Nov. 7, 1933. G. W. GILMAN 1,934,602

SELECTIVE ANTENNA CIRCUIT

Filed Oct. 6, 1932 2 Sheets-Sheet 1

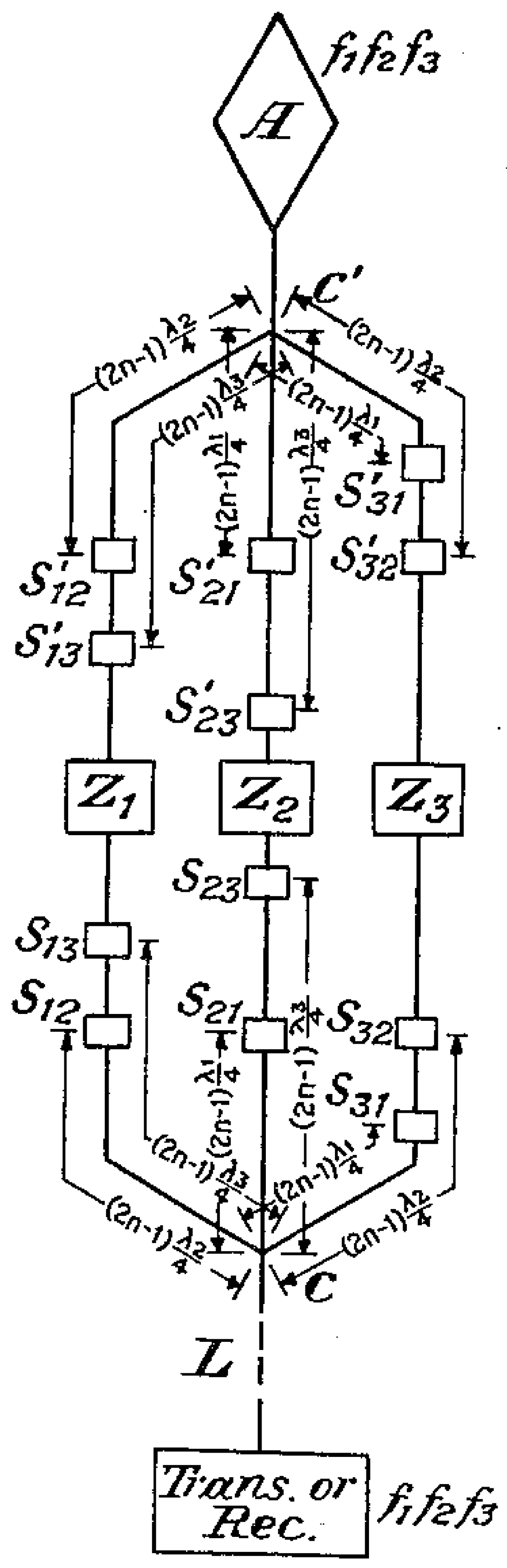

Fig. 1

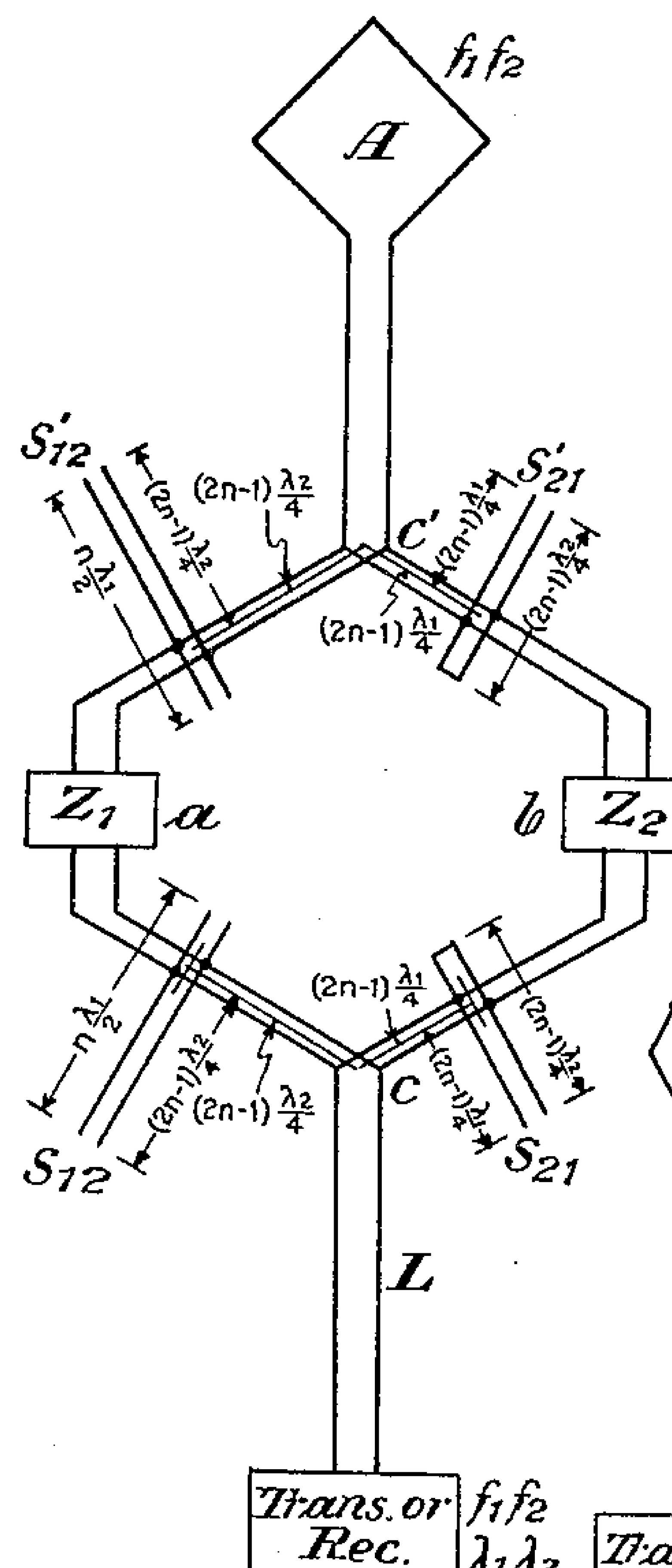

Fig. 2

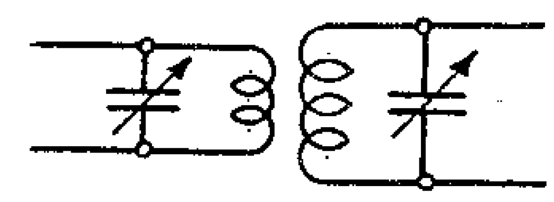

Fig. 3a

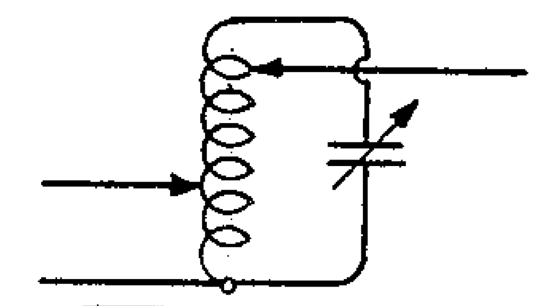

Fig. 3b

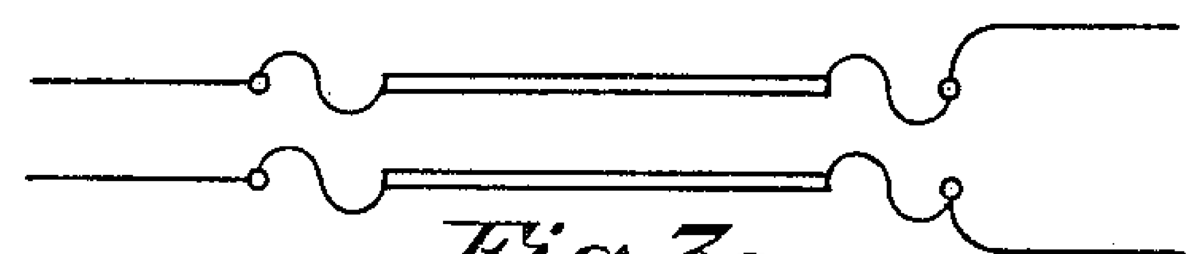

Fig. 3c

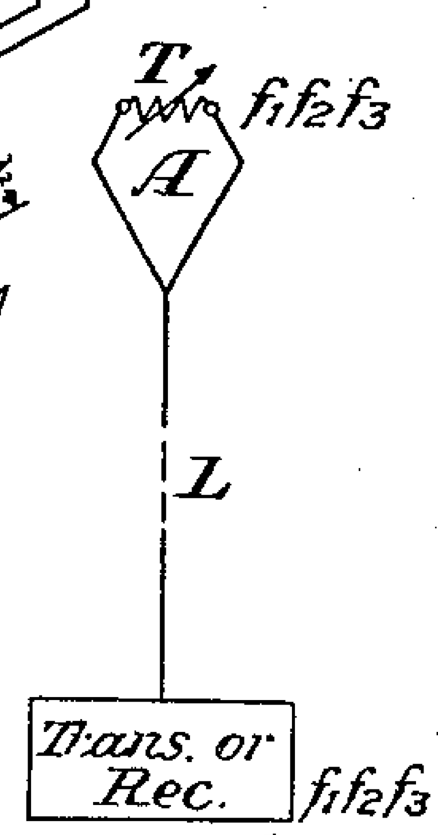

Fig. 4

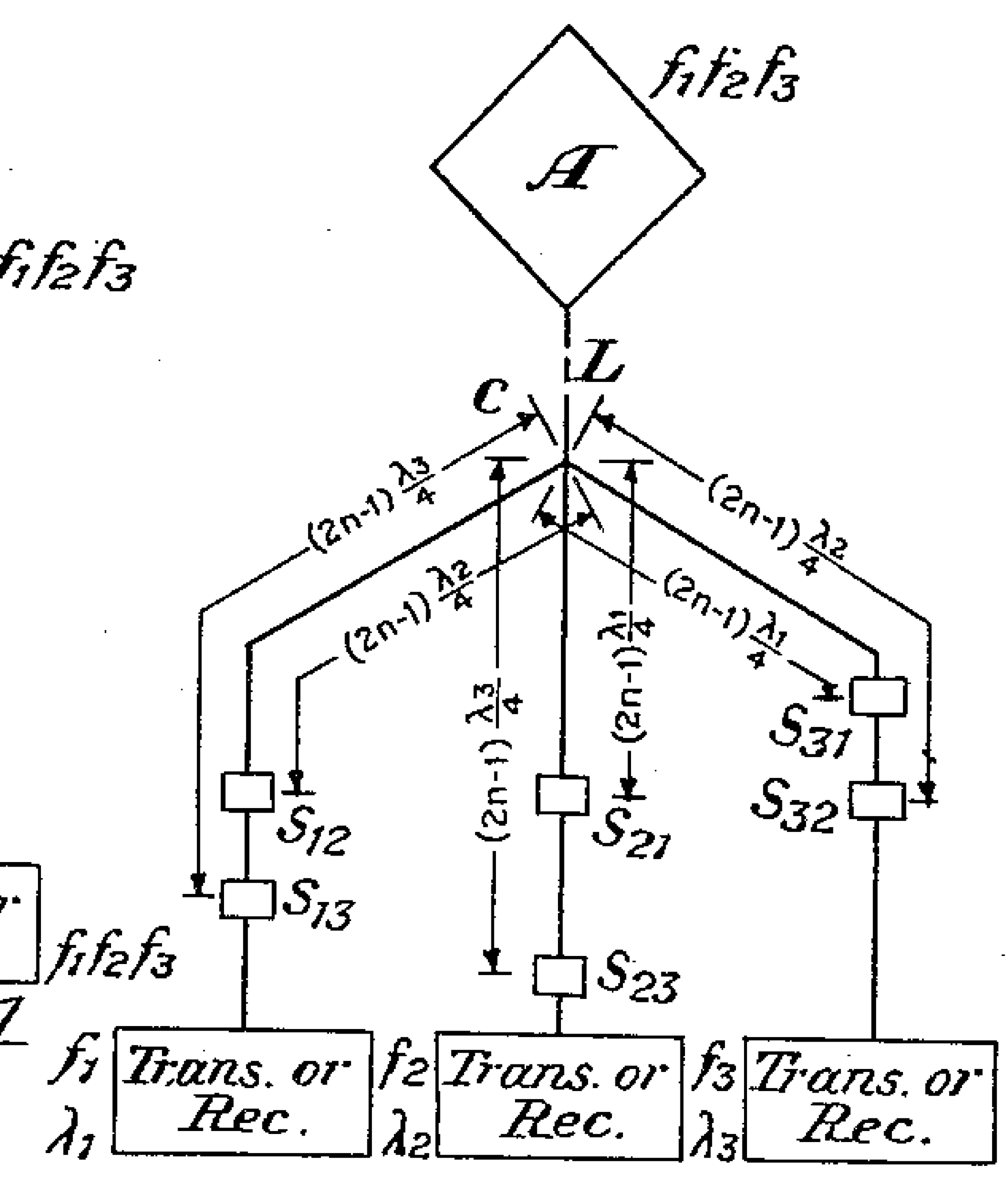

Fig. 7

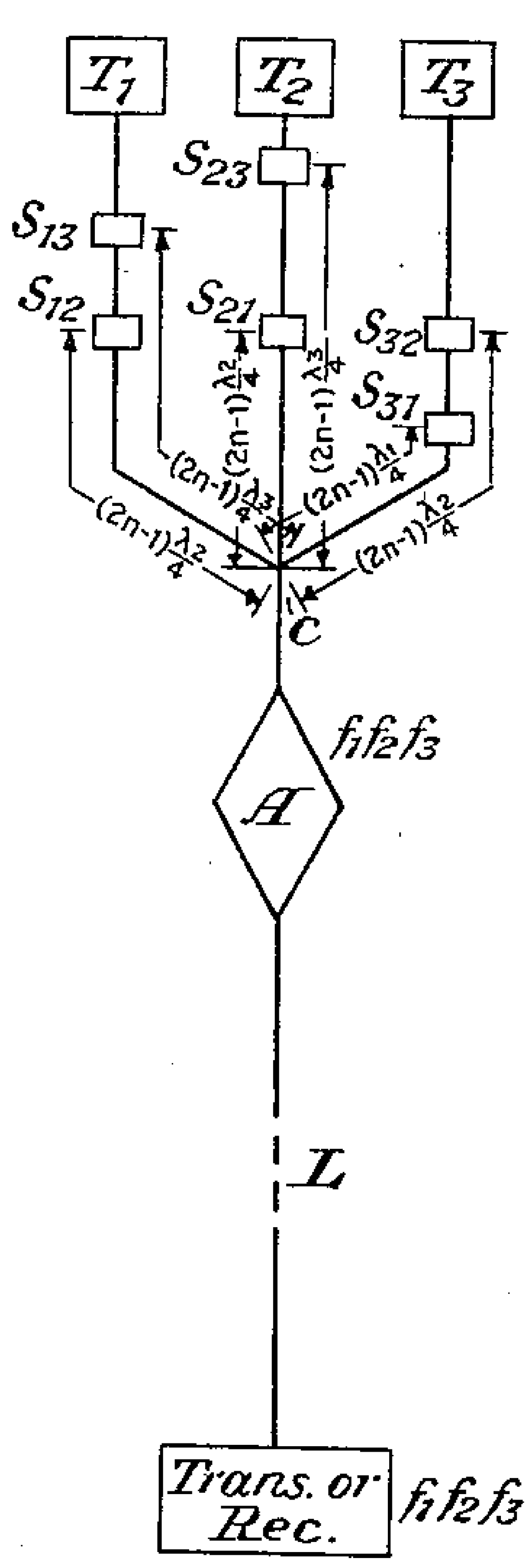

Fig. 5

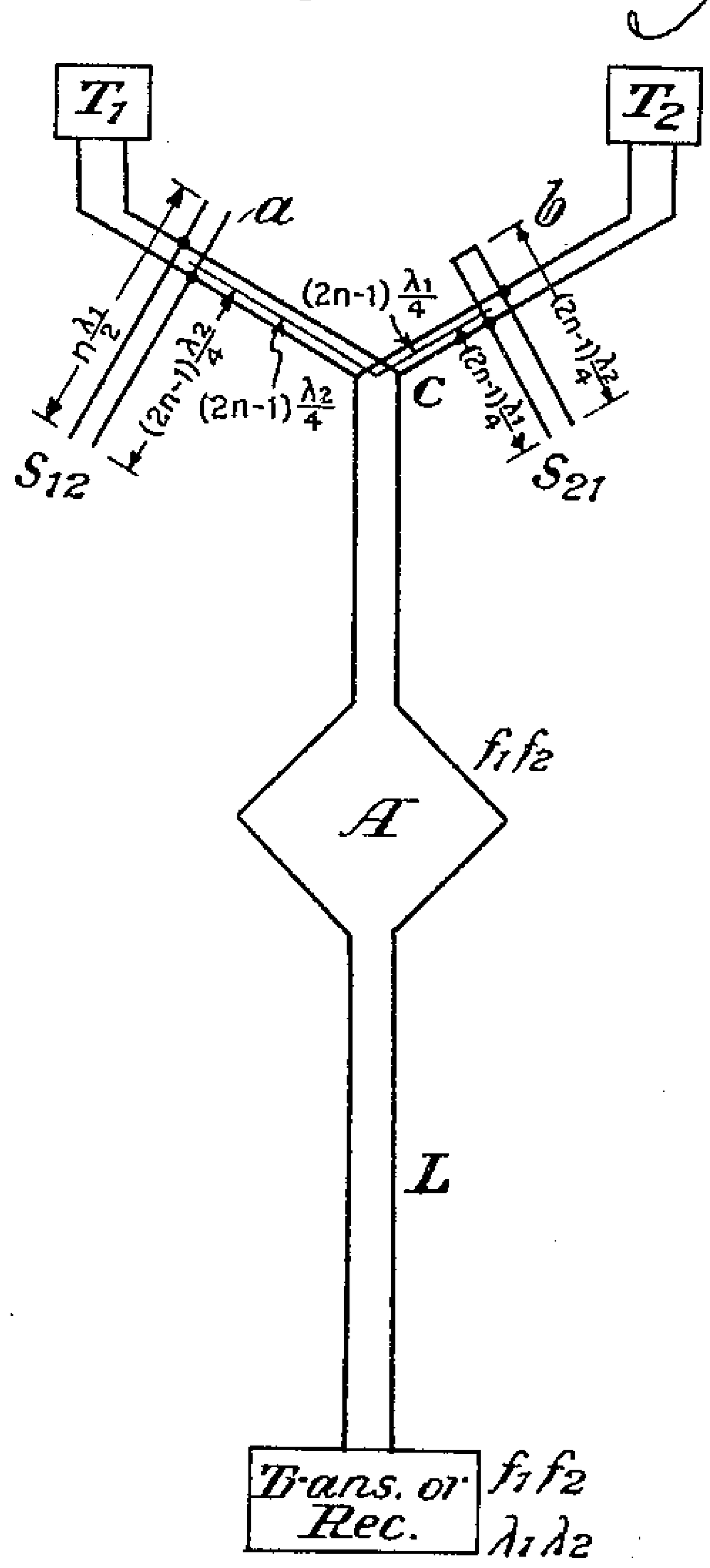

Fig. 6

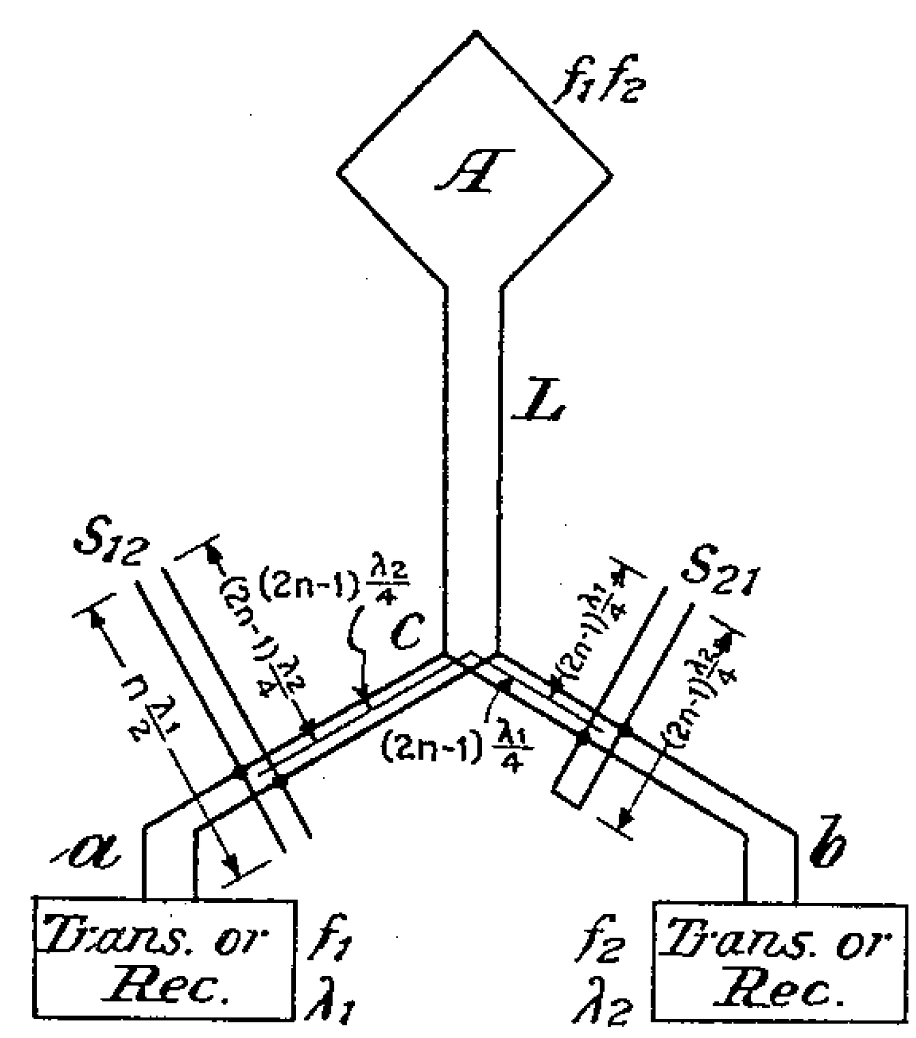

Fig. 8

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SELECTIVE ANTENNA CIRCUIT

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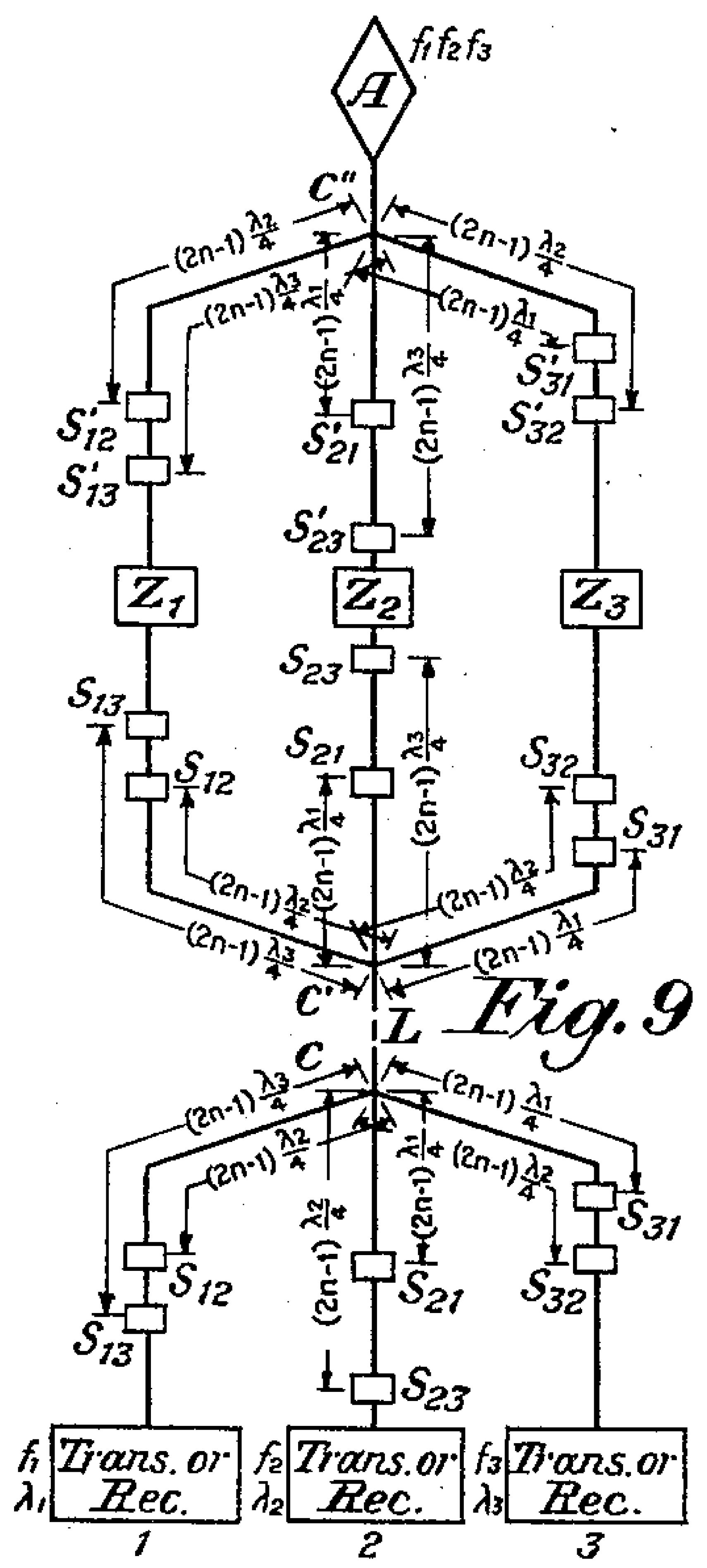

Fig. 9

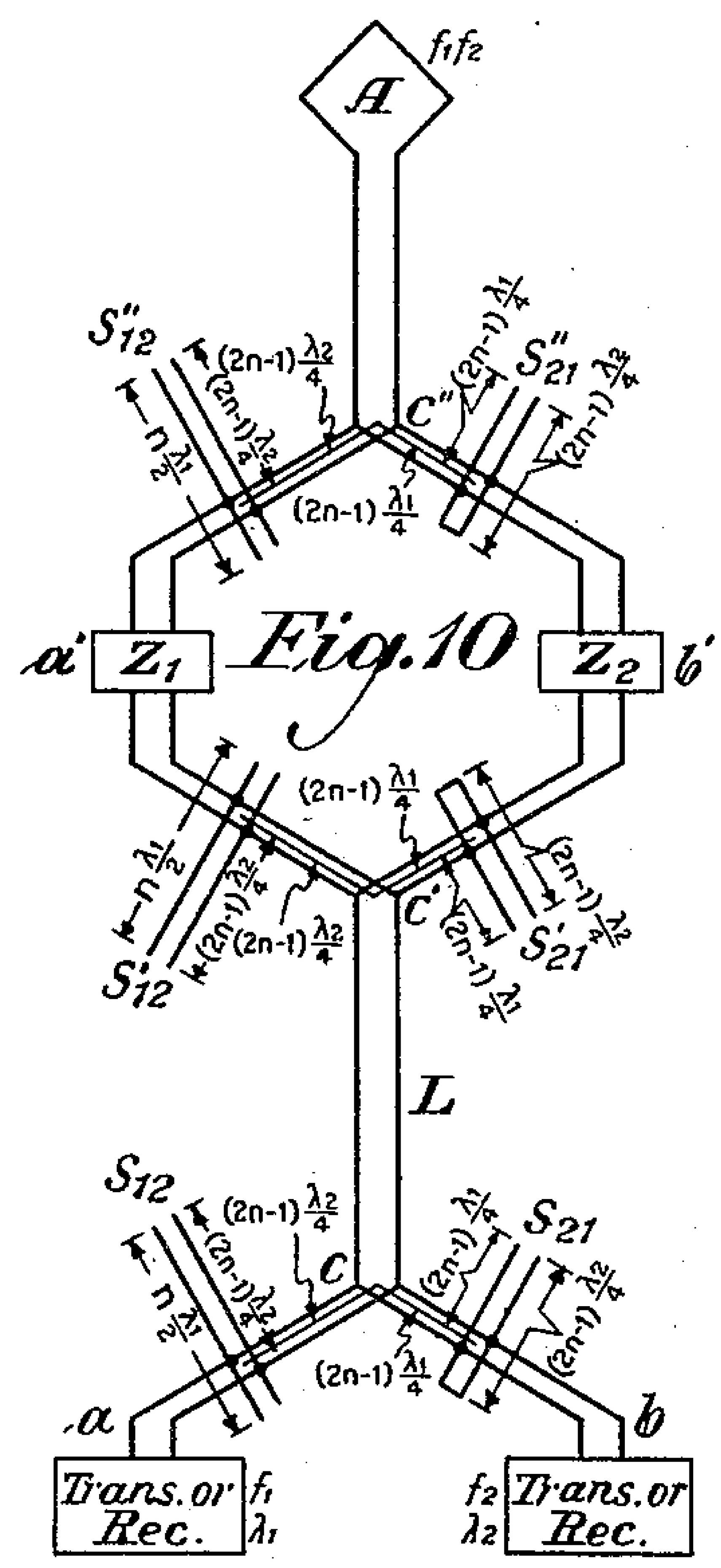

Fig. 10

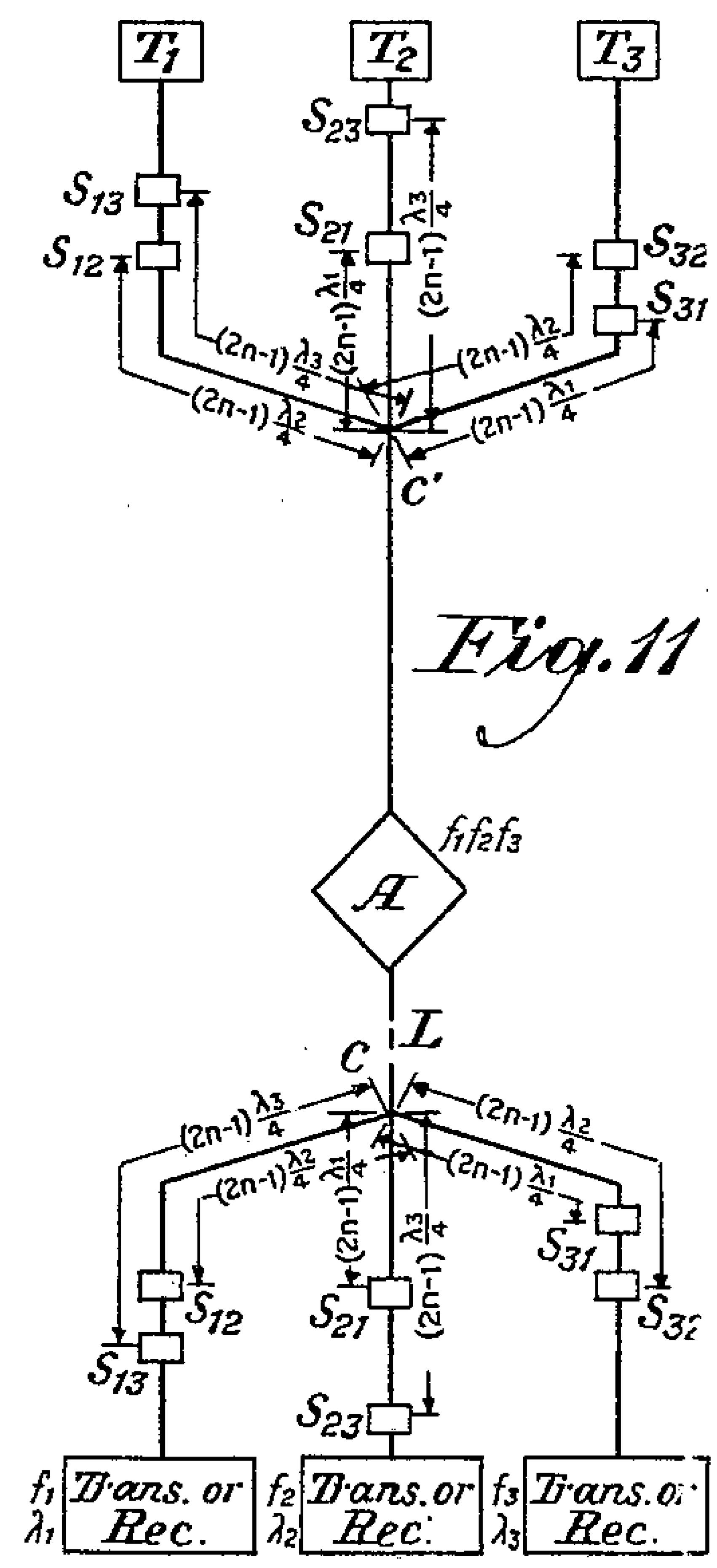

Fig. 11

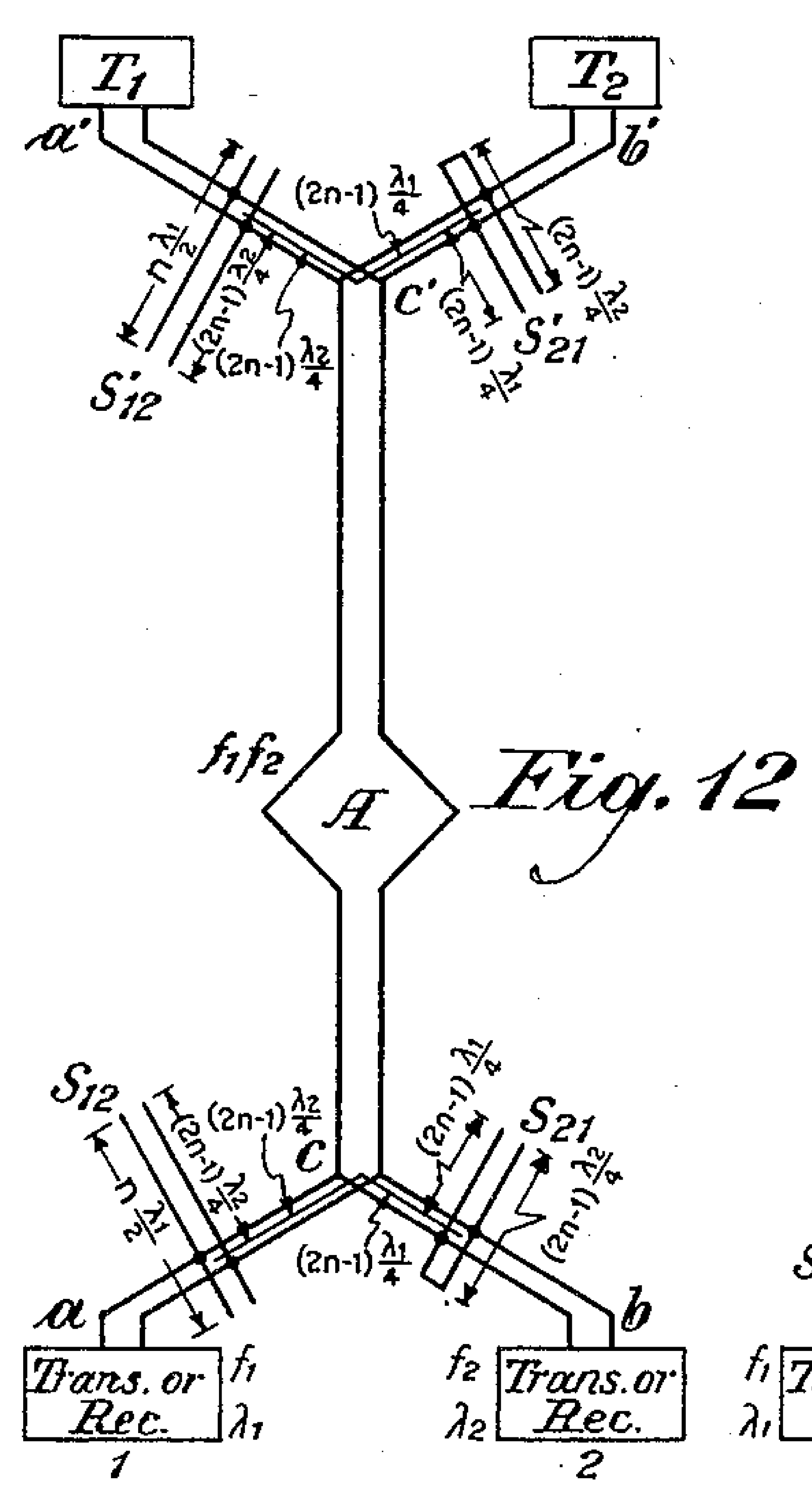

Fig. 12

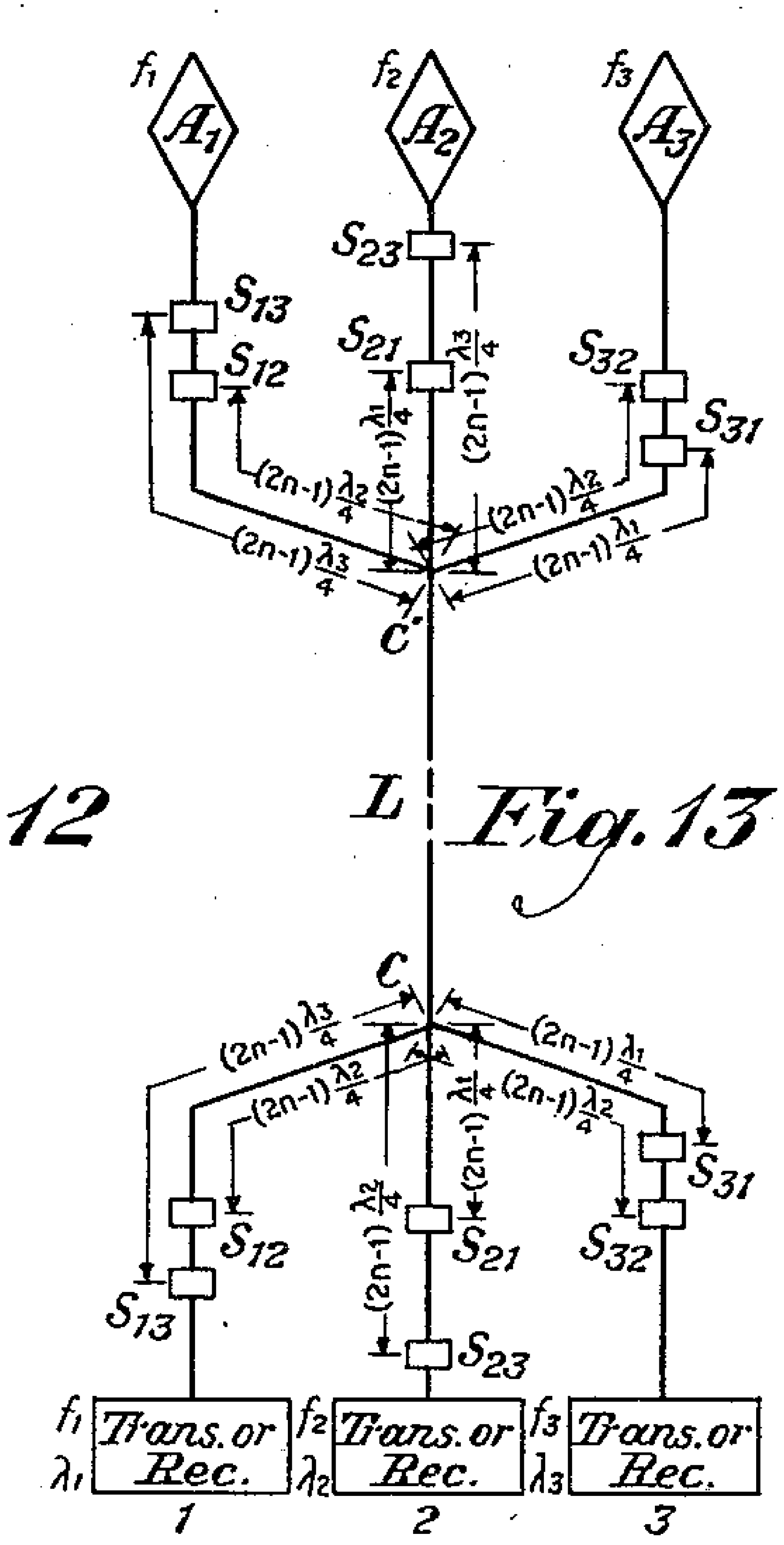

Fig. 13

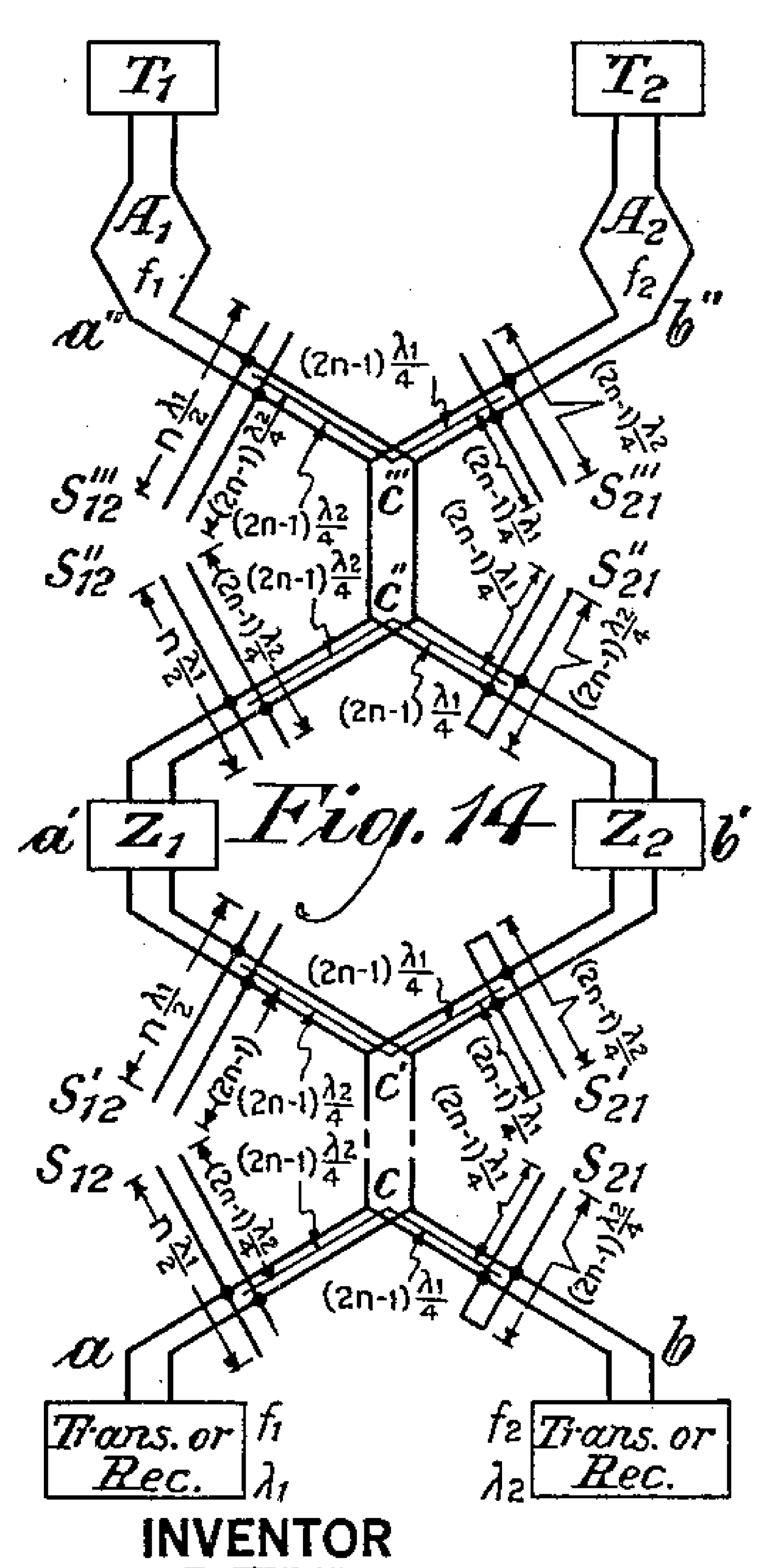

Fig. 14

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UNITED STATES PATENT OFFICE

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SELECTIVE ANTENNA CIRCUIT

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Application October 6, 1932. Serial No. 636,597

24 Claims. (Cl. 250—33)

This invention relates to selective antenna circuits and is a further development of the inventions disclosed in my applications, Serial No. 480,246, filed September 6, 1930 and Serial No. 569,778, filed October 19, 1931.

The purpose of the invention is to devise an antenna system operative on different frequencies and so connected that the frequency of the entire station may be changed simply by changing the frequency of the wave used.

Another purpose is to accomplish this without the use of mechanical or electrical switching means calling for any moving parts.

More specifically the purpose of the invention is to devise circuit arrangements by which, and in which, the antenna shall at all times be operative for any or all of a number of chosen operating frequencies either as a transmitting or a receiving antenna under such conditions that there will be impedance matching between different portions of the circuit for each of the operating frequencies, there will be proper impedance terminations to prevent undesirable reflections, and there will be prevention of transfer of energy from the local circuit appropriate for one operating frequency to the local circuit appropriate for another.

The invention will be better understood by reference to the following specification and accompanying drawings, in which Figure 1 shows an antenna system provided with means for matching the impedance of the antenna to the surge or characteristic impedance of the transmission line L; Fig. 2 shows a more specific application of such matching to a system for signaling on two frequencies; Figs. 3*a*, 3*b* and 3*c* illustrate specific means for the impedance matching; Fig. 4 illustrates the termination of an antenna system in a manner to prevent undesirable reflection; Fig. 5 shows the application of this to an antenna system adapted for operating on a plurality of frequencies; Fig. 6 shows in greater detail the application to a system for two operating frequencies; Figs. 7 and 8 illustrate the application of my invention to a system comprising a plurality of terminal stations associated with a single antenna, with means to prevent transfer of energy from one terminal station to another; Figs. 9 and 10 show combinations of impedance matching and prevention of transfer of power between local circuits; Figs. 11 and 12 show the application of my invention to proper impedance termination and prevention of transfer of energy between local circuits; Fig. 13 shows a plurality of antennæ and a plurality of terminal stations joined by a single transmission line, but with means for preventing transfer of energies from the one to the other, and Fig. 14 shows in greater detail the application of all of these features in one system.

The invention is based on various circuit arrangements of the selective circuits shown in my applications, Serial Nos. 480,246 and 569,778 mentioned above. In the latter application it was shown how two selective circuits could be obtained by properly bridging short sections of line, comprising two parallel wires, across a transmission line. Each of these sections of line or selectors will operate to exclude an undesired wave from a circuit, and yet not interfere with the wave to be transmitted. One of these selectors or short transmission lines is open at one end and short-circuited at the other, and is of a length equal to an odd multiple of a quarter wave at the frequency to be passed. The other selector is open at both ends and is of a length equal to a multiple of a half wave at the frequency to be passed.

The terminal impedance of both of these bridging selectors is very high, substantially infinite, if attenuation is assumed negligible, irrespective of the point of attachment, providing said point of attachment is not at a distance from one of the open ends equal to an odd multiple of a quarter wave. Under the latter condition, however, the terminal impedance is very low, substantially zero, if attenuation is assumed negligible. Utilizing this characteristic the selectors are attached to the transmission line at a point along the selector length which is at a distance from one of their open ends equal to an odd multiple of a quarter wave at the frequency to be excluded. Thus, these selectors shunt the line with a high impedance for the frequency to be passed and with a low impedance for the frequency to be excluded.

In a system comprising two circuits in parallel a selector is bridged across each branch at a point which is at a distance from the junction of the branches equal to an odd multiple of a quarter wave at the frequency to be excluded from that particular branch. Shunting the line with a low impedance at this particular point results in the circuit offering a very high impedance at the junction point to the undesired wave. It was also shown in the above mentioned application, that in the special case of a two branch circuit the selector on the branch over which the longer wave is to be transmitted should preferably be a short-circuited quarter wave selector, while on the branch for the shorter wave the selector should preferably be an open line of half wave length.

Referring now more specifically to Fig. 1, as a single line diagram, there is shown a terminal or local station which may be a transmitter or receiver, operative at the frequencies f_1, f_2, f_3 and connected with an antenna A operative at the same frequencies. A transmission line would ordinarily extend from the terminal station to the antenna. In general, in such a station, the impedance of the terminal station and of the antenna are different, the terminal station as a rule having a small impedance compared to that of the antenna. Furthermore, these impedances are a function of the frequency. It is well known that in any transmission circuit reflection occurs at points of impedance irregularities, and these reflected waves are such as to seriously upset the best operation of the antenna system. For this reason I desire to obtain impedance matching between the terminal station and the antenna, and to do this at each of the operating frequencies without the necessity of mechanical switching or the use of other moving parts. The impedance matching may be obtained by any suitable devices such as impedances Z_1, Z_2 and Z_3, and I bring these into operation so far as Fig. 1 is concerned, by dividing the transmission line L into three parallel circuits, each containing one of the impedance matching devices, and then bringing these circuits together again to continue to the antenna A. It is important, however, that only power corresponding to the frequency of one of the impedance matching devices should flow through that device, all other frequencies being excluded. To this end I place in series with matching device Z_1 certain devices which will exclude the frequencies appropriate to Z_2 and Z_3. Similarly, Z_2 and Z_3 have associated with themselves selectors which will exclude in each case all but the frequency appropriate for a particular branch. The type of selector or excluder which is used, and its position, is in accordance with the inventions described in my applications, Serial Nos. 480,246 and 569,778. I have shown these selectors by the reference letters S and S′, using in addition with each of these letters a double subscript, the first subscript indicating the frequency to be passed, and the second subscript the frequency to be excluded. Thus, S_{13} would indicate that f_1 is to be passed and f_3 is to be excluded. In this case also, since there is a terminal station on the one side of the impedance matching devices and an antenna on the other side, there are two junction points at which exclusion is to be exercised. It is therefore necessary to have selectors on both sides of the matching devices, and I use the letter S to indicate the selector on the side towards the terminal station and S′ the selector on the side towards the antenna. Also, in accordance with my previous invention, each selector is placed at a distance from the junction point equal to an odd number of quarter wave lengths of the wave to be excluded, all this being clearly shown in Fig. 1. In this figure it is to be understood that the transmission line L is comparatively long, whereas the distances given over to the parallel paths and to the connection from the junction point C′ to the antenna A, are both about as short as physically convenient. Under these conditions, the only one of the operating frequencies which will pass through the branch 1 is the frequency f_1, the only frequency through the branch 2 is f_2, and the only frequency through the branch 3 is f_3.

The impedance matching devices Z_1, Z_2 and Z_3 may take on a number of forms and the specific form which they take on does not constitute a part of my invention. A suitable device would be a transformer of the type shown in Fig. 3*a*, and since, in general, the impedance of the antenna A will differ from the surge or characteristic impedance of the transmission line, the transformer will have an impedance ratio other than unity. The windings of such a transformer should preferably have bridged across them variable condensers in order that the circuits may be tuned to the desired frequency. Another form which the matching device may take on is that of Fig. 3*b*, which consists of a tuned autotransformer with adjustable contacts from both sides. In Fig. 3*c* there is shown still another form of impedance matching, this being the type of "transformer" described in an article by Sterba and Feldman in the Proceedings of the Institue of Radio Engineers for July 1932, page 1163.

While Fig. 1 has been described as having three operating frequencies, it is to be understood that this is for illustrative purposes only, and that the number may be made as large or as small as desired. Thus, Fig. 2 shows the application of this same feature of my invention to a system with the two operating frequencies f_1 and f_2. The transmission line L from the terminal station, which may be either a transmitting or receiving station, goes to the junction point C and there divides into the parallel branches *a* and *b*, the one having the impedance matching device Z_1, and the other the matching device Z_2. From each of these, parallel wires come to the junction point C′ and from there extend to the antenna A. In the branch *a*, which we here assume is for the shorter wave length, and adjacent to the junction point C, is bridged the short transmission line S_{12} which in this case is shown as open at both ends, and therefore is of a length equal to a whole number of half wave lengths of the frequency which is to be passed. This selector S_{12} is connected at a distance from the junction point equal to an odd number of quarter waves of f_2, and the point of attachment to the selector is at a distance from one of the open ends equal to an odd number of quarter waves of f_2. Identically the same arrangement is followed in connection with the selector S_{12}', with reference to the junction point C′. A similar arrangement could be followed in the branch *b*, but a preferred alternative, inasmuch as the wave length in this branch is longer, is to make the selector S_{21} a short transmission line open at one end and short-circuited at the other, and of a length equal to a quarter wave of the frequency f_2 which is to be passed. The distances of connection from the open end of the selector and from the junction point C′ are both an odd number of quarter waves of f_1 which is to be excluded. The same arrangement holds for S_{21}'.

One of the features which I find to be important in connection with such wave antenna systems as here considered, is that there shall be no reflection from the remote end of the antenna to the terminal station. The elimination of such reflection may be obtained by connecting across the remote end of the antenna, which in all of these figures is taken to be of the rhombic type, a resistance T shown in Fig. 4. If this resistance T is chosen of the proper value to match the impedance of the antenna system as seen looking from that resistance, then there will be no reflection at that point. Since, however, the impedance of the antenna is a function of the frequency, it becomes necessary to use a different terminating impedance for each frequency. This, obviously, may be accomplished by mechanical adjusting or switching of some form, but in my invention I provide a plurality of terminating impedances each of which is physically connected to the circuit at all times, but is electrically effective only for the frequency for which it is adapted. This is illustrated more fully in the single line diagram of Fig. 5 where, connected to the far end of the antenna A, are three terminating impedances T_1, T_2 and T_3, each of a value to give proper termination to the antenna for the corresponding frequencies f_1, f_2 and f_3. It is important, however, that the current of the frequency f_1 shall flow only in the termination T_1, and similarly, for the other frequencies. To this end I introduce into the branch leading to T_1 a plurality of selectors, one for each of the frequencies to be excluded from that branch. Thus, in this illustration there are shown the selectors S_{12} and S_{13}, each at a distance from the junction point C equal to an odd number of quarter waves of the frequency to be excluded. The principle of the operation will be evident from the previous description, and still more specifically by reference to Fig. 6 which shows the application to a system for two frequencies. In this case, in the branch *a*, which is to pass the shorter wave length, there is bridged the selector S_{12} open at both ends, and therefore a multiple of half wave lengths of the frequency to be passed. Similarly, in branch *b*, there is bridged a selector open at one end and closed at the other, and therefore an odd number of quarter wave lengths of the frequency to be passed.

In some cases I find it desirable to have separate terminal stations for the different operating frequencies, still using a single antenna A suitable for all the operating frequencies. As shown in the single line diagram of Fig. 7, the stations 1, 2 and 3 have transmission lines coming to the junction point C from which the common transmission line L extends to antenna A. It is important, in case the terminal stations are transmitters, that no power shall be fed from one transmitter station to another, and I find that I can bring about this condition by introducing in each branch selectors of the type previously described, and properly positioned with respect to the junction point C. This is shown in further detail in Fig. 8 which is a two line diagram for a two frequency system, the understanding of which will be obvious from the description given heretofore.

In some cases it will be desirable to combine the systems of Figs. 1 and 2 with that of Figs. 7 and 8, and such combination is shown in Figs. 9 and 10, the first of these being a single line diagram for three terminal stations operating at different frequencies in connection with a single antenna A. The transmission line L in this Fig. 9 will, in general, be quite long and the portions given over to the impedance matching devices and selectors would be as short as physically feasible. The details for the two frequency system are shown more fully in the two line diagram of Fig. 10.

My invention includes various other arrangements. Thus, in Fig. 11, there is shown in a similar manner the combination of a plurality of terminal stations and a single antenna A, and a plurality of terminating impedances T_1, T_2 and T_3, this figure thus representing the combination of Figs. 5 and 7. Similarly, Fig. 12 represents the combination of Figs. 6 and 8.

In some cases I find it desirable to use separate antennæ A_1, A_2 and A_3 for the different operating frequencies and at the same time to have separate terminal stations, but having these all combined to operate over a single transmission line L. There thus comes into being two junction points C and C′, and again, by the use of my selectors, there is present in any one branch only that frequency appropriate to that branch. This is shown in Fig. 13.

Finally, in Fig. 14, I have shown the system of Fig. 10 but with a plurality of antennæ A_1 and A_2 with their appropriate terminating impedances T_1 and T_2.

It should be pointed out that in case the frequency excluding devices are of the short transmission line type, as shown in Fig. 2 and other figures, it would be difficult to use more than two branches unless some of the frequencies used are harmonically related. In the event of using three or more branches, as shown in Fig. 1, it will be simpler to use the lumped type of impedance described in my application Serial No. 480,246, referred to above, but in that case there is no limit to the number of branch circuits which may be used.

While these selective devices may find their chief usefulness at a transmitting station where the energy of the system originates at a single source or a plurality of sources and is transferred to a single antenna or a plurality of antennæ, they are equally applicable to a receiving station where the energy of the system originates at a single antenna or a plurality of antennæ and is transferred to a single receiver or a plurality of receivers.

Although in this application I have shown my invention as applied to certain specific cases, it is to be understood that various other applications and arrangements and combinations are possible, and these will be apparent to those skilled in the art. For example, operation may be singular on one antenna or simultaneous on all antennæ, the proper separation of the waves of different frequencies being effected at the junction points by the selective devices herein described.

What is claimed is:

1. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, said line over a portion of its length being divided into parallel paths one for each operating frequency, and means in each said path for matching the impedance between the antenna and the terminal station for the frequency corresponding to that branch.

2. In a radio system an antenna adapted to operate on a plurality of frequencies and a receiving station, a transmission line connecting the antenna to the receiving station, said line over a portion of its length being divided into parallel paths one for each operating frequency, and means in each said path for matching the impedance between the antenna and the receiving station for the frequency corresponding to that branch.

3. In a radio system an antenna adapted to operate on a plurality of frequencies and a transmitting station, a transmission line connected between the antenna and the transmitting station, said line over a portion of its length being

divided into parallel paths one for each operating frequency, and means in each said path for matching the impedance between the antenna and the transmitting station for the frequency corresponding to that branch.

4. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, said line over a portion of its length being divided into parallel paths one for each operating frequency, means in each said path for matching the impedance between the antenna and the terminal station for the frequency corresponding to that branch, and additional means in each branch to exclude all frequencies except the frequency corresponding to that branch.

5. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, said line over a portion of its length being divided into parallel paths one for each operating frequency, means in each said path for matching the impedance between the antenna and the terminal station for the frequency corresponding to that branch, and short transmission lines bridged across each branch and adjusted at the optimum length to exclude from that branch all frequencies except the frequency corresponding to that branch.

6. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, said line over a portion of its length being divided into parallel paths one for each operating frequency, and transformers in each said path for matching the impedance between the antenna and the terminal station for the frequency corresponding to that branch.

7. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, said line over a portion of its length being divided into parallel paths one for each operating frequency, transformers in each said path for matching the impedance between the antenna and the terminal station for the frequency corresponding to that branch, and short transmission lines bridged across each branch and adjusted at the optimum length to exclude from that branch all frequencies except the frequency corresponding to that branch.

8. The combination of claim 7 characterized by the location of said short transmission lines, one line on each side of each of the said transformers for the purpose set forth.

9. The combination of claim 7 characterized by a bridge on each side of each transformer, each bridge being connected at a point distant from the junction equal to an odd number of quarter waves for the frequency to be excluded.

10. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, said line over a portion of its length being divided into parallel branches one for each operating frequency, means in each said branch for matching the impedance between the antenna and the terminal station for the frequency corresponding to that branch, and short transmission lines bridged across each branch of such length as to exclude from that branch all frequencies except the frequency corresponding to that branch, some of the bridges being open pairs of wires of half wave lengths of the frequency to be transmitted and some of pairs of wires short-circuited at one end and of quarter wave lengths of the frequency to be transmitted.

11. The combination of claim 10 characterized by the fact that each short transmission line is connected to its branch at a distance from the junction of the branch and the main transmission line of a quarter of the wave length of the frequency to be excluded.

12. The combination of claim 10 characterized by the fact that each short transmission line is connected to its branch at a distance from the junction of the branch and the main transmission line of a quarter of the wave length of the frequency to be excluded, and the connection to the short transmission line is at a distance from an open end thereof of a quarter of the wave length of the frequency to be excluded.

13. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, a plurality of impedances terminating the antenna, one for each operating frequency, and each having its impedance value determined by the value of the respective operating frequency, and means operatively connected with the terminating impedances to exclude from each such impedance all of the operating frequencies except the one corresponding to that impedance.

14. In a radio system an antenna adapted to operate on a plurality of frequencies and a terminal station, a transmission line connected therebetween, a plurality of impedances in parallel terminating the antenna, each having its impedance value determined by the value of the respective operating frequency, short transmission lines bridged across each impedance and adjusted in length and position to exclude from each such impedance all the operating frequencies except the one corresponding to that impedance.

15. The combination of claim 14 characterized by the fact that some of the bridges are pairs of wires short-circuited at one end and of a length equal to an odd number of quarter waves of the frequency to be transmitted and some are open pairs of wires of a whole number of half wave lengths of the frequency to be transmitted.

16. The combination of claim 14 characterized by the fact that some of the bridges are pairs of wires short-circuited at one end and of a length equal to an odd number of quarter waves of the frequency to be transmitted, and that each short transmission line is connected to its branch at a distance from the junction of the branch and the main transmission line of a quarter of the wave length of the frequency to be excluded.

17. The combination of claim 14 characterized by the fact that some of the bridges are pairs of wires short-circuited at one end and of a length equal to an odd number of quarter waves of the frequency to be transmitted, and that each short transmission line is connected to its branch at a distance from the junction of the branch and the main transmission line of a quarter of the wave length of the frequency to be excluded and the connection to the short transmission line is at a distance from an open end thereof of a quarter of the wave length of the frequency to be excluded.

18. The combination of claim 14 characterized by the fact that there is a bridging circuit across

each impedance for each frequency to be excluded, and that some of the bridges are pairs of wires short-circuited at one end and of a length equal to an odd number of quarter waves of the frequency to be transmitted, and some are open pairs of wires of a whole number of half wave lengths of the frequency to be transmitted.

19. In a radio system an antenna adapted to operate on a plurality of frequencies, a plurality of terminal stations one for each operating frequency, transmission lines from each station to a common junction and a common transmission line therefrom to the antenna, and means in each of the first-named transmission lines to exclude all of the operating frequencies except the one appropriate to its terminal station, said means consisting of selective impedances one for each frequency to be excluded and tuned to that frequency, each placed at a definite portion of a wave length of the frequency for which it is tuned from the common junction point.

20. In a radio system an antenna adapted to operate on a plurality of frequencies, a plurality of terminal stations, one for each operating frequency, transmission lines from each station to a common junction and a common transmission line therefrom to the antenna, and means in each of the first named transmission lines to exclude all of the operating frequencies except the one appropriate to its terminal station, said means consisting of short bridging transmission lines one for each frequency to be excluded and each placed at a definite portion of a wave length of the frequency which it is to exclude from the common junction point.

21. In a radio system an antenna adapted to operate on a plurality of frequencies, a plurality of transmitting stations, one for each operating frequency, transmission lines from each station to a common junction and a common transmission line therefrom to the antenna, and means in each of the first-named transmission lines to exclude all of the operating frequencies except the one appropriate to its transmitting station, said means consisting of short bridging transmission lines one for each frequency to be excluded and each placed at a definite portion of a wave length of the frequency which it is to exclude from the common junction point.

22. In a radio system an antenna adapted to operate on a plurality of frequencies, a plurality of receiver stations, one for each operating frequency, transmission lines from each station to a common junction and a common transmission line therefrom to the antenna, and means in each of the first-named transmission lines to exclude all of the operating frequencies except the one appropriate to its receiver station, said means consisting of short bridging transmission lines one for each frequency to be excluded and each placed at a definite portion of a wave length of the frequency which it is to exclude from the common junction point.

23. The combination of claim 5 characterized by a plurality of impedances in parallel terminating the antenna each with an impedance appropriate for one of the operating frequencies, short transmission lines bridged across each impedance and adjusted at the optimum length to exclude from each such impedance all the operating frequencies except the one corresponding to that impedance.

24. The combination of claim 19 characterized by the fact that the transmission line over a portion of its length is divided into parallel paths one for each operating frequency, means in each said path for matching the impedance between the antenna and the terminal station for the frequency corresponding to that branch, and additional means in each branch to exclude all frequencies except the frequency corresponding to that branch, the combination being further characterized by a plurality of impedances terminating the antenna, one for each operating frequency and with an impedance appropriate for each operating frequency, and means associated with the terminating impedances to exclude from each such impedance all of the operating frequencies except the one corresponding to that impedance.

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