Sept. 12, 1933. C. W. HANSELL 1,926,807

IMPEDANCE TRANSFORMER

Filed April 14, 1928

Fig. 1

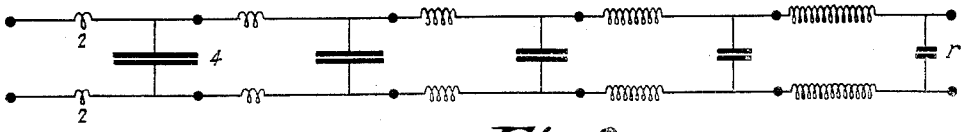


Fig. 2

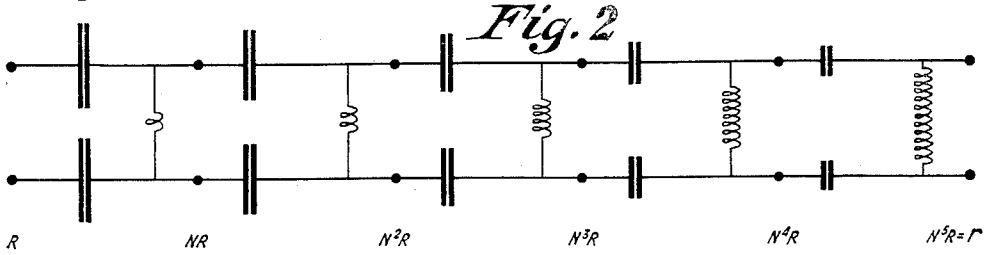


Fig. 3

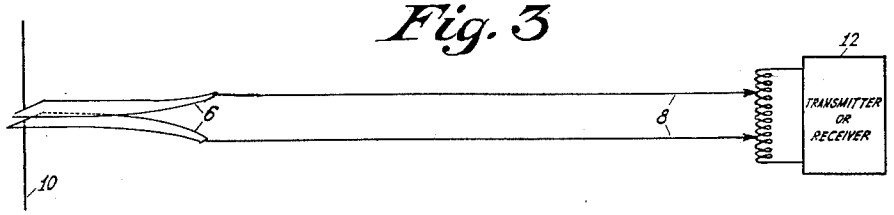


Fig. 4

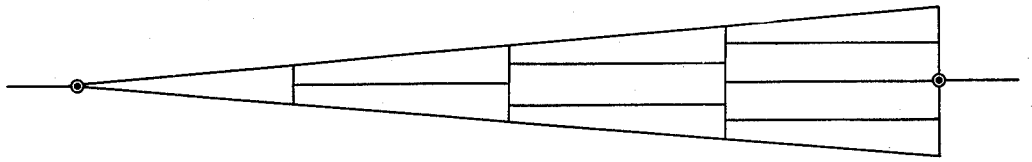
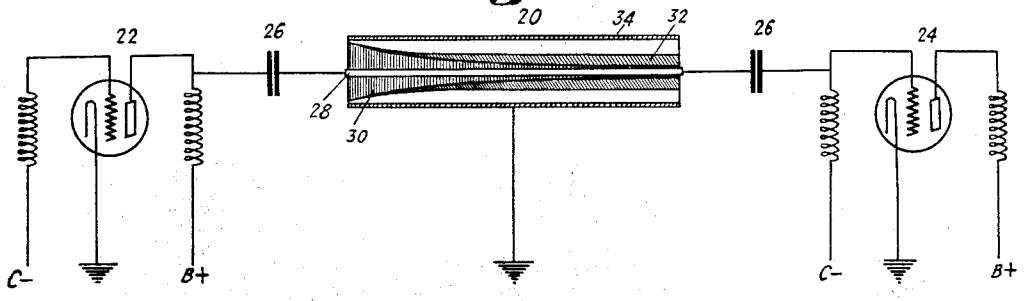


Fig. 5



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Patented Sept. 12, 1933 1,926,807

UNITED STATES PATENT OFFICE

1,926,807

IMPEDANCE TRANSFORMER

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Application April 14, 1928. Serial No. 269,939

5 Claims. (Cl. 178—44)

This invention relates to impedance transformers, and more particularly to a novel transformer consisting of a line the inductance and capacitance characteristics of which are varied to obtain the desired impedance transformation.

At high frequencies it becomes exceedingly difficult to construct efficient transformers, and accordingly the tendency is towards various forms of direct coupling which, by a suitable combination of reactances, serve to produce the desired impedance change. These methods are accompanied by the disadvantage that the degree of coupling and transformation varies with the frequency, a difficulty which is experienced to a considerable degree even in the range of lower frequencies where the use of transformers is practicable, and which is still more marked with directly coupled reactance arrangements.

It is a primary object of my invention to provide an impedance transformer which is independent of frequency, or otherwise stated, which experiences no resonance phenomena. This I propose to do by coupling the circuits through a natural or artificial line the inductance and capacitance characteristics of which are such that the impedance at one end equals one of the desired impedances, and the impedance at the other end equals the other desired impedance, while the impedances at points intermediate the ends vary exponentially between the desired end impedances.

The underlying idea may be explained by its analogy with the now well known exponential horn, which is no more than an air impedance changing device. At the diaphragm or small end of the horn there is a high air impedance, while at the mouth or large end of the horn there is a very low air impedance, and the horn serves to change from one to the other. By varying the cross section of the horn exponentially along its length it is found that resonance phenomena within the horn may be effectually prevented. In a similar way, I propose to couple two electrical circuits of differing electrical impedances with an impedance changing device which transforms the impedance gradually and progressively in amounts which vary in exponential or geometric progression, so that the impedance transformer is aperiodic.

The invention is described more in detail in connection with the accompanying drawing, in which

Figure 1 shows an artificial line built up of a number of sections each having series inductance and shunt capacitance;

Figure 2 shows a similar arrangement having series capacitance and shunt inductance;

Figure 3 indicates a line and antenna coupled together by an aperiodic transformer employing no lumped reactances;

Figure 4 is a modification; and

Figure 5 shows interstage coupling for exceedingly high frequencies.

Referring to Figure 1 there is an artifical line made up of a number of sections comprising series inductances 2 and shunt condensers 4. Now in accordance with the present invention if a total impedance change from R to r is required, and if X sections are to be employed, the impedance ratio for each section, N, is made equal to the total impedance ratio, $\frac{r}{R}$, raised to an exponent which is the reciprocal of the number of sections, X. In this way, as can be seen from the notation below Fig. 2, the impedance is varied exponentially along the artificial line, so that after five sections, as shown in Figure 1 as a simple illustration, the impedance is N^5R, and since this is to be equal to r, it is obvious that N equals the 5th root of the ratio $\frac{r}{R}$.

The arrangement shown in Figure 1 may be explained more in detail as follows. It is well known that the surge impedance of a line having series inductance and shunt capacity is approximately

$$z=\sqrt{\frac{L}{C}}$$

In case the impedance is to be stepped up the value of L may be increased, or the value of C decreased, or both. When an artificial line, consisting of lumped inductances and capacitances is used, instead of a natural line, the resulting sections are low pass filter sections, and it is necessary to so select the reactance values that the cut off frequency lies far above the frequency range with which the line is to be used as a transformer. The cut off frequency is given by the expression

$$f=\frac{1}{\pi\sqrt{LC}}.$$

It should be noticed that if the impedance along the line is varied by increasing L and decreasing C each by the desired factor the impedance of the line will be increased by that factor, inasmuch as

$$z=\sqrt{\frac{L}{C}},$$

and at the same time the cut off frequency will remain constant, inasmuch as the product LC will remain constant.

The legend "L" appearing in the equations above, represents the inductance per section or per unit of length of an artificial line. With reference to Fig. 1 for example, "L" is the portion of the inductance per section of the line which may be assigned to each of the capacities. Thus,

[illegible] and half of the [illegible] the first [illegible] total "L" [illegible] section is [illegible] all of the [illegible] two coils, one [illegible] two in- [illegible] the [illegible] they may be replaced [illegible] coil whose total inductance is equal to [illegible] may be defined as the [illegible] between condenser [illegible] that the coil sections [illegible] the limits of the [illegible] of ½ L [illegible] the values [illegible] and the values [illegible] along the [illegible]

[illegible]

waves, and if it is a receiver, the line impedance is matched because the [illegible] obtain maximum energy [illegible] from the antenna.

In place of strips of metal such as [illegible] indicated in Figure 3, a structure [illegible] conductors may be employed [illegible] such an arrangement for one conductor is [illegible] in Figure 4. It is clear that in a two wire [illegible] structures are employed, and the [illegible] between them may be constant, as [illegible] in Figure 3.

The desired change in either inductance, capacitance or both may be obtained by [illegible] a conductor with varying amounts of [illegible] material or insulation [illegible] Thus in Figure 5 such an [illegible] is shown [illegible] together [illegible] transformer [illegible] the output circuit of a [illegible] input circuit of a [illegible]

[illegible]

In the claims [illegible] "appended" [illegible] in the [illegible] intended to be [illegible] in [illegible] the specifications [illegible]

I claim:

1. A radio frequency [illegible] device whose terminals are [illegible] different impedances comprising a plurality of [illegible] posed conductors [illegible] continuously along [illegible] impedance of said device [illegible] continuously along its length [illegible] tial [illegible] impedance [illegible] equal to the impedance [illegible]

2. A radio frequency [illegible] device whose terminals are [illegible] different impedances comprising a plurality of [illegible]

posed conductors whose areas vary substantially continuously along the length of the device, the impedance of said device varying exponentially along its length whereby its terminals present impedances having values which are equal to the impedances to be faced.

3. In combination, a pair of radio frequency electrical circuits having different impedances, an impedance matching device whose terminals are adapted to connect together said pair of circuits, each terminal of said device having an impedance whose value corresponds to the impedance of the electrical circuit which it faces, said device comprising a plurality of superposed conductors the impedance of which as a whole tapers continuously along the length of the device.

4. A radio frequency impedance matching device whose terminals are adapted to face different impedances comprising a plurality of superposed conductors, at least one of which varies smoothly and continuously in mass along its length, the impedance of said device tapering substantially continuously along its length whereby its terminals present impedances having values which are equal to the impedances to be faced.

5. In combination, a radio transmitter having a predetermined impedance, a radiating antenna having a different impedance, and a radio frequency impedance matching device therebetween whose terminals are adapted to face said two different impedances comprising a plurality of conductors, at least one of which varies in mass substantially continuously along its length, the impedance of said device tapering substantially continuously along its length whereby its terminals present impedances having values which are equal to the respective impedances to be faced.

CLARENCE W. HANSELL.