the resistance **16**, the direct current through R may be varied from zero to i_a (i_a representing the anode current through the tube) and the coupling between the circuits **10**, **11** and **12**, **13** adjusted accordingly.

If the variation afforded by an arrangement of this type is insufficient; that is to say, if the variation of the current from zero to i_a is too small to secure band widths or selectivity variations over a sufficient range to suit existing requirements, an improved circuit as shown in Fig. 6 may be employed. In the latter, the current from the high tension source first flows through the coupling impedances **18** and **14** and is then branched and partly passed through the tube **24** (current i_a) and partly through the regulating resistor **16** (resistance values r) and a limiting resistor **31** in series therewith (resistance value r_1). In a circuit of this type the current through the coupling impedance **14** or **18** may be varied from i_a to i_{r1} which latter is the limit current determined by the resistor **31** adapted to maintain the variation of the direct anode potential of the tube within admissible limits.

Referring to Fig. 7, this illustrates a combination of the features of the circuits according to Figs. 5 and 6 by which the variation of the current through impedance coupling element **14** and/or **18** is determined by the limits zero to i_a+i_{r1}. In certain cases the variation of the coupling afforded by the arrangements as described including Fig. 7, may be still insufficient and greater variations may be desirable. In the latter case the circuits according to Figs. 8 and 9 may be resorted to.

According to Fig. 8, which is substantially similar to Fig. 5, a differential coupling is provided between the circuits **10**, **11** and **12**, **13**. The variable coupling element **14** is shunted by a condenser **30** and the coils **10** and **12** are in inductive relationship with each other to secure a direct magnetic coupling k_1 acting in an opposite sense to the coupling k_2 afforded by the impedance **14**. By suitably dimensioning the several elements of the circuit, a theoretical resultant coupling variation from 0 to $k_1=k_2$ is obtained by an arrangement of this type.

In the modification according to Fig. 9, the coupling is afforded by the element **14** in series with a parallel tuned circuit formed by an inductance **18** shunted by a condenser **33** and connected in series with the variable coupling element **14**. This system affords coupling variations and corresponding band width control within a considerably increased range compared with the systems heretofore described.

By the employment of variable band selectors or filters of the type described hereinbefore, it was found that it is possible to secure an effective regulation of the band width over a substantial range without materially affecting the shape or other characteristics of the selectivity curve such as by the formation of humps or depressions or other irregularities encountered in systems heretofore known in the art.

The principle of employing impedance elements whose impedance value may be varied by the variation of an electric current or biasing potential as a coupling means between the circuits or units of a band selector favorably lends itself to the attainment of an automatic band width control in a radio receiver or the like depending on the strength of the transmitting station being received.

By the provision of a well known automatic volume control arrangement (AVC) the anode current of a high frequency or intermediate frequency amplifying tube varies inversely proportional to the strength of the carrier frequency. Thus, if a circuit of the type shown in Figs. 1 to 8 is embodied in a radio receiver provided with an AVC arrangement, simultaneously an automatic band width control is secured; that is, a narrowing or widening of the frequency band to which the receiver is receptive, dependent on the strength of the transmitting station being received. The range of the automatic regulation may be adjusted by means of the regulating resistance **16** to suit any desired requirements. The resistance **16** may serve for adjusting several amplifying stages simultaneously, thereby resulting in a great simplification and increased operating efficiency. An arrangement of this type is shown in Fig. 10.

The system according to Fig. 10 may constitute a part of a radio receiver such as the high frequency or intermediate frequency amplifying system and in the example shown comprises four amplifying tubes **35**, **36**, **37** and **38** connected in cascade by means of coupling devices **39**, **40** and **41** of the type according to the invention and described in the previous figures. The coupling or band pass circuit **39** is connected to the output circuit of the first or input tube **35** and coupled with the grid circuit of the succeeding tube **36** through a grid coupling condenser **43** and grid leak **42**, and the band pass selectors **40** and **41** are coupled with their respective tubes **37** and **38** in a similar manner as shown. The grids of the tubes are shown biased negatively with respect to their cathodes by the provision of a biasing resistance **44** in the cathode leads shunted by decoupling condensers **45** in accordance with customary practice. The input signals are impressed upon the terminals e, f in series with an AVC potential supplied from a subsequent portion of the receiver, such as a diode detector (not shown) connected to the output terminal g and h of the last tube **38** through a biasing resistance **45'** in a manner well known in the art. The biasing current for the variable coupling element of the band pass selectors **39**, **40** and **41** is branched off the positive terminal of the high tension or anode potential source through a variable adjusting resistance **16** in a manner similar as described herebefore.

In an arrangement of this type, if the signal strength increases, an increased negative potential is applied in a known manner to the grid of the several tubes by the function of the automatic volume control arrangement, thus causing a decrease of the anode current through the several tubes and in turn a decrease of the biasing current passing through the variable coupling impedance element of the band pass selectors **39**, **40** and **41**. This in turn results in an increase of the coupling by the differential action between the inductive couplings between the circuit and the coupling through the variable coupling impedance (see Figure 8), and in turn a corresponding widening of the band width. Vice versa, a decrease of the signal strength will result in a narrowing of the frequency selective curve or band width of the receiver, as is understood.

If a receiver of the type according to **Fig.**

5 or Fig. 10 is used in a locality with strong local electric interference, the band width adjusted by the receiver automatically would become inadmissably wide when receiving a very strong transmitter. In order to definitely limit the band width, an additional resistance 16′ is connected in parallel to the variable or band selecting resistance 16 as shown in Figs. 8, 9 and 10. The resistance 16′ is adjusted once in accordance with the existing interference or noise level and then may remain in fixed position.

It is customary to provide optical tuning indicators for securing an accurate tuning, especially in high quality radio receivers. At the same time it is desirable to provide means for decreasing the volume of the receiver to a fraction of its normal value during the tuning operation. For this purpose the resistance 16′ may be used by connecting or disconnecting the same, such as by means of a switch 46 as shown in Fig. 10 whereby the volume may be decreased to the desired value (due to the extremely loose coupling of the filter circuits) and a convenient oral tuning afforded in this manner by reason of the fact that through the considerably decreased gain the AVC system is no longer effective. The curve *a* in Fig. 10 illustrates the variation as compared with the normal condition *b* whereby the output voltage *c* is plotted as a function of the receiving field strength applied to the input of the receiver. At the same time the arrangement as is understood from Fig. 10 acts as a blocking means in such a manner as to enable only strong transmitters capable of providing sufficient volume to be received.

In modern radio receivers, it is furthermore customary to provide a so-called silent tuning arrangement whereby the sensitivity of the receiver at a minimum receiving field strength is decreased to zero or, in other words, the receiver completely blocked. Since this blocking limit as well as the minimum band width both depend upon the existing noise or interference level, it is advisable to interconnect both adjustments with each other. Thus, if the resistance 16 or 16′ is simultaneously operated with the silent tuning adjustment, the receiver is blocked at a minimum band width either during the tuning period (operation at 16′) or during the band width selection (variation of 16).

Referring to Fig. 12, there is shown an arrangement for combining the two functions in a purely electrical manner. For this purpose the regulating current for adjusting the band width is passed through a resistance 48 adapted to provide a bias for a diode detector serving as a rectifier for the high frequency oscillations applied thereto through a coupling condenser 50 and for securing audio frequency signal variations applied to a succeeding low frequency amplifier through a coupling condenser 51 and coupling resistance 49. In a circuit of this type if the current through the adjusting resistance 16 and the biasing resistance 48 increases corresponding to small band width of the receiver, the bias of the diode increases, thus causing a blocking action for the receiving signals. In place of a diode, a discharge tube with a grid as the control element may be provided for securing the same effects, as will be understood.

Referring to Fig. 13, this is substantially similar to the arrangement according to Fig. 12 with the only difference of the connection of the cathode of the tube 24 directly to the cathode of diode 47. As a result of this connection, the variation of the anode current of the tube 24, or in other words, of the receiving field strength applied to the input of the receiver also effects the bias of the diode 47 in such a manner that with increasing field strength the anode current or the bias, will decrease thereby decreasing or interrupting the blocking action.

It will be evident from the above that the invention as described in connection with the specific embodiments shown herein for illustration is susceptible of numerous variations and modifications differing from those illustrated and coming within the broad spirit and scope of the invention as defined in the appended claims.

I claim:

1. In a band-pass filter for transmitting electric wave energy, a pair of resonant circuits each comprising an induction coil shunted by a condenser, an independent coupling path connecting one end of said induction coils, said coupling path including an impedance element adapted to vary its electrical impedance in accordance with biasing current applied thereto, and a source of variable direct current for controlling said impedance.

2. In a band-pass filter for transmitting electric wave energy, a pair of resonant circuits each comprising an induction coil shunted by a condenser, an independent coupling path connecting the high potential ends of said induction coils, said coupling path including an impedance element adapted to vary its electrical impedance in accordance with a biasing current applied thereto, and a source of variable direct current for controlling said impedance.

3. A band-pass filter as claimed in claim 2, wherein said impedance element consists of an iron core induction coil, and means whereby current from said source controls the magnetization of said coil.

4. A band-pass filter as claimed in claim 2, wherein said impedance element consists of a metal wire mounted in a vessel containing a gaseous atmosphere, and means for passing current from said source through said metal wire.

5. In a band pass selector, a pair of resonant circuits each comprising an induction coil shunted by a condenser; an independent coupling path connecting one end of said induction coils; said coupling path including both reactive and non-reactive impedance elements at least one of which is adapted to vary its impedance value in accordance with an electrical biasing current applied thereto; a source of direct current connected across the remaining ends of said induction coils; a variable resistance in series with said source; and a by-pass condenser across said source and variable resistance.

6. In an amplifier for modulated carrier signals, a first amplifying valve, a second amplifying valve, a band-pass filter connecting said valves in cascade, said filter comprising a first resonant circuit connected to the output of the first valve and a second resonant circuit connected to the input of the second valve, each of said resonant circuits comprising an induction coil shunted by a condenser, an independent coupling path connecting the high potential ends of said induction coils, an impedance element inserted in said coupling path, said impedance element being adapted to vary its electrical impedance in accordance with an electrical biasing current passed therethrough, a source of anode current, and a pair of direct current circuit paths from said source to said first valve, one of said circuit paths including the induction

coil of said first resonant circuit and the other of said circuit paths including the induction coil of said second resonant circuit and said coupling path in series.

7. In an amplifier as claimed in claim 6 including a variable resistance inserted in one of said circuit paths.

8. In an amplifier for modulated carrier signals, a pair of amplifying electron valves each having a cathode, anode and a control electrode, a band-pass filter connecting said valves in cascade, said filter comprising a first resonant circuit connected to the output of the first valve and a second resonant circuit connected to the input of the second valve, an independent coupling path connecting the high potential ends of said resonant circuits, an impedance element in said coupling path, said impedance element being adapted to vary its electrical impedance in accordance with a biasing current affecting the same, an anode current source for said valves, and circuit connections from said source to the anode of said first valve through said coupling path for controlling said impedance by the anode current through said first valve.

9. In an amplifier as claimed in claim 8 including means for automatically increasing and decreasing the anode current of at least said first valve with increasing and decreasing strength, respectively, of the carrier component of a modulated signal applied to the input of said first valve.

10. In an amplifier for modulated carrier signals, a pair of amplifying valves each comprising a cathode, an anode and a control grid, a band-pass filter connecting said valves in cascade, said filter comprising a first resonant circuit connected to the output of the first valve and a second resonant circuit connected to the input of the second valve, each of said resonant circuits comprising an induction coil shunted by a condenser, an independent coupling path connecting the high potential ends of said resonant circuits, an impedance element inserted in said coupling path, said impedance element being adapted to vary its electrical impedance in accordance with variations of a biasing current controlling the same, a source of anode current for said valves, a first direct current path from the positive pole of said source to the anode of the first valve through the induction coil of said first resonant circuit, a second direct current path from the positive pole of said source to the anode of said first valve, means whereby the current through said second direct current path controls said impedance element, an adjustable resistance in at least one of said current paths, and means for automatically decreasing and increasing the electron current through at least said first valve with increasing and decreasing strength, respectively, of the carrier component of a modulated carrier signal applied to the input of said first valve.

11. In an amplifier for modulated carrier signals, a pair of amplifying valves each comprising a cathode, an anode and a grid, a band-pass filter connecting said valves in cascade, said band-pass filter comprising a first resonant circuit connected to the output of the first valve and a second resonant circuit connected to the input of the second valve, each of said resonant circuits comprising an induction coil shunted by a condenser, an independent coupling path connecting the high potential ends of said induction coils, an impedance element inserted in said coupling path, said impedance element being adapted to vary its electrical impedance in accordance with a biasing current controlling the same, a source of anode current for said valves, a pair of direct current paths from the positive pole of said source to the anode of at least the first valve, one of said current paths including the induction coil of said first resonant circuit and the other current path including the induction coil of said second resonant circuit, means whereby the current through said second current path controls said impedance element, automatic volume control means for varying the average electron current through at least the first valve in inverse relation to the strength of the carrier component of a modulated carrier signal applied to the grid of said first valve, and regulating means for adjusting the current through said first direct current path.

12. In an amplifier as claimed in claim 11 including a fixed impedance in parallel to said regulating means, and means for connecting and disconnecting said last mentioned impedance.

13. A variable band-pass filter comprising a first resonant circuit forming an input, a second resonant circuit forming an output, a shunt circuit across said first resonant circuit comprising an impedance element in series with said second resonant circuit, said impedance element being adapted to vary its impedance value in accordance with an electric biasing current affecting the same, and means for controlling the bias of said impedance element.

14. A variable band-pass filter comprising a first resonant circuit forming an input, a second resonant circuit forming an output, a shunt circuit across said first resonant circuit including at least one reactive impedance element in series with said second resonant circuit, said impedance element being adapted to vary its impedance value in accordance with an electric biasing current affecting the same, and means for controlling the bias of said impedance element.

15. A variable band-pass filter comprising a first resonant circuit forming an input, a second resonant circuit forming an output, a shunt circuit across said first resonant circuit comprising an inductive impedance, said second resonant circuit and a condenser in series, said impedance being adapted to vary its inductance in accordance with an electric biasing current affecting the same, and means for controlling the bias of said impedance.

16. A variable band-pass filter comprising a first resonant circuit forming an input, a second resonant circuit forming an output, a shunt path across said first resonant circuit comprising an impedance element and said second resonant circuit in series, said impedance element being adapted to vary its impedance value in accordance with an electric biasing current affecting the same thereby to cause a variable energy transfer from said first circuit to said second circuit, a further direct coupling between said resonant circuits arranged to act in opposition to the coupling effected by said impedance element, and means for controlling the bias of said impedance element.

17. A variable band pass filter comprising a first resonant circuit forming an input, a second resonant circuit forming an output, a shunt circuit across said first resonant circuit comprising an iron core inductance coil in series with said second resonant circuit, a direct current circuit for controlling the pre-magnetization of said in-

ductance coil, and a further inductive coupling between said resonant circuits arranged to act in opposition to the coupling effected by said induction coil.

18. A four-terminal circuit comprising an input resonant circuit and an output resonant circuit, one end of said resonant circuits being connected to a common reference potential point, an independent coupling path connecting the remaining ends of said resonant circuits, an impedance element inserted in said coupling path to determine the transfer of electric wave energy from said first to said second resonant circuit, said impedance element being adapted to vary its electrical impedance according to an electric biasing current applied thereto, and a source of variable current controlling said impedance element.

19. A four-terminal circuit comprising an input resonant circuit and an output resonant circuit, one end of said resonant circuits being connected to a common reference potential point, an independent coupling path connecting the remaining ends of said resonant circuits, a reactive impedance element inserted in said coupling path to determine the transfer of electric wave energy from said first to said second resonant circuit, said reactive impedance element being adapted to vary its electrical impedance according to an electric biasing current applied thereto, and a source of variable current controlling said reactive impedance element.

20. A four-terminal circuit comprising an input resonant circuit and an output resonant circuit, one end of said resonant circuits being connected to a common reference potential point, an independent coupling path connecting the remaining ends of said resonant circuits, a reactive and a non-reactive impedance element inserted in said coupling path to determine the transfer of electric wave energy from said first to said second resonant circuit, at least one of said impedance elements being adapted to vary its electrical impedance according to an electric biasing current applied thereto, and a source of variable current controlling said last mentioned impedance element.

21. A four-terminal circuit comprising an input resonant circuit and an output resonant circuit, one end of said resonant circuits being connected to a common reference potential point, an independent coupling path connecting the remaining ends of said resonant circuits, a reactive and a non-reactive impedance element inserted in said coupling path to determine the transfer of electric wave energy from said first to said second resonant circuit, said non-reactive impedance element being adapted to vary its electrical impedance according to an electric biasing current applied thereto, and a source of variable current controlling said last mentioned impedance element.

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