July 30, 1940. J. B. DOW 2,209,813

ANTENNA SYSTEM

Filed July 20, 1936 2 Sheets-Sheet 1

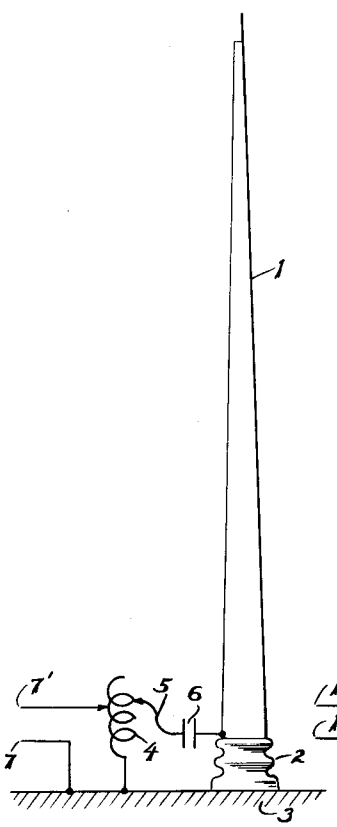


Fig. 1

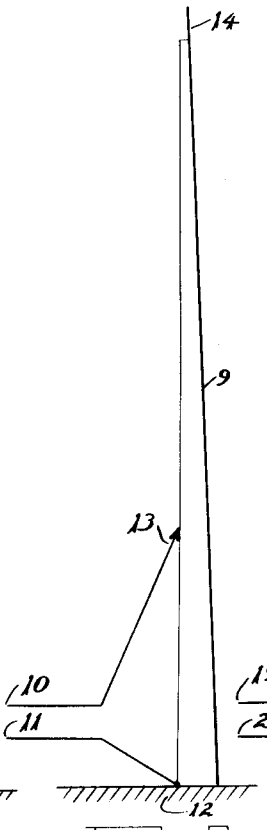


Fig. 3

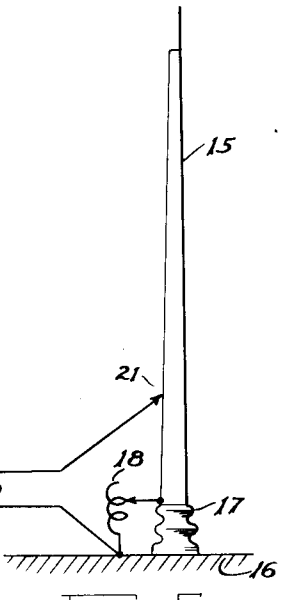


Fig. 5

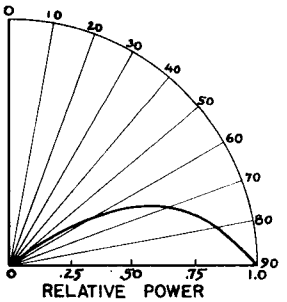


Fig. 2

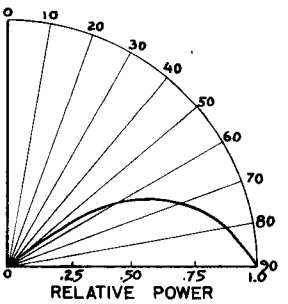


Fig. 4

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July 30, 1940. J. B. DOW 2,209,813

ANTENNA SYSTEM

Filed July 20, 1936 2 Sheets-Sheet 2

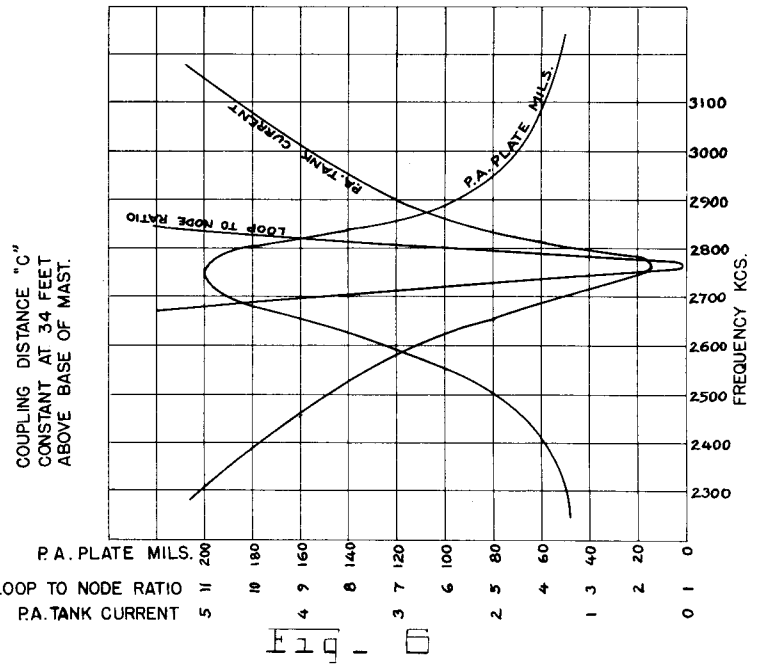


Fig. 6

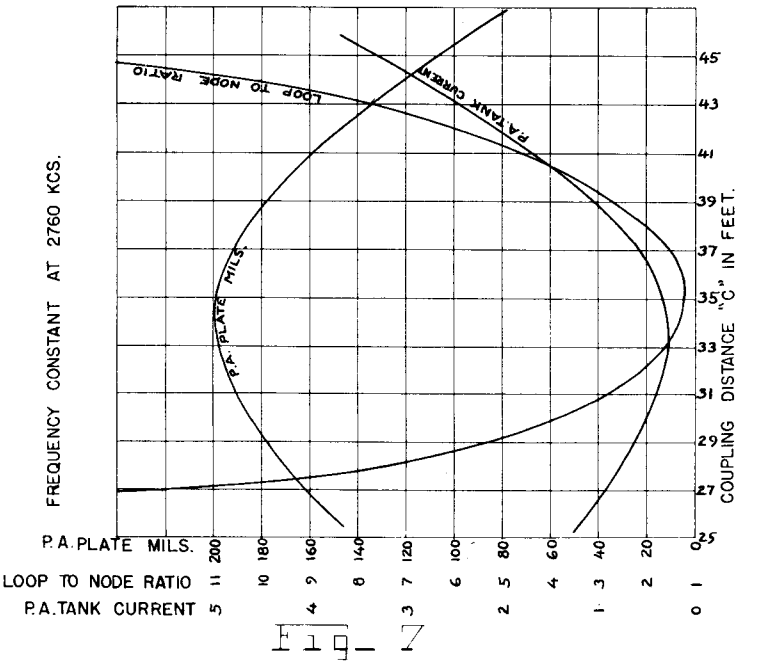


Fig. 7

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ANTENNA SYSTEM

Jennings B. Dow, Washington, D. C.

Application July 20, 1936, Serial No. 91,571

10 Claims. (Cl. 250—33)

(Granted under the act of March 3, 1883, as amended April 30, 1928; 370 O. G. 757)

My invention relates broadly to antenna systems and connections for electrically exciting such systems.

One of the objects of my invention is to provide means for exciting a metallic radiator having one end connected to a relatively large capacity area.

Another object of my invention is to provide means for exciting a metallic radiator such as a steel tower having the lower end grounded.

Another object of my invention is to provide means for overcoming the need for insulating from earth tower structures used as radiators for radio broadcast stations and the like.

A still further object of my invention is to provide a relatively simple coupling circuit for interconnecting a radio transmitter with a grounded tower structure for efficiently utilizing such structure as a radiator.

Other and further objects of my invention will be understood from the specification hereinafter following by reference to the accompanying drawings, in which:

Fig. 1 shows a conventional arrangement of a vertical antenna structure insulated at the base from earth and coupled to a transmission line in a conventional manner.

Fig. 2 shows a polar plot of the relative power radiated in the vertical plane for a vertical antenna one-half wave length long, insulated at the base from earth.

Fig. 3 shows an antenna structure and connections therefor arranged in accordance with the principles of my invention.

Fig. 4 shows a polar plot of the relative power radiated in the vertical plane for a vertical antenna approximately one-quarter wave length long grounded at the base.

Fig. 5 shows a special embodiment of my invention.

Fig. 6 shows a plot of certain electrical measurements obtained by varying the frequency of the excitation source which feeds the system shown in Fig. 3.

Fig. 7 shows a plot of certain electrical measurements obtained while varying the position of the tap connection along the tower structure shown in Fig. 3.

Many antenna structures, particularly those employed for the transmission of entertainment programs, comprise vertical steel structures approximately 0.4 to 0.6 wave length in length and insulated at the base from earth. The principal advantage of such an antenna is that a substantially uniform low angle radiation pattern is provided about the antenna. An antenna of this type is shown in Fig. 1, where reference character 1 indicates a steel tower or mast supported at the base by insulating member 2 which effectively insulates the mast 1 from earth. The word "mast" will be employed hereafter to indicate a metallic mast, tower or other structure employed as a radiator. The mast is the antenna or radiating member and owing to the method of operating same as a radiator, insulating member 2 must be constructed not only to withstand the weight of the entire mast 1 and the stresses introduced by weather but must provide adequate insulation for the high potentials existent at the base with respect to earth 3.

A necessarily expensive form of construction must be employed in such a support.

Moreover, for properly exciting such an antenna structure at a high potential point such as exists at the base, a tuning inductance 4 and a building for protecting such inductance from weather is usually also required.

In addition, such an arrangement as that shown in Fig. 1 introduces complications to the mast lighting facilities required as a safeguard to aircraft transportation.

The remaining elements of Fig. 1 comprise connection 5 from tuning inductance 4 to the base of mast 1 through capacity 6 and conductors 7 and 7' comprising the transmission line for feeding the system with radio frequency energy from a distant radio transmitter. Transmission line 7 may be of the open type of construction or may be of the concentric type, in which event conductor 7 would consist of a conducting tube surrounding conductor 7'. Such lines are characterized by substantially uniformly distributed electrical constants and have a readily calculated or measured surge impedance.

Fig. 2 shows a plot in the vertical plane of the radiation pattern of a one-half wave vertical radiator having the lower end close to earth but insulated therefrom. Curve 8 shows the power radiated for any angle from the vertical relative to the radiation existent at 90 degrees from the vertical.

Fig. 3 shows an antenna structure arranged in accordance with the principles of my invention. Reference character 9 indicates a mast which is not insulated from earth. For entertainment broadcast purposes I prefer to make mast 9 approximately one-quarter wave length long, although for other purposes it may be made much longer, preferably odd quarter wave lengths in

length such as one-quarter, three-quarters, five-quarters, etc. The transmission line in Fig. 3, is similar in construction to that shown in Fig. 1.

Instead of connecting the transmission line through a coupling system having lumped constants such as the inductance coil 4 of Fig. 1, I have found that a proper electrical match between the line and radiator 9 can be obtained by connecting one branch 11 of the line to earth 12 or to the base of mast 9 and the other branch 10 to a selected point 13 along the tower. This arrangement provides a very convenient coupling system for matching the antenna to the line.

A radiator arranged according to the principles of my invention is simpler electrically and far less expensive than the conventional arrangement shown in Fig. 1 because (*a*) expensive base insulation is made unnecessary, (*b*) the system is more rugged in the absence of base insulation, (*c*) the mast may more easily be made self-supporting, (*d*) the base of the mast is at ground potential and it is unnecessary to prevent personnel from coming in contact with same, (*e*) the need for a tuning coil, such as 4 in Fig. 1, is eliminated as well as the protective building for same, (*f*) mast lighting conductors may be run directly up the mast from the base, and (*g*) the arrangement as a whole is very efficient electrically.

Fig. 4 is a polar plot of the radiation pattern of a one-quarter wave radiator for comparison with that of the half-wave antenna radiation pattern shown in Fig. 2. The half-wave radiator pattern is somewhat to be favored, although the two are for all practical purposes substantially identical.

It is well known that the length of resonant antennas is, in general, a critical function of operating frequency and I have found it desirable in exciting mast structures to make the main body of such structures slightly shorter than the theoretically correct length and provide at the top a simple pipe extension 14 which may be raised or lowered during the adjusting stage. This considerably simplifies the final adjustment of such radiators.

I have found also that the principles of my invention may be applied to masts less than a quarter-wave length long which are insulated at the base from earth. Such an application of my invention is shown in Fig. 5, where 15 represents the mast structure insulated from earth 16 by base insulator 17. A loading inductance 18 is connected across insulator 17 for increasing the electrical length of tower 15. Transmission line 19, 20 and tap connection 21 complete the arrangement of Fig. 5. This same arrangement may be applied to structures of other lengths.

It is obviously possible to apply the principles of my invention to the excitation of the metal framework of buildings and other structures. It is apparent also that the principles of my invention may be applied to the use of grounded metal structures for radio receiving purposes simply by connecting the feed lines 10—11 and 19—20 to the input of a radio receiver.

Fig. 6 is a plot of certain electrical data obtained while exciting a grounded steel mast 88 feet in height and approximately 4 feet in diameter when such mast was coupled to a radio transmitter by the arrangement shown in Fig. 3. The data of Fig. 6 were obtained by first adjusting tap connection 13 of Fig. 3 to what appeared to be an optimum position and varying the excitation frequency, between 2300 and 3100 kilocycles per second. The curve marked "P. A. plate mils" shows the variation in plate current to the power amplifier stage. The curve marked "P. A. tank current" shows the variation in radio frequency tank current in the power amplifier stage. The tank circuit was adjusted to resonance with each change in frequency. The curve marked "Loop to node ratio" shows the standing wave condition in the transmission line, i. e., the ratio of loop current to node current. When this ratio is unity, no standing waves exist in the line and the radiator is matched with the line. This is equivalent to stating that the impedance of the load viewed from the end of the transmission line is equal to the surge impedance of the transmission line. When this condition exists the load is said to be non-reflective. It is apparent from Fig. 6 that this condition closely exists at a frequency of approximately 2760 kilocycles per second. For this frequency, the power amplifier plate current is a maximum and the power amplifier tank current is a minimum. If an impedance match does not exist between line and load, the load is said to be reflective and standing waves exist along the line resulting in a loop to node current ratio which is greater than unity. This condition is shown in Fig. 6 on either side of 2760 kilocycles. For example, at a frequency of 2700 kilocycles, the loop current is approximately eight times as great as the node current. The same condition exists at 2825 kilocycles.

Fig. 7 is a plot of data taken while maintaining the excitation frequency constant at 2760 kilocycles per second and varying the position of tap connection 13 of Fig. 3. The abscissae of Fig. 7 indicate the distance between tap connection 13 and the base of the mast 9. It is evident from Fig. 7 that for the particular mast employed in obtaining the data of Figs. 6 and 7 that optimum coupling existed at 35 feet. On either side of this optimum coupling, the loop to node current ratio rises as a result of the mismatch of load and line impedances.

The data of Figs. 6 and 7 and the simple arrangement of circuit structure serve to show the effectiveness of my invention. Obviously, many modifications of my invention are possible without departing from the principles disclosed. A tuning unit such as that designated by elements 4 and 6 of Fig. 1 may be employed with the arrangement shown in Fig. 3 in order to obtain a radiator to line match for some other position of tap connection 13 than that used in obtaining the data of Figs. 6 and 7. I desire it to be understood, therefore, that no limitations upon my invention are intended other than are imposed by the scope of the appended claims.

The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

What I claim as new and desire to secure by Letters Patent of the United States is as follows:

1. An antenna system for high frequency wave signaling comprising a self-supporting metallic mast one extremity of which is connected to earth through a connection of negligible impedance at said high frequency, and means for electrically exciting said mast, said means comprising an electric transmission line possessing uniformly distributed electrical constants over a

substantial portion of its length, said line having a connection along said mast at such point that the impedance of the mast as measured at the end of the transmission line nearest the mast is substantially equal to the surge impedance of said transmission line.

2. An antenna system in accordance with claim 1 wherein said transmission line comprises a plurality of parallel conductors at least one of which is connected to that extremity of the mast which is connected to earth and one other conductor of said transmission line is connected to a point along said mast.

3. An antenna system in accordance with claim 1 wherein said transmission line comprises a plurality of parallel conductors at least one of which is connected to earth and one other conductor of said transmission line is connected to a point along said mast.

4. An antenna system for high frequency wave signaling comprising a metallic mast the base of which is connected to earth through a connection of negligible impedance at said high frequency, and means for electrically exciting said mast, said means comprising an electric transmission line having two parallel conductors, one of which is connected to earth adjacent the base of said mast, the second conductor being connected to a coupling circuit for said line having a connection along said mast at such point that the impedance of said mast and coupling circuit as measured at the end of said transmission line nearest said coupling circuit is substantially equal to the surge impedance of said transmission line.

5. An antenna system comprising a continuous metallic mast the base of which is imbedded in earth and means for electrically exciting said mast, said means comprising a two conductor electric transmission line possessing uniformly distributed electrical constants over a substantial portion of its length, one conductor of said line being connected to a coupling circuit, said coupling circuit having one connection to a point along said mast, the second conductor of said line having a circuit connected to earth adjacent said mast, said point along the mast being so chosen that the impedance of said mast and coupling circuit as measured at the end of said transmission line nearest said coupling circuit is substantially equal to the surge impedance of said transmission line.

6. An antenna system comprising a self-supporting metallic mast, a circuit connection between the base of said mast and earth, means for electrically exciting said mast, said means comprising an electric transmission line comprising two substantially parallel conductors terminated in a coupling circuit for said line, said coupling circuit having one connection to a point along said mast and a second connection to earth adjacent to said mast.

7. A high frequency antenna system comprising a vertical self-supporting metallic mast, a connection having negligible impedance at the operating frequency of said system connecting the lower extremity of said mast to earth, said mast having a height corresponding substantially to any odd number of quarter wave lengths of the high frequency wave employed therewith, a high frequency transmission line comprising two parallel conductors, one of which is connected to earth and the second of which is connected to a high frequency current path between said line and a point along said mast such that the impedance of said mast and current path as measured at the point of connection to said line and at the operating frequency of said system, is equal substantially to the surge impedance of said line.

8. A high frequency antenna system comprising a metallic mast, a connection of negligible impedance at the operating frequency of said system, connecting the base thereof to a large capacity area, said mast having a length corresponding approximately to any odd number of quarter wave lengths of the operating wave length employed therewith, a transmission line comprising two parallel conductors one of which is connected to said capacity area and the second of which is connected to a circuit connection between said line and a point along said mast such that the high frequency impedance of said system as viewed from that end of the line nearest said mast is equal substantially to the surge impedance of said line.

9. A high frequency antenna system comprising a self-supporting metallic mast, means connecting the base thereof to a relatively large capacity area, a transmission line comprising two parallel conductors, one of which is connected through a high frequency current path to said capacity area and the second of which is connected through a high frequency current path to a point along said mast such that the impedance of said system as viewed from that end of the line nearest said mast and measured at the operating frequency of said system is equal substantially to the surge impedance of said line.

10. In a high frequency antenna system comprising a self-supporting metallic mast connected at the base to a large capacity area, a transmission line having at least two substantially parallel conductors, one of said conductors having an alternating current conductive path to said base and a second of said conductors having an alternating current conductive path to a point along said mast, said point being so selected that the high frequency impedance of said conductive paths and mast measured at the operating frequency of said system is equal substantially to the surge impedance of said line.

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