Jan. 17, 1928. 1,656,225

M. OSNOS

ELECTRIC WAVE FILTER

Filed Feb. 20, 1923

Fig. 1

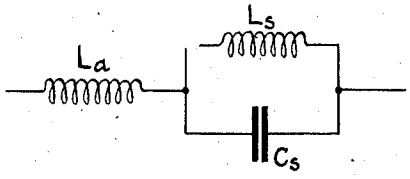


Fig. 2

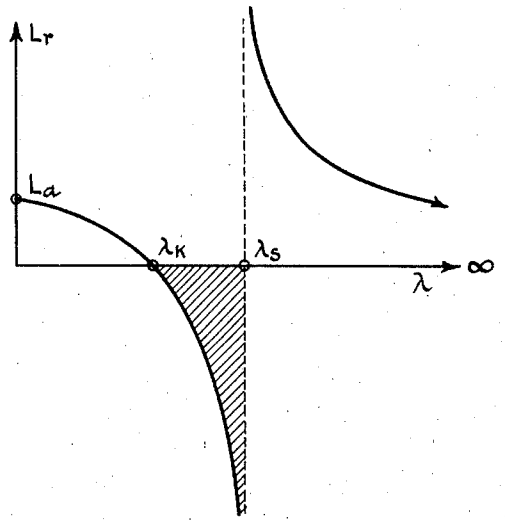


Fig. 3

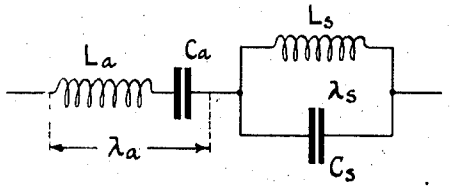


Fig. 4

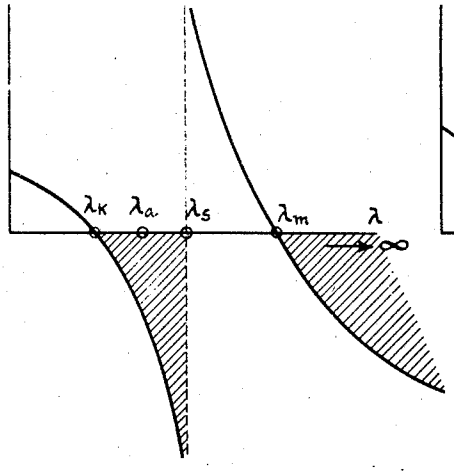
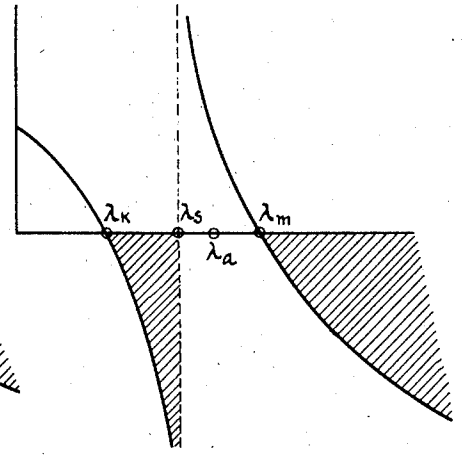


Fig. 5



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UNITED STATES PATENT OFFICE.

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ELECTRIC WAVE FILTER.

Application filed February 20, 1923, Serial No. 620,221, and in Germany February 22, 1922.

In the art of high frequency transmission use is often made of a tuned branch circuit which constitutes a short-circuit for waves of certain predetermined length and a considerable impedance for waves of all other lengths.

The usual exemplification of such a tuned short-circuit is that in which a self-induction and a capacity are connected in series. The combined self-induction L_r of this system, and, if the ohmic resistance is so small that for practical purposes it may be left out of consideration, the total impedance of the system is equal to zero for the frequency ω_0 or for the wave length λ_0 to which the system is tuned. On the other hand, for another frequency ω or wave length λ this self-induction has the value:

$$L_r = L\left(1 - \frac{\lambda^2}{\lambda_0^2}\right) \quad \text{(1)}$$

This equation is positive for all waves λ, which are shorter than λ_0, and negative for all waves which are longer than λ_0. This means that for $\lambda < \lambda_0$ the reactance is inductive, but for $\lambda > \lambda_0$ it is capacitive. However, in many instances a capacitive reactance is not only no obstacle for an alternating current but aids its passage, e. g. when an E. M. F. is present which is strengthened by an advancing current.

In order to obviate the drawback which results from this, in accordance with the present invention, the short-circuit for the desired wave is provided in such a manner that it presents an inductive reactance for all the other undesired waves which are present in the system. This is always possible when e. g. an inductance or an inductance and a capacity are provided in series with a branch comprising an inductance and a capacity connected in parallel therewith, and if the various elements are proportionately dimensioned.

In the drawing

Figure 1 is a diagrammatic representation of a short-circuit in which the invention may be embodied.

Figure 2 is a graphic illustration of the reactance of the short-circuit shown in Fig. 1 plotted against the wave length.

Figure 3 is a diagrammatic representation of a different form of short-circuit from that shown in Fig. 1 and comprising a system having inductance and capacity arranged in series with each other and with a second system comprising inductance and capacity arranged in parallel, and

Figures 4 and 5 are graphic illustrations of the reactance of the short-circuit shown in Fig. 3 plotted against the wave length, for the case in which the wave length of the system comprising inductance and capacity arranged in series is smaller than the wave length of the system comprising inductance and capacity arranged in parallel and vice versa.

In Fig. 1 a self-inductance L_a is provided in series with a branch comprising a capacity C_s and a self-induction L_s. If the natural wave length of the closed circuit C_s, L_s is equal to λ_s, then the impedance R_r of the whole short-circuit arrangement may be represented for a desired frequency ω or wave length λ as follows:

$$R_r = \omega L_r = \omega\left(L_a - \frac{\lambda^2 L_s}{\lambda_s^2 - \lambda^2}\right) \quad \text{(2)}$$

From this we obtain the resulting equivalent self-induction L_r.

$$L_r = L_a - \frac{\lambda^2 L_s}{\lambda_s^2 - \lambda} \quad \text{(3)}$$

These equations may be easily derived by setting down the equation for the impedance of the circuit arrangement shown in Fig. 1 and placing the capacity C_s in terms of the inductance L_s and the wave length for which L_s and C_s is tuned. The impedance is then expressed in terms of the equivalent of inductance. The impedance has an inductive character for a positive value of L_r and a capacitive character for a negative value of L_r. As a function of λ, L_r develops as shown in Fig. 2. For infinitely small values of λ, L_r is equal to L_a. It decreases when λ increases, and is equal to zero for certain value of λK. Then as λ still further increases L_r will be negative, i. e. the reactance will be capacitive. L_r approaches the value ∞ when λ approaches the natural wave λ_s of the branch C_s, L_s. If λ exceeds the value λ_s, then the value L_r will become and remain positive because it decreases from plus ∞ and when the value λ increases it approaches asymptotically the value L_a plus L_s.

In order to obtain the result aimed at by the present invention, the system must be so

proportioned that two requirements will be satisfied:

First, for the predetermined wave λ_n which filters through without being weakened, the impedance R_r must present either a complete or partial capacitive short-circuit, i. e. λ_n must be either equal to or slightly longer than λK which satisfied the equation

$$O = L_s - \frac{\lambda_K^2 L_s}{\lambda_s^2 - \lambda_K^2} \quad \text{---------- (4)}$$

λK is longer than any wave of the station shorter than λ_n.

Second, the individual wave λ_s of the branch L_s, C_s must be longer than λ_n, but shorter than the next longest wave which may occur in the station.

Let us assume, for instance, that in accordance with the present invention the seventh harmonic filters through the tuned short circuit without being weakened, but the other waves are destroyed and furthermore, that in the system we may generate only all the possible odd harmonics $\lambda 3$, $\lambda 5$, $\lambda 7$, $\lambda 9$, etc. Under these conditions the above described system may be so tuned that first its λK be equal to or slightly shorter than the seventh harmonic $\lambda 7$, but that under all circumstances it be longer than the ninth harmonic $\lambda 9$. Second λ_s must be longer than $\lambda 7$ but shorter than $\lambda 5$. The resulting impedance R_r will now be inductive for all harmonics which occur in the system except the seventh harmonic.

In the embodiment shown in Fig. 3, an additional capacity C_a is connected in series with L_a. The natural wave length of the part L_a, C_a, is assumed to be λ_a, that of the circuit C_s, L_s, λ_s as above, the corresponding individual frequencies being ω_a and ω_s. Disregarding ohmic resistances, the impedance of the whole system may be expressed as follows:

$$R_r = \omega L_r = \omega L_a - \frac{\frac{L_s}{C_s}}{\omega L_s - \frac{1}{\omega C_s}} - \frac{1}{\omega C_a} \quad \text{----------(5)}$$

and the resulting equivalent self induction:

$$L_r = L_a\left(1 - \frac{\lambda^2}{\lambda_a^2}\right) - \frac{L_s \lambda^2}{\lambda_s^2 - \lambda^2} \quad \text{----------(6)}$$

Fig. 4 shows the development of the value L_r as a function of λ for the case when λ_a is smaller than λ_s, and Fig. 5 for the case when λ_a is larger than λ_s. In both cases the function passes twice through zero from the positive to the negative. This means that in each case there are really two possible values of λ, a smaller λK and a larger λ_m. For these the system presents a practically perfect short circuit. The values of λ_a and λ_s are between λK and λ_m. The capacitive reactance is represented by the shaded areas the first of which is between λK and λ_s and the second to the right of λ_m.

In order to insure that none of the harmonics of the system except the one which it is desired should filter through without being weakened, fall in the capacitive area, the system is tuned as follows:

(1) The shorter short-circuit natural wave λK of the system is so selected that it be equal to or slightly shorter than the harmonic λ_n which must be permitted to pass without being weakened.

(2) The longer natural wave of the short-circuit λ_m is so selected that it be longer than the longest wave occurring in the system, in a given case the basic wave λ_1. If, however, it is desired to permit also the passage of the basic wave without weakening it then λ_m is so selected that it be equal to or slightly shorter than λ_1 but longer than the next harmonic.

(3) Both natural waves λ_a and λ_s must be longer than λK and shorter than λ_m.

(4) λ_s must be longer than the harmonic λK the unweakened passage of which is desired but shorter than the next longest harmonic that may occur in the system.

If for instance, it is desired to permit the passage only of the seventh harmonic and that of the basic wave without materially weakening them, and to weaken all the other harmonics, and if only all the odd harmonics may be produced in the system, then the short circuit arrangement in accordance with Fig. 3 must be so tuned that λK be equal to or slightly shorter than $\lambda 7$ but longer than $\lambda 9$, λ_m be equal to or slightly shorter than λ_1 but longer than $\lambda 3$. λ_a and λ_s must be between λK and λ_m and λ_s between $\lambda 7$ and $\lambda 5$.

The invention is of particular importance in one stage frequency amplification. See for instance my application Serial No. 609,215, filed Dec. 27, 1922, for circuit arrangement for high frequency sending stations, whereby by means of a transformer or iron choke coil, a plurality of different harmonics are produced only one of which is desired so that all the others must be destroyed or suppressed.

Having described my invention what I claim is—

1. In an electric system having a plurality of wave lengths present, a filter, comprising a first circuit having an inductance and a capacity arranged in series with each other, and a closed circuit in series with said first circuit, said closed circuit comprising an inductance and a capacity arranged in parallel with each other, the elements of the filter being so constituted that the shorter wave length to which the filter as a whole, is tuned is shorter than the desired wave length but longer than the undesired next

shortest wave length and the longer wave length to which the short circuit, as a whole, is tuned is longer than any undesired wave length.

2. In an electric system having a plurality of wave-lengths present, a filter, comprising a first circuit having an inductance and a capacity arranged in series with each other, and a closed circuit in series with said first circuit, said closed circuit comprising an inductance and a capacity arranged in parallel with each other, the elements of the filter being so constituted that the shorter wave length to which the filter, as a whole, is tuned is shorter than the desired wave length but longer than the undesired next shortest wave length and the longer wave-length to which the short circuit, as a whole, is tuned is longer than any undesired wave length, and the wave lengths to which the closed circuit is tuned and to which the first circuit is tuned lie between the two wave lengths to which the filter, as a whole, is tuned.

3. In an electric system having a plurality of wave-lengths present, a filter, comprising a first circuit having an inductance and a capacity arranged in series with each other, and a closed circuit in series with said first circuit, said closed circuit having an inductance and a capacity arranged in parallel with each other, the elements of the filter being so constituted that the shorter wave length to which the filter, as a whole, is tuned is shorter than the desired wave length but longer than the undesired next shortest wave length and the longer wave length to which the filter, as a whole, is tuned is slightly shorter than a second desired wave length but longer than the undesired wave lengths between the second desired wave length and the desired wave length.

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