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DIODE BANDSWITCH LOOP ANTENNA

Filed June 27, 1966

Sheet 1 of 2

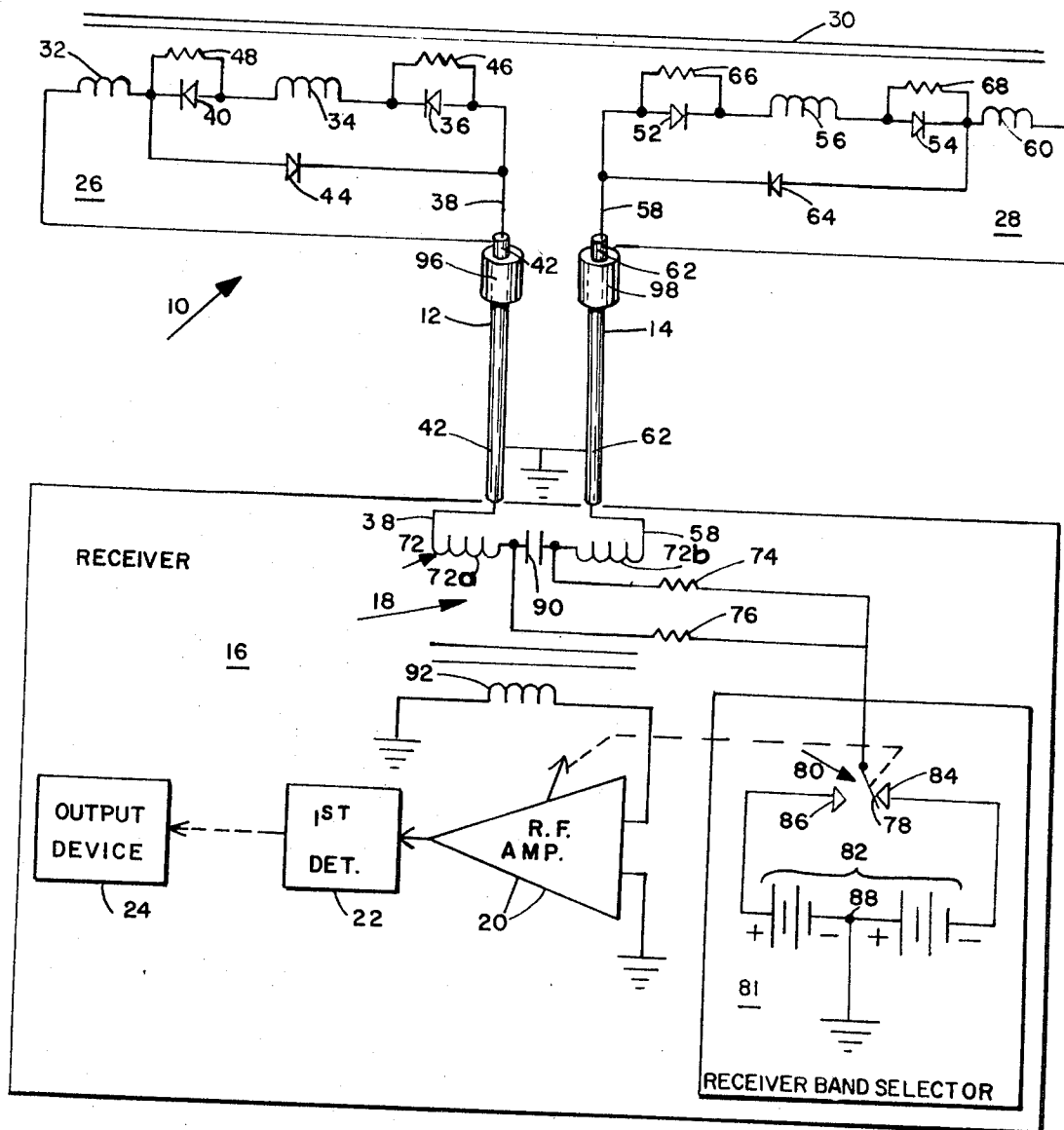


FIG. 1.

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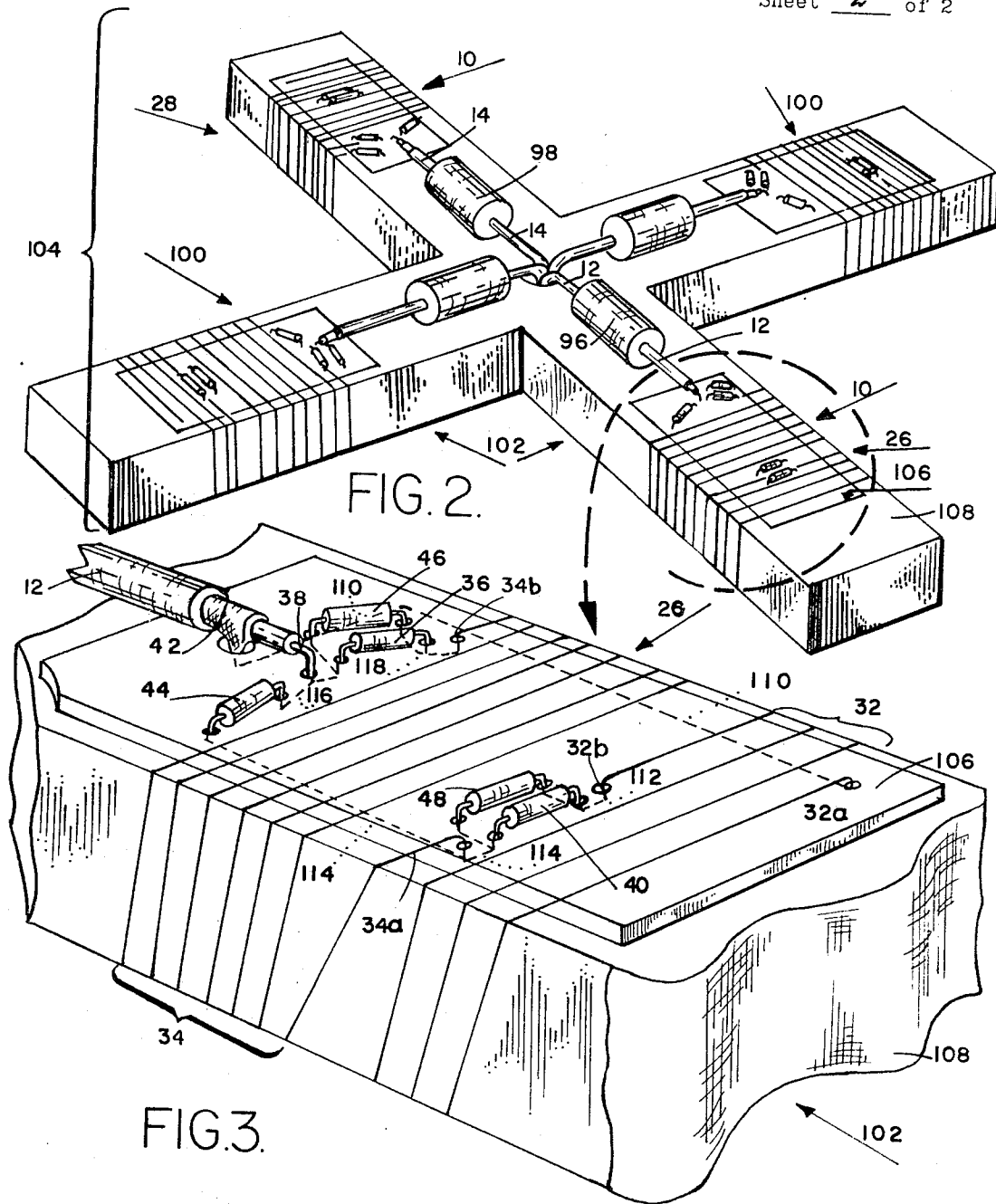
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Sheet 2 of 2



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DIODE BANDSWITCH LOOP ANTENNA
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8 Claims

ABSTRACT OF THE DISCLOSURE

A multiple turn loop antenna contains switching elements in series with the turns such that by selectively switching certain elements, it is possible to isolate certain turns from the active turns and from the receiver, to thereby provide a broadband antenna whose output impedance matches the receiver input impedance over a wide range of operating frequencies.

This invention relates to an antenna that develops essentially the same output impedance, or selected different output impedances, when operated in different frequency bands. It also relates to a multiple band radio receiving system incorporating such an antenna.

The invention specifically provides a compact construction for incorporating switching elements in a loop antenna in order to select the number of turns that operate at any time. This makes it possible for the region of optimum performance to be changed readily to one of two or more frequency bands.

In a receiving system, the antenna output impedance, i.e. the impedance measured at the antenna terminals, generally should be relatively well matched to the receiver input impedance. With matched impedances, the antenna will deliver maximum signal power to the receiver. Further, a proper impedance level at the input of the receiver is desirable to maximize the signal to noise ratios of received signals.

However, the attainment of this matched impedance condition with loop antennas is generally difficult. This is because the output impedance of a loop antenna is similar to that of an inductor, i.e. it varies in proportion to the operating frequency. The input impedance of most receivers, on the other hand, is fairly uniform, at least within each operating frequency band.

In the prior art, a multiple band radio direction finding or other receiving system conventionally employs several complete loop antennas, each antenna being used in a different frequency band. Transmission line switches, typically relatively large mechanical devices, connect the receiver to the respective antennas according to the frequency at which the system is to operate. Each antenna is arranged to develop at its particular frequency an output impedance that is substantially matched to the receiver input impedance. This is often done by having a different number of turns in each antenna.

Aside from being costly, such a system requires a relatively large space, for the antennas must be sufficiently spaced apart to minimize mutual coupling and other interaction between them. In addition, the interconnecting transmission lines and switches generally present considerable shunt capacitances that degrade the performance of the system.

Accordingly, it is an object of this invention to provide an improved multiple band radio receiving system. Particularly, it is an object to provide such a receiving system that has high performance and yet has relatively low cost. Further, the receiving system should be compact.

Another object of the invention is to provide an improved multiple band loop antenna. More particularly, it

is an object to provide such an antenna that develops a selected output impedance at each frequency band. A further object is that the antenna develop substantially the same output impedance in each frequency band.

A further object of the invention is to provide a loop antenna in which the number of active turns can readily be changed. It is also desirable that the antenna be free of moving parts.

Moreover, it is an object of the invention to provide a loop antenna of the above character which has a relatively small size and which can be fabricated at low cost.

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

The invention accordingly comprises the features of construction, combination of elements, and arrangement of parts exemplified in the construction 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 is a schematic representation of a multiple band direction finding system embodying the invention;

FIG. 2 is a perspective view of a loop antenna embodying the invention, and

FIG. 3 is an enlarged view of one loop of the antenna of FIG. 2.

A multiple band receiving system embodying the invention has the same multiple turn loop antenna connected to a radio frequency receiver for each of several operating bands. The antenna has switching elements, such as semiconductor diodes, in series in the turns. Optimum operation in each frequency band is achieved by operating the switching elements to connect into the circuit the number of turns that develop an impedance matched to the receiver input impedance. The switching elements also isolate the remaining turns from the active turns and from the receiver.

Each switching element is preferably aligned spatially with the turns it interconnects so that when the switching element is closed, the signal path through it has substantially the same physical form as the interconnected turns. This optimizes the operation of turns as a single loop antenna. Further, with this arrangement, stray reactances are maintained at a low level and a high degree of isolation can be attained between the active turns and the turns not being used.

More particularly, as shown in FIG. 1, a receiving system embodying the invention has an antenna indicated generally at 10 connected by coaxial transmission lines 12 and 14 to a receiver 16. A radio frequency transformer 18 in the receiver couples the antenna signal from the transmission lines 12 and 14 to a tunable radio frequency amplifier 20, and a first detector 22 receives the amplified signal from the amplifier 20. Successive conventional stages (not shown) of amplification, detection, and demodulation in the receiver convert the intermediate frequency signal from the detector 22 to a signal that causes an output device 24 to produce the desired response to the antenna signal.

The loop antenna 10 shown in FIG. 1 comprises two identical loops 26 and 28 having a common ferrite core 30. The loop 26 has two windings 32 and 34 wound in the same direction on the core. A first diode 36 is connected between one end of the winding 34 and the inner conductor 38 of the transmission line 12. Another diode 40 is connected between the windings 34 and 32, while the other end of the winding 32 is directly connected to the outer conductor 42 of the transmission line 12. A third diode 44 is connected from the inner conductor 38 to the interconnection of the winding 32 and the diode

40. The diodes 36 and 40 are arranged to conduct forward current in the same direction relative to the inner conductor 38, and the diode 44 conducts forward current in the opposite direction. The loop 26 also has two resistors 46 and 48 connected respectively in parallel with the diodes 36 and 40.

As also shown in FIG. 1, the antenna loop 28 is constructed in the same manner. Thus it has diodes 52 and 54 arranged to connect a winding 56 in series between the inner conductor 58 of the transmission line 14 and a winding 60 that is connected directly to the transmission line outer conductor 62. A diode 64 is connected between the inner conductor 58 and the interconnection of the winding 60 and the diode 54. Resistors 66 and 68 are in parallel with the diodes 52 and 54, respectively.

At the receiver end of the transmission lines 12 and 14, the outer conductors 42 and 62 are connected to ground and the inner conductors 38 and 58 are connected to opposite ends of a split primary winding 72 on the transformer 18. That is, the transformer primary winding 72 has two sections 72a and 72b, and each inner conductor is connected to one end of a different section as shown.

A by-pass capacitor 90, having a negligible impedance at radio frequencies, is connected between the sections 72a and 72b of the transformer primary winding. The transformer secondary winding 92 is connected across the input to the amplifier 20. The transformer 18 thus impresses across the secondary winding 92, and hence across the amplifier 20, a radio frequency voltage corresponding to the algebraic sum of the radio frequency antenna signals on the two transmission lines 12 and 14.

As also shown in FIG. 1, resistors 74 and 76 are connected between the inner ends of the two primary winding sections 72a and 72b and the transfer contact 78 of a single-pole, double-throw switch 80 in a receiver band selector 81. A center-tapped battery 82 in the band selector is connected between the contacts 84 and 86 of the switch 80, and the battery center tap 88 is connected to ground.

With this arrangement, the transformer 18 applies the direct voltages from the band selector battery 82 to the transmission lines 12 and 14 for application to the diodes in the loop antenna. The resistors 74 and 76 block the radio frequency signals in the transformer 18 from the band selector. Also, they equalize the forward bias applied to the diodes in the two loops 26 and 27.

In particular, as shown in FIG. 1, the battery 82 maintains the switch contact 84 negative with respect to ground and maintains the other contact 86 positive. Therefore, with the switch transfer contact 78 in the position shown, the resistors 74 and 76 and the transformer primary winding 72 apply a portion of the negative voltage on the contact 84 equally to the transmission line inner conductors 38 and 58.

At the antenna 10, this negative direct voltage reverse biases the diodes 36 and 40 in the loop 26. Hence, these diodes isolate the winding 34 of the loop from the other winding 32 and from the transmission line 12. The resistors 46 and 48 equalize the back bias on these diodes. The remaining diode 44 in the loop 26 is forward biased by the negative direct voltage on the inner conductor 38. Accordingly, this diode 44 forms a low impedance path that in essence connects the winding 32 to the inner conductor 38.

In the antenna loop 28, the negative direct voltage on the inner conductor 58 similarly back biases the diodes 52 and 54 and forward biases the diode 64.

Hence, with the band selector switch 80 in the position shown, only the turns in the windings 32 and 60 are active in the antenna 10. The back biased diodes isolate the remaining turns, i.e. the windings 34 and 56, from the active windings 32 and 60 and from the transmission lines 12 and 14.

In this condition, the antenna has a relatively small inductance and hence the impedance it presents to the

receiver 16, as measured anywhere along each transmission line 12 and 14, is matched to the relatively high input impedance of the receiver 16 at relatively high frequencies. To operate the receiving system in a lower frequency band, where the relatively few turns in the antenna windings 32 and 60 have a considerably lower impedance than the receiver, the transfer contact 78 of the switch 80 is moved to the contact 86. The transmission line inner conductors 38 and 58 then receive a portion of the positive voltage from the battery 82. In the antenna loop 26, this positive direct voltage forward biases the diodes 36 and 40 and back biases the diode 44. Accordingly, there is a relatively low impedance path between the winding 32 and the inner conductor 38 through the diodes 36 and 40 and the winding 34, but a considerably higher impedance between the same points through the diode 44. Thus the series combination of the two windings 32 and 34 in the loop 26 is effectively connected across the transmission line 12.

The positive direct voltage on the transmission line inner conductor 58 similarly biases the diodes 52, 54 and 64 so that the series combination of both windings 56 and 60 in the loop 28 is operatively connected between the conductors 58 and 62 of the transmission line 40. The path through the diode 64 has a relatively high impedance and hence is effectively out of the circuit.

The resultant relatively large number of turns now active in each loop 26 and 28 develops essentially the same high impedance in the lower frequency band as the few turns of the windings 32 and 60 alone developed in the higher frequency band. Hence the antenna 10 is fairly well matched to the high receiver input impedance in each operating frequency band.

By way of example, an antenna conforming to FIG. 1 and having three turns in each winding 32 and 68 and seven turns in each winding 34 and 56 was relatively well matched to a 50 ohm load at the middle of a high frequency band covering from 1.0 mHz. to 8.0 mHz. when the band selector switch 80 was in the position illustrated. When the switch was moved to the other position, where all four windings are active, the antenna operated well into the same 50 ohm impedance in a lower band from 0.1 mHz. to 1.0 mHz.

Considering the antenna 10 in further detail, when each diode is back biased, it appears electrically as a relatively small capacitor. Accordingly, the isolation through each back biased diode decreases with increasing frequency. Generally, the isolation of a single diode is sufficient. However, where additional isolation is desired, particularly for operation at high radio frequencies, two or more diodes can be connected in series with each other in place of each single diode shown in FIG. 1. A resistor, such as those illustrated, should be connected in parallel with each diode that is operated in series with another diode.

Further, where the circumference of a single turn is a significant part of the operating wavelength, one or more diodes can be connected between successive turns, and even between parts of a single turn, of a winding that is not used at certain frequencies. When the winding is inactive and each of these diodes is back biased, the high impedances of the diodes in effect "break" the winding up into short lengths of conductor that have negligible effect on the other active windings.

Also, it may not always be necessary to reverse bias the diodes in order to isolate one winding from other windings in the same loop. This is because with zero bias voltage, certain semiconductor diodes such as silicon junction diodes have sufficient forward resistance to provide adequate isolation, particularly at relatively low radio frequencies.

As also shown in FIG. 1, the illustrated antenna 10 includes a short cylinder 96 of high permeability ferrite material around the outer conductor of the transmission line 12 adjacent the end connected to the antenna loop

26. Another identical ferrite cylinder 98 similarly encircles the end of the outer conductor 62 of the transmission line 14.

These ferrite cylinders 96 and 98 block radio frequency signals, such as noise induced on the transmission line outer conductor from the antenna loops 26 and 28. This blocking operation is due to the fact that the inductance, and hence the impedance, of the section of each outer conductor within the ferrite cylinder is comparatively high, being many times greater than elsewhere along the outer conductor. However, the ferrite cylinders have no effect on the normal radio frequency signals within the transmission lines, i.e. in the space between the outer and inner conductors of each transmission line.

With further reference to the receiving system of FIG. 1, the illustrated band selector switch 80 is coupled to the radio frequency amplifier 20 so that the amplifier is switched to the selected frequency band simultaneous with the operation of the band selector to apply the corresponding bias voltage to the diodes in the antenna 10.

Turning to FIG. 2, the antenna 10 of FIG. 1 can be combined with another two-loop antenna 100 on a four-arm ferrite core 102 to form a four-loop direction finding antenna structure indicated generally at 104.

The two antennas 10 and 100 can be connected to separate receivers in the manner shown in FIG. 1. Alternatively, they can be fed to a single receiver on a time-sharing basis with switches, a goniometer or other conventional devices.

The construction of each loop of the antenna structure 104 is preferably identical with that of the loop 26 of FIG. 1, which will now be described in detail with reference to FIG. 3.

A printed circuit board 106, having several printed circuit branches (shown with dashed lines) on its bottom surface, is secured to an arm 108 of the four-arm core 102. The winding 32 comprises three turns of insulated wire wound around both the core arm 108 and the printed circuit board. The winding 34 is similarly formed with seven turns.

A printed circuit branch 110 connects one end 32a of the winding 32 to the outer conductor 42 of the transmission line 12. Another printed circuit branch 112 connects the other end 32b of the winding 32 to the diode 40 and the resistor 48, which are mounted above the printed circuit board. A printed circuit branch 114 connects the other ends of these components together to one end 34a of the winding 34.

The printed circuit branch 114 also connects the winding end 34a to the diode 44. And a printed circuit branch 116 connects the other end of this component to the transmission line inner conductor 38. The diode 36 and the resistor 46 are connected by a printed circuit branch 118 to the other end 34b of this winding, and the other ends of these components are connected by way of the printed circuit branch 114 to the transmission line inner conductor 38.

With further reference to FIG. 3, the windings 32 and 34 of the antenna loop 26 are formed as distributed windings. That is, the turns are substantially uniformly spaced apart, as in a helix. The diodes 36, 40, and 44 are disposed substantially in the surface defined by the windings. Moreover, they are at least roughly in line with the windings to which they connect; this is particularly true of the diode 40 between the two windings.

As a result of this arrangement, when each diode is forward biased, it forms a substantially in-line path with the winding to which it connects. This enhances the transfer of radio frequency energy by the forward biased diode between the windings it interconnects. In particular, when the diode 40 between the windings 32 and 34 is forward biased, it appears as an essentially continuous part of the combined helical path of these two windings.

This construction of the loop antennas 10 and 100 also is relatively free of stray inductances and capaci-

ties between different active windings and between each active winding and the windings not being used at a particular frequency. As a result, the antenna operates with comparatively uniform and high gain over relatively wide frequency bands.

Further, loop antennas constructed in this manner are highly compact and mechanically rugged.

It will thus be seen that the objects set forth above, among those made apparent from the preceding description, 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. Radio frequency apparatus comprising

(A) a transmission line having first and second conductors,

(B) a first loop antenna winding,

(C) a second loop antenna winding, and

(D) said first and second loop antenna windings being comprised of distributed turns of conductive material,

(E) switch means substantially in line with said turns

(1) having a first condition and a second condition, and

(2) interconnecting said windings with said transmission line conductor so that

(a) in said first condition said first winding is operatively in the circuit between said transmission line conductors and said second winding is substantially isolated therefrom, and

(b) in said second condition said first winding being serially connected at one end to said secondary winding such that both said windings are operatively in circuit between said transmission line conductors, and

(F) antenna support means which

(1) maintains said windings in a fixed geometry along a first surface, and

(2) support said switch means substantially at said first surface.

2. Radio frequency apparatus according to claim 1

(A) wherein said windings and switch means presents to said transmission line a first impedance when said switch means is in said first condition and a second impedance when said switch means is in said second condition,

(B) further comprising a radio frequency device

(1) selectively operative at one of first and second frequencies,

(2) connected to the end of said transmission line, remote from said loop antenna windings,

(3) having an input impedance that is substantially matched to said first impedance at a first radio frequency and is substantially matched to said second impedance to said second radio frequency, and

(C) further comprising control means

(1) in circuit with said switch means and with said radio frequency device, and

(2) arranged to place said switch means in said first condition and simultaneously operate said device at said first frequency, and, alternatively, to place said switch means in said second condition and simultaneously operate said device at said second frequency.

3. Radio frequency apparatus according to claim 1 wherein said switch means are
- (1) semiconductor rectifying elements substantially in line with said turns, and
 - (2) arranged to be placed in any one of said first and second conditions by signals on said transmission line conductors.
4. Radio frequency apparatus comprising
- (A) a transmission line having first and second conductors,
 - (B) a first loop antenna winding connected at one end to said first transmission line conductor,
 - (C) a second loop antenna winding,
 - (D) first switch means connected in series with said second winding between the other end of said first winding and said second transmission line conductor,
 - (E) second switch means connected between said second transmission line conductor and the interconnection of said first switch means and said first winding,
 - (F) each of said switch means being remotely electrically operable to be substantially open and, alternately, substantially closed, and
 - (G) switch control means
 - (1) in circuit with each of said first and second switch means,
 - (2) arranged
 - (a) to close said first switch means and simultaneously open said second switch means, whereby said first and second windings are coupled in series with each other between said transmission line conductors, and
 - (b) alternately to open said first switch means and simultaneously close said second switch means whereby only said first winding is coupled between said transmission line conductors.
5. Radio frequency apparatus according to claim 4 wherein said first switch means comprises a semiconductor rectifying element disposed substantially in line with said first and second windings.
6. Radio frequency apparatus according to claim 4
- (A) wherein said first switch means is connected between said first and second windings,
 - (B) further comprising third switch means connected between said second winding and said second transmission line conductor, and
 - (C) wherein said switch control means opens and closes said third switch means when it respectively opens and closes said first switch means.
7. Radio frequency apparatus according to claim 4
- (A) wherein each of said switch means includes a semiconductor rectifying element that is substantially closed when it receives a forward biasing direct voltage,
 - (B) wherein each rectifying element of said first switch means is arranged to conduct forward current in a first direction relative to said second transmission line conductor and each rectifying element of said second switch means is arranged to conduct forward current in a direction opposite to said first direction,
 - (C) wherein said control means includes a direct voltage supply producing the forward-biasing voltages for said rectifying elements,
 - (D) further comprising circuit means
 - (1) connected between said control means and said transmission line,

- (2) arrange to apply the direct voltage from said supply to said rectifying elements, and
 - (3) further arranged to isolate radio frequency signals on said transmission line from said control means.
8. Radio receiving apparatus comprising
- (A) an antenna support,
 - (B) first and second loop antenna windings wound on said support,
 - (C) third and fourth loop antenna windings wound on said support,
 - (D) a first transmission line port formed with first and second conductors,
 - (E) a second transmission line port formed with third and fourth conductors,
 - (F) a first semiconductor diode disposed at said support,
 - (1) said first winding and said first diode and said second winding being successively arranged in series with each other between said first and second conductors with said first diode arranged to conduct forward current in a selected direction relative to said second conductor,
 - (G) a second semiconductor diode
 - (1) disposed at said support,
 - (2) connected between said second conductor and the interconnection of said first winding and said first diode,
 - (3) arranged to conduct forward current in a direction opposite to that of said first diode,
 - (H) a third semiconductor diode disposed at said support,
 - (1) said third winding, said third diode and said fourth winding being successively arranged in series with each other between said third and fourth conductors with said third diode arranged to conduct forward current in a selected direction relative to said fourth conductor,
 - (I) a fourth semiconductor diode,
 - (1) disposed at said support,
 - (2) connected between said fourth conductor and the interconnection of said third winding and third diode,
 - (3) arranged to conduct forward current in a direction opposite to that of said third diode,
 - (J) a transformer having first and second primary winding sections each of which is in circuit at one end thereof with one of said second and fourth conductors,
 - (K) capacitance means connected between the other ends of said winding sections, and
 - (L) diode controlling supply means arranged to apply diode controlling voltages to the interconnection of each winding section and said capacitance means.

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ELI LIEBERMAN, *Primary Examiner.*

U.S. Cl. X.R.

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UNITED STATES PATENT OFFICE
CERTIFICATE OF CORRECTION

Patent No. 3,447,159 Dated May 27, 1969

Inventor(s) Chester Stromswold

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Column 5, line 6, the word "conductor" should read --conductors--; line 15, the word "reeciving" should read --receiving--. Column 6, line 4, the word "agin" should read --gain--; line 27, delete the word "and"; line 64, change the word "to" to --at--. Column 7, line 23, change the word "alternately" to --alternatively--; line 33, change the word "alternately" to --alternatively--.

SIGNED AND
SEALED
MAY 5 1970

(SEAL)

Attest:

Edward M. Fletcher, Jr.

Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents