Nov. 2, 1926. 1,604,981

H. W. ELSASSER

SELECTIVE CIRCUIT

Filed August 19, 1920 2 Sheets-Sheet 1

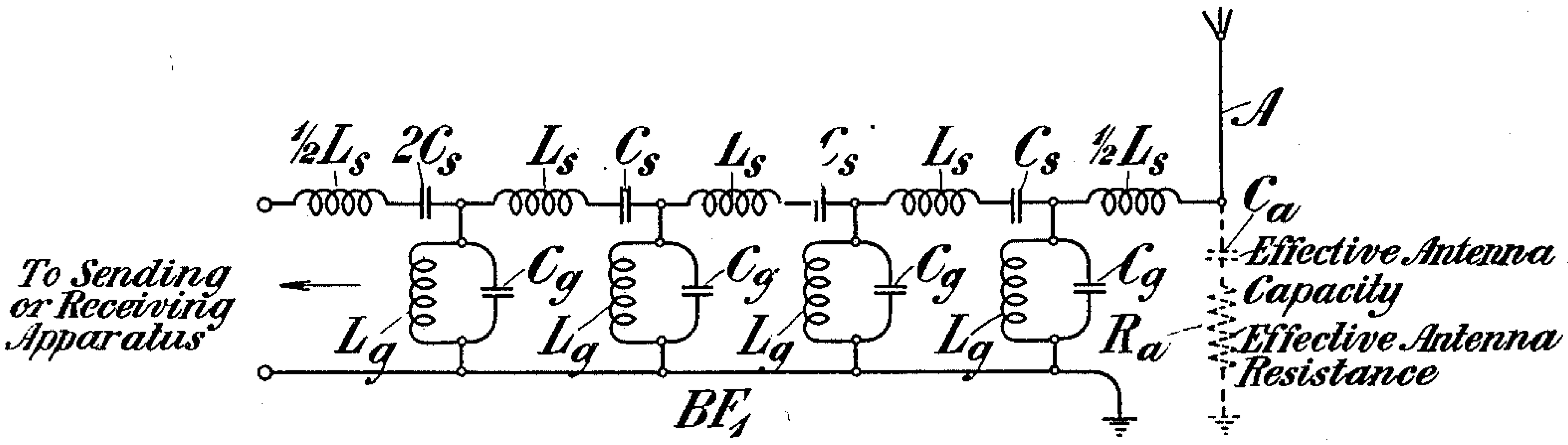

Fig. 1

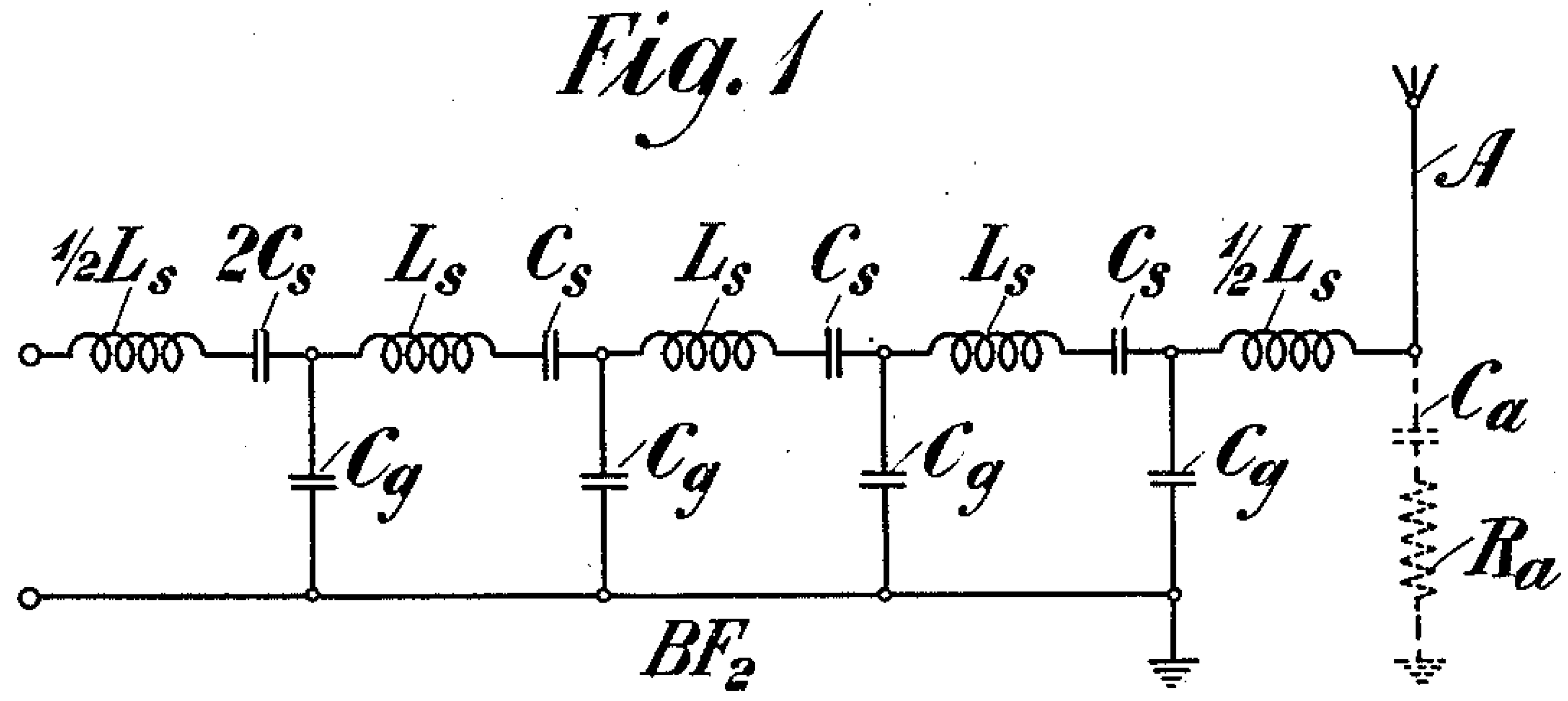

Fig. 2

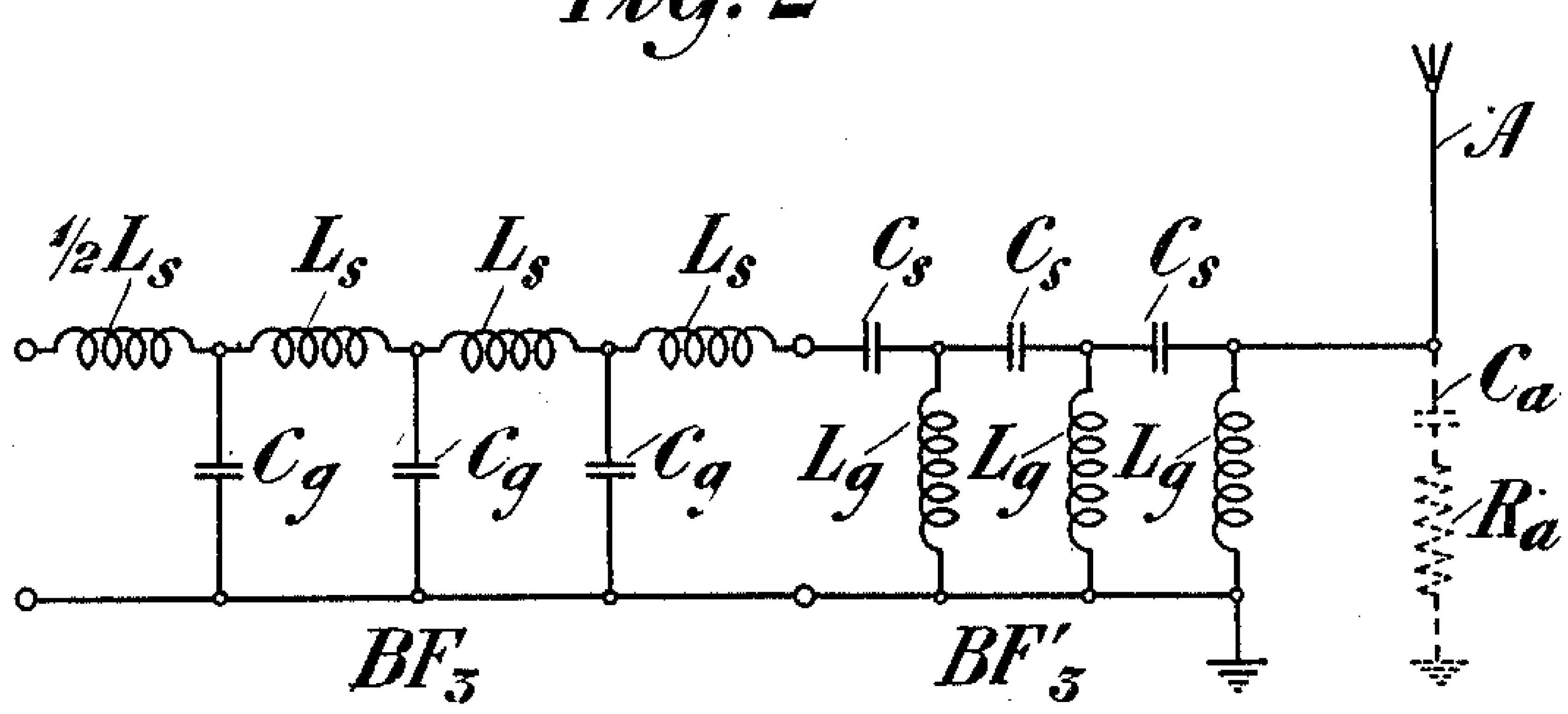

Fig. 3

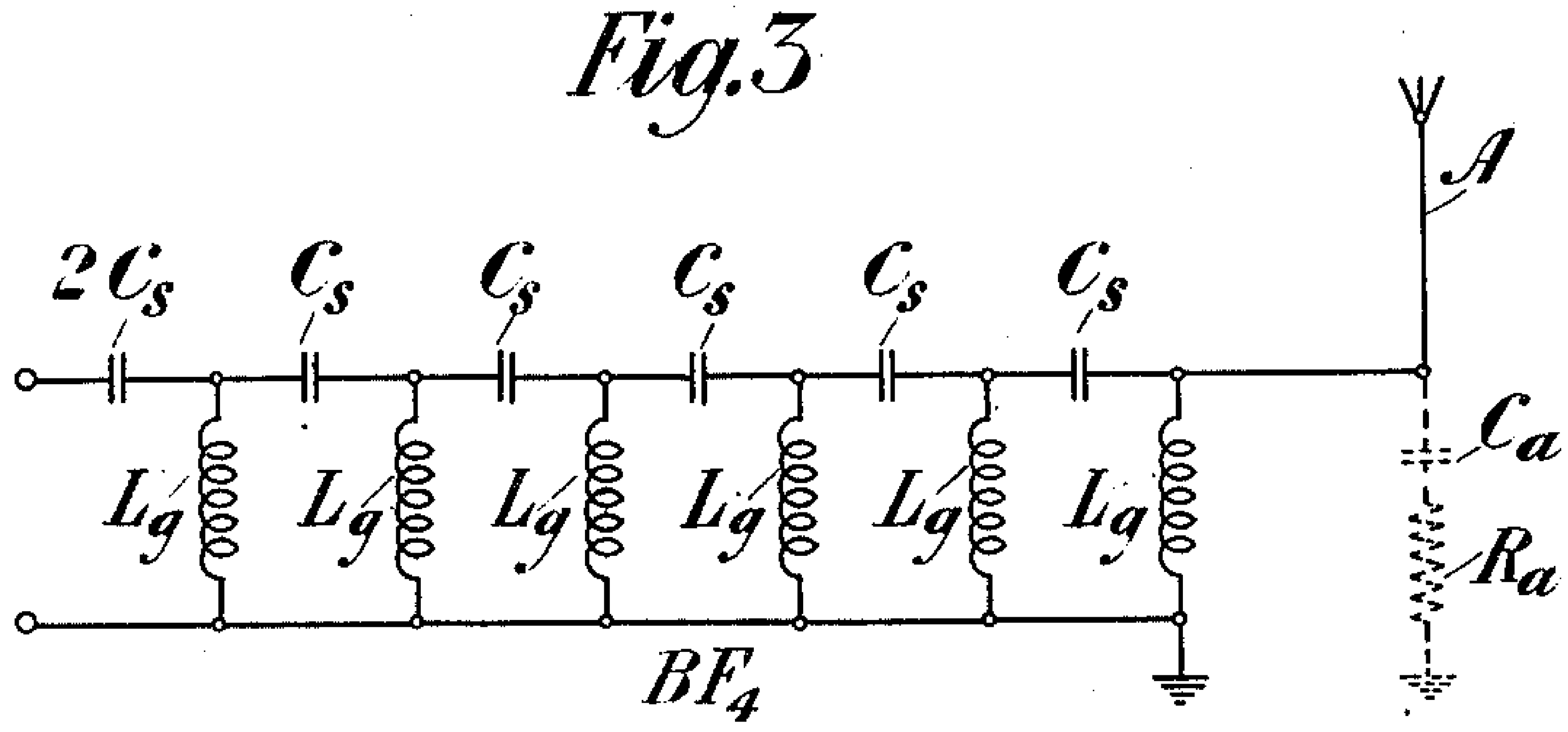

Fig. 4

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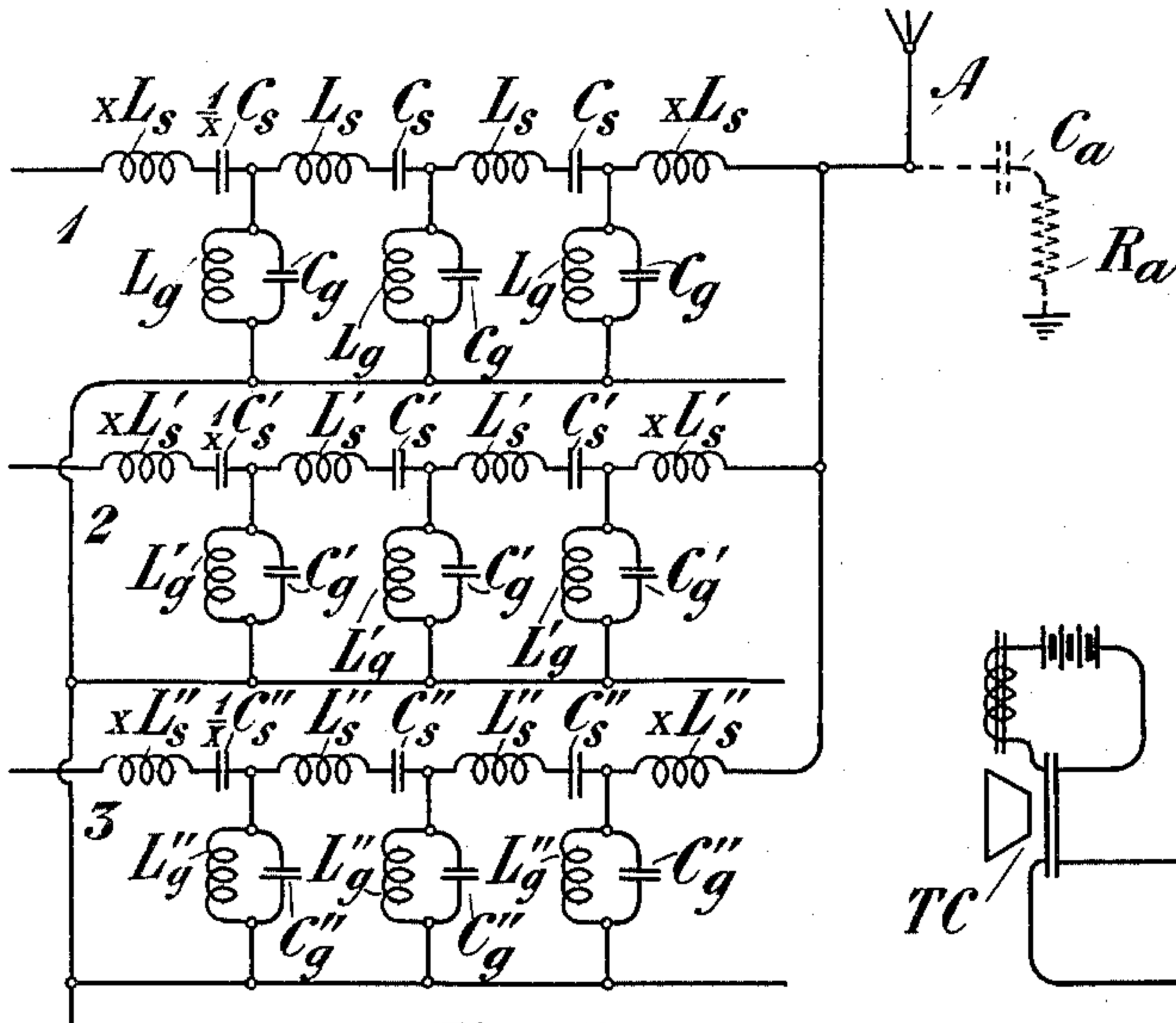

Fig. 5

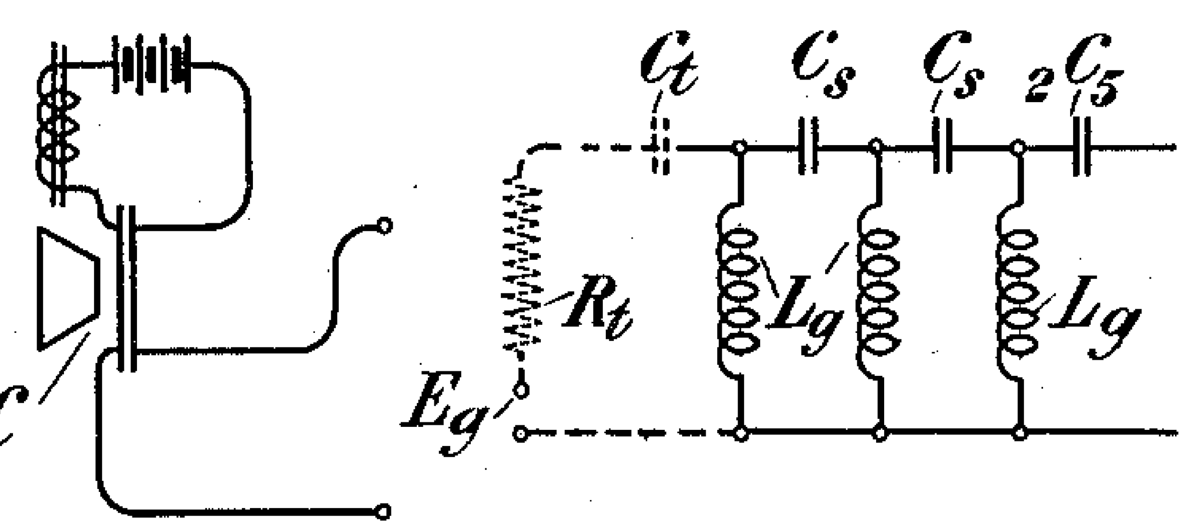

Fig. 8

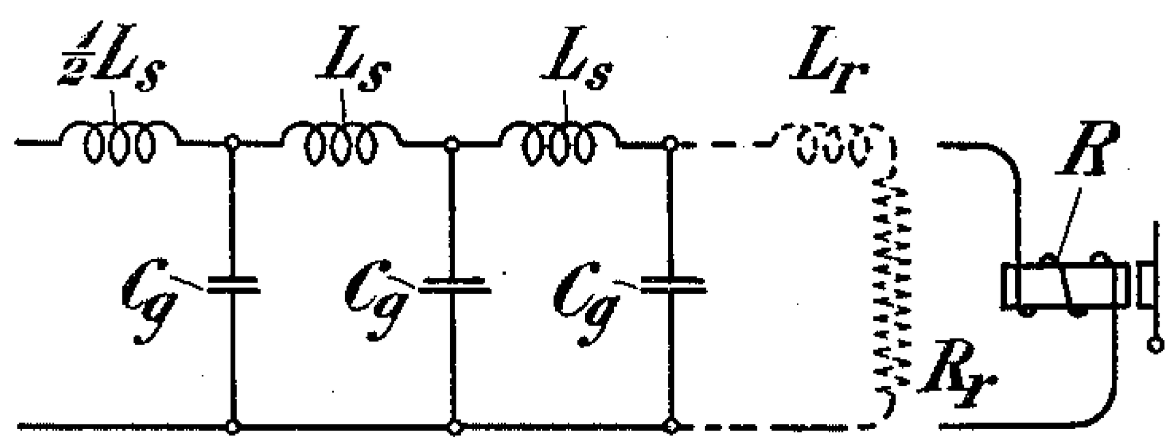

Fig. 6

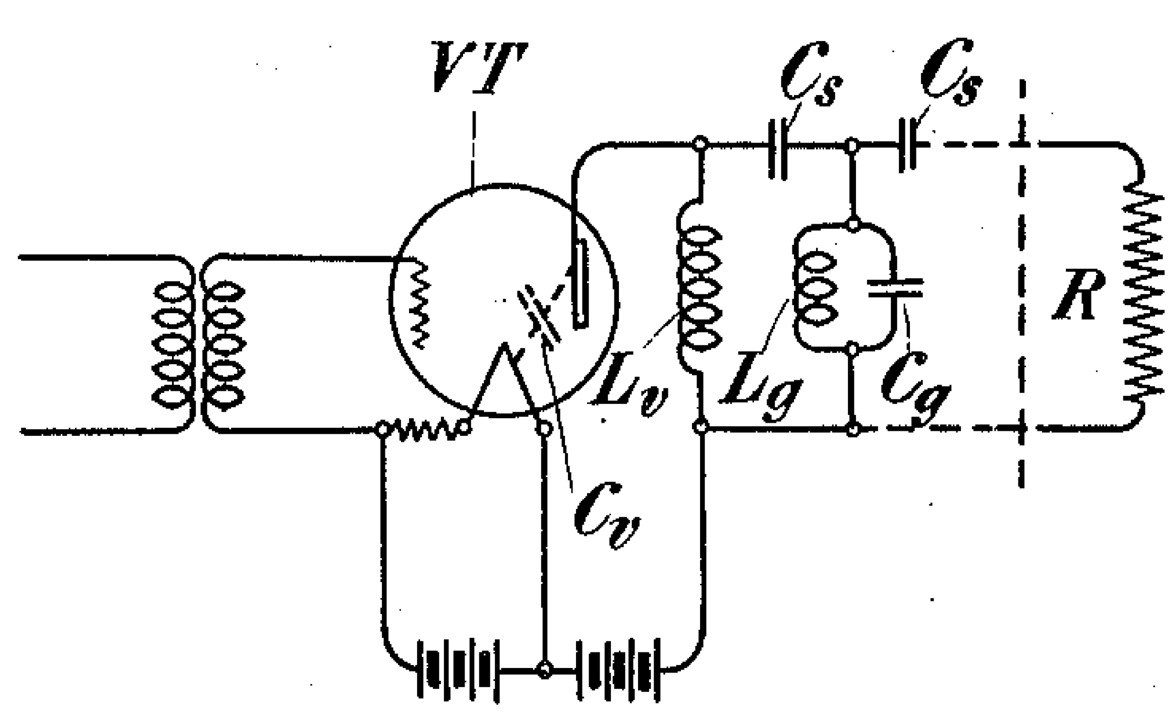

Fig. 9

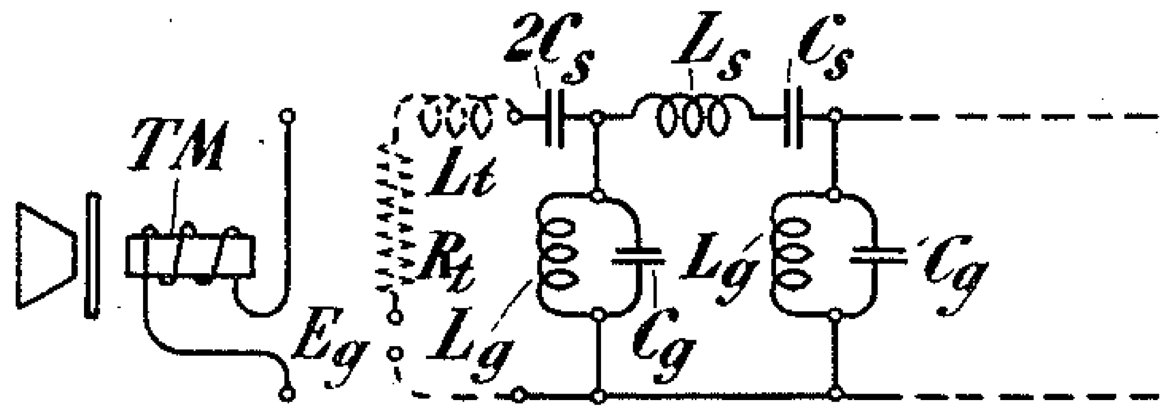

Fig. 7

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Patented Nov. 2, 1926. **1,604,981**

UNITED STATES PATENT OFFICE.

HENRY W. ELSASSER, OF NEW YORK, N. Y., ASSIGNOR TO AMERICAN TELEPHONE AND TELEGRAPH COMPANY, A CORPORATION OF NEW YORK.

SELECTIVE CIRCUIT.

Application filed August 19, 1920. Serial No. 404,679.

This application is a continuation, as to common subject matter, of application Serial No. 327,556, filed September 30, 1919. The invention of this application relates to signaling systems, and more particularly to selective apparatus for such systems.

One of the objects of the invention is to provide a method of combining a wave filter with terminal apparatus. Another object of the invention is to utilize the reactance component of the impedance of the terminal apparatus or device as the whole or part of the impedance of the end section of the wave filter, and to utilize the resistance component of the terminal arrangement or device as the terminating impedance of the wave filter and to overcome the distortion effect of the antenna or other terminal apparatus. Other and further objects of the invention will more fully appear hereinafter.

The impedance of many transmitting and receiving devices such as relays, telephone receivers and antennæ, are functions of the frequency. These impedances, furthermore, are reactive and their reactive components may, in many cases, be represented by simple inductances and capacities or by an inductance and a capacity placed in series or in parallel. When such devices are used for receiving, the amount of received energy varies with the frequency (even though the resistance component does not vary) unless the reactance component is annulled. Similarly, when such apparatus is used for transmitting, the amount of energy transferred to the receiving device will vary with the frequency.

Wave filters, which are approximately non-dissipative structures, are made up of combinations of inductances and capacities. By utilizing the reactance component of the terminal device as the whole or part of the reactance of the terminal section of the filter, it is possible to prevent or counteract the variation with frequency of the energy transmitted, which is caused by the variation of the reactance of the terminal impedance with the frequency.

The manner in which it is proposed to apply these ideas may be more fully understood from the following description when read in connection with the accompanying drawings, Figures 1 to 4 inclusive of which show various arrangements for combining an antenna with a wave filter so as to utilize the reactance component of the antenna as an element of the end section of the filter; Fig. 5 of which illustrates an arrangement for utilizing the reactance component of an antenna as an element of the end sections of each of the plurality of wave filters connected in parallel; Figs. 6, 7 and 8 of which show arrangements for employing the reactance components of transmitting and receiving devices as elements of the end sections of wave filters; and Fig. 9 of which illustrates an arrangement for employing the capacity between the filament and plate of a vacuum tube as an element of the end section of a filter with which the vacuum tube is associated.

Referring to Fig. 1, A represents an antenna of any ordinary construction, having associated therewith a band filter BF_1, the purpose of the filter being to enable the combination of antenna and filter to freely transmit or receive the desired range of frequencies. The band filter is of the general type disclosed in the U. S. patents to George A. Campbell, Nos. 1,227,113 and 1,227,114, issued May 22, 1917. The band filter BF_1, as illustrated, comprises a number of sections, each section including a series impedance element consisting of a series inductance L_s and a series capacity C_s, said inductance and capacity being serially related to each other. Each section of the filter also includes a shunt impedance element comprising a parallel combination of inductance L_g and capacity C_g. The one side of the filter and the antenna are connected to ground.

The series and shunt impedance elements of the various filter sections are so proportioned and related to each other, in accordance with the principles of the above mentioned patents to George A. Campbell, that the filter as a whole will freely transmit a desired band of frequencies with uniform attenuation, while substantially suppressing frequencies lying without the desired range. Since the impedance of the antenna structure tends to vary rapidly with frequency, the transmission obtained for the different frequencies lying in the free range of the filter would vary considerably if the filter was associated with the antenna in the same manner as a filter of this kind may be associated with a wire transmission line. Accordingly it is proposed by this invention to so design the elements of the filter section that the effective antenna capacity indicated in dotted lines at C_a may be utilized as the whole or a part of the series capacity element of the last section of the filter. By means of this expedient the sharply resonant characteristic of the combination of the antenna and the usual receiving apparatus disappears and the antenna becomes in effect an element of a network which functions as a band filter of the Campbell type.

The underlying theory of the Campbell filter, however, presupposes a filter having an infinite number of sections. In practice it is not expedient to provide such an infinite number of sections and only a relatively small number of sections will ordinarily be provided. In associating such a filter with a transmission circuit such as an antenna, reflection losses will be set up, which would impair the transmission over the circuit, such reflection losses being due to the difference in impedance between the antenna and the filter. In order to prevent these reflection losses, the antenna is so designed or adjusted, or the filter is so designed with respect to the antenna, that the effective resistance R_a of the antenna will afford a proper terminating impedance for the filter.

In referring to filter "sections" as in the foregoing part of this specification, the sections intended to be understood are mid-series sections. Looking at the left of Fig. 1, it will be seen that the series impedance depends on $1/2L_s$ and $2C_s$, whereas the other series impedances depend on L_s and C_s. This shows that the series impedance at the left is only half as much as in the other cases. The first section, beginning at the left, is to be thought of as extending far enough through the first L_s, C_s combination to take half of its impedance, and then the second section is to be thought as beginning and comprising the remainder of the impedance of the same L_s, C_s combination.

Following the mid-series sections through from left to right, it will be noticed that the last series impedance is again only one-half of L_s, and to complete this mid-series section of the filter requires a capacity of value $2C_s$, just as at the extreme left. This capacity is found in the "Effective antenna capacity", as labeled on Fig. 1.

Fig. 2 illustrates the same principle applied to a band filter in which the shunt impedance element consists simply of capacities C_g, the series elements comprising inductances L_s and capacities C_s as before. In this case the antenna is so designed that its effective capacity C_a will function as the whole or part of the series capacity of the last section, while its effective resistance R_a will function as a terminating impedance for the filter.

As pointed out in the patents to Campbell, above mentioned, a simple form of filter freely transmitting all frequencies below a definite frequency and known as the low pass filter, may be formed by a series of sections, the series element of each of which is a simple inductance and the shunt element of each of which is a simple capacity. So also a so-called high pass filter which will freely transmit all frequencies above a limiting value, may be constructed by arranging each section so that the series element is a simple capacity and the shunt element a simple inductance. By designing two filters of this character so that the lower limit of transmission of the high pass filter is below the upper limit of transmission of the low pass filter and connecting the two filters in series, the combination will freely transmit a band of frequencies lying between the two limiting frequencies of the two filters, while suppressing frequencies on either side of the limiting frequencies. Fig. 3 illustrates the invention as applied to such an arrangement of filters. In this figure BF_3 is a low pass filter, the sections of which are made up of series inductance L_s and shunt capacity C_g, while BF_3' is a high pass filter whose sections are made up of series capacity elements C_s and shunt inductance elements L_g. The effective capacity C_a of the antenna A is arranged to function as the whole or part of the series capacity element of the last section of the filter, while the effective resistance R_a forms the terminating impedance for the filter.

Fig. 4 illustrates the invention as applied to a high pass filter BF_4 made up of sections, each section comprising series capacity C_s and shunt inductance L_g. Here also the effective capacity C_a of the antenna is utilized as the series capacity of the last section of the filter and the effective resistance R_a of the antenna serves as the terminating impedance for the filter structure.

Fig. 5 illustrates an extension of the scheme to provide for the efficient reception or transmission on a single antenna of a number of frequency bands. As indicated, three band filters, 1, 2 and 3, are connected in multiple to a common antenna structure A, the lower side of each of the filters being connected to ground. These filters may be of any type, but are illustrated as band filters of the Campbell type, employing for each full section a series element comprising an inductance L_s in series with a capacity C_s and a shunt element comprising an inductance L_g in parallel with a capacity C_g. Where a number of filters are connected in parallel, it is always possible to terminate each filter so that its impedance in the non-transmission range is large compared to its impedance in the free transmission range. If each of the filters is so terminated as to produce this result, it will be apparent that with regard to the filter 1, for example, the filters 2 and 3 will act as shunts across its terminal which is connected to the antenna, but as the impedances of each of the filters 2 and 3 will be extremely large in the transmitting range of the filter 1, said filters may be practically disregarded so far as their effect upon transmission through the filter 1 to the antenna A is concerned. It is, therefore, possible to employ the effective capacity C_a of the antenna A at the average transmitting frequency of the filter 1, as a part of the terminating section of the filter 1, regardless of the fact that the other filters are also connected to the antenna.

For example, if the filter in Fig. 5 is to have a series termination, that is, if the filter is to terminate in the series element of a complete section or a fractional part thereof, the series element of the end section may be composed of an inductance xL_s and a capacity

$$\frac{1}{x} C_s,$$

where x represents the fractional termination. If the antenna A at the average frequency of the free transmission range of the filter 1 has a capacity reactance equivalent to a capacity C_a, the filter 1 may be designed by making C_s equal to xC_a. In some cases it may also be possible to modify the antenna constants if this is desirable in order to obtain satisfactory designs for the filters. This will determine the element C_s of each filter section and in a well known manner, the elements L_s, L_g and C_g may be chosen so as to give the filter the desired range of free transmission and an impedance which substantially prevents reflection losses. It is, of course, well known to any one skilled in the art, that for maximum efficiency the filter should be so designed that its impedance in the free range is approximately equal to the resistance of the antenna. The effective capacity C_a will then function with the inductance xL_s as the end section of the filter and the effective resistance R_a of the antenna will form a suitable termination for the filter 1 to prevent substantial reflection losses in the range of free transmission of the filter, it being understood that within this range the impedance of the filter will act as a pure resistance.

With regard to the filter 2, it will in general be found that the effective capacity C_a of the antenna A will be different at the average frequency of free transmission for the filter 2 from its value in the range of free transmission of the filter 1. Having determined the value of this effective capacity for the average frequency of free transmission of the filter 2, however, the elements of the filter 2 may be designed by setting the effective capacity C_a equal to

$$\frac{1}{x} C_s'.$$

This will determine the value of the element C_s' for the filter 2, and the remaining inductances and capacities may then be determined in a well known manner with reference to the limits of free transmission and the characteristic impedance of the filter. The effective capacity C_a of the antenna at the frequency of free transmission of the filter 2 will then constitute with the inductance xL_s' the series element of the terminating section of the filter. The effective capacity will thus act in the range of free transmission of the filter 2 regardless of its relation to the filters 1 and 3, for in this range of free transmission, the filters 1 and 3, as already stated, will have impedances so large that their shunting effect upon the filter 2 may be neglected.

In a similar manner, the filter of Fig. 3 may be designed with respect to the effective capacity of the antenna A at the average frequency of free transmission for the filter, so that the effective capacity of the antenna will function with the inductance xL_s'' as the fractional series element of the end section, while the effective resistance will form a proper termination for the filter with regard to reflection losses.

The principles already described are also capable of application to the connection of filters with other apparatus than antenna structures. For example, a receiving device or a transmitting device may be associated with a filter in such a manner that the reactance component of the transmitting or receiving device will function as one of the reactance elements of the filter, and the resistance component will function as a terminal arrangement for the filter. In general, any translating apparatus of this character may be combined with a filter of any type, although for purposes of illustration, several different types of translating devices are shown associated with but a single form of filter, in order to avoid the unnecessary illustration of combinations which will be apparent to anyone skilled in the art.

For example, Fig. 6 illustrates the association of a filter with a magnetic receiving device R, which may be either a relay or an ordinary telephone receiver. The full series element of each section of the filter is illustrated as being formed of an inductance L_s and the shunt element as being formed of a capacity C_g. The terminal section of the filter may be of any character desired but since it is common in practice to terminate a filter in a mid-series section, that is, a section having a series element whose value is one-half of a full series element, the filter is shown as being terminated at the incoming end in a series element $\frac{1}{2}L_s$. The inductance of the receiver R is schematically indicated at L_r. Its value may be made equal to the element $\frac{1}{2}L_s$ so that the inductance of the receiver acts as the series element of the last section of the filter. Likewise, if the receiver is properly designed, or if the filter is properly designed with respect to the receiver, the equivalent resistance R_r of the receiver will have such a value as to correspond to the characteristic impedance of the filter over the range of free transmission. The characteristic impedance of the filter over this range will be substantially a pure resistance so that if the equivalent resistance of the receiver has the proper value, the reflection losses will be negligible for practical transmission purposes.

Fig. 7 illustrates the association of an electro-magnetic transmitter TM with a band filter, of which the series element of a full section comprises an inductance L_s and a capacity C_s, while the shunt element comprises an inductance L_g and a capacity C_g. In this case, the equivalent inductance L_t of the transmitter will function as the inductance element of the last section of the filter, and the equivalent resistance R_t of the transmitter will form the terminating impedance for the filter. Since the transmitter functions to generate an alternating current, the equivalent circuit shown in dotted lines may be considered to have a potential E_g applied to the open terminals as illustrated.

Fig. 8 shows a similar arrangement for a condenser transmitter TC. The reactance of the transmitter TC is a capacity reactance C_t and this capacity reactance may function as one of the capacity elements of the filter as indicated in dotted lines. Since the transmitter functions as a generator, the potential E_g may be considered as applied to the terminals of the circuit as indicated, and the equivalent resistance R_t will function as the terminal impedance to be connected across the filter.

An arrangement is illustrated in Fig. 9 for associating a vacuum tube VT with a filter. As is well known, a vacuum tube is usually provided with an inductance L_v connected across its output circuit to afford a path for the plate current flowing between the filament and the plate. A certain amount of capacity exists between the filament and the plate of the vacuum tube, and at high frequencies this capacity acts as a shunt across the output circuit. This result may be avoided by arranging this capacity to act as one of the capacity elements of the filter with which the vacuum tube is associated. This filter is illustrated as having sections whose series elements comprise capacity C_s and whose shunt elements comprise inductances L_g in parallel with capacities C_g. It is possible, if the filter is terminated in a shunt termination, to utilize the capacity C_v of the tube in parallel with the inductance L_v as the shunt termination of the filter. It will be understood, of course, that by a shunt termination is meant a termination in which the shunt impedance element of the terminal sections will be equal to or have a fractional value of that of the full shunt element. The values of the full shunt impedance elements of each filter section may be so chosen that the inductance L_v, in parallel with the capacity C_v, will function as the proper end section termination of the filter.

It will be obvious that the general principles herein disclosed may be embodied in many other organizations widely different from those illustrated, without departing from the spirit of the invention as defined in the following claims.

The sections of the filter disclosed herein are similar in the sense that each section is made up of like reactances, coils and condensers similarly arranged. The corresponding reactances in successive sections may be equal, but the use of the word "similar" is not intended to imply that they are necessarily equal, for they may be graded along the filter from section to section.

What is claimed is:

1. The combination with an antenna, of a filter comprising a plurality of similar sections, each section including series and shunt impedance elements so proportioned that the filter structure will freely transmit with equal attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, the effective capacity of the antenna functioning as at least a portion of the series impedance of the last section of the filter.

2. The combination with an antenna, of a filter comprising a plurality of similar sections, each section including series and shunt impedance elements so proportioned that the filter structure will freely transmit with equal attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, the effective capacity of the antenna functioning as at least a portion of the series impedance of the last section of the filter, and the effective resistance of the antenna functioning as a terminating impedance for the filter, to substantially prevent reflection losses.

3. The combination with an antenna, of a filter comprising a plurality of similar sections, each complete section consisting of lumped series and shunt impedance elements, the series impedance element of each section including a capacity, and said series and shunt impedance elements being so propor-

tioned and related that the filter will freely transmit with uniform attenuation a band of frequencies, while substantially supressing frequencies lying without said band, the effective capacity of the antenna functioning as a capacity element of the last section of the filter.

4. The combination with an antenna, of a filter comprising a plurality of similar sections, each section including series and shunt impedance elements, the series impedance element of each section including a capacity, and said series and shunt impedance elements being so proportioned and related that the filter will freely transmit with uniform attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, the effective resistance of the antenna functioning as a terminating impedance for the filter to substantially prevent reflection losses.

5. The combination with an antenna, of a broad band filter comprising a plurality of similar sections, each section including series and shunt impedance elements, the series impedance elements comprising an inductance and capacity in series with each other, and said series and shunt impedance elements being so proportioned and related that the filter will freely transmit with substantially equal attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, and the effective capacity of the antenna functioning as a series capacity element of the last section of the filter.

6. The combination with an antenna, of a broad band filter comprising a plurality of similar sections, each section including series and shunt impedance elements, the series impedance elements comprising an inductance and capacity in series with each other and said series and shunt impedance elements being so proportioned and related that the filter will freely transmit with substantially equal attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, the effective capacity of the antenna functioning as a series capacity element of the last section of the filter, and the effective resistance of the antenna functioning as the terminating impedance for the filter, to substantially prevent reflection losses.

7. In a selective circuit arrangement, a filter comprising a plurality of similar sections, each complete section consisting of lumped reactive series and shunt impedance elements so proportioned that the filter structure will transmit with substantially equal attenuation a predetermined band of frequencies of a considerable range, while substantially suppressing frequencies lying without the band, and a translating device associated with said filter, said translating device being so connected to the filter and the reactance values of said impedance elements and of said device being so related that the reactance of said device functions as at least a portion of the series reactance element of the last section of the filter.

8. In a selective circuit arrangement, a filter comprising a plurality of similar sections, each complete section consisting of lumped reactive series and shunt impedance elements so proportioned that the filter structure will transmit with substantially equal attenuation a predetermined band of frequencies of a considerable range while substantially suppressing frequencies lying without the band, and a translating device associated with said filter, said translating device being so connected with the filter and its reactance and resistance values being so related with the reactance values of said impedance elements that the effective reactance of said device functions as at least a portion of one of the reactance elements of the filter and the effective resistance of said device functions as terminating impedance for the filter to substantially prevent reflection losses.

9. In a selective circuit arrangement, a filter comprising a plurality of similar sections, each complete section consisting of lumped reactive series and shunt impedance elements so proportioned that the filter structure will transmit with substantially equal attenuation a predetermined band of frequencies of a considerable range while substantially suppressing frequencies lying without the band, and a translating device associated with said filter, said translating device being so connected to the filter and its resistance value being so related to said impedance elements that the effective resistance of said device functions as a terminating impedance for the filter to substantially prevent reflection losses.

10. In a selective circuit arrangement, a filter comprising a plurality of similar sections, each complete section consisting of lumped reactive series and shunt impedance elements so proportioned that the filter structure will transmit with substantially equal attenuation a predetermined band of frequencies of a considerable range, while substantially suppressing frequencies lying without the band, and a translating device associated with said filter, said translating device being so connected to the filter and its reactance and resistance values being so related to said impedance elements that the reactance of said device functions as a series reactance element of the last section of the filter, and the effective resistance of said device functions as a terminating impedance for the filter to substantially prevent reflection losses.

11. In a selective circuit arrangement, a

filter comprising a plurality of similar sections, each section including reactive series and shunt impedance elements, so proportioned that the filter structure will transmit with equal attenuation a predetermined band of frequencies, while substantially suppressing frequencies lying without the band, and a translating device associated with said filter, said translating device being so connected to the filter that its effective capacity functions as a series capacity element of the last section of the filter.

12. The combination with an antenna, of a filter comprising a plurality of similar sections, each complete section consisting of lumped series and shunt impedance elements so proportioned that the filter structure will freely transmit with equal attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, the reactance of the antenna functioning as at least a portion of the series impedance of the last section of the filter.

13. The combination with an antenna, of a filter comprising a plurality of similar sections, each section including series and shunt impedance elements so proportioned that the filter structure will freely transmit with equal attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, the reactance of the antenna functioning as at least a portion of the series impedance of the last section of the filter, and the effective resistance of the antenna functioning as a terminating impedance for the filter, to substantially prevent reflection losses.

14. The combination with an antenna, of a filter comprising a plurality of similar sections, each complete section consisting of lumped series and shunt impedance elements, the series impedance element of each section including a capacity, and said series and shunt impedance elements being so proportioned and related that the filter will freely transmit with uniform attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, the reactance of the antenna functioning as an impedance element of the last section of the filter.

15. The combination with an antenna, of a band filter comprising a plurality of similar sections, each complete section consisting of lumped series and shunt impedance elements, the series impedance elements comprising an inductance and capacity in series with each other, and said series and shunt impedance elements being so proportioned and related that the filter will freely transmit with substantially equal attenuation a band of frequencies, while substantially suppressing frequencies lying without said band, and the reactance of the antenna functioning as a series impedance element of the last section of the filter.

In testimony whereof, I have signed my name to this specification this 17th day of August 1920.

HENRY W. ELSASSER.