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HIGH FREQUENCY SIGNALING SYSTEM

Original Filed Dec. 15, 1922

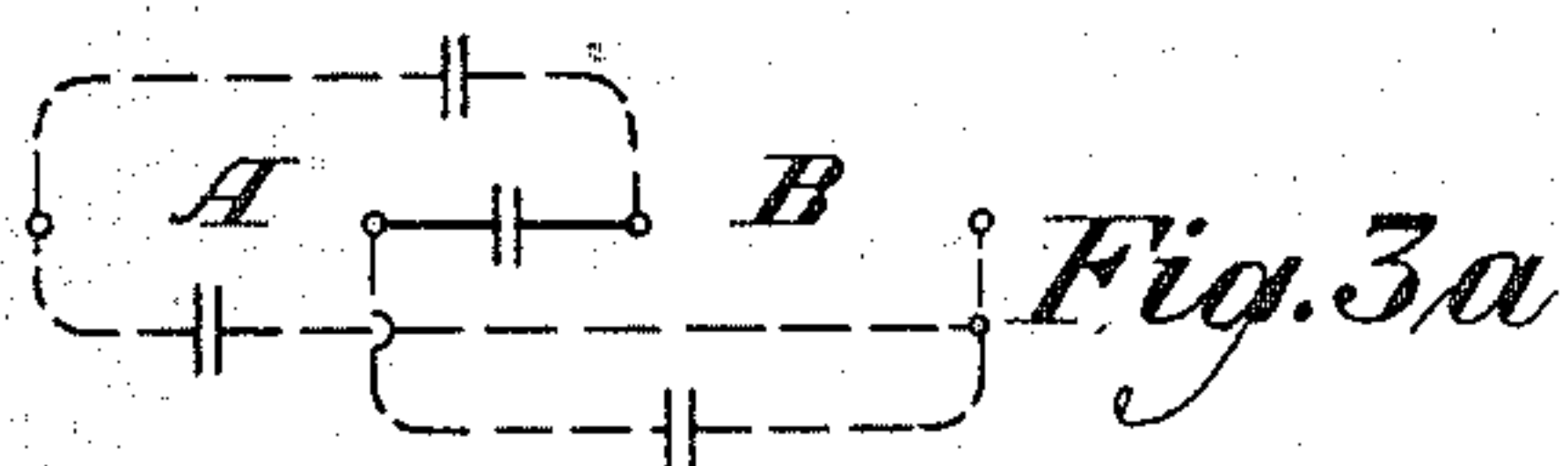
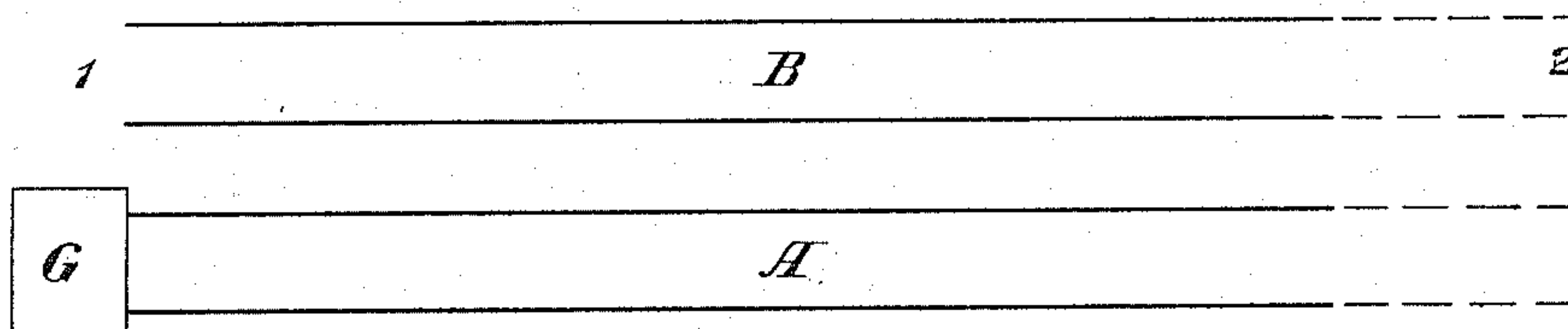
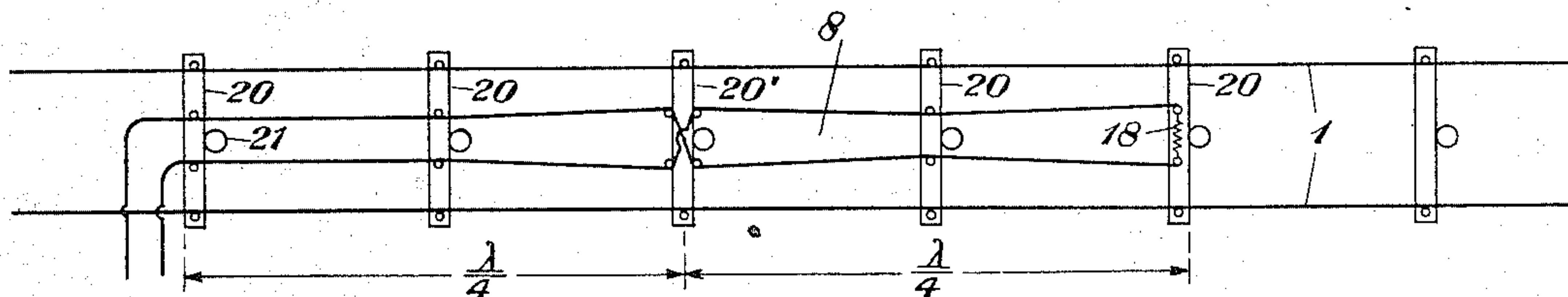
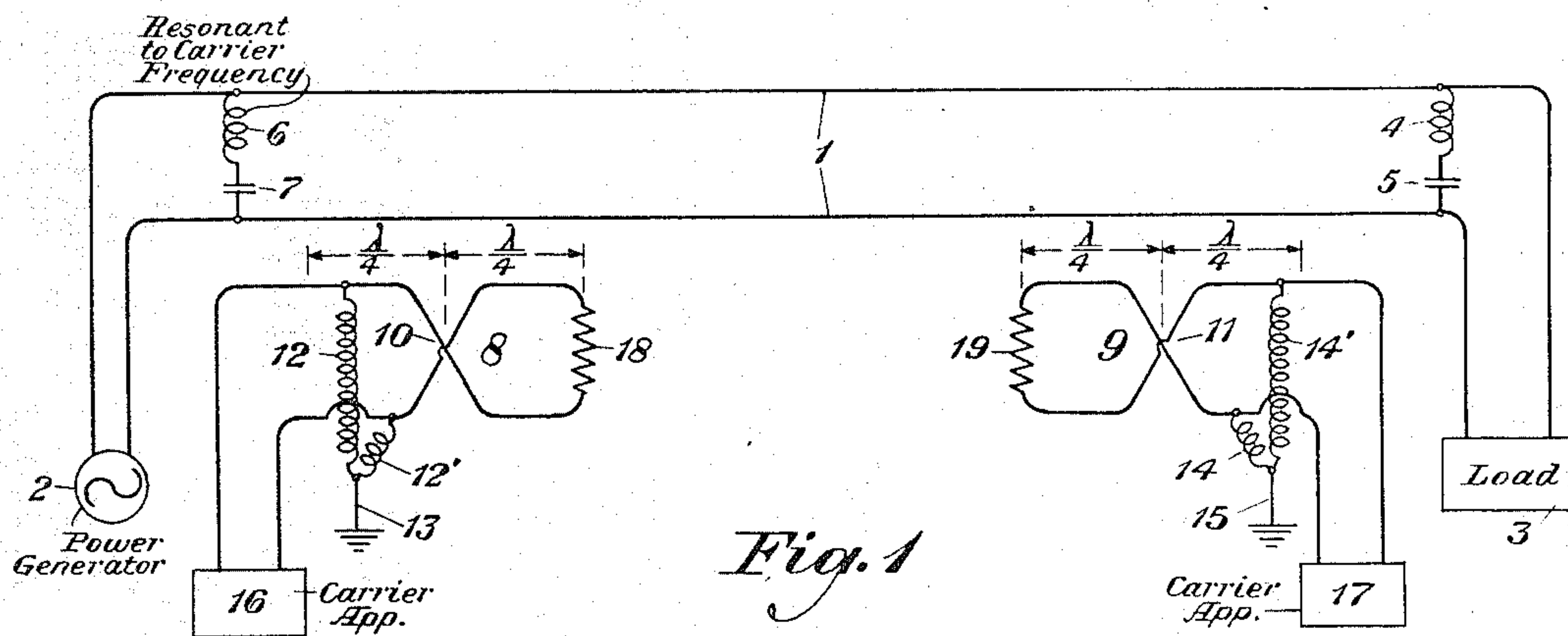
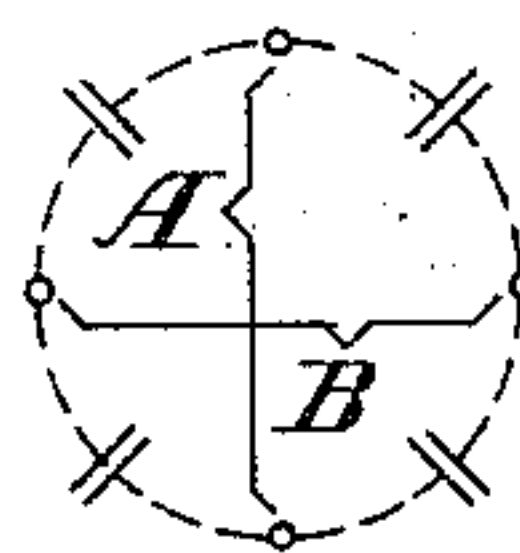
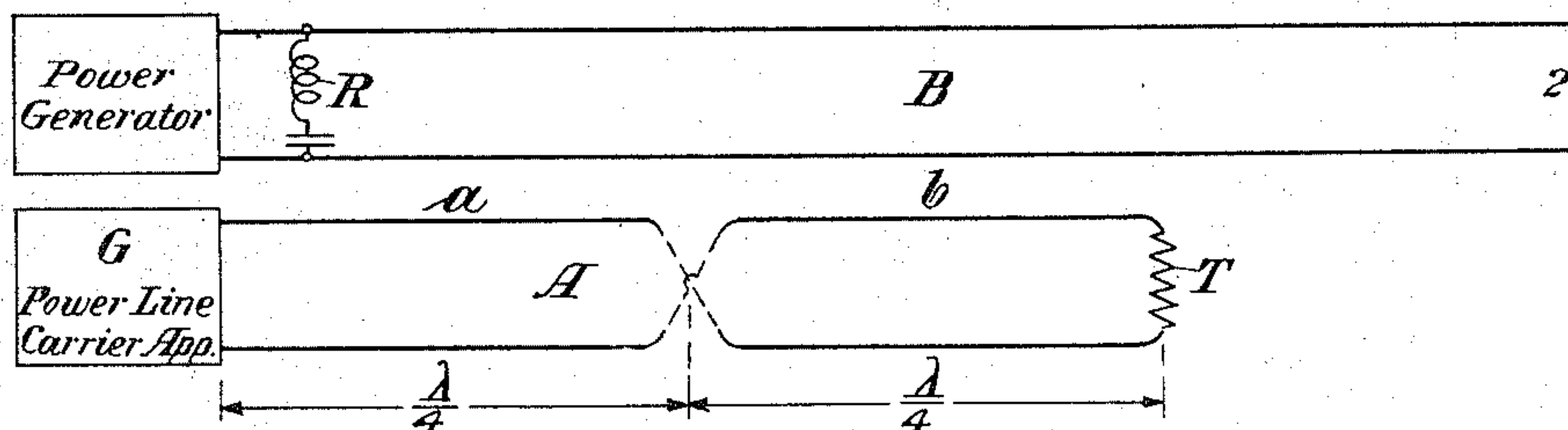


Fig. 3b



Wires crossed
Capacity Unbalance = 0
Also no mutual
inductance.



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HIGH FREQUENCY SIGNALING SYSTEM

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1927. Divided and this application December
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7 Claims. (Cl. 177—352)

This invention relates to high frequency signaling systems, and particularly to means for rendering such systems highly selective.

This is a division of the applicant's copending application Serial No. 607,193 filed December 15, 1922, which issued as Patent No. 1,615,896 on February 1, 1927.

In the development of the radio art, various methods and means have been disclosed, the object of which has been to increase the selectivity of signaling circuits. The best known of all methods consisted in sharply tuning the circuit so as to make it highly selective of the frequencies that it was desired to transmit or receive.

It is one of the objects of this invention to obtain greater selectivity in the antenna circuits themselves by employing long loop circuits and by transposing the conductors of the loop, which may be either a completely metallic circuit, or a partly metallic and partly grounded circuit, at intervals properly related to the wave length intended to be received.

Other objects of this invention will be apparent from the following description, when read in connection with the attached drawing of which Fig. 1 shows schematically the application of the invention to a system for transmitting carrier frequency signals over a power transmission line simultaneously with the transmission thereover of the power current; Fig. 2 is a plan view of a transmission line showing the relative position of the power line and the antenna; and Figs. 3, 3a, 3b and 4 illustrate the principle underlying the invention.

In Fig. 1 the power transmission line 1 has connected therewith a power generator 2 which would normally be of the low frequency type and at the distant end a load 3. Bridged across the line 1 near the right-hand end is an inductance 4 and a condenser 5, and similarly, near the left-hand end an inductance 6 and a condenser 7, the purpose of the said inductances and condensers being to provide, in effect, a low impedance short circuit of the line for the signaling carrier frequencies. Associated with this tuned section of the line near the left-hand end is a loop 8 having inserted therein a transposition 10 which in combination with the tuned circuit, if the loop is of the proper length, that is, one-half of the carrier wave length λ , and the transposition is located at the midpoint of the said loop, will render the transmission between the said loop circuit and the line highly selective to the carrier frequency and discriminatory to the power frequency. The loop 8 is terminated in a resistance 18 equal to the

characteristic impedance of the loop, for the purpose of avoiding undesirable reflection effects at the end of the loop which might negative the desirable effects that the loop is capable of producing. Bridged across the sides of the loop are the drainage coils 12 and 12' connected to ground by conductor 13, the object of which is to prevent currents set up by potentials induced between the loop circuit and ground from affecting the carrier apparatus connected with the loop circuit. This carrier apparatus which is designated 16 may be of any well-known type having means for detecting the signal superimposed on the carrier wave, and need not be particularly described here. A

similar loop 9 whose length also is $\frac{\lambda}{2}$ and which has a transposition 11 at its midpoint, is inductively related with the transmission line 1 at the other end of the tuned section of the said line. This loop circuit has bridged across its sides the coils 14 and 14' which are connected to ground by conductor 15. Carrier apparatus 17, preferably similar to 16, is connected with the said loop circuit for transmitting and receiving purposes.

The principle underlying this invention is briefly as follows: If the carrier apparatus 16 is transmitting signals, the current set up in the transmission line 1 by the antenna 8 will be partly due to the mutual inductive relations between those circuits and partly due to the capacity unbalance relationships. The voltage in line 1 due to the mutual inductive effect manifests itself as a voltage induced serially in the line wires; the voltage due to the unbalance capacity effect manifests itself as a voltage across line wires. There are, furthermore, phase differences between those two voltages and also phase effects that depend upon the relation between the length of the line circuits and the frequencies employed. The resultant voltage is therefore a combination of those effects. The current wave resulting therefrom will tend to travel toward the terminals of the line 1. It has been found both by theory and practice that the current wave traveling toward the distant terminal of the line 1 tends to become substantially zero because the magnetic and capacitative effects referred to tend to oppose each other with little or no resultant effect. In the absence of the low impedance short circuit for the carrier frequencies comprising the inductances and condensers bridged across the line 1, the current wave would also tend to travel in the direction toward the generator 2. Furthermore, the current wave that flows in the transmission line toward the generator 2 is much larger than

the part that flowed toward the distant terminal since the conditions governing wave propagation and phase change are different in the two directions. That current would be absorbed by the power generator circuit if the latter had an impedance approximately equal to the characteristic impedance of the line circuit. I have found that this "near-end" current may be usefully employed in effecting transmission of signals to the distant terminal. That result is obtained by using the resonant shunt 6—7 that is tuned to the carrier frequency. That causes a reflection approaching in degree 100 per cent of the current that normally would flow to the generator 2. Furthermore, the transposing of the loop 8 substantially increases the "near-end" current in the line 1 which, as pointed out, is reflected to the distant terminal. If the loop 8 is one-half of the length of the carrier wave and is transposed at its midpoint, a substantial increase in the "near-end" current takes place that greatly increases the effectiveness of transmission of the system.

The physical relation of the loop antenna and the power line is shown, in simple form in Fig. 2, in which the conductors of the power line 1 are supported by insulators on pins at the extremities of the crossarms 20 upon the poles 21. The loop antenna 8 comprises the conductors 22 supported by insulators on pins near the midpoint of each crossarm, which conductors are parallel to those of the power line. As previously mentioned, the total length of the loop equals $\lambda/2$, where λ is the length of the carrier wave, and is transposed at its midpoint, viz, at crossarm 20'. Bridged across the conductors at their right-hand end is the resistance 18, which may be supported in a housing (not shown) attached to the crossarm or pole. The left-hand ends of the conductors are connected by suitable leads to the carrier transmitting and receiving apparatus located at the terminal station. Other variations are obvious. The antenna need not be in the same plane as the conductors of the power line, since the former may be above or below the latter.

It will be apparent from the foregoing description of the arrangement shown in Fig. 1 that the loop circuits with which the carrier frequency receiving and transmitting apparatus is associated and inductively related with the power line, permit the modulated signals to be transmitted from the loop circuits to the tuned section of the power line by virtue of the inductive relationship existing between them. These loop circuits, or short inducing lines, should be transposed in such manner that the potentials induced by the power energy will tend to balance out by virtue of the relatively low frequencies and relatively small phase change involved, but the carrier frequencies will be efficiently transferred in both directions between the power lines and the short inducing lines 8 and 9, due to their considerably greater phase change.

The manner by which those results are accomplished will be clearly understood from the following description when read in connection with Figs. 3, 3a, 3b and 4 that illustrate the basic principles underlying the invention.

If we take two paralleling line circuits in proximity, such as shown in Fig. 3 of the drawing, and apply to circuit A a voltage from generator G, current will be induced in circuit B. This current will be partly the result of the mutual inductive relations between the two circuits and partly because of capacity unbalance relationships, i. e., the capacitance between the

wires concerned will be dissymmetrical, as shown in Fig. 3a, for the wires will not be at equal distances from one another. These effects will be true for practically any disposition of the two pairs with respect to one another with a few exceptions, such as the case, shown in Fig. 3b, where the two pairs are crossed.

That voltage which is induced in circuit B from circuit A, due to the mutual inductive effect, manifests itself as a voltage induced serially in the line wires. That resultant voltage which is due to the unbalance capacity effects, manifests itself as a voltage applied across the line wires. Furthermore, there are phase differences between these two voltages. There are also phase effects because the line circuits may be of such a length as to represent fractions of or perhaps even many wave lengths for the frequencies concerned. This is particularly true of the high frequencies which are used in power line carrier transmission work. The resultant induced voltage and current in the circuit, such as B from circuit A, is therefore a combination of these several effects. It has been noted by theory and practice that under these conditions, that current which tends to travel toward terminal 2 of circuit B, or what, in telephone practice, is called a "far-end crosstalk", tends to be substantially zero, because the magnetic and capacitative effects referred to above tend to oppose each other with little or no resultant effect. This is true, even though in circuit A transpositions are applied, at which points the line wires of the circuit are crossed.

Therefore, if circuit B is considered as a power line, and circuit A a loop circuit which is erected to parallel the power line B for the purpose of inducing currents from a power line carrier system connected at G, and if the other terminal of the power line carrier system is in the direction of 2, very little current from the power line carried system will reach the further terminal.

However, the current induced in circuit B from circuit A must not only be considered from the standpoint of its far-end effects, as noted above, but also in the direction backward toward the generator circuit. Under these conditions, the wave propagation and phase change effects are such that the situation differs from the far-end effect noted above. A much larger near-end induced current or crosstalk exists. This current would, however, be absorbed in the power generator circuit itself, if the latter had an impedance approximately equal to the characteristic impedance of the power line circuit. For the purpose of making this near-end current effective in the carrier transmission, however, a short circuit in the form of the resonant circuit R is applied, effective for the carrier frequency, as shown in Fig. 4. Therefore this current is reflected to a degree approaching 100 per cent, and reverses its direction to be transmitted to the desired terminal 2. Furthermore a very substantial increase in the near-end current induced in circuit B occurs when the inducing circuit A is transposed at distances which are one-quarter wave length apart for the carrier frequency. In other words, if the carrier frequency employed were 100,000 cycles or 3000 meters, and if the inducing line A were made 1500 meters in length, and if the transposition point is made in the middle of this inducing line, a substantial increase in the near-end induced current will take place. This, in turn, by being reflected to the far end 2 will therefore greatly increase the ef-

fectiveness of transmission of the system. It has been estimated that this increase in effectiveness of transmission might be something the order of 10 to 1, an improvement which could very well mean the difference in success or failure of a system operated in this manner. The inducing circuit A in Fig. 4 is shown terminated in a resistance equal to its characteristic impedance T for the purpose of avoiding undesirable reflection effects at the end of the inducing wires which might void the desired effects noted above. This transposition applied in the inducing circuit is effective because of its relation to the carrier wave length, not only in increasing the inductive effects between the two circuits, but also because the power generating wave length is so much longer it greatly decreases the voltage induced in circuit A from the power line itself.

While, as noted above, the theory underlying the inductive effects between two circuits including both the magnetic and capacitive components of the induced currents is rather complicated, and not particularly simple of explanation, especially in the case of far-end effects where the two components tend to cancel each other, it is not difficult to see why the near-end effects are increased by the addition of a transposition in the inducing circuit as noted above. For this purpose one might consider the current induced at the near end of circuit B, where the short circuit is applied, to be the combined effects of currents induced from the two sections of the inducing circuit *a* and *b*, respectively. If the current induced from section *a* at point R is regarded as of unit magnitude and zero phase, then the average current induced from section *b* will return to point R at a lagging phase of $\lambda/2$ or 180° . This is because there will be a lag of 90° in transmission from the generator to section *b*, and 90° more in returning the same length of circuit over the power line. The combined effect at point R will therefore tend to be zero, because of the annulling effect of the currents at 180° phase displacement. On the other hand, it is obvious that if a transposition is applied at the center of the inducing circuit, that current which is the result of induction from section *b* of the inducing line A will return in phase with the current induced from *a*, and therefore the two will add, and the effects will be substantially improved, as noted above.

Although this invention has been described as embodied in a particular form and arrangement of 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. In a high frequency signaling system, the combination with a power transmission circuit of means connected across the said circuit to pro-

vide low impedance paths to a frequency differing from the power frequency, loop circuits in inductive relation with the said transmission circuit and transposing means to render the said loop circuits selective to the said different frequency.

2. In a high frequency signaling system, the combination with a power transmission circuit of means connected across the said circuit to provide low impedance paths to a frequency differing from the power frequency, loop circuits in inductive relation with said transmission circuit, the said loop circuits being in length equal to a definite fraction of the length of the wave of the said different frequency and being transposed at their midpoints to render them selective to the said different frequency.

3. In a high frequency signaling system, the combination with a transmission line capable of transmitting a plurality of frequencies of a shunt across the sides of the said line providing a low impedance path for a certain frequency, and a transposed loop coupled with the said line responsive to the said certain frequency.

4. In a high frequency signaling system, the combination with a transmission line capable of transmitting a plurality of frequencies of a shunt across the sides of the said line providing a low impedance path for certain of said frequencies and a loop coupled with the said line, the said loop being in length equal to one-half that of the wave of the said certain frequency and being effectively transposed at its midpoint.

5. In a high frequency signaling system, the combination with a transmission line capable of transmitting a plurality of frequencies of shunts across the sides of the said line, providing low impedance paths for a certain frequency, and a transposed loop coupled with the said line responsive to the said certain frequency.

6. In a high frequency signaling system, the combination with a power transmission line capable of transmitting currents of a power frequency and a carrier frequency, of a loop coupled with the said line, the said loop being transposed in such manner that the potentials induced by the currents of power frequency will tend to balance out in said loop but the carrier frequencies will be effectively transferred between said line and said loop and vice versa, and terminal apparatus connected to the said loop responsive to the said carrier frequency.

7. In a high frequency signaling system, the combination with a power transmission line capable of transmitting currents of a power frequency and a carrier frequency, of a loop coupled with the said line, the said loop being in length equal to one-half that of the wave to be set up in the said loop and also being effectively transposed at its midpoint, and terminal apparatus connected to the said loop responsive to the said carrier frequency.

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