Feb. 24, 1959

A. G. KANDOIAN

2,875,443

ANTENNA

Filed June 21, 1954

Fig. 1

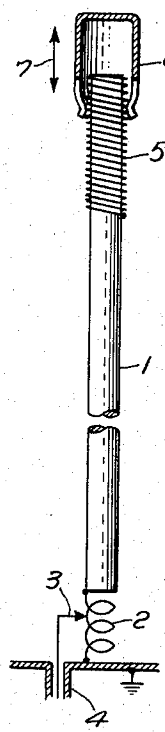


Fig. 2

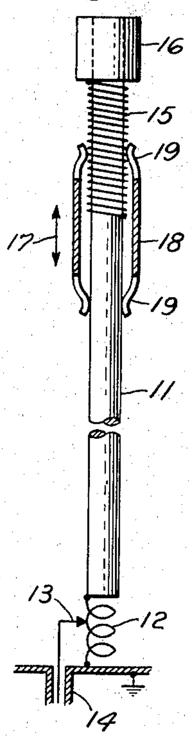


Fig. 4

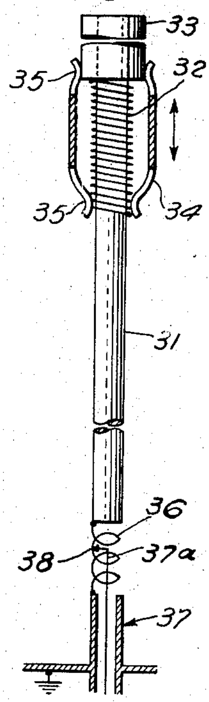


Fig. 5

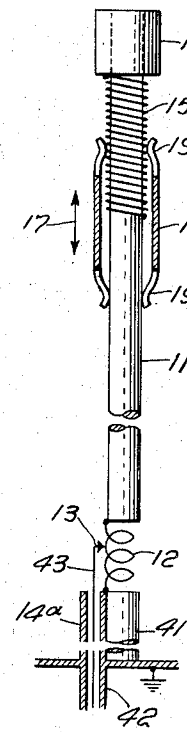
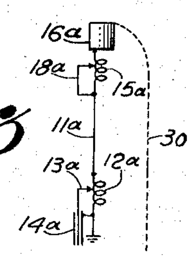


Fig. 3



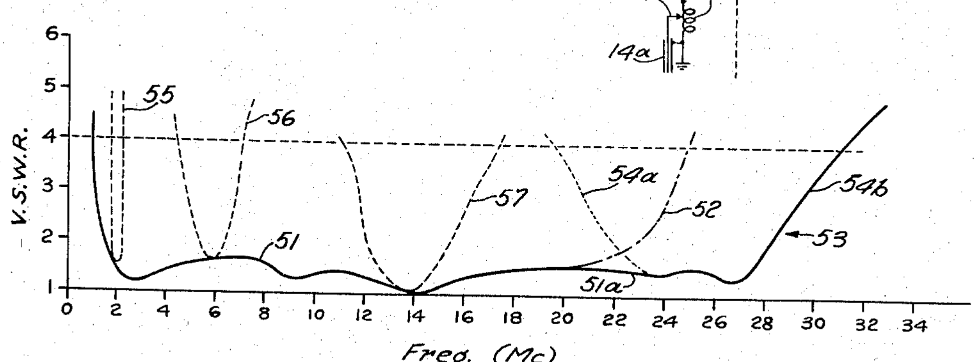


Fig. 6

INVENTOR
ARMIG G. KANDOIAN

BY Ernest Fanwick
ATTORNEY

United States Patent Office

2,875,443

Patented Feb. 24, 1959

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2,875,443

ANTENNA

Armig G. Kandoian, Glen Rock, N. J., assignor to International Telephone and Telegraph Corporation, Nutley, N. J., a corporation of Maryland

Application June 21, 1954, Serial No. 438,222

5 Claims. (Cl. 343—895)

This invention relates to antennas and more particularly to a tunable dipole antenna having an effective electrical length which can be adjusted to equal desired fractions of wavelengths over a relatively broad band of frequencies.

In practice, it is often necessary to provide a single antenna preferably of fixed length which is capable of satisfactory operation over a broad band of frequencies in such a manner that a satisfactory impedance match with a transmission line is assured at each of the frequencies. Normally such antennas, particularly those of fixed length and having a maximum dimension which is small compared to the operating wavelength, have impedance characteristics which vary very rapidly with frequency. Such antennas therefore require complex tuning and matching networks in order to properly match the impedance of the transmission line coupled thereto. There are, of course, many antenna systems which are capable of being used at a plurality of frequencies, but which require the retuning of the matching circuit of the antenna system as the frequency of operation is changed. In the past, however, such antenna systems have usually had to vary the input coupling in some manner in order to maintain a constant input impedance over the broad band of operating frequencies. Also, the antenna systems known to the prior art which were capable of operation over a wide band of frequencies have usually had a current distribution which was not uniform along their length and such a distribution is less favorable than a uniform current distribution.

It has long been recognized that the object in designing a vertical grounded antenna which is necessarily a quarter wavelength or less in height is to make the current loop or current maximum come as near the top of the antenna as possible and to maintain the current as large as possible throughout the length of the vertical antenna. This requires "top loading" which in effect appears to add height to the antenna so far as energy traveling up to the top end of the antenna is concerned. This brings the maximum current to the top of the antenna. It is possible to simulate the effect of a missing length by concentrating capacitance at the top of the antenna. The capacitance is not of the usual type which would be ineffective, since the capacitance is of necessity one sided, but it normally consists of a metallic structure which exhibits the necessary capacitance to space. Practically any sufficiently large metallic structure can be used for the purpose, but simple geometric forms such as the sphere, cylinder and disks are preferred because of the relative ease with which their capacity can be calculated.

One of the objects of this invention, therefore, is to provide a tunable dipole antenna system capable of being operated over a broad band of frequencies by varying the effective length of a helical coil in the antenna circuit and having a substantially constant input impedance over the entire band.

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Another object of this invention is to provide a relatively wide band dipole antenna of fixed length having a substantially uniform radiation current distribution along its axial length.

A further object of this invention is to provide a single antenna capable of having its effective electrical length varied to offer maximum effectiveness for the radiation of energy at two or more frequencies without requiring a complex tuning or matching network to maintain a constant input impedance characteristic.

In accordance with one embodiment of my invention, a tunable dipole antenna preferably of fixed length capable of operation over a wide band of frequencies and having a current distribution which is substantially flat with the same current level at the base and near the top of the antenna is provided by utilizing a vertical antenna connected at its top end to a suitable helical coil which is terminated by a capacitive top loading. The vertical antenna is coupled to ground through an input impedance matching inductance to which the input energy is coupled. The antenna system is tuned over the wide band of frequencies by varying the effective length of the helical coil in the antenna circuit while the input impedance remains substantially constant.

In another embodiment of my invention, the input coupling coil is coupled to ground through an antenna stub which is grounded and thus yields an antenna of extremely wide band frequency characteristics.

The above-mentioned and other features and objects of this invention will become more apparent by reference to the following description taken in conjunction with the accompanying drawings, in which:

Fig. 1 is a schematic drawing of one embodiment of an antenna in accordance with the principles of my invention;

Fig. 2 is a schematic diagram of a second embodiment of an antenna in accordance with the principles of my invention;

Fig. 3 is a schematic drawing to show the current distribution along the axial length of the antenna of Fig. 2;

Fig. 4 is a schematic drawing of still another alternate embodiment of an antenna system in accordance with my invention;

Fig. 5 is a schematic drawing of still another embodiment of my antenna for use over an extremely wide band of frequencies in accordance with the principles of my invntion; and

Fig. 6 is a graphic illustration helpful in explaining the advantages of my invention.

Referring to Fig. 1 of the drawing, a tuned dipole antenna system in accordance with the principles of my invention is shown to comprise for the main portion of the axial radiator of the antenna system a vertically disposed tubular radiator **1**. The vertical radiator **1** is terminated to ground through an input impedance matching inductance **2** to which a variable tap **3** couples the input energy from a transmitter (not shown) over coaxial cable **4**. The upper end of the vertical radiator **1** is coupled to a helical coil **5** which is terminated in a capacitive top loading which as illustrated takes the form of a cylinder **6**. The top loading cylinder **6** is disposed to slide over the helical portion **5** of the antenna. The coupling **3** from the input cable **4** to the antenna system is adjusted so as to produce substantially a 50-ohm input impedance which remains substantially constant at all frequencies to which the antenna is tuned in the 2–30 mc. range. In order to tune the antenna to resonance, the top loading cylinder **6** is moved up and down as indicated by arrow **7** thus shorting out a varying number of turns of coil **5**. The maximum frequency to which the antenna system of Fig. 1 can be tuned (the minimum wavelength) is obtained when the top load cylinder **6** shorts out all the turns of helical coil 5 and thus the minimum effective electrical length of the antenna system shown in Fig. 1 comprises the length of vertical radiator 1 from the input coupling point 3 plus the vertical height of the capacitive cylinder 6. The minimum frequency (the maximum wavelength) to which the antenna system shown in Fig. 1 can be tuned is reached when the capacitive top loading cylinder 6 shorts out none of the turns of the helical coil 5 and thus the maximum effective electrical length of the antenna 2 shown in Fig. 1 includes the effective length of the helical coil 5 and the length of the vertical radiator 1.

Referring to Fig. 2 of the drawing, a tunable dipole antenna system having a fixed physical height in accordance with the principles of my invention is shown to comprise a conductive tubular vertical radiator 11 which is terminated to ground by an input matching inductance 12 to which an energy supply line 14 is adjustably coupled by variable tap 13. The energy supply line 14 is disposed coaxially with the inductance 12 and in line with radiator 11. The upper end of the vertical radiator 11 is coupled to helical tuning coil 15 which is terminated by a capacity surface unit 16 for top loading which, in this example, takes the form of a cylinder although it is apparent to those skilled in the art that other forms of "loading" would be satisfactory. A tuning slide 18 is disposed to slide over a portion of the helical tuning coil 15 and vertical radiator 11 as indicated by arrow 17. The spring contacts 19 ensure that a good electrical contact is made between the sliding short 18 and both the tubular member 11 and the helical coil 15. The slide 18 shorts out turns of coil 15, which are covered by the slide 18, to tubular member 11 so that the effective electrical length of the portion of the helical coil 15 covered by slide 18 is substantially equal to the physical length of the covering portion of slide 18.

When tuning the antenna shown in Fig. 2, the effective electrical length added to the length of vertical radiator 11 by coil 15 is equal to the length of wire in coil 15 provided the coil turns are not shorted out, whereas when the coil 15 is shorted by slide 18 the effective electrical length added to the radiator 11 is substantially equal to the physical axial length of the coil 15. Thus, the antenna system shown in Fig. 2 can be tuned from a maximum wavelength equal to the height of radiator 11 plus the length of wire in coil 15 to a minimum wavelength equal to the length of vertical radiator 11 plus the axial length of tuning coil 15. It is well-known, of course, that the maximum frequency to which the antenna can be tuned is dependent upon the minimum quarter wavelength which is achieved by the tuning mechanism and conversely the minimum frequency that can be tuned is dependent upon the maximum quarter wavelength to which the antenna system can be tuned.

Referring to Fig. 3 of the drawing, a schematic diagram of the antenna system shown in Fig. 2 is illustrated. Dashed line 30 graphically represents the current distribution along the length of the antenna system. The tuned antenna of my invention has a better current distribution than the usual dipole antenna of equivalent size and length. It is well-known that in the usual short dipole of a length equal to the quarter wavelength of the operating frequency the current distribution is approximately linear being maximum at the base of the antenna and linearly going to zero at the top of the dipole. In the antenna of my invention, it is seen from curve 30 of Fig. 3 that the current distribution is substantially flat, the current level at the base being substantially equivalent to the current level near the top of the antenna. The current level must decrease from this maximum at a point near the capacitive surface to zero at the very top of the cylinder and thus the very end portion of the antenna current distribution curve goes in a linear fashion from a maximum to a minimum. One of the principal advantages of my invention is that the linear current distribution provides a substantial increase in coupling of the antenna to space, which in other words means that my antenna system enables the achievement of a substantially high radiation resistance, particularly at a low end of the band. In addition to the linear current distribution, my antenna system has a voltage near ground at the lower end of the antenna which is quite small, being substantially the equivalent to the voltage present on a 50-ohm line. This small voltage near ground must be compared with the extremely high voltages present across the base insulator of the standard short vertical radiators. It is also apparent from the schematic drawing of Fig. 3 that the entire antenna system is directly grounded.

Referring to Fig. 4 of the drawing an alternate embodiment of an antenna system in accordance with the principles of my invention is shown to comprise a vertical tubular radiator member 31 as in Fig. 1, which is terminated at its upper end by a helical conductor 32 terminated in a capacitive cylinder 33 for top loading. A shorting slide 34 is disposed for movement in an axial direction to short a varying number of turns of helix 32 to the cylinder 33. Spring contact fingers 35 ensure good electrical contact between helix 32 and the cylinder 33. The radiator 31 is coupled to ground through an input impedance matching coil 36. An energy transmission line 37 has its inner conductor 37*a* disposed coaxially with the matching coil 36 and is terminated in an adjustable tap 38.

Referring to the drawing of Fig. 5, an improved embodiment of an antenna system in accordance with the principles of my invention is shown to comprise an antenna system substantially similar to the antenna system shown in Fig. 2 with corresponding parts carrying corresponding reference numerals. The tuning inductance 12 instead of being directly grounded as it is in the antenna system of Fig. 2 is coupled to a conductive tubular member 41 in the antenna system of Fig. 5 and the conductive member 41 is connected to ground. The outer conductor 42 of energy transmission line 14*a* is coupled along the entire length of the tubular member 41 and the inner conductor 43 terminates in variable tap 13. As explained heretofore, the maximum frequency that can be reached is dependent upon minimum quarter wavelength which can be physically achieved when the slide 18 completely shorts out all the turns of helical tuning coil 15. Assuming it is desired to operate the antenna of this invention at 30 megacycles the wavelength will equal approximately 10 meters or roughly 30 feet and a quarter wavelength will equal roughly 7.5 feet. Assume that the coupling coil 12 coupled to ground adds an inductive impedance, as it must, it can be assumed that the antenna of this invention would operate satisfactorily at 30 megacycles provided it had a physical height of 6 feet rather than 7.5 feet required without the inductive impedance. The minimum frequency or maximum wavelength to which the antenna can be tuned is when the sliding short 18 is in its lowest position shorting out none of the turns of tuning coil 15. In order to obtain the correct radiation resistance at the low end of the frequency band it may be assumed that it will be necessary to operate the entire antenna system at a height of 10 feet. Producing an antenna having a physical height of 10 feet would be satisfactory for the low end of the band, but at the high frequency end the standing wave ratio present upon the radiator without returning the input coupling would become intolerable since the impedance would not be matched when the antenna was operating at the high end of the band. By adding tubular member 41 and coupling the outer conductor 42 of the coaxial transmission line to the tubular member 41, the standing wave ratio is reduced at the high end of the band since at the high frequencies the effective length of the radiator may be assumed to be the effective length between coupling point 13 and the end of top loading cylinder **16** while at the low end of the band the effective electrical length of the antenna system has added to it the effective electrical length of tubular member **41**.

Referring to Fig. 6, a graphical illustration of the voltage standing wave ratio present on the various antenna systems of this invention versus the operating frequency in megacycles is shown. It is assumed that it is desirable to provide an antenna which without extreme input impedance mismatch is tunable between 2 and 30 megacycles and on which the VSWR never exceeds 4:1. The solid curve **51** between the 2 megacycle and 20 megacycle frequencies is substantially common for the antenna system shown in Fig. 1, Fig. 2, Fig. 4 and Fig. 5. The portion of the curve **52** at the high end of the frequency range shows how the antenna systems of Fig. 1 and Fig. 2 have a mismatch present because of the discrepancies in the physical height pointed out in the above description. By utilizing the embodiment shown in Fig. 5, the curve **53** is achieved. This curve is partly due to the extended range of the curve **51** by curve **51*a*** and partly due to the self-resonance of the antenna shown by curve **54*a*** and curve **54*b***. Curves **55**, **56** and **57** show the self-resonance of the antenna system of Fig. 4 for various frequencies in the operating range. It is to be noted that as the tuned frequency increases the self-resonance of the antenna becomes broader at the high end of the frequency band since the diameter of the tubular member **11** is a substantial part of a wavelength which it is not at the low end of the frequency band, it is seen that the self-resonance curves **54*a*** and **54*b*** effectively increases the tuning range of the antenna system.

While I have described above the principles of my invention in connection with specific apparatus, it is to be clearly understood that this description is made only by way of example and not as a limitation to the scope of my invention as set forth in the objects thereof and in the accompanying claims.

I claim:

1. An antenna system tunable over a broad band of frequencies comprising a vertically disposed radiator with capacitive and inductive top loading members coupled to the upper end of said radiator and having adjustable tuning means to change the effective length of said inductive top loading member to tune said antenna system over said broad band of frequencies, a second helical conductor coupling the lower end of said radiator to ground and means coupling a transmission line of fixed characteristic impedance to said second helical conductor so that the impedance of said antenna system is relatively constant and does not vary beyond chosen limits when said tuning means is adjusted to tune the antenna system to a frequency in said broad band of frequencies.

2. An antenna system tunable over a broad band of frequencies comprising a vertically disposed radiator, a helical conductor coupled to the upper end of said radiator, a hollow cylindrical capacitive member enclosing a portion of said helical conductor and adjustably coupled thereto so as to change the effective length of said helical conductor to tune said antenna system over said broad band of frequencies, a second helical conductor coupling the lower end of said radiator to ground and means coupling a transmission line of fixed characteristic impedance to said second helical conductor so that the impedance of said antenna system does not vary beyond chosen limits when said tuning means is adjusted to tune said antenna system to any frequency in said broad band of frequencies.

3. An antenna system tunable over a broad band of frequencies comprising a vertically disposed radiator, a helical conductor coupled at its one end to the upper end of said radiator, a capacitive member coupled to the other end of said helical member, adjustable tuning means coupling said helical conductor to said radiator so as to adjust the effective length of said helical conductor to tune said antenna system over said broad band of frequencies, a second helical conductor coupling the lower end of said radiator to ground and means coupling a transmission line of fixed characteristic impedance to said second helical conductor so that the impedance of said antenna system does not vary beyond chosen limits when said tuning means is adjusted to tune said antenna system to any frequency in said broad band of frequencies.

4. An antenna system tunable over a broad band of frequencies comprising a vertically disposed radiator, a helical conductor coupled at its one end to the upper end of said radiator, a capacitive member coupled to the other end of said helical member, adjustable tuning means coupling said helical conductor to said capacitive member so as to adjust the effective length of said helical conductor to tune said antenna system over said broad band of frequencies, a vertically disposed cylindrical stub of conductive material orientated in axial relationship with said radiator and coupled to the outer member of a coaxial type transmission line and to ground, a second helical conductor coupling the lower end of said radiator to the top of said stub and means coupling the center member of said coaxial type transmission line of fixed characteristic impedance through said stub to said second helical conductor so that the impedance of said antenna system does not vary beyond chosen limits when said tuning means is adjusted to tune said antenna system to any frequency in said broad band of frequencies.

5. An antenna system tunable over a broad band of frequencies comprising a vertically disposed radiator, a helical conductor coupled at its one end to the upper end of said radiator, a capacitive member coupled to the other end of said helical member, adjustable tuning means coupling said helical conductor to said radiator so as to adjust the effective length of said helical conductor to tune said antenna system over said broad band of frequencies, a vertically disposed cylindrical stub of conductive material orientated in axial relationship with said radiator and coupled to the outer element of a coaxial type transmission line of fixed characteristic impedance and coupled also to ground at its bottom end, a second helical conductor coupling the lower end of said radiator to the top of said cylindrical stub and means coupling the center member of said coaxial type transmission line to said helical conductor so that the impedance of said antenna system does not vary beyond chosen limits and essentially matches the characteristic impedance of said transmission line when said tuning means is adjusted to tune said antenna system to any frequency in said broad band of frequencies.

References Cited in the file of this patent

UNITED STATES PATENTS

1,517,570	Mauborgne et al.	Dec. 2, 1924
2,101,674	Done	Dec. 7, 1937
2,119,692	Voigt	June 7, 1938
2,209,813	Dow	July 30, 1940
2,424,598	Willoughby	July 29, 1947
2,485,177	Wehner	Oct. 18, 1949