July 24, 1934. P. S. CARTER 1,967,395

ANTENNA

Filed April 9, 1930 2 Sheets-Sheet 1

Fig. 1

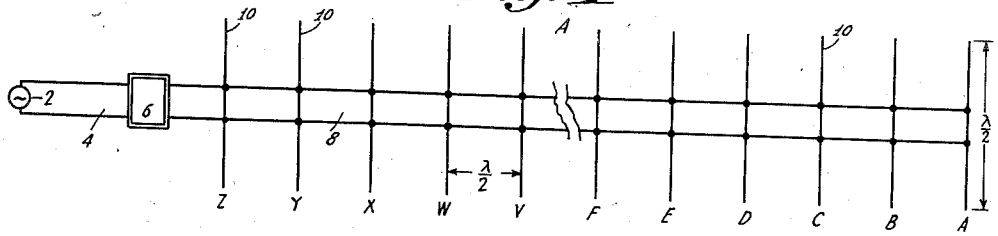


Fig. 2

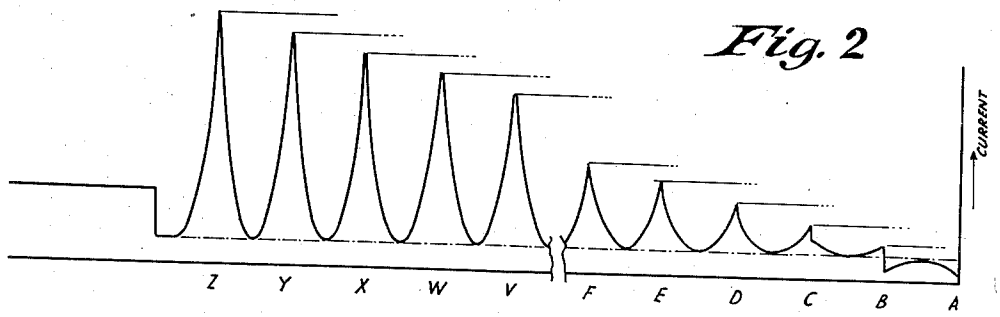


Fig. 3

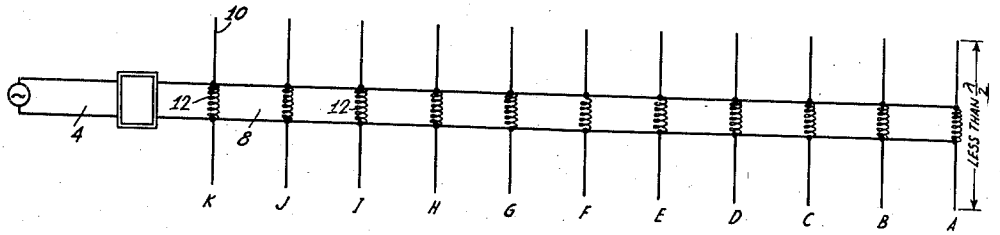
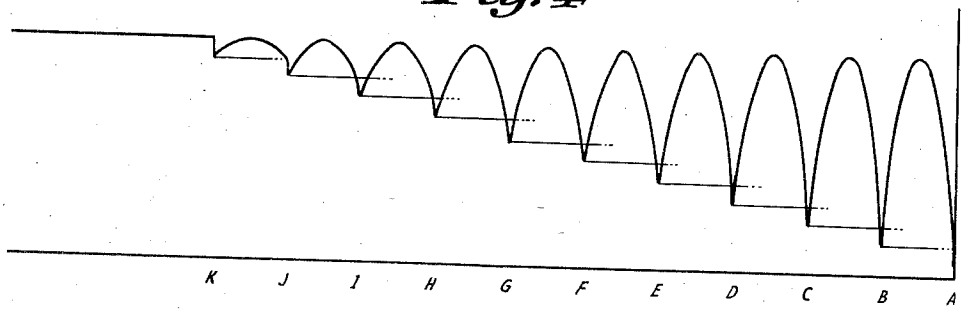


Fig. 4



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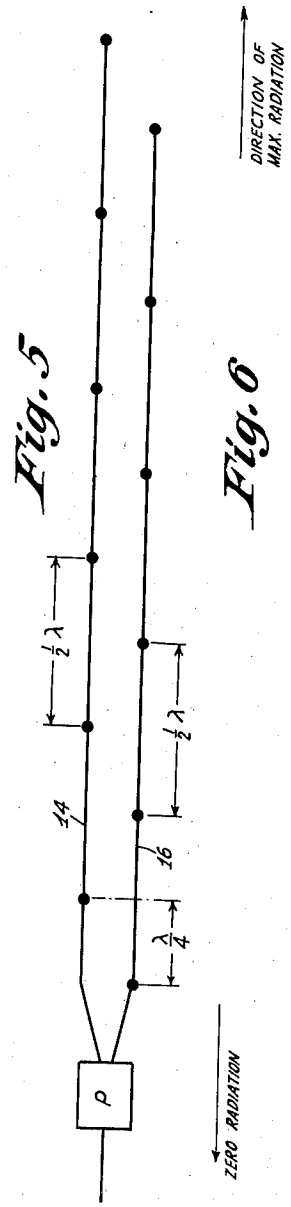


Fig. 5

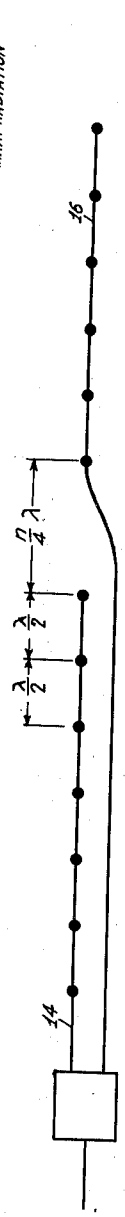


Fig. 6

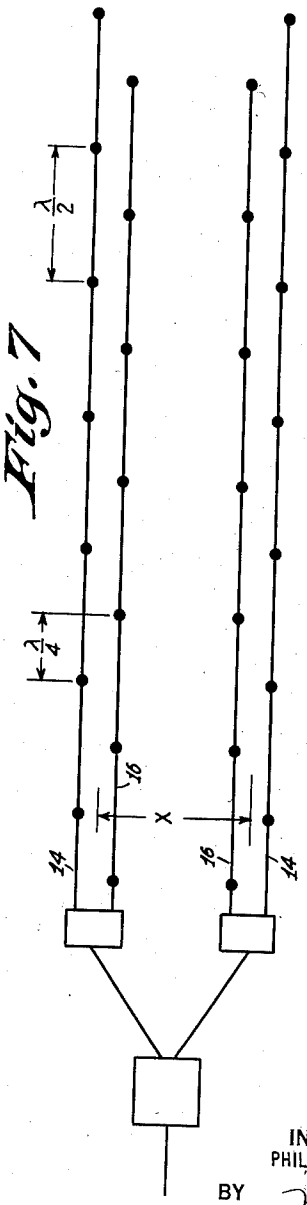


Fig. 7

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UNITED STATES PATENT OFFICE

1,967,395

ANTENNA

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Application April 9, 1930, Serial No. 442,765

11 Claims. (Cl. 250—33)

This invention relates to antennae and especially to antennae of the end-on variety; that is to say antennae in which radiant action occurs principally along the direction of their greatest length.

I have found that if any transmission line having a length equal to a half wave length or any multiple of a half wave length of the working frequency is loaded at the far end with a load which is the equivalent of a pure resistance; for example, a tuned circuit tuned to the working frequency, the impedance offered to the voltage at the input end of the line is a pure resistance of the same value as the load resistance. And this, I have found, is true regardless of the amount of reflection. In other words, neglecting the effect of line losses (which may be done since by suitable design they may be made negligible) the ratio of the load resistance to the surge impedance of the line has no effect upon the value of the impedance at the input end of the line.

Furthermore, at the load end of the line such as described, the phase lag of the current in the load with respect to the input current is the same as that for a line on which there is no standing wave or reflection.

It is an object of my invention to provide an end-on antenna system embodying the hereinbefore outlined principles and I do this by externally coupling to linear feeder members or a transmission line, transversals one half wave length long and spaced apart along the members one half wave length. Each transversal being tuned, is effectively a pure resistive load across the line. Accordingly, in view of what has been said hereinbefore, successive transversals or radiators will draw equal currents the current in each radiator, because of the transversal spacing along the line, will be 180 degrees out of phase with the current in a preceding radiator, thereby engendering most efficient radiant action along the line of the feeder members.

A further object of my invention is to improve the directivity of my antenna and this I do by providing pairs of antennae of the character described spaced in the direction of principal radiation such that in a desired direction radiant action becomes additive. To further improve radiant action, I provide pairs of spaced pairs of antennae.

Although my invention is defined with particularity in the appended claims, it may best be understood both as to its organization and method of operation by referring to the accompanying drawings, in which,

Figure 1 diagrammatically indicates an antenna, constructed according to the principles outlined, and illustrates half wave length transversals connected to a transmission line, the transversals being spaced apart along the line one half wave length,

Figure 2 is a graph illustrating current distribution in the linear feeder members of the antenna of Figure 1,

Figure 3 illustrates the modification wherein internally connected tuning elements are used to tune the transversals,

Figure 4 illustrates the current distribution in the transmission line of the antenna shown in Figure 3,

Figures 5 and 6 illustrate spaced antennae for improving end-on or in line radiant action, and

Figure 7 illustrates an arrangement of pairs of spaced or staggered antennae for still further improving axial radiant action.

Referring to Figure 1, energy to be radiated is fed from a source 2, transmission line 4 and impedance matching device 6 to an antenna A. The antenna may, of course, be used for reception in which case source 2 would be replaced by a radio receiver. This is true, of course, of all of the antennae or antenna systems which will be described hereinafter. Impedance matching device 6 matches the impedance of antenna A to transmission line 4 so that undue reflection will not occur on transmission line 4.

As shown antenna A consists of feeder members or a relatively closely spaced transmission line 8 to which transversally and externally coupled thereto are transversals or linear radiators 10. Transversals 10 as indicated are made one half wave length long and are spaced along the feeder members or transmission line 8 one half wave length apart.

Since each of the transversals is one half wave length long it is tuned and is effectively a pure resistive load connected across the feeder members 8. And, as the radiators 10 are of the same size, they will draw equal currents from the line 8 which currents, in successive radiators, because of the radiator spacing of one half wave length along the transmission line, will be out of phase 180 degrees. Accordingly, current in the line 8 will be uniformly reduced as shown in Figure 2 at points corresponding to the connection points of the linear radiators.

Because of the equal current distribution in each of the radiators and because of the phase relationship of those currents, most efficient radiation will be end-on or, along the axis of the

extensive antenna shown; in other words, in the direction of the feeder members 8.

Where space is limited or where dimensions become excessive, as in the case of transmission on the longer wave lengths, it may be desirable to make each less than one half wave length long. Under such circumstances, however, it will be necessary, in order to maintain correct phase relationship of the currents in the transversals, to tune them.

In Figure 3 I have shown an arrangement for carrying out the preceding suggestions. Transversals 10 as indicated are less than one half wave length long and are directly coupled to the transmission line 8. For tuning purposes a tuning element is connected serially with each radiator. The elements, as shown, take the form of tuning inductances 12 which tune the transversals making them effectively, resistive loads. By suitable design a current distribution may be had as shown in Figure 4 where the antenna system matches the surge impedance of the main line 4 without the use of a matching circuit. As in Figure 1, transversals 10 of Figure 3 are closely coupled to the feeder members since they are directly connected to the transmission line 8.

Shortening the length of the radiators decreases the radiation resistance and thus increases the effective resistance of each tuned system of a radiator and a coil. With a given number of radiators in the system the length can be made such that the effective resistance of the system will equal, for example, 600 ohms (average value of surge impedance met with in practice) and thus match the impedance of the main transmission line.

As an illustration assume a system of 9 radiators (of the kind shown in Figure 3). If the length of each radiator is made of the correct value an effective resistance of 5400 ohms can be obtained. This will result in an input resistance of

$$\frac{5400}{9} \text{ or } 600 \text{ ohms}$$

and will eliminate the necessity of an impedance matching circuit for prevention of standing waves on the main line 4. Figure 4 shows the current distribution in such a system and from radiator I to the power source no standing waves take place.

In order to increase directivity, spaced antennae as shown in Figures 5 and 6 may be used. In Figure 5 spaced antennae 14, 16 shown in plan of the type illustrated in either Figure 1 or 3 are spaced apart in the direction of radiant action one quarter of a wave length. By virtue of the stagger of the antennae, the system becomes, predominantly unidirective for the reason that the field radiated from one line of radiators cancels that radiated from the other line of radiators at point P by virtue of the difference in length of paths and the phase angle difference between the currents in the two lines of radiators. This action is more fully described in United States Patent 1,821,402, granted to Harold O. Peterson September 1, 1931, and in United States Patent No. 1,884,006, granted October 25, 1932, to Nils E. Lindenblad.

In Figure 6 the antennae 14, 16 are arranged in line but spaced apart n times a quarter wave length where n is an odd number. In this manner one antenna acts in a fashion similar to a reflector for the other antenna.

To still further improve directivity, and, in the case of transmission, to further concentrate the radiated beam of energy, pairs of spaced or staggered pairs of antennae may be used as shown in Figure 7. The spacing of the antennae 14, 16 is similar to that given in connection with Figure 5. The spacing of the pairs of spaced antenna indicated by legend X on the drawings is variable and depends in the main upon the length of the antenna used in connection with the system. The spacing for a given degree of directivity may readily be determined by trial or calculation.

Having thus described my invention what I claim is:

1. An end-on antenna comprising a straight two wire transmission line and transversals externally coupled to each wire of said transmission line, said transversals having an overall length of one half wave length and being successively spaced one half wave length apart along each wire of the transmission line, the wires of the transmission line being parallel throughout the length of said antenna structure whereby each succeeding radiator is fed in phase opposition to the preceding one.

2. An end-on antenna comprising a two wire transmission line and tuned transversely externally coupled to both wires of said line and spaced successively a multiple of one half wave length apart along the line, the wires of said transmission line being parallel throughout the length of said antenna structure whereby each succeeding radiator is fed in phase opposition to the preceding one.

3. An end-on transmitting antenna comprising a relatively closely spaced two wire linear transmission line, and closely and externally coupled to both said two wires transversals effectively one half wave length long and successively spaced apart one half wave length along the line, the wires of said transmission line being parallel throughout the length of said antenna structure whereby each succeeding radiator is fed in phase opposition to the preceding one.

4. An end-on transmitting antenna comprising a two wire transmission line, transversals successively spaced one half wave length apart directly and externally coupled thereto, and a tuning inductance in series with each transversal for tuning it to the frequency of the energy to be transmitted, the wires of said transmission line being parallel throughout the length of said antenna structure whereby each succeeding radiator is fed in phase opposition to the preceding one.

5. An extensive end-on antenna system for transmitting radiant energy comprising feeder members relatively closely spaced and linear radiators one half wave length long transversally, externally and directly connected thereto, successive radiators connected to each feeder member being one half wave length apart, said feeder members being parallel throughout the length of said antenna structure whereby each succeeding radiator is fed in phase opposition to the preceding one.

6. An extensive end-on antenna system comprising antennae spaced apart in the direction of principal radiant action an odd number of quarter wave lengths, each antenna comprising feeder members to which are coupled radiators tuned so as to be effectively one half wave length long, the radiators being spaced one half wave length apart along the feeder members.

7. An extensive end-on antenna system com-

prising pairs of spaced pairs of antennae, each antenna comprising feeder members to which transversally, directly, and externally coupled thereto are linear radiators effectively one half wave length long and spaced one half wave length apart along the feeder members said pairs of antennae being arranged an odd number of quarter wave lengths apart in the direction of the feeder members.

8. An end-on antenna comprising a substantially straight closely spaced pair of conductors, and linear radiators one-half wave length long conductively connected at their mid portions to said both conductors of said pair, said linear radiators being successively spaced apart one-half wave length, said pair of conductors being parallel throughout the length of said antenna structure whereby each succeeding radiator is fed in phase opposition to the preceding one.

9. An end-on antenna system comprising a two wire transmission line and transversals in a single plane directly connected to both wires of said line, said transversals being successively spaced apart from each other along the transmission line by one half wave length distances, the two wires of said transmission line being parallel throughout the antenna structure whereby each succeeding radiator is fed 180 degrees out of phase with respect to the preceding one.

10. An end-on antenna comprising a straight two wire transmission line, the wires of which are parallel throughout the length of the antenna structure, and transversals effectively one half wave length long and successively spaced at equal distances a multiple of a half wave length apart along said line, said transversals being externally and directly coupled to said transmission line, each of said transversals being connected to both wires of said transmission line.

11. An end-on antenna comprising a straight two wire transmission line, the wires of which are parallel throughout the length of the antenna structure, and tuned transversals effectively one half wave length long and successively spaced at equal distances a multiple of a half wave length apart along said line, said transversals being externally and directly coupled to said transmission line, each of said transversals being connected to both wires of said transmission line.

PHILIP STAATS CARTER.