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SPIRAL MODE SELECTOR CIRCUIT FOR A TWO-WIRE ARCHIMEDEAN SPIRAL ANTENNA

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FIG. 1

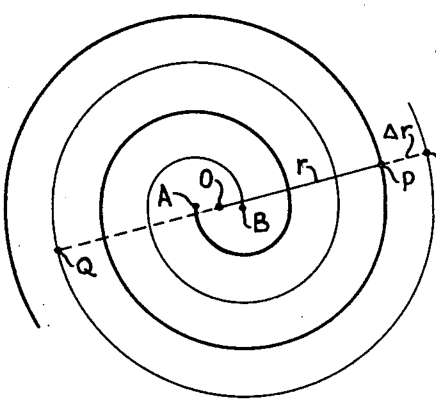


FIG. 2

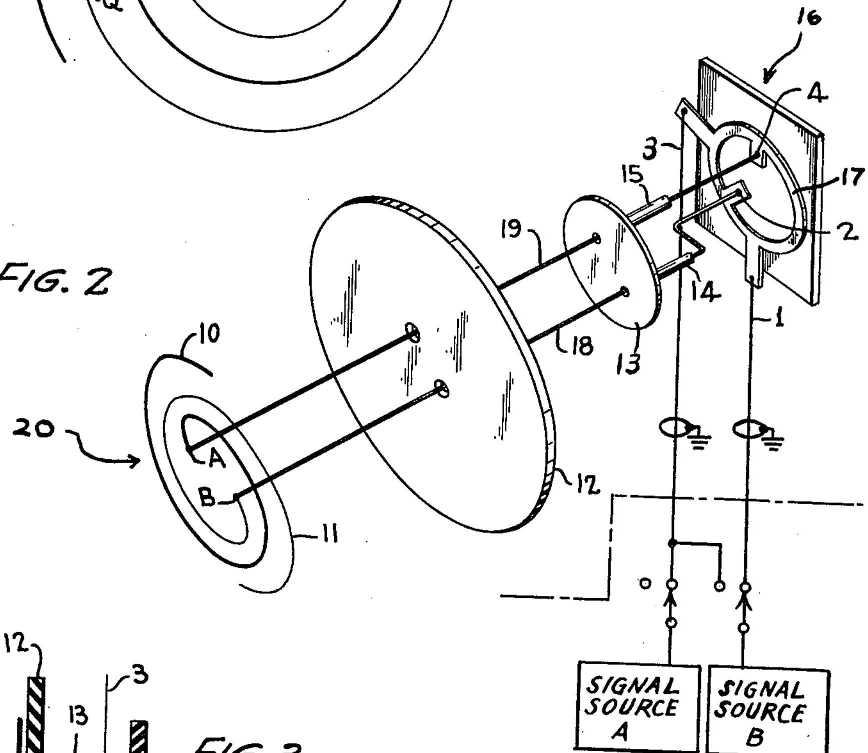
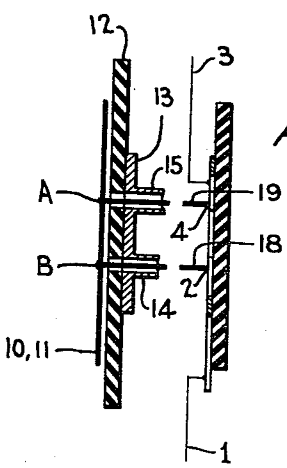


FIG. 3



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SPIRAL MODE SELECTOR CIRCUIT FOR A TWO-WIRE ARCHIMEDEAN SPIRAL ANTENNA

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(Granted under Title 35, U.S. Code (1952), sec. 266)

The invention described herein may be manufactured and used by or for the Government for governmental purposes without the payment to me of any royalty thereon.

This invention relates generally to spiral antennas and is more specifically directed to a two-wire Archimedean spiral antenna in which any desired radiation mode can be selected.

The spiral antenna, although a relatively recent development, has received much attention because of its broad-band characteristics which make it eminently suitable for radar countermeasures, as well as other related fields. When a spiral antenna is energized at its input terminals, it radiates a broad circularly polarized beam to either side of the spiral. Each radiated beam is normal to the plane of the spiral, and the sense of circularity of polarization of the beam on one side corresponds to the winding sense of the spiral as viewed from the opposite side. Accordingly, the two radiated beams are identical except that the rotational sense of polarization of the radiated field on one side is the opposite of that on the other. In most applications, however, it is desirable that the spiral radiate to one side only. This is readily accomplished by appropriately backing the spiral on one side by a ground plane or cavity.

I have discovered that the spiral antenna can be excited in any one of a plurality of transmission modes, characterized as the 1st, 2nd, 3rd, 4th, etc. modes. Although this description will be limited to the 1st and 2nd modes, it should be realized that a spiral antenna can also be excited in an infinite number of higher order modes. Such an antenna is extremely useful for radar scanning, and can also be utilized as a simultaneous transmit-receive device by transmitting in one mode and receiving in another.

Accordingly, an object of this invention is to provide a circuit for energizing a spiral antenna in any preselected radiation mode.

A further object of this invention is to simultaneously energize a spiral antenna in a plurality of transmission modes.

These and other objects, features, and advantages of this invention will be apparent from the following specification taken in conjunction with the drawings, in which:

FIG. 1 is a diagrammatic representation of an Archimedean spiral antenna;

FIG. 2 represents a schematic diagram of the instant invention, and

FIG. 3 is a side view of the assembled components of the invention.

The two-wire spiral antenna behaves generally as though it were a two-wire transmission line which gradually, by virtue of its spiral geometry, transforms itself into a radiating structure or antenna. It is well known that a two-wire transmission line of narrow spacing relative to wavelength and of any length yields a negligible amount of radiation when excited at its terminals. This is due to the fact that the currents in the two wires of the line at any normal cross-section are always 180° out-of-phase so that radiation from one line is effectively cancelled by the radiation from the other.

Suppose now that a two-wire transmission line is formed into the spiral configuration of FIG. 1. Let P be a point on one wire of the transmission line at a distance measured along the wire from the input terminal A. Then the point Q on the other wire at the same distance from the input terminal A is situated diametrically opposite the point P with respect to the center O, and both P and Q lie on the same circle centered at O. This implies that the point P and its neighboring point P′ on the other wire directly alongside P lie at such distances from A and B respectively, that the difference of these distances is precisely the arc length QP′ along the spiral. If Δr, the spacing between wires, is much smaller than r, the arc length QP′ is approximately equal to πr. This difference in wire lengths is constant regardless of the number of turns within r, provided only that the spacing between wires is uniform.

There are two items of interest that attach to a particular point on the two-wire spiral line: the total difference in wire lengths of the two-wire line to the point and the circumference or path length of the particular turn on which the point lies. For the circular spiral where the wires are equally spaced, at a point whose radial distance from the spiral center is r, the difference in line lengths equals πr and the circumference equals $2\pi r$. When r is $\lambda/2\pi$, the phase change is $\lambda/2$ and the circumference is λ. Assuming that each wire supports a progressive wave of current and that these current waves are anti-phase at the input terminals A and B, it is clear that the difference in phase of the two current elements at any point PP′ on the two wire line, measured in radians is π (the input phase difference)$+2\pi/\lambda(\pi r)$. Thus neighboring current elements start anti-phase at the feed points A and B, and gradually come into phase as they proceed outward along the spiral two wire line. When r is $\lambda/2\pi$, these currents are precisely in phase and radiation is a maximum. Moreover, the condition for precisely in-phase currents occurs at two points diametrically opposite each other relative to the center O.

Radiation from the spiral then is centered in a ring of turns of one wavelength mean circumference. This property makes the spiral antenna an inherently broad-band device, the basic requirement being only that the radius be large enough to allow a half wavelength of phase shift. Also, inasmuch as the radiating ring is a wavelength in circumeference for all frequencies over which the spiral operates, a constant beam width is maintained.

Radiation from the one-wavelength ring as described above is termed the first mode of radiation, because this represents the first occasion for which conditions are correct for radiation. Currents existing beyond the one-wavelength ring will continue experiencing phase change as they progress outward, and assuming the spiral structure is large enough, these currents will be out of phase again at a radius where the circumference is two wavelengths and in phase at the three-wavelength circumference. No radiation occurs from the two-wavelength ring because the currents on adjacent filaments are anti-phase. At the three wavelength ring radiation can occur if currents exist, giving rise to the third mode of radiation. It follows that currents which are anti-phase at the input terminals can excite only the odd modes of radiation. If on the other hand the two center terminals are tied together and excited in some manner, currents start in-phase at the center of the spiral. In progressing outward these currents experience phase change. When the one-wavelength circumference is reached they are anti-phase and no radiation occurs. At the two wavelength circumference, which is defined as the locus of the second radiation mode, the currents are once again in phase, and radiation is once again strong. Currents around the two wavelength circumference of a circular spiral, are in such phase as to cause a radiation pattern of minimum field on-axis and maximum field, which is omni-directional, in the plane of the spiral. Since the second mode diameter for the circular spiral is approximately

$$\frac{2\lambda}{\pi}$$

a very broad pattern in the plane of the spiral axis is obtained. Thus, the first radiation mode is characterized by maximum gain along the axis and 360° phase change per spiral revolution and the second radiation mode is characterized by maximum gain in the plane of the spiral and 720° phase change per revolution.

Referring now to the exploded view of FIG. 2 and the assembled side view of FIG. 3 the invention is shown as comprising a two-wire Archimedean spiral antenna **20** consisting of wires **10** and **11**. Ring network **16** consisting of input terminals **1** and **3**, output terminals **2** and **4** and conducting strip **17** is a standard microwave component in which currents entering terminal **1** arrive at terminals **2** and **4** in phase opposition while currents entering terminal **3** arrive at terminals **2** and **4** in phase. Metal plate **13** is provided for use as a ground plane to insure launching of the energy onto the spiral. Terminals **2** and **4** of the ring network are connected to the input terminals A and B of the two-wire spiral by the inner conductors **18** and **19** of coaxial cables having outer conductors **14** and **15** which are electrically attached to the ground plane **13**. Dielectric plate **12** is provided to insulate the ground plate **13** from the antenna when the components are assembled as shown in FIG. 3.

If it were desired to operate the antenna in the first radiation mode for example, current would be fed into arm **1** of the ring network **16**. This may be accomplished, for example, by positioning the switch associated with signal source A in the left-hand position and the switch associated with signal source B in the right-hand position. The current would then reach the terminals A and B anti-phase and as described above, at the one wavelength circumference the currents would be in phase and radiation would occur. On the other hand, if it were desired that the antenna operate in the second mode of radiation, current would be fed into terminal **3** of the ring network **16** and the currents would consequently reach terminals A and B in phase. This may be accomplished, for example, by positioning the switches associated with signal sources A and B in the left-hand position. The currents would then be out of phase at the one wavelength circumference and in phase again at the two wavelength circumference where radiation would occur. In order to excite the antenna in a higher-order mode of radiation, such as the third or fourth mode, it would be necessary to provide input terminals further out along the spiral, for example at the two-wavelength circumference. Then, wires **18** and **19** would be attached to these terminals rather than to terminals A and B and the operation would be similar to that described for the first and second modes. That is, in order to excite the antenna in an odd mode, current would be fed into input terminal **1** of ring network **16** and for the even modes current would be fed into arm **3** of the ring network.

It is also possible to simultaneously excite the two-wire spiral in a plurality of transmission modes since adjacent modes are inherently isolated from one another. Thus, the circuit could be utilized as a simultaneous transmit-receive device by transmitting, for example, in the first mode and receiving in the second mode. By the same token, it is possible to transmit in two modes simultaneously such as the first and second modes. This may be accomplished, for example, by positioning the switches associated with signal sources A and B in the right-hand

position. This results in a phenomenon called beam cock. The resultant field obtained from adding the first radiation mode characterized by maximum gain along the axis and 360° phase change per spiral revolution, and the second radiation mode characterized by maximum gain in the plane of the spiral and 720° phase change per revolution, is generally a pencil beam that points other than along the spiral axis. The amount of beam cock is dependent upon the relative amplitude of the two radiation modes and the direction is determined from the relative phases. Such a radiation field is desirable in devices such as direction finders and radar detectors where beam directivity is required.

Thus, there has been described a circuit which permits a spiral antenna to be operated in any of a plurality of radiation modes either individually or concurrently and which lends itself to a wide variety of highly useful applications in the fields of radar, direction finders and simultaneous transmit-receive devices. It should be realized that the embodiment described is only exemplary and that many modifications can be made in the instant circuit without departing from the scope of the invention. For example, in place of the circular spiral antenna described, a square spiral or rectangular spiral can similarly be utilized and the same considerations would apply to the operation of these embodiments as those described in connection with the circular spiral.

I claim as my invention:

1. A selective mode spiral antenna system which is adapted to radiate in either odd or even modes alternately or both odd and even modes simultaneously comprising a two-wire Archimedean spiral antenna having two input terminals; a ring network having two output terminals, a first input terminal which passes applied current to said output terminals in phase opposition, and a second input terminal which passes applied current to said output terminals in phase, two coaxial cables each having an outer conductor and an inner conductor, said inner conductors being electrically connected between the output terminals of said ring network and the input terminals of said spiral antenna; a metal ground plane interposed between said ring network and said spiral antenna, said outer conductors being electrically connected to said ground plane; and a dielectric insulator interposed between said spiral antenna and said ground plane.

2. A spiral antenna system which is capable of electrically scanning a target area while maintaining the antenna in a fixed position comprising a two-wire Archimedean spiral antenna having two input terminals; means for causing said antenna to radiate a pencil beam having a predetermined orientation with respect to the plane of said spiral; said means comprising a ring network having two output terminals, a first input terminal which passes applied current to said output terminals in phase opposition, and a second input terminal which passes applied current to said output terminals in phase, means connecting the output terminals of said ring network to the input terminals of said antenna, and means for applying current simultaneously to said first and second input terminals of the ring network.

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