

[54] **OMNIDIRECTIONAL LOOP ANTENNA ARRAY**
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 [58] Field of Search.....**343/741, 744, 743, 742, 787, 343/748, 788**

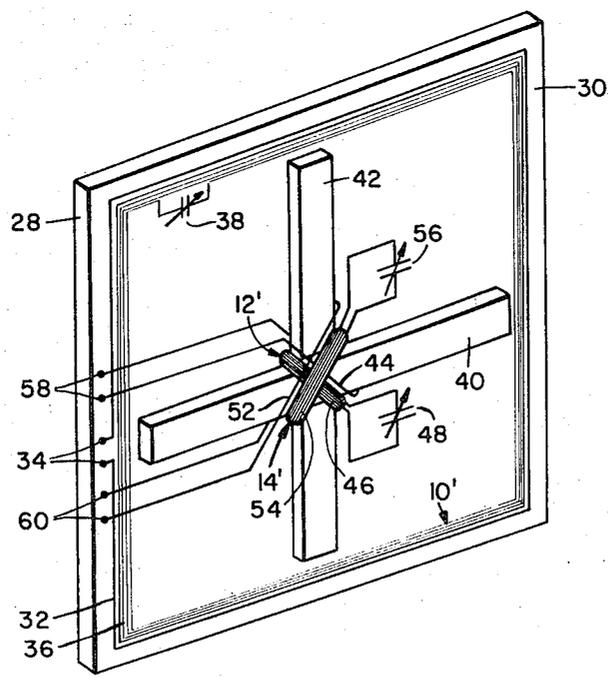
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[57] **ABSTRACT**
 An antenna array for use with a system for receiving signals from a radio capsule disposed within a patient's gastrointestinal tract. The array of antennas comprises three mutually perpendicular loop antennas, two of which are ferrite-core loop antennas disposed near the center of the array, the third being a loop antenna surrounding the two ferrite-core antennas. The antenna array includes means for matching the impedance of the loop antennas to transmission lines to which they are to be connected.

15 Claims, 3 Drawing Figures



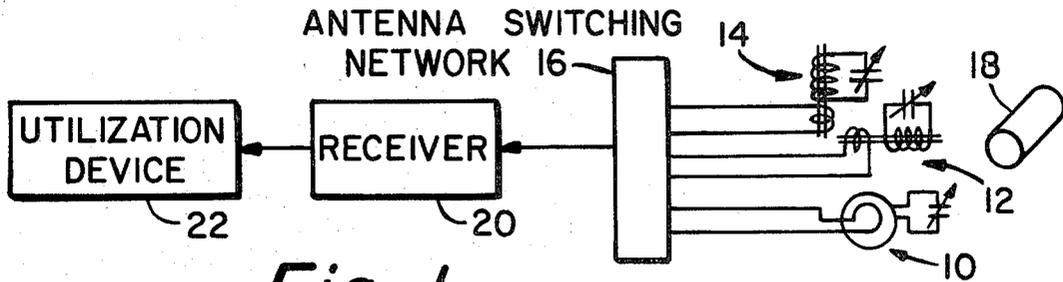


Fig. 1

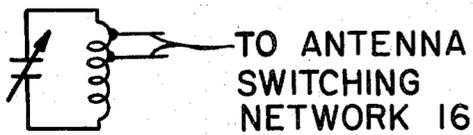


Fig. 3

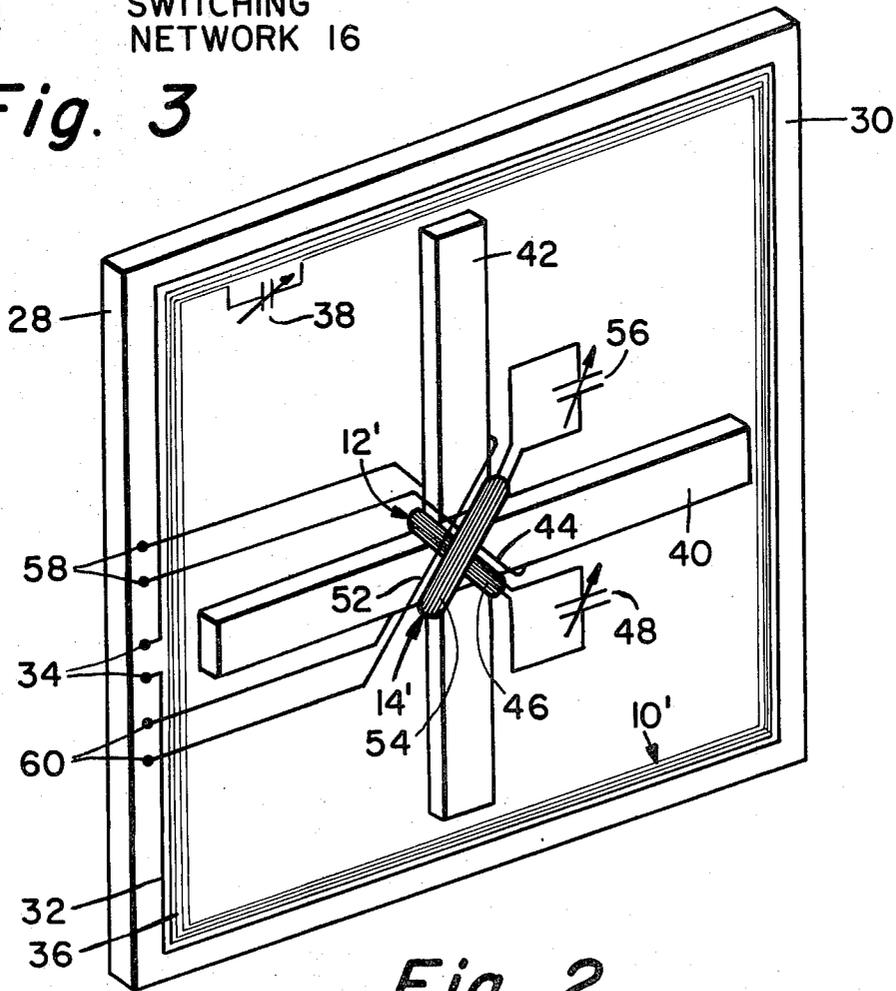


Fig. 2

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OMNIDIRECTIONAL LOOP ANTENNA ARRAY

BACKGROUND OF THE INVENTION

This invention concerns an omnidirectional antenna array, and more particularly an antenna array for receiving signals emanating from a radio capsule disposed within the stomach or intestines of a patient.

Stomach and intestinal examinations have been carried out by means of a radio capsule which can be swallowed. A coil-type transmitting antenna located within the capsule radiates a signal which is received and evaluated to provide an indication of some condition within the gastro intestinal tract such as temperature, pressure, pH value, bleeding, or the like. Since a radio capsule may have a transmitting range of two or three feet, a major problem encountered in receiving signals therefrom is that as the capsule continuously tumbles about in the stomach or intestines, the relatively weak electromagnetic field pattern radiating therefrom continuously changes orientation. When the capsule assumes a position such that the signal is cross-oriented to the receiving antenna, the signal induced in the antenna disappears.

It is impractical to attempt to design a transmitting antenna to provide a usable omnidirectional signal; however, several different types of receiving antennas have been utilized in an attempt to overcome this problem. One such receiving antenna arrangement employs an electric motor to spin a small loop antenna. In addition to being cumbersome, this antenna does not receive a usable signal for all orientations of the radio capsule. Another technique employs three antennas, two loops and a ferrite-core loop in a belt arrangement which is placed around the patient's body. The receiver automatically switches to another of the three antennas when the signal disappears in the antenna to which the receiver had been connected. Since the three antennas are arranged in a belt around the body, at least one of them is always relatively far from the capsule, and the signal can disappear in the receiver with certain capsule orientations in the stomach or intestines. Since a weak signal is radiated by the capsule, it is desirable that the receiving antenna be disposed as close to the capsule as possible. This is impossible with the belt arrangement wherein the particular antenna switched to the receiver may be the farthest from the radio capsule.

SUMMARY OF THE INVENTION

It is therefore an object of the present invention to provide an antenna array which is capable of receiving signals from a radio capsule regardless of the orientation thereof within the stomach or intestines of a patient.

Another object of the present invention is to provide a compact omnidirectional receiving antenna array.

Still another object of the present invention is to provide an array of loop antennas having a low input impedance, thus permitting the connection of a transmission line directly to each antenna.

Briefly, this invention relates to a compact, omnidirectional array of antennas which is suitable for use in a system for receiving signals from a radio capsule. Any one of the array of antennas, which is suitable for disposition adjacent to a patient that has swallowed a radio capsule, is connected by switching means to a radio receiver. The array of antennas is characterized

in that it comprises a first ferrite-core loop antenna, a second ferrite-core loop antenna, the axis of which is perpendicular to that of the first loop antenna, and a third loop antenna surrounding the first and second loop antennas. The axes of the first and second loop antennas are perpendicular to that of the third loop so that at least one of the antennas receives a useful signal from the radio capsule regardless of the orientation thereof.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic illustration of a system in which the present invention can be utilized.

FIG. 2 is an oblique view of an antenna array constructed in accordance with the present invention.

FIG. 3 is a schematic illustration of an alternative method of coupling a transmission line to a loop antenna.

DETAILED DESCRIPTION

A system for receiving and processing signals transmitted by a radio capsule is schematically illustrated in FIG. 1. An array of antennas comprising three mutually perpendicular loop antennas 10, 12 and 14 is connected to an antenna switching network 16. Each of the antennas includes an impedance matching section consisting of a single loop of wire which is connected to the switching network, a multi-turn loop of wire being wound adjacent to each single loop. Each of the multi-turn loops is connected in series with a variable capacitor which is adjusted to such a value that the resultant series circuit is series resonant at the operating frequency of the radio capsule transmitter. As shown schematically in FIG. 1, the axes of the loop antennas are mutually perpendicular so that at least one of the antennas of the array receives a signal of adequate strength from radio capsule 18 to give an accurate indication of the value of the condition being monitored.

Antenna switching network 16 may be one of the conventional types which are used in conjunction with diversity signal reception systems. The output of network 16 is coupled to receiver 20, the output of which may be connected to utilization device 22 which may be a meter which indicates the value of the measured condition. Network 16 may be of the type which connects one of the antennas 10, 12 and 14 to the receiver and maintains that connection until the coupling between the transmitter antenna of capsule 18 and the receiver antenna is so low that no useful signal is obtainable from that antenna, the signal voltage being less than or equal to the noise voltage. When this occurs, switching network 16 connects another antenna to receiver 20 and maintains such new connection so long as an adequate signal is available from that antenna. Alternatively, switching network 16 could continuously monitor the signal levels provided by each of the antennas 10, 12 and 14 and connect the antenna having the greatest signal strength to the receiver 20.

The antenna array of FIG. 1 is shown in greater detail in FIG. 2, similar components being designated by primed reference numerals. To provide the greatest signal, it is desirable that the three antennas be located in one flat compact package that can be placed over the stomach or intestines, i.e., as close to the radio capsule as possible. Therefore, all three antennas 10', 12',

and 14' are disposed on a supporting substrate 28 which preferable consists of a dielectric material such as glass, ceramic, plastic, or the like.

Antenna 10' consists of a one-turn input loop 32 wound around the periphery of a surface 30 of substrate 28, the ends of that loop being connected to a pair of terminals 34. A multi-turn closed loop 36, which is in series with a capacitor 38, is disposed adjacent to loop 36. Although each of the input loops is shown separate from the multi-turn loops for the sake of clarity, it is to be understood that the one-turn loops can be wound directly on or with the multi-turn loops. Antenna 10' is sensitive to magnetic fields which are parallel to the axis thereof, said axis extending through the center of the antenna and being perpendicular to the plane in which this antenna is disposed, i.e., it is substantially perpendicular to surface 30. Antennas 12' and 14' consist of smaller loops wound across the intersection of crossed ferrite rods 40 and 42 at an angle of 45° with respect to the axes thereof in such a manner that the axes of the loops 40 and 42 are mutually perpendicular as well as being perpendicular to the axis of antenna 10' which substantially surrounds antennas 12' and 14'. Antenna 12' consists of a one-turn loop 44 which is wound adjacent to a multi-turn loop 46 having a capacitor 48 in series therewith. Antenna 14' consists of a one-turn loop 52 which is wound adjacent to a multi-turn loop 54 which has a capacitor 56 in series therewith. The one-turn loops 44 and 52 are connected to terminals 58 and 60, respectively.

In one actual embodiment of the present invention each of the multi-turn loops consisted of a 20 turn loop, and the capacitors 38, 48 and 56 were adjusted so that the multi-turn loops were series-resonant with the capacitors at 1.90 mHz. This coupled-coil arrangement gave maximum sensitivity while still maintaining a 50 ohm impedance to match the transmission line which connected the antennas to the switching network.

In a preferred embodiment, the entire antenna array was about five inches square by 1 inch thick and was small enough in size to be placed over a patient's stomach and held in place by a belt. This embodiment was constructed by gluing the two ferrite rods together and then wrapping the loops 44, 46, 52 and 54 around the intersection thereof. A dielectric peg was affixed to each corner of substrate 28 and the loops 32 and 36 were wound around them. The ferrite rods were then attached to substrate 28 by string, and the entire array was put into a thin container.

The antenna array can be potted in epoxy or some similar potting compound to produce a rugged structure. The antennas of the described array provided a good impedance match to a 50 ohm transmission line. The input loops 32, 44 and 52 could consist of more than one turn if the impedance of the transmission lines were other than 50 ohms or if the multi-turn antenna loops 36, 46 and 54 had a correspondingly higher number of turns.

As shown in FIG. 3 the multi-turn antenna loops could be matched to transmission lines by tapping one or more turns of the multi-turn antenna loops.

The above described preferred embodiment was very effective because all of the antennas could be located as close as possible to the radio capsule since they were all disposed in a single small package. Within the cap-

sule's transmitter range, there was no orientation of the capsule that caused loss of signal in this antenna system.

I claim:

1. In a system for receiving signals from a radio capsule, wherein any one of an omnidirectional array of antennas suitable for disposition adjacent to a patient is connected by switching means to a radio receiver, said array of antennas being characterized in that it comprises:

a first ferrite-core loop antenna,
a second ferrite-core loop antenna, the axis thereof being perpendicular to that of said first loop antenna, and

a third loop antenna surrounding said first and second loop antennas, the axes of said first and second loop antennas being perpendicular to that of said third loop antenna so that at least one of said antennas can receive a usable signal from said radio capsule, regardless of the orientation of said radio capsule.

2. A system in accordance with claim 1 wherein said array of antennas further comprises first, second and third pairs of terminals, first means for matching the impedance of said first antenna to said first pair of terminals, second means for matching the impedance of said second antenna to said second pair of terminals and third means for matching the impedance of said third antenna to said third pair of terminals.

3. A system in accordance with claim 2 wherein said first loop antenna comprises a first multi-turn loop, said first means comprising a first one-turn loop wound adjacent to said first multi-turn loop, the ends of said first one-turn loop being connected to said first pair of terminals, said second loop antenna comprises a second multi-turn loop, said second means comprising a second one-turn loop wound adjacent to said second multi-turn loop, the ends of said second one-turn loop being connected to said second pair of terminals, and said third loop antenna comprises a third multi-turn loop, said third means comprising a third one-turn loop wound adjacent to said third multi-turn loop, the ends of said third one-turn loop being connected to said third pair of terminals.

4. A system in accordance with claim 3 further comprising first, second and third variable tuning capacitors in series with said first, second and third multi-turn loops, respectively.

5. A system in accordance with claim 4 wherein said first and second ferrite-core loop antennas comprise first and second elongated crossed ferrite rods, said first and second single turn loops and said first and second multi-turn loops being disposed on said ferrite rods.

6. A system in accordance with claim 5 wherein said array of antennas is further characterized in that said first and second single-turn loops and said first and second multi-turn loops are disposed at the intersection of said first and second ferrite rods, both of said rods disposed within each of said loops.

7. A system in accordance with claim 2 wherein said first, second and third means comprise electrical connections from said first, second and third pairs of terminals to taps on said first, second and third loop antennas, respectively.

8. An antenna array comprising

a pair of elongated crossed ferrite rods,
 a first multi-turn loop antenna wound around said rods at the intersection thereof,
 a second multi-turn loop antenna wound around said rods at the intersection thereof, the axis of said second loop antenna being perpendicular to the axis of said first loop antenna,
 a third multi-turn loop antenna surrounding said first and second loop antennas, the axes of said first and second loop antennas being perpendicular to that of said third loop antenna,
 first, second and third variable tuning capacitors in series with said first, second and third loop antennas, respectively,
 first, second and third pairs of terminals,
 first means for matching the impedance of said first antenna to said first pair of terminals,
 second means for matching the impedance of said second antenna to said second pair of terminals, and
 third means for matching the impedance of said third antenna to said third pair of terminals.

9. An antenna array in accordance with claim 8 wherein said first means comprises a first one-turn loop wound adjacent to said first multi-turn loop, the ends of said first one-turn loop being connected to said first pair of terminals, said second means comprises a second one-turn loop wound adjacent to said second multi-turn loop, the ends of said second one-turn loop being connected to said second pair of terminals, and said third means comprises a third one-turn loop wound adjacent to said third multi-turn loop, the ends of said third one-turn loop being connected to said third pair of terminals.

10. An antenna array in accordance with claim 8 wherein said first, second and third means comprise electrical connections from said first, second and third pairs of terminals to taps on said first, second and third loop antennas, respectively.

11. An antenna array in accordance with claim 8

wherein said first means comprises a fourth loop wound adjacent to said first multi-turn loop, the ends of said fourth loop being connected to said first pair of terminals, said second means comprises a fifth loop wound adjacent to said second multi-turn loop, the ends of said fifth loop being connected to said second pair of terminals, and said third means comprises a sixth loop wound adjacent to said third multi-turn loop, the ends of said sixth loop being connected to said third pair of terminals, said fourth, fifth and sixth loops comprising fewer turns than said first, second and third loops, respectively.

12. An antenna array in accordance with claim 11 wherein said first, second and third loop antennas each consists of a first number of loops and said third, fourth and fifth loops each consists of a second number of loops.

13. A system in accordance with claim 1 wherein said first and second ferrite core loop antennas comprise first and second elongated crossed ferrite rods and first and second multi-turn loops disposed on both of said rods at the intersection thereof.

14. A system in accordance with claim 13 wherein said third loop antenna is disposed in a plane which is parallel to the axes of said first and second ferrite rods.

15. An antenna array comprising
 a flat substrate,
 a pair of elongated crossed ferrite rods disposed on said substrate,
 a first multi-turn loop antenna wound around said rods at the intersection thereof,
 a second multi-turn loop antenna wound around said rods at the intersection thereof, the axis of said second loop antenna being perpendicular to the axis of said first loop antenna, and
 a third multi-turn loop antenna disposed on said substrate and surrounding said first and second loop antennas, the axes of said first and second loop antennas being perpendicular to that of said third loop antenna.

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