Oct. 4, 1932. W. A. MacDONALD 1,881,284

WAVE SIGNALING SYSTEM

Filed Dec. 1, 1930 2 Sheets-Sheet 1

Fig. 1,

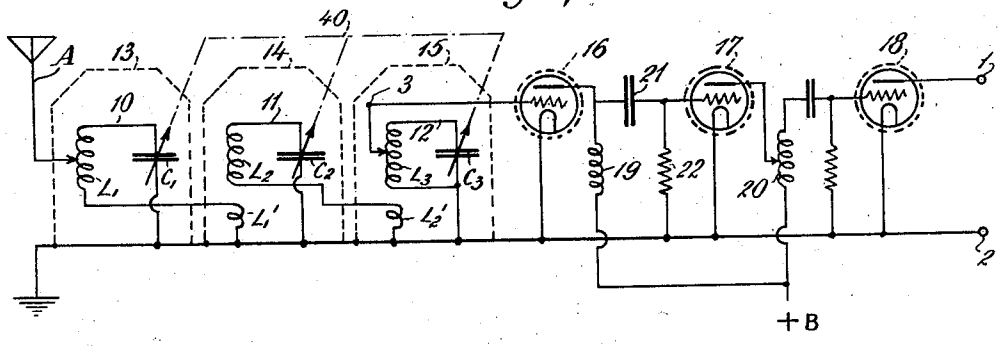


Fig. 2,

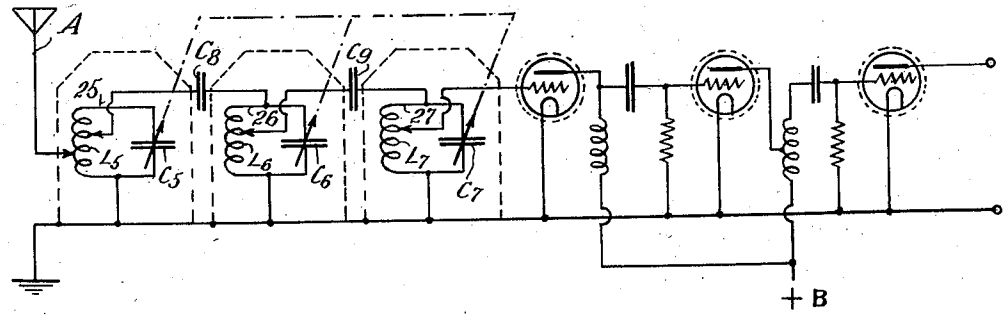
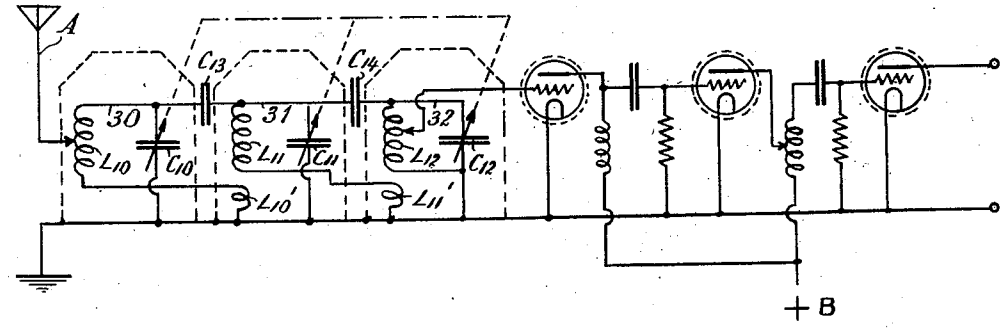


Fig. 3,



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Fig. 4.

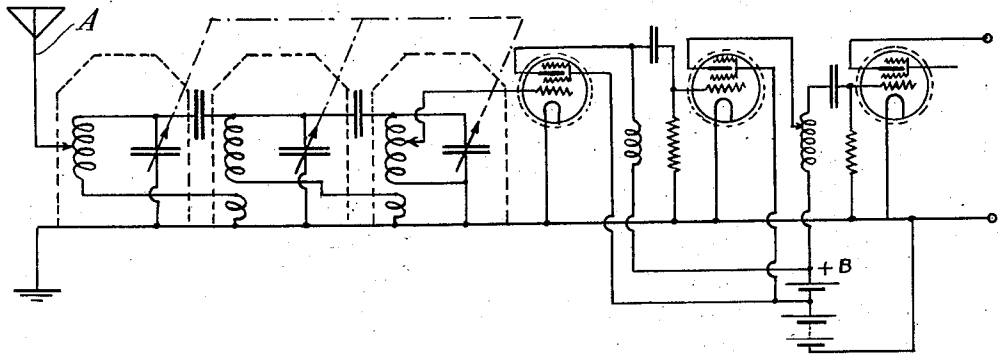


Fig. 5.

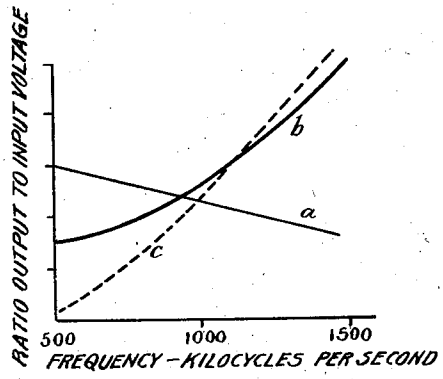
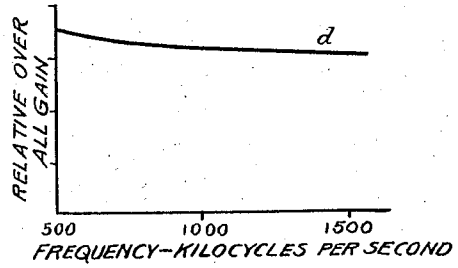


Fig. 6.



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WAVE SIGNALING SYSTEM

Application filed December 1, 1930. Serial No. 499,229.

This invention relates to high frequency signaling, and more particularly to systems especially adapted to the selection and amplification of radio-frequency waves.

The principal object of the invention is to obtain in a radio-frequency amplifing system, a high degree of sensitivity, selectivity and fidelity and at the same time to reduce the tendency toward oscillation of the repeating elements of the amplifier.

Broadly stated, the system by which the above object is accomplished comprises an untuned radio-frequency amplifier preceded by a tuning, or band-frequency selective, system comprising a plurality of tuned circuits coupled by the proper amount of coupling to provide substantially the maximum possible transfer of energy from one tuned circuit to the next, consistent with a band transmission characteristic suited to freely transmit all the important frequencies of the sidebands and to discriminate against all other frequencies. Such a band selective system is disclosed in my co-pending application Serial No. 469,487, filed July 21, 1930.

A feature of the invention is the radio-frequency amplifier, which is of the untuned, that is, untunable, type and has interstage coupling means so designed that each stage is non-regenerative. The amplifier repeating elements are preferably coupled by impedance coupling arrangements which effectively place capacitive loads upon the output circuits of each repeater over the tuning frequency range. These capacitive reactances are preferably provided by a choke coil or transformer connected between the anode and cathode of each repeater. The chokes or transformers are so constructed that their distributed capacity resonates with their inductance at a frequency slightly below the lowest frequency of the tuning range; thereby causing the chokes or transformers to be effectively capacitive throughout the tuning range. It is understood, of course, that the distributed capacity includes that of the associated amplifying tubes and any associated circuit elements.

There are certain advantages inherent in an untuned radio frequency amplifier, particularly when the output impedance connected to a repeating element is capacitive. One advantage resides in the fact that the coupling impedances of the amplifier can be made resonant somewhat below the tuning range, thereby causing the voltage transfer to the succeeding stage to be a maximum at the low frequency range. At the high frequency range the voltage decreases with increased frequency. That this is an advantage follows from the fact that most tuning or selective systems which must, of necessity, be associated with a radio-frequency amplifier, are characterized by an energy transfer which increases with increasing frequency. By properly proportioning the coupling elements of the amplifier, then, compensation of the characteristic of the tuning system may be effected, and the overall response characteristic of the amplifier and selective system may be made uniform or at least regulated within wide limits.

A second important advantage in the use of an untuned radio-frequency amplifier is the ease with which oscillation can be prevented. It is well known that when the impedance connected to the output of a vacuum tube amplifier is capacitive, any voltage fed back from the output to the input of the amplifier is in the wrong phase to aid the input voltage, and hence the condition required for oscillation is non-existent. In consequence, when the output impedance is made to resonate below the tuning range, it is capacitive throughout that range and not conducive to oscillation.

Another feature of the invention is the manner of coupling the several tuned circuits of the tuning, or preselecting, system so that its response characteristic compensates for that of the amplifier, or gives to the receiver a desired over-all characteristic. It is contemplated to regulate the characteristic of the tuner by the proper combination of magnetic and capacitive coupling between the tuned circuits.

The combination of an untuned amplifier with a preselecting system possesses advantages not found in an ordinary tuned radio-frequency amplifier. In the first place, the

presence of the several tuned circuits, ahead of the first repeating element effectively suppresses currents of undesired frequencies and substantially prevents harmful modulations which produce cross-talk. Furthermore there is attained a high degree of selectivity together with high amplification and freedom from oscillation.

A further and more complete understanding of the invention may be had from the following detailed description and the accompanying drawings, of which:

Fig. 1 illustrates an untuned radio-frequency amplifier connected to the output of a three-circuit tuning, or pre-selecting, system of which the circuits are coupled inductively;

Fig. 2 shows a combination of a untuned amplifier and a preselecting system, which is similar to that of Fig. 1 except that the circuits of the pre-selecting system are coupled capacitively instead of inductively;

Fig. 3 illustrates an arrangement similar to those of Figs. 1 and 2, in which the circuits of the preselector are coupled both inductively and capacitively;

Fig. 4 illustrates the combination with a preselecting system of an untuned amplifier comprising screen-grid tubes;

Fig. 5 shows the variation over the tuning range of the ratio of output to input voltage of the various couplings illustrated in the preceding figures; and

Fig. 6 shows a typical over-all response characteristic obtainable in the arrangements of the invention.

Fig. 1 illustrates a radio-frequency receiving system comprising a receiving antenna, a tuning arrangement and a radio-frequency amplifier connected to the output of the tuning arrangement. The tuning or pre-selecting arrangement comprises three tuned circuits 10, 11 and 12 respectively composed of inductances L_1, L_2, L_3 and capacities C_1, C_2 and C_3. The tuned circuit 10 is coupled to tuned circuit 11 by a small inductance L_1' in series with L_1, L_1' being magnetically associated with coil L_2 of circuit 11. Likewise circuit 11 is coupled to circuit 12 by a small inductance L_2' in series with inductance L_2.

The small coupling inductances L_1' and L_2' preferably are constituted by one or two turns of wire and are located at the low potential ends of inductances L_1 and L_2, respectively, so that substantially optimum coupling is obtained. Optimum coupling as used herein, means the degree of coupling which results in the maximum transfer of energy from one tuned circuit to the next while maintaining but a single resonant peak; the order of this optimum coupling is about one or two per cent.

To minimize undesired electro-static coupling between the several tuned circuits of the pre-selector, metal shields 13, 14 and 15, shown by dotted lines, are arranged to effectively isolate the tuning coils so that the only coupling between the successive circuits is electromagnetic.

While coupling coils have been shown as inductances separate from the tuned circuit inductances, it should be understood that the coupling may be obtained without these additional coils simply by so situating inductances L_1, L_2, and L_3 that the necessary co-efficient of coupling between them is obtained.

The three circuits 10, 11 and 12 are tuned by means of the variable condensers C_1, C_2, and C_3, respectively and the circuits are simultaneously tuned to the same frequency by ganging the condensers in a uni-control arrangement as indicated by the dotted line 40.

The radio-frequency amplifier, which is connected to the output of the pre-selector, is of the untunable type and comprises three thermionic repeaters, 16, 17 and 18, joined in tandem. In practice, the output terminals 1 and 2 of the amplifier are connected to a detector and voice frequency amplifying system, but for convenience the detector and voice frequency amplifier are omitted as are also the power supply sources for the thermionic repeaters, inasmuch as these are well-known and constitute no part of the invention.

The untuned coupling arrangements between the amplifier tubes are of the "impedance" type. Considering the coupling between the repeating tubes 16 and 17, the arrangement comprises a radio-frequency choke coil 19 connected between the anode of tube 16 and the positive terminal of the B-battery. A blocking condenser 21 is connected between the anode of tube 16 and the control electrode of tube 17. The usual high grid-leak resistance 22 is connected between the control electrode and the cathode of tube 17. The untuned coupling arrangement between tubes 17 and 18 is very similar to that between tubes 16 and 17 except that the anode lead of tube 17 is tapped into the coupling coil 20 by means of a variable contact, thus effectively making coil 20 an auto-transformer.

The coupling coils 19 and 20 are preferably wound with fine wire and supported upon cylindrical forms, although this construction is not essential. By winding the coils in this manner, however, the distributed capacity of the coils is reduced to an extremely low value. The coils, however, may be constructed by any of the well-known methods for securing low distributed capacity. The coupling coils 19 and 20 are characterized by being capacitively reactive over the entire tuning range of frequency; that is, the inductance is sufficiently large so that it resonates with the distributed capacity of the winding, the output capacity of the associated tube and the input capacity of the next succeeding tube at a frequency lower, but not greatly lower, than the lowest frequency of the tuning range. As a

result, the impedance of the interstage coupling arrangement is higher for the lower frequencies of the tuning range than for the higher frequencies; hence the ratio of output to input voltage of a tube and its associated coupling arrangement is higher for the low frequency range than for the high frequency range. At the same time the capacitive load of the plate circuit shifts the phase of the output currents sufficiently so that the internal plate to grid coupling of the tube does not cause positive re-generation.

In the chart of Fig. 5, the ordinates indicate voltage ratios and the abscissas represent frequencies of the ordinary broadcasting range, that is, from 500 to 1500 kilocycles per second. Curve "*a*" illustrates a typical voltage ratio or response characteristic of one of the untuned amplifier coupling systems. The curve shows that the highest voltage is developed at the lower frequencies, that is, near the resonant frequency of the coupling coil. At the high frequency end the voltage ratio is only about one-half of that at the low frequency end.

The signals are impressed upon the first tuned circuit 10 of the preselector by an antenna A, the lead from which is preferably tapped into coil L_1 a few turns from the low potential end. Although in the schematic circuit diagram, coil L_1 is shown as an auto-transformer, a two-winding transformer may be employed with equal facility.

The first tuned circuit composed of inductance coil L_1 and variable condenser C_1 is tuned to resonance and the resonant current is transferred to the second tuned circuit composed of inductance coil L_2 and variable capacity C_2 by means of the small coupling coil L_1'. The second tuned circuit is likewise tuned to resonance and the energy conveyed therefrom to the third tuned circuit composed of inductance coil L_3 and variable capacity C_3 by means of the coupling coil L_2'. The third tuned circuit is similarly tuned to resonance and the desired signal voltage applied to the input of the amplifier. When the tuning condensers are ganged together, as illustrated, the three circuits are simultaneously tuned by a uni-control device. The high potential terminal 3 of the preselector is adjustable so that any desired signal voltage may be impressed upon the untuned amplifier. This variable connection, although desirable under some conditions, is not necessarily essential to the invention. Tapping in across a portion of the third tuned circuit in the manner described has been found to be particularly effective when the negative regeneration of the untuned amplifier is high, for with this connection a smaller loading effect occurs in the third tuned circuit; hence, the selectivity is better than it might otherwise be.

In addition to the loading effect resulting from the negative regeneration of an untuned amplifier, the adjustable connection of the system from the preselecting system to the amplifier furnishes a very satisfactory method of securing volume control, for as the high potential lead is moved toward the grounded end of inductance L_3 the voltage across the output terminals of the preselector diminishes, thus effecting control of the signal voltage.

It is not essential that the signal voltage to the amplifier be supplied by an auto-transformer connection such as terminal 3 of coil L_3; but it may be supplied to the amplifier with equal facility by means of a two-winding transformer of which the mutual inductance between the primary and secondary is made variable to accomplish the desired volume control.

A tuning system composed of coupled tuned circuits alone, such as that of Fig. 1, in which the tuned circuits are coupled magnetically, is characterized by a response which rises with increasing frequency over the tuning range. When the antenna is naturally resonant above the tuning range, as is usually the case, its impedance is effectively capacitive; which causes the voltage delivered by the antenna to the selector system to increase with increasing frequency. Since the voltage characteristics of the antenna and of the magnetically coupled tuner both slope upward with frequency, the over-all response characteristic of the antenna and preselecting system of Fig. 1 rises with frequency as shown by curve "*b*" of Fig. 5.

Fig. 2 illustrates a radio-frequency receiving system which is in general similar to that of Fig. 1. The preselector, however, instead of utilizing magnetic coupling between successive tuned circuits, employs capacitive coupling. The preselector comprises three tuned circuits 25, 26 and 27, each including an inductance tuned by a variable capacity as in the preselector of Fig. 1. The tuned circuits are coupled only by coupling condensers C_8 and C_9.

In the drawings each coupling condenser is shown as being connected between a tap in one tuning coil and the high potential end of the next succeeding tuned circuit. It is not essential that the coupling condensers be tapped into the coils in this manner, but it is often convenient to follow this expedient for with this connection the coupling capacities may be larger and are not required to have such precise values, as would be the case if the high potential ends of all succeeding tuned circuits were directly coupled by the capacities.

The pre-selector system of the receiver shown in Fig. 2 is characterized by a voltage ratio or response which increases toward the higher end of the tuning range. This increasing response results from the fact that

the coupling capacities convey more current at higher than at lower frequencies. A typical response characteristic of the capacitively coupled pre-selector system, including the antenna, is illustrated by curve "*c*" of Fig. 5. Due to the effect of the capacitive coupling, the response rises more rapidly with frequency than that of the antenna and pre-selector system of Fig. 1, illustrated by curve "*b*".

Fig. 3 illustrates a receiving arrangement similar to those of Figs. 1 and 2 except that the pre-selecting system is composed of tuned circuits which are coupled both magnetically and capacitively. Referring to the pre-selector, it comprises three tuned circuits, 30, 31 and 32. Circuit 30 is magnetically coupled to circuit 31 by a small coil L_{10}', and circuit 31 is magnetically coupled to circuit 32 by a similar coil L_{11}'. Coils L_{10}' and L_{11}' correspond to coils L_1' and L_2', respectively of Fig. 1 and may be constructed and arranged in the same manner. In addition to being magnetically coupled the tuned circuits are also coupled capacitively by means of condensers C_{13} and C_{14} in the manner of the capacitive coupling of the pre-selector of Fig. 2. Condensers C_{13} and C_{14} may be tapped respectively into coils L_{10} and L_{11} in the manner explained in connection with the pre-selector of Fig. 2, if desired.

The dualistic coupling between the several tuned circuits of the pre-selector of Fig. 3 may be made use of to provide the receiving system with desired response characteristics. The capacitive and magnetic couplings may be arranged to mutually aid or to mutually oppose each other depending upon the result desired. The addition or the subtraction of the coupling effects makes possible an alteration of the voltage ratio, or response characteristics of the pre-selective system within wide limits. For example, the magnetically coupled pre-selectors have a substantially uniform response over the tuning range, while the effect of the capacitive coupling is to transfer the greatest energy at the higher frequencies. If it is desired, therefore, to obtain an extremely steep gain characteristic between the input and the output of the tuning system, favoring the higher frequencies, the capacity coupling should be arranged to aid the magnetic coupling. If, on the other hand, a more uniform gain characteristic between the input and the output of the tuning system is desired, the capacity coupling should be arranged to oppose the magnetic coupling.

Fig. 4 illustrates a radio-frequency receiving system similar to that of Fig. 3 except that the untuned amplifier utilizes four-element amplifying tubes of the screen-grid type, instead of three-element tubes shown in Fig. 3. The use of screen grid tubes is often advantageous because of the higher amplifications that can be secured as compared with the conventional three-element tubes.

Fig. 6 shows the over-all gain characteristic of a receiver employing an antenna, a selector system composed of three tuned circuits and an untuned amplifier composed of several stages of repeating elements having capacitively reactive loads in the output circuits. The response characteristic shown in this figure is obtained by designing the antenna and preselector system to have a voltage ratio characteristic which is complementary to that of the untuned amplifier; hence, the over-all characteristic is substantially uniform over the tuning range. The importance of being able to alter the slope of the response characteristic of the selecting system becomes apparent when it is considered that the slope of the characteristic of the untuned amplifier may not lie wholly within the control of the designer. For example, it may be necessary to employ amplifying tubes having either extremely small or extremely large input and/or output capacities; and the amplification characteristic will depend upon the tubes employed. The slope of the response characteristic of a multi-stage amplifier will vary in accordance with the number of amplifying stages. The over-all response, or voltage ratio, of the amplifier will be the product of that of the several stages. For example, if the characteristic of a single stage varies from an amplification factor three at the high frequency end to six at the low frequency end, then if four stages of amplification be employed, the slope of the over-all amplification characteristic at the frequency limits will be in the ratio of 16 to 1. In order to provide a substantially uniform gain characteristic for the completed radio-frequency receiver, it is necessary to slope the again characteristic of the antenna and preselector system in the opposite manner to that of the amplifier and to provide a slope having an amplification at the ends of the tuning range in the ratio of 1 to 16.

What is claimed is:

1. In a radio receiving system, in combination, an untunable radio-frequency amplifier and a frequency-selecting arrangement comprising a plurality of coupled tunable circuits, said amplifier comprising a thermionic repeater having an output load which is capacitive over the receiving frequency range whereby said amplifier operates in a stable condition, said selecting arrangement being connected in tandem, ahead of said amplifier whereby said system is selective and free from cross-talk.

2. A radio receiving system in accordance with claim 1 in which said tunable circuits are coupled electro-magnetically.

3. A system in accordance with claim 1

in which said tunable circuits are coupled both electro-magnetically and electro-statically.

4. A system in accordance with claim 1 in which said tunable circuits are coupled both electro-magnetically and electro-statically in phase opposition, whereby the voltage ratio between the input and output of said plurality of tunable circuits is approximately uniform over the tuning range.

5. A system in accordance with claim 1 in which said tunable circuits are coupled electro-magnetically and electro-statically, said electro-static and electro-magnetic coupling being arranged to mutually aid each other, whereby the ratio between the input and output voltages of said plurality of tunable circuits varies over said frequency range at a rate more rapid than it would if said plurality of tunable circuits were only electro-magnetically coupled.

6. In a radio receiver a preselector comprising a plurality of variably tuned circuits arranged in tandem and coupled together, and an untunable radio-frequency amplifier comprising an untuned amplifying stage, the output circuit of said amplifying stage including a coil having the characteristic that its impedance is effectively capacitively reactive throughout the frequency range to be received, whereby the ratio of output to input voltage of said amplifying stage decreases with increased frequency, the ratio of output to input voltage of said preselector increasing with increased frequency, whereby the over-all voltage ratio of said receiver is substantially uniform over the frequency range to be received.

7. In a radio receiver, including a series of resonant circuits tunable over a certain frequency range, an untunable amplifier comprising at least one stage of amplification, a coil connected to the output circuit of said amplifier stage having such value of inductance that it is resonant at a frequency fixed lower, but not greatly lower, than the lowest frequency of said range, whereby the ratio of output to input voltage of said amplifying stage decreases with increased frequency, and grounded metallic shields interposed between the series of tunable resonant circuits whereby undesired coupling between said series of tunable circuits is reduced.

8. In a radio receiver a tuning system comprising a plurality of tunable circuits arranged to be syntonously tuned over a range in frequency, an untunable amplifier stage comprising a vacuum tube having an anode circuit and a load in the anode circuit which is capacitively reactive throughout the tuning range of frequencies, a mutually inductive coupling between the output of said tuning system and the input of said amplifier, and means for variably adjusting the impedance of said inductive coupling, whereby the strength of signal voltages supplied to said amplifier may be regulated.

In testimony whereof I affix my signature.

WILLIAM A. MacDONALD.