Nov. 7, 1933. G. W. GILMAN 1,933,669

SELECTIVE ANTENNA CIRCUITS

Filed Oct. 19, 1931

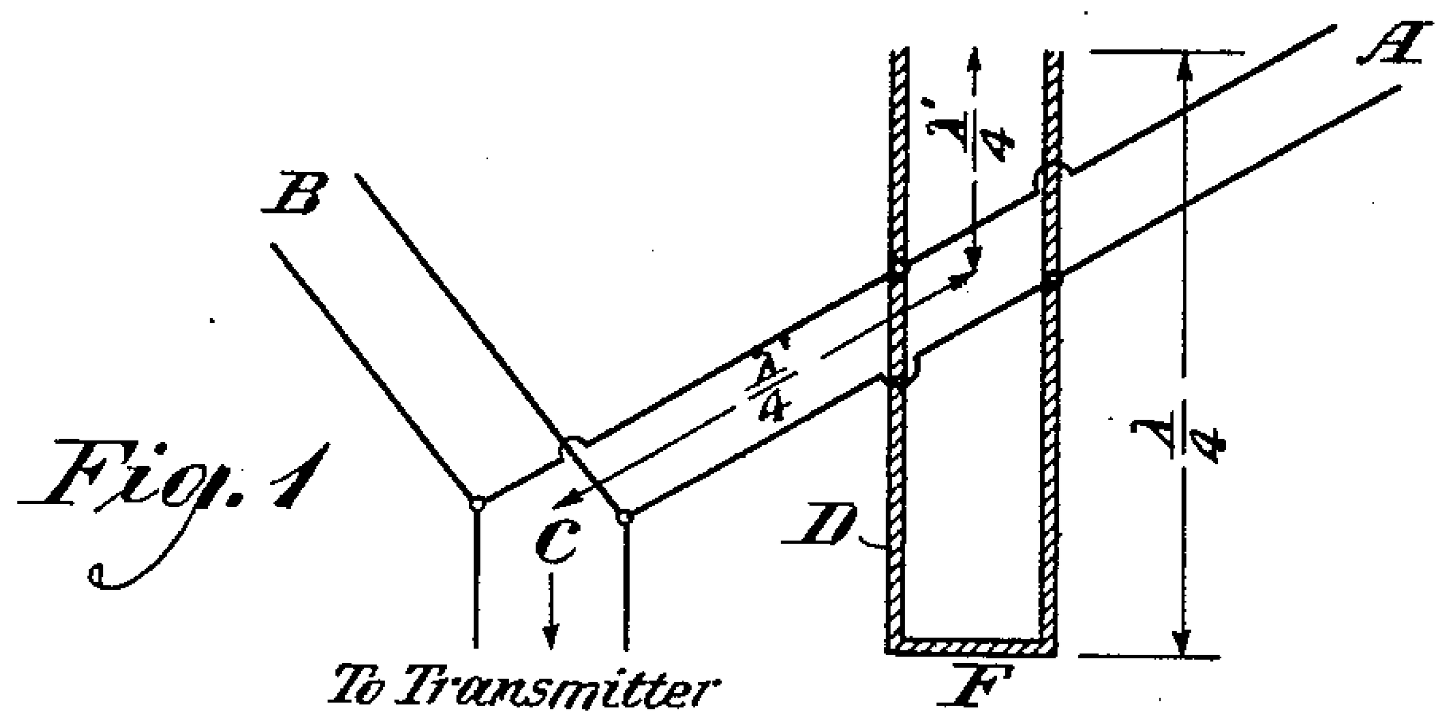

Fig. 1

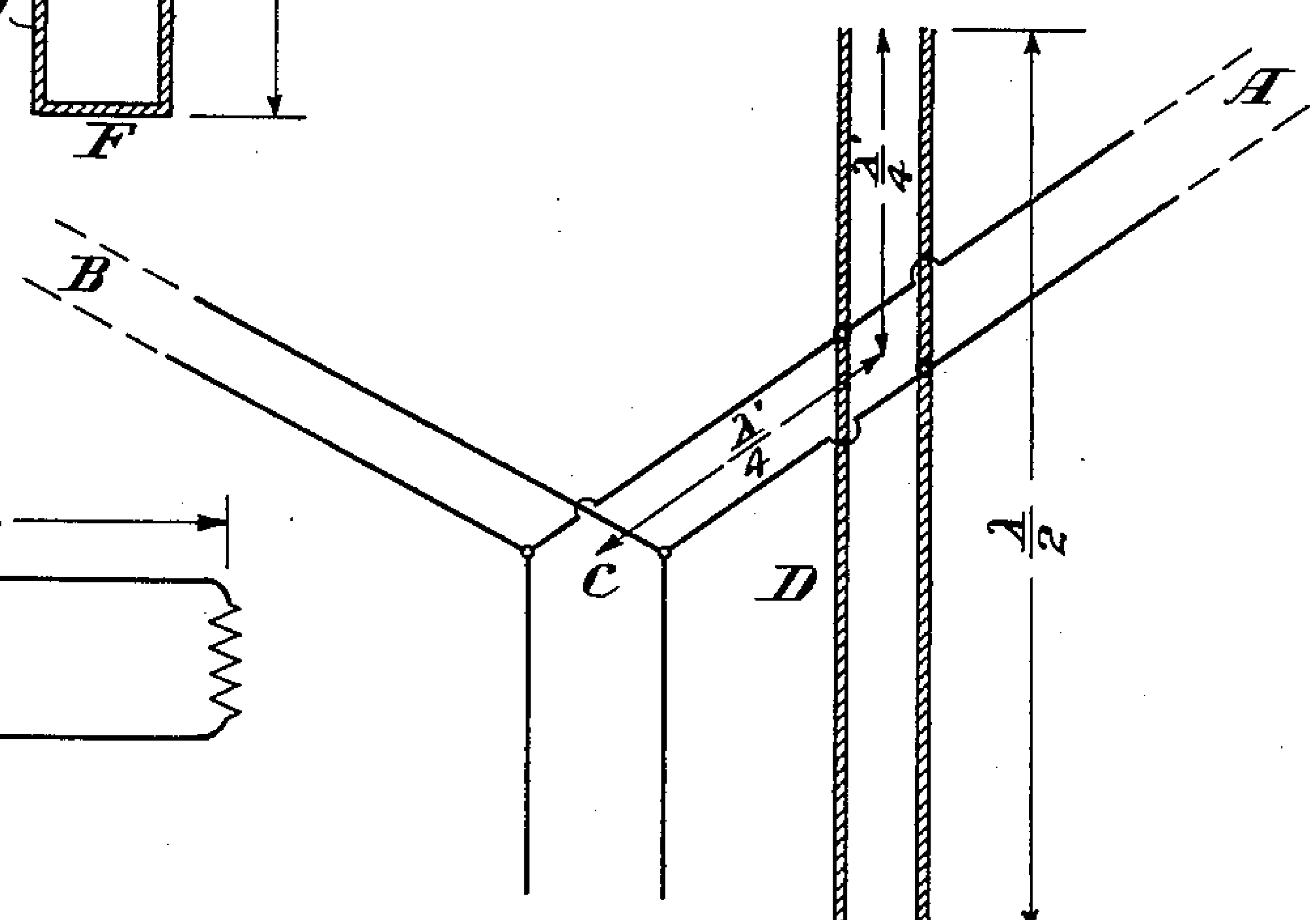

Fig. 2

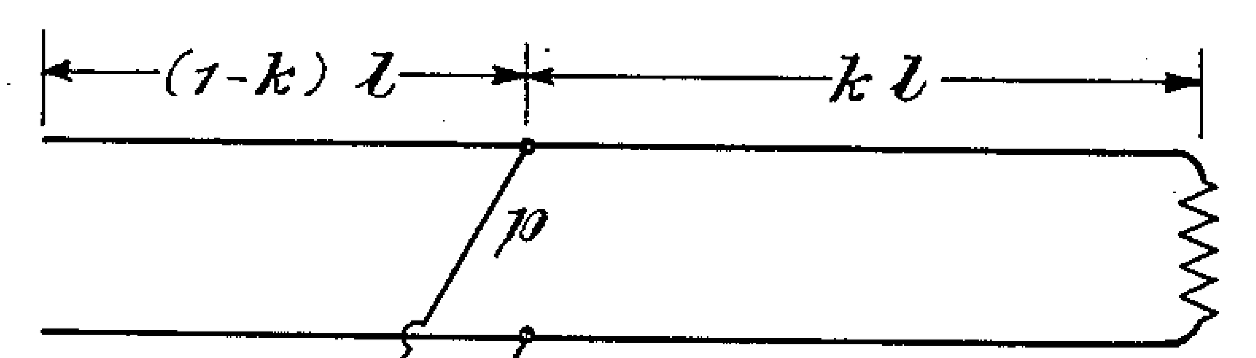

Fig. 3

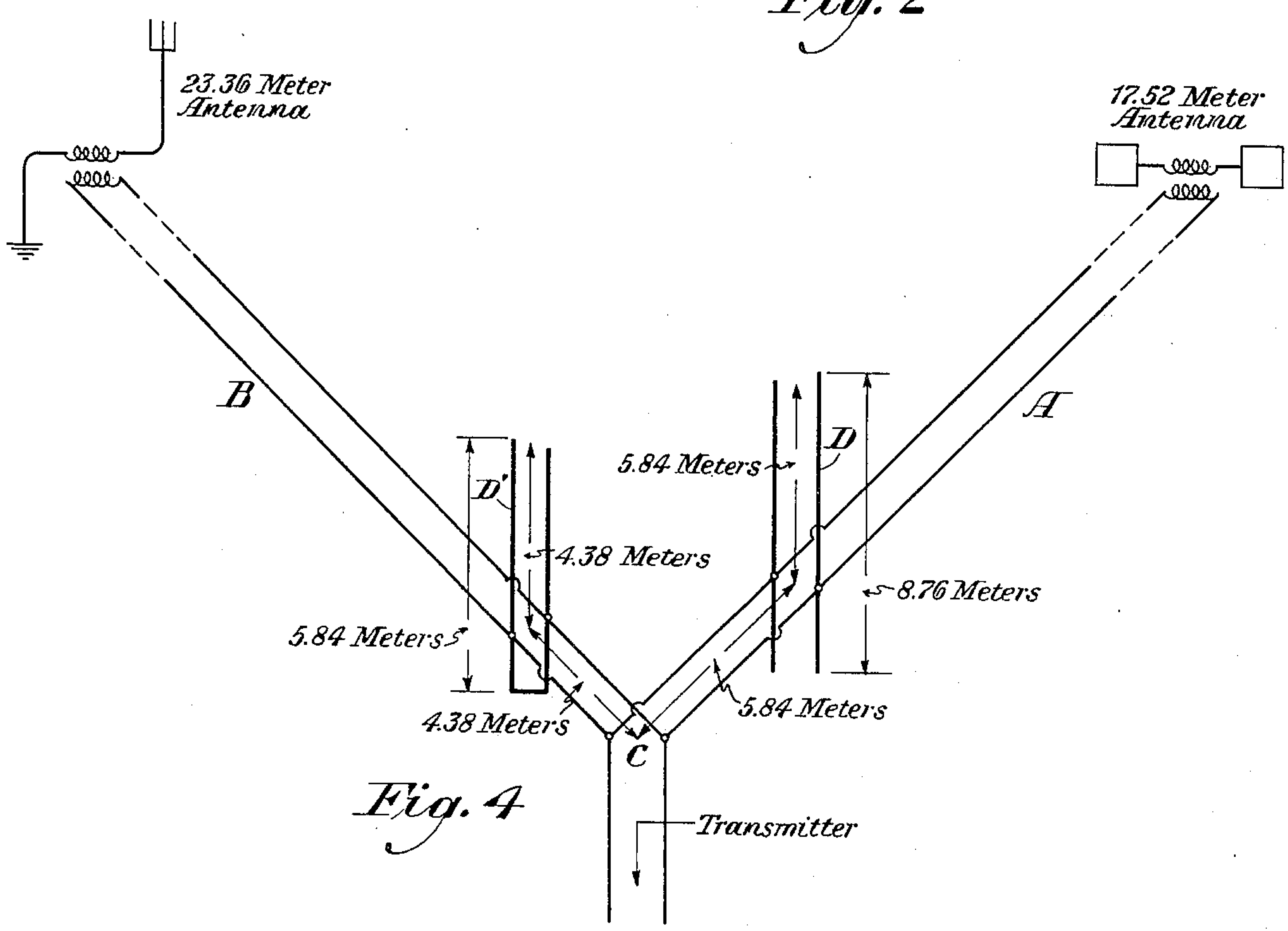

Fig. 4

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Patented Nov. 7, 1933 1,933,669

UNITED STATES PATENT OFFICE

1,933,669

SELECTIVE ANTENNA CIRCUITS

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Application October 19, 1931. Serial No. 569,778

9 Claims. (Cl. 178—44)

This invention relates to selective antenna circuits and is a further development of the invention disclosed in my application, Serial No. 480,246, filed September 6, 1930.

The purpose of the invention is to devise an antenna system designed for different frequencies to be 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.

In my application cited above, it was shown that if a transmission line is divided with a branch going to each of a plurality of antennas tuned to different frequencies, it is possible, in transmission, to arrange the line so that energy of a given frequency will flow only down that branch leading to the appropriate antenna. This was accomplished in one case by providing at a certain point in one of the branches, a plurality of networks each of which acted as a short-circuit for one of the waves to be excluded from that branch, thus excluding all but the desired wave. Each branch was shown as treated in a similar manner.

In this invention I show how the above results may be attained in a similar manner, especially for the case of two antennas.

The invention will be better understood by reference to the following specification and accompanying drawing, in which Figures 1 to 3 are diagrammatic circuits for explaining the invention, and Fig. 4 shows one mode of application to an antenna system.

In each of Figs. 1 and 2 there is shown a transmission line divided at the point C into branches A and B leading to antennæ operative respectively, at frequencies n and n', or wave lengths λ and λ'. In the branch A it is desired to exclude wave length λ'. Two conditions arise, one where γ is greater than λ', and the other where λ is less than λ'. The first is shown in Fig. 1 where there is connected to, or bridged across the line at a distance

$$\frac{\lambda'}{4}$$

from the point of departure C, a short transmission line D of length

$$\frac{\lambda}{4}$$

and short-circuited at the one end F. The connection of this section D is at a point

$$\frac{\lambda'}{4}$$

from the open end, and under these conditions the branch is effectively short-circuited for the wave λ' which is to be excluded. For the wave λ, however, the result is the same as if the bridging circuit were removed, all of which can be shown by the following considerations.

In Fig. 3 there is shown a smooth line of two parallel wires of characteristic impedance Z_0 open at one end and terminated in a resistance at the other end, the line being of length l and of negligible resistance and leakance. It can be demonstrated by electric circuit theory that if the terminating resistance equals zero the impedance looking towards the short-circuited end and measured from a point p of distance kl from the short-circuited end is

$$Z_{ps} = jZ_o \tan k\theta \quad (1)$$

and the impedance looking toward the open end is

$$Z_{po} = -jZ_o \frac{1}{\tan (1-k)\theta} \quad (2)$$

The impedance of the two portions in parallel as seen from p is

$$Z = \frac{Z_{ps}Z_{po}}{Z_{ps}+Z_{po}} = jZ_o \frac{\tan k\theta}{1-\tan k\theta \tan (1-k)\theta} \quad (3)$$

where θ="angle of the line"=

$$l\omega\sqrt{LC}.$$

Here L and C are inductance and capacitance of the line per unit length, $\omega = 2\pi \times$ frequency. It will be recognized that the angle of the line depends upon the wave length and is given more specifically by

$$\theta = \frac{2\pi l}{\lambda}$$

where l is the length of the line under consideration.

It will be noted that if

$$\theta = \frac{\pi}{2}$$

at some frequency, say f_o, that is if l is

$$\frac{\lambda}{4}$$

then Equation (3) becomes

$$Z = \frac{jZ_o \tan k\frac{\pi}{2}}{1-\tan k\frac{\pi}{2} \cot k\frac{\pi}{2}} \quad (4)$$

In other words, for that frequency for which the line is a one-quarter wave length, the impedance offered to a source is infinite, no matter where the source may be connected so long as it is not in the short circuit; that is, so long as k is not equal to zero. On the other hand, Z is equal to zero if $\tan(1-k)\theta=\infty$; that is, if

$$(1-k)\theta=\frac{n\pi}{2},$$

where n is any odd integer. Taking the condition where n has the value of unity, and inserting the value of θ, it appears that

$$(1-k)l=\frac{\lambda}{4}.$$

In other words, if the branch A is connected to the transmission line D at a distance

$$\frac{\lambda'}{4}$$

from the open end of D, then the impedance for the frequency corresponding to the wave λ' is equal to zero, and the transmission line A behaves for that frequency as though it were short-circuited, whereas, for the wave length λ it behaves as though the bridging circuit were of infinite impedance, or as though it were removed. In this way, the bridging transmission line accomplishes for the branch A the purpose desired.

In order to make it possible to transmit a wave length of λ' over branch B without loss due to the bridging effect a branch A, the transmission line D is connected to this latter branch at a distance

$$\frac{\lambda'}{4}$$

from the point of division C. From what has preceded, it is evident that, for the frequency corresponding to wave λ', the impedance of branch A as seen from point C is infinity. In other words, at such a frequency the branch A is effectively removed from the circuit.

The conditions given above can be readily realized physically so long as λ is greater than λ', but, obviously, cannot be realized if λ is less than λ'. However, the same condition of infinite impedance for the wave λ may be accomplished if the short circuit at F is removed, and the conductor is increased to a length

$$\frac{\lambda}{2}.$$

This structure is shown in Fig. 2. While this conclusion is apparent by analogy with organ pipes, or any system in which standing waves may be set up, it may be demonstrated mathematically in a manner similar to that used in connection with Fig. 1. Such treatment would lead to the expression for the impedance of the line or network D of Fig. 2 as seen from the point of attachment

$$Z=-jZ_o\frac{1+\tan\theta\tan k\theta}{\tan\theta(\tan^2 k\theta+1)} \quad (5)$$

In this Fig. 2 then, the impedance of the line D is infinity for the wave length λ no matter where the point of attachment may be, so long as it is not at the mid-point. On the other hand, by making the attachment at the distance of

$$\frac{\lambda'}{4}$$

from one end, this transmission line acts as a short-circuit for the wave length λ'.

One embodiment of my invention is now shown in Fig. 4 in which the transmission line divides at the point C into two branches A and B in which for illustrative purposes I have used the wave lengths 17.52 and 23.36 meters, respectively, the first of which will be indicated by λ and the second by λ'. Bridged across the branch A is a transmission line open at both ends and of wave length

$$\frac{\lambda}{2},$$

the connection being made at a distance

$$\frac{\lambda'}{4}$$

from one end of the line D, and at a distance of

$$\frac{\lambda'}{4}$$

from the junction C. Similarly in the branch B there is connected a transmission line D' at a distance from the junction C of

$$\frac{\lambda}{4}.$$

Since for this branch λ' is greater than λ, the length of the line D' is shown as equal to

$$\frac{\lambda}{4'},$$

and the connection is made at a distance from the open end of D' of

$$\frac{\lambda'}{4}.$$

Obviously, this line D' could be open at both ends in which case its length would then be

$$\frac{\lambda'}{2}$$

or twice that actually shown.

In the treatment above, the impedance has been considered only for those waves or frequencies of particular interest, but it is evident that variations of impedance from minus to plus infinity occur at other higher frequencies in the frequency range. However, from f_o to $2f_o$ of Fig. 1, the network has but one zero and two infinite impedance points.

While the invention has been described in connection with a transmission line which has two branches, adapted, therefore, for two frequencies, it is apparent that the principles of the invention may be extended to a larger number of frequencies. Thus, in Fig. 1, a plurality of transmission lines could be bridged across the line at appropriate distances from the junction C, each of these bridged transmission lines being of the length

$$\frac{\lambda}{4},$$

and each connected at a distance from the open end of one-quarter of the wave length to be excluded. In this case, however, additional networks will be required in connection with some of the bridging transmission lines, to cause them to have an infinite impedance at more than one frequency. Thus, the invention may be extended to a multiplicity of antennæ.

Various other modifications of my invention will be apparent to those skilled in the art. For instance, it will be evident that the invention is equally applicable for the case where a single antenna is to be used at several frequencies requiring the use of impedance matching devices. In that event, the networks or transmission lines would be used to select automatically the proper impedance matching equipment without the intermediary of mechanical switching devices.

Again, the principles of the invention may be applied to the case where an antenna is fed at a plurality of frequencies, simultaneously, from a plurality of sources. In this case the branch lines A and B of Fig. 4 would be connected to the sources, instead of to the antennas, and the main transmission line would be connected to the antenna rather than to the single transmitter.

What is claimed is:

1. In radio transmission, a plurality of antennæ, a transmission line, a branch therefrom to each antenna, and a transmission line bridged across one branch and of a length to permit the flow of the desired frequency down that branch and to exclude other waves of another frequency.

2. In radio transmission, a plurality of antennæ, a transmission line, a branch therefrom to each antenna, and a transmission line bridged across one branch, the line being open at both ends and of a length equal to an integral multiple of one-half the wave length of the wave to be transmitted.

3. In radio transmission, a plurality of antennæ, a transmission line, a branch therefrom to each antenna, a transmission line bridged across one branch, the line being open at both ends and of one-half the wave length of the line to be transmitted, and attached at a distance from one end of one-quarter wave length of a frequency to be excluded.

4. In radio transmission, a plurality of antennæ, a transmission line, a branch therefrom to each antenna, and a transmission line bridged across one branch, the said line being open at one end and closed at the other end and of a length equal to one-quarter of the wave length to be transmitted.

5. In radio transmission, a plurality of antennæ, a transmission line, a branch therefrom to each antenna, a transmission line bridged across one branch, the said line being open at one end and closed at the other end and of a length equal to an odd multiple of one-quarter of the wave length to be transmitted, and attached at a distance from the open end of one-quarter of the wave length of a frequency to be excluded.

6. In radio signaling systems, a transmission line, two branches therefrom, one to each of two antennæ, a supplemental transmission line bridged across each branch the length of the line in the branch for the longer wave length being an odd multiple of one-quarter of the wave length of the wave to be transmitted and the length of line in the other branch being an integral multiple of one-half the wave length of the wave to be transmitted by that branch, the first bridging line being closed at one end and the second bridging line being open at both ends.

7. The combination of claim 6 further characterized by the fact that the two bridging lines are connected to the branches at distances from the open end of one-quarter of the wave to be excluded.

8. The combination of claim 5 further characterized by the fact that the bridging line is connected at a distance from the junction point of the branches of one-quarter of the wave length of the frequency to be excluded.

9. The combination of claim 6 characterized by the fact that the two bridging lines are connected to the branches at distances from an open end of the bridging line, of one-quarter of the wave to be excluded, and that each bridging line is connected to its branch at a distance from the junction point of the transmission line equal to one-quarter of the wave length of the wave to be excluded.

GEORGE W. GILMAN.