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R. BARRAR ET AL

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TELESCOPING FOLDED MONOPOLE WITH CAPACITANCE AT INPUT

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2 Sheets-Sheet 1

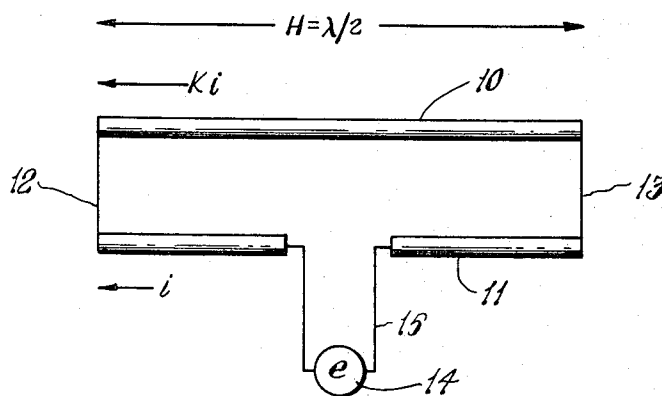


Fig. 1

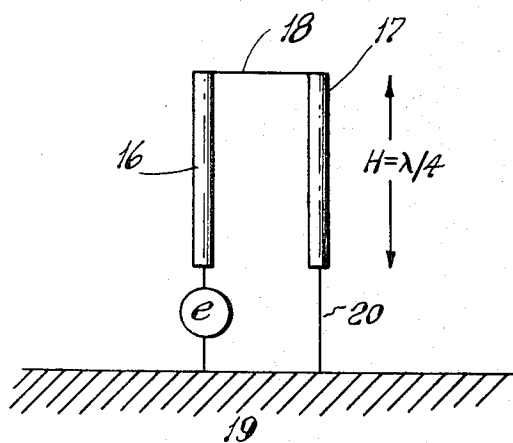


Fig. 2

INVENTORS.
RICHARD BARRAR
ALBERT R. GIDDIS
BY Ernest & Weinberger
Max W. Hammer
ATTORNEYS

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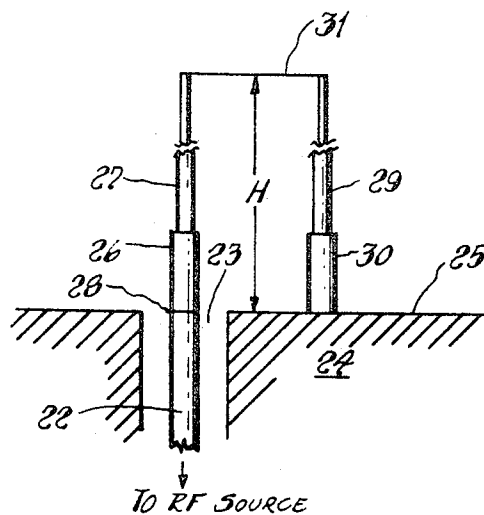


Fig. 3

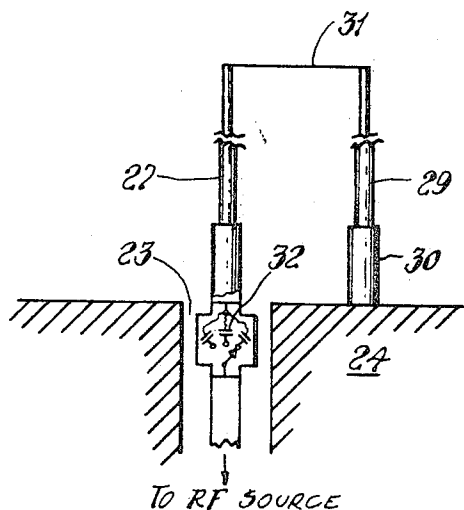


Fig. 4

INVENTORS
RICHARD BARRAR
ALBERT R. GIDDIS
BY Ernest & Weinberger
Max S. Farmer
ATTORNEYS

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TELESCOPING FOLDED MONOPOLE WITH CAPACITANCE AT INPUT

Richard Barrar, Beverly Hills, Calif., and Albert R. Giddis, Lowell, Mass., assignors, by mesne assignments, to the United States of America as represented by the Secretary of the Navy

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1 Claim. (Cl. 343-745)

This invention relates in general to broadband antenna systems and their impedance matching and more particularly to adjustable monopole antennas.

In antennas of all types it is essential for efficient and proper operation that the antenna be matched, with respect to impedance, to a load or to the source of energy over its operating frequency range. Clearly an antenna of proper physical proportions can be constructed whereby it is tuned either for one particularly frequency or over a limited bandwidth. In the alternative the antenna may be composed of a number of individually tuned elements all cooperating to achieve tuned conditions over an extended range. Numerous solutions in increasing the bandwidth characteristics of antennas have been suggested and some employed quite successfully but this problem has not been overcome in the case of a particular type of antenna, namely, the folded monopole. For efficient operation the monopole antenna must be impedance matched to the R.F. source and must be characterized by a sufficient radiation resistance. In view of the foregoing, it is an object of this invention to provide a tunable broadband folded monopole antenna capable of operation over an extended range which may be simply matched to its driving source.

Another object is to provide a structurally simple, inexpensive, easily tunable, folded monopole antenna having means, also tunable, for extending the frequency range of the antenna below its physical limitations.

Other objects and advantages will appear from the following description of an example of the invention, and the novel features will be particularly pointed out in the appended claim.

In the accompanying drawings:

FIG. 1 is a schematic representation of a half-wave folded dipole antenna;

FIG. 2 is a schematic representation of a standard quarter-wave folded monopole antenna; and

FIGS. 3 and 4 are schematic representations of folded monopole antennas embodying the principles of this invention.

Extreme conditions of low input resistance are often encountered in antennas and may be due to short electrical length, or to mutual effects of other nearby radiators, or both. In consequence, coupling networks must be designed to transform the antenna resistance up to the level where it provides the desired load impedance for the driving source. The general class of "folded antennas," including folded dipoles and folded monopoles, represents the attempt to secure part of a desired impedance transformation within the antenna itself.

Since half-wave folded dipoles are used extensively and the principle of their operation is well known, they will be first considered for purposes of subsequent explanation. It consists of a half-wave dipole 10 with another half-wave dipole 11 proximate the first and joined to the first at the ends, by elements 12 and 13, as shown in FIG. 1. Energy is supplied to the driven dipole 11 from an R.F. source 14 which is connected thereto by transmission line 15. The voltage at the end of each dipole is maintained the same by the end connections 12 and 13. Consequently, the currents in each dipole will

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be in phase, maximum at the middle, and minimum at the ends.

Let the maximum current in the section 11 driven by a voltage e be I , and that in the folded section be KI , where K is determined by the relative diameters of the two sections. Assuming P to be the power input to the dipole, and letting R be the input resistance to the dipole, then, $P=I^2R$. Assuming further that all the input power is radiated, then $P=(I+KI)^2R_a$ where R_a is the radiation resistance of an ordinary, single half-wave dipole. Equating the input power to the radiated power, $I^2R=(I+KI)^2R_a$, then $R=(1+K)^2R_a$. This expression shows that by using the folded structure, the input resistance R of the half-wave dipole is increased by the factor of approximately $(1+K)^2$.

The folded monopole is essentially a folded dipole operated against ground and is illustrated schematically in FIG. 2. In this discussion, and only for this purpose, the ground plane is assumed infinite in extent and infinite in conductivity; in short, a perfect ground plane.

It should also be borne in mind that in the case of the quarter-wave folded monopole, the impedance transformation is that for the half-wave folded dipole with the input resistance and radiation resistance both divided by a factor of two (2). Here the two radiating quarter-wave sections, namely, the fed section 16 and unfed section 17 are joined by element 18 at their respective upper ends. The opposite end of the unfed section is spaced from the ground plane 19 and joined to it by conductor 20 while source 21 is electrically disposed between the end of fed section 16 and the ground plane.

The folded monopole antenna structure offers distinct advantages when short vertical radiators, having the inherent undesirable features of low radiation resistance and large reactance must be used due to physical limitations placed on the height of the antenna, as for example, where it is disposed in a confined area.

The particular illustrated embodiment to be discussed below delineates the principles of this invention without restricting the invention to the particular forms of structures or networks or numerical values introduced by way of this sole example of an application utilizing the adjustable broadband impedance-matching antenna system.

In the embodiment illustrated in FIG. 3, a transmission line 22 passes through an aperture 23 in ground plane 24 and terminates level with the upper surface 25 of ground plane 24. The lower-most base element 26 of series telescoping fed antenna section 27 is electrically coupled to the end of transmission line 22 at point 28. The unfed section 29 is identical to the above described section 27 with its lowermost base element 30 supported by and electrically connected to the upper surface of the ground plane. The antenna sections are spaced apart with an electrically coupling section 31 joining their upper free ends. Both antenna sections extend vertically outwardly of the ground plane and their physical dimensions height H above ground and spacing determined from the presently available literature since folded monopole structures are well known in the art.

In operation, the folded monopole is adjusted in length to resonate at its effective quarter-wave length. As a practical matter, it is not always feasible to adjust this length beyond a certain value. This value defines a lower frequency limit for quarter-wave resonance tuning. The impedance behavior of a folded monopole makes it practicable, however, to vary the length of the folded monopole below this lower frequency limit to values which produce an input resistance which is identical to that at quarter-wave resonance. The antenna reactance at these long lengths is in general not zero. A reactance matching network coupled to the ungrounded end of the folded monopole compensates for the antenna reactance at these

lengths to produce a purely resistive antenna input impedance.

A typical impedance curve characterizing the variation with length and frequency of the resistive and reactive components of the input impedance of a quarter-wave monopole fed at its base as the embodiment of FIG. 3 may be plotted. The values so obtained would reflect the order of magnitude and basic frequency-length dependence of any folded monopole whose feed point is located at the level of the ground plane. The discussion to follow pertains to matching the antenna to a 100-ohm transmission line.

The complex impedance of the folded monopole for a length, for example, of $H=0.18\lambda_0$, where λ_0 is the free-space wavelength at which radio-frequency transmission or reception occurs, is approximately $100-j\ 50$ ohms. Thus, a standing-wave ratio of less than 2 to 1 is obtained for a driving source impedance of $100\pm j\ 0$ ohms by changing the physical length of the folded monopole according to a corresponding change in frequency in order to maintain a constant height-to-wavelength ratio. In a typical example, the maximum length limitation of the folded monopole may be restricted to 35 feet. The matching technique just described, namely, adjusting the physical length, will be effective for frequencies down to approximately 5 megacycles per second (mc./s.). Any further decrease in frequency necessitates an increase in length of antenna for any given diameter of conductors and for the same conditions under which the matching technique is applicable down to 5 mc./s. Since this increase in antenna length is prohibited by the condition of the example, namely, that the maximum length is restricted to 35 feet, which corresponds to about 5 mc./s. for the folded monopole being used to exemplify the operation of the matching technique, then to secure a match with decreasing frequency, it is observed that a change in length such that the length-to-wavelength ratio is $H/\lambda_0=0.07$ yields a complex impedance of about $100+j\ 300$ ohms. Thus, by maintaining the length of the folded monopole at $H=0.07\lambda_0$, the antenna is matched below 5 mc./s. A representative lower frequency, though not the absolute limit, is 2 mc./s. for high-frequency work. A representative upper frequency is 30 mc./s. for high-frequency work.

The relatively large inductive reactance (300 ohms) at the input to the antenna, that is at its base, can be compensated by a capacitive reactance in series with the antenna impedance and whose magnitude and sign are respectively equal and opposite to the inductive reactance. A 186 micromicrofarad capacitor in series with the $100+j\ 300$ ohms over the 2 to 5 mc./s. frequency band will result in a net impedance at the input to the capacitive reactance which varies between $100+j\ 129$ to $100-j\ 129$ ohms. If this impedance operates into a 100-ohm transmission line, the standing-wave ratio is less than 4 to 1 over the 2 to 5 mc./s. frequency band.

In order to obtain an even lower standing wave ratio in the 2 to 5 mc./s. frequency band, a 214 micromicrofarad capacitor can be used in the 2 to 3.16 mc./s. band, and a 136 micromicrofarad capacitor can be used in the 3.16 to 5 mc./s. band. In this case, the antenna input impedance of $100+j\ 300$ ohms is transformed into an impedance which varies between $100+j\ 69$ and $100-j\ 69$ ohms over the 2 to 5 mc./s. band. For a driving source impedance of $100\pm j\ 0$ ohms, the standing-wave ratio is consequently less than 2 to 1 over the entire frequency band of operation. This embodiment is clearly illustrated in FIG. 4 where a selectable reactive element such as capacitors 32 is inserted in series between the transmission line 22 and the base element 26 of fed antenna section 27. Here a single pole-multithrow switch 33 provides

a selection from a plurality of capacitors such that a wide range of low frequencies is available.

In practical application, these capacitors could consist of fixed capacitors that are switched in at the appropriate frequencies or continuously variable capacitors that change value corresponding to changes in antenna impedance due to changing frequency when the antenna is set at its maximum length. The instant invention presents a unique method for matching the output impedance of a driving source (such as, but not limited to, a transmitter output transformer or coaxial transmission line) to a radiator of radio-frequency energy, namely, a folded monopole, by adjusting the length of the antenna and the height above a ground plane of the antenna, so that its input resistance is identical to its quarter-wave resonant resistance, and so that its input reactance is a relatively low value. To achieve a matched condition, the non-zero reactance is minimized with a reactance of opposite sign and of a magnitude equal to the antenna reactance. The complexity of the network depends upon the degree of reactive mismatch to be tolerated, upon the bandwidth over which the radiating system is to be operated, upon the insertion loss of the network that is achievable and that is to be tolerated, and upon such practical factors as size, shape and weight.

It will be understood that various changes in the details, materials and arrangements of parts (and steps), which have been herein described and illustrated in order to explain the nature of the invention, may be made by those skilled in the art within the principle and scope of the invention as expressed in the appended claim.

We claim:

1. An adjustable broadband folded monopole antenna system for operation in conjunction with a ground plane which comprises:
 - a fed metallic antenna section having a plurality of extensible intertelescoping elements,
 - an unfed metallic antenna section having a plurality of extensible intertelescoping elements,
 - said ground plane having an aperture therethrough opening outwardly thereof,
 - said unfed section having one end thereof affixed to said ground plane and extending outwardly thereof,
 - said fed section disposed with one end proximate said aperture, aligned with and isolated from said ground plane,
 - a series capacitance connected to said one end of said fed section and disposed entirely within said aperture,
 - said capacitance having an impedance equal to the inductive impedance of said antenna at its lowest tuned frequency, and
 - a coupling electrically connecting the free ends of said sections,
- whereby when a transmission line is connected to said one end to feed R.F. energy thereto and therefrom, the length of said antenna may be adjusted to provide proper broadband matching and radiation characteristics.

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ELI LIEBERMAN, *Primary Examiner.*