July 10, 1928. 1,676,240

H. A. AFFEL

RADIO SIGNALING SYSTEM

Filed Aug. 31, 1922 2 Sheets-Sheet 1

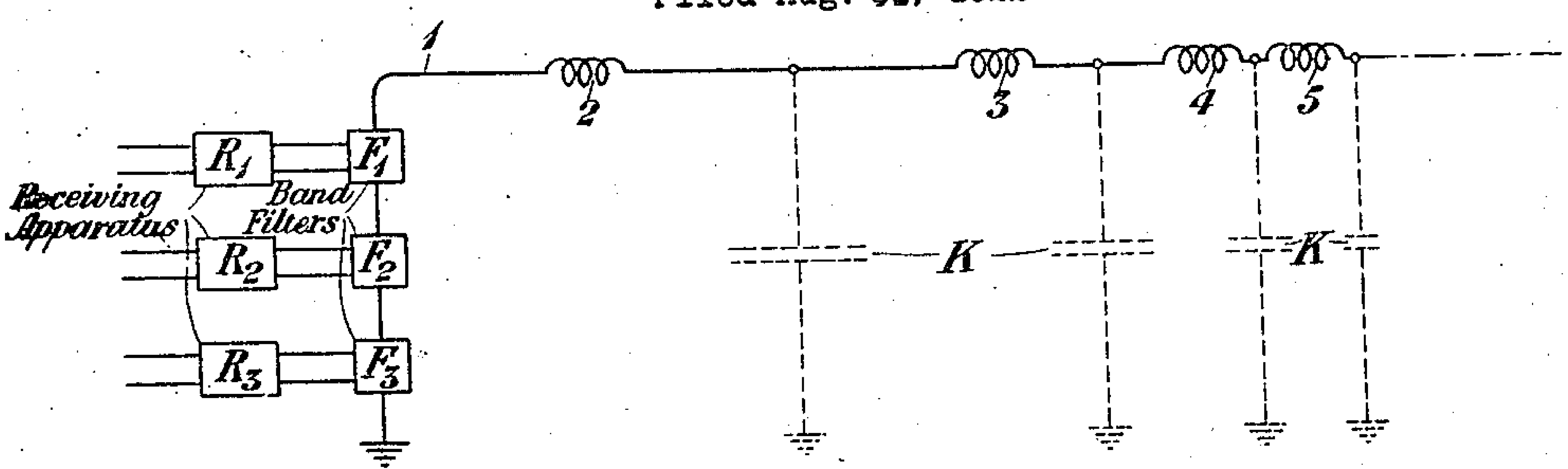

Fig. 1

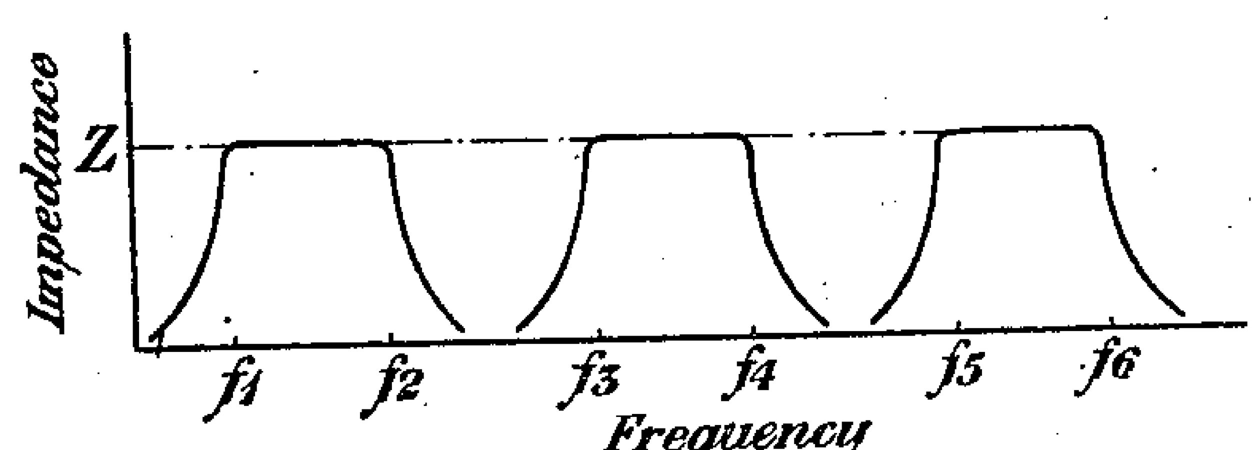

Fig 1a

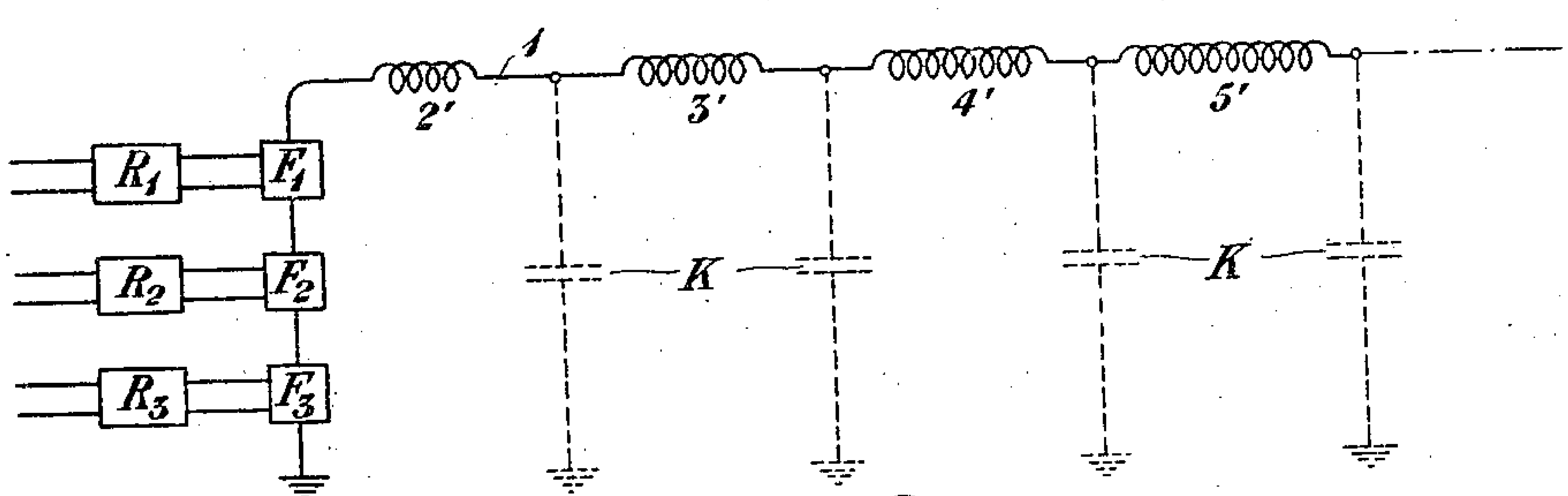

Fig. 2

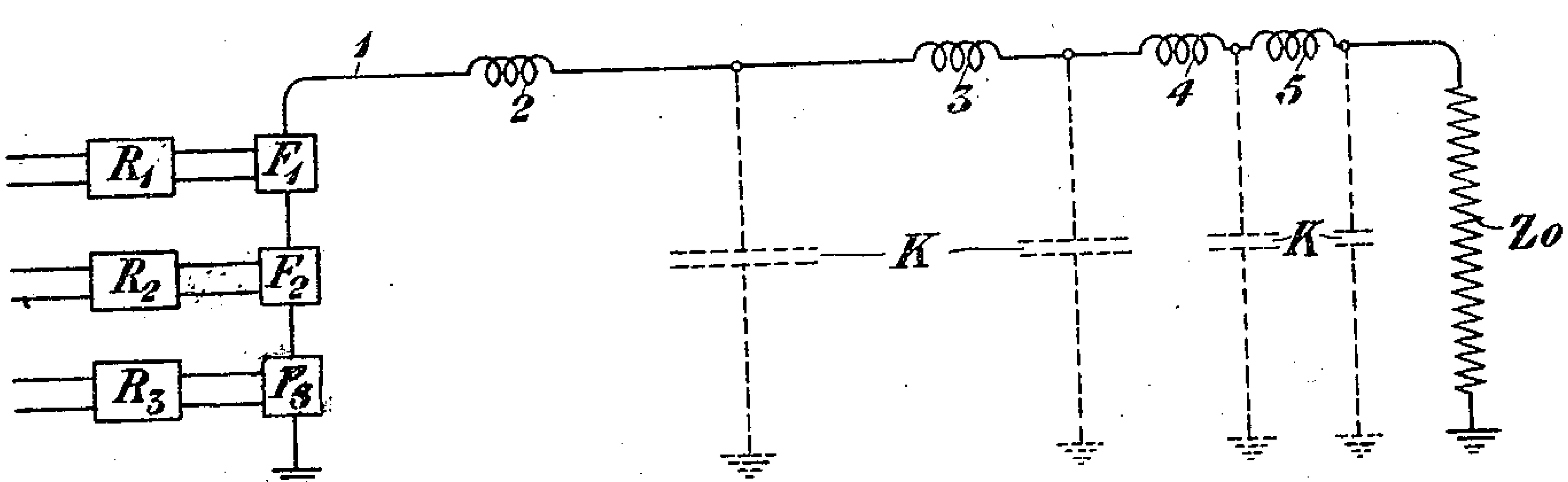

Fig. 3

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RADIO SIGNALING SYSTEM

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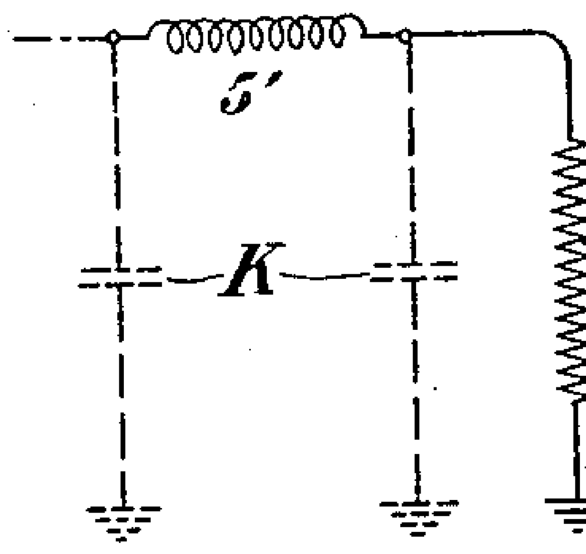

Fig. 4

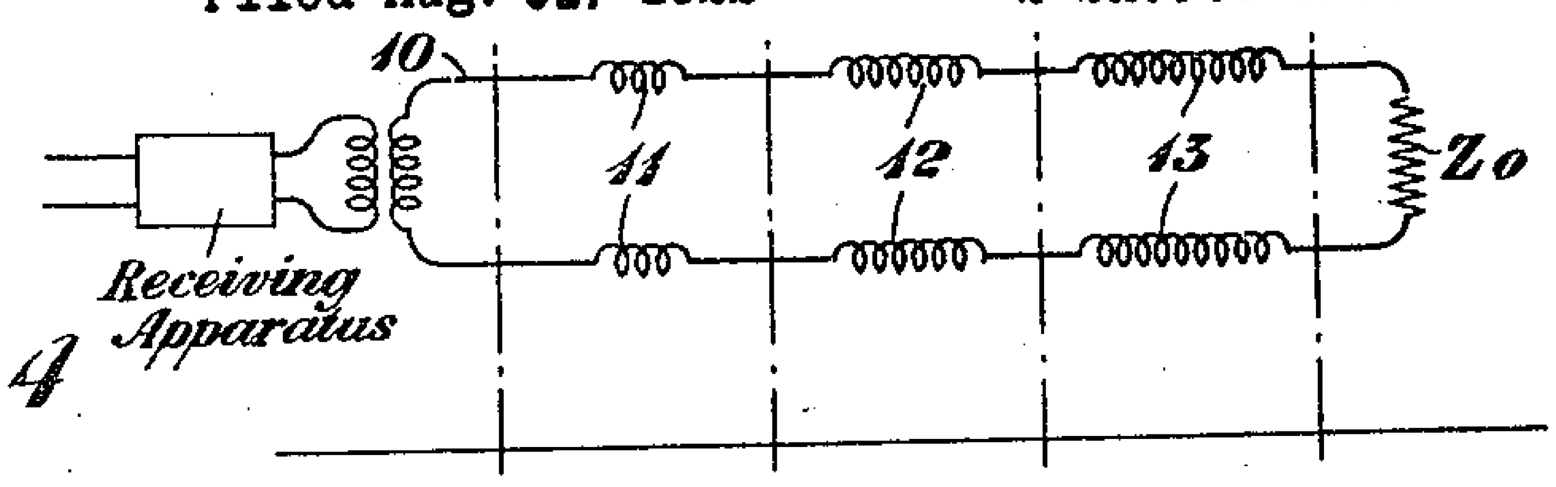

Fig. 5

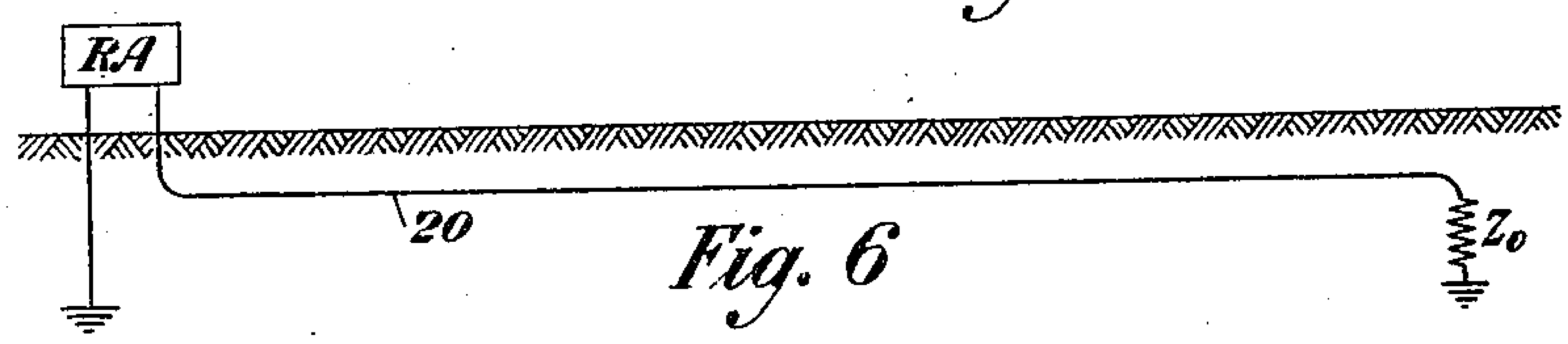

Fig. 6

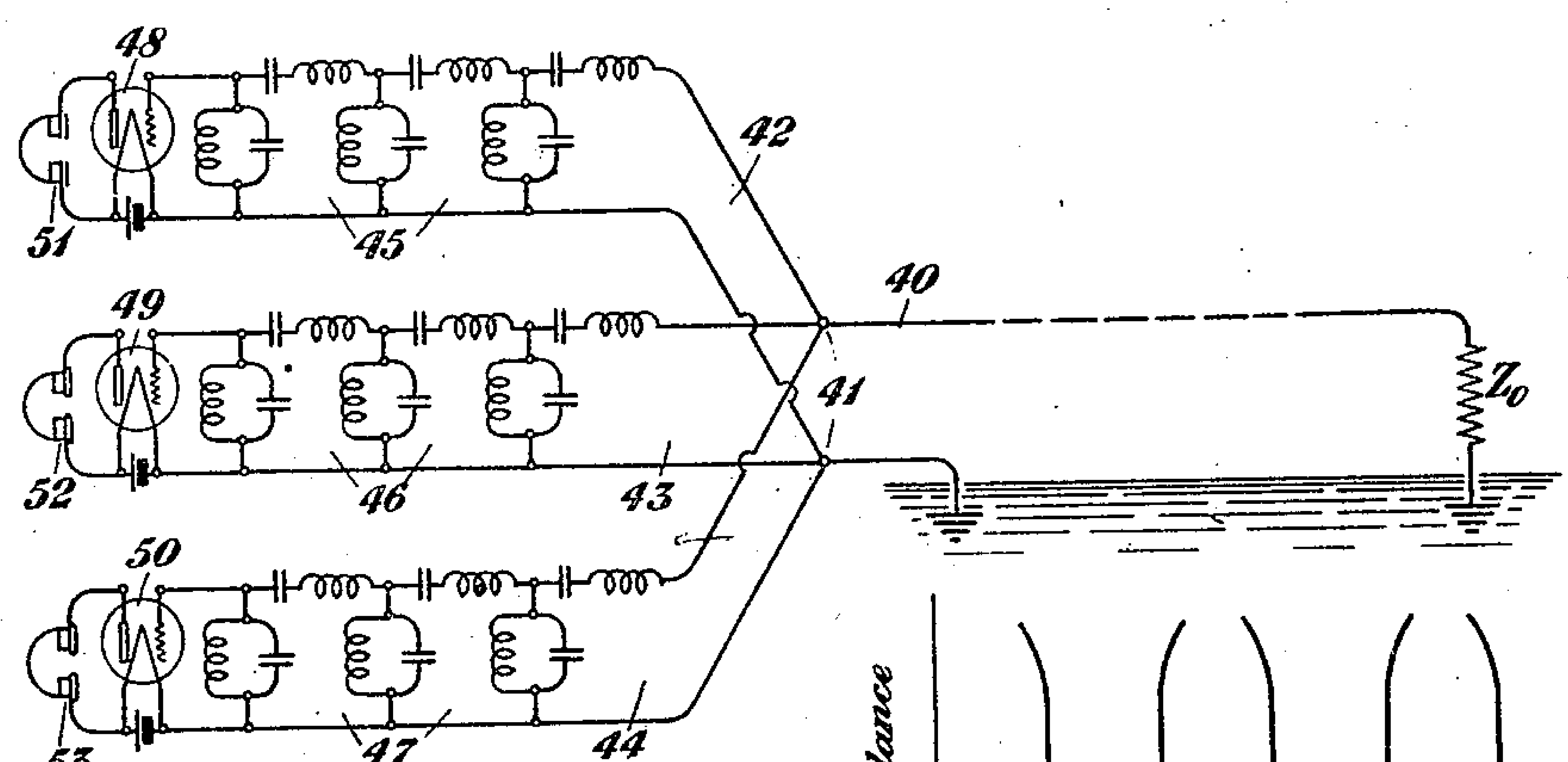

Fig. 7

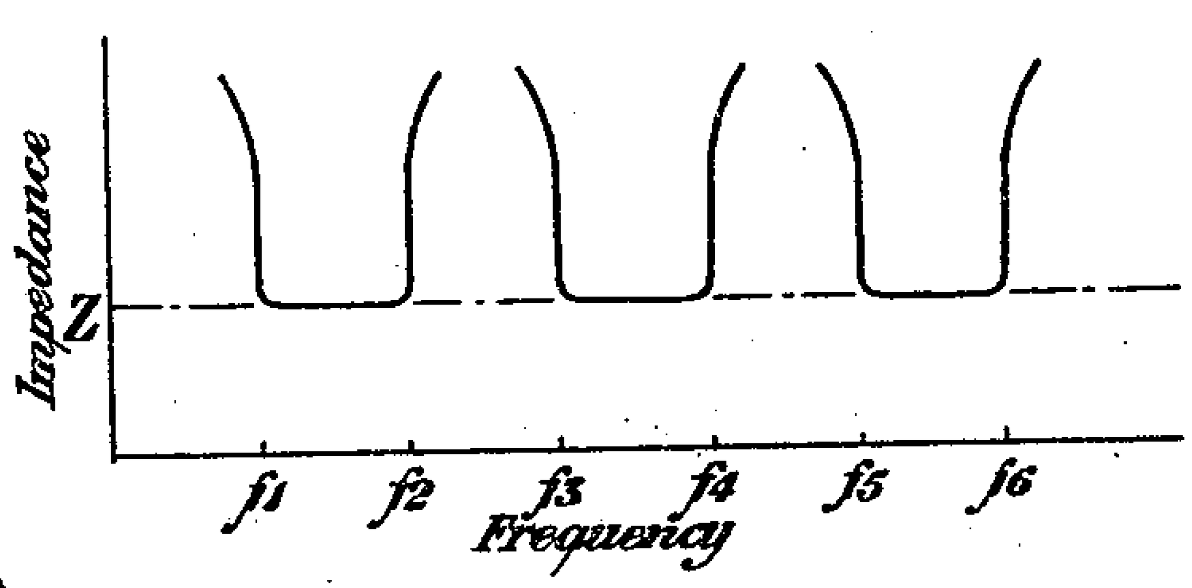

Fig. 7a

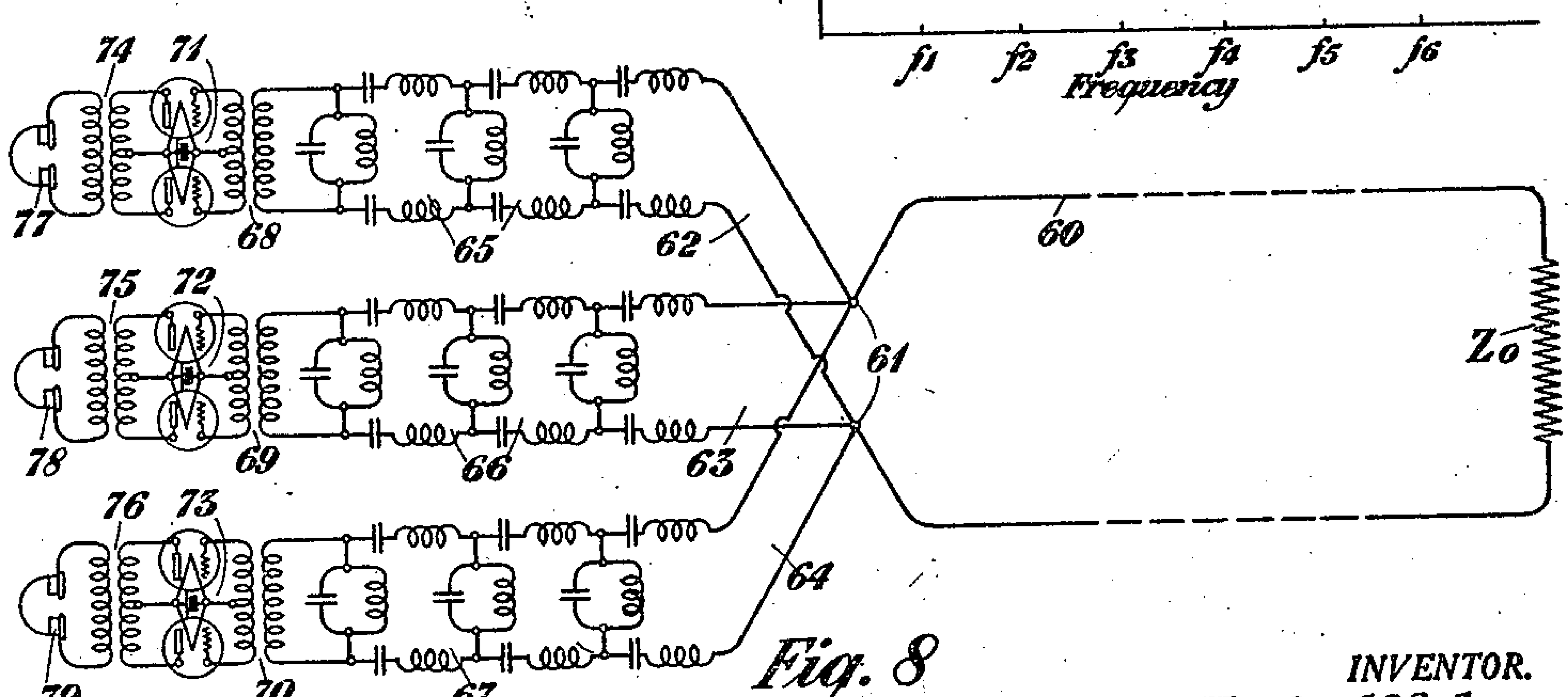

Fig. 8

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Patented July 10, 1928. 1,676,240

UNITED STATES PATENT OFFICE.

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RADIO SIGNALING SYSTEM.

Application filed August 31, 1922. Serial No. 585,435.

This invention relates to radio signaling systems, and particularly to methods for loading and terminating antenna structures in order to minimize the losses and therefore to increase the efficiency of such structures.

As is well known to those familiar with the art, various types of loaded antenna structures have been proposed, substantially all of which have had in view the object either of tuning the antenna for a particular frequency or of making it adapted to transmit more efficiently a particular band of frequencies. An arrangement adapted to attain the first of the above mentioned objects is disclosed in the patent to Latour 1,317,025, dated September 23, 1919. An arrangement for attaining the second object is disclosed in the patent to Espenschied 1,353,735, dated September 21, 1920. In both of these patents and in all the prior art known to me, the inductance with which the antenna is loaded has been distributed uniformly or at uniform intervals throughout the length of the antenna. It is one of the objects of my invention to provide a tapered loaded antenna in which the inductance is located either actually, or in effect, at unequal intervals throughout the length of the antenna, thereby diminishing the losses introduced by the reception of signals in such antennæ.

Another object of my invention consists in terminating a tapered loaded antenna by means of a grounded network consisting of pure resistance, which simulates electrically the surge impedance of the antenna structure. This results in the diminution of reflection losses in an antenna of this type.

A further object of my invention consists in combining a tapered loaded antenna having a broad band characteristic with a plurality of receiving circuits so as to provide for multiplex operation, the connection between the antenna and the receiving circuits being such as to afford minimum impedance to all frequencies except those intended for the particular receiving circuit.

Other objects of this invention will be apparent from the following description when read in connection with the attached drawing of which Figure 1 shows a tapered loaded antenna in which equal inductances are spaced at progressively decreasing intervals apart in the direction toward the normally open end of the antenna; Fig. 1^a shows the impedance-frequency characteristic of the filter arrangement shown in Fig. 1; Fig. 2 shows an antenna of similar type in which unequal inductances are spaced at equal intervals apart in the direction toward the open end of the antenna; Fig. 3 shows the combination with a tapered loaded antenna, such as is shown in Fig. 1, of a terminating network equal to the surge impedance of the antenna structure; Fig. 4 shows a similar network adapted for connection with the antenna shown in Fig. 2; Fig. 5 shows a loop antenna of the tapered loaded type terminated by an impedance as in Figs. 3 and 4; Fig. 6 shows an underground antenna terminated by an impedance, which antenna may be loaded in the manner shown in Figs. 1 and 2; Fig. 7 shows a long horizontal antenna, which may be loaded and terminated as shown in the preceding figures, and which has a plurality of receiving circuits connected therewith in parallel, instead of in series, as shown in Figs. 1 and 2; Fig. 7^a shows the impedance-frequency characteristic of the filter arrangement shown in Fig. 7; and Fig. 8 shows a similar arrangement of terminal circuits for a loop antenna circuit.

In Fig. 1, 1 represents an antenna of the L type, which is grounded at what may be termed its "near" end through a plurality of band filters F_1, F_2, F_3. The antenna 1 has connected therewith a plurality of inductance coils 2, 3, 4 and 5, which are preferably of the same magnitude. The condensers, which are shown by dotted lines and indicated "K" are intended to represent the capacity of the antenna to ground. The inductances 2, 3, 4 and 5 are spaced at progressively decreasing distances apart in the direction from the near end of the antenna toward the distant end. The spacing of these inductances should preferably be in accordance with a decreasing geometrical progression; but I do not wish to limit my invention to any particular type of mathematical progression, because other forms will render practicable a satisfactory structure. Since the capacity between the antenna and ground is uniformly distributed throughout its length (assuming uniform separation), the combination of an inductance with the shunt capacity forms a series of networks of increasing impedance in the direction from the near end of the antenna toward the distant end, thereby producing an antenna structure having relatively low impedance characteristics, looking from the near end, and high impedance characteristics when viewed from the distant end. With such an antenna, if the distant end is left open, less irregularity will be introduced at the near end, to which the terminal circuits are connected, than with an antenna in which the loading is uniformly distributed or uniformly lumped throughout its length. Such an antenna will therefore have substantially constant impedance to correspond to the impedance of a plurality of individual selecting circuits that may be connected to it for multiplex operation.

Connected with the filters F_1, F_2, F_3 are the circuits having associated therewith receiving apparatus designated R_1, R_2, R_3 respectively. Since the filters are in series, it is desirable, for efficient operation, that each of the filters shall offer a minimum impedance to all frequencies outside the range that they are designed to transmit to their respective receiving apparatus. This is made clear by Fig. 1ᵃ, which shows the impedance-frequency characteristic of such group of filters. Filter F_1, which is designed to transmit to the receiving apparatus R_1 a band of frequencies lying between f_1 and f_2, will have an impedance Z for all frequencies lying between f_1 and f_2, but will have substantially less impedance for the frequencies outside this range. The filter F_2, which transmits the band of frequencies between f_3 and f_4, and the filter F_3, which transmits the band between f_5 and f_6, likewise have an impedance Z for all frequencies within their respective bands, but substantially no impedance for the frequencies outside their band. By means of a tapered loaded antenna having a broad band characteristic such as to transmit readily frequencies lying between f_1 and f_6, and having connected therewith a plurality of filters having the characteristics shown in Fig. 1ᵃ, it is possible to effect multiplex operation with the minimum of loss is signaling efficiency.

Another form of tapered loaded filter is shown in Fig. 2. It differs from the arrangement shown in Fig. 1 in that the inductances 2′, 3′, 4′ and 5′ are spaced along the antenna 1 at equal intervals. These inductances, however, are not equal in magnitude, but are designed to have increasingly greater magnitudes in the direction from the near end of the antenna toward the distant end. This is shown in the drawing by an increasing number of turns or convolutions of the succeeding inductances. While no definite rule can be laid down as to the magnitudes of succeeding inductances, since this is dependent upon the constants of the antenna structure, it should be understood that the impedance of succeeding subnetworks, viz, combinations of the inductance with the uniformly distributed capacities represented by K should increase uniformly in the direction from the near end toward the distant end of the antenna, so that such an antenna will have relatively low impedance when viewed from the near end and relatively high impedance when viewed from the distant end.

While antennæ may be constructed in accordance with the principles heretofore stated, which will tend to reduce the irregularity of impedance existing between the open end of the antenna and the ether, this irregularity cannot be entirely eliminated in the structures heretofore described. It is accordingly desirable to terminate a tapered loaded antenna, such, for example, as that shown in Fig. 1, by means of a network which has the same impedance as the characteristic impedance of the antenna which in this case would be the characteristic impedance of the end section. Such a mode of termination is shown in Fig. 3, in which the distant end of the antenna is terminated through an impedance Z_0, which is pure resistance. This is true because the characteristic impedance of a circuit, consisting of a long wire to ground, or a parallel pair of wires, has been found to be practically pure resistance with little or no reactance component when measured at high frequencies such as are used in radio signaling. Such a terminating network as the resistance Z_0 has the effect of prolonging the tapered loading so as to eliminate sharp irregularity between the end of the antenna and the ether, thereby reducing reflection losses.

A similar resistance, such as is shown in Fig. 4, may be used in connection with the tapered loading of the type shown in Fig. 2.

The application of the foregoing principles to a loop antenna is shown in Fig. 5, in which the inductances 11, 12 and 13 of unequal magnitude are spaced at equal distances apart throughout the length of the antenna 10. The distant end of the antenna is terminated by a resistance Z_0 equal to the characteristic impedance at high frequency of the antenna. Receiving apparatus may be coupled or otherwise connected with the antenna 10 in the manner shown in the figure. Although this figure shows the application thereto of the type of tapered loading represented in Fig. 2, it is to be understood that the type shown in Fig. 1 is equally applicable to loop antenna structures. Fig. 6 represents an underground antenna 20, having receiving apparatus RA connected at the near end thereof and the distant end terminated through the resistance Z_0. Although this is not represented as a loaded antenna, it is to be understood that the principles of loading shown in Figs. 1 and 2 may be applied to such type of antennæ. In Fig. 7, I have shown the parallel method of connecting the terminal receiving circuits with the antenna structure as an alternative form of the series arrangement shown in Fig. 1. In this figure antenna 40, which may have any type of tapered loading, and which may or may not be terminated by the impedance Z_0, has connected at the points 41 a plurality of branch circuits 42, 43 and 44 which have connected therewith band filters 45, 46 and 47 respectively, to the distant ends of which are connected the vacuum tube devices 48, 49 and 50 respectively having associated therewith the receivers 51, 52 and 53 respectively. The said filters have the impedance-frequency characteristics as shown in Fig. 7ª. Thus filter 45, which is designed to transmit the band of frequencies lying between f_1 and f_2 will offer the minimum impedance for frequencies lying within this range, and the maximum impedance for frequencies without the range. These filters, it will be seen, have a different impedance-frequency characteristic from those shown in Fig. 1.

The arrangement shown in Fig. 8 is an expansion of the idea disclosed in Fig. 7 to loop antenna structures. In this figure the antenna 60, which may be loaded in accordance with the principles disclosed in Figs. 1 and 2, and may, if desired, be terminated through a resistance Z_0, has connected across the terminals 61 a plurality of branch terminal circuits 62, 63 and 64, which have associated therewith band filters 65, 66 and 67 having the impedance frequency characteristics shown in Fig. 7ª. These filters are coupled by transformers 68, 69 and 70 respectively with the balanced detecting devices 71, 72 and 73 respectively, which, in turn, are coupled to the receivers 77, 78 and 79 respectively by means of the transformers 74, 75 and 76 respectively.

It will accordingly be seen that my invention, as disclosed in the foregoing description and in the drawing, consists not only in the application of tapered loading to an antenna structure, but also in the combination of an antenna of this type with a terminating network, consisting of pure resistance and simulating electrically the surge impedance of such antenna structure. Furthermore, my invention comprises the combination of the foregoing elements together with receiving circuits connected with the antenna structure in such manner as to afford the minimum impedance to currents of frequencies other than those which are intended to be impressed upon a particular branch terminal circuit.

Although this invention has been disclosed as embodied in particular forms and arrangements of the parts, it is to be understood that it is capable of embodiment in other and different forms within the spirit and scope of the appended claims.

What is claimed is:

1. An antenna having inductances connected serially therein at predetermined points, the distance between successive inductances diminishing in the direction away from the point of a connection of terminal apparatus with the said antenna.

2. An antenna having inductances connected serially therein at predetermined points, the distances between successive inductances being in decreasing geometrical progression from the point of connection of the terminal apparatus with the said antenna.

3. An antenna having inductances connected serially therein at progressively decreasing intervals along said antenna in the direction away from the point of connection of the terminal apparatus with the said antenna.

4. In a radio signaling system, the combination with a loaded antenna adapted for connection with terminal apparatus, the said antenna having inductances connected serially therein at progressively decreasing distances away from the point of connection of the said terminal apparatus with the said antenna and a resistance simulating electrically the surge impedance of the said loaded antenna at its operating frequency connected across the normally open end of the said antenna.

5. In a radio signaling system, the combination with a loaded antenna having inductances connected serially therein at progressively decreasing distances from its near end toward its distance end of a resistance equal to the surge impedance of the said antenna, connected between the distant end of the said antenna and ground.

6. In a radio signaling system, the combination with a loaded antenna having inductances connected serially therein at progressively decreasing distances from its near end toward its distance end and having its distant end grounded through a resistance equal to the surge impedance of the said antenna, of a plurality of terminal circuits connected with the near end of the said antenna, the connecting means being such as to offer minimum impedance to currents of frequencies other than those intended for the circuit of the particular connecting means.

7. In a radio signaling system, the combination with a tapered loaded antenna having a plurality of inductances connected serially therein, of a plurality of terminal circuits connected therewith by means of series filters, the said filters being so designed as to offer minimum impedance to all frequencies other than those intended to be transmitted therethrough to the particular terminal circuit connected therewith.

In testimony whereof, I have signed my name to this specification this 29th day of August, 1922.

HERMAN A. AFFEL.