

July 8, 1941.

H. F. ELLIOTT
CARRIER WAVE SYSTEM
Filed Aug. 23, 1934

2,248,343

3 Sheets-Sheet 1

Fig. 4.

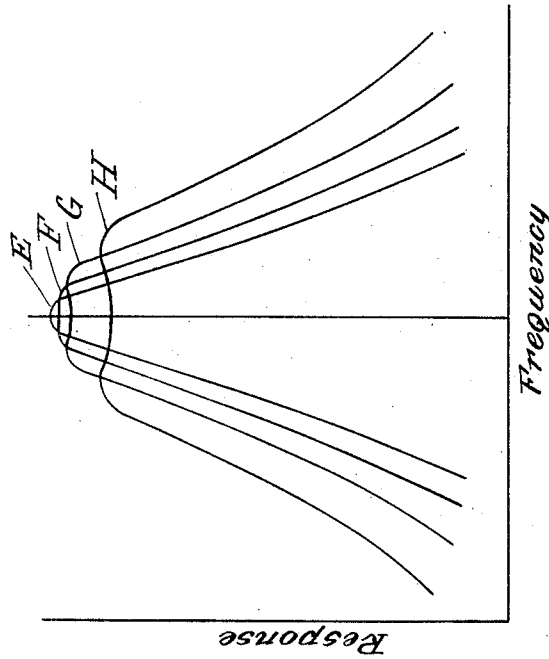
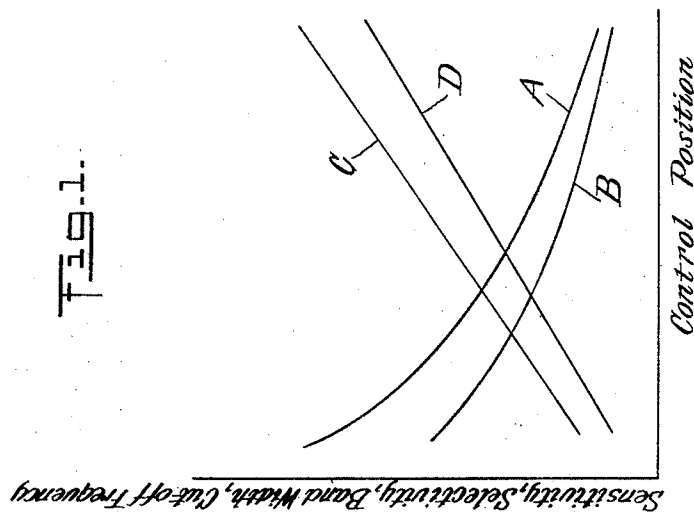


Fig. 1.



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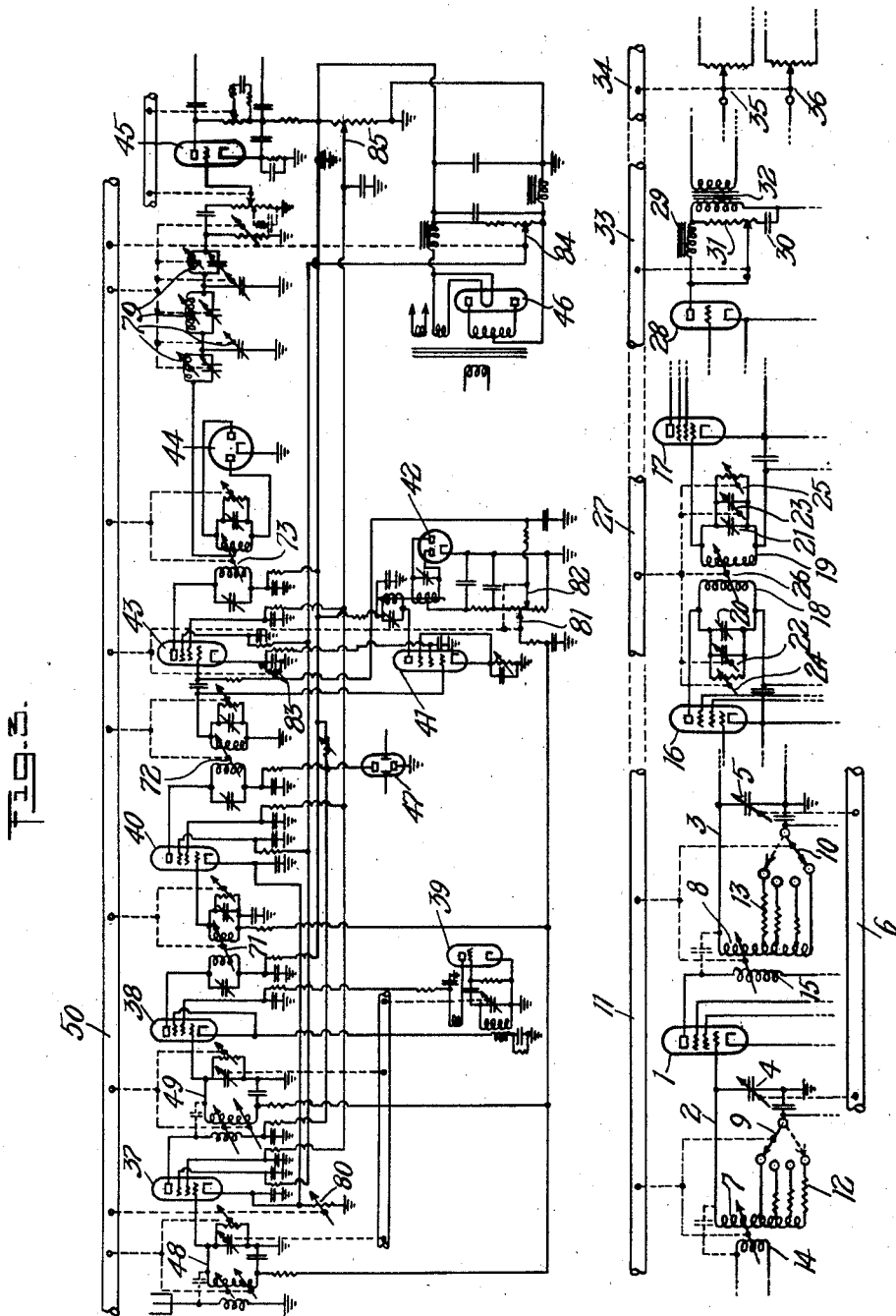
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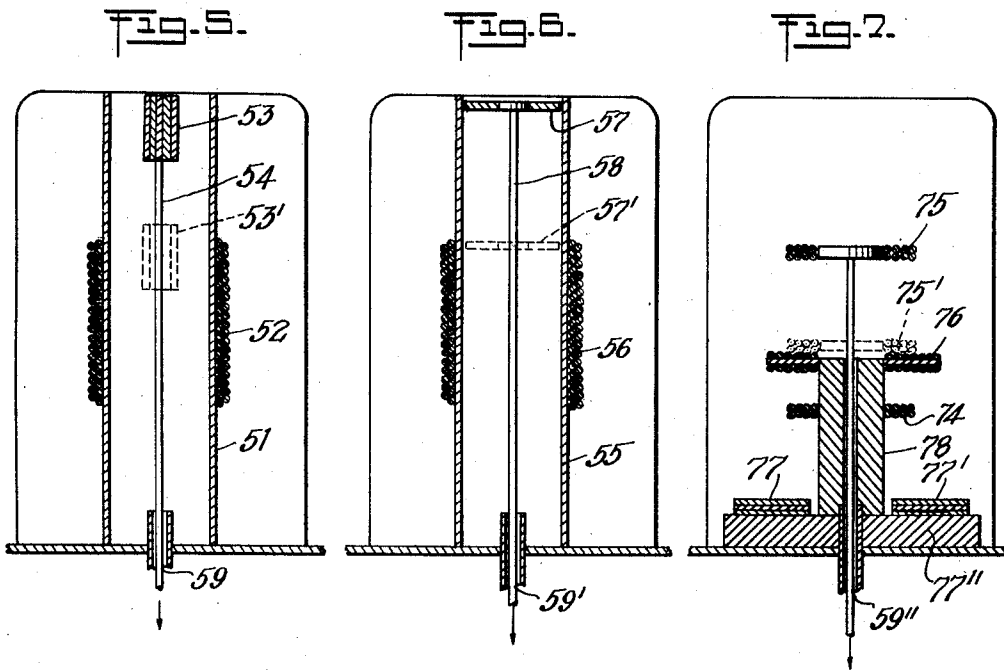
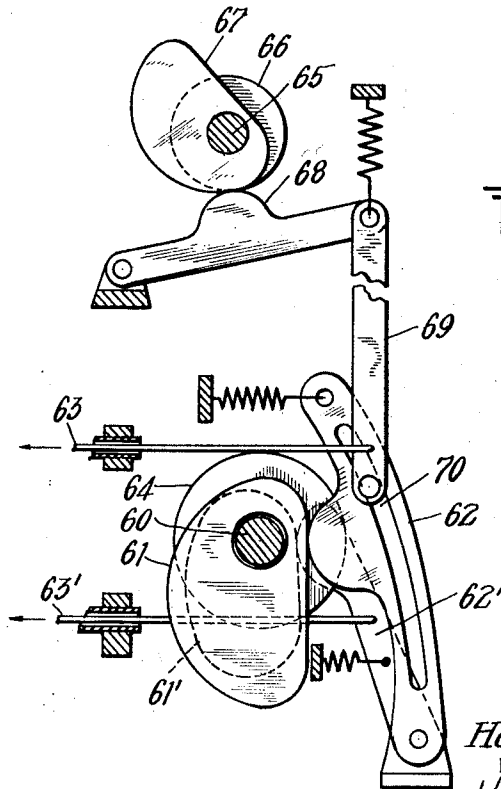
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3 Sheets-Sheet 3



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CARRIER WAVE SYSTEM

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Application August 23, 1934, Serial No. 741,139

25 Claims. (Cl. 250—20)

My invention relates to carrier wave systems such as are used for the transmission of intelligence by wire or radio in the form of telegraphy, telephony, facsimile, television, etc. In particular my invention relates to means for controlling and coordinating the sensitivity, selectivity and quality of the transmissions of such systems and to means for extending and improving their ranges and utility. In the past, a carrier wave system, or a circuit thereof such as a radio receiver, has been limited in its utility to a comparatively narrow range determined by the specific purpose for which it was designed. For example, in a radio broadcast receiver designed so that it had the sensitivity and selectivity required for receiving distant stations without interference, it has been necessary to limit the reception to comparatively narrow side bands, with a resultant detriment of quality, or fidelity, in the reproduction. Conversely, if side bands sufficiently wide to give high quality reproduction have been admitted, selectivity sufficient to cut out locals when receiving distance has been sacrificed. Some attempts have been made to provide a switch for passing a wider band when receiving local stations but none of the systems appearing to date have been satisfactory and the added switch has been confusing to the average user as well as imperfect in its action.

One object of my invention is to provide a carrier wave system with a coordinated sensitivity, selectivity and quality control which makes it possible to adjust the response of the system so that it is suitable for any of the transmission conditions normally met in practice. Another object is to provide means of making such adjustment so simple that the average user can readily understand and intelligently employ it. Another object is to provide means whereby the so called "tone control" knob commonly provided on radio broadcast receivers can be interlinked with or replaced by a sensitivity, selectivity, quality control which suitably adjusts the sensitivity, the width of the side bands passed by each unit in the receiver, and the tone quality, simultaneously and in proper coordination, thereby making it possible adequately and fully to adjust and control the response characteristics of the receiver for various transmission conditions without adding controls beyond those with which the average user is already familiar. Another object is the accomplishment of the foregoing increase in utility, range and quality by simple and inexpensive means, suitable for quantity production. These and other objectives will be outlined more fully in the accompanying figures and description which are illustrative of a few examples of my invention and its methods of application but are not to be taken in a limiting

sense as to the scope of the invention which is defined in the appended claims.

In the accompanying drawings in which like numerals of reference indicate similar parts throughout the several views:

Figure 1 indicates the relative trends, although not necessarily the magnitudes, of the functions controlled by the knob which determines the sensitivity, selectivity and quality of output of a receiver embodying my invention;

Figure 2 shows in outline one arrangement of coordinated circuit elements suitable for carrying out the various functions in a radio receiver embodying my invention;

Figure 3 shows in further detail a radio receiver embodying still further forms of the invention;

Figure 4 shows relative response curves of carrier frequency amplifier stages embodying my invention;

Figures 5, 6, 7, and 8 show in outline illustrative examples of electrical and mechanical elements for carrying out the invention.

Referring to Figure 1, the curves A, B, C and D show the relative trends of the sensitivity, selectivity, carrier band width and audio cut off characteristics of a receiver embodying my invention and having a single knob, or other control device, operating to control these characteristics in cooperative and coordinated relation. For example, when the knob is rotated to the left, the receiver is made highly sensitive as indicated by curve A and also highly selective as indicated by curve B so that it is possible to receive distant stations without interference. In order to attain the desired selectivity, the band of frequencies passed by the various carrier frequency amplifier stages is made relatively narrow as indicated by curve C and at the same time the band of frequencies passed by the audio amplifier as indicated by curve D is correspondingly narrowed so that beats from adjacent carriers and other interfering frequencies are suppressed. The narrowing of the admitted band of audible frequencies also reduces the hiss arising from tube and circuit noises when the receiver was in a highly sensitive condition; also the extraneous noises arising from static and other interference tending to override a weak carrier are reduced.

When it is desired to receive nearer or stronger stations, the knob may be rotated toward the right, reducing the sensitivity and selectivity, increasing the width of the band admitted by the carrier amplifiers and selectors and widening the band of frequencies passed by the audio amplifier. For high quality local transmissions, the knob may be rotated as far as desired to the right, serving as a tone control which adjusts the cut off frequency of the audio and carrier ampli-

fiers and selectors. In order that the knob controlling these functions may be operated to obtain the sensitivity, selectivity and quality desired without upsetting other relations in the receiver it is important that effective and automatic means be provided for holding constant the level of the signals applied to the detector or demodulator, so that the level of the signals delivered to the loudspeaker or succeeding apparatus will be maintained constant and not disturbed by the other adjustments. The provision of such means and its coordination with the sensitivity, selectivity and quality control is an important feature of my invention. For controlling volume or output suitable manual means preceding or succeeding the detector or demodulator may be used. A compensator for raising the relative level of the low frequencies may be interlinked with the volume control if desired. A suitable control knob for tuning the variable capacitors or other carrier selector means will of course be used and switches may be provided for selecting various wave bands if desired. Means for suppressing carrier noise while tuning may, of course, be provided when desired.

Figure 2 shows one form of circuit control which may be utilized for carrying out the sensitivity, selectivity and quality control features of my invention. Tube 1 represents a carrier frequency amplifier preceded by a tuned selector circuit 2 and succeeded by another such circuit 3, the circuits being tuned by variable capacitors 4 and 5 which have a common tuning control 6. In the arrangement illustrated, the inductors 7 and 8, have taps and switches 9 and 10 with a common control 11, whereby the inductance of circuit may be increased while at the same time the inductance of circuit 3 is decreased. Two sets of variable resistors 12 and 13 are provided and so arranged that the resistance of circuit 2 is increased as its inductance is increased, while the resistance of circuit 3 is increased as its inductance is decreased. If the circuits are designed so that each is exactly resonant to a given carrier frequency when the switches 9 and 10 are in the positions shown in full lines, the amplifier stage comprising tube 1 and circuits 2 and 3 will then have a comparatively sharp resonant curve as illustrated by E in Fig. 4. When switches 9 and 10 are thrown to the positions shown in dotted lines, and suitable values are chosen for the added and subtracted inductances and the added resistances, a responsive curve shaped like that shown at H in Fig. 4 may be obtained. Similarly, intermediate curves as shown at F and G may be obtained by suitable choice of inductances and resistances. Thus the amplifier stage may be made highly sensitive and highly selective when operating on curve E, and progressively less sensitive and less selective when operating upon curves F, G and H. Carrier frequency amplifiers may thus be proportioned so that relatively narrow bands are passed in the selective position while bands suitable for high quality reproduction of speech, music or other intelligence are passed in the less selective positions. The couplings between the primaries 14 and 15 and their respective secondary coils 7 and 8 may be fixed or may be made variable and adjusted in coordination with the motion of switches 9 and 10 as indicated by the arrows and dotted lines when necessary to obtain the desired electrical relations and response characteristics. If capacitive coupling is used, either in conjunction

with inductive coupling or separately, this may also be varied if necessary.

An amplifier stage of the type just described is suitable for carrier frequency amplification in transmission systems, receivers or transmitters of a variety of forms. It is well suited, for example, for the radio frequency stage, or stages, of either tuned radio frequency or superheterodyne types of radio receivers. It may be used also for the intermediate frequency stages of superheterodyne receivers.

Another circuit arrangement suitable for a variety of services and especially well adapted for intermediate frequency stages in superheterodyne receivers is shown in connection with tubes 16 and 17 in Fig. 2. These tubes are shown as interconnected by a fully tuned carrier frequency transformer, such as is widely used in broadcast receivers for the intermediate frequency stages. The primary and secondary 18 and 19 have tuning capacitors 20 and 21, which, may be of any of the usual types. Supplementary adjustment for controlling the band width and tuning characteristics of the stage may be incorporated directly in the main tuning elements, coils 18 and 19, capacitors 20 and 21, and coupling 22, or alternatively, supplementary elements such as variable capacitors 22 and 23 and variable resistors 24 and 25 may be employed, with suitable common control 27. A great variety of arrangement may be employed to give the desired result, which is a family of characteristic curves of the type shown in Fig. 4. Thus, a curve of the type given at E may be obtained by employing low loss capacitors and inductors at 22—21 and 18—19, relatively loose coupling at 26 and very high resistances, or none at all, at 24 and 25. The tuning characteristic may then be broadened by increasing the coupling at 26 and suitably lowering resistors 24 and/or 25, giving progressively curves as shown at F, G and H. If required, capacitors 22 and 23 may be used for supplementary adjustment the one being increased while the other is decreased. The resistors 24 and 25 may be replaced by suitable series resistors if desired.

For the control of the low frequency response characteristics of the receiver, any suitable form of band filter, tone control or the like may be employed, using either continuous variation or stepwise control with switches. By way of example, tube 23 in Fig. 2 may be an audio frequency amplifier in a broadcast receiver in which tube 1 serves as a radio frequency amplifier and tubes 16 and 17 operate at intermediate frequencies. Tube 23 may have suitable filters in either its input or output circuits, or both. In Fig. 2, an output tone control filter is shown, comprising inductor 28, capacitor 30, potentiometer 31 and transformer 32. The control 33 of these elements may be interlinked with the controls 11 and 27 of the preceding stages so that the band width, selectivity, sensitivity and tone quality are all varied simultaneously and in suitable relation. If it is desired, the sensitivity variation arising from the change of resistances associated with the selector circuits of the carrier frequency stages may be supplemented with variation of the amplification of the tubes employed by changing the potentials on the elements of the tubes as by control 34 operating potentiometers 35 and 36. For example, if pentode type multi-mu tubes are employed for the carrier stages, the amplification and sensitivity may be controlled by adjusting

the potentials on any or all of the grids. Potentiometer 35 may be employed to adjust the relative levels of the control grids and cathodes and 36 may be used on either the suppressor grids or screen grids. Alternatively a third potentiometer may be utilized and all three grids varied. The anode-cathode potential may also be used for control purposes if desired. Added controls of one or more of these types may be used where necessary to keep the level of signals at the demodulator within the desired limits, the rate of variation of the potentiometer or resistor being proportioned so that this objective is attained.

Figure 3 shows the circuits of a radio broadcast receiver of the superheterodyne type embodying my invention. Tube 37 is a radio frequency amplifier, tube 38 a frequency converter or first detector, tube 39 an oscillator, tube 40 an intermediate frequency amplifier, tubes 41 and 42 are governor or automatic gain control tubes, tube 43 is an automatic gain compensator operating at intermediate carrier frequency, tube 44 is a demodulator, tube 45 is an audio amplifier, tube 46 is the usual rectifier for energizing the anode and grid circuits and 47 is a tuning indicator. The functions performed by the foregoing tubes are similar to those of standard superheterodyne receivers except the governor and compensator tubes which, with the associated circuits, operate to give signals of very constant level at the demodulator 44. The manner in which this is accomplished is described in detail in my copending application, Serial Number 703,054 filed Dec. 19, 1933, and therefore need not be gone into here beyond stating that the governor tubes 41 and 42 receive carrier wave signals from the intermediate frequency amplifier 40, amplify and rectify these signals and supply potentials to the gain control circuits of tubes 37, 38 and 40. This much of the system constitutes a carrier wave amplifier with automatic gain control delivering signals at the output of tube 40 whose level rises slowly as the strength of the signals applied at the input of tube 37 increases. Compensator tube 43 which is interlinked with governor tubes 41 and 42, receives the slowly changing carrier wave signals delivered by tube 40 and automatically compensates for the variations, delivering carrier wave signals substantially free from distortion or change in level to the demodulator 44.

Referring now to the elements associated with the coordinated sensitivity, selectivity and quality control shown in Fig. 3, the radio frequency amplifier 37 has a tuned input 48 and feeds into a tuned output circuit 49 through the medium of coupling means which may be of any form suitable to the frequency and operating conditions. When the sensitivity, selectivity, quality control 50 is adjusted for maximum sensitivity and selectivity, circuits 48 and 49 are both tuned closely to the incoming carrier frequency and have minimum damping. As the control 50 is shifted to decrease sensitivity and selectivity and to increase the width of the admitted band of frequencies, the resonant period of one of the circuits is increased while the other is decreased and the damping of both is increased, that is, their losses are increased. This action is similar to that described for tube 1 in Fig. 2, but in the case shown in Fig. 3, continuously variable means instead of switches are provided for changing the inductances and resistances of the circuits. There are a wide variety of ways of accomplishing this; the inductors may be made wholly or partially in

the form of variometers, one of which is increased as the other is decreased; the inductors may be constructed with short circuited discs or rings which advance into or recede from the coils to decrease or increase their effective inductance; alternatively the capacitances of the circuits may be increased and decreased by manipulating the main tuning capacitors or by operating upon capacitors in shunt or series relation thereto. The damping of the circuits may be varied simultaneously with the change in resonant period by either shunt or series resistors of suitable values and suitable resistance variation characteristics.

Two very simple and effective methods of accomplishing the desired continuous variation in the resonant periodic and dampings of the circuits are shown in Figures 5 and 6. Referring first to Fig. 5, numeral 51 indicates a coil form and 52 is a coil of suitable inductance wound thereon. A laminated iron core 53 is provided and so arranged that it may be drawn into the magnetic field of the coil or withdrawn therefrom by means of a small rod 54 or other suitable mechanism. When core 53 is outside the field of the coil 52, it of course has no influence thereon, but when it is drawn into the field as shown in dotted lines at 53', it will have an influence upon the effective inductance and resistance of the coil and the nature of this influence will depend upon the size and shape of the laminations, their thickness, their material, and the frequency of the current in the coil. If the laminations are of very thin iron, or if a core of very finely divided iron or other magnetic material is used, the inductance of the coil will be materially increased and the resistance will be only nominally increased as the core is drawn into the coil. If thicker laminations are used, the increase in inductance will be less and the increase in resistance will be greater. If a solid core is used, the inductance may even be reduced while the resistance is increased, both due to the effect of eddy currents in the core. By a suitable choice of material, size and thickness of lamination, it is therefore possible to increase the inductance and the resistance each in suitable proportion to obtain the desired tuning characteristics.

If circuit 48 has its inductance and resistance increased by operation in a given direction of control 50, then circuit 49 will require a decrease of inductance and an increase of resistance. Fig. 6 shows one simple and effective way of accomplishing this. Numerals 55 and 56 indicate a coil form and a coil respectively. A disc, or short-circuited ring, or a winding of suitable resistance material is shown at 57 with operating rod 58. This has no effect on the coil when out of the field thereof, but when drawn into the field as shown in dotted lines at 57', it decreases the effective inductance and increases the effective resistance of the coil. If the material is of low electrical resistance, a considerable decrease in inductance may be obtained with very little increase in effective resistance, but if higher resistance material is used the change in inductance will be less marked and the increase in resistance greater. By suitable choices of materials, size, and motions for core 53 and ring 57, coils 52 and 56 may have their inductances increased and decreased and their resistances increased so that a family of tuning curves like those shown at E, F, G and H in Fig. 4 may be obtained.

The motion of the cores and discs may be worked out in a great variety of ways, by levers, cams or other linkages. One simple system

which permits the coils and their cores, shields and other parts to be located in any desired arrangement upon an amplifier base or chassis is to use flexible wire controls as indicated in outline at 59 and 59' in Figures 5 and 6, together with suitable cams and followers as shown in outline in Fig. 8. Numeral 60 represents a shaft carrying cams, shown at 61 and 61', with followers 62 and 62' which in turn manipulate flexible wires or other linkages 63 and 63', leading to the elements to be operated. Such a system may, of course be designed to give almost any desired law of motion. Shaft 60 may also operate one or more reactors, resistors, potentiometers or other elements indicated in outline at 64. If desired, any or all of these motions may be interlinked with other motions in the apparatus to obtain desired mutual relations. For example, shaft 65, controlling one or more reactors, resistors, potentiometers or other elements within the set, indicated in outline at 66, may be connected with a cam 67, follower 68, link 69 and auxiliary cam 70 in follower 62, so arranged that the motion of 63 depends upon the motion of both shafts 60 and 65. An example of the utility of such an arrangement is the case wherein shaft 65 operates capacitors used to tune radio frequency amplifier circuits 48 and 49, Fig. 3, while cam 61, follower 62 and control 63, control core 53 and ring 57, Figures 5 and 6 which regulate the width of the band passed by the amplifier. By a suitably shaped auxiliary cam at 70, the motion of 63 may be made such that bands of substantially the same numerical width are passed by the amplifier over its whole tuning range even though the circuits have quite different constants at different points in the range. Another application of such an arrangement would be the interlinkage of a volume control and a band width control. Usually, however, such elaborate mechanisms are unnecessary, and simple shafts, cams or levers may be used to operate core 53, ring 57 and other elements which are to be controlled simultaneously with them. The options which are available in the sizes, shapes and materials of the moving elements, such as 53 and 57 usually make it possible to obtain the desired operating relations without resorting to elaborate motion mechanisms.

Depending upon tube characteristics and circuit requirements, any suitable form of coupling may be used between coils 52 and 56 and the associated tubes and input and output circuits. If variable inductive coupling is indicated this may be operated in conjunction with controls 59 and 59', or separate controls cooperating with the control mechanism 55 may be used. If variable capacitive coupling is employed any suitable form may be used and interlinked with control 50 directly or through cams.

Fig. 7 shows in outline a form of tuned transformer which may frequently be found very effective for amplifier stages such as those shown at 71, 72 and 73 in Fig. 3. One coil 74, usually the primary, may be mounted upon a suitable fixed support as shown in Fig. 7. The other coil 75 may be made movable and connected through a suitable operating linkage as 59'', to the central control 50. When sharp tuning is desired to give high sensitivity and selectivity, coil 75 may be in the position shown in full lines, with a resultant tuning curve of the type shown at E or F in Fig. 4. When less sensitivity and selectivity and a broader band of passed frequencies are

desired, the coil 75 may be moved toward the position shown in dotted lines at 75'. This brings its field into close relation with 75 which may be an open or partially open circuit tertiary winding of resistance material or a split ring of iron or other suitable material. Often a simple split iron washer will be found satisfactory. It may be located between coils 74 and 75 in such a position that it only nominally effects the coupling and losses when the coils are separated as shown in full lines, but so that material losses are introduced into the system when tighter coupling is employed. The double humps which would accompany the closer coupling are then smoothed out and tuning characteristics of the type shown at G and H in Fig. 4 are obtained.

For tuning the coils 74 and 75 any suitable form of capacitors may be used as for example the variable air and mica dielectric capacitors frequently employed in superheterodyne indicated in outline at 77 and 77' in Fig. 7. A base for the capacitors is outlined at 77'' and a support for the coil and ring is indicated at 78. Obviously an almost endless variety of arrangements may be employed for the details of mechanisms such as are outlined in Figures 5, 6 and 7. No attempt is made to go into such details here since their inclusion is not necessary to an understanding of the principles involved and would only add confusion to the drawings.

In the circuit diagram, Fig. 3, the tuned transformers 71, 72 and 73 are shown as comprising two coils with adjustable tuning capacitors, variable coupling and variable resistance. The combination shown in Figure 7 gives results equivalent to such a circuit arrangement. Obviously, if desired, two simple variably coupled coils may be employed and variable resistors either in series or shunt relation to either or both circuits may be used to adjust the losses and smooth the tuning humps in place of the ring or winding 76. Alternatively, coils, cores and rings of the type shown in Figures 5 and 6 may be utilized, or tapped coils and switches as shown at 9 and 10 in Fig. 1 may be used. The objective is that each circuit employed in the amplifiers and selectors operating at carrier frequencies shall be coordinated with each other circuit in the provisions for adjusting the width of the admitted side bands and that filters or tone controls used in the audio frequency amplifiers shall be coordinated and controlled with the carrier frequency band varying mechanism.

In a carrier wave device employing several frequencies such as the superheterodyne receiver shown in Fig. 3, the numerical width of the band passed should preferably be approximately the same for each unit. For example when the radio frequency amplifier 37 and associated circuits 48 and 49 are adjusted to pass side bands 3,000 cycles wide, the intermediate frequency amplifier 40, compensator 43 and associated transformers 71, 72 and 73 should also be adjusted to pass side bands of approximately 8,000 cycles. Likewise the audio frequency filters or tone control circuits associated with the demodulator 44, and audio amplifier 45 or subsequent audio frequency apparatus should be adjusted to pass approximately 8,000 cycles. When, as in the superheterodyne, more than one carrier frequency is employed, it will be evident that the band passed expressed in percentage relative to the associated carrier frequency becomes larger as the carrier frequency becomes lower and is in fact inversely proportional to the carrier fre-

quencies. For example, a side band of 8,000 cycles may be 0.8% of a carrier frequency of 1,000,000 cycles in the radio frequency amplifier 37, and 5% of a carrier frequency of 160,000 cycles in the intermediate frequency amplifier 40. It is not essential that absolutely mathematical precision be attained in coordinating the relations between the widths of the bands passed and the cut off frequencies of the various sections and stages of the selectors and amplifiers. The coordination should be such, however, that each section performs its own functions properly in each position and condition of adjustment. For example, if the coordinating control is set so that side bands of 8,000 cycles are admitted, it may be desirable to have the audio frequency filter cut off quite sharply above this frequency so as to suppress 10,000 cycles carrier whistles and other beats or overlapping fringes between side bands of adjoining carriers. At the same time, the intermediate frequency section may be adjusted so as to attenuate adjoining carriers 10,000 cycles from the admitted carrier and to suppress also the side bands associated with the lower frequency modulations of the adjoining carriers. The radio frequency amplifier section may be required to aid in these selections or its main function may be that of suppressing the "image frequencies" which are a problem in superheterodyne type receivers.

In a radio receiver or other apparatus of the type described, it is important to have means of gain control which automatically hold the output of the system substantially constant over wide variations of input and also over wide variations of sensitivity as determined by the controls. Also it is important to have suitable means for indicating the optimum setting of the tuning control. The method of automatic gain control and the tuning indicator shown in Fig. 3 are especially well suited to accomplish these objectives. The method of automatic gain control, which is described in detail in my copending application S. N. 703,054 filed Dec. 19, 1933, to which reference has previously been made, holds the input to the demodulator, and therefore the output, very constant over a wide range of input potentials. It also serves to hold the level at the demodulator very constant over a wide range of adjustment of the sensitivity-selectivity-quality control. As described further hereinafter, suitable supplementary adjustments coordinated with this control may be provided to maintain proper balance in the gain of the various amplifier, governor, and compensator tubes if necessary. However, the automatic gain control system can usually be proportioned to maintain the conditions at the demodulator sufficiently constant without supplementary controls. In connection with the tuning indicator, the resonant circuits which interlink the governor amplifier 41, and the governor rectifier 42, may be made highly selective and the coupling between them set so that a single sharply defined peak resonant at the carrier frequency is obtained. By having these circuits sharply tuned to the carrier at all times, a tuning indicator, as 47, associated with any portion of the circuits having currents or potentials responsive to the output of the governor will indicate when the receiver is tuned to a carrier regardless of the adjustment of the sensitivity-selectivity-quality control. The circuits in the amplifiers, such as 48, 49, 71, 72 and 73 may be broadened to pass bands on either side of the carrier but with the circuits asso-

ciated with the governor sharply tuned to the carrier at all times, the tuning indicator will show when the tuning control is centered on the carrier. Obviously many forms of tuning indicator, either instruments or tubes, may be used. The example shown in outline at 47 is a gaseous glow indicator tube with supplementary electrodes suitable for suppressing carrier noises when tuning. Other indicators or other forms of noise suppression may of course be employed, as desired.

In connection with the audio frequency apparatus, a great variety of filters and tone control circuits are available and the choice will depend upon the operating conditions and permissible expenditure. Often a simple tone control or a single section filter of one of the well known types will suffice. In other cases a more elaborate filter with several sections having either tapped or variable inductors, capacitors and resistors may be used. In Figure 3, a filter 79 of two sections employing variable reactors and a variable terminal load resistor is shown. Ordinarily only a portion of the elements would be made variable, the choice depending upon the characteristics to be obtained and the factors of cost and convenience. The filter may be located at any convenient point in the audio system, its characteristics being proportioned to match the terminal conditions.

In coordinating the control of sensitivity, selectivity and quality of reproduction, it may be desirable to interlink with the central control 50, one or more of the elements which determine the gain and operating characteristics of some of the amplifier, converter, governor or compensator tubes. Examples of such interlinkage are shown in rheostat 80 which may be used to control the gain of tubes 37 and 40, potentiometer 81 controlling the governing action on tubes 37, 38 and 40, potentiometer 82 and resistor 83 associated with compensator tube 43, and potentiometers 84 and 85 controlling grid and screen potentials in any or all of the tubes. Ordinarily these added controls will not be required since the losses introduced in the various selector circuits in increasing the passed band widths automatically reduce the sensitivity as the selectivity is reduced. However, directly controlled or cam operated variable resistors and potentiometers may be employed when the need for refinement in operating conditions indicates their necessity. In some cases, a suitably proportioned potentiometer or resistor at 82 and/or 83 may be desirable for controlling the output of compensator 43 when control 50 is operated.

It will be obvious that an almost endless variety of modifications may be employed in carrying out details connected with various applications of the invention. For example, in some instances it may be desirable to use switches and tapped or lumped elements of reactance and resistance throughout. In some cases, it will be desirable to use only continuously variable means while in still other cases a combination of switching means and continuously variable elements may be found best. In some instances it may be desirable to use switches with contacts having varying or overlapping arcs of rotation in combination with continuously variable apparatus at other points. When movable cores or rings or coils are used, these may often be mounted directly on a coordinating control shaft which also operates variable resistors, potentiometers, reactors or switches for changing other elements.

Again a single shaft carrying suitable cams may be used to control the motions of cores, rings and coils in the carrier frequency sections in unison with resistors, reactors and potentiometers of suitable proportions in the audio frequency section. In some cases it may be found convenient to vary couplings or introduce losses by variations in capacitance or through suitable dielectric variations. Often circuits such as are shown in connection with intermediate frequency amplifiers hereinbefore will be found useful for radio frequency stages and vice versa. The examples of applications of the invention have all been given in connection with radio receivers, but its methods and means are not limited to this use but may be applied to repeaters, filters, transmitters and transmission systems of all sorts.

It may be well to point out that the arrangements of tubes shown in the various figures are subject to wide variations. For example, in many instances, several functions may be combined in a single tube where two or more tubes, each with its own function, have been shown in the diagrams for the sake of clarity. By way of examples, the frequency converter tube 38 and the oscillator 39 may be combined in any of the several ways now in common use; the amplifier and rectifier functions of tubes 41 and 42 may be combined by utilizing combination tubes now available; also tubes 43 and 44 may sometimes be combined. Rectifiers of the copper oxide or other types may be substituted for tubes 42 and 44 if desired. The volume control for the audio amplifier 45 may have either electrically or mechanically operated means for compensating tone quality as volume is varied. My invention is not limited to the particular methods and systems disclosed but covers broadly the contributions to the art defined in the appended claims.

Having thus described my invention, I claim:

1. A radio wave system comprising means for amplification and selection in successive stages operating at a plurality of frequencies, variably coupled and variably damped selectors for varying and coordinating the passed band widths in at least two of said stages and at least two of said frequencies separately, variable cut-off audio frequency tone control means, and single control means for operating the selectors simultaneously and in unison with said tone control means.

2. In combination in a carrier wave system, means for selecting waves at at least one carrier frequency, variably coupled and variably damped means for varying the widths of the bands passed at said frequency, separate tone control means for varying the cut-off at audio frequency, and single control means for controlling and coordinating said varying means and said tone control means.

3. In a superheterodyne radio receiver having separate means for selection and amplification at radio frequency, intermediate frequency and audio frequency, variably coupled and variably damped means for varying the band widths passed at at least one frequency, tone control means for varying the cut-off at audio frequency, and single control means for operating said varying means in coordination and in unison with said tone control means.

4. In a radio receiver having variably coupled and variably damped carrier frequency selecting means, demodulating means and separate variable audio frequency selecting means, single control means varying the width of the band

passed by the carrier frequency selecting means in unison and in coordination with tone control means varying the audio frequency cut-off.

5. In combination in a radio receiver, variable cut-off audio frequency tone control means, variably coupled and variably damped carrier frequency selective means, and single control means for operating the tone control means and adjusting the width of the band passed by the carrier frequency selective means by varying both the coupling and the damping in proportion to the cut-off period of the tone control means.

6. In a superheterodyne radio receiver having a radio frequency amplifier with tuned input and output circuits, an intermediate frequency amplifier with variably coupled and variably damped tuned coupling transformers and an audio frequency amplifier with filter circuits for varying the frequency response characteristic thereof, single control means varying both the coupling and the damping for varying the selective characteristics of the radio frequency amplifier circuits and the intermediate frequency coupling transformers in unison and coordination with the audio frequency filter circuit variations.

7. A carrier frequency receiver having variably coupled and variably damped carrier frequency selectors whose passed band width is variable, audio frequency filters whose passed frequency characteristic is variable and single control means for adjusting the passed band width by varying both the coupling and the damping and adjusting the passed frequency characteristic simultaneously and in predetermined proportion to one another.

8. A carrier frequency amplifier having tuned coupling circuits with variable means for increasing the coupling and increasing the damping simultaneously wherein the variable means comprises means for varying the relative coupling between two coils and also between at least one coil and means for producing electrical energy loss.

9. In a radio receiver, a plurality of coupled tuned circuits, means for varying the coupling between any two of said tuned circuits, means for varying the damping of at least one tuned circuit, variable audio tone control means and common means for effecting variation of all aforesaid means.

10. A carrier frequency amplifier having a tuned input circuit and a tuned output circuit with continuously variable means for simultaneously increasing the periodicity of one circuit, decreasing the periodicity of the other circuit and increasing the damping of both, said means for increasing the periodicity and damping of one circuit comprising a movable ring of resistive material and the means for decreasing the periodicity and increasing the damping of the other circuit comprising a core of resistive magnetic material.

11. A carrier frequency amplifier having tuned coupling circuits with continuously variable means comprising a mass of resistive material and a coil and a second coil movable relative to the first said coil and mass of resistive material for increasing the coupling and increasing the damping of the circuits simultaneously and automatic means for holding the power output substantially constant.

12. A carrier frequency amplifier having tuned

coupling circuits with continuously variable means for increasing the coupling and increasing the damping simultaneously wherein the continuously variable means comprises means for varying the relative spacings between two coils and also between at least one coil and a ring of resistive material.

13. A radio receiver comprising a tuned radio frequency amplifier with a movable ring of resistive material for simultaneously increasing the periodicity and increasing damping of one circuit and a movable core of resistive magnetic material for simultaneously decreasing the periodicity and increasing the damping of another circuit, an intermediate frequency amplifier with tuned coupling circuits having coils movable relative to one another and also relative to a ring of resistive material, an audio frequency amplifier having variable cut-off characteristics and single control means for operating the variable elements of the amplifiers in predetermined relationship with one another.

14. A radio receiver in accordance with claim 13 wherein the single control means comprises cams and linkages operated by a single knob for adjusting the rings, cores and coil spacings in unison.

15. A radio receiver in accordance with claim 13 with the addition of auxiliary cam means interconnecting the single control means and means controlling other response characteristics of the receiver.

16. A carrier wave system comprising successive amplifier stages operating at a plurality of frequencies with separate selectors for varying the widths of bands passed at each frequency, variable cut-off audio frequency tone control means and single control means for operating said selectors and tone control means in unison and adjusting the width of the band passed at each frequency in inverse proportion to the frequency.

17. A carrier frequency coupling transformer comprising a tuned input circuit, a tuned output circuit, damping means for introducing losses in at least one circuit by induction, and adjustable means for varying the effective coupling between the two circuits and between at least one circuit and the damping means with the damping increasing as the coupling increases.

18. The method of controlling the response characteristics of carrier wave apparatus which comprises adjusting the cut-off at audio frequency and varying the coupling and damping to vary the width of the band passed at at least one carrier frequency simultaneously and in predetermined relationship.

19. The method of controlling the response characteristics of carrier wave apparatus having variable cut-off audio frequency tone control means and variably coupled and variably damped carrier frequency selecting means which comprises simultaneously adjusting the tone control cut-off and the effective coupling and the effective damping to vary the response in the same direction.

20. The method of controlling the response characteristics of carrier wave apparatus having variable cut-off audio frequency tone control means and variably coupled and variably damped carrier frequency selecting means which comprises providing simultaneous relatively low audio frequency cut-off loose coupling and light damping for weak signals, and providing simultaneous relatively high audio frequency cut-off

close coupling and increased damping for strong signals and providing automatic control of amplification to maintain constant power output.

21. A radio wave system in accordance with claim 1 with the addition of automatic gain control.

22. A radio receiving system comprising, in combination, a source of signal-modulated high frequency incoming waves, a local source of high frequency waves for beating with the incoming signal waves, means for combining said waves to produce a signal-modulated beat frequency wave, means for converting said beat frequency wave into a signal wave of audio-frequency, an adjustable coupling system comprising variable coupling and variable damping means interposed between said first mentioned means and said second mentioned means, said coupling system being designed to pass only a relatively narrow band of frequencies including the beat frequency but having means for rendering adjustable the width of the band passed, an audio-frequency low-pass filter having its input connected to said second mentioned means, said filter being provided with means for adjustably varying the point of cut-off thereof, and means common to said coupling system and said filter for effecting the aforementioned adjustments in unison.

23. A superheterodyne receiver including a frequency converter, an intermediate frequency amplifier, an intermediate frequency detector, and a low-pass filter connected to said detector, a plurality of coupling systems in cascade interposed between said frequency converter and said detector, each of said coupling systems being designed to pass a relatively narrow band of frequencies including the intermediate frequency and having variable coupling and variable damping means rendering adjustable the width of the effective frequency band passed thereby, said filter including means for adjusting its point of cut-off, and means common to said coupling systems and said filter for effecting the aforementioned adjustments in unison.

24. In a superheterodyne receiver, a source of signal-modulated high frequency incoming waves, a local source of high frequency waves for beating with the incoming signal waves, a translator for combining said waves to produce a signal-modulated intermediate frequency wave, an intermediate frequency amplifier including, in combination, a plurality of transformer units, each having a stationary winding, said transformer units having a movable winding inductively coupled thereto and means for varying the damping simultaneously with variations in the coupling, a coupling adjusting mechanism common to said units and operable to effect movement of said movable windings in unison, a detector operable to convert the intermediate frequency wave into a signal wave of audible frequency, and tone control means operatively connected with the coupling adjusting mechanism.

25. In a superheterodyne receiver having a radio frequency amplifier with tuned input and output circuits, an intermediate frequency amplifier with variably coupled and variably damped tuned coupling transformers and an audio frequency amplifier with filter circuits for varying the frequency response characteristic thereof, single control means for varying the coupling transformers in unison and coordination with the audio frequency filter circuit variations.

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