

Sept. 5, 1950

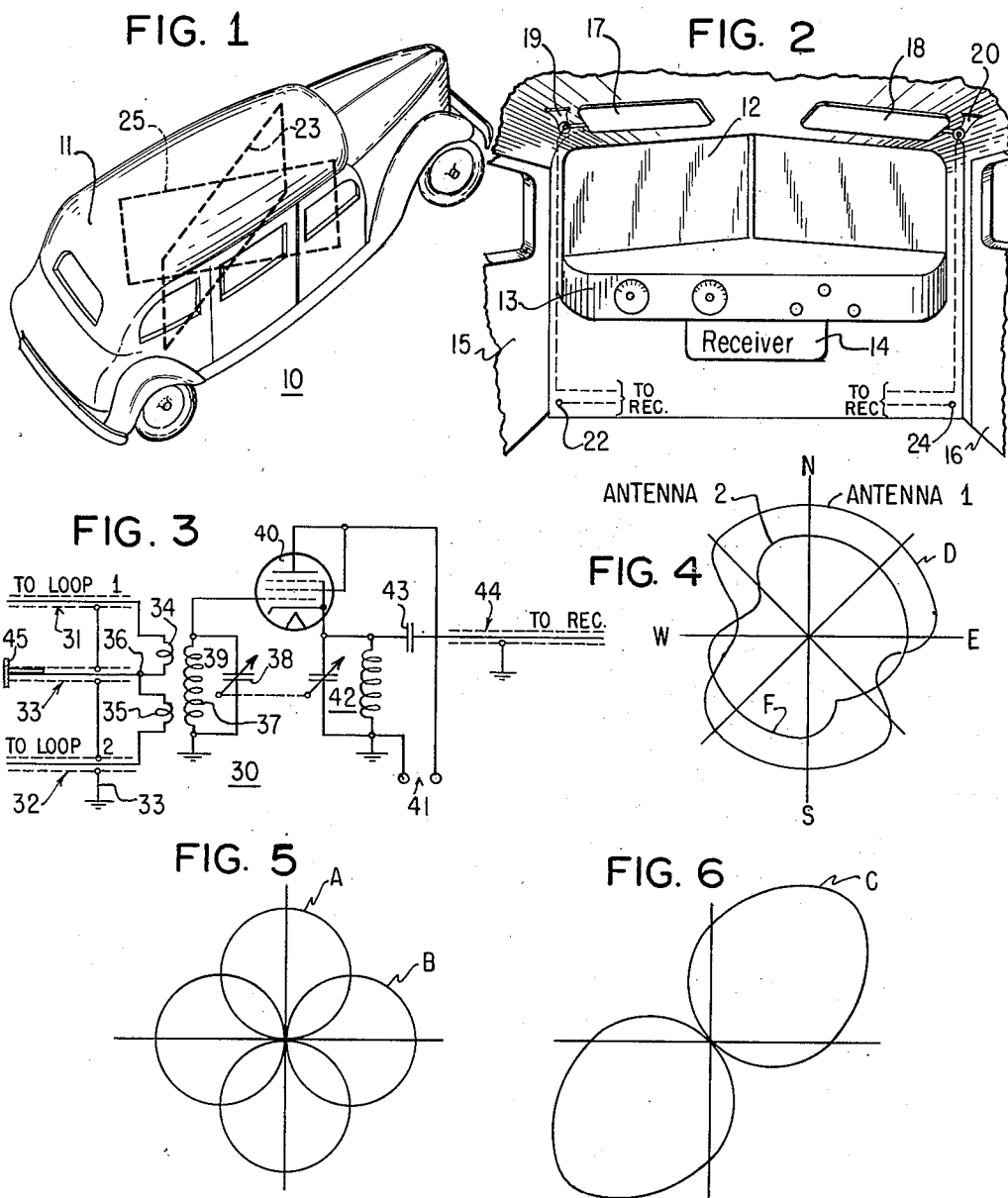
F. B. WILLIAMS ET AL

2,520,984

ANTENNA SYSTEM

Filed Jan. 25, 1947

3 Sheets-Sheet 1



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ANTENNA SYSTEM

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FIG. 7

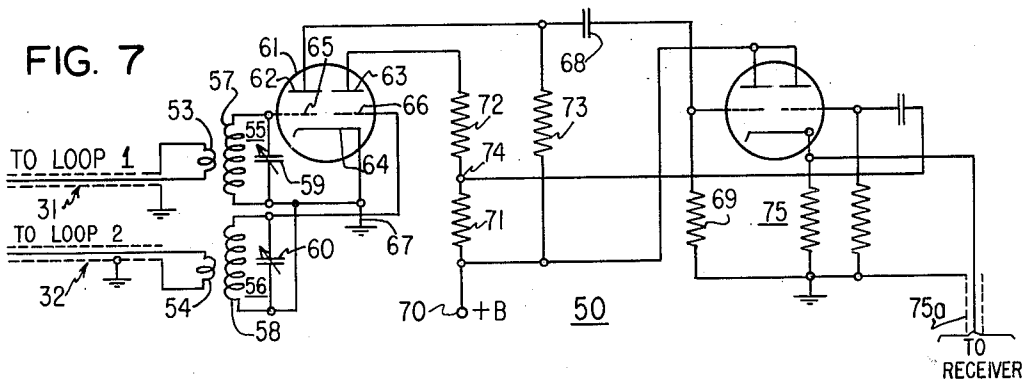


FIG. 8

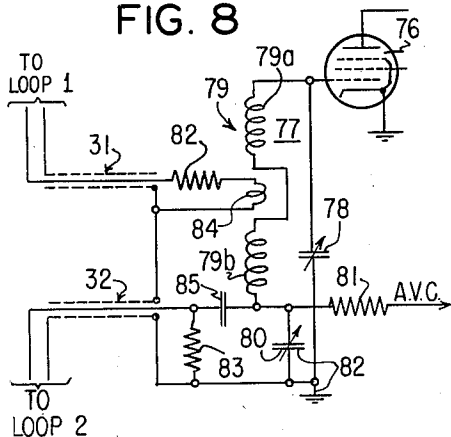


FIG. 9

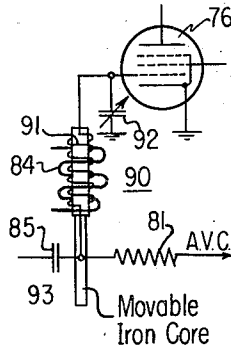
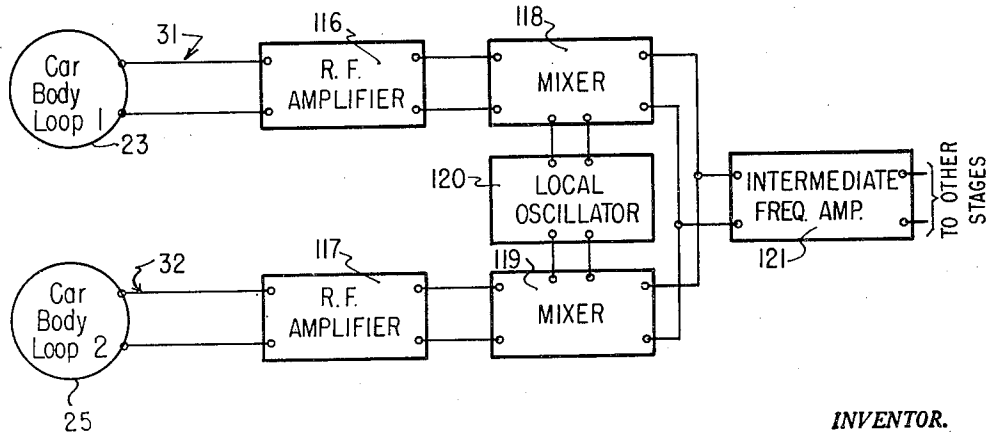


FIG. 15



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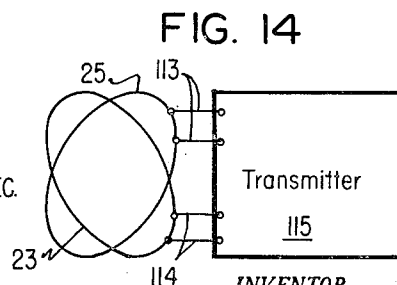
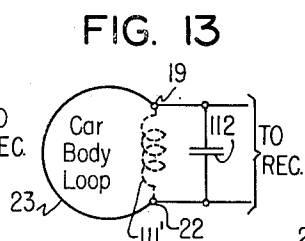
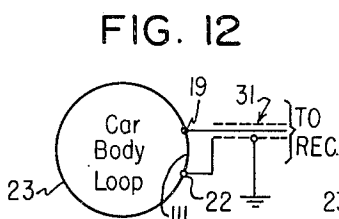
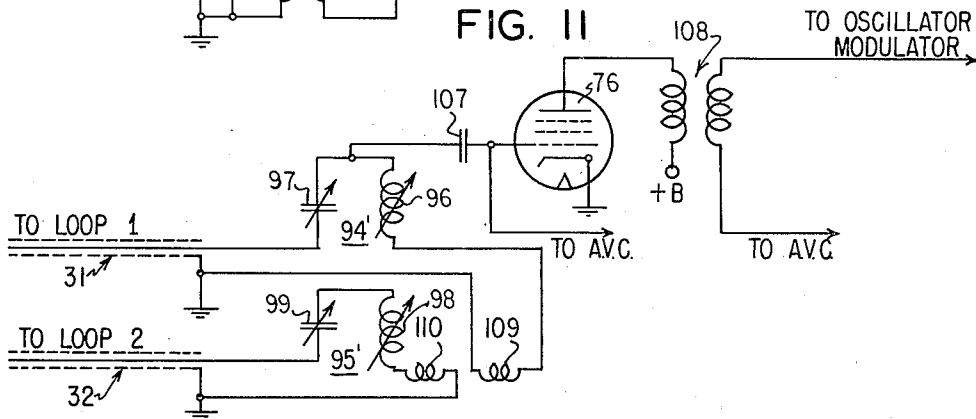
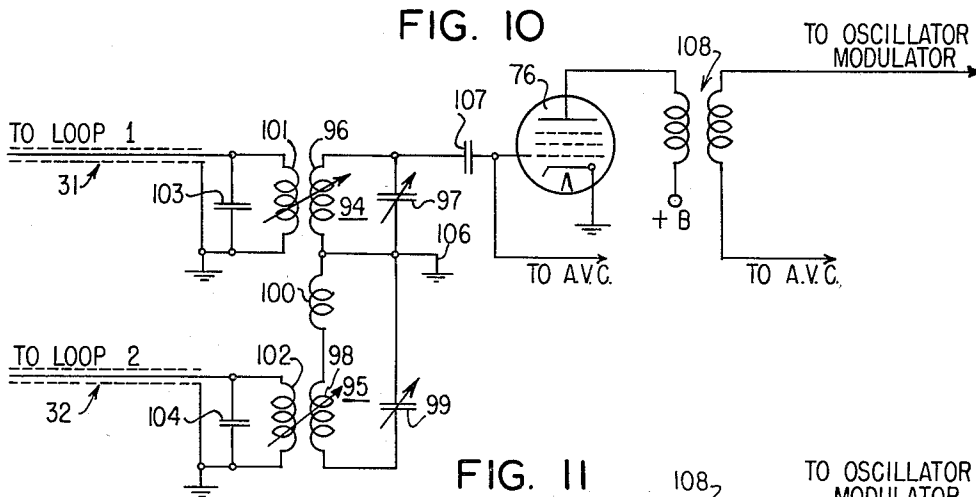
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F. B. WILLIAMS ET AL  
ANTENNA SYSTEM

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3 Sheets-Sheet 3



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## UNITED STATES PATENT OFFICE

2,520,984

## ANTENNA SYSTEM

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19 Claims. (Cl. 250-33)

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This invention relates to antennas and antenna systems for wave signal devices and more particularly relates to such an antenna and antenna system for a three dimensional conducting body as for example mobile vehicles wherein the signal radiating or signal pickup portion of the antenna system comprises solely portions of the conducting body.

In connection with wave signal devices for use on mobile craft such as automobiles, trains, boats and airplanes whether they are radio receivers or transmitters, there has always existed the problem of providing effective signal pickup means in the case of a receiver or signal radiating means in the case of a transmitter. This is primarily due to the fact that generally a limited mounting space is provided and in the case of radio receivers, for example, such limited space militated against obtaining adequate signal strength at the receiver in the presence of a large amount of undesirable electrical interference generally present in connection with the prime movers of such mobile craft.

Although these problems have been present to a greater or lesser degree in connection with various types of mobile vehicles they have been especially present and most serious in connection with automobiles, trucks and airplanes. In the former, the mounting space has generally been very limited whereas in connection with airplanes the question of providing antenna means which do not produce any additional drag or interfere with the streamlining thereof has always been a problem. In connection with both automobiles and airplanes there are always the factors of appearance, installation, and the like.

In recent years in connection with automobiles, perhaps the antenna employed most extensively was the vertical jointed pole type antenna which is mounted on the outside of an automobile body or at least extends outside and above the automobile body when in full operating position. Antennas of this type often are costly in and of themselves and the installation problems involved are relatively great even aside from the question of cost which is substantial. Such antennas usually require cutting through the body of the automobile and in many cases, the cut comprises a permanent defacement. In addition, there has always been the criticism of outside antennas on the automobiles from the appearance standpoint. Also, such antennas often interfere with the movement of the automobile while entering a garage or the like when not retracted thus requiring the operator to remember

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to retract the antenna which is an additional inconvenience.

Various parts of the automobile such as the bumper and the grill over the front of the radiator have been insulated from the automobile body and employed as the antenna or signal pickup means in the case of a receiver. However, these installations require that the particular part is permanently insulated from the body thus greatly increasing the expense.

The jointed pole type antenna and the other antenna mentioned above used in connection with mobile vehicles such as automobiles, although very satisfactory when used on the open road, have been found to be quite unsatisfactory in various shielded areas such as under viaducts as well as in sections of the country such as in certain regions having extensive deposits of iron ore and the like. It would be desirable, therefore, to provide an antenna which would overcome the objections set forth above in connection with previous types of antennas which would in itself be inexpensive, require no additional installation cost, cause no defacement of the mobile vehicle, and which would provide very satisfactory operation whether used with a receiver or a transmitter, being substantially unaffected by adjacent bodies such as viaducts and the like. It would furthermore be desirable to provide an antenna by employing therefor a part of the mobile vehicle which has another primary function but would also act as an antenna. There have been numerous attempts made to employ the bodies of mobile vehicles as antennas. In the various arrangements suggested heretofore employing the automobile body or body of the mobile vehicle itself as the antenna, difficulties have been encountered in obtaining sufficient signal strength without too much noise and also to eliminate the directional characteristics in some forms of these antennas. In the case of a receiver for example employing the car body in one prior art type of antenna very fine reception might be obtained from a particular station when driving along one street or along one highway while when changing direction of travel, the signal strength might become very unsatisfactory. Obviously, an antenna employed in connection with mobile vehicles likely to travel in any direction must not have directional characteristics. It would be desirable, therefore, to provide an antenna for mobile vehicles employing the conducting body of a vehicle as an antenna which antenna is a loop antenna having no directional characteristics and furthermore, which antenna

is very satisfactory from the standpoint of signal strength and the like being much less affected by adjacent bodies than similar devices used heretofore.

Accordingly, it is an object of the present invention to provide a new and improved antenna system for mobile vehicles.

It is another object of the present invention to provide an antenna for three dimensional conducting bodies in which the antenna portion wholly comprises the three dimensional body portion which body portion has a primary function other than that of serving as an antenna.

It is another object of the present invention to provide a pair of loop antennas which in conjunction with a special coupling circuit produce a non-directional antenna pattern and which loop antennas are formed solely of the body of mobile vehicles and consequently which eliminate installation costs and defacement of the vehicle as was required heretofore.

It is a further object of the present invention to provide an antenna system for mobile vehicles which is inexpensive, which provides more satisfactory signal reception or transmission than antennas employed heretofore and which is very pleasing in appearance.

It is another object of the present invention to provide an antenna which is formed by the conducting body of a mobile vehicle for example which provides reception or transmission at least equal to and generally superior to antennas employed heretofore with much lower installation and maintenance costs.

Still another object of the present invention is to provide an antenna system for mobile craft of improved type which has no objectional appearing outside antenna or signal pickup means in the case of a radio receiver.

It is a feature of the present invention to provide an antenna system for mobile vehicles in which taps are provided on the conducting body of the vehicle which form the terminals of a plurality of effective conducting loops formed in the conventional body, said effective loops being displaced in phase from each other in the car body and electrically displaced by phase shifting circuits so as to provide a non-directional antenna.

Further objects and advantages of the present invention will become apparent as the following description proceeds and the features of novelty which characterize this invention will be pointed out with particularity in the claims annexed to and forming a part of this specification.

For a better understanding of the present invention, reference may be had to the accompanying drawings in which:

Fig. 1 is a perspective view of a mobile vehicle embodying the present invention with dotted lines indicating the effective paths of the antenna loops formed of the car body itself;

Fig. 2 is an interior view of a mobile vehicle showing a specific example of terminals provided on the car body which are the terminals of a plurality of loop antennas formed solely of the mobile vehicle body;

Fig. 3 is a circuit diagram of an arrangement for connecting the antenna of Figs. 1 and 2 to a radio receiver for testing purposes to show the effectiveness of first one loop then a second loop and then both loops combined;

Fig. 4 is a diagram of the reception patterns of the two loop antennas shown in Fig. 1 taken

separately by means of the circuit shown in Fig. 3;

Figs. 5 and 6 are representative reception pattern diagrams of loop antennas to aid in understanding the non-directional characteristics of the antenna of the present invention;

Fig. 7 is a circuit diagram by means of which the antenna of Figs. 1 and 2 may be used with any radio receiver;

Fig. 8 is a circuit diagram illustrating another embodiment for coupling the antenna of Fig. 1 to a radio receiver;

Fig. 9 illustrates still another modification of the arrangement shown in Fig. 8;

Figs. 10 and 11 illustrate still other modifications of the arrangement of Fig. 8;

Fig. 12 is a schematic diagram of one loop of the antenna of Fig. 1;

Fig. 13 is an equivalent circuit diagram of the schematic diagram of Fig. 10 showing a modification of the present invention;

Fig. 14 is a block diagram of the present invention as applied to a transmitter; and

Fig. 15 is a block diagram illustrating still another modification of the present invention.

In practicing the present invention, there is provided a radio receiver or a radio transmitter associated with a mobile vehicle having a conducting body generally formed of metal. In accordance with the present invention, this body is used as the sole signal pickup means. In connection with a radio receiver for example, connections are made to the conducting body so as effectively to provide two loop circuits displaced in phase from one another so that regardless of the orientation of the mobile vehicle with respect to a particular broadcasting station, the signal strength in the case of a receiver will be substantially constant and substantially unaffected by various bodies adjacent thereto, such, for example, as viaducts, overhead structures and the like. The terminals of the two loop circuits uninsulated from each other and formed wholly of the mobile vehicle body are connected through suitable means to a receiver or transmitter.

Referring now to the drawings, there is illustrated in Fig. 1 a mobile vehicle generally indicated at 10. It should be understood that although the invention is particularly disclosed in connection with its application to an automobile, it might equally be applicable for use with other mobile vehicles and as will become apparent as the following description proceeds, with various three dimensional conducting bodies other than mobile vehicles as for example helmets and the like where it is especially desirable that the presence of an antenna is not discernible. At the present time most modern automobiles are constructed of bodies formed of conducting material, and it has been the use of such conducting or metal bodies that has militated against antennas being built into the motor vehicle itself since the metal body would shield the antenna. In accordance with the present invention, the mobile vehicle 10 specifically illustrated as an automobile is provided with a metal body 11 of conventional form and as shown in Fig. 2 of the drawings, includes a suitable windshield 12 and a dash or instrument panel 13 adjacent which a radio receiver such as 14 is customarily mounted. As shown in Fig. 2 of the drawings, the body is also provided with doors such as 15 and 16. The modern automobile is often provided with a pair of visors such as 17 and 18 which are usual-

ly mounted to suitable frame members such as 19 and 20, respectively.

It is apparent that the conducting body of a mobile vehicle such as an automobile would provide a closed loop which could be used as an antenna which would act as a signal collector in the case of a receiver or a signal radiator in the case of a transmitter. Extensive tests have indicated that by tapping the conducting body at spaced points a radio frequency signal can be obtained from a broadcasting station when the mobile vehicle is disposed within the range of such broadcasting station. It is not known just what path the radio frequency currents take in travelling through the loop circuit furnished by the conducting body. However, it is a well known fact that a loop antenna has a directivity pattern somewhat in the form of a figure 8 with maximum radiation or reception along the plane of the loop. Consequently, tests have indicated that for certain connections made to the car body, a loop is provided which has the same directional characteristics as an equivalent loop since by properly orientating the mobile vehicle, maximum reception in the case of the receiver can be obtained for one position and substantially no reception for some other positions. In other words, the reception pattern like that of a loop antenna has a null point. It is for this reason that the use of a metal body such as the body of an automobile has not been used successfully heretofore as the loop antenna of a radio receiver associated therewith since obviously a mobile vehicle cannot satisfactorily employ a directional antenna which is the characteristic feature of a loop antenna.

Non-directional loop antennas have been employed which have substantially a circular directivity pattern. Such antennas have usually comprised two separate loop circuits displaced in space from each other by approximately ninety degrees. It is apparent that the reception patterns of each of two loop antennas might be somewhat in the form of a figure 8 and in Fig. 5, there is illustrated the reception pattern A for one loop antenna, and the reception pattern B for another loop antenna which latter is displaced in space from the former by ninety degrees. These patterns each represent the ideal reception or radiation patterns for loop antennas with no external objects affecting the field. It is apparent that if the reception patterns A and B for the two space displaced loop antennas were superimposed by direct addition or subtraction that a composite reception pattern such as is illustrated in Fig. 6 by the curve C could be obtained. An examination of Fig. 6 of the drawings which shows the combination of the two patterns A and B of Fig. 5 indicates that the null point has not been eliminated but it has merely been shifted to a point between the two patterns A and B. In other words, the two radiation patterns A and B of Fig. 5 combine such that at particular points the two in-phase components add and the two of opposite phase cancel to produce a resultant field. The maximum signals of Fig. 6 are stronger than the maximum signals of either of the antennas producing the patterns A and B of Fig. 5 and also the minimum signals or null points are somewhat sharper.

If the loop antennas which are displaced in space from each other by an angle of approximately ninety degrees were connected so that the phase relationship of the signals received or transmitted were shifted such that at all angles

of orientation the signals were additive, and the signals for each loop were of equal magnitude then a substantially circular pattern would result and consequently, a non-directional loop antenna would be provided. It has been found in connection with antennas that currents are caused to flow in closed loops by the magnetic component of the electromagnetic radio waves. Thus, where interfering bodies such as overhead structures, viaducts and the like are involved loop antennas are superior to types of antenna which pick up the electric component of the electromagnetic waves since the overhead structures act as an electrostatic shield attenuating the electric component more than the magnetic component.

It is apparent that if the body of an automobile, for example, were formed of various conducting parts insulated from each other that the problem of employing the body as a non-directional loop antenna would be considerably simplified. However, modern automobiles have their bodies formed of sheet metal stampings of substantially continuous conducting portions so that heretofore the possibility of obtaining effective space phase displaced conducting loops in the electrically interconnected conducting body was unknown as was also the additional problem of tapping voltage from two closed space displaced loops. In an attempt to solve this problem, tests were made in connecting various points on the car body with a radio receiver, and it was found that for various connections to the body, effective loop circuits were provided which were orientated differently from each other as was determined by varying the position of the mobile vehicle relative to a broadcasting station to which the receiver associated with the vehicle was tuned and noting that the null points for various effective loop circuits occurred at different orientations of the automobile. Consequently, attempts were made to provide a plurality of taps on the car body which could be the terminals of a plurality of effective loops employing the car body itself as the loops which were displaced from each other sufficiently to give a non-directional antenna. It was found that by trying various points on the body of the mobile vehicle for signal pickup points that various signal strengths were obtained and in addition, it was found that these various points were associated with effective loops in the car body for the radio frequency current which loops were orientated in their effective operation in various ways. It was found, for example, that if a tap connection to the car body were made at the support 19 for the visor 17 above the windshield and at a point 22 directly below the support 19 below the instrument panel 13 of the mobile vehicle that a very satisfactory signal could be received. Such connections, it was found by determining the null point, provided an effective loop circuit that went from the front to the rear of the body which path might be represented by the dotted line 23 in Fig. 1 of the drawings. It should be understood that the particular paths which the radio frequency currents took through the body are unknown and probably many and diverse paths were taken. The resultant of these radio frequency currents, however, was shown by tests to be the same as if the body were replaced by a single loop circuit similar to the circuit 23 of Fig. 1. In other words, the conducting body of the automobile provided an effective loop circuit 23 which would function substantially like

such a loop circuit 23 if it were built into a non-conducting body such as a plastic body for example. Tests further indicated that by making connections to the body as indicated at the visor support 20 at the upper right-hand corner of the body 11 and to the point 24 on the opposite side of the car from the point 22 that the car body 11 acted as an effective loop circuit which could be replaced by the loop circuit shown in dotted lines at 25 in Fig. 1 of the drawings. Actual tests indicated that these effective loop circuits were displaced from each other in space by an angle in the neighborhood of forty-five degrees. Theoretically, it would be desirable for these effective loop circuits 23 and 25 to be displaced from each other by ninety degrees but it was found that a displacement around forty-five degrees was very satisfactory by virtue of the fact that the small variations in signal strength, due to the fact that the reception pattern of the substantially non-directional antenna differed slightly from a true circle, would be compensated for in modern radio receivers which employ automatic volume control or automatic gain control means. Actual tests indicated that with very sensitive receivers for example it would be possible to employ loops displaced in space from each other by an angle considerably less than forty-five degrees with fairly satisfactory results. It should be understood that the closer the phase displacement in space approaches ninety degrees, the more nearly the reception pattern in the case of a receiver approaches a true circle which is the ideal situation. With the ideal situation it would not be necessary to employ automatic volume control.

It should be understood that many connections for the effective loop circuits 23 and 25 in the conducting body are possible and it is not intended in this application to limit the particular points of connection to those specifically described. There are several criteria for these points of connection, however, which are important. First of all, these points of connection should be such that two loop circuits are obtained displaced in space from each other preferably between forty-five and ninety degrees, although in some cases less than forty-five degrees is satisfactory, thereby insuring a substantially non-directional antenna. Secondly, these points of connection should be such that they are readily available for connection to the receiver. It is apparent, for example, that a connection to a door of the automobile or some such point might be undesirable due to the awkwardness in the first place and the complications necessitated to permit movement of the door. Since the automobile receiver is customarily mounted on or adjacent to the instrument panel, it is desirable for the connections to be not too far removed therefrom thereby reducing the length of electrical connections between the receiver and the terminals on the car body which act as the antenna. The particular connection points shown in Fig. 2 by way of example are desirable in that the visor supports are already available and providing that they are electrically connected with the car body provide a very satisfactory means without the automobile manufacturer having to make any changes. The terminals or taps such as 22 and 24 could be provided in the manufacture of the automobile as by providing a screw welded directly to the body for example. Actually, the manufacturer would not need to cooperate in any way whatever since the body is

usually provided with numerous openings in the general area around the terminals 22 and 24 through which a suitable bolt or other connecting means might be extended. In any event, the particular connections on the car body such as 19, 22, 20 and 24 could be determined by each manufacturer so as to provide the most desirable connection points for every automobile whereby the automobile would be provided, with substantially no additional cost, with a built-in wave signal antenna. In this way, a radio installation for an automobile whether it involved a radio transmitter or a radio receiver or both would require no antenna expense nor antenna installation expense.

In Fig. 3 there is illustrated a circuit diagram of a testing device generally indicated at 30 which enables one to determine experimentally the most effective connections on an automobile body whereby such body formed of conducting material may provide a non-directional loop antenna. It should be understood that such a testing device 30 could be employed in connection with any mobile vehicle and reference to its use with automobile bodies is by way of example only. As illustrated, the testing circuit 30 of Fig. 3 comprises three coaxial cables designated at 31, 32 and 33, respectively, which coaxial cables are provided with a common ground connection 33. These cables 31 to 33 are connected to a pair of primary windings 34 and 35 having a common connection 36. The common connection 36 is connected to the coaxial cable 33 while the other terminals of the windings 34 and 35 are connected to the coaxial cables 31 and 32, respectively. A secondary winding 37 is inductively coupled to the windings 34 and 35 and is connected in parallel with a variable capacitor 38 to provide a tuned circuit generally indicated at 39. A suitable amplifier comprising the electron discharge valve 40 is provided whose plate circuit includes a source of potential generally designated at 41 and a tuned circuit 42. The output of the amplifier 40 is connected through a suitable coupling capacitor 43 with a coaxial cable 44 leading to the conventional receiver in the case of a radio receiver. The coaxial cables 31 to 33 are adapted to be connected in a predetermined manner to the taps provided on the automobile body which effectively are the terminals of the loop circuits in the conducting body. By shorting one of the coaxial cables as by means of a shorting plug such as is indicated at 45 in Fig. 3 of the drawings, it is possible to operate the receiver from one loop circuit at a time or from both loop circuits. For example, if the coaxial cable 31 were connected to the terminals 19 and 22 and the coaxial cable 32 were connected to the terminals 20 and 24 with the loop antenna 23 being referred to as antenna No. 1 and the loop antenna 25 being referred to as antenna No. 2, it is possible to obtain the directivity patterns of each of these antennas separately by orientating the automobile relative to a particular broadcasting station. If the shorting plug 45, for example, were connected to short the coaxial cable 32, then the reception pattern for the loop antenna 23 having the terminals 19 and 22 could be obtained. Such a reception pattern as shown by actual tests is designated by the curve D in Fig. 4. By employing the shorting plug 45 in connection with the coaxial cable 31 a reception pattern for antenna No. 2 may be obtained and such a reception pattern obtained by actual tests for antenna No. 2 is illustrated by the

curve F in Fig. 4 of the drawings. By shorting the coaxial cable 33 with the shorting plug 45, a reception pattern for the combined antennas could be obtained. It is apparent that with such an arrangement the manufacturer of an automobile could readily find the most desirable connections for a non-directional loop antenna employing the automobile body which would give the desired signal strength and furthermore, would be located in a most satisfactory position for making electrical connections to a wave signal device while requiring substantially no expense in the manufacture thereof.

For the purpose of coupling the two loop antennas such as 23 and 25 effectively formed as a part of the mobile vehicle body of Fig. 1 to a radio receiver so as to provide a non-directional loop antenna, various coupling circuits may be employed. In Fig. 7 there is illustrated a coupling circuit whereby any present radio receiver installation in a mobile vehicle may be converted to employ the automobile body as a non-directional loop antenna. This coupling circuit, generally designated at 50 in Fig. 7, comprises the coaxial cables 31 and 32 which are adapted to be connected to the terminals 19 and 22 and 20 and 24, respectively. The coaxial cable 31 terminates in a primary winding 53, while the coaxial cable 32 terminates in a primary winding 54. These primary windings 53 and 54 are inductively coupled with tuned circuits 55 and 56, respectively, comprising the secondary windings 57 and 58 and the variable capacitors 59 and 60. The tuned circuits 55 and 56 are arranged to be supplied to the input circuits of a twin triode amplifier 61 having anodes 62 and 63, a cathode 64 and control electrodes 65 and 66. The cathode 64 is grounded as indicated at 67. The signal from loop No. 1 appears in amplified form in the plate circuit comprising anode 62, while similarly the signal picked up by the loop No. 2 appears in amplified form at the plate circuit of anode 63. In order to combine these signals suitable phase shifting means comprising a capacitor 68 and a resistor 69 are provided in the plate circuit of the twin triode 61 comprising the anode 62 thereby causing a 90 degree phase shift of the signals picked up by antenna No. 1 or whatever amount of phase shift is desired in order to cause the reception patterns to combine into a substantially circular pattern. A suitable source of +B potential is provided as indicated at 70 which is connected through suitable resistors 71 and 72 to the anode 63 and through a suitable resistor 73 to the anode 62. The total resistance of the series resistors 71 and 72 connected to the anode 63 is equal to that of the single resistor 73 connected to the anode 62. The reason for this arrangement is to take care of the decrease in the signal strength obtained from the loop No. 1 produced by the phase shifting elements 68 and 69. It is desirable to decrease the signal strength of the signals which are not shifted in phase so that the two signals after the phase shifting operation is performed are substantially equal. The output signal is obtained at the terminal 74 between the resistors 71 and 72 in the case of the radio frequency signal appearing in the circuit including the anode 63. With the arrangement described thus far, it is desirable to provide an impedance transforming device which may take the form of a cathode follower generally indicated at 75 whereby the high impedance output of the amplifier circuit may be coupled to a low input impedance radio receiver through the

coaxial transmission line 75a for example. It is well known that a cathode follower circuit has an inherently low output impedance and a high input impedance. It should be understood that any other suitable impedance matching circuit may be employed if desired.

In order that the non-directional loop antenna formed of the conducting body of a mobile vehicle may be satisfactorily coupled to a radio receiver without employing additional tubes or the like, the arrangement illustrated in Fig. 8 of the drawings may be employed. The coaxial cables 31 and 32 are adapted to be connected to the input circuit of a radio receiver of which the first tube or electron discharge valve 76 is illustrated. Such electron discharge valve might be a radio frequency amplifier or the like. It will be understood that in conventional radio receivers a tuned circuit such as is indicated at 77 is connected to the input circuit of electron discharge valve 76. Such a tuned circuit may include a fixed inductance and a variable capacitance, or a fixed capacitance and a variable inductance. As illustrated in Fig. 8, a variable capacitance 78 is illustrated and a fixed inductance generally indicated at 79 is also provided which comprises the two sections 79a and 79b. A suitable padding condenser 80 is provided for causing tracking with the other tuned circuits in the radio receiver and an automatic volume control circuit including the resistor 81 is normally connected to the electron discharge valve 76 through tuned circuit 77. A ground connection for the tuned circuit 77 is indicated at 82.

For the purpose of coupling the loop antennas connected to coaxial cables 31 and 32 to the tuned circuit 77 in a manner to produce the desired phase shift mentioned above which phase shift may be with reference to only one of the received signals or which phase shift may be with reference to both of the received signals, there is provided the coupling circuit comprising phase shifting resistances 82 and 83 and coupling means 84 and 85. With this arrangement, the radio frequency signal from coaxial cable 31 is inductively coupled through coupling means 84 comprising a winding inductively related with the winding 79. The series resistor 82 causes a phase shift of 45 degrees or thereabouts in one direction of the radio frequency signal supplied through coaxial cable 31. The radio frequency signal supplied through the coaxial cable 32 on the other hand is shifted in phase in the other direction by an amount of the order of 45 degrees by means of a parallel resistor 83. In this case the capacitor 85 directly couples the coaxial cable 32 with one end of the inductive winding 79. The coupling capacitor 85 also prevents the automatic volume control circuit including the resistor 81 from being shorted to ground. The magnitude of the resistors 82 and 83 are varied to give the desired phase shift between the two input signals and then the inductive coupling of the coupling means 84 is adjusted to give the same input sensitivity as that of the capacitive coupling means 85 to insure equal signals from each loop antenna. Actual tests on the circuit of Fig. 8 have indicated it to be very satisfactory. In view of the detailed description included above, the operation of the coupling means of Fig. 8 will be understood by those skilled in the art.

As was mentioned above, many radio receivers employed in connection with mobile vehicles such as automobiles employ as the tuning means thereof variable inductances rather than the

variable capacitance such as 78. In Fig. 9 there is illustrated a portion of the coupling circuit of Fig. 8 showing the same electron discharge valve 76 having its input circuit connected to a tuned circuit 93 including a variable iron core inductance 91 and a substantially fixed capacitance 92 which may be variable to the extent of providing the necessary trimmer action. The coupling means 84 having the same reference numeral as the corresponding means in Fig. 8 of the drawings comprises a few turns wound in inductive relation with inductance 91. The problem involved in this arrangement is to get the same amount of mutual coupling throughout the entire tuning range or throughout the entire movement of the movable core 93.

In the arrangements described thus far for coupling the two loop circuits to a radio receiver so as to effectively provide a non-directional loop antenna, phase shifting means employing resistors and the like have been described. It will be apparent that changes in temperature of the ambient medium and the like will cause a change in the resistance of such resistors whereby the desired ninety degree phase shift will not be realized. In Fig. 10 there is illustrated a phase shifting circuit in which the ninety degree phase shift once it is obtained will be insured regardless of temperature changes and the like. The corresponding parts of Fig. 10 are designated by the same reference numerals as in Fig. 8. In order to couple the two loop antennas to the radio receiver in Fig. 10, there are provided two tunable resonant circuits 94 and 95. The resonant circuit 94 comprises a variable inductance 96 preferably of the so-called permeability tuned type and a suitable capacitor 97 which is adjustable for trimming purposes. The tuned circuit 95 includes a similar variable inductance or tuning inductance 98 and a capacitor 99 also variable for trimmer purposes. In addition, the tuned circuit 95 includes a winding 100 comprising a few turns inductively coupled with the winding 96, the number of turns being a small percentage of the number of turns in the inductance 98. Actually, the inductances 96 and 98 comprise the secondary windings of transformers having primary windings 101 and 102 respectively. The primary windings are connected to the coaxial cables 31 and 32, respectively, with suitable capacitors 103 and 104 shunted across the primary windings 101 and 102, respectively. Each of the resonant circuits 94 and 95 are provided with a common ground indicated at 106 which ground is connected to each resonant circuit at a point adjacent on terminal of the capacitors 97 and 99, respectively. It is apparent that the current and voltage of resonant circuit 94 are in phase as is also the case with reference to the resonant circuit 95. The currents in the resonant circuits 94 and 95 can also be adjusted to be in phase. The voltage across winding 100 which is inductively coupled with the winding 96 causes a component of current to flow in the resonant circuit 94 which is ninety degrees out of phase with the current flowing in resonant circuit 94 whereby the two components of wave signal current from the effective loop circuits 23 and 25 are displaced electrically by ninety degrees and supplied through a suitable coupling capacitor 107 to the electron discharge valve 76. Preferably, the plate circuit of electron discharge valve 76 is connected through a broad band coil generally designated at 108 to the next stage of the receiver such as the oscillator-modulator. It will be understood that in Fig. 10 the

ninety degree phase shift between the wave signal components obtained from loop No. 1 and loop No. 2 is by virtue of the magnetic coupling of two tuned or resonant circuits.

In Fig. 11 there is illustrated a modification of Fig. 10 in which the primary windings 101 and 102 of Fig. 10 are eliminated. The corresponding parts of Fig. 11 are designated by the same reference numerals as in Fig. 11. The resonant circuit 94' includes a series winding 109 while the resonant circuit 95' includes a series winding 110 inductively coupled with the winding 109. The phase shift in this case will be identical with that discussed in Fig. 10 and for the same reasons. The circuits of Figs. 10 and 11 have considerable advantage over the circuits previously described and the following three advantages are obtainable therewith: (1) Greater sensitivity; (2) Full ninety degree phase shift which is not possible with phase shifting circuits employing resistance and inductance; and (3) A constant phase shift across the entire frequency band.

From the above discussion, it will be appreciated that each of the loop antennas such as 23 and 25 forming an integral part of the conducting body of the mobile vehicle are essentially closed loops across a portion of which the input to the wave signal device is connected. In Fig. 12 there is illustrated a schematic diagram of one of the loop circuits such as 23 for example to which is connected the coaxial cable 31. It is noted that between the terminals 19 and 22 there is a conducting portion 111 which to a certain extent short circuits or provides a short circuit across the loop circuit 23 and across the coaxial cable 31. Axially, this short circuit portion represented by the numeral 111 in Fig. 12 of the drawings is a small inductance for high frequency currents designated by the numeral 111' in the equivalent circuit diagram of Fig. 13 of the drawings. The part of the inductance of the total loop circuit of the automobile or mobile vehicle body loop across which it is convenient to make the connections is a small portion of the total inductance of the loop. A considerably improved performance can be obtained in accordance with the present invention by adding the capacitor 112 across the terminals 19 and 22, for example, which capacitor 112 has such a value as to tune the inductance 111' of the car loop circuit 23 between the terminals 19 and 22 to resonance within the frequency range of the wave signal device associated therewith. The resonant circuit formed of the inductance 111' and the capacitor 112 provides a very high impedance or substantial open circuit between the points 19 and 22 thereby eliminating the short circuit across the terminals of the loop.

Although the invention heretofore has been described primarily in connection with a wave signal receiver, it will be understood that the antenna system of the present invention is equally applicable for use with radio transmitters. In Fig. 14 there is illustrated in block diagram a non-directional loop antenna formed of the car body of Fig. 1 shown schematically by the loop portions 23 and 25 which are connected by suitable connections 114 and 113 respectively with the transmitter 115. It will be understood that for certain applications the same antenna formed of the body of the mobile vehicle may be used both for a wave signal receiver or a wave signal transmitter in a manner well understood by those skilled in the art.

Although coaxial or shielded cables have been

described for making connections between the antenna and the receiver, it will be understood that for many applications ordinary connections may be employed.

In the coupling circuits for coupling the non-directional loop antenna formed of the body of the mobile vehicle described above, the phase shifting means employed cause a loss of signal strength in connection with the signal associated with at least one of the loop circuits and since it is necessary for the signal strength of each loop circuit to be the same, it effectively causes a reduction in the signal strength available. In addition to the loss due to the phase shifting operation required the mixing of the two radio frequency signals in the antenna coil causes the Q of the secondary coil to be low and to provide very little gain. It is a well known fact that the local oscillator circuit of most modern radio receivers, for example, provides very satisfactory means for shifting the phase of the signals and in addition, ample power is available at that point for accomplishing this purpose. Accordingly, in Fig. 15 there is illustrated in block diagram the loop circuits 23 and 25 of Fig. 1 which are individually connected through separate radio frequency amplifiers 116 and 117, respectively, and through separate mixer stages 118 and 119, respectively, which are associated with a common local oscillator stage 120. The outputs of the local oscillator should be ninety degrees out of phase with each other to produce the desired phase shift in the mixer whereby the output circuits of the mixer may be combined and fed to an intermediate frequency amplifier 121 and thence to the remaining stages of the radio receiver. With this arrangement, the loss in signal strength at the antenna circuit is eliminated and the phase shift is obtained at the local oscillator where plenty of power is available. It will be understood that the circuits will not be unduly complicated by employing the arrangement of Fig. 15 since the two separate radio frequency amplifiers may be embodied in a dual tube as may also the mixer stages 118 and 119.

From the above description, it is apparent that by means of the present invention the body of a mobile vehicle or the body of some other device such as a helmet or the like having another primary function may be employed as a non-directional loop antenna for a wave signal device whether it be a transmitter or a receiver. Furthermore, with the present invention, the directional characteristics heretofore preventing the use of such bodies as the antennas have been eliminated and a non-directional loop antenna less affected than prior antennas by adjacent objects which interfere with radio reception or transmission is provided. In addition, there is no outside apparatus detracting from the appearance of the mobile craft and no defacement of the body is required in order to provide a satisfactory antenna. It will be understood that if the automobile manufacturers, for example, should go to plastic bodies that a non-directional loop antenna for such type of vehicle can readily be provided by the manufacturer in molding the body initially.

It will be apparent to those skilled in the art that the present invention is not limited to the particular constructions shown and that changes and modifications may be made without departing from the spirit and scope thereof. It is aimed

in the appended claims to cover all such changes and modifications.

What is claimed as new and desired to be secured by Letters Patent of the United States is:

1. An antenna system including a three dimensional conducting body which defines a plurality of closed loop circuits effectively extending in planes disposed at angles with respect to each other, a plurality of taps on said body constituting the terminals of said loop circuits, all of said loop circuits being defined substantially entirely by electrically interconnected portions of said conducting body, and means including a phase shifter for connecting said loop circuits so as to provide a non-directional antenna.

2. An antenna for a mobile vehicle having a body formed of conducting material, a plurality of taps on said body so positioned to serve as terminals of a plurality of physically displaced loop circuits in said conducting body, each loop circuit being defined substantially entirely by portions of said conducting body, and means for coupling said loop circuits together in such phase relation as to provide a substantially non-directional antenna.

3. In a wave signal system for an automobile having a metal body, an antenna including a plurality of loop circuits wholly defined in said metal body, at least two of said loop circuits being effectively displaced from each other, and means including a phase shifter for coupling said two loop circuits to a wave signal device in such phase relation as to provide a substantially non-directional antenna.

4. In a wave signal system for a mobile vehicle having a conducting body, said body defining a pair of loop circuits the planes of which are displaced from each other by an angle of the order of forty-five degrees, a plurality of taps on said body at readily available points within said body constituting terminals on said loop circuits, and means for connecting the terminals of said two loop circuits to a wave signal device so that said loop circuits act as a non-directional antenna.

5. In a wave signal receiver for a mobile vehicle having a metal body, said body defining a pair of effective loop circuits displaced from each other by an angle of the order of forty-five degrees, a plurality of taps on said body at readily available points within said body constituting terminals on said loop circuits, and means for connecting said loop circuits to said wave signal receiver including phase shifting means for shifting the relative phase positions of the wave signals received by said loop circuits so that the phases thereof at said receiver add vectorially, whereby a non-directional antenna is provided for said mobile vehicle.

6. An antenna system for an automobile having a metal body and a windshield, said body defining a plurality of loop circuits effectively extending in planes disposed at angles with respect to each other, a plurality of pairs of electrical connections to said body, one of said pairs of connections being disposed at one side of the interior of said body adjacent an upper and a lower corner of said windshield, said pairs of connections constituting the terminals of said loop circuits, all of said loop circuits being defined substantially entirely by electrically interconnected portions of said metal body, and means for coupling said pairs of connections together in such phase relation as to provide a substantially non-directional antenna system.

7. In a wave signal receiver for a mobile vehicle having a metal body, said body defining a pair of independent effective loop circuits extending in planes displaced from each other by an angle of between forty-five and ninety degrees, a plurality of electrical connections on said body at readily available points at the interior of said body constituting terminals on said effective loop circuits, and means for connecting said loop circuits to a wave signal receiver disposed within said body including phase shifting means for shifting the relative phase of the wave signals received by said loop circuits so that a non-directional antenna is provided for said receiver.

8. In a wave signal receiver for a mobile vehicle having a conducting body, a plurality of taps on said body at readily available points within said body constituting terminals on a pair of effective loop circuits wholly defined in said conducting body, said loop circuits being displaced from each other by an angle of the order of forty-five degrees, and coupling means for connecting said loop circuits to said wave signal receiver including phase shifting means for shifting the relative phase positions of the wave signals received by said loop circuits so that a non-directional antenna is provided for said receiver, one of said coupling means comprising an inductive element.

9. An antenna for a radio transmitter in a mobile vehicle having a conducting body which defines a plurality of closed loop circuits effectively extending in planes disposed at angles with respect to each other, a plurality of terminals on said body constituting taps on said loop circuits, each loop circuit being defined substantially entirely by portions of said conducting body, and means for coupling said transmitter to said terminals whereby said body acts as a non-directional antenna.

10. In a wave signal receiver of the super-heterodyne type for a mobile vehicle having a conducting body, said body defining a pair of effective loop circuits extending in planes disposed with respect to each other at a substantial angle, a plurality of taps on said body at readily available points within said body constituting terminals on said effective loop circuits, means for individually connecting said loop circuits to said wave signal receiver, and means at the output of the local oscillator of said receiver for combining the signals received by said loop circuits so that a substantially non-directional antenna is provided for said mobile vehicle.

11. An antenna system for an automobile having a metal body and a windshield, said body defining a plurality of effective loop circuits extending in planes disposed at angles with respect to each other, a plurality of pairs of electrical connections to said body, one of said pairs of connections being disposed at one side of the interior of said body adjacent an upper and a lower corner of said windshield, another of said pairs of connections being disposed at the other side of the interior of said body adjacent an upper and a lower corner of said windshield, said pairs of connections constituting the terminals of said loop circuits, all of said loop circuits being defined substantially entirely by electrically interconnected portions of said metal body, and means for coupling said pairs of connections together in such phase relation as to provide a substantially non-directional antenna system.

12. An antenna system for an automobile having a metal body and a windshield, said body de-

fining a plurality of loop circuits extending in planes disposed at angles with respect to each other, a plurality of pairs of electrical connections to said body, one of said pairs of connections being disposed at one side of the interior of said body adjacent an upper and a lower corner of said windshield, said pairs of connections constituting the terminals of said loop circuits, and means for coupling said pairs of connections together in such phase relation as to provide a substantially non-directional antenna system.

13. In a wave signal system for an apparatus having a conducting three dimensional body which defines a pair of independent closed circuits having substantially different orientations, a plurality of taps on said body at relatively available points constituting the terminals on said closed circuits wholly defined in said conducting body, means for connecting said terminals to a wave signal device, and phase shifting means connected to said last-mentioned means including a pair of magnetically coupled tuned circuits for shifting the relative phase of the currents obtained from said closed circuits so that said closed circuits effectively provide a non-directional antenna.

14. In a wave signal system for an apparatus having a conducting three dimensional body which defines a pair of independent closed circuits having substantially different orientations, a plurality of taps on said body at relatively available points constituting the terminals on said closed circuits wholly defined in said conducting body, means for connecting said terminals to a wave signal device, and phase shifting means connected to said last-mentioned means including a pair of tuned circuits, one of said tuned circuits including a winding inductively coupled with the other tuned circuit.

15. An antenna system in accordance with claim 1 in which said connecting means includes means for tuning the short conducting portion of each loop circuit between the terminals thereof whereby said short conducting portion in effect becomes an open circuit.

16. An antenna system for a radio set mounted in a vehicle, such system comprising a three-dimensional conductive vehicle body of such configuration as to define a plurality of loop circuits effectively extending in planes disposed at substantial angles with respect to each other, all of said loop circuits being defined substantially entirely by electrically interconnected portions of said conducting body, and means for coupling said loops individually to the radio set in such phase relation as to make the antenna system non-directional.

17. An antenna system for a radio set mounted in a vehicle, such system comprising a three-dimensional conductive vehicle body of such configuration as to define a pair of closed loop circuits effectively extending in planes disposed at substantial angles with respect to each other, said body having a primary function other than that of providing said loops, with each loop circuit being defined substantially entirely by portions of said conducting body, and means for coupling said loops individually to the radio set in such phase relation as to make the antenna system non-directional.

18. An antenna system for a radio set or the like mounted in a vehicle, such system comprising a three-dimensional conductive vehicle body of such configuration as to define a plurality of loop circuits effectively extending in separate

planes at least two of which are angularly displaced by a substantial amount, each of said loop circuits being defined substantially entirely by portions of said conducting body, and means for coupling said loops individually to the radio set in such phase relation as to make the antenna system non-directional.

19. An antenna for a radio set mounted in a vehicle, such system comprising a three-dimensional conductive vehicle body of such configuration that said body affords two crossed loop circuits therein, two pairs of taps on said body, each pair being located on one of said loop circuits, and means for coupling said pairs of taps to the radio set including phase-shifting means for obtaining a resultant antenna pattern which is substantially non-directional.

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