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2,336,498

SELECTIVE TRANSFER OF ELECTRICAL OSCILLATORY ENERGY

Filed Aug. 30, 1940

2 Sheets-Sheet 1

Fig. 1.

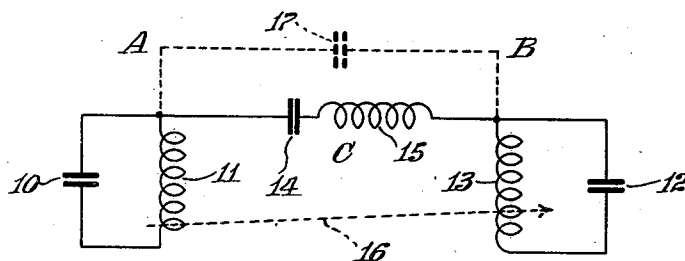


Fig. 2.

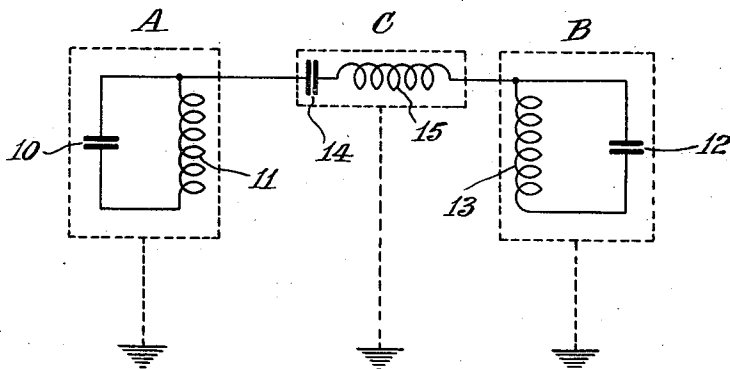
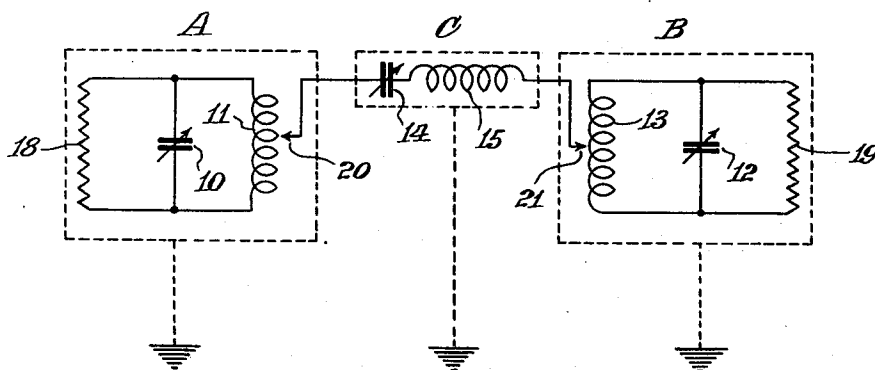


Fig. 3.



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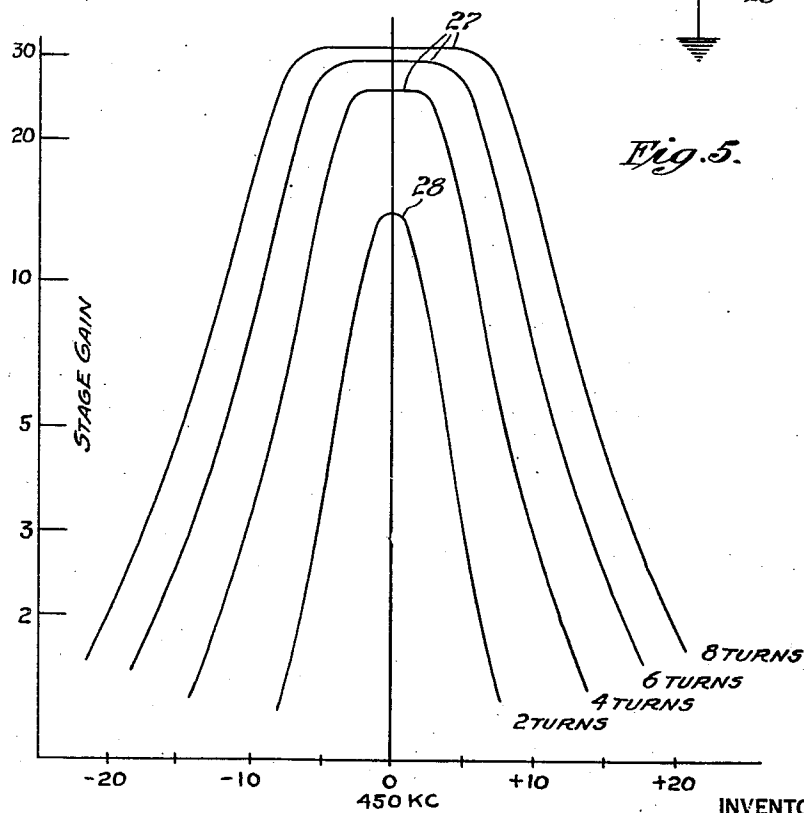
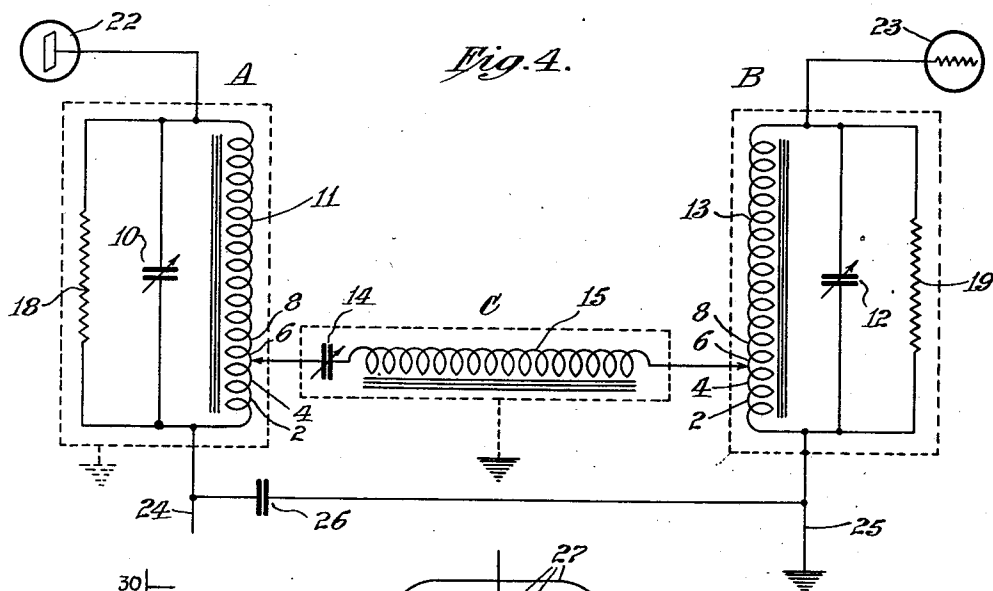
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2 Sheets-Sheet 2



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SELECTIVE TRANSFER OF ELECTRICAL
OSCILLATORY ENERGYJerry B. Minter, 2nd, Mountain Lakes, N. J., as-
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2 Claims. (Cl. 178—44)

This invention relates to a method and apparatus for transferring energy in the form of electrical oscillations from one circuit or point to another. More particularly it deals with the transfer of such energy which lies within a pre-determined range or band of frequencies, to the more or less complete exclusion of energy lying without such band.

In the transmission of electrical oscillatory energy, it is frequently of great advantage to be able to provide means for the transfer of energy in a selective fashion, with respect to the frequency thereof. As an example of such, the transfer of energy between the anode circuit of one thermionic valve and the input circuit of another valve frequently takes place in electrical signalling systems, in which systems it is desired that only that energy which lies within a certain band of frequencies be transmitted, while it is desired that energy of other frequencies lying without the band be barred from passage from one valve to the other, or at least that the efficiency of transmission of the desired frequencies be many fold that of the undesired frequencies.

A transmission characteristic which is especially useful is one which will allow the transmission of substantially zero energy at frequencies lying between zero and a predetermined frequency, will then allow the transmission of substantially the entire amount of energy at any frequencies lying between this first and a second predetermined frequency, and then again will bar the passage of energy lying at frequencies higher than this second frequency. Additionally it is often desirable to be able to shift the transmission characteristics, so that the difference between these two predetermined frequencies may be made to assume varying values, by the shift of one or both of the frequencies delimiting the region of effective transmission.

As one example of shift of transmission characteristics in the art of transmitting speech, music and other signals by means of electrical oscillations, it frequently is desired to provide circuits located either at the transmitter or at the receiver, or at both points, which circuits shall pass therethrough a band of frequencies varying in width from 1000 cycles to 20,000 cycles, and in certain applications of the transmission of intelligence, such as in television, it often is desired that a much wider band of frequencies be transmitted. Of course in any case, it is desired that frequencies lying outside the desired band be attenuated or suppressed to as great degree as possible, in order that only de-

sired signals be delivered to the reproducing device of the system.

Transmission circuits have been proposed for the foregoing purposes, but have suffered from various defects and difficulties, such as varying efficiencies of transmission at different portions of the band of frequencies intended to be passed thereby, inability to vary the width of such passed band over wide limits or to vary it to any desired degree within such limits. Other difficulties have been the complexity of such transfer circuits and devices, entailing great precision and high cost of manufacture and rendering adjustment thereof very difficult, especially when such transfer circuits were incorporated into apparatus placed in the hands of the laity, such as in the case of household radio receivers.

One object of my invention is to provide a transmission device of the character described which shall be relatively simple and therefore easy and economical to manufacture in quantities.

Another object is to provide such a device, wherein all oscillatory or tuned circuits shall have substantially the same natural resonant period and shall be formed of substantially identical components, whereby ease of production and simplicity of adjustment when once installed is promoted.

Yet another object is to provide such a device wherein the width of the band of frequencies effectively transmitted therethrough may easily be varied over wide limits, by a simple switching action and without the need of altering the position of various components with respect to one another, such as is frequently done in systems of this type in order to vary the width of the frequency band passed thereby.

Another purpose of this invention is to provide a transmission device which shall have constant amplitude and linear phase shift over substantially the entire width of the band of transmitted frequencies.

Yet a further purpose is to provide such a device having transmission characteristics so that a very sudden change of transmission efficiency occurs at predetermined points, so that sharp and precise discrimination between frequencies lying adjacent such points may be made, according to the direction in which they lie relative to these points.

Another object of my invention is to provide a transmission device having band pass characteristics which remain symmetrical, even through the width of the band be altered over wide limits.

An additional object is to obtain, using only apparatus constructed of conventional components and therefore relatively inexpensive, sharp cut-off points and variable band pass effects, which results hitherto have been obtained only with the use of elaborate, delicate and therefore relatively expensive means, such as circuits using piezo-electric crystals and the like.

Yet another purpose of my invention is to provide a transfer circuit capable of passing a wide band of frequencies, which circuit shall be capable of quick and easy adjustment, so that all portions thereof will transmit a substantially identical band of frequencies. Furthermore, my invention allows such adjustment to be readily made in such cases as household, radio and television receivers, without the need of elaborate and expensive equipment for this so-called "peaking" of the transmission circuits.

In order better to understand my invention, reference is made to the drawings hereunto appended, wherein:

Figure 1 is a schematic illustration of a transmission device such as already known in the art.

Figure 2 is a transmission device similar to that shown in Figure 1, but so modified that the energy passing from the input circuit to the output circuit is confined to a single path.

Figure 3 shows schematically one form of my invention, allowing the band pass width to be varied.

Figure 4 is a circuit showing my invention as applied to the transmission of oscillatory energy from the output of one thermionic valve to the input of another valve, as for example in the beat frequency circuit of a radio receiver of the double detection or superheterodyne type, using a suitable intermediate frequency, such as for example, 450 kilocycles.

Figure 5 shows a family of transmission curves illustrating the variable band pass results obtained by the device shown in the circuits of Fig. 4.

In Fig. 1 there are schematically shown two circuits, A and B. Energy is to be transferred from one of these circuits to the other. Both circuits are of the resonant type, circuit A including capacity 10 and inductance 11 while circuit B includes capacity 12 and inductance 13. In each case the respective inductances and capacities are connected in parallel. Transfer circuit C is provided and comprises capacity 14 and inductance 15, in a series connection. However, besides the actual transfer of energy by means of the circuit C energy is also transferred between circuits A and B by means of the inductive or magnetic coupling shown by the dotted arrow 16 as well as by the capacitive or static coupling indicated by the dotted lines and capacity 17. While circuits of the type shown in Figure 1 have been published, yet the art has been unable successfully to employ such circuits in actual practice. Numerous attempts have been made to construct apparatus according to the diagram of Fig. 1, but invariably the transmission curves obtained by such apparatus have failed to correspond to those which would be indicated by the theoretical performance of the circuit shown.

I have discovered that the unsatisfactory results hitherto obtained by the art, have in some measure been due to the fact that the inductive or magnetic and the capacitive or static couplings shown by the dotted lines of Fig. 1 have been neglected, or else various methods have been em-

ployed to offset or neutralize these couplings, all of which methods have proven to be ineffective. I have found that it is impossible to obtain satisfactory results with the circuits of Fig. 1 even when couplings 16 and 17 are reduced substantially to zero values. Yet apparatus constructed with a transmission circuit basically according to this diagram, when such spurious couplings are reduced to zero and when certain other changes hereinafter described are made, yields results which are so markedly improved that a transmission device of this basic type, when constructed according to my invention becomes a very practical and efficient device. The degree of improvement obtained by elimination of the spurious couplings and by further modifications hereinafter to be described is so very great as to be utterly unexpected. In the relatively long period of time which has elapsed since this basic transmission circuit, as shown in Fig. 1, was first published, the art has been completely unable to utilize in a practical fashion this transmission circuit, but by the employment of my invention, I am enabled to construct transmission circuits of this basic type which will in use give actual results extremely close to those predicated by theory. The results which I have obtained have enabled me to construct practical apparatus, employing a modified form of this relatively simple circuit and yet yielding results which hitherto have required extremely complex circuits such as those using a large number of individual frequency selective sections coupled to one another.

In Figure 2 I have indicated how circuits A, B and C can be completely shielded from one another, as by enclosing each circuit in an individual grounded shield or container shown in dotted lines. This container may be constructed so as completely to shield both the electrostatic and the electromagnetic lines of force proceeding from the components making up each one of the circuits. The construction of such shields is well known in the art, but for use with my invention, it is advisable that the degree of shielding be carried to the greatest possible degree that is practical. Apparatus has hitherto been constructed in which circuits A and B were each completely shielded per se. It was then assumed that circuit C would act satisfactorily. However, I have found that further couplings will necessarily exist between the circuit C and other apparatus connected to circuits A and B, in such fashion that secondary couplings ultimately will exist between each of circuits A and B, and circuit C. Even though such ultimate secondary couplings may be a very low value, yet they will be sufficient to render practical operation of this transmission circuit a failure.

In Figure 3, circuit A is provided with a load resistance 18 and circuit B with a load resistance 19. These load resistances are preferably connected in parallel with each anti-resonant circuit, but it is possible to employ series connected resistances rather than shunt connected resistances. Furthermore, it is possible so to construct inductances 11 and 13 that each of these circuits will have in itself sufficient resistance to act as a load. However, I have found that most satisfactory results will be obtained when the respective loads are lumped as much as possible and are put in parallel with the tuned circuits, as illustrated in this figure. I have also here shown the input and output leads of circuit C as connected to taps 20 and 21, taken off upon inductances 11 and 13 respectively. These taps may

be variable as indicated and by a variation thereof it is possible to vary the width of the band of frequencies passed between the circuits A and B.

In Figure 4, valve 22 and valve 23 are coupled by circuits according to my invention. Anode energy feed 24 and input circuit ground return 25 are as usual, and by-pass condenser 26 therebetween is to help reduce unwanted coupling. Each inductance has 240 turns on a powdered iron core, so as to give a higher Q and better coupling when a lower tap is used for the connection thereto of the coupling circuit, and each has a value of about 0.7 millihenry. The number of turns in the various taps are schematically indicated upon the drawings by the numbers 2, 4, 6, and 8, and they are very small compared with the total turns in each inductance. The load resistances are of 100,000 ohms each, but the exact values of these resistances as well as the values of the condensers, depend upon frequencies to be used, Q of the coils, and other factors hereinafter to be discussed. In general the capacities are chosen so that the tuned circuits will resonate at a single frequency such as at 450 kc.

In Figure 5 I have shown the results actually obtained by measurement of a transmission device using a circuit according to the diagram of Figure 4 and it can be noted how the band pass width decreases as the turns are reduced in number, and how the respective tops of the graphs for the larger number of turns are nearly flat as shown at 27, so that equal transmission of various frequencies lying therein is obtained. When 2 turns are used, the various circuits may be readily tuned by the simplest means, even by ear in the case of a household radio receiver, since the pass action is now well peaked as shown at 28. Then when a greater number of turns are used, the circuits will continue to be correctly tuned. It is to be understood that the above values are merely illustrative of a certain embodiment of my invention and are not to be taken as in any way limiting the values of the various components to be used, which will vary according to principles well known in the art, and also according to special factors later herein discussed.

It would be possible to alter the position of the inductance taps so as to give a step-up action, in case that the circuits to be coupled are of very low impedance, such as valves of low output impedance. Connecting the plate and grid to lower respective taps upon the inductances also minimizes the effect of detuning due to the variation in interelectrode capacity of the tubes under varying bias control, as in the case of automatic volume control receiver circuits and when replacing one tube by another one. The tube effective output and input capacities become relatively more important as the capacities 10 and 12 are made smaller, and the respective tube capacities become a larger percentage of the total capacity. These interelectrode capacities are also more troublesome variables in the case of some of the high transconductance pentode types of tubes, so that the use of lower taps may be desirable when such tubes are employed.

I have found it important to keep all the tuned circuits including the coupling circuit C of low resistance and to have the coupling between tap turns and the coils as near 100% as possible. The use of iron core inductances aids in obtaining this result, as well as giving a higher Q, which latter tends to make the corners of the curves of Fig-

ure 5 more nearly square, i. e., tends to make the discriminatory action upon frequencies lying near the critical cut-off points, more pronounced.

The use of iron core coils also permits so-called "permeability tuning": adjustment of the inductance by moving the iron core in and out of the coil or by otherwise altering the effectiveness of the core. This method of tuning is especially practical for the circuits of Figures 3 and 4, since here there exist no mutual inductance values which would be altered by such changes in the inductance of each coil as would be the case for most circuits of the usual type, such as the circuit shown in Figure 1.

One element of my invention which is of very great importance is the use of the load resistances 18 and 19, connected respectively to the two circuits to be coupled to one another. Without the use of these loads, the transmission circuit fails to act properly, to such an extent that no practical results can in most cases be obtained. Of course these resistances are not completely lumped, although so indicated for convenience in the drawings. As well known to those skilled in the art, the inductances and the valve circuits connected to the circuits, will in themselves possess unavoidable resistances. The slight resistance losses of the capacities may usually be neglected when modern low components are used. While it would be possible to select valves and coils which would together give the desired resistance effects, I prefer to make the effect of these components so low that additional resistance must be used to raise the total resistance to the desired value, thus allowing adjustments of this total value to be made, since the precise value of resistance to be used for the optimum results cannot be exactly obtained by computation, although this latter will give a more or less close approximation thereto.

While as above explained, the optimum results may be obtained with my invention, when the elements are made adjustable over a slight range, yet it is possible to compute approximate values for these elements in designing a practical circuit, so that only slight adjustments will be needed when the transmission circuit has once been constructed in accordance therewith. A discussion of these methods of computation is here given.

In the following discussion—

a is the step-down ratio between the entire inductance coil and the portion thereof used to couple to circuit C.

ω_0 is twice times the frequency at the centre of the band to be passed, expressed in cycles.

w is twice times the width of the band in cycles. C, L, R, and Q have their conventional meanings in the art.

For unity coupling in the coil step-down action, we have

$$a = \frac{\sqrt{2}\omega_0}{w}$$

but since the coupling can closely approach, but never reach unity, the actual tap for a desired bandwidth will differ slightly from that indicated by this formula, and may easily be determined by one skilled in the art.

Since L, C, and R are all variable, it may be necessary to assume values for certain elements and compute the other elements by the following formulae;

$$C = \frac{1}{Rw} \quad L = \frac{Rw}{(\omega_0)^2}$$

Since R represents the total or effective load

resistor at each end of the transmission circuit, and since the factors w and C are frequently the given ones, so that R is to be computed by means of formulae, it may be noted that R can be considered as composed of two portions, defined by the following equations, where R_b is the effective resistance of the tuned circuit, expressed as equivalent shunt resistance and R_s is the resistance to be added externally:

$$R_b = \frac{Q}{\omega_0 C} \quad R_s = \frac{RR_b}{R_b - R}$$

These formulae also neglect the losses in the coupling circuit C . It is possible to minimize the shunt resistance effects of the valves themselves by making the anode and grid connections therefrom from lower taps on the inductances, as previously explained.

While I have illustrated my invention by the description of certain examples thereof and certain applications, such illustrations are not exclusive, and the scope of my invention is only limited by the hereunto appended claims, since many modifications and adaptations will be apparent to those skilled in the art.

I claim:

1. A device for selectively transferring oscillatory electrical energy, including a first input circuit wherein the energy is present, a second output circuit to which said energy is to be transferred and a coupling circuit connecting said first-mentioned circuits, said input and output circuits each comprising inductance, capacity and resistance in parallel and being anti-resonant to a predetermined frequency and said coupling circuit comprising inductance and capacity in series, being resonant to said predetermined frequency and being connected between points upon the respective inductances of the input and the output circuits lying intermediate the ends thereof, the product of the respective inductances and capacities of said three resonant circuits being of the same electrical values, and a return path for said coupling circuit connected between one end of the input inductance and the corresponding end of the output inductance, in which device the total effective resistance, R , in parallel with each of the input and output circuits, respectively, is determined according to the formula

$$L = \frac{Rw}{(\omega_0)^2}$$

where L is the inductance of the respective circuit, w is twice π times the width of the band pass in cycles, and ω_0 is twice π times the frequency at the centre of the band pass, and in which device

the actual resistance R_s , to be added externally to said input and said output circuits, respectively, is determined according to the formula

$$R_s = \frac{RR_b}{R_b - R}$$

where R_b is the effective equivalent shunt resistance of the respective input and output circuits before said external resistance has been added thereto.

2. A device for selectively transferring oscillatory electrical energy, including a first input circuit wherein the energy is present, a second output circuit to which said energy is to be transferred and a coupling circuit connecting said first-mentioned circuits, said input and output circuits each comprising inductance, capacity and resistance in parallel and being anti-resonant to a pre-determined frequency and said coupling circuit comprising inductance and capacity in series, being resonant to said predetermined frequency and being connected between points upon the respective inductances of the input and the output circuits lying intermediate the ends thereof, the respective inductances and capacities of said three resonant circuit being of the same electrical values, and a return path for said coupling circuit connected between one end of the input inductance and the corresponding end of the output inductance, in which the step down ratio, a , between the entire inductance in the respective input and output circuits and the portion thereof used to effect coupling through said resonant coupling circuit is determined according to the formula

$$a = \frac{\sqrt{2}\omega_0}{w}$$

where the quantity ω_0 is twice π times the frequency at the centre of the band pass in cycles and w is twice π times the width of the band pass in cycles, and in which device the capacity, C , is determined according to the formula

$$C = \frac{1}{Rw}$$

where R is the total effective shunt resistance of the respective resonant circuits, and in which device the inductance L is determined according to the formula

$$L = \frac{Rw}{(\omega_0)^2}$$

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