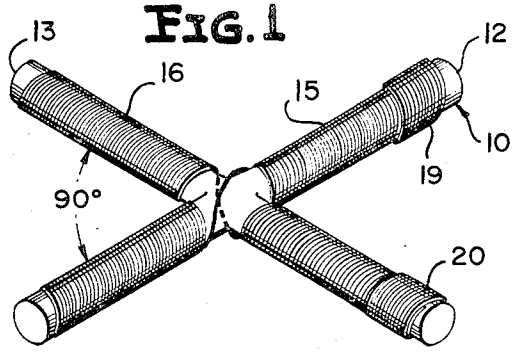
April 22, 1969 G. E. GAUTNEY 3,440,542

OMNIDIRECTIONAL LOOP ANTENNA

Filed March 9, 1965

FIG. 1



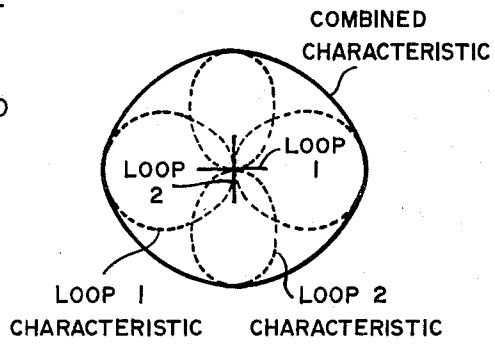


FIG. 4

FIG. 2

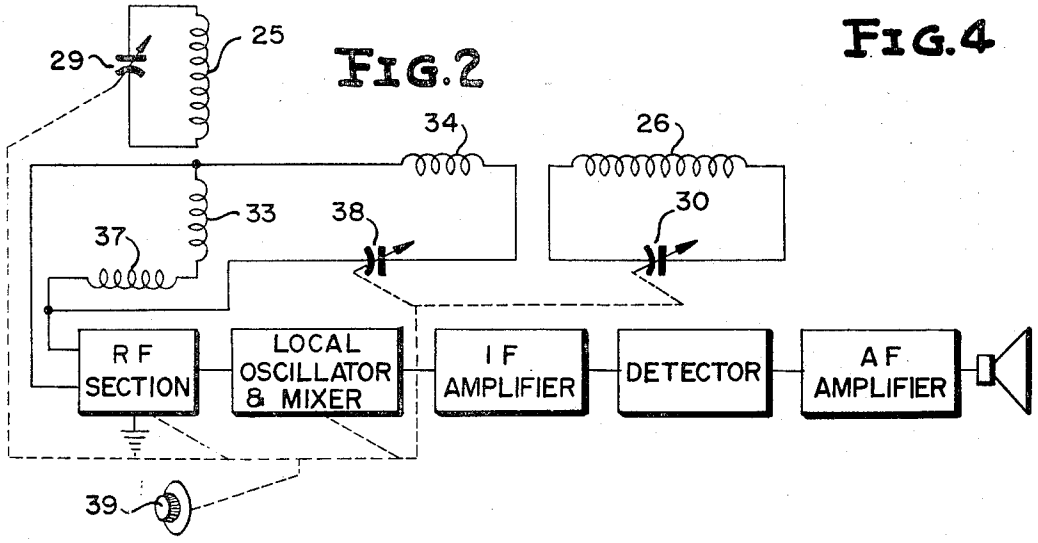
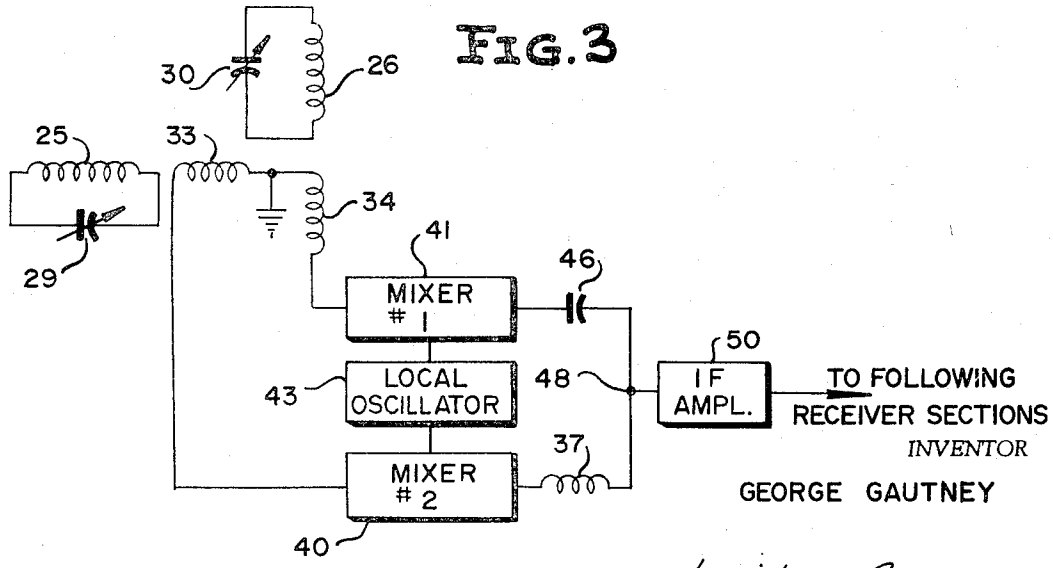


FIG. 3



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United States Patent Office 3,440,542 Patented Apr. 22, 1969

3,440,542

OMNIDIRECTIONAL LOOP ANTENNA

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Filed Mar. 9, 1965, Ser. No. 438,253
Int. Cl. H04b 1/16; H01q 7/08
U.S. Cl. 325—373 11 Claims

ABSTRACT OF THE DISCLOSURE

A loop antenna for omnidirectional reception of RF signals comprising a pair of mutually orthogonal loops wound respectively about the crossed arms of a magnetic core, each loop including a first and second winding inductively coupled, the first winding of each loop being connected in resonant circuit, and the second winding of each loop being provided with reactive impedance components to produce a phase quadrature relationship between currents induced in the two loops in the presence of an external field about the antenna.

The present invention relates generally to antennas and more particularly to antennas for omnidirectional reception of RF signals.

In describing the invention in various practical embodiments, reference will be made to operation within the standard broadcast band. It is to be emphasized, however, that antennas and signal reception systems employing antennas in accordance with the present invention are not to be taken as limited by such references; rather, as will be understood by those skilled in the art upon consideration of the ensuing detailed description, the invention is applicable both in principle and in practice to systems designed for either fixed or variable frequency operation within any of the several alloted bands throughout the RF region of the electromagnetic spectrum.

It is accordingly a primary object of the present invention to provide improved omnidirectional antennas to meet the operational requirements of RF signal reception systems.

The disadvantages of known antennas and antenna systems with respect to undesired directional characteristics are most vividly illustrated by a consideration of radio receivers of the type employed in the home, that is, receivers designed for operation in the broadcast band of approximately 535 to 1650 kilocycles (hereinafter called the standard broadcast band).

The home radio listener is well aware that "changing of stations", that is, the tuning of the receiver from the frequency at which one station broadcasts to that at which another broadcasts, is frequently accompanied by noticeable loss of reception. Primarily, such adverse behavior is the result of the directional characteristic or pattern of the antenna employed in the receiver. Even those listeners who are completely unfamiliar with the technical concepts underlying the operation of signal reception systems are nevertheless generally accustomed to varying the orientation or position of the receiver to "tune in" the desired station. It is not, in fact, uncommon for a listener, through familiarity with the particular operational characteristics of his receiver, to employ a variety of different receiver orientations corresponding respectively to the positions of best reception of the "stations" to which he frequently litsens. However, of this situation it may truly be said that "familiarity breeds contempt"; neither conceptual awareness nor awareness derived from custom can be expected to compete, in the view of the operator, with the provision of a built-in corrective component. The desirable operation requires not merely

an omnidirectional antenna, but an omnidirectional antenna which is at once simple, inexpensive, efficient, and compact.

A typical antenna of the type used in the early radio receivers comprised several turns of wire wound about the periphery of a flat plastic or paperboard form to provide an air core loop antenna, which was generally mounted as a part of the rear cover of the receiver chassis. More recently, loop antennas of reduced dimensions have been employed in the form of a larger number of tightly wound turns of wire on a tubular paper coil form or cylindrical magnetic core. The loop antenna has retained its popularity over other antenna types among manufacturers of standard broadcast band receivers because of its adaptability to mass production techniques in sizes appropriate for use within the receiver cabinet, its relatively simple configuration, and its low production and mounting costs. Not the least important of these considerations is the latter since the highly competitive nature of the receiver market requires that a manufacturer maintain his retail prices in line with those of other manufacturers to maintain a favorable consumer position. This requirement, of course, necessitates a compromise between receiver quality and cost of production.

Prior art loop antennas, such as those which have been described, are characterized by a figure-eight pattern having sharp nulls at the center of the loop in a direction perpendicular to the plane of the loop. Thus, radio waves directed perpendicular to the plane of the loop or within a relatively wide angular sector about the normal to the plane at either side are inherently rejected or significantly discriminated against. While, as previously noted, it is possible to orient the receiver cabinet for best reception by a process of trial and error at each broadcast frequency, such process is not only annoying and time-consuming but in some cases is not feasible. Fixed frequency radio signaling systems have been proposed, for example, for the broadcasting of instructional and alert messages to the indoor public, at a frequency in the standard broadcast band, in the event of civil defense emergencies. It is expected, or at least it is hoped, that such broadcasts will be rather infrequent. Nevertheless, it is obviously important that these messages be received with a high degree of certainly and that the response of the public thereto be prompt. If the receiving equipment for such systems were to utilize antennas of the prior art directional type, it would require that the receiver be always positioned in accordance with the antenna orientation of optimum reception. Obviously that position could not readily be ascertained by a trial and error process because of the infrequent broadcasts. Moreover, the particular orientation of household furnishings and appliances is often selected purely from the standpoint of decor, and it is not unreasonable to assume that such a consideration would be a prime factor in the positioning of a radio receiver irrespective of its intended use. Therefore, it may be presumed that the use of a directional antenna in such fixed frequency alert receivers would ultimately result, in many cases, in the broadcast messages going unheard.

With the above considerations in view, it is a further object of the present invention to provide an improved omnidirectional antenna for use in receivers adapted for operation at one or more frequencies within the standard broadcast band.

It is a further object of the present invention to provide an improved omnidirectional receiving antenna which is simple, efficient, reliable and inexpensive.

In accordance with an embodiment of the present invention, there is provided a loop antenna comprising a pair of perpendicularly oriented, i.e. mutually orthogonal,

loops wound respectively about the crossed arms of a magnetic core of high permeability. Each loop includes a first and a second winding coupled in mutual inductive relation. The first winding of each loop is connected in resonant circuit with a capacitance, the resonant circuits being tuned to the frequency of the broadcast signal of interest. The second windings of the loops are provided with additional reactive impedance components in the form of a series inductance and a series capacitance, respectively, of sufficient magnitude to produce a phase guadrature relationship between currents induced in the two loops in the presence of an external field about the antenna. In this manner, the antenna is tuned for maximum energy extraction from the field produced by radio waves at the frequency of interest, and the perpendicularly oriented identical characteristics of the two loops result in a combined pattern which is substantially circular in the plane of the core. For reception of vertically polarized signals, such as the amplitude modulated waves in the standard broadcast band, the plane of the core is positioned in the receiver cabinet in horizontal orientation relative to the earth when the cabinet is in its normal upright position. The omnidirectional characteristic of such an antenna permits the uniform reception of RF signals irrespective of the location of the transmitter relative to the receiver.

For operation in conjunction with fixed frequency receivers, antennas in accordance with the present invention may be tuned by fixed components to achieve resonance at the desired frequency and to provide the proper phase relationship for an omnidirectional characteristic.

On the other hand, when employed in receivers operable over a band of frequencies, e.g. the standard broadcast band, the antenna may be tuned and phased for operation throughout the band by variable components, such as adjustable capacitors, which may be mechanically ganged with adjustable tuning elements in the resonant circuitry of appropriate sections of the receiver. In this manner the tracking and alignment of the receiver and antenna may be synchronized through a single dial.

It is therefore a further object of the present invention to provide an antenna for use in RF signal receiving systems wherein the antenna is adapted for omnidirectional reception of signals by the introduction of a phase quadrature relationship between the angularly oriented pair of magnetic core loops of which the antenna is comprised.

It is still another object of the present invention to provide a tunable antenna for omnidirectional reception of RF signals throughout a frequency band and wherein tracking and alignment is maintained with the tuning of the receiver to which the antenna is coupled.

The above and still further objects, features and attendant advantages of the present invention will become apparent from a consideration of the following detailed description of specific embodiments thereof, especially when considered in conjunction with the accompanying drawings wherein:

FIGURE 1 illustrates an embodiment of an antenna in accordance with the present invention;

FIGURE 2 is a schematic diagram of the antenna of FIGURE 1 in conjunction with a typical superheterodyne receiver;

FIGURE 3 is a schematic diagram of the antenna of FIGURE 1 in conjunction with a modified form of the superhetrodyne receiver; and

FIGURE 4 is a planar diagram of the characteristic or pattern of the antenna of FIGURE 1.

Referring now to the drawings, an exemplary embodiment of an antenna in accordance with the present invention comprises a ferrite core **10** having a pair of cylindrical arms **12, 13** which cross perpendicularly, or substantially perpendicularly, at their centers. The core may be fabricated of any of the well known high permeability ferrites (such as Fe_2O_3 in compound with metallic oxides) in combination with suitable binders and compressed into the desired shape in a conventional manner. The particular techniques employed for fabricating such ferrite cores are part of a highly developed and publicized art and, since the fabricating process forms no part of the present invention, will not be discussed in detail.

On each of the arms of ferrite core **10** are wound a primary coil **15, 16** having several turns and extending substantially the entire length of the arm, and a secondary coil **19, 20** of fewer turns and shorter length than the associated primary. Each of secondary coils **19, 20** may be disposed on one side of the arm about which it is wound, as shown, or may comprise an equal number of turns on each side of the arm so that a symmetrical configuration is obtained (not shown). In either case, the respective primaries and secondaries are wound in mutual inductive coupling relation. Along the central portion of core **10** at which arms **12** and **13** cross, one of the primary coils (**15** in FIGURE 1) may be wound under and the other primary over the core structure so that each coil extends continuously from one end to the other of its respective arm. The secondary windings may extend across the central portion in a similar manner if a symmetrical configuration is desired. The ends of each winding are suitably connected to separate terminals which may be located at or near the center of the core.

As shown more clearly in the schematic diagram of FIGURE 2, a pair of variable capacitors **29, 30**, having a corresponding range of capacitance values, are connected in circuit with respective ones of the identical primary windings **25, 26**. Each of the secondary windings **33, 34**, are connected in circuit to the RF section of the receiver (superheterodyne in FIGURE 2) to respectively provide phase retardation of 45° and phase advance of 45° of the currents induced therein, so that the two loops are phased 90 electrical degrees apart (phase quadrature). To this end, an inductor **37** is connected in series with one of the secondary windings (**33**) and a capacitor **38** in series with the other secondary winding (**34**). These two components are so adjusted (or preselected) that the inductive and capacitive reactances of the respective loops are of equal magnitude, although they are, of course, of opposite sign. In practice the tuning and phasing components may be variable and ganged with tuning elements in the RF section and local oscillator of the reeciver to which the antenna is connected so that the several circuits may be subjected to substantially uniform tracking and alignment as the receiver is tuned by a single dial **39** through the broadcast band.

The high permeability ferrite core permits a reduction in size of the antenna, compared to that of a loop antenna having an air core, by virtue of its significant increase in the inductive reactance, and thus the Q, of the coils. The resonant circuits formed by the primary coils and their associated variable capacitors are tuned to the frequency of the desired RF signal by appropriate adjustment of the capacitance values. Hence, the combination of the tuned primary windings and the ferrite core will permit a high degree of extraction of energy from the field produced by the RF signal under observation, resulting in a substantial improvement in signal reception over conventional loop antennas. Moreover, extremely sharp tuning is avoided by the relatively high loop resistance provided by the large number of primary turns and that reflected by the secondary coupling. The antenna, however, is not sufficiently broadband to enable operation throughout the broadcast band without the provision of a control adjustment of the variable capacitors, and to this end the capacitors may be ganged in a conventional manner via a common shaft with tuning capacitors in the resonant circuitry of the receiver (as shown by the dotted mechanical coupling in FIGURE 2).

To provide the antenna with the desired omnidirectional characteristic variable capacitor **38** is adjusted to introduce a capacitive reactance equal in magnitude, but

opposite in sign, to the inductive reactance supplied by inductor **37** so that the currents induced in the two loops of the antenna are in quadrature. It has been found in practice that a sufficient inductive reactance may be present because of mutual coupling to require the use of only a capacitor in series with one of the secondaries (i.e. no separate inductor may be necessary). In any event, the reactive components of the loops are readily ascertainable by conventional techniques, such as bridge measurements, from which the magnitude of inductance and/or capacitance to be added may be obtained. Again, the quadrature-adjusting variable capacitor may be ganged with the other tuning elements of the receiver, although in this case it may be necessary to proportion the relative capacitance changes by the addition of series and shunt padding capacitors in circuit with the variable capacitor or to properly shape the movable plates of the capacitor. Such proportioning arrangements are merely extensions of techniques conventionally employed in receivers and are deemed to be within the skill of the art.

By arranging the two loops in phase quadrature there results a substantially circular combined pattern, or omnidirectional characteristic, in the plane of the antenna core. This phenomenon is demonstrated in FIGURE 4. As shown, each loop has a figure-eight pattern but the two patterns are perpendicularly oriented so that the nulls of one are located in the regions of maximum energy extraction of the other. In the combined characteristic the nulls are virtually eliminated and the pattern approaches a circular shape. Thus, RF signals originating from a direction perpendicular to the plane of one of the loops, an unfavorable orientation for reception if only that loop were present as previously discussed, will result in substantial excitation of only the other loop. For signals received from a direction within any quadrant between the two loops, the loops will be excited proportionally by currents in phase quadrature, and hence without any discernible loss of reception at the receiver.

In one practical embodiment of a standard broadcast band receiving antenna, the arms of the core were each approximately four inches in length, the inductance of each primary coil was approximately 480 microhenrys (μh.), and of each secondary coil about 6 μh. The capacitance ranges for the primary tuning capacitors and the quadrature-adjusting capacitor were 15 picofarads (pf.) to 200 pf. and 9 pf. to 400 pf., respectively. Antennas in accordance with the present invention are therefore conveniently installed in conventional receivers of the portable type, such as are adapted for operation in the standard broadcast band, without any increase in cabinet size. In general, the size of the core, the loop inductance and the tuning and phasing capacitance values will be dictated by the operating frequency of interest.

As previously noted, the use of my antenna in fixed frequency receivers will permit the employment of fixed capacitors in place of the variable capacitors which have been described. In either event, the capacitors will generally be mounted on the receiver chassis and connected to the respective antenna terminals at which the ends of the windings are fastened. That is, the basic antenna configuration may be manufactured in the form of the crossed arm core having wound thereon the two loops, and the capacitors appropriately installed in the receiver during manufacture of the latter or added to existing receiver structure. The necessary connections may then be made during the wiring of the receiver after the antenna has been mounted.

In superheterodyne receivers, of the type conventionally used for operation in the standard AM broadcast band, the variable capacitors associated with the antenna can conveniently be ganged with tuning capacitors in the resonant circuits of the RF and local oscillator sections. Such an arrangement is merely an extension of known techniques and is not considered to be a departure from the scope of the present invention.

The embodiment of FIGURE 3 is similar to that of FIGURE 2, except that two mixers (or first detectors) are employed to permit the use of fixed phasing components in the variably tuned receiver. Mixers **40** and **41** are identical and, in conjunction with local oscillator **43**, operate to translate the RF signal to an intermediate frequency in the superheterodyne receiver. For example, in receivers adapted for operation throughout the standard broadcast band the IF is generally set at 455 kc., the local oscillator frequency being variable by a conventional coupling arrangement between the RF section and local oscillator tuned circuitry so that the IF is maintained at a fixed frequency irrespective of the RF signal to which the receiver is tuned.

While it is still necessary to provide mechanical coupling, i.e., a ganged relationship, between the tuning elements of the antenna, RF and local oscillator sections of the receiver of FIGURE 3, the proper phase relation may be maintained with fixed components. To this end, antenna loop secondary windings **33** and **34** are connected respectively to input terminals of mixers **40** and **41**. Local oscillator **43** is connected to the other input terminal of both mixers for heterodyning the RF signal to the proper IF. Fixed capacitor **45** and fixed inductor **37** are coupled respectively from the output terminals of mixers **41** and **40** to the input terminal of IF amplifier **50** to provide the phase advance and phase retard action at the intermediate frequency. Since the IF is a fixed frequency for all RF frequencies in the band through which the receiver operates, once inductor **37** and capacitor **41** have been selected to provide the necessary reactive components in the loop impedances, as previously discussed, the quadrature phasing is maintained throughout the tuning range of the receiver. It is again to be emphasized that this principle is applicable to any receiver employing heterodyne action, irrespective of the RF frequency or frequency band under consideration. The effective combined characteristic of the antenna system of FIGURE 3 is omnidirectional in the plane of the core, as shown in FIGURE 4.

For reception of vertically polarized RF signals, as those in the standard AM broadcast band, the antenna is mounted in the receiver cabinet with the core lying in a horizontal plane relative to the earth.

The term "portable," as used herein in reference to portable radio receivers, is employed in the general sense rather than in the limited sense of a battery operated or convertible AC-DC unit. Thus, antennas in accordance with the present invention may be utilized in conjunction with table model radios, consoles, AM-FM-phonograph combinations, battery operated receivers, and the like. Of course, it is not strictly necessary that the antenna be employed in a portable type of receiver, although it is contemplated that its primary use may lie in such applications.

While I have described certain embodiments of my invention it will be apparent that various changes in the specific details of construction and operation may be resorted to without departing from the true spirit and scope of the invention as defined by the appended claims.

I claim:

1. An omnidirectional antenna comprising a planar magnetic core, a pair of conductive loops wound in mutually perpendicular relation in the plane of said core, each of said loops including a primary winding and a secondary winding inductively coupled to said primary winding via said core, means for tuning the primary winding of each loop to the same resonant frequency, and reactance means coupled to each secondary winding for establishing a phase relationship of substantially 90 electrical degrees between signals developed by said loops.

2. The combination according to claim **1** wherein said primary windings have a large number of turns of rela-

tively fine wire providing windings having high resistances.

3. In a signal receiving system, an antenna for omnidirectional signal reception, said antenna comprising a magnetic core having a pair of crossed arms oriented in substantially perpendicular relation, a pair of separate loops each wound about a respective one of said arms, each of said loops comprising a tunable primary winding and a secondary winding inductively coupled to said primary winding via said core, means for establishing a phase quadrature relationship between signals developed by said loops, and means for coupling each of said secondary windings to the receiver of said signal receiving system.

4. The combination according to claim 3 wherein said magnetic core includes high permeability ferrite material.

5. The combination according to claim 4 wherein said primary windings have a large number of turns of relatively fine wire providing windings having high resistances.

6. The combination according to claim 3 wherein each of said primary windings is tunable to the same resonant frequency by variable capacitance means connected thereacross, and wherein said means for establishing phase quadrature includes variable reactance means connected to said secondary windings and ganged to said variable capacitance means, said reactance means providing a capacitive reactance in one of said loops equal in magnitude to the inductive reactance of the other of said loops.

7. The combination according to claim 3 comprising means for tuning each of said primary windings to the same resonant frequency and wherein said means for establishing phase quadrature includes variable reactance means connected to at least one of said secondary windings, a receiver having tunable elements to select a frequency to be received, said means for tuning each of said primary windings being ganged with the tunable elements of said receiver for concurrent operation of all tuning members to maximize reception of a single frequency.

8. The combination according to claim 3 wherein said secondary windings are wound on top of respective ones of said primary windings.

9. An omnidirectional antenna for a receiver adapted for operation over a band of frequncies, comprising a magnetic core, a pair of loops wound about said core in mutually orthogonal relation, each of said loops including inductively coupled first and second windings, means for tuning said first winding of each loop to a frequency within said band of frequencies, means for maintaining the tuning of said receiver and said loop tuning in tracking alignment throughout said band of frequencies, means for connecting the secondary winding of each loop to said receiver, and means for phasing said loops at a difference of substantially 90 electrical degrees.

10. An omnidirectional antnna for a superheterodyne receiver, said antenna comprising a magnetic core, a pair of substantially identical loops wound in mutually orthogonal relation about said core, means for tuning said loops to resonance at the tuned RF frequency of said receiver, said receiver comprising an IF amplifier and a pair of mixers, coupling means for coupling each said mixer to a separate one of said loops and responsive to the RF currents induced in said loops and to the receiver local oscillator frequency to provide a fixed intermediate frequency signal at each of the mixer output terminals, and fixed reactive components connected respectively to the output terminals of said pair of mixers and through a common junction to the IF amplifier of said receiver for maintaining the respective IF signals from said pair of mixers in phase quadrature throughout the RF frequency band of said receiver.

11. The combination according to claim 10 wherein said coupling means comprises a pair of secondary windings each wound about a different one of said loops.

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U.S. Cl. X.R.

343—788