July 28, 1953 L. C. SMEBY 2,647,211

RADIO ANTENNA

Filed Jan. 11, 1949 3 Sheets-Sheet 1

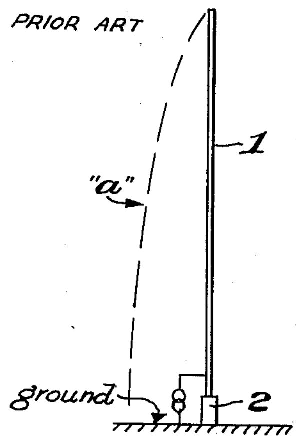

Fig. 1

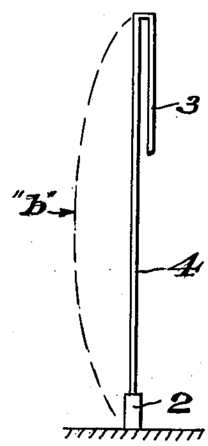

Fig. 2

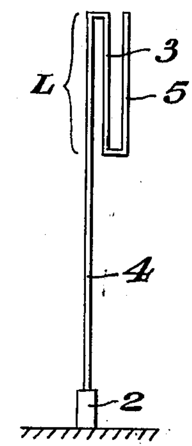

Fig. 3

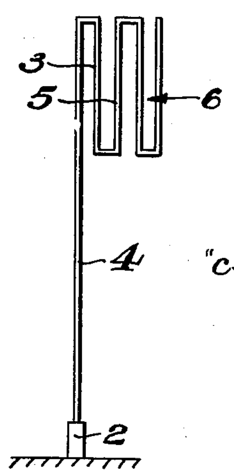

Fig. 4

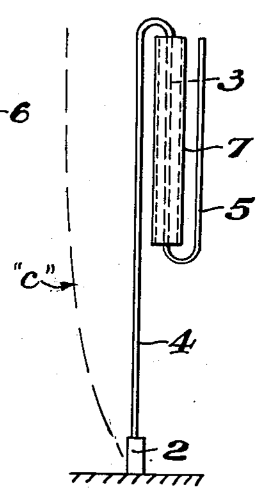

Fig. 5

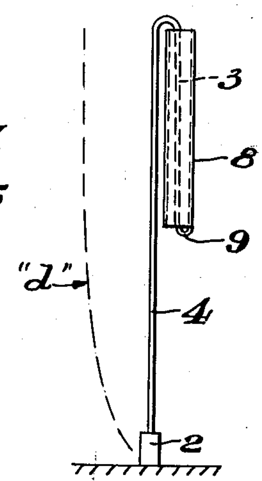

Fig. 6

Inventor:
Lynne C. Smeby,

By Homer R. Montague

ATTORNEY

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RADIO ANTENNA

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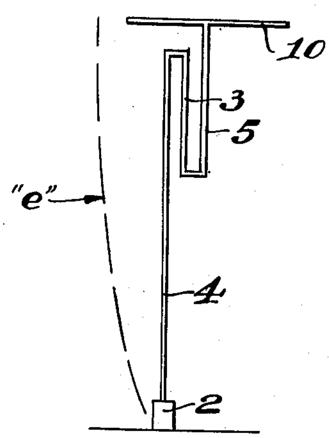

Fig. 7

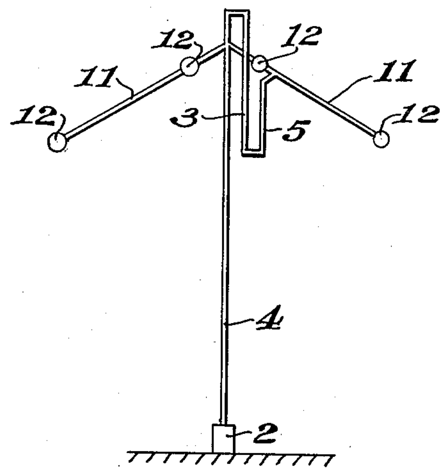

Fig. 8

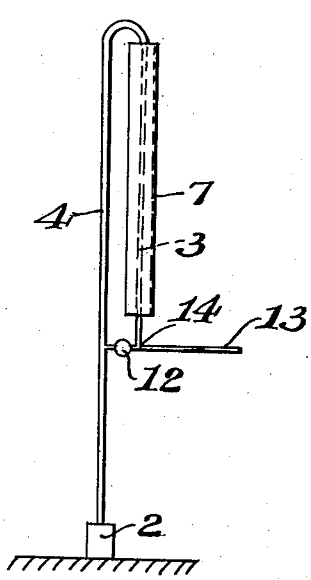

Fig. 8A

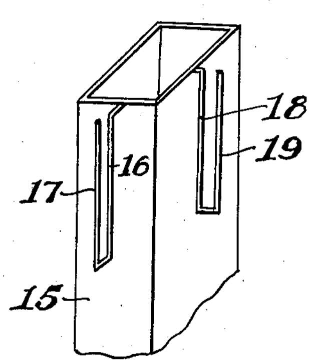

Fig. 8B

Inventor:
Lynne C. Smeby,

By Homer R. Montague

ATTORNEY

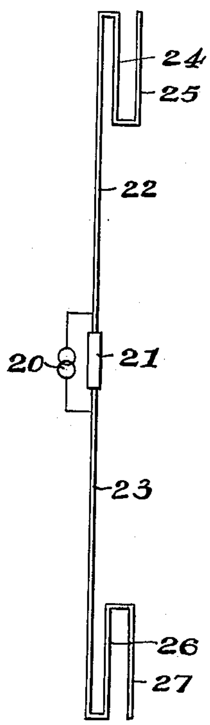

Fig. 9

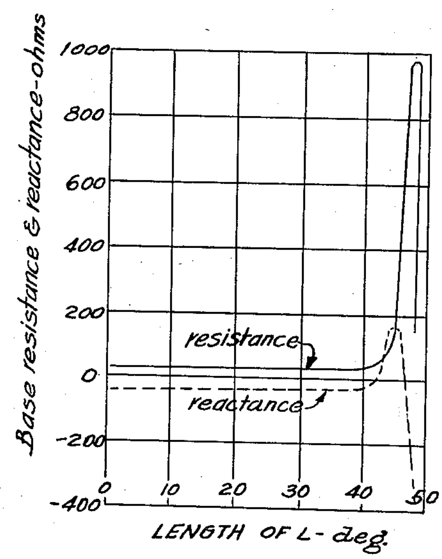

Fig. 10

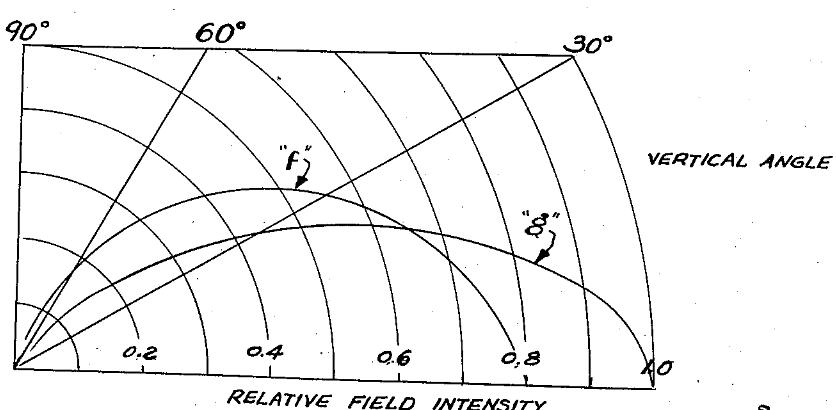

Fig. 11

Inventor:
Lynne C. Smeby,

By Homer R. Montague

ATTORNEY

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RADIO ANTENNA

Lynne C. Smeby, Washington, D. C.

Application January 11, 1949, Serial No. 70,333

7 Claims. (Cl. 250—33)

This invention relates to radio communication, and particularly to an improved form of antenna for the propagation of radio frequency energy from a transmitter, and for the purpose of receiving radio signals; while the features of the invention are described herein in terms of transmitting, these features are also applicable to improving the performance of receiving antennas.

It is a principal object of the invention to provide an antenna design which permits an accurate control of the base impedance and radiation characteristics thereof, without mechanical complication and in general with a reduced installation cost.

Another object of the invention is to provide such a design that is applicable either to series-fed, or shunt-fed antennas, as well as to antennas with other types of feeds, and which will be useful over a wide range of propagation frequencies, but most particularly at relatively lower frequencies in which the dimensions of conventional antenna structures become so large as to represent costly and bulky structures.

A further object of the invention is to provide an antenna design which will permit a desirable distribution of excitation current lengthwise of the antenna itself (that is to say, generally in the vertical direction of a vertical radiator), whereby the vertical pattern of the radiation may effectively be controlled.

Another and very important object of the invention is to provide means operable to strengthen and reenforce the radiation from the upper portion or portions of a generally vertically arranged radiator, by means which are mechanically simple and which do not interfere with the mechanical bracing or guying generally required with vertical radiators of practical heights.

An ancillary object of the invention is to provide an antenna having the above objects achieved in such a way as to facilitate the use of lumped capacitance-to-earth at the upper end of the radiator, known in the prior art as "top loading," in combination with a current and impedance controlling element or array in accordance with my invention, whereby the combined advantages of such devices may be obtained with a minimum increase in cost, and indeed with an actual saving in cost when the possible reduction in overall mast or radiator height is taken into consideration.

The above and other objects and advantages of my invention will best be understood by referring to the following detailed specification of certain selected and preferred embodiments thereof,

chosen by way of illustration and not limitation, and by a like reference to the accompanying drawings forming a part hereof, in which:

Fig. 1 is a schematic elevational view of a simple antenna of the series-fed, vertical radiator type well known in the prior art,

Fig. 2 is a similar view of an antenna of the same type which has been modified in accordance with the invention,

Fig. 3 is a like view of a further development of the invention,

Fig. 4 is a similar illustration of a further refinement in accordance with the invention showing multiple folds of the basic top loading elements shown in Figs. 2 and 3,

Fig. 5 is a like illustration of a further refinement in accordance with the invention showing one element of the basic arrangement within a shield,

Fig. 6 is a like view of a further development of the invention showing one of the elements within a shield and the shield itself used as one of the elements,

Fig. 7 is a like view of a further refinement showing the combination of the control feature of the invention in physical combination with a species of top loading known in the prior art as a hat,

Fig. 8 is a similar illustration of a further refinement in accordance with the invention showing the combination of the control feature of the invention in physical combination with a species of top loading known in the prior art as an umbrella.

Fig. 8A illustrates a further refinement in accordance with the invention showing the combination of the control feature of the invention in physical combination with a lumped or capacity loading situated in relation to the main radiator at a location other than the top.

Fig. 8B is a like view of a further refinement showing the use of multiple units of the control feature of the invention,

Fig. 9 is an illustration of the control feature of the invention applied to a radiator in free space,

Fig. 10 is a graphical presentation of the change in base impedance characteristics of a radiator obtainable with the improved structure, and

Fig. 11 is a graphical presentation of the change in vertical radiator characteristic of a radiator obtainable with the improved structure.

Fig. 1 of the drawings illustrates a well known form of series-fed transmitting antenna consisting of a single wire radiator 1 standing substantially vertical above earth. A single wire is used for purposes of illustration only, and any conventional type of radiator may be employed. The radiator is excited by a radio frequency generator connected across the insulator 2 directly or by a conventional transmission line. Such a radiator will have an impedance across the insulator known as the base impedance, and a vertical radiation characteristic primarily in accordance with the length of radiator 1 in comparison with the wavelength of the energy from the generator. Such an antenna usually has a length between 36° and 225° (where 360° is a full wavelength), although greater and lesser lengths are sometimes used. As an illustration, in some broadcasting station applications, a simple vertical radiator as shown in Fig. 1 with a height as low as 60° is satisfactory; whereas in other applications, a height as great as 225° is used. The greater the height of the radiator up to 225°, the greater will be the ground wave radiation due to the improved radiation characteristics. At increasing heights (up to 180°) the radiation at angles above the horizon will be decreased in proportion to the ground plane radiation and above heights of 180° there will be a decrease in radiation at certain angles above horizontal and an increase at others. The higher the radiator is up to 225°, the greater the base radiation resistance as measured across the insulator 2 shown in Fig. 1 will be, within limits. There is always present in a grounded antenna a loss resistance in the ground system. Ordinarily the ohmic loss of the radiator itself is negligible. Therefore, the higher the radiation resistance, the greater will be the efficiency of the antenna system, thereby producing a greater radiation field.

At antenna heights below approximately 90°, the base reactance is negative and therefore an inductance coil is required to tune the radiator to resonance. Such a tuning coil has resistance and therefore involves a loss of power with a consequent reduction in field strength. With decreasing height of radiators, the tuning coil required becomes larger and larger thereby increasing the loss of power in the coil. As the height of the radiator is decreased, the coil losses become serious in the neighborhood of 40° antenna heights.

When two or more radiators are operated in a directional antenna array, the self-impedance of each radiator is modified due to the mutual effect between the radiators. In some arrays, the radiation resistance of the directional array as a whole is reduced to a point where the ground system losses become appreciable. In general, the higher the radiators in a directional system, the greater will be the effective radiation resistance of the system and hence, the smaller the ground system losses. This is because the higher the radiators, in general, the higher is the self-resistance of each individual radiator operating by itself.

In the prior art, lumped capacitance in a form known as a "hat" has been connected to the top of the radiator in order to increase the base radiation resistance and/or to improve the vertical radiation characteristic. Another method of obtaining approximately the same end has been to sectionalize a radiator by placing an insulator approximately in the center of the radiator with a loading coil connected across the insulator. These methods have been limited in their effect

because in the case of the lumped capacitance at the top of the radiator, there are mechanical restrictions as to how large the loading can be, and in the case of the sectionalized radiator the limitation arises from the loss sustained in the loading coil.

I have found that the radiation efficiency of a vertical wire antenna having a length which is only a fraction of the radiated wave length may be greatly increased by artificially creating a redistribution of antenna current such that the current density at the upper end of the radiator is increased, and that at its lower portion correspondingly decreased (as compared with the conventional, which has a maximum current at or near its base and zero current at its upper extremity as shown in curve *a* of Fig. 1), by folding a portion of the top of the radiator back upon itself to provide a radiating leg spaced from and generally parallel to the upper portion of the antenna, as is indicated by the folded portion 3 at the upper end of a fractional wavelength radiator 4 in Fig. 2. In this figure the amplitude of the antenna current at each vertical level is indicated by the dashed curve line *b*, and a comparison with the similar dashed curve *a* of Fig. 1 will illustrate the manner in which this change provides a current distribution having a substantial value well up the radiator and zero amplitude at the base, with consequent improvement in base impedance and/or in vertical radiation characteristic.

It must be clearly borne in mind that the folded-back portion 3 of the antenna of Fig. 2 is to be distinguished from the usual and well-known top loading structure heretofore utilized to provide in effect a capacitance-to-earth in parallel with the current conducting path provided by the radiator. Such top loading capacitance is effective only to alter the condition of resonance existing, for instance, at the base of the antenna; the capacitance to ground, however, of the short vertical section 3 of Fig. 2 is practically trivial. This section acts in combination with the main antenna section 4 as a true radiating portion, and in effect permits the same base impedance to be obtained as would be the case if the actual length of the antenna were the sum of the lengths of portions 3 and 4, but with a considerable saving in overall height, and hence in construction and maintenance costs. While the drawings show the antenna as a simple vertical wire, it is intended to include within the scope of this invention the application of the same arrangements to vertical mast radiators of all kinds.

Fig. 3 of the drawings illustrates the development of the principles of the invention in which the same mechanical arrangement is used as illustrated in Fig. 2, with the addition of an element 5 folded back up the radiator, and again in conductive relation to the main vertical radiator 4.

The principles of Fig. 3 may be carried forward by providing one or more multiply-folded auxiliary radiating portions such as illustrated by numeral 6 in Fig. 4. In this case, the base impedance is altered to any given degree by a shorter length of elements than is obtained by the use of the arrangement shown in Fig. 3.

Fig. 5 of the drawings illustrates a development of the principles of the invention in which one of the elements is enclosed in a shield. Numeral 7 indicates a conductive shield surrounding a folded-over element 3, such that the radiation from 3 is substantially suppressed. The radiation from the radiator 4 and from the element 5 are in phase, with a consequent adding in phase of the fields produced by their respective currents. The field produced by the current flow in element 3 of Fig. 3 is out of phase with the field produced by the flow of current in elements 4 and 5. In the arrangement shown in Fig. 5, the radiation from element 3 is substantially suppressed thereby producing a further crowding of the total effective current towards the top of the radiator, as shown by curve *c*.

A further development of the principles of the invention is shown in Fig. 6. The folded-over element 3 is placed within a conductive shield 8 which in turn is insulated from the radiator 4. The top of element 3 is connected conductively to the radiator 4, and the bottom of element 3 is connected to shield 8 as illustrated by numeral 9. The radiation from element 3 which is out of phase with the radiation from radiator 4 and shield 8 is substantially suppressed by the shielding effect of shield 8. This produces a crowding of the total effective current towards the top of the structure as illustrated by a curve *d*.

In Fig. 7, numeral 4 again indicates a radiator of conventional design. Numeral 10 indicates a capacitance loading of the conventional type known in the prior art as a "hat." Numerals 3 and 5 indicate elements following the principles of the invention connecting the top of the radiator 4 to the hat 10. In Fig. 7, the principles of the invention combine with the conventional type of top loading to produce a crowding of the current on the radiator towards the top as shown by the current distribution curve *e*. The principle of the invention may be combined with any other species of top loading known in the prior art such as a sphere, portions of the top guy wires of a tower, or specially installed wires such as shown in Fig. 8. Numeral 11, in Fig. 8 indicates a portion of guy wire or specially installed wire connected to the radiator numeral 4 by elements 3 and 5 embodying the principles of the invention, such portions 11 being defined between suitable insulators 12. While Fig. 8 shows only two radiating elements 11, ordinarily three or more such elements spaced at equal azimuth angles are employed. All of the elements would be connected together.

In Fig. 8A numeral 4 illustrates a conventional radiator in combination with the control features of the present invention and a lumped or capacity loading located at a height other than the top of the radiator 4. Element 3 is a folded-back conductor surrounded by a shield 7. The top of 3 is connected at or near the top of radiator 4, and the shield 7 may be insulated from 4 or connected conductively at one or more places. Numeral 13 indicates a horizontal conductor; however, this is intended to represent any sort of lumped capacitance loading such as a hat insulated from the main radiator 4, a set of guy wires insulated from radiator 4, a set of especially installed wires insulated from radiator 4 or any other species of lumped capacitance. The lumped capacitance 13 is connected to the conductor 3 by the connection indicated by numeral 14. By placing the lumped capacitance 13 at an elevation below the top of radiator 4, the mechanical arrangement is made easier and the required strength of the tower reduced, thereby effecting a saving in cost. In addition, for any given mechanical size of the lumped capacitance 13, the capacity to ground is increased if 13 is moved from the top of the tower towards the ground, thereby increasing the effective electrical loading. The current flowing in the conductor 3 is 180° out of phase with the current flowing in the main radiator 4 and therefore if 3 were not shielded, the field produced by it would subtract from the field produced by the radiator 1 thereby reducing the effectiveness of the invention. Therefore, shield 7 is provided to substantially reduce the radiation from element 3. This is not intended to preclude the use of the invention without the shield 7. In addition to feeding the lumped capacitance 13, the conductor 3 will have a standing wave on it producing additional effective loading at the top of the radiator 4, and thereby further improving the operation of the antenna.

The use of multiple units of the features of the invention is shown in Fig. 8B. Numeral 15 indicates a vertical metallic radiator of the square cross section type by way of illustration, it being intended that multiple units may be disposed about radiators of any other cross section. Numerals 16 and 17 indicate the folded-back conductors of the invention as illustrated in Fig. 3. Such conductors may also be provided on a second face of the radiator 15 as indicated at numerals 18 and 19. Progressively, additional units in accordance with the invention may be added, not necessarily at azimuth angles such that they are placed on different faces of the radiator 15.

The units may be of different lengths depending on the desired results. While Fig. 8B shows each unit perpendicular to a face, each unit may have its axis parallel to the axis of the radiator 15 or at any other angle thereto. The initial element of each unit such as 16 need not necessarily start at the top of the radiator 15, and the last element in each unit need not necessarily be terminated level with the top of radiator 15. The ends of respective last elements in each unit may be connected together in any manner such as by a ring or bringing ends of the units together above the radiator 15. It is intended that multiple units of the same or different species of the invention may be combined depending upon the results desired.

Figs. 1 thru 8B illustrate radiators standing above earth. The principles of the invention may equally well be applied to radiators in free space. Fig. 9 shows a free space radiator fed by a generator 20 connected across the insulator 21. Elements 22 and 23 are the conventional radiators, each provided with one of the species of the invention by way of illustration shown in Fig. 9 by the folded-back portions 24 and 25 at one end of the radiator and like portions 26 and 27 at the other.

Fig. 10 is a plot of reactance and resistance measurements that were made on an embodiment of the invention as shown in Fig. 3. Fig. 10 shows that the reactance at the base of the radiator with zero length of folded-back portion L was negative and that the reactance could be shifted over to a positive value by the proper selection of the length of L (Fig. 3). This would allow the use of a capacity to tune the radiator to resonance instead of an inductance, thereby eliminating the loss that would have resulted if the features of the invention had not been used and a coil tuning unit had been employed. Fig. 10 also shows the change in base resistance. By the proper selection of the length of L, the base radiation resistance of the radiator may be materially increased thereby increasing the ratio of radiation to radiation plus ground resistance, consequently increasing the effective radiated field.

Curve *f* of Fig. 11 illustrates the vertical radiation characteristic of a conventional 120° tall radiator. With the employment of the principles of the invention, the 120° tall radiator can be made to simulate electrically a radiator of 180° height. The vertical radiation characteristic would be then as shown in curve *g* of Fig. 11. It is seen that the ground plane radiation would be increased and the intensities of radiation at higher angles would be decreased in proportion to the radiation in the ground plane.

I claim:

1. An antenna comprising a linear conductor, an auxiliary conductor connected to one end of the first named conductor and lying parallel to but spaced from said first-named conductor, and a radiating shield disposed to shield said auxiliary conductor and electrically connected to that end of said auxiliary conductor which is more remote from the connection between the first-named conductor and said auxiliary conductor.

2. An antenna system comprising a substantially vertical linear main conductor, an auxiliary conductor connected to the upper end of said main conductor and extending downwardly therefrom in parallel spaced relation to said main conductor, and capacity loading means connected to the lower end of said auxiliary conductor and having substantial extension in a horizontal plane.

3. The invention in accordance with claim 2, and means for shielding at least a portion of said auxiliary conductor.

4. An antenna system comprising a substantially vertical linear main conductor, an auxiliary conductor connected to the upper end of said main conductor and having at least one leg extending downwardly from said upper end of the main conductor in spaced parallel relation thereto, and capacity loading means connected to said auxiliary conductor and having substantial extension in a horizontal plane.

5. An antenna system comprising a substantially vertical linear main conductor, an auxiliary conductor connected to the upper end of said main conductor and having at least one leg extending downwardly from said upper end of the main conductor in spaced parallel relation thereto, and capacity loading means connected to the extremity of said auxiliary conductor and having substantial extension in a horizontal plane.

6. An antenna system comprising a substantially vertical linear main conductor, an auxiliary conductor connected to the upper end of said main conductor and having a plurality of parallel legs connected in series with one another and all lying in spaced parallel relation to said main conductor, and capacity loading means connected to that leg of said auxiliary conductor most remote from said main conductor, said loading means having substantial extension in a horizontal plane.

7. An antenna system in accordance with claim 6, in which said loading means comprises an umbrella assembly of connected, substantially radial conductors.

LYNNE C. SMEBY.

References Cited in the file of this patent

UNITED STATES PATENTS

Number	Name	Date
1,696,402	Horton	Dec. 25, 1928
1,839,426	Von Arco	Jan. 5, 1932
2,130,387	Franklin	Sept. 20, 1938
2,283,914	Carter	May 26, 1942
2,344,171	Rote	Mar. 14, 1944
2,417,793	Wehner	Mar. 18, 1947
2,511,931	Masters	June 20, 1950

FOREIGN PATENTS

Number	Country	Date
581,567	Great Britain	Oct. 17, 1946