(12) UK Patent Application (19) GB (11) 2 234 859(13) A

(43) Date of A publication 13.02.1991

(21) Application No 9014536.8

(22) Date of filing 29.06.1990

(30) Priority data
(31) 8915047 (32) 30.06.1989 (33) GB

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(51) INT CL[5]
H01Q 1/36 9/27

(52) UK CL (Edition K)
H1Q QDJ
U1S S2204 S2205

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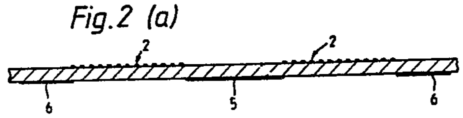
(58) Field of search
UK CL (Edition K) **H1Q QDJ QKA**
INT CL[5] **H01Q**

(54) **Spiral antenna**

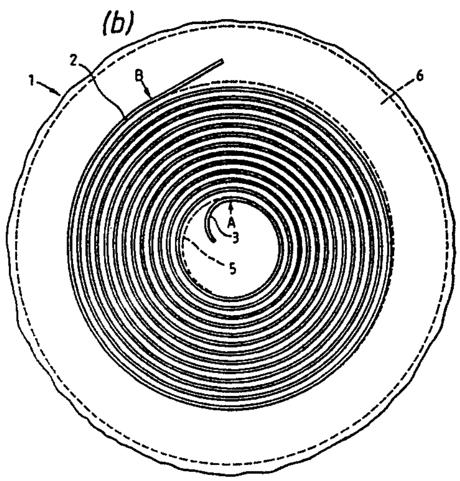
(57) A spiral antenna 1 for circularly polarised radiation has a single regular or irregular spiral arm 2 and a port A, B is formed by a truncation 3 at a minimum or maximum circumference of the spiral 2. The port is arranged to be directly coupled to an RF system.

In the preferred example, the antenna has ports A and B at both the minimum and maximum circumferences respectively and is arranged to be coupled to the RF system at one or both of the ports. The antenna may be formed as a microstrip circuit. The diameters at which the antenna is truncated by the ports may be such that the phase difference between each port and the next adjacent turn of the spiral 2 is approximately $(2n+1)\pi$. An inner disc shaped ground plane 5 and an outer annular ground plane 6 define the minimum and maximum circumferences.

Fig.2 (a)



(b)



At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig. 1

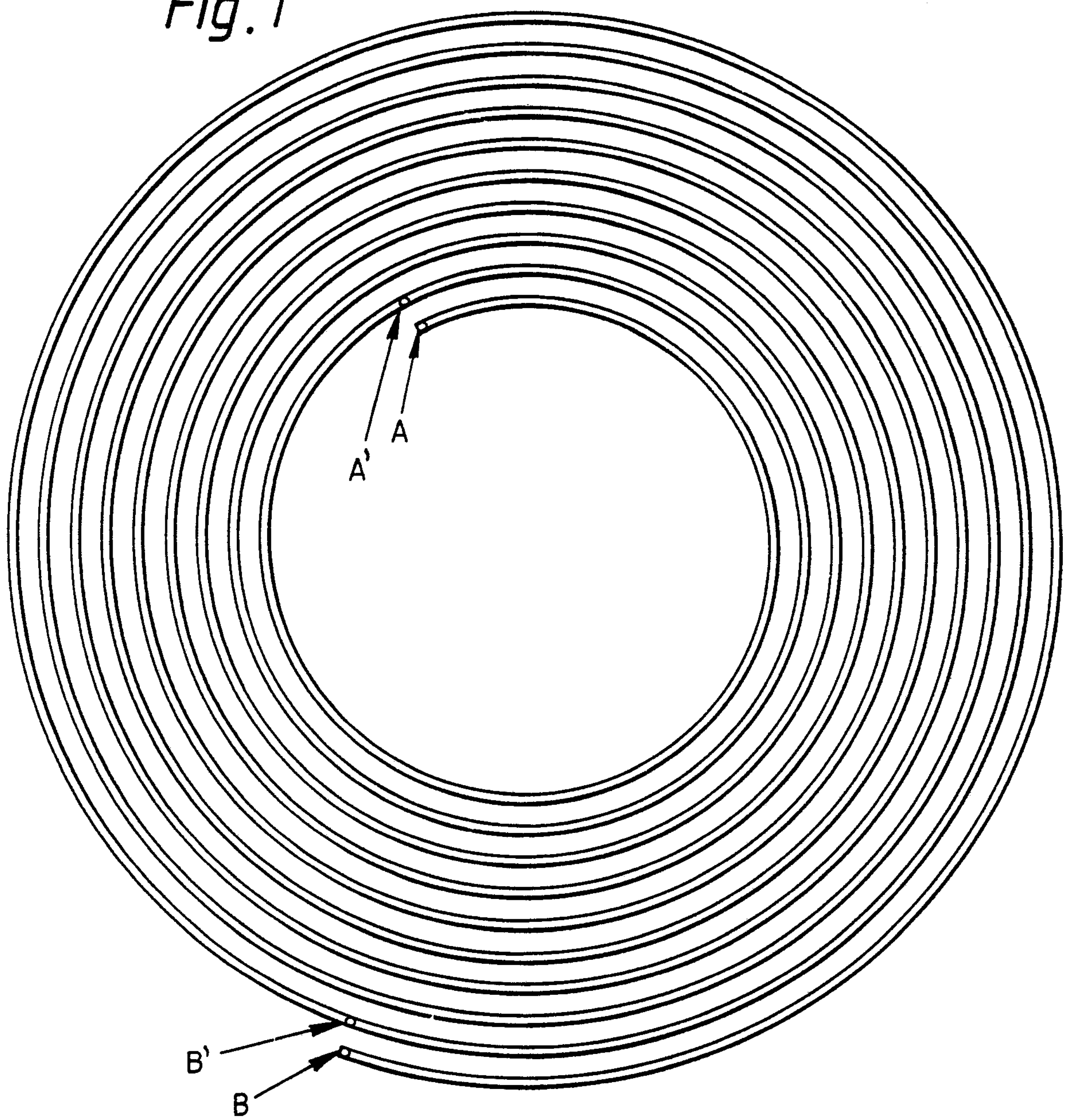
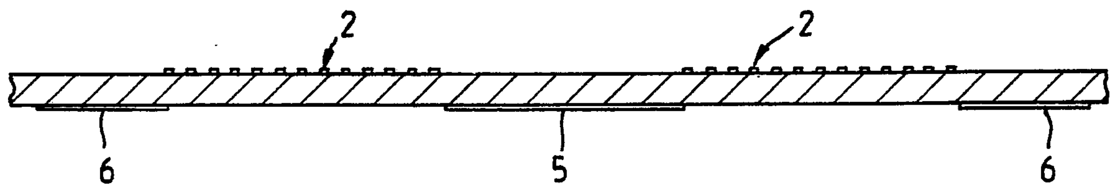


Fig.2 (a)



(b)

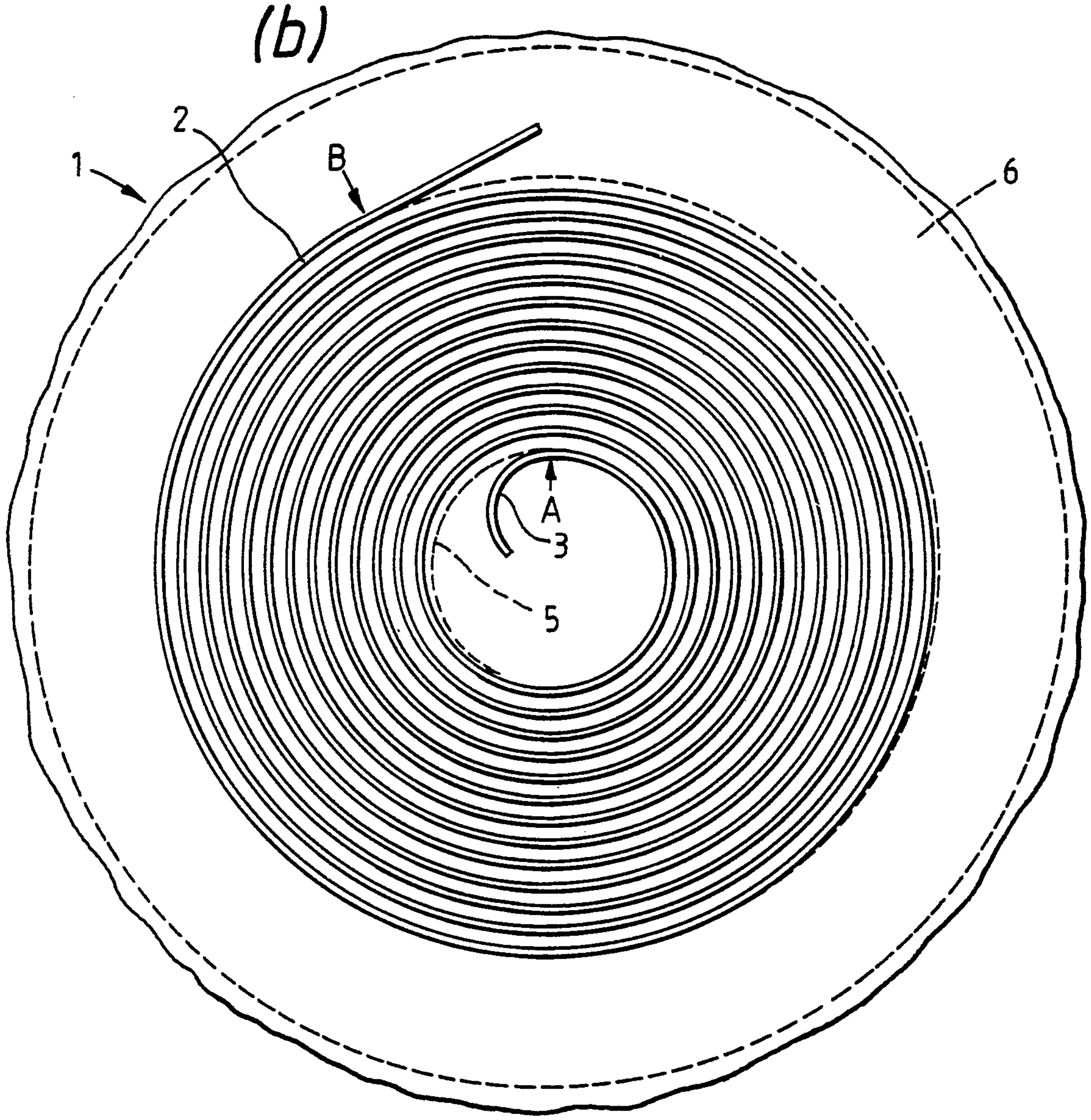
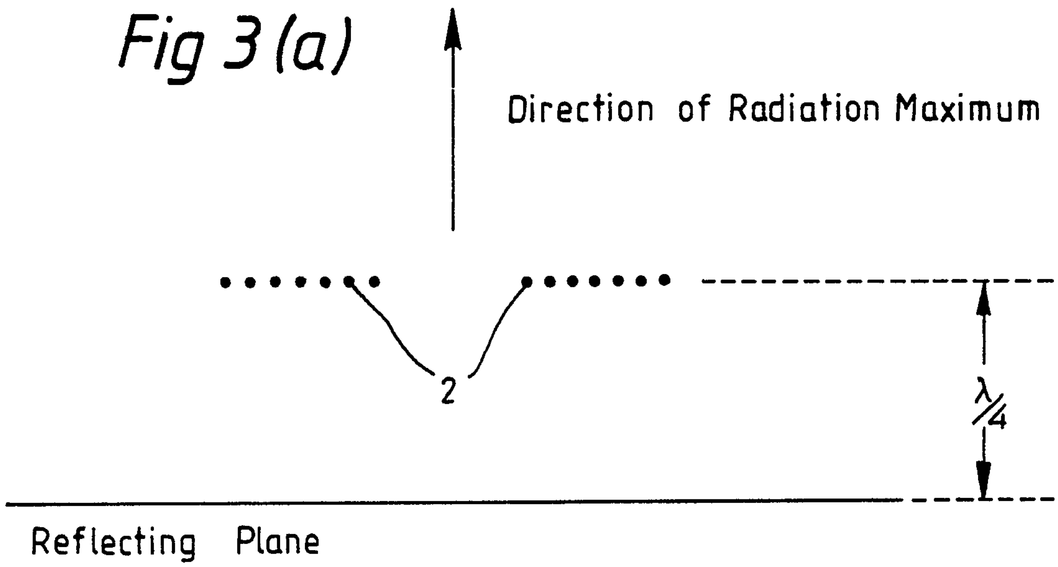
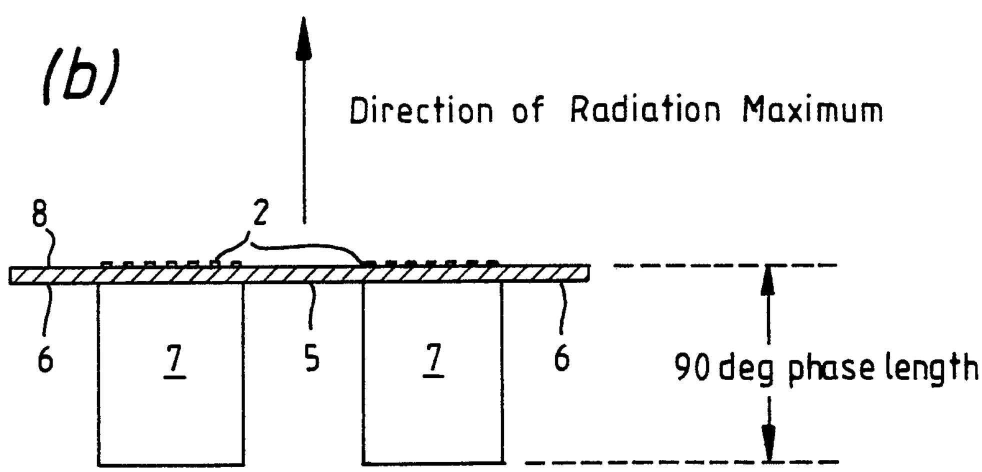


Fig 3 (a)


Direction of Radiation Maximum
2
λ/4
Reflecting Plane

(b)


Direction of Radiation Maximum
8
2
6
7
5
7
6
90 deg phase length

SPIRAL ANTENNA

The present invention relates to a spiral antenna for transmitting or receiving circularly polarised radiation.

A typical spiral antenna consists of two spiralling conducting arms both in the same plane but angularly displaced by 180°. A requirement of such a spiral is that the currents excited in the two arms are equal in amplitude and 180° of out phase. To achieve this the spiral must be fed in balanced fashion, typically accomplished by connection to some form of twin lead transmission line and a 'balun'. The balun connects the balanced line to the unbalanced coaxial transmission line used to connect the antenna system to the RF transmitter or receiver. This balun represents a significant part of the manufacturing cost of spiral antennas and if not designed properly, some imbalance of the currents in the two arms of the spiral can occur causing the radiated beam of the spiral antenna to distort with consequent degradation of the inherent circular polarisation of the spiral. A secondary purpose of the balun is to provide an impedance matching function between the balanced and unbalanced transmission lines which make up a part of the composite two arm spiral antenna structure.

Although it is desirable to provide two ports, one at the spiral centre and one at the outer truncated edge which produce opposite senses of circular polarisation, a standard two arm spiral is only a one port device which provides only one sense of circular polarisation and attempts by designers to achieve two port antennas have met with little success.

According to this invention, a spiral antenna for circularly polarised radiation comprises a single regular or irregular spiral arm having at least one port formed by a truncation at a minimum or maximum circumference of the spiral and arranged to be directly coupled to an RF system.

Preferably the antenna includes a pair of ports formed at the minimum and maximum circumferences respectively and arranged to be coupled to the RF system at one or both of the ports.

The present invention provides an antenna capable of similar performance to that of a multiple arm spiral but using only a single arm with one or preferably two ports. This structure avoids many of the disadvantages of multiple arm spirals and in particular makes it possible to couple the antenna directly to a transmitter or receiver without using a balun.

Preferably the diameter of the or each port is such that the phase difference between a port and the next adjacent turn of the spiral is substantially $(2n+1)\pi$, where n=o,1,2,..... .

The phase number n may be different for the inner and outer ports.

The principles of operation of the one-arm spiral antenna apply to any geometrical form of the spiral pattern of the conducting arm, whether it be Archimedean, equiangular, planar, non-planar of regular or of irregular configuration. The spiral conductor pattern is truncated at some minimum circumference and some maximum circumference. These truncations form the inner and outer ports of the antenna, which provides circularly polarised radiation with opposite hands of polarisation depending upon the input port used.

The one arm spiral may be used equally in either receive or transmit mode as a nominally circularly polarised one-port device with the port at either the inner or outer truncation of the spiral, providing corresponding opposite hands of polarisation. Alternatively the one arm spiral may be used as a dual-circularly polarised two-port device with the port at each truncation of the spiral receiving either hand of polarisation, the inner port having polarisation of opposite hand to the outer port.

The cross-sectional geometry of the spiral arm may be varied along its length as required to tailor its performance.

Preferably the antenna is formed on a microstrip circuit board.

When the antenna is formed on a microstrip circuit board microstrip circuits can be formed on the same substrate, providing a means of directly feeding the antenna.

An antenna in accordance with the present invention will now be described in detail with reference to the accompanying drawings in which:

Figure 1 is a plan;

Figure 2 is a side elevation and plan; and,

Figure 3 shows side elevations of the generic form and microstrip example of the invention.

An antenna 1 comprises a planar spiral 2 of regular geometry.

An inner port A is formed at a minimum circumference of the spiral 2 and an outer port B at the maximum circumference. In this preferred example the spiral 2 is formed as a microstrip circuit. An inner disc-shaped ground plane 5 and outer annular ground plane 6 define the minimum and maximum circumferences and hence the position of the ports A,B. At the point of the truncation the microstrip extends onto the region overlying the ground plane to form a microstrip transmission line for coupling RF to or from the respective port A,B.

The spiral conductor pattern is shown in Figure 1. The diagram depicts a clockwise winding up of the spiral, though there is no preference over an anticlockwise winding. The inner truncation is the inner port A of the antenna and the outer truncation is the outer port B of the antenna. The region from which radiation is received or transmitted lies in the annular region bounded by the circumferences of these two truncations. The direction of radiation maximum is orthogonal to the plane of the spiral. Radiation maxima occur within this zone at circumferences which are whole multiples of the wavelength in the transmission medium, so that the fundamental mode is radiated at a circumference of one wavelength, and higher order modes at circumferences of two or more wavelengths.

The means by which a travelling wave, injected at either port, is guided to the radiating region, is by truncating the spiral at a circumference which yields the desired phase relationship between the injection point and the nearest point to it on the first following turn of the spiral arm (ie points A and A' for the inner port, and B and B' for the outer port). This phase difference affects the complex impedance at the port. If the phase difference is $(2n + 1)\pi$ (where $n = 0,1,2,\ldots$), then the two adjacent points on the consecutive turns of the arm will be in antiphase, and these turns will thus act as a "twin-lead" transmission line. This initial phase difference may conceivably be chosen as a value different from $(2n+1)\pi$, in order to match the input impedance to the output of the device connected to it, but the preferred phase difference would be $(2n+1)\pi$ to provide a purely real impedance.

In common with other spiral antennas, a planar one-arm spiral radiates opposite hands of circular polarisation into the two half-spaces bounded by its plane. If radiation is required into just one of these half-spaces, one may simply influence the radiation into the other half-space by backing the spiral with absorbent material (if the radiation energy is unwanted), or, with a reflecting structure or cavity in the backward half-space, to reflect the energy into the forward half-space to combine with that radiated directly. For example, a parallel reflecting plane placed an effective 90° electrical distance (ie. accounting for the refractive index of the medium) behind the spiral will invert the phase of incident wave, and the total on-axis path will result in the reflected wave passing through the spiral and adding coherently (with the same hand of polarisation) on axis with the forward wave. This "end-fire" effect will improve the directivity of the absorber-backed antenna by up to 3dB, depending upon the construction of the spiral and any ohmic losses in its support medium. The shape and position of the reflecting surface may be tailored to create a range of beam shapes if required.

If fed at the inner port, the spiral would therefore yield radiation of the (n+1) th order mode, and if fed at the outer port it would yield radiation of the n th order mode. A typical design would use n=0 for the inner port, and n=1 for the outer port.

An important aspect of this invention is therefore the geometry of the conductor pattern at the truncated edges. This geometry simultaneously provides an impedance matching function and the appropriate phasing of the currents on adjacent turns of the spiral near these edges. The latter can be considered a balun function as required by multiple arm spirals in that a structure is provided which facilitates the interconnection between, for example, an unbalanced circuit and a one-arm spiral wherein the adjacent conductor pattern turns at the edge can be considered to be twin lead transmission line. Note that the circumferences shown in Figure (1) in terms of wavelengths represent the effective wavelengths with any dielectric media (if present) taken into account and are therefore not necessarily free space wavelengths. Also, λ_{01} and λ_{02} are the effective wavelengths at the centre frequencies f_{01} and f_{02} of the operating bands of the inner and outer ports respectively, which may have equal or unequal bandwidths and may coincide, overlap or be separated.

In order to achieve optimum performance from the composite structure described above, by creating a purely real impedance at the ports, certain design constraints should therefore be adhered to, these are:

1. The circumference of the inner boundary should be made $(2n+1)\ \lambda_{01}/2$ at the inner port design centre frequency (f_{01}). This will produce radiation of the (n+1) th order mode.

2. The circumference of the outer region should be made $(2n+1)\ \lambda_{02}/2$ at the outer port design centre frequency (f_{02}). This will produce radiation of the n th order mode.

In the example shown in Figure 2 there are certain design points which illustrate the means by which the spiral may be fed at the inner A and outer B truncated edges.

1. The spiral (which is printed on the upper surface of the substrate) is bounded by two microstrip circuit regions, the edges of whose ground planes (printed on the lower surface) define the inner and outer truncated edges of the spiral. In order to provide connections at each end of the spiral arm, it is printed such that it continues into these two microstrip regions, to become simple microstrip transmission line. The spiral conductor geometry should continue into the central and outer microstrip regions at least until the full width of

the conductor lies above the ground plane. Depending upon the size and geometry of the spiral, there is therefore the option to integrate it with microstrip circuits in either or both of these regions, on the same substrate 8.

2. The conductor width to conductor gap ratio will determine the radiation impedance of the spiral which will also be affected by the thickness and permittivity of the dielectric substrate upon which all conductors reside. The conductor width chosen for the spiral may or may not be of the correct width in the microstrip circuit regions to yield a matched impedance at the boundaries. If for this reson, an impedance match does not occur, matching circuits must be included in the microstrip circuit regions.

Taking the one-arm spiral in its general conceptual form, the maximum circumference at the truncated edge for the fundamental mode is two wavelengths at the highest operating frequency. In this situation the asymptotic bandwidth limits for the composite structure operating in the fundamental radiation mode are 3:1 for the inner port and 2:1 for the outer port, based upon the radiation mechanism of the structure. However, in the example realised on the microstrip, the impedance matching function of the structure at the inner and outer edges of the spiral where the balun transition to the microstrip circuits occur will be degraded over these wide asymptotic bandwidth limits. A more practical bandwidth limitation for the composite structure when impedance matching is considered is of the order of 25%.

The presence of the dielectric substrate and the ground planes for the peripheral microstrip regions in this example would also affect, to a certain degree, the performance of the antenna with a rear reflecting plane as compared with the generic from. Figures 3a and 3b illustrate the difference between the generic form of such an arrangement and its physical realisation on microstrip, for an antenna radiating in the fundamental mode. The radiating zone of the spiral (being towards the centre-line of the annulus) is sufficiently removed from the microstrip regions for the reflecting plane to be limited to the annular cylindrical space immediately behind the turns of the spiral, creating a coaxial cavity 7. This therefore allows rear access to the two microstrip regions for interconnection.

<u>CLAIMS</u>

1. A spiral antenna for circularly polarised radiation comprising a single regular or irregular spiral arm having at least one port formed by a truncation at a minimum or maximum circumference of the spiral and arranged to be directly coupled to an RF system.

2. An antenna according to claim 1, including a pair of ports formed at the minimum and maximum circumferences respectively, and arranged to be coupled to the RF system at one or both of the ports.

3. An antenna according to claim 1 or 2, in which the diameter of the or each port is such that the phase difference between a port and the next adjacent turn of the spiral is substantially $(2n+1)\pi$, where $n = 0,1,2...$.

4. An antenna according to any one of the preceding claims, in which the spiral arm is formed on a microstrip circuit board.

5. An antenna according to claim 4, in which at least part of an RF system directly feeding the spiral arm is formed as a microstrip circuit on a common substrate with the spiral arm.

6. An antenna according to claim 4 or 5, further comprising an annular reflective cavity having radial dimensions generally matched to those of the spiral arm positioned coaxially with the spiral arm adjacent the microstrip substrate.

7. An antenna according to claim 6, including central and peripheral ground planes defining the minimum and maximum circumferences of the spiral arm formed integrally with the reflective cavity underlying the microstrip substrate.

8. A system for receiving or transmitting circularly polarised radiation, comprising an antenna according to

any one of the preceding claims coupled to an RF system at one port only.

9. A system for transmitting or receiving dual-circularly polarised radiation comprising an antenna according to any one of the preceding claims coupled to an RF system at both of an inner and outer ports so as to receive radiation polarised in opposite senses at either port.

10. An antenna substantially as described with respect to the accompanying drawings.

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