Sept. 2, 1969 C. STROMSWOLD ET AL 3,465,345

WIDE BAND DIRECTION FINDER MAST

Filed June 29, 1966 2 Sheets-Sheet 1

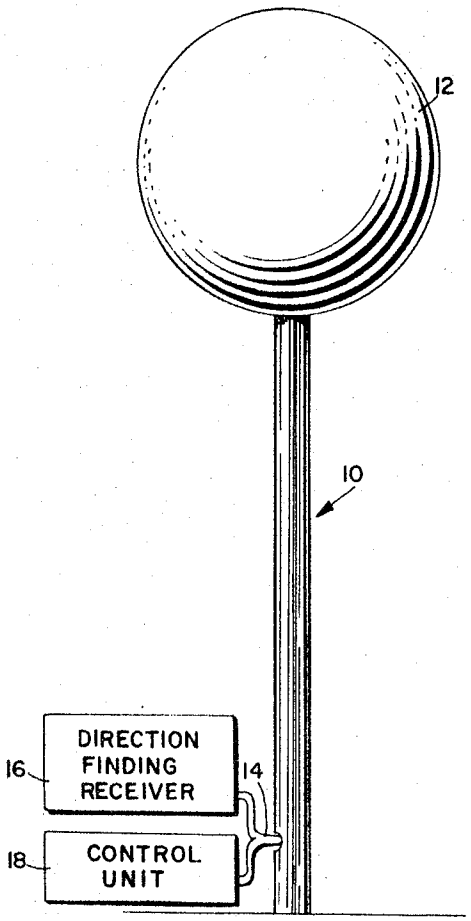


FIG. 1.

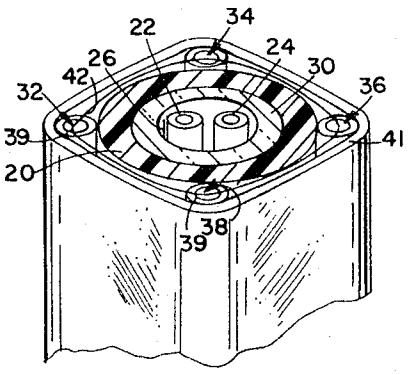


FIG. 3.

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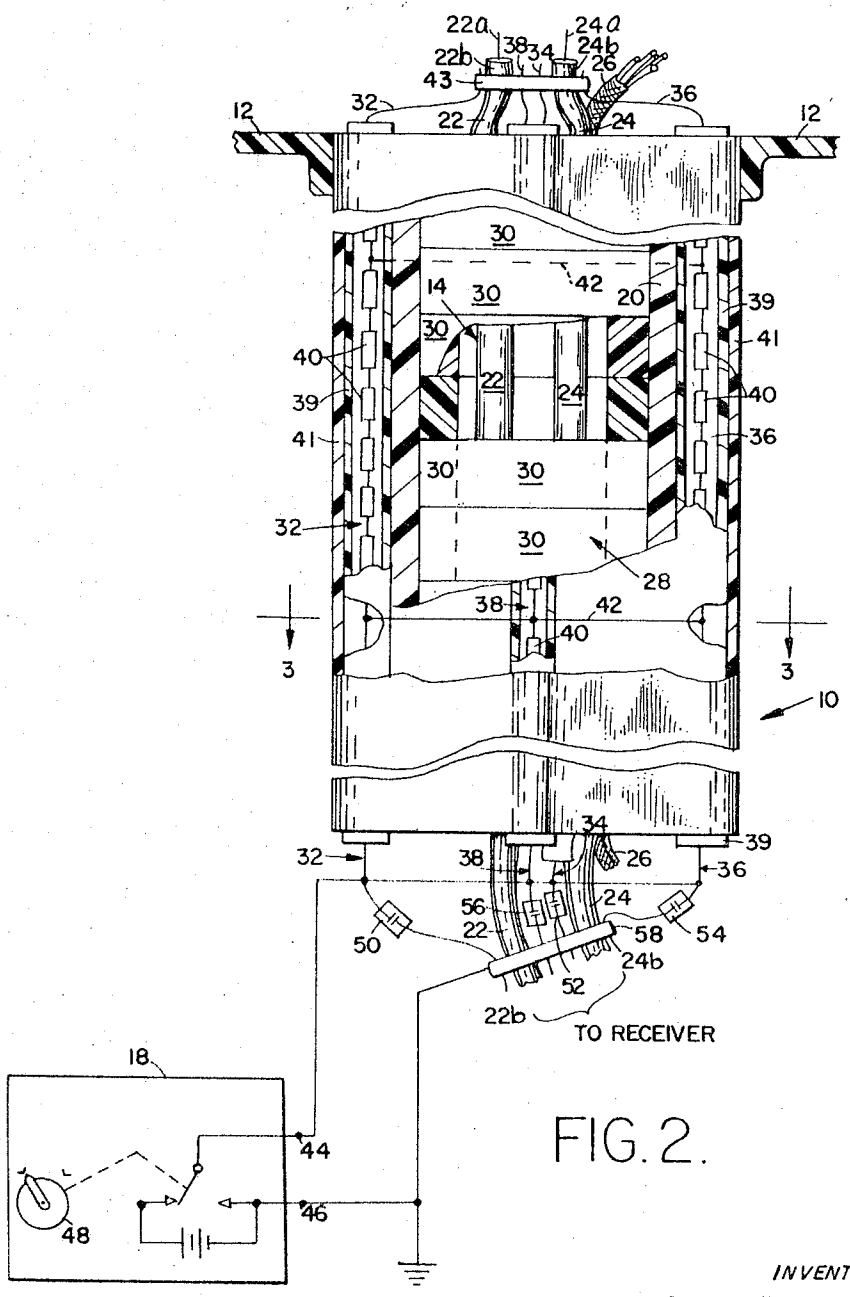


FIG. 2.

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WIDE BAND DIRECTION FINDER MAST

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U.S. Cl. 343—885 13 Claims

ABSTRACT OF THE DISCLOSURE

The antenna mast structure described herein contains the means to vary the inductive reactance thereof such that the resonant frequency of the mast is outside of the selected operating frequency band of the antenna. More specifically, the means comprises a plurality of variable impedance paths which extend parallel with but outside of the conductors which pass through the mast. The mast also contains a stack of closed magnetic rings which surround the conductors but are inside of the variable impedance paths.

This invention relates to an antenna mast subject to electrical resonance with the antenna mounted on it. More particularly, the invention provides means for selectively changing the inductance of a mast structure so that it only resonates with a multiple-band antenna at a frequency outside the selected operating band.

A mast structure as used herein, includes the structural support member commonly associated with a mast and all the electrical conductors, both radio frequency transmission lines and lower frequency control conductors, passing up the structural support.

Consider an installation where a hollow pole of insulating material supports an antenna above an object, typically ground, or a grounded building or vehicle. One or more radio frequency conductors from a receiver or transmitter pass up the pole to the antenna. At radio frequencies, there is a significant capacitive reactance between the antenna and the grounded structure from which it is spaced. In addition, the conductors connected to the antenna have a net inductive reactance. These conjugate reactances can resonate with each other at a frequency within the range of antenna operation. This resonance may interfere with the operation of the antenna and hence may be highly undesirable, if not intolerable.

In a direction finding system, for example, the antenna converts radio frequency radiation incident on it to signals from which the location and/or nature of the radiation source can be determined. The radiation incident on the antenna is also incident on the mast structure. Normally this has little or no effect on the system operation. However, when the mast structure resonates with the antenna, the conductors in the mast structure reradiate a considerable portion of the energy incident on them. The antenna is generally incapable of distinguishing this reradiated energy from the other energy incident on it, and hence the system is essentially of no use at the resonant frequency.

It is an object of this invention to provide an antenna mast structure that does not interfere with the operation of the antenna on it at any frequency within a relatively wide range of radio frequencies. A more particular object is to provide means for selectively shifting the mast structure-antenna resonance to different frequencies outside alternate bands of antenna operation.

Another object of the invention is to provide means for selectively changing the inductance of a mast structure between different values. It is a further object that these inductances differ by a relatively large amount.

A further object is to provide an antenna mast structure of the above character at a relatively low cost.

Another object is to provide such an antenna mast structure that is convenient to use.

It is also desired that the mast structure have relatively little additional mass and bulk as compared with prior art masts supporting the same type of antenna.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

The invention accordingly comprises the features of construction, combinations of elements, and arrangement of parts exemplified in the constructions hereinafter set forth, and the scope of the invention will be indicated in the claims.

For a fuller understanding of the nature and objects of the invention, reference should be had to the following detailed description taken in connection with the accompanying drawings, in which:

FIG. 1 shows an antenna system employing a mast structure embodying the invention;

FIG. 2 shows an enlarged side view, partly broken away, of a mast structure and associated electrical equipment embodying the invention; and

FIG. 3 is a perspective view of the mast structure of FIG. 2 taken along line 3—3 therein.

One prior antenna mast structure employs a hollow pole of Fiberglas or other strong dielectric material as the principal support element. The transmission lines and other conductors pass up the mast inside the pole. Where the inductance of these conductors resonates with the antenna at the desired operating frequency, the resonance can be shifted to a lower frequency outside the desired operating band by enclosing the conductors in a stack of magnetic cores, i.e. closed rings of a material having relatively high magnetic permeability.

However, where the system is to be operable selectively at any one of several bands within a wide frequency range, such a "ferrite-loaded" mast structure often still has a resonance in one of the desired lower frequency bands. Hence, such a single mast structure has heretofore often not been adequate, and wide-band systems have required separate masts, with separate antennas.

The present invention provides means for selectively changing the inductance of a mast structure of the above type. This makes it possible to shift the mast-antenna resonance between different frequencies. As a result, a single mast can support an antenna that operates at different bands within a fairly wide frequency range.

More particularly, FIG. 1 shows a radio frequency direction finding system in which a mast structure indicated generally at **10** supports a radome **12** housing a conventional direction finding antenna. The mast structure **10** includes conductors **14** such as radio frequency transmission lines connecting a direction finding receiver **16** to the antenna and control conductors, at least some of which pass between a control unit **18** and resonance-controlling apparatus on the mast.

As shown in greater detail in FIGS. 2 and 3, the support element of the mast structure **10** is a tubular dielectric pole **20**, suitably of Fiberglas. The illustrated conductors **14** within the pole include cabled control conductors **26** and two coaxial transmission lines **22** and **24** having inner conductors **22***a* and **24***a* and outer conductors **22***b* and **24***b*. A stack **28** of ferrite cores **30** encloses the conductors within the pole **20**; the stack preferably extends over the full length of the enclosed conductors.

In addition, four strings **32**, **34**, **36** and **38** of longitudinally extending, series-connected diodes **40** are uniformly spaced around the pole **20**. The diode strings are preferably coextensive with each other along the ferrite core

stack **28**. Each diode string is preferably supported in a dielectric tube **39** secured to the outer surface of the pole **20** with a dielectric tape **41** or other wrapping.

The diodes **40** in each string **32–38** are arranged to conduct forward current in the same direction and, in the illustrated mast structure, this direction of forward current is the same for all the strings. Further, the distance between adjacent diode junctions in each string is preferably fairly uniform and small, generally much less than one-eighth wavelength at the highest frequency at which the antenna is to operate. In one embodiment of the invention, a total lead length of roughly 1 centimeter between adjacent encapsulated diodes was satisfactory for shifting the mast-antenna resonance from 6 megahertz to 80 megahertz.

Further, each diode **40** preferably has a high resistance, substantially equivalent to a reverse-biased condition, with a zero-volt bias between its leads. Silicon junction diodes have this characteristic and are therefore preferred for the diode strings.

As also shown in FIGS. 2 and 3, shunt conductors **42—42** are connected between all the diode strings at several places along the mast. In the above example, the spacing between successive parallel conductors **42** was approximately 15 centimeters.

With further reference to FIG. 2, at the upper end of the mast structure **10**, a strap **43** connects the ends of the diode strings **32–38** to the transmission line outer conductors **22***b* and **24***b*. At the bottom of the mast structure, the ends of the diode strings are together connected to a terminal **44** on the control unit **18**. In addition, capacitors **50**, **52**, **54** and **56** are connected between the lower ends of the diode strings **32–38** and a strap **58** is connected to the transmission line outer conductors. The strap is also connected to another terminal **46** on the control unit and is preferably grounded.

With this arrangement, the diode strings are in parallel with each other and are in parallel with the transmission line outer conductors at radio frequencies. However, the capacitors **50–56** isolate direct voltages at the control unit terminal **44** from the grounded strap **58** and transmission line outer conductors.

The illustrated control unit **18** has a battery and a switch arranged to apply between the terminals **46** and **58** either zero volt, so that the diodes **40** have a high resistance, or a direct voltage that forward biases all the diodes and thus provides a relatively low resistance through each diode string **32–38**. The selection is made with a knob **48**.

When the diodes receive a zero bias and hence have high resistances, each string appears electrically as a succession of disconnected short conductors. This structure presents a relatively high radio frequency impedance between the straps **43** and **58** and therefore has essentially no effect on the electrical characteristics of the rest of the mast structure. The only low impedance radio frequency paths between the two ends of the mast that enter into the mast-antenna resonance phenomena are on the outer conductors **22***b* and **24***b* and control conductors **26**. The control conductors, it should be noted, are capacitively coupled to the outer conductors due to their proximity and hence are at essentially the same radio frequency potential as the outer conductors.

These conductors **22***b*, **24***b* and **26** are inside the ferrite cores **30—30**. As a result, they have a relatively high inductance that resonates with the capacitance associated with the antenna, and with any other stray capacitances present, at a relatively low radio frequency, typically in the HF region.

When, on the other hand, the diodes **40** are forward biased, the strings **32–38** form a low impedance radio frequency path in parallel with the conductors **22***b*, **24***b* and **26**. Specifically, the radio frequency impedance through the forward biased diode strings between the straps **43** and **58** is considerably less than the impedance along the conductors **22***b*, **24***b* and **26**. With this low impedance path, and because high frequency currents are confined to the outer surface of a conductor (the path formed by the diode strings is outside the other conductors), the diode strings carry most of the radio-frequency current induced in the mast structure. Thus, the inductance between the straps **43** and **58** is essentially the inductance of the diode strings. The ferrite cores have little or no effect on this inductance because they are inside the diode strings. Consequently, with the diodes forward biased, the inductance between the ends of the mast is considerably lower than otherwise. In fact, in one embodiment conforming to FIGS. 2 and 3, the inductance of the mast structure with the diodes unbiased is approximately 30 times greater than the inductance with the diodes forward biased.

This relatively low inductance when the diodes are forward biased resonates with the antenna and other capacitances at a high radio frequency, typically in the VHF region.

The amount by which the forward biased diode strings increase the frequency at which the mast structure resonates with the antenna increases with the extent to which the diode strings shield the conductors **22***b*, **24***b* and **26**. Introducing a conductive tubular structure around the pole **20** would provide the optimum shielding and, correspondingly, the largest shift in the resonance. And additional diode strings in parallel with those shown will generally increase the change in the resonant frequency over that of the illustrated embodiment. However, it has been found that a relatively small number of strings as illustrated provides an ample shift in resonance for most antenna systems. In fact, a single string of diodes, as the string **32**, will produce a considerable change in inductance and in the resonant frequency.

The purpose of the parallel conductors **42—42** is to maintain the greater portion of all the diode strings **32—38** operative in the event one or more diodes **40** becomes inoperative. When, for example, a diode in the string **38** burns out, only a short section of the string **38** between two conductors **42** becomes inoperative. The conductors **42** at the ends of the defective section apply bias voltage and radio frequency currents to the remaining lengths of the string **38**.

At frequencies other than the two where the mast structure resonates with the antenna, the mast structure has essentially no effect on the operation of the antenna, regardless of the bias applied to the diode strings.

Referring again to FIGS. 2 and 3, the present invention can also be used with a mast structure that has no ferrite cores enclosing the radio frequency and control conductors. However, the change in inductance of such a no-ferrite mast structure, and hence in the mast structure, and hence in the mast structure-antenna resonance, when the diodes **40** are switched from the high resistance condition to the low resistance condition is considerably less than with the illustrated ferrite-loaded mast structure. Accordingly, the illustrated construction is generally preferred.

Although the present principal use of this invention is in mast structures for antennas, it can also be used for remote control of the inductance of other conductive structures. Also in some instances it may be desirable to use switching devices other than diodes in the shielding conductors. For example, gaseous or other solid state switching devices may be useful in place of semiconductor diodes.

The invention thus provides a means for selectively changing the inductance of antenna mast and like structures. This makes it possible for a radio receiving system operating at different bands within a relatively wide radio frequency range to employ a single mast structure and yet be free of degradation resulting from resonances with the mast structure.

It will thus be seen that the objects set forth above, among those made apparent from the preceding descrip-

tion, are efficiently attained and, since certain changes may be made in the above constructions without departing from the scope of the invention, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the following claims are intended to cover all of the generic and specific features of the invention herein described, and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

Having described the invention, what is claimed as new and secured by Letters Patent is:

1. In combination with an elongated support member and conductor means extending along it, apparatus comprising
- (A) circuit means forming a radio frequency path of controllable impedance in parallel with and outside of said conductor means,
- (B) ferrite core means and being disposed inside said circuit means, and
- (C) control means
  - (1) connected with said circuit means,
  - (2) operable to place said circuit means in a first condition where the impedance of said path is substantially greater than the impedance of said conductor means, and
  - (3) alternatively operable to place said circuit means in a second condition where the impedance of said path is less than the impedance of said conductor means.

2. The combination defined in claim **1**
- (A) wherein said circuit means comprises a plurality of switching elements arranged in at least one string extending along at least a portion of the length of said conductor means,
  - (1) said switching elements in each string being in series with each other and arranged to be closed, thereby forming a substantially continuous electrical path when placed in said first condition and further arranged to be substantially open when placed in said second condition.

3. The combination defined in claim **1** wherein
- (A) said circiut means comprises at least a first string of semiconductor diodes,
  - (1) said string extending along said conductor means,
  - (2) the diodes in said string being spaced apart along said support member and in series with each other and arranged to conduct forward current in the same direction,
- (B) said control means is connected with both ends of said string and is arranged selectively to forward bias said diodes.

4. The combination defined in claim **3** wherein
- (A) there are a plurality of semiconductor diode strings, each of which is substantially identical to said first string,
  - (1) said strings being laterally spaced apart around said conductor means, and
- (B) said control means is arranged selectively to forward bias said diodes in each string at the same time.

5. The combination defined in claim **4** wherein said circuit means further comprises second conductor means connecting said diode strings in parallel with each other at least at one position intermediate the ends of said strings.

6. The combination defined in claim **4** wherein
- (A) said strings of diodes are substantially coextensive with each other, and
- (B) one end of each diode string is connected to said conductor means extending along said support member and the other end of each diode string is capacitively coupled to said conductor means.

7. An antenna mast structure comprising
- (A) a hollow dielectric pole arranged to support an antenna and conductors that lead to the antenna,
- (B) at least two strings of series-connected switching means,
  - (1) said strings
    - (a) extending along said pole substantially coextensive with each other,
    - (b) being laterally spaced apart and spaced from the center of said pole, thereby to be outside of and therefore to enclose conductors that extend along the mast to the antenna, and
    - (c) having their opposed ends arranged to be electrically coupled to said conductors at least at radio frequencies,
  - (2) said switching means in each string being spaced apart along said mast structure and forming a substantially short circuit path between the opposed ends of the string when a first electrical signal is applied across the ends of the string, and
  - (3) each switching means having a relatively high impedance between the two switching means between which it is connected when a second electrical signal is applied across the ends of the string.

8. A mast structure according to claim **7**
- (A) wherein said switching means are semiconductor diodes,
  - (1) said diodes in each string being arranged to conduct forward current in the same direction, and
  - (2) each diode has a relatively high forward resistance when zero volt is applied across the two leads thereof.

9. A mast structure according to claim **7**
- (A) arranged to support an antenna that operates over a first range of radio frequencies, and
- (B) wherein adjacent switching means in each string are spaced apart by substantially less than an eighth wavelength at the highest frequency in said range.

10. An antenna mast structure comprising
- (A) a hollow dielectric pole,
- (B) a column of ferrite core means substantially coaxial with said pole for at least a part of the length of said pole, and
- (C) a plurality of strings of semiconductor diodes,
  - (1) said diodes in each string being in series with each other and arranged to conduct forward current in the same direction,
  - (2) said diode strings being substantially coextensive with each other along at least said part of said pole and substantially uniformly spaced apart outside said ferrite core means,
  - (3) said diode strings being arranged to form a relatively low impedance radio frequency path along at least said part of said pole when said diodes are forward biased.

11. An antenna mast according to claim **10**
- (A) further comprising at least one conductor within said ferrite core means,
- (B) further comprising means capacitively coupling one end of each diode string to said conductor, and
- (C) wherein the other end of each diode string is arranged to be electrically coupled to said conductor at least at radio frequencies so that when said diodes are forward biased, said strings form a relatively low impedance radio frequency path in parallel with said conductor.

12. An antenna mast according to claim **11** wherein
- (A) said ferrite core means comprises a stack of ferrite cores disposed within said dielectric pole,
- (B) said conductor is the outer conductor of a coaxial transmission line having an inner conductor, and

(C) one end of each diode string is connected to said transmission line outer conductor and the other end of each diode string is capacitively coupled to and electrically insulated from said transmission line outer conductor.

13. An antenna mast according to claim 12

(A) wherein each diode has a relatively high forward resistance when zero volt is applied between the leads thereof, and

(B) further comprising control means arranged to apply a direct voltage between the two ends of each diode string, said control means being arranged selectively to control the value of said direct voltage

to either zero volt or a voltage that forward biases the diodes in each string thereof.

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343—890; 333—12