Oct. 23, 1934. P. O. FARNHAM 1,978,255

TRANSMISSION CIRCUIT

Filed Jan. 31, 1933

Fig. 1.

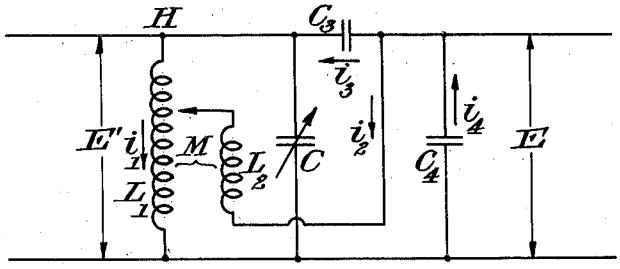


Fig. 2.

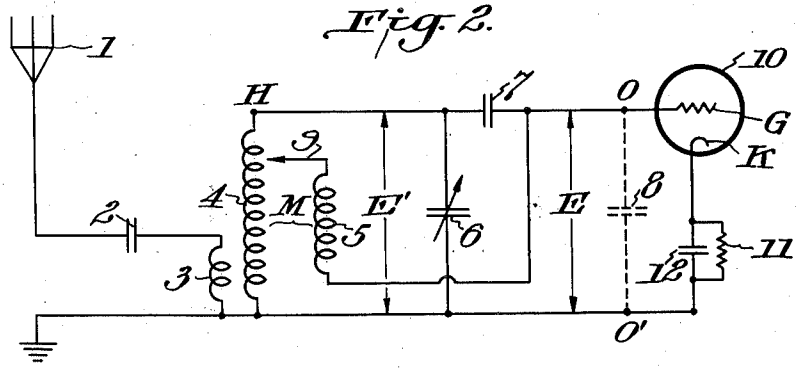
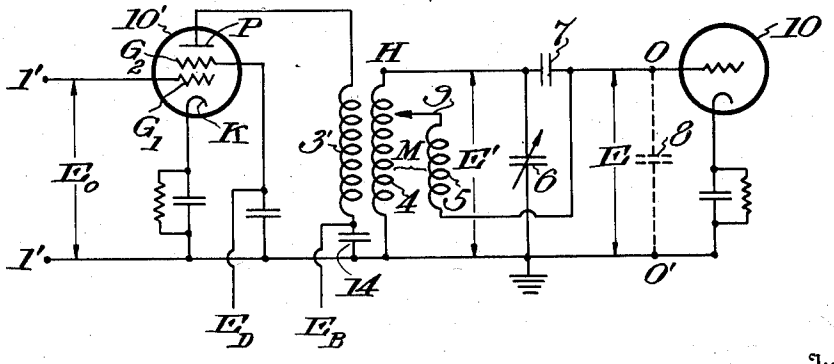


Fig. 3.



Inventor:

Paul O. Farnham,

By Byrnes, Townsend & Potter,

Attorneys.

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TRANSMISSION CIRCUIT

Paul O. Farnham, Boonton, N. J., assignor to Radio Frequency Laboratories, Incorporated, Boonton, N. J., a corporation of New Jersey

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18 Claims. (Cl. 178—44)

This invention relates to tuned transmission circuits and more particularly to a type useful in tuned radio frequency coupling apparatus.

It has long been recognized that the elementary coupling circuits tuned over a range of frequency by variable capacities exhibit unsatisfactory transmission characteristics. An important disadvantage is the non-uniformity of transmission at resonance as the system was tuned over its range of frequency. The transmission at resonance of such elementary circuits usually varies at a rate that is nearly proportional to the resonant frequency, so that if several such circuits were to be used in cascade, as for example, in the case of radio broadcast receivers, the transmission-frequency characteristic being proportional to the product of those of the several units, might well vary as much as fifty to one over a frequency range of slightly less than three to one.

Various methods have been employed to overcome this defect such as "lossing" the tuned circuits with resistance, effective at the higher frequency portion of the tuning range, or feeding the tuned circuit through a complex coupling adapted to decrease the transmission at the higher frequencies. The "lossing" method has the obvious disadvantage of impairing selectivity at the higher frequencies. The second method, in the case of coupling an antenna or collector to a tuned circuit, does not lend itself readily to an efficient adjustment for a wide range of antenna capacities because of difficulties of alignment of the input circuit with succeeding tuned circuits.

An object of the present invention is to provide a coupling system, for use with tuned circuits, which will secure a desired transmission frequency characteristic. Another object is to provide a method of obtaining a substantially uniform transmission frequency characteristic by suitable couplings to the output of tuned circuits. Still another object of the invention is to provide a method of coupling an antenna through a tuned circuit to an amplifying stage to secure a substantially uniform gain-frequency characteristic without introducing difficulties, due to variations in the capacity of the antenna, in the "tracking" of the system with succeeding tuned circuits for single-control operation.

These and other objects and advantages of the invention will be apparent from the following specification taken together with the accompanying drawing in which:

Fig. 1 is a circuit diagram of the coupling system applied to the output of a tuned circuit;

Fig. 2 is a circuit diagram of an antenna input system embodying the invention; and

Fig. 3 is a circuit diagram of a typical radio frequency amplifier stage embodying the invention.

The circuit of Fig. 1 will aid in a clear understanding of the operation of the coupling system contemplated by the invention. The voltage E' across the main tuning coil L_1 is here considered the input voltage to the system. Connected across the coil L_1 is a tuning condenser C which resonates the system to the impressed frequency, but which is not a part of the coupling system. Two capacities C_3 and C_4 are also connected in series across the coil L_1 which capacities are relatively fixed, that is, they are not readily capable of adjustment during the operation of the system, as is the tuning condenser C.

Connected between the junction of these capacities and any point along the coil L_1 is a second coil L_2 which may be magnetically coupled to coil L_1, as shown at M. The output voltage E is taken across the capacity C_4, i. e., the output is taken between the low-potential end of coil L_1 and the junction of the two serially connected capacities.

Disregarding for the moment the coil L_2, the two capacities C_3 and C_4 constitute a voltage divider having end terminals connected across the input coil L_1, with the opposite terminals of condenser C_4 serving as the output terminals of the voltage divider, thus making the output voltage a constant fraction of the input. The assumed directions of the currents in the several branches are indicated by arrows i_1, i_2, etc. It is evident that with the capacity voltage divider alone, formed by condensers C_3 and C_4, the voltage output E is less than the input E' since, with these assumed conditions, $i_4=i_3$ and $E/E'=C_3/(C_3+C_4)$.

By introducing coil L_2, the additional current i_2 is established which, having the direction shown in the diagram, tends to reduce the current i_3 and to increase the current i_4. By this means, the output voltage E may be increased until it equals or even exceeds the input voltage E'. The magnitude of the current i_2 with respect to the currents i_3 and i_4 is controlled by the reactances of the circuit elements so that it may be made to vary with the frequency at which the system is operated. Thus any variation with resonant frequency of the voltage E' across the tuned circuit may be compensated by the coupling network to produce any desired variation, within wide limits, of the output voltage E. If, as is usually the case with condenser-tuned am-

plifier stages and antenna input circuits, the voltage E' tends to decrease with decreasing resonant frequency the coupling system may be designed to give a substantially constant output voltage.

For applications similar to the one just mentioned in which it is desired to make the ratio E/E' increase with decreasing frequency, the following general rules may be noted. Current i_2 should be controlled by a positive reactance, thus indicating that coil L_2 should be large compared with L_1. The sign of the mutual inductance M should correspond to that shown in the figure in order that i_2 may have the proper direction as shown. If the mutual inductance M has the opposite sign and the reactance controlling current i_2 is positive, current i_2 will tend to decrease voltage E so that at some frequency within the tuning range of the condenser C the voltage ratio E/E' may become nearly zero. Capacities C_3 and C_4 will generally be small compared with the maximum value of C in order that most of the current at resonance shall circulate in the main tuned circuit L_1C.

As the reactance which controls current i_2 approaches zero, the effective series resistance of the tuned circuit will increase above its normal value and tend to broaden the shape of the selectively characteristic. This is usually desirable in offsetting the normal sharpening of the selectivity characteristic when condenser tuned circuits are operated over the low-frequency portion of their range.

In Fig. 2, the reference numeral 1 identifies an antenna or collecting structure which is coupled by the serially connected capacity 2 and coil 3 to the main tuned circuit composed of coil 4 and tuning condenser 6. Condenser 2 serves as a limiting capacity, to limit the amount of capacity reflected from the antenna into the main tuned circuit in a well-known manner. Coil 3 comprises relatively few turns compared with those of coil 4, and is preferably formed by winding the turns of coil 3 adjacent those of coil 4, beginning at the ground or low-potential end thereof.

Or alternatively the antenna may be connected directly to a suitable tap on coil 4 through condenser 2. Thus far the circuit corresponds to those which have long been in use and it is well known that in such a circuit the ratio of voltage across the tuning condenser at resonance to the voltage induced in the antenna rises considerably as the system is tuned to the higher frequencies. To alter this characteristic to one that is substantially uniform or even sloping in the opposite direction while still giving efficient transmission, the invention contemplates a departure from conventional practice by the addition of the coupling system of Fig. 1. The equalizing network inserted between the tuned circuit and the output terminals, indicated as O, O', consists of a coil 5 which may be coupled to coil 4, as indicated by M, and a capacity 7 connected from the high potential side of the tuned circuit to coil 5. The other end of coil 5 is shown at tap 9 indicating a connection to any point along coil 4 between the high radio-frequency potential terminal H and the opposite terminal which is at zero reference radio potential. The capacity 8, shown in dotted line, represents the input capacity of the output circuit, being in this case the effective grid to cathode capacity of vacuum tube 10.

By choosing the inductance of coil 5, the mutual inductance M between coils 5 and 4, and the capacity of condensers 7 and 8 to have the proper relations, we may make the voltage ratio E/E' at resonance of the tuned circuit rise with decreasing resonant frequency. In this way, even though voltage E' decreases with decreasing resonant frequency, the output voltage E may be kept substantially constant. It will be noted that the circuit constants affecting this output characteristic E/E' are independent of the antenna constants.

The circuit diagram of Fig. 3 illustrates the application of this coupling system to a typical stage, either amplifier or detector, of a cascade tuned radio receiver. The input voltage E_0 across terminals 1', 1' is applied to the grid cathode circuit of vacuum tube 10' which is preferably of the shielded type having a screen grid G_2, a control grid G_1 and an output element or anode P. The plate-cathode or output circuit of tube 10' contains the primary coil 3' of an ordinary radio-frequency transformer and bypass condenser 14, together with source of steady anode potential indicated at E_B. The main tuned output circuit comprises coil 4 and tuning condenser 6 and such a system, as thus far described, constitutes a conventional radio-frequency amplifier stage in which the voltage ratio E'/E_0 varies rapidly with frequency as the stage is tuned to respond to various frequencies within its range. In place of coupling the plate to coil 4 through a coil 3' preferably forming a twin winding with the low potential portion of coil 4, the plate may be directly connected, for radio frequency currents, to a tap at any desired point along coil 4.

In accordance with the invention, additional circuit elements are associated with the coil 4, such additional elements being the same as those shown in Fig. 2, and being identified by like reference numerals. The operation of the coupling system in this case is identical with that described in connection with Fig. 2. Thus by a proper choice of coupling network constants the voltage ratio E/E' may be made substantially to compensate for the normal falling off with decrease in resonant frequency of the ratio E'/E_0, thus providing a substantially uniform overall stage gain E/E_0.

In fact, if for any reason it is desired to over compensate the normal characteristic, E'/E_0 vs. frequency, the coupling constants may be chosen so that the ratio E/E_0 actually rises with decreasing resonant frequency. Thus the system as described affords a wide latitude in the type of transmission frequency characteristic that may be obtained, and is therefore particularly suitable in the solution of problems arising in the design of tuned radio amplifier systems.

The following values for circuit constants are given as examples in the cases of two circuits shown in Figs. 2 and 3 when a substantially uniform gain-frequency characteristic is desired over the frequency range from 550 to 1500 kilocycles.

For the circuit of Fig. 2:

Coil 4=100 turns No. 30 enamel wire close wound on 1¼" form and having approximately 220 microhenries inductance;

Coil 3=18 turns No. 34 double silk covered wire, wound turn for turn with coil 4 beginning at low potential end.

Condenser 2=200 mmfds.

Condenser 7=3 mmf.

Capacity 8=10 mmf.

Coil 5=8.1 millihenries.

Tap 9 connected to low potential end of coil 4.
Mutual inductance M=342 microhenries.
Condenser 6=15–400 mmfds.
Resistance of antenna=20 ohms.
Tube 10=Type 58.
For the circuit of Fig. 3:
Coils 4 and 5, mutual inductance M, condenser 6, and capacity 8 same as for Fig. 2 circuit.
Condenser 7=15 mmfds.
Coil 3'=100 turns No. 36 double silk covered wire wound turn for turn with coil 4.

From the described method of operation of the invention, those familiar with the design and construction will understand that, by appropriate changes in the circuit constants, the gain-frequency characteristic may be given within limits, other desired shapes.

I claim:

1. In an alternating current transmission system, the combination with a tuned circuit, of a reactive voltage divider connected across said circuit, said voltage divider having output terminals which include between the same a section of said voltage divider which constitutes a fractional part of the total reactance of said voltage divider, and reactive means for increasing the flow of alternating current in the said section of said voltage divider above that value represented by the ratio of the reactance of said section to the total reactance of the voltage divider.

2. The invention as set forth in claim 1, in combination with an input circuit coupled to said tuned circuit, and wherein said reactive means is independent of said input circuit.

3. In a radio receiver, the combination with input elements, a tuned circuit coupled to said input elements, a vacuum tube having the input terminals thereof coupled to said tuned circuit, and means for reducing the frequency variation of the ratio of the radio voltage of said input elements to the resultant output voltage developed by said tube; said means including a reactive coupling, operative independently of the capacity of said input elements, between said tuned circuit and said tube.

4. The invention as set forth in claim 3, wherein said input elements comprise a collector structure.

5. In a radio receiver, the combination with a collector structure, a tuned input circuit, means coupling said collector structure to said input circuit, a vacuum tube having its grid and cathode connected to opposite terminals of said tuned circuit, a capacity in the connection to said grid, whereby said capacity and the input capacity of said tube constitute a voltage divider, and means coupled to said tuned circuit and independent of the capacity of said collector structure for establishing a radio frequency current flow through the branches of said voltage divider additional to the current flow therein due to voltage divider action.

6. In a radio receiver, the combination with a vacuum tube having input elements between which there is an inherent capacity, a tuned circuit connected across said input elements through a series condenser, and an additional reactive coupling cooperating with said series condenser and capacity between said input elements to increase the voltage established by said tuned circuit across said input elements beyond that value which arises from said connection through said series condenser.

7. In a radio receiver as claimed in claim 6, wherein said reactive coupling comprises an inductance coupled to the inductance of said tuned circuit and connected between a point in the inductance of said tuned circuit and one input element of said tube.

8. In a radio receiver, a tuned circuit comprising an inductance and an adjustable condenser, means coupled to said circuit for establishing a radio voltage across the same, a pair of serially connected capacities connected across said circuit, output circuit terminals at the junction of said capacities and the other terminal of one of said capacities, and a coupling between the inductance of said tuned circuit and the junction of said capacities.

9. A radio receiver as claimed in claim 8, wherein said coupling includes a tap adjustable along a portion of said tuned circuit inductance and an inductance coupled to said tuned circuit inductance.

10. A tuned amplifier stage adapted to be tuned by one of the substantially identical sections of a gang condenser, said stage comprising an input element coupled to a tuned input circuit, a vacuum tube having a grid and cathode, capacity connected between the high radio potential terminal of said circuit and the grid of said tube, a connection from the other terminal of said circuit to the cathode of said tube, and reactive coupling means between the grid of said tube and a point on the inductance of said tuned circuit.

11. A tuned amplifier stage as set forth in claim 10, wherein said input element comprises a collector structure, and said reactive coupling means is independent of the capacity of said collector structure.

12. A tuned amplifier stage as set forth in claim 10, wherein said input element is included in the plate circuit of a preceding stage.

13. An amplifier stage as set forth in claim 10, wherein said coupling means comprises an inductance coupled to the inductance of said tuned circuit.

14. An amplifier stage as set forth in claim 10, wherein said coupling means comprises an inductance coupled to the inductance of said tuned circuit to increase the radio voltage developed by said tuned circuit across the tube grid and cathode above that value due solely to the connection of said tuned circuit to said grid and cathode through said capacity.

15. In the operation of an amplifier stage including a tube having a tuned input circuit coupled to a collector structure, and in which the inductance of said input circuit is to be tuned by one section of a gang condenser, the method of facilitating the alinement of the said input circuit with the circuits tuned by other sections of said gang condenser, which comprises capacitively connecting said input circuit to said tube, and inductively coupling the grid of said tube to the inductance of said input circuit.

16. In an alternating current transmission system, the combination with a tuned circuit, of a reactive voltage divider connected across said circuit, terminals on said voltage divider for connecting a succeeding circuit across a portion of said voltage divider, and reactive means for establishing in the said portion of the voltage divider a flow of alternating current additional to that due to the action of the voltage divider.

17. An alternating current transmission system as claimed in claim 16, wherein said reactive voltage divider comprises a pair of capacities serially connected across said tuned circuit, and

said reactive means includes an inductance coupled to said tuned circuit and connected between a point on said tuned circuit and the junction of said capacities.

18. An alternating current transmission system as claimed in claim 16, wherein said reactive voltage divider comprises a pair of capacities serially connected across said tuned circuit, and said reactive means includes an inductance coupled to said tuned circuit and connected between a point on said tuned circuit and the junction of said capacities, the coupling between said inductance and tuned circuit being of that sense which increases the flow of alternating current in the said portion of the voltage divider.

PAUL O. FARNHAM.