June 23, 1931. G. A. SOMERSALO 1,811,443

SYSTEM OF SELECTIVE SIGNALING

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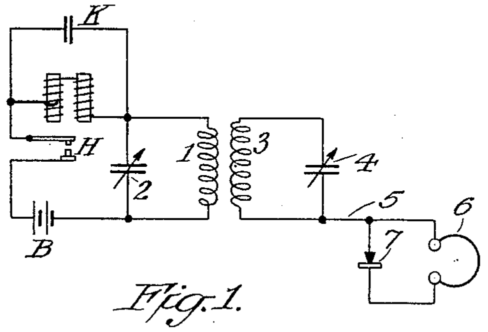

Fig. 1.

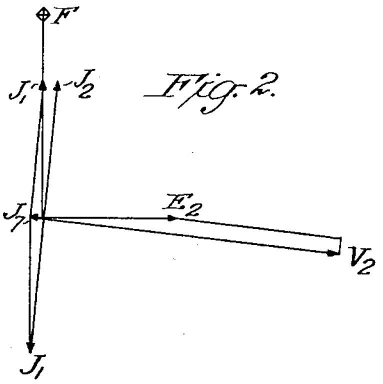

Fig. 2.

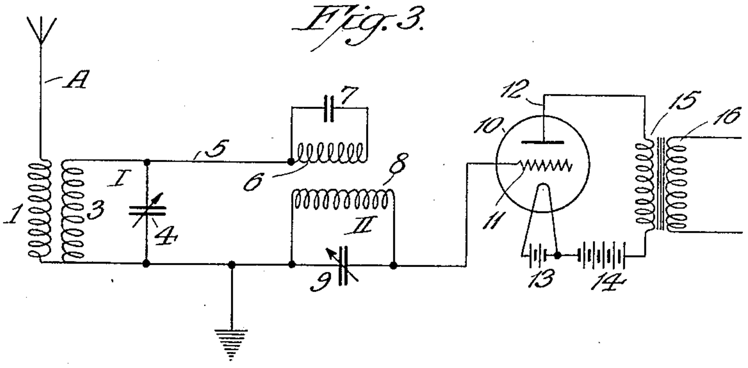

Fig. 3.

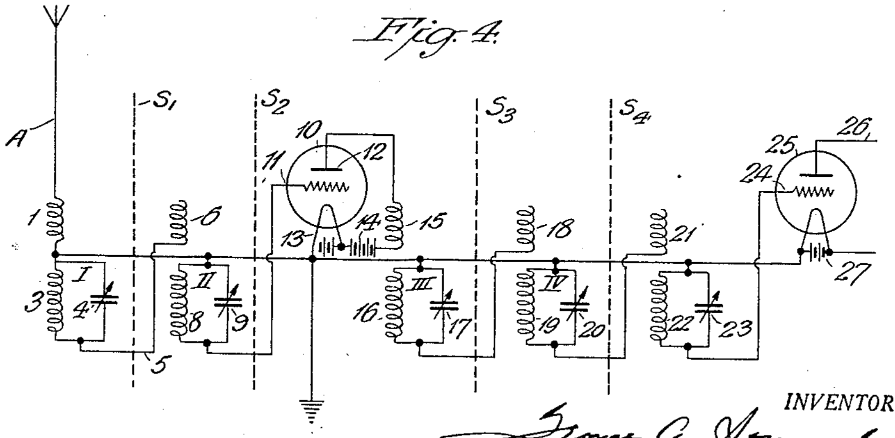

Fig. 4.

INVENTOR.

George A. Somersalo

BY

G. Willard Rich

his ATTORNEY.

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Fig. 5.

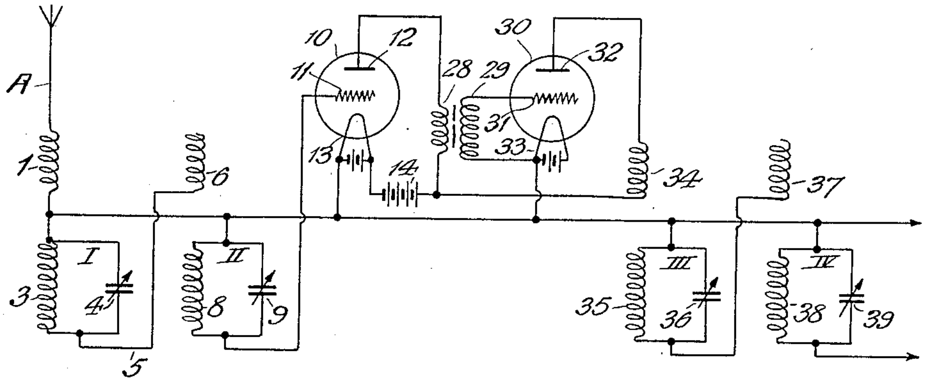


Fig. 6.

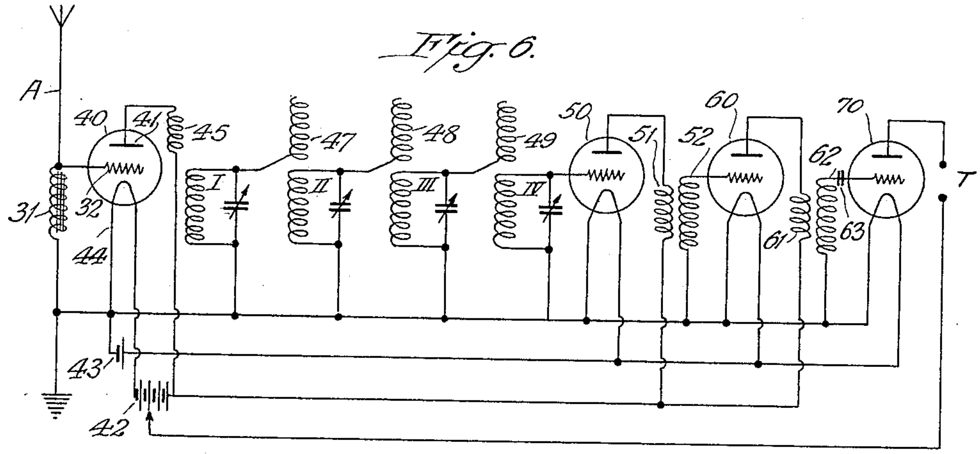
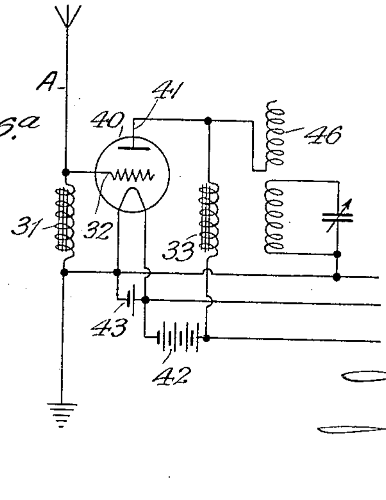


Fig. 6a



INVENTOR.

George A. Somersalo

BY

J. Willard Rice

His ATTORNEY

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UNITED STATES PATENT OFFICE

GEORGE A. SOMERSALO, OF NEW YORK, N. Y.

SYSTEM OF SELECTIVE SIGNALING

Application filed August 15, 1927. Serial No. 212,872.

My invention relates to an electric circuit for the selective translation of oscillating currents of a desired frequency or band of frequencies.

In particular, my invention relates to a selective electric circuit in which a number of tuned circuits are connected in cascade by a special form of coupling to reduce to a minimum the reaction of one tuned circuit upon another.

Heretofore, in systems for the selective transmission of waves, it was common practice to connect several tuned circuits in cascade by one of several types of coupling in which there was always an appreciable amount of reaction between two adjacent circuits. The reaction between the circuits destroys the selective property of the tuned circuits and flattens out the resonance curve, and, in the limit, may produce a double-peaked resonance curve. In prior arrangements, the coupling between circuits had to be made very loose in order to prevent the reaction from destroying the selectivity. But, loose coupling prevents the efficient transfer of energy from one circuit to another. In one known arrangement, in order to reduce the reaction, and at the same time obtain good energy transfer between circuits, it was proposed to couple adjacent circuits by vacuum tube relays, thus taking advantage of the supposedly unilateral coupling effect of the tube. But it is now common knowledge that a vacuum tube relay is not unilateral in its coupling effect, due to the inherent capacity effect between its various electrodes, but will produce undesired reactions between the coupled circuits.

It is, therefore, an object of my invention to devise a selective circuit in which full advantage is obtained of the selective property of all the coupled circuits and, at the same time, efficient energy transfer is obtained without the use of vacuum tube relays.

While my invention is capable of use generally where it is desired to select waves of a particular frequency or band of frequencies to the exclusion of others, it is particularly useful as a selective element in a radio receiving set.

I have illustrated certain features of my invention in the accompanying drawings, in which,

Fig. 1 is a diagram of a wavemeter calibrating circuit employing the well known unilateral type of connection to the detector, which type of connection is used in a new relation in my invention.

Fig. 2 is a vector diagram showing the relations between the various electric quantities in the circuit of my invention.

Fig. 3 is a diagram of a circuit embodying the principles of my invention.

Fig. 4 is a circuit diagram of a modified form of my invention.

Fig. 5 is a circuit diagram of still another form of my invention.

Fig. 6 is a circuit diagram showing the preferred form of my invention as embodied in a commercial radio receiving set.

Fig. 6^a is a slightly modified form of the preferred circuit.

Referring to Fig. 1, a well known arrangement for calibrating wavemeters is shown, and is reproduced here for the purpose of explaining the principle of operation of my invention. A standard wavemeter circuit including an inductance 1 and a variable condenser 2 is excited in a known manner by a buzzer H, which is provided with a shunting condenser K and an operating battery B. The wavemeter to be calibrated comprises a variable condenser 4 and an inductance coil 3 inductively coupled to coil 1. A telephone 6, shunted by a detector 7, is connected by a single wire 5 to one terminal of the wavemeter circuit 3, 4. This is known as a unilateral connection. When wavemeter 3, 4 is tuned to the currents generated by the standard wavemeter, the buzzer note will be audible in telephone 6, notwithstanding the fact that there is no return connection of either the phone or the detector to the circuit 3, 4. This phenomena is known to those skilled in the art, and does not require an explanation, but for the purpose of explaining my present invention I offer the following theory: When circuit 3, 4 is excited, there will be a variable current pressure in lead 5. This current pressure is similar to that in any conductor connected with an electric circuit. As the current pressure in a cable forces the electrons nearer the surface, the electrons here will be forced to the end of the lead 5 and from here to the telephone coil. If the telephone coil were not shunted by a detector 7, nothing would happen. Now the electrons will be forced partly through the telephone coil 6, and partly against the detector 7. The reaction of these two against such a pressure is different. The coil will act like an elastic wall, the action and the reaction being equal and opposite. The first transient wave impulse will magnetize the core and the magnetization will set up an opposing electromotive force. This counter electromotive force will send a current through the circuit 6, 7. This refers to the audio frequency wave, since the telephone coil will act as choke towards radio frequency current. The detector 7 will rectify the current thus making the system operative.

My invention is embodied in the circuit diagrammatically illustrated in Fig. 3. In this figure, an antenna A is connected to ground through the primary 1 of an oscillation transformer. The secondary 3 of the transformer is shunted by a variable condenser 4 to form a tunable circuit generally indicated by I. One side of tuned circuit I is grounded, and the other side is connected to one end of a coil or open conductor 6 which is provided with a shunt condenser 7. Coil 6 is in inductive relation to another coil 8 which, with variable condenser 9, forms a second tuned circuit II. One side of circuit II is grounded, preferably the side adjacent the end of coil 6 which is conneceted to circuit I, and the other side of circuit II is connected to grid 11 of a vacuum tube 10. The vacuum tube may serve as a repeater, an amplifier or a detector, as desired. The plate 12 of the tube is connected to the battery 14 and the filament 13 through the primary winding 15 of a transformer, the secondary 16 being connected to the output circuit. The transformer may or may not be provided with an iron core, as desired. Coil 8 is arranged in non-inductive relation to coil 3.

The arrangement shown in Fig. 3 is somewhat similar to that shown in Fig. 1, but the operation of Fig. 3 has to do only with the effect of the radio frequency currents. The operation of Fig. 3 is as follows:

The incoming signal sets up a circulating current through the coil 3 and the variable condenser 4. The current pressure will be propagated through the lead 5 to the coil 6 and condenser 7. The first transient wave impulse will force the electrons through the windings of the coil and against the condenser, but the reaction of the coil to such a wave is different from that of the condenser. The coil will act like an elastic wall, and will react upon the current impulse, the action and reaction being equal and opposite. The transient current magnetizes the core and the flux sets up a counter-electromotive force. When again the electron current strikes the condenser, these electrons will be first stored, as in a reservoir, then discharged during the next half cycle. Consequently the counter-electromotive force set up in the coil 6 will send a current through the condenser 7, this current being in step with the current in the circuit 3, 4. The current in the lead 5 will be small, the pressure of the current in the circuit 3, 4 being opposed by the pressure of the current in the circuit 6, 7. Current flowing in coil 6 induces current in coil 8 and excites tuned circuit II. Potential variations across tuned circuit II are impressed upon grid II to operate vacuum tube 10.

While I have shown an external condenser 7 connected in shunt to coil 6, it is to be understood that the coil may be so designed that its natural distributed capacity will serve the function of condenser 7, and an additional capacity need not be employed.

I do not intend to be limited to any particular quantities or dimensions of the various elements of my invention, but for the purpose of illustration only, I find that for a tuning range from 200 to 550 meters satisfactory results are obtained when coil 6 is 2½ inches in diameter and has approximately 42 turns, while coil 8 it 2½ inches in diameter and has approximately 66 turns. Condenser 7 or its equivalent should be 0.00025 mmf. or less. The correct value of the condenser 7 will depend upon the design of coil 6. The coupling between coils 6 and 8 should be preferably 50 per cent, or more.

Instead of employing a vacuum tube amplifier directly after circuit 8, 9 a third tuned circuit may be added, or any other kind of a relay may be used.

The series of tuned circuits connected in cascade may be termed a "filter," and in my invention each tuned circuit is connected with the succeeding one by means of unilateral, aperiodic coils or circuits. It is possible to obtain voltage amplification of the waves within the filter itself. The ratio of the voltage across coil 8 to the voltage across coil 3 may be either a step-up or a step-down ratio depending upon the efficiency of energy transfer through the filter. Of course, this step-up in voltage does not mean increased energy, since there is no energy amplification within the filter itself.

The manner of transfer of energy through the filter may be explained with the aid of the vector diagram shown in Fig. 2. J_1' represents the current circulating in circuit I. If the current were free to flow through the lead 5, coil 6 and some way back again without reducing the amount of current circulating in the circuit I, the current pressure per unit cross section in the windings of 6 would be the same as in the other part of the circuit, in this case equal to that in circuit 3, 4. This is the amount of magnetizing current, and the magnetic flux produced denoted by F (Fig. 2) will have the same phase. Following the common way of drawing vector diagrams the electromotive force E_2 set up in the secondary winding 8 will lag 90 degrees behind the flux. The condenser 9 being tuned to resonance, the secondary load current J_2 flowing through it will lead the voltage by nearly 90 degrees. It will be opposed by the load component J_1 of the current in the primary winding 6, and consequently this load component will be nearly 180 degrees out of phase with the flux, and nearly opposed to magnetizing current J_1'. The vector sum of both—the actual current J_7 through the condenser 7—will thus be small compared with both of them, the magnetizing current and the load current. A comparatively small current in the aperiodic coil 6 (Fig. 3) will cause a large circulating current in the circuit II. The terminal voltage V_2 across coil 8 will be greater, equal to or smaller than the terminal voltage across coil 3, depending upon the nature of the coil 6 and condenser 7. This coil and condenser should be preferably so designed that a step-up voltage ratio exists.

The comparative efficiency of this energy transfer can be seen from the vector diagram. The energy transferred from coil 6 to the circuit 8, 9 will be proportional to the current vector J_2, the energy lost in coil 6 will again be proportional to the vector J_7. Thus only a small portion of energy is lost.

Another way to explain this filter circuit would be to consider the unilateral coil as a diminutive transmitting aerial with a very small natural capacity, but a great self-inductance. This diminutive aerial is inductively coupled to the next filter stage acting as receiver. Notwithstanding the small size of the unilateral coil, compared with an aerial, the former may be very efficient. The natural capacity may be smaller, but it has a far greater self-inductance. In an aerial the energy will be stored mainly in the conductor itself and in the electrical field surrounding it, in the unilateral coil the energy will be stored and transferred by the magnetic field.

It is to be noted that coil 6 is conductively coupled to the preceding tuned circuit and inductively coupled to the succeeding circuit. Thus, there is a combined conductive and inductive coupling between tuned circuits, which has the advantage of great selectivity which cannot be obtained by direct inductive or capacitative coupling. Take for example, the ordinary transformer type of coupling in which two tuned circuits are inductively coupled. Considering each circuit alone, the voltage and current are at a miximum when the circuit is tuned to resonance, but when the two are coupled together the resonance curve generally shows two peaks, which broaden the curve and destroy selectivity. In order to eliminate the double-hump in the curve the coupling must be reduced. This so-called optimum coupling, however, is very loose, and does not permit efficient transfer of energy.

In my system there is no such harmful reaction between the tuned circuits. The amplification curve for each circuit shows a single peak, the resonance peak of the second circuit being sharper than that of the first. If a number of filter stages are connected in cascade, the resonant peak of each circuit will show an increasing sharpness, the last circuit having the sharpest peak. Hence each succeeding circuit is more selective than the preceding one. If all circuits are tuned simultaneously, the last circuit will have the greatest effect upon the selectivity, and with the number of stages the selectivity will rise not in geometric progression, but in a progression steeper than the geometric. The energy transfer will be greatest for the frequencies near the resonance, whereas for frequencies farther away this transfer is very small. It may be said that a part of the peak energy has been transferred to the next circuit. There is no tendency to build up a double peak.

The arrangement shown in Fig. 4 is an extension of the circuit shown in Fig. 3, and like elements are represented by the same reference numerals. In this arrangement there are five tuned circuits I–V in the entire filter, but an amplifying tube 10 is inserted between circuit II and circuit III for the purpose of compensating for energy loss within the filter and for amplifying the voltage. Tuned circuits III to V comprise coils 16, 19 and 22 with corresponding tuning condensers 17, 20 and 23. Circuit III is inductively coupled to coil 15 in the plate circuit of tube 10. Aperiodic coupling coils 18 and 21 serve respectively to couple circuits III and IV to the succeeding circuits. Coil 16 may be coupled to the output circuit of tube by any other suitable type of coupling instead of the inductive coupling shown. In order to reduce the effect of natural capacity between coil 6 and coil 8, it will be advantageous to place coil 6 at the grounded end of coil 8. This applies also to coils 15, 18 and 21. If there be considerable capacity between coils 6 and 8, this capacity will provide a return path to circuit

I for the current in lead 5, and the selectivity would be decreased. Each of the tuned circuits are properly shielded from each other by suitable conducting shields indicated at S_1, S_2, S_3, and S_4 for the purpose of preventing magnetic coupling between the various circuits. These shields should be preferably entirely closed metallic boxes. In other figures of the drawings these shields are not shown, but it is to be understood that the coils belonging to different filter stages should not have any magnetic coupling. The highly selected signal obtained at the terminals of circuit V is impressed upon a second amplifying tube 25.

It is to be noted that the function of the tubes is to supply additional energy to the waves to compensate for the loss in the filter and to amplify the voltage. The tubes are not relied upon to prevent reaction between the circuits, and the number of tubes inserted in the filter is kept as small as possible consistent with the amplification required.

In Fig. 5 I provide additional amplification by connecting an amplifying tube 30 in cascade with tube 10 through an untuned transformer 28—29. This transformer may or may not be provided with an iron core, as desired. Fig. 5 is similar in other respects to Fig. 4.

In the preferred form of my invention, shown in Fig. 6, I first amplify the incoming signal before entering the filter by amplifying tube 40, the grid of which is connected directly to the antenna, and to ground through a choke coil 31. The choke coil is preferably so designed as to render the antenna circuit aperiodic. The filter in this arrangement consists of an unbroken cascade of resonant circuits I to IV, or as many as desired. After passing through the filter the waves are impressed upon an untuned voltage amplifier consisting of vacuum tubes 50 and 60, coupled by a transformer 51, 52. The last amplifier tube is coupled by transformer 61, 62 to a detector tube 70, which detects the high frequency wave and derives therefrom the low frequency signal. If desired, the low frequency signal current may be amplified by an audio frequency amplifier indicated at T.

The advantage of the arrangement shown in Fig. 6 is that by first amplifying the incoming signal wave before it reaches the filter a longer and more selective filter may be used before the voltage amplification stage. The first amplifying tube 40 will, of course, also amplify the voltage. In this position a special tube giving great energy amplification may be employed.

In Fig. 6^a the amplifying tube 40 is coupled to the first filter circuit I by means of a unilateral coil 46. A choke coil 33 has been added to connect the plate with the battery 42. This way of coupling shows a greater selectivity than that of Fig. 6, a unilateral coupling is more selective than the transformer coupling.

While I have offered certain theories of operation in the foregoing description of my invention, it is to be understood that the scope of my invention is not to be restricted or limited in any manner by any particular theory of operation, it being sufficient that the physical embodiment of my invention is so described that one skilled in the art may construct and use my invention.

What I claim is:

1. An electric wave receiving system comprising a number of tuning stages connected in cascade, means for inductively coupling these stages with substantial elimination of mutual impedances between adjacent stages, said means including an open coil, and means of amplification associated with these stages.

2. An electric signaling system comprising a number of tuning stages connected in cascade, means for coupling said stages, including a substantially open coil in conductive relation to a stage and inductively coupled to the following stage, said coil having a substantial distributed capacity, and means of amplification associated with the stages.

3. An electric wave filter comprising a number of tuning stages connected in cascade and means for coupling said stages, these means including a substantially open coil in conductive relation to a stage and inductively coupled to the following stage and having a negligible coupling capacity.

4. An electric wave filter comprising a number of stages connected in cascade, each stage consisting of a coil shunted by a condenser, said coil and condenser forming a circuit resonant to the desired frequency, and means for coupling said stages, these means including a substantially open coil in conductive relation to a resonant stage and inductively coupled with the coil of the following resonant stage, there being no substantial magnetic coupling between the corresponding coils in each stage.

5. An electric wave filter comprising a number of stages connected in cascade, each stage including a circuit resonant to the desired frequency, and means for coupling said circuits including a substantially open coil in conductive relation to a resonant circuit and inductively coupled to the following circuit, said coil having a substantial distributed capacity, the corresponding parts in each circuit having no common magnetic field.

6. An electric wave filter comprising a number of stages connected in cascade, each stage including a circuit resonant to the desired frequency, and means for coupling two consecutive circuits including a substan-

tially open coil connected with one and inductively coupled with the other circuit, the corresponding parts of each circuit having substantially no common magnetic or electric field.

7. A system for selecting electric waves comprising a pair of circuits resonant to the frequency to be selected and an open coil in non-inductive conductive relation with one of the circuits and inductively coupled to the other circuit said coil having a substantial distributed capacity.

8. A system for selecting electric waves comprising a series of independent tuned circuits arranged in cascade, and means for coupling said circuits comprising an open coil external to both circuits and connected to the preceding circuit and inductively coupled to the following circuit, said coil having a shunted capacity.

9. A system for selecting electric waves comprising a series of independent tuned circuits arranged in cascade, each circuit comprising an inductance coil shunted by a condenser, each coil inductively coupled to an open coil having one end connected to the preceding circuit.

10. An electric signal selecting system comprising two resonant circuits connected in cascade each of the circuits consisting of an inductance shunted by a capacity, the inductances being in non-inductive relation to each other, the circuits having one common point, and an open coil having one end free and its other end connected to a point of the preceding circuit differing from the common point, said coil being inductively coupled to the coil in the succeeding circuit.

11. An electric signaling system comprising an aerial, a selector, and an amplifier, said selector forming a continuous unit comprising a number of tuning stages connected in cascade, and means for substantially eliminating resonance distortive reaction of a stage upon the preceding stage, said means including an open coil.

12. An electric wave receiving system comprising an antenna, a selector consisting of a number of stages in cascade, each stage including a circuit resonant to the desired frequency, and of means including an open coil for coupling said stages with substantial elimination of resonant distortive reaction therebetween, and means for preventing variations in the antenna constants from affecting the tuning adjustments of said selector, said last mentioned means comprising an electron discharge device coupling the selector to the antenna.

GEORGE A. SOMERSALO.