

March 17, 1942.

S. I. RAMBO ET AL

2,276,873

VARIABLE FREQUENCY COUPLING

Filed Jan. 8, 1941

Fig. 1.

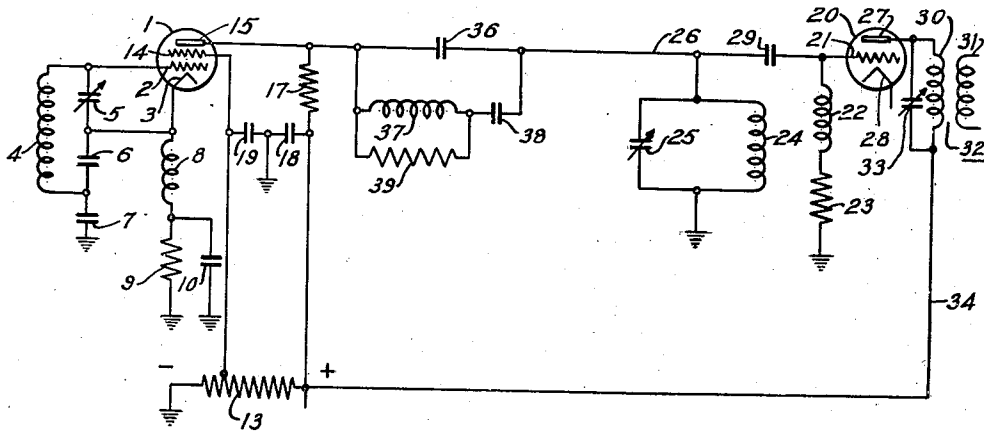
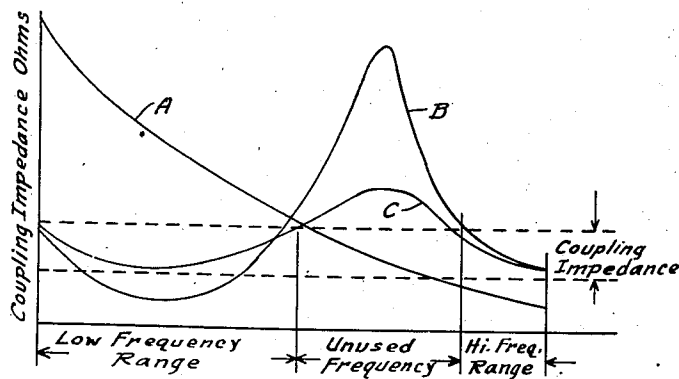


Fig. 2.



WITNESSES:

H. F. Lussier
H. Z. Bartholomew

INVENTORS

Reuben Lee and
Sheldon I. Rambo.
BY

BY
Hyman M. Marmar
ATTORNEY

UNITED STATES PATENT OFFICE

2,276,873

VARIABLE FREQUENCY COUPLING

Sheldon I. Rambo, Baltimore, and Reuben Lee, Catonsville, Md., assignors to Westinghouse Electric & Manufacturing Company, East Pittsburgh, Pa., a corporation of Pennsylvania

Application January 8, 1941, Serial No. 373,616

6 Claims. (Cl. 179-171)

This invention relates to high frequency electrical circuits and more particularly to a coupling circuit for energy transfer between portions of a high frequency system operating at a wide band of frequencies.

In circuits of the above type it is frequently necessary to transfer high frequency energy from one portion of a network to another which is at a widely different direct current potential. Hence the coupling circuit must be of such character as to offer infinite impedance to direct current while having a relatively low impedance to currents at the operating frequency. In systems which operate at a wide band of frequencies the coupling impedance being necessarily a capacity has the disadvantage of non-uniform transfer characteristics, in that at the lower frequency of the operating range the impedance will be high, whereas at the high frequency it will be low. The variation of coupling so introduced in some cases may be tolerable within wide limits, whereas in certain applications, as for example, when the coupling entails the transfer of energy from an oscillator to a succeeding power amplifier, it is required that the energy transfer shall be substantially uniform at various operating frequencies in order to maintain satisfactory voltage input to the amplifier and avoid overloading the oscillator, resulting in a frequency change. Purely capacitive coupling heretofore used has the disadvantage that the driving power if of sufficient magnitude at the low frequency of the operating range will be excessive at the higher frequencies causing serious overloading of the oscillator. On the other hand, if the driving power gives satisfactory excitation of the amplifier at the higher frequencies, the excitation voltage input will fall off considerably at the lower frequencies.

A particular feature of this invention is that in systems of the above type the energy transfer is maintained substantially uniform within certain limits over a wide range of operating frequencies. To this end means are provided for compensating the effect of the variable impedance of the capacitive coupling by an associated coupling circuit having reactive components of such character as to oppose the impedance change. The invention is particularly applicable to systems wherein the operation includes a desired range of operating frequencies followed by an undesired range which is also followed by another desired frequency range. The entire frequency range includes a wide band of frequencies from a certain low frequency to a maxi-

mum high frequency. The undesired frequency range is at such point where the effective coupling impedance decreases and consequently tends to overload the oscillator.

Another feature of this invention is that the coupling circuit is of such character as to maintain a substantially uniform coupling impedance within desired ranges of operation while offering relatively high impedance at the undesired frequency portion of the operating frequency range.

Another advantage of the coupling circuit in accordance with this invention is that while the impedance is substantially constant within certain limits over the entire operating frequency range, it is of infinite impedance to direct current.

Other features and advantages will be apparent from the following description of the invention pointed out in particularity by the appended claims and taken in connection with the accompanying drawing in which:

Figure 1 is a schematic circuit arrangement illustrating the coupling circuit of the invention applied between an oscillator and a power amplifier stage; and

Fig. 2 shows in a series of curves the value of the resultant coupling impedance within the various operating frequency ranges of the system shown in Fig. 1.

Referring to Fig. 1 for the purpose of illustration, an electron-coupled oscillator stage is shown to which is coupled a power amplifier of conventional design. The invention concerns itself only with the particular elements forming the coupling circuit. Therefore, only such essential parts of the associated components are shown which are necessary for the understanding of the invention.

It is to be understood that the coupling system is not to be limited in its application to the particular type of oscillator or amplifier herein shown, and may be used as well in all types of couplings wherein either between different amplifying stages or networks it is necessary to maintain a substantially uniform coupling impedance.

The oscillator includes the vacuum tube 1, the input circuit of which between grid 2 and cathode 3 contains a frequency determining element of the oscillator in the form of the inductance 4 and associated condensers 5 and 6. The condenser 7 effects ground potential at radio frequencies for the lower terminal of the inductance 4, whereas the feed-back from the output cir-

cuit is effected by the connection between condensers 5 and 6 and the cathode 3. The latter is connected to ground through inductance 8 in series with resistance 9, the latter being by-passed by the condenser 10. The operation of the oscillator circuit need not be referred to in detail. Suffice it to say that the grid and cathode elements form the main oscillation circuit of the tube and the coupling between the oscillator and the output thereof is transferred to the plate circuit of the tube 1 by means of the electron stream within the tube. Different operating potentials are indicated as being derived from the resistor 13 which forms a voltage divider between the screen grid electrode 14 and the anode electrode 15. The operating voltage source is not shown here and may be derived from any suitable apparatus which energizes the whole system.

The anode circuit of the tube 1 includes the load resistance 17, the return terminal of which, together with the screen grid 14 being bypassed by condensers 18 and 19, respectively. The input circuit of the amplifier tube 20 comprises the grid 21, the grid load impedance 22 and resistor 23 in series therewith and connected to ground. The grid input tuned circuit contains the inductance 24 and the condenser 25 in parallel therewith between the input lead 26 and ground. This circuit is coupled to the grid 21 by means of a coupling condenser 29. The output circuit between anode 27 and cathode 28 is in the conventional form of a tuned circuit including the primary winding 30 and the secondary winding 31 of the transformer 32. The primary winding is tuned by means of the condenser 33. The anode circuit is also connected to the voltage divider by means of conductor 34.

The circuit above described is conventional as to its various components and is widely used as a circuit portion of radio transformers. As mentioned before, this invention concerns the type of coupling between the oscillator and the succeeding radio frequency amplifier. In common practice this coupling comprises solely a condenser which isolates the direct current potential of the anode 15 of the tube 1 from the grid circuit which is at ground potential. When the transmitter has a wide range of operating frequencies the coupling capacity shown here by the condenser 36 offers a variable impedance due to frequency change resulting in a non-uniform excitation of the succeeding radio frequency amplifier. For efficient operation it is desirable that the driving power will be uniform throughout the operating frequencies. It is important, however, to isolate the tuned circuit comprising inductance 24 and condenser 25 as much as possible from the oscillator plate circuit to prevent the voltage which is built up across the tuned circuit from reacting on the oscillator and causing a change in frequency. Such isolation requires that the plate impedance comprising the resistor 17 be of low value but not too low or insufficient driving power will be supplied to the amplifier grid. Furthermore, the impedance of the coupling condenser 36 should be high but not too high or the oscillator frequency will change with tuning of the condenser 25. For satisfactory operation over an extended frequency range it is difficult to find a satisfactory low value for the plate load resistor 17 and a high constant value for the coupling condenser 36. While the plate load resistor 17 is not subject to change in impedance value due to changes in the operating frequency, the coupling capacity 36 will consid-

erably change its impedance, increasing with the decrease of frequency and decreasing as the operating frequency increases. The result is that the coupling capacitor 36 is of sufficiently high impedance to reduce the driving power at low frequencies or may be of sufficiently low impedance to react on the oscillator frequency.

Referring now to Fig. 2, the curve A shows the variation of the coupling impedance when the coupling is only a condenser over the various frequency ranges. It is seen that at the low frequency range the coupling impedance is very high, and at the high frequency range comparatively low. The dotted lines indicate the permissible limits of the change of coupling impedance within which satisfactory and substantially uniform excitation of the succeeding radio frequency amplifier may be obtained.

When the operating ranges include within the desired frequencies a portion of the band which is not used, the problem of satisfactory coupling between the oscillator and the succeeding amplifier becomes even more difficult for, in the unused frequency portion between the lowest and the highest desired frequency ranges, the effective coupling impedance may be within the limits for best operation, instead of being high to give less excitation to the amplifier grid 21. To obviate the above difficulties, the present invention proposes a modified coupling circuit by providing a series tuned circuit in parallel with the condenser 36. This circuit includes the inductance 37 and the capacity 38, and a suitable damping resistor 39 in parallel with the inductance 37. While the tuned circuit will modify the effective coupling impedance with respect to the radio frequency currents over the entire operating frequencies, it will not change the isolation as to direct current potentials, inasmuch as condensers 36 and 38 will offer infinite impedance to direct currents.

The series tuned circuit is so proportioned as to be series resonant at a frequency near the low frequency end of the operating range. Consequently this shunt path provides a lower impedance coupling at the lower frequencies, in fact, for frequencies somewhat higher than the resonant frequency of the inductance 37 and the capacity 38. At a still higher frequency the impedance of the shunt path together with the coupling condenser 36 forms a parallel resonant circuit and offers a very high impedance coupling. With proper circuit constants for the shunt path and the coupling condenser 36, the parallel resonance frequency may be so chosen as to be in the unused portion of the operating range. At higher frequencies following the unused portion, the combination of the inductance 37, the capacity 38 and the coupling capacity 36 offers a net capacitive reactance of decreasing value with frequency and consequently lower impedance coupling.

Referring again to Fig. 2, the curve B shows the variation of the effective coupling impedance considering the addition of the shunt path comprising inductance 37 and capacity 38 across the coupling condenser 36 without the damping resistor 39. It is seen that the effective coupling impedance is very low at the low frequency range, lower even than necessary for optimum performance, and rises sharply to a very high value at the unused frequency portion, at which frequency parallel resonance occurs. The curve slopes down at the high frequency range coming within

the permissible limits for the coupling impedance.

The addition of the resistor 39 results in a modified curve C which reduces the variation of the impedance to such a value as to maintain both good frequency stability and sufficient driving power. In the low frequency range the coupling impedance varies within the permissible limits shown by the dotted lines and rises above these at the unused frequency and is again within the required limits at the high frequency range.

The improvement of the above arrangement can be further illustrated in comparing the values obtained from a practical demonstration of the circuit. The following values of circuit constants were used in a practical embodiment:

Resistor 17	ohms	3000
Bypass condenser 18	mfd	.025
Coupling capacitor 36	mmfd	25
Capacitor 25	mmfd	375
Capacitor 29	mfd	.01
In the series tuned shunt circuit and the Capacitor 38	mmfd	50
Inductance 37	mh	1
Grid input inductance 22	mh	2.5
Grid series resistance 23	ohms	15,000
Damping resistance 39	ohms	50,000

The low frequency range of the transmission system was from 350 to 1500 kc., the high frequency range from 3000 to 5000 kc., and the unused frequency portion from 1500 to 3000 kc.

When condenser 36 was the sole coupling impedance there was a variation of output or driving power as indicated by grid current variation in the radio frequency amplifier from 6.9 milliamperes at the high-frequency end of the band to 2.2 milliamperes at the low-frequency end of the band, and the frequency deviated up to a maximum of .0147% when the circuit consisting of inductance 24 and condenser 25 was detuned. The permissible limits were 3 milliamperes minimum for grid current and .01% for frequency. With the addition of the series resistance circuit including the damping resistor 39, the grid current varied from 9 to 5.3 milliamperes and the frequency up to .01%.

We claim as our invention:

1. In a high frequency transmission system operable within a wide range of frequencies wherein certain desired ranges of frequencies are separated by an undesired range, a circuit for energy transfer between the output circuit of a vacuum tube and the input circuit of a succeeding vacuum tube, said first mentioned circuit including a coupling element whose impedance changes within said wide band of frequencies causing undesirable variation in said energy transfer, means for maintaining the effective coupling impedance substantially the same in one said desired range as in the other comprising a circuit in parallel with said coupling element including reactive components, the combined impedance of which changes in the opposite sense than does said coupling element in passing from one said desired range to the other, said reactive components, together with said element, forming an effective coupling impedance which is greater at said undesired range than in said desired ranges.

2. In a high frequency transmission system operable within a wide range of frequencies wherein certain desired ranges of frequencies are separated by an undesired range, a circuit for energy transfer between the output circuit of a vacuum tube and the input circuit of a succeeding vacuum tube, said first mentioned circuit including a coupling element whose impedance decreases with the increase of frequency within said wide band of frequencies causing undesirable variation in said energy transfer, means for maintaining the effective coupling impedance substantially the same in one said desired range as in the other comprising a circuit in parallel with said coupling element including inductive and capacitive components, the combined impedance of which changes in the opposite sense than does said coupling element in passing from one said desired range to the other, said components, together with said element, forming an effective coupling impedance which is greater at said undesired range than in said desired ranges.

3. In a high frequency transmission system operable within a wide range of frequencies wherein certain desired ranges of frequencies are separated by an undesired range, a circuit for energy transfer between the output circuit of a vacuum tube and the input circuit of a succeeding vacuum tube, said first mentioned circuit including a coupling element whose impedance decreases with the increase of frequency within said wide band of frequencies causing undesirable variation in said energy transfer, means for maintaining the mean effective coupling impedance substantially the same in one said desired range as in the other comprising a circuit in parallel with said coupling element including reactive components, the combined impedance of which changes in the opposite sense than does said coupling element in passing from one said desired range to the other, said components, together with said element, forming an effective coupling impedance which is greater at said undesired range than in said desired ranges, said effective coupling impedance being substantially of infinite impedance to direct current.

4. In a high frequency transmission system operable at certain desired ranges of frequencies separated by an undesired portion of the operating frequency range, a coupling circuit including a coupling capacitor, and a series resonant circuit in parallel therewith, said last mentioned circuit approaching resonance at a frequency below said undesired portion and said coupling circuit including said capacitor being resonant at a frequency within said undesired portion.

5. In a high frequency transmission system operable at certain desired ranges of frequencies separated by an undesired portion of the operating frequency range, a coupling circuit including a coupling capacitor, a circuit comprising a self-inductance and a capacity in series effectively in shunt with said capacitor, said last mentioned circuit being series resonant at a frequency below said undesired range, said coupling circuit in combination with said capacitor being parallel resonant at a frequency within said undesired portion.

6. In accordance with claim 5 in which said series resonant circuit includes a resistive element in shunt with said self-inductance.

SHELDON I. RAMBO.
REUBEN LEE.