June 1, 1926. 1,587,098

H. WHITTLE

TRANSFORMER CIRCUITS

Filed Jan. 25, 1924

Fig. 1

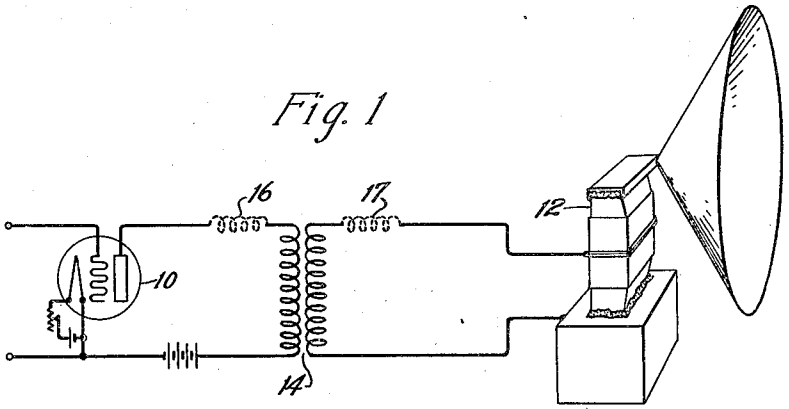


Fig. 2

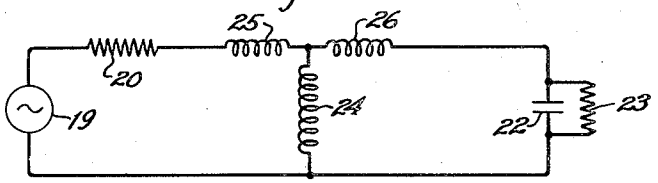


Fig. 3

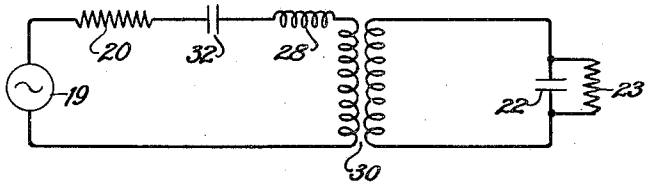
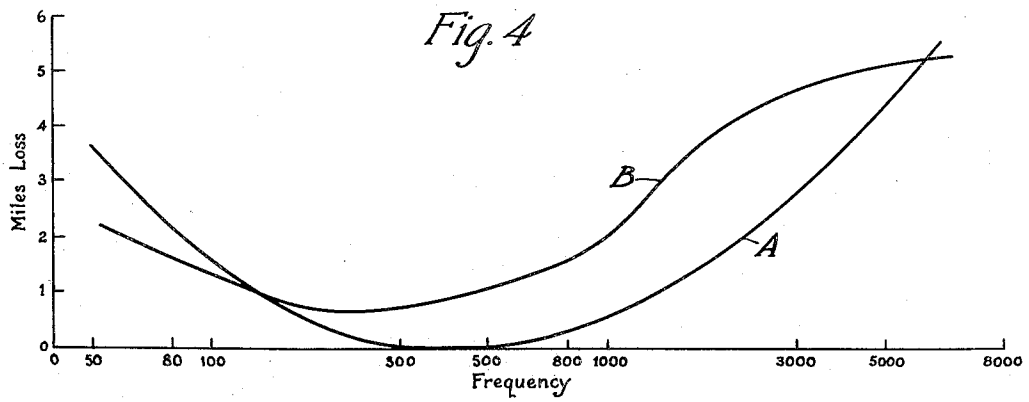


Fig. 4



Inventor:
Horace Whittle,
by E. W. Adams. Atty

Patented June 1, 1926. 1,587,098

UNITED STATES PATENT OFFICE.

HORACE WHITTLE, OF NEW YORK, N. Y., ASSIGNOR TO WESTERN ELECTRIC COMPANY, INCORPORATED, OF NEW YORK, N. Y., A CORPORATION OF NEW YORK.

TRANSFORMER CIRCUITS.

Application filed January 25, 1924. Serial No. 688,376.

This invention relates to the transmission of multifrequency currents and has for its object to improve the uniformity of transmission of such currents between circuits where one of the circuits has an impedance having a substantial negative angle or capacitative reactance component.

In accordance with this invention, the circuit which may be a resistance circuit, such as the output circuit of a three electrode vacuum tube and a capacitative circuit, such as the electric circuit of a piezo-electric loud speaker, are connected by a transformer having an impedance ratio equal to that of the interconnected circuits at a frequency to be transmitted. An ideal transformer, i. e., one having infinite mutual and self-inductances and no dissipative losses, would give maximum transfer of energy at the frequency of impedance matching, with transmission losses at other frequencies varying with the extent of variation of the ratio of actual impedances from the transformer ratio. In order to compensate for these losses, one or more resonance conditions are established. This may be done by assigning a value to the mutual inductance or leakage inductance of the transformer or to a separate inductance to cause it to be in resonance with the capacity of the circuit having negative impedance at a frequency near the frequencies at which the greatest losses would occur. The effect of this resonance is to build up the voltage across and the current in the capacitative circuit at these frequencies. In general, sufficient damping is present in the circuit to prevent too great an increase in transmission at any frequency to be transmitted.

In the referred circuit arrangement, the transformer has a ratio to match the impedances at a frequency in the intermediate portion of the range to be transmitted, the mutual inductance is made to resonate with the capacity of the reactive circuit at a frequency near the lower end of the range, and the transformer has leakage inductance of a value to resonate with the capacity of the reactive circuit at a frequency near the upper end of the range.

With the above and similar arrangements embraced in this invention, the transmission characteristic can be made more uniform with frequency, without the introduction of losses which are incident to the use of attenuation equalizers of the usual type. As is well known, the latter comprise networks which decrease the amplitude of the frequencies which are favored by the circuit to which they are applied, so as to bring them down to the level of the most attenuated frequencies.

The invention will be more fully understood by reference to following detailed description and claims taken in connection with the accompanying drawings, in which Fig. 1 represents diagrammatically, a circuit employing the invention, Fig. 2 represents a circuit which is equivalent to that of Fig. 1, Fig. 3 represents a modification, and Fig. 4 is a graphical representation of a characteristic of the circuit in Fig. 1.

Referring to the drawings by reference numerals, the vacuum tube 10 which is of the ordinary three-electrode type is coupled to a piezo-electric loud speaker 12 which may be of the type shown in the application of A. M. Nicolson Serial No. 683,643, filed December 31, 1923, by means of a transformer 14. As is well known, the impedance of a crystalline Rochelle salts receiver has a substantial negative angle in the frequency range of music and speech. The transformer 14 has an impedance ratio to match the impedance of the vacuum tube 10, which is substantially constant with frequency, to that of the receiver 12 at a frequency in the intermediate portion of the speech and music frequency range. The impedance ratio of a transformer may be defined by the expression

$$\frac{N_1^2}{N_2^2}$$

where N_1 and N_2 represent the number of turns on the two widings respectively. The transformer is designed to have leakage inductance represented by the dotted line elements 16 and 17. The mutual inductance and leakage inductance of the transformer will have values assigned to them for purposes which will be better understood by reference to Fig. 2.

In Fig. 2, which shows a circuit substantially equivalent to that of Fig. 1, the vacuum tube 10 is represented by a source of electromotive force 19 and resistance 20. The loud speaking receiver is represented by the condenser 22 having in parallel therewith a resistance 23. The transformer is represented by a T-network comprising a

mutual inductance 24 and leakage inductances 25 and 26. Since the T-network does not have a transformation ratio, one of the interconnected impedances should be considered to have been multiplied by the impedance ratio of the transformer 14. The leakage inductance 25—26 is given a value to resonate with the capacity 22 at a frequency near the upper end of the speech and music range, the mutual inductance 24 at this frequency being sufficiently high to be negligible, and the mutual inductance 24 is assigned a value to resonate with the capacity 22 at a frequency near the lower end of the range, the leakage inductance being sufficiently low at this frequency to be negligible. The effect of this arrangement is to make the transmission characteristic of the circuit more uniform with frequency as will be seen by reference to Fig. 4 in which the curve A represents the loss in miles at various frequencies which would be obtained by applying an ideal transformer to couple the vacuum tube to the receiver, the transformer having an impedance ratio to match the interconnected impedances at about 400 cycles, as compared with the transmission which could be obtained by the use of a transformer which would match impedances at all frequencies. Curve B represents the transmission loss with reference to the same standard, which was actually obtained with the circuit of Fig. 1. The characteristic shown in curve B is much more uniform with frequency than that of curve A. The gain at the higher frequencies is not as great as that at the lower frequencies due to the fact that dissipative losses in the transformer are greater at the higher frequencies. The fact that curve B shows a loss at certain frequencies as compared with curve A, is due to the fact that curve A does not take into account losses due to dissipation in the transformer. If these were taken into account, it is believed that curve A would lie above curve B at substantially all of the frequencies of the range shown.

The leakage inductance may, of course, be replaced by one or more actual inductances. This is indicated in Fig. 3 where the inductance 28 is in series with the primary winding of the transformer 30. In this figure is shown a condenser 32 which may be made to resonate with the inductance looking to the right at some low frequency preferably different from the lower of the resonance frequencies above mentioned.

The invention obviously may assume other forms within the scope and spirit of the appended claims.

What is claimed is:

1. A transmission system comprising two portions in tandem, one of said portions having a capacitative impedance, and a transformer circuit connecting said portions and having an impedance ratio equal to the ratio of the impedance of said portions at a frequency within a band of frequencies to be transmitted, said transformer circuit comprising inductance resonating with the reactance of said capacitative portion at a different frequency in said band.

2. A transmission system comprising two portions in tandem, one of said portions having a capacitative impedance, and a transformer circuit connecting said portions and having an impedance ratio equal to the ratio of the impedance of said portions at a frequency within a band of frequencies to be transmitted, said transformer circuit comprising inductance components, resonating with the reactance of said capacitative portion at a plurality of widely separated frequencies in or near said band.

3. A transmission system comprising a sending end portion having a substantially pure resistance impedance characteristic, a receiving end portion having a capacitative impedance characteristic, means for transferring energy within a given frequency range from said sending end portion to said receiving end portion, said means comprising a transformer having an impedance ratio to match the impedances of said portions at a frequency in the intermediate portion of said range, the mutual inductance of said transformer having a value to form with the receiving end impedance effectively a loop circuit resonant at a frequency near the lower end of said range said means comprising inductance effectively in series with said portions and having a value to resonate with said receiving end impedance at a frequency near the upper end of said range.

4. In combination, a vacuum tube translating device, a receiver having a capacitative reactance, and a circuit for transferring electric waves of a band of frequencies from said tube to said receiver, said circuit comprising means tending to favor the transmission of certain frequencies as compared with other frequencies in said band, said circuit comprising reactance for annulling the reactance of said receiver to compensate for the unequal transmission of said means.

In witness whereof, I hereunto subscribe my name this 24th day of January A. D., 1924.

HORACE WHITTLE.