

IMPROVED ANTENNA ARRANGEMENT

Field of the Invention

This invention relates to antenna arrays, and particularly to arrays containing multiple radiating elements in the form of helical antenna elements.

5 **Background**

Antenna systems such as those for use in satellite communications are often required to operate on structures for which space is a premium. Examples of such applications are a satellite antenna on a warship, or on a mobile terrestrial vehicle.

Minimising weight is also an important factor.

10 In these situations, traditional parabolic reflector antennas are not practical as they are both heavy and require a relatively large volume of space in which to operate. Accordingly, other antenna systems have been developed for use in such applications.

An example of such a system is a helical antenna array, which consists of a plurality of individual antenna elements through which the antenna radiation pattern can be controlled by controlling the feeding signals to individual antenna elements as will be understood by the person skilled in the art.

A base is provided to support the plurality of antenna elements, and each is fed by way of a network of radio frequency transmission elements such as printed transmission lines to guide the signals to each antenna element from a main feed input or to an output.

Figure 1A shows a typical helical antenna array 10 having a base 20 supporting a plurality of helical antenna elements 30. The base 20 may comprise an assembly of metal ground plane, dielectric substrate material and printed transmission lines.

Figure 1B is a view from below of the antenna 10 of **Figure 1A**, showing a typical feed network 50 to feed signals from a signal splitter 40 having an input for receiving a drive signal and multiple outputs for feeding the required signal to the appropriate antenna element(s).

5 The feed network 50 is typically formed by printing transmission lines onto the base 20 as will be understood by the person skilled in the art.

 An example of a helical antenna array is shown in US 6,243,052 to Goldstein et al, in which two arrays are disposed side by side, one array for transmitting signals and the other array for receiving signals.

10 Another problem with prior art systems is the difficulty in maintaining control over the beam pattern emitted by the antenna array. Many factors contribute to this difficulty, including the variability of characteristics of feeding signals applied to the antenna elements distributed over the base. These problems are exacerbated by the printed transmission lines which attenuate the feed signal. The degree of attenuation is
15 dependant on the length of the path that the signal has to travel along the transmission line. Accordingly, as the feed signals travel different distances to reach antenna elements located at different positions around the array from the feed input, the ultimate signal power applied to the antenna elements can vary quite dramatically. Such variability reduces the performance of the antenna in reducing the directivity and increases the side
20 lobes.

 Some prior art systems have attempted to address this problem by designing in deliberate attenuations throughout the transmission line network to maintain a consistent level of attenuation. Clearly this adds to the complexity of design and manufacture, and is not always successful.

Summary

It is an object of the present invention to substantially overcome, or at least ameliorate, one or more disadvantages of existing arrangements.

Disclosed are arrangements which seek to address the above problems by
5 interspersing transmit antenna elements and receiving antenna elements on a common base, arranging, in sub-arrays, subsets of the transmit antenna elements and subsets of the receiving antenna elements, using respective printed transmission lines to interconnect transmit antenna elements and receive antenna elements on each sub-array, and in regard
10 and the interconnected receiving antenna elements sub-arrays to the antenna input and output.

According to one aspect of the present invention, there is provided an antenna array comprising:

a plurality of sub-arrays each comprising a plurality of transmitting
15 antenna elements and a plurality of receiving antenna elements, said plurality of sub-arrays being arranged on a base; wherein

each said sub-array further comprises at least one printed transmission line interconnecting the plurality of transmitting antenna elements and at least one printed transmission line interconnecting the plurality of receiving antenna elements; and wherein

20 the transmitting antenna elements of the plurality of sub-arrays are interspersed with the receiving antenna elements of the plurality of sub-arrays; and wherein

for each sub-array the antenna array further comprises:

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a cable for connecting the interconnected transmitting antenna elements to an antenna input; and

a cable for connecting the interconnected receiving antenna elements to an antenna output.

5 According to another aspect of the present invention, there is provided a base module for an antenna array comprising:

a plurality of sub-arrays each comprising a plurality of transmitting antenna elements and a plurality of receiving antenna elements, said plurality of sub-arrays being arranged on a base; wherein

10 each said sub-array further comprises at least one printed transmission line interconnecting the plurality of transmitting antenna elements and at least one printed transmission line interconnecting the plurality of receiving antenna elements; and wherein

the transmitting antenna elements of the plurality of sub-arrays are interspersed with the receiving antenna elements of the plurality of sub-arrays; and

15 wherein

for each sub-array the antenna array further comprises:

a cable for connecting the interconnected transmitting antenna elements to an antenna input; and

20 a cable for connecting the interconnected receiving antenna elements to an antenna output; wherein the base upon which the sub-arrays are arranged comprises a plurality of said base modules, upon each of which is arranged a said sub-array.

According to another aspect of the present invention, there is provided an antenna array comprising a plurality of transmitting antenna elements for transmitting radio frequency signals and a plurality of receiving antenna elements for receiving radio

frequency signals, wherein the transmitting antenna elements and the receiving antenna elements are interspersed with each other.

Preferably, the plurality of transmitting antenna elements and the plurality of receiving antenna elements are arranged in sub-arrays.

5 Preferably each sub-array has at least one transmitting antenna element and at least one receiving antenna element.

Preferably, each sub-array has a plurality of transmitting antenna elements and a plurality of receiving antenna elements.

10 Preferably, the plurality of transmitting antenna elements in one of the sub-arrays are connected to each other via a printed transmission line and the printed transmission line is connected to a signal input via a first cable and the plurality of receiving antenna elements in the sub-array are connected to each other via a second printed transmission line and the second printed transmission line is connected to a signal output via a second cable.

15 According to another aspect of the present invention, there is provided an antenna array comprising a plurality of antenna elements for transmitting radio frequency signals and/ or receiving radio frequency signals, the plurality of antenna elements being distributed on a base, wherein the base is made from a plurality of base modules connected together to form the base.

20 Preferably, each of the plurality of base modules has some of the plurality of antenna elements.

Preferably, the some of the plurality of antenna elements disposed on a single base module are interconnected by way of a printed transmission lines.

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Preferably, the plurality of base modules are connected to a signal input or output by way of cables.

Preferably the plurality of antenna elements include a plurality of transmitting antenna elements for transmitting radio frequency signals, and a plurality of receiving
5 antenna elements for receiving radio frequency signals.

Preferably, each of the plurality of base modules has some of the plurality of transmitting antenna elements and some of the plurality of receiving antenna elements.

Preferably, the some of the plurality of transmitting antenna elements disposed on a single base module are interconnected by a first printed transmission line and the
10 some of the plurality of receiving antenna elements are interconnected by a second printed transmission line.

Preferably, the plurality of base modules are connected to a signal input or output by way of cables.

Preferably, the first printed transmission line on the single base module is
15 connected to a signal input by a first cable and the second printed transmission line is connected to a signal output by a second cable.

Preferably, the base forms a common ground plane for the plurality of antenna elements.

According to another aspect of the present invention, there is provided a module
20 for a base for an antenna array, the module comprising:

a port for receiving at least one antenna element for radiating or receiving radio frequency signals;

a printed transmission line for conducting signals to or from the at least one antenna element; and

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a connector for connecting the printed transmission line to a cable for electrical connection to an input or an output of the signals.

Preferably, the module further comprises a second port for receiving a second antenna element.

5 Preferably, the at least one antenna element is a transmitting antenna element and the second antenna element is a receiving antenna element.

Preferably, the transmission line is for connection to the transmitting antenna element and the module further comprises a second printed transmission line for connection to the receiving antenna element.

10 Preferably, the connector is for connecting the transmission line to the signal input and the module further comprises a second connector for connecting the second transmission line to the signal output.

According to another aspect of the present invention, there is provided an antenna array comprising a plurality of antenna elements for transmitting and/ or
15 receiving radio frequency signals, wherein the plurality of antenna elements are arranged in sub-arrays.

Preferably, the antenna elements arranged in a single array are connected to each other by a printed transmission line.

Preferably, the printed transmission line is connected to a signal input or a signal
20 output by a cable.

Preferably each sub-array has at least one transmitting antenna element and at least one receiving antenna element.

Preferably, each sub-array has a plurality of transmitting antenna elements and a plurality of receiving antenna elements.

Preferably the at least one transmitting antenna element is connected to a signal input via a first cable and the receiving antenna element is connected to a signal output via a second cable.

Preferably, the plurality of transmitting antenna elements in one of the sub-arrays are connected to each other via a printed transmission line and the printed transmission line is connected to a signal input via a first cable and the plurality of transmitting antenna elements in the sub-array are connected to each other via a second printed transmission line and the second printed transmission line is connected to a signal output via a second cable.

Other aspects of the invention are also disclosed.

Brief Description of the Drawings

Some aspects of the prior art and one or more embodiments of the present invention will now be described with reference to the drawings and the **APPENDIX**, in which:

Figure 1A shows a prior art arrangement for a helical array antenna;

Figure 1B shows the underside of the helical array antenna of **Figure 1A**;

Figure 2 is a perspective view of a helical array antenna according to an aspect of the present invention;

Figure 3 is a plan view of the antenna of **Figure 2**;

Figure 4 shows a conceptual representation of the array modularisation aspect of the present invention;

Figure 5 is a view from underneath of the antenna of **Figure 3**;

Figure 6 shows a modelled beam pattern of the antenna of the present invention;

Figure 7 shows the helix antenna disclosed in International Patent Application No. PCT / AU03/00690;

Figure 8 shows side and plan views of the antenna in **Figure 7**; and

APPENDIX A contains an extract of relevant material from International Patent
5 Application No. PCT / AU03/00690 (W003/107483).

Detailed Description including Best Mode

Where reference is made in any one or more of the accompanying drawings to steps and/or features, which have the same reference numerals, those steps and/or features have for the purposes of this description the same function(s) or operation(s), unless the
10 contrary intention appears.

As will be understood by the person skilled in the art, in the use of helical antennas for communication with satellites, it is necessary to have two different sets of helical antenna elements to provide full duplex operation, i.e. to both transmit signals to the satellite and to receive signals from the satellite. In particular, the C band satellite
15 spectrum comprises two separate frequency assignments, particularly, a transmit frequency band between 5.85 and 6.425 GHz and a receive frequency band between 3.625 and 4.2 GHz. The helical antenna elements are not sufficiently broad band to cover both transmit and receive frequency bands, so two distinct sets of helices are required.

In the prior art systems such as disclosed in US 6,243,052 to Goldstein et al., the
20 two sets of helical antenna arrays are disposed side by side, one array for transmitting and one array for receiving. This physical separation has traditionally been necessary in duplex systems. The power of the signal from the transmitting part of the array far outweighs the power of the signal received at the receiver, by many tens of dBs.

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According to a first disclosed arrangement, the transmit and receive helical antenna elements are integrated so as to further reduce the area required to contain a full duplex satellite antenna.

Figure 2 shows an integrated antenna arrangement according to the present disclosure. The integrated helical antenna array 100 consists of a plurality of helical antenna elements 300 arranged and supported on a base 200. Other types of antenna elements may be used, however in all cases, the transmitting antenna elements and the receiving antenna elements should have opposite polarization to improve the inter-element isolation, unless the system using the antenna array operates in half-duplex mode.

In this disclosed arrangement, transmitting antenna elements are interspersed with receiving antenna elements, eliminating the need for two separate areas or regions to provide a full duplex operation. Antenna elements 300 may be provided by any suitable helical antenna as known to the person skilled in the art, including that disclosed in International Patent Application No. PCT / AU03/00690 (W003/107483), the contents of which are hereby incorporated by reference (see **APPENDIX A**).

It will be noted that some of the antenna elements are shorter than others. In this particular case, the shorter elements are the transmitting elements and the longer elements are the receiving elements. This difference has no bearing on the present disclosed arrangement, and is illustrated accordingly to clearly show the interspersed or interleaved nature of the transmitting and receiving antenna elements. In practice, all the antenna elements could be the same length or in fact, the receiving elements could be shorter than the transmitting elements.

According to a second disclosed arrangement, the base 200 is constructed from a number of base modules 210, 220, 230, 240 (as can be seen in **Figure 2**) and also base

modules 250,260,270 and 280 (as further seen in **Figure 3**, being a plan view of the disclosed arrangement of **Figure 2**).

These base modules each support a mix of transmitting antenna elements and receiving antenna elements. Specifically, referring now to **Figure 3**, and considering base
5 module 210 for example, it can be seen that base module 210 supports four transmitting antenna elements 320 and four receiving antenna elements 310. Base modules 220, 230 and 240, together defining the outer perimeter of base 200, similarly support respective sets of transmitting and receiving antenna elements.

Base 200 is also made up of further base modules 250, 260, 270 and central base
10 module 280, each supporting a respective set of transmitting and receiving antenna elements.

It will be understood that a base 200 may be any suitable shape and may be made up of any number of a plurality of base modules (i.e. two or more). Furthermore, this modular disclosed arrangement need not be limited to use in an integrated antenna array
15 according to the first disclosed arrangement, but may equally be applicable to an antenna array solely used for transmitting and an antenna array solely used for receiving.

Furthermore, the number of antenna elements per base module may be varied depending upon the requirements of the particular array and indeed, a base module making up a base need not support the same number of antenna elements as another base
20 module making up that base.

It will be appreciated however, that manufacturing benefits will be achieved by having base modules of the same configuration. In the embodiment shown in **Figure 3**, only three different module designs ((210,220,230,240), (250,260,270) and 280) need to be implemented to provide a full base 200.

This disclosed arrangement provides significant advantages in design, manufacturing, storage, transport, maintenance and installation. In particular, a single base module may be used in a number of antenna arrays and lends itself well to modular design and manufacturing techniques. It will be clear that storing and transporting a plurality of modules is far more convenient than storing and transporting whole assembled bases or antenna arrays. Once installed, maintenance may also be facilitated by the modular design in that if parts of the antenna array are damaged or become otherwise non-functioning, it may be possible to simply replace one module rather than have to replace an entire array.

A further advantage of this type of modular design is that antenna arrays can be custom-made using pre-designed and manufactured antenna modules. For example, referring to **Figure 3** again, module 280 may be used by itself to provide an array with 12 antenna elements. In another design, module 280 may be combined with modules 250, 260 and 270 to provide a different antenna configuration. In another example, base 200 may be provided without the internal module 280 to provide yet another antenna design.

According to yet another disclosed arrangement, the design of the antenna array allows the use of a combination of printed transmission lines and cables for use in connecting the antenna elements to the feed components. The term “printed transmission line” is taken to include microstrip and/or strip-line implementations.

As illustrated in **Figure IB**, traditional forms of connecting each radiating element to a feed element is by way of printed transmission lines. One drawback of such systems is that printed transmission lines can result in significant radio frequency leakage or interference between adjacent lines of transmission or receiving transmission line

networks in duplex systems. Furthermore, signal attenuation can occur in long tracks of printed lines, resulting in variations of power of the signal applied to the antenna element from the antenna input.

As previously discussed, problems are caused due to the variability of characteristics of feeding signals applied to the antenna elements distributed over the base. These problems are exacerbated by the printed transmission lines which attenuate the feed signal. The degree of attenuation is dependant on the length of the path that the signal has to travel along the transmission line. Accordingly, as the feed signals travel different distances to reach antenna elements located at different positions around the array from the feed input, the ultimate signal power applied to the antenna elements can vary quite dramatically. Such variability reduces the performance of the antenna in reducing the directivity and increases the side lobes.

The differences in signal paths in the transmission lines also produces variations in the phase of the signal applied to different antenna elements at different locations about the array, which further reduces the ability to predictably control the beam pattern.

Accordingly, this disclosed arrangement provides for a combination of cable connection from signal input or to signal output ports, to sub arrays of antenna elements, which then connect the cable output or input to the individual antenna elements by way of printed transmission lines. This disclosed arrangement is shown conceptually in **Figure 4**, where there is shown three sub-arrays 300', 300" and 300"', each having a series of transmitting antenna elements 320 and receiving antenna elements 310.

Looking at sub-array 300', transmitting antenna elements 320 are connected together via printed transmission line 225 and receiving antenna elements 310 are connected together via printed transmission line 221. The spacing between the printed

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transmission line 225 interconnecting the transmitting antenna elements 320, and the printed transmission line 221 interconnecting the receiving antenna elements 310 is made sufficient to provide the desired amount of isolation between the transmitting antenna elements 320 and the receiving antenna elements 310. Printed transmission line 225 is
5 connected to antenna input 400 by cable 600 and printed transmission line 221 is connected to antenna output 500 by cable 610. Sub-arrays 300" and 300'" are similarly connected.

In order to maintain the desired degree of isolation between antenna elements on different sub-arrays, similar considerations apply in regard to spacing between printed
10 transmission lines as apply on a single sub-array. Thus, having regard to a pair of sub-arrays such as 300' and 300'', the spacing between the printed transmission line interconnecting the transmitting antenna elements on the sub-array 300', and the printed transmission line interconnecting the receiving antenna elements on the sub-array 300'', is made sufficient to provide the desired amount of isolation between the said transmitting
15 antenna elements and the said receiving antenna elements.

The use of multiple cables to connect sub arrays directly to an input signal source reduces the effective length of printed transmission lines thus reducing the instance of signal degradation, and also reduces the amount of radio frequency energy leaking into the receiver tracks.

20 It will be appreciated that in some prior systems which use only cable connections to each antenna array element, a large number of cable connectors are required to connect every antenna element to the input signal source, increasing manufacturing and installation complexities.

This disclosed arrangement provides a unique blend of advantages from both systems.

In particular, the use of cables according to this disclosed arrangement provides the following advantages:

5 a) The use of connecting cables provides a mechanism for providing a high level of radio frequency signal isolation between the high powered transmit and very low level receive signals. This is essential to support full duplex communication which is a system requirement for most broadband communication networks;

10 b) The use of connecting cables provides identical signal power connection from the input of the antenna to the sub-array modules, so ensuring that the antenna array performance is optimized in terms of maximizing the antenna directivity and minimizing the antenna side lobes;

15 c) The use of printed transmission line which are typically used to provide the interconnections between array elements and the antenna feed connection, would lead to signal attenuation which is proportional to the length of the transmission line, such that remote antenna sub-arrays would not have identical signal amplitude as to the closest elements - the use of cables to bring the identical signal to a smaller array of elements reduces this problem;

20 d) By having integrated sub-arrays with small number of antenna elements connected by classical transmission line techniques, enables the number of interconnecting cables to be reduced and also allows the antenna performance to be optimized by ensuring the antenna can be constructed in a series of concentric rings with different spacings of Tx and Rx elements at different spacings.

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Thus for example, having regard to **Figure 3**, the receiving antenna element 310 is a member of a ring of receiving antenna elements, and the transmitting antenna element 320 is a member of a ring of transmitting antenna elements that lies inside of, and is concentric with, the ring of which the receiving antenna element 310 is a member.

5 Similarly, the receiving antenna element 330 is a member of a ring of receiving antenna elements that lies inside of, and is concentric with, the ring of which the transmitting antenna element 320 is a member. Similarly, the transmitting antenna element 340 is a member of a ring of transmitting antenna elements that lies inside of, and is concentric with, the ring of which the receiving antenna element 330 is a member.

10 Although **Figure 3** illustrates an example in which the antenna array 100 is circular, the approach of having integrated sub-arrays with small number of antenna elements connected by classical transmission line techniques enables antenna arrays having other shapes such as elliptical, or even square or rectangular, in which the transmitting and receiving antenna elements are arranged along respective alternating
15 concentric curves of appropriate shape.

Hence, the configuration of the individual helices remains fixed in terms of constant pitch and design, and the spacings between elements is altered to optimise the antenna performance. The use of standard helical antenna elements is advantageous from both performance and ease of manufacturing.

20 **Figure 5** is a view from below of base 200 of **Figure 3** and shows a specific embodiment of the concept illustrated in **Figure 4**. There can be seen the disclosed arrangement of printed transmission lines on the reverse, or under side of base 200. Looking at base module 220 for example, the printed transmission line 225 provides a transmission path for signals to be fed to each of the transmitting antenna elements 320

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through respective inputs 226. Connection point 227 provides an input connection for a cable (not shown) which would be attached at one end at point 222 and at the other end to a signal splitter (not shown) itself providing a general signal input to the array. The signal splitter will split the general input signal to other cables for feeding to other base modules.

Printed transmission line 221 on base module 220 provides the transmission path for the receiving antenna elements 310, via connection point 222 to cable connection point 223 to transmit the signals received by the antenna elements to a signal combiner (not shown) via cable (not shown) to provide the general output of the antenna array.

Holes 224 provide a means to mechanically retain the antenna elements to base 200.

Figure 6 is the Copolar performance of the transmitting part of the antenna array design. Figure 6 relates to Tx El Cut, Theory 35T-75B Copol Freq=6.1 GHz $\phi=90^\circ$.

It will be appreciated that while this particular embodiment is shown in the context of the second disclosed arrangement, being the modular design of base 200, this aspect of a combination of printed transmission lines and cables may equally be applied to an integral base design.

Furthermore, this disclosed arrangement may be equally applied to an antenna array providing only a transmitting function or only a receiving function, and need not be limited to use with an integrated array. In this embodiment, the disclosed arrangement would appear as in Figure 4 with sub-arrays 300', 300" and 300''' having only the transmitting antenna elements 320, printed transmission line 225, cable 600 and antenna input 400 for a transmitting antenna array or in the case of a receiving array, only

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receiving antenna elements 310, printed transmission line 221 and cable 610 connecting the line to antenna output 500.

Industrial Applicability

It is apparent from the above that the disclosed arrangements described are
5 applicable to the telecommunication industry.

It will be understood that the various aspects of the present invention have been described in the context of specific embodiments and that many variations and modifications are possible within the scope of the various aspects of the present invention.

10 Thus, although the description has been directed primarily to helical antenna elements, other antenna elements such as printed patches can be used.

APPENDIX A

Figure 7 shows the disclosed helix antenna. The antenna comprises a conductive ground plane 706 above which is disposed a helical coil 704 (alternately
5 referred to in this description as a “helix”, a “helical coil” or the like) that is electrically terminated at the upper end of the helix 704 with a spiral 702. The helix antenna is depicted as having a vertical axis 700.

In a preferred embodiment, the helical coil 704 comprises between 1.5 and 3.5 turns. However, other numbers of turns can be used. Furthermore, the helix 704 is
10 approximately one wavelength plus minus 10% of a wavelength in circumference. In addition, the spiral 702 comprises between 2 and 4 turns, in a flat configuration normal to the axis 700.

Although the ground plane 706 is depicted as having a circular shape in **Figure 7**, in fact the extent of the ground plane 706 is not critical, provided that it has an area
15 greater than two thirds of a wavelength in diameter.

Figure 8 shows a side view 824 of the helix 704 and the spiral 702, and also a plan view 832 thereof. Turning to the side view 824 the helix 704 has a first end 814 that is disposed a distance 816 above the ground plane 706. This first end 814 of the helix 704 has a radial position about the axis 700 as depicted by a reference numeral 814' in the
20 plan view 832.

The helix 704, when wound in a clock-wise direction produces right hand circular polarization, and when wound in a counter-clockwise direction, produces left hand circular polarization. The number of turns of the helix can typically vary between 1.5 and 3.5, however the number of turns can be varied outside these limits.

The helix 704 in **Figure 8** depicts one example of a helix being wound in a counter-clockwise direction commencing from the first end 814 and comprises three and a quarter turns. The three and a quarter turns comprise a first turn 812-810, a second turn 808-806, a third turn 804-802, and a final quarter turn 800. The final quarter turn 800 of the helix 704 runs from a radial position depicted by the arrow 814' to a radial position depicted by the arrow 838 which is the upper end of the helix 704. The upper end of the helix is connected to the outer end of the spiral 702 at a radial position 838.

The first quarter turn of the helix 704, which extends from the first end 814 to a point 846, describes an angle 844 with respect to a dashed line 822. The remainder of the helix 704 is uniformly wound with a pitch angle 820, which can vary between 3 and 7 degrees, referred to the horizontal reference line 822. The angle 844 can be adjusted to achieve a desired impedance at the input of the helix 704. Although the angle is depicted as being greater than the pitch angle 820, this is illustrative only, and other angles can be adopted according to the desired impedance. Furthermore, although an abrupt change between the angles 844 and 820 occurs at the point 846 in **Figure 8**, in practice a smooth angular transition can be used.

The angle 844, together with the distance 816 of the helix first end 814 from the ground plane 706 establishes a distance 828 which is located a quarter turn from the helix first end 814. The radial location of the distance 828 is depicted by the reference numeral 838 in the plane view 832. The one quarter turn segment of the helix 704 between 814 and 838 forms a tapered transmission line with the ground plane 706. As noted, the distance 816 can be advantageously adjusted, for example by adjusting the angle 844, in order to match an input impedance of the helix 704 as desired.

The helix 804 has a second end 742 that is situated, in the present arrangement, three and a quarter turns from the first end 814 of the helix 704. The spiral 702 is connected by an outer end thereof to the second end 842 of the helix 704 at a radial location depicted by the reference numeral 838. The spiral 702 has a uniform inter-turn
5 pitch distance 836, and spirals inwards from the aforementioned outer end that is connected to the second end 842 of the helix, to an inner end 834 of the spiral 702. Other types of spiral can also be used.

In a preferred arrangement the spiral 702 is located in a plane horizontal to the axis 700. The spiral 702 can however, in other arrangements, be formed to have a conical
10 shape pointing either upwards or downwards.

Instead of a tapered transmission line being formed using the one quarter turn segment of the helix 704 between 814 and 838 and the ground plane 706, other impedance matching techniques such as quarter wave transmission line matching sections can be used to connect the first end 814 of the helix 704 to the intended communication
15 apparatus thereby achieving the desired impedance matching.

The helix can be made of wire, wound on a low loss, low dielectric constant former to support the helix and spiral. Alternately, the helix can be etched in copper on a thin low loss dielectric film which is then rolled to form a cylinder. Either method provides the necessary mechanical support for reliable operation and causes minimal
20 disturbance to the radiated wave.

This antenna element can be advantageously used in the frequency band between 1 GHz and 8 GHz, however it can also be used outside this frequency band. Furthermore, the addition of the spiral 702 to terminate the helix 704 is found to provide improved beam shaping and a significant decrease in the antenna axial ratio. The antenna is ideally

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suited for two-way communications via satellite to vehicles, vessels or aircraft. The antenna is a compact, low profile radiator exhibiting circular polarisation, making it ideally suited for use where size and performance are paramount such as in marine, aeronautical and land transport services.

The claims defining the invention are as follows:

1. An antenna array comprising:

a plurality of sub-arrays each comprising a plurality of transmitting antenna
5 elements and a plurality of receiving antenna elements, said plurality of sub-arrays being
arranged on a base; wherein

each said sub-array further comprises at least one printed transmission
line interconnecting the plurality of transmitting antenna elements and at least one printed
transmission line interconnecting the plurality of receiving antenna elements; and wherein

10 the transmitting antenna elements of the plurality of sub-arrays are
interspersed with the receiving antenna elements of the plurality of sub-arrays; and
wherein

for each sub-array the antenna array further comprises:

a cable for connecting the interconnected transmitting antenna elements
15 to an antenna input; and

a cable for connecting the interconnected receiving antenna elements to
an antenna output.

2. An antenna array according to claim 1, wherein in regard to each sub-array, said
20 at least one printed transmission line interconnecting the plurality of transmitting antenna
elements and said at least one printed transmission line interconnecting the plurality of
receiving antenna elements are spaced sufficiently far apart to maintain a desired amount
of isolation between said respective transmitting antenna elements and said respective
receiving antenna elements.

3. An antenna array according to claim 1, wherein the base upon which the sub-arrays are arranged comprises a plurality of base modules, upon each of which is arranged a said sub-array.

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4. An antenna array according to claim 3, wherein in regard to each pair of base modules, said at least one printed transmission line interconnecting the plurality of transmitting antenna elements on one said base module, and said at least one printed transmission line interconnecting the plurality of receiving antenna elements on the other
10 said base module, are spaced sufficiently far apart to maintain a desired amount of isolation between said respective transmitting antenna elements and said respective receiving antenna elements.

5. An antenna array according to claim 1, wherein the plurality of transmitting
15 antenna elements and the plurality of receiving antenna elements are arranged along respective alternating concentric curves.

6. A base module for an antenna array comprising:
a plurality of sub-arrays each comprising a plurality of transmitting antenna
20 elements and a plurality of receiving antenna elements, said plurality of sub-arrays being arranged on a base; wherein each said sub-array further comprises at least one printed transmission line interconnecting the plurality of transmitting antenna elements and at least one printed transmission line interconnecting the plurality of receiving antenna elements; and wherein

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the transmitting antenna elements of the plurality of sub-arrays are interspersed with the receiving antenna elements of the plurality of sub-arrays; and wherein

for each sub-array the antenna array further comprises:

5 a cable for connecting the interconnected transmitting antenna elements to an antenna input; and

 a cable for connecting the interconnected receiving antenna elements to an antenna output; wherein the base upon which the sub-arrays are arranged comprises a plurality of said base modules, upon each of which is arranged a said sub-array.

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7. An antenna array comprising a plurality of transmitting antenna elements for transmitting radio frequency signals and a plurality of receiving antenna elements for receiving radio frequency signals, wherein the transmitting antenna elements and the receiving antenna elements are interspersed with each other.

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8. An antenna array according to claim 7, wherein the plurality of transmitting antenna elements and the plurality of receiving antenna elements are arranged in sub-arrays.

20 9. An antenna array according to claim 7, wherein each sub-array has at least one transmitting antenna element and at least one receiving antenna element.

10. An antenna array according to claim 7, wherein each sub-array has a plurality of transmitting antenna elements and a plurality of receiving antenna elements.

11. An antenna array according to claim 7, wherein the plurality of transmitting antenna elements in one of the sub-arrays are connected to each other via a printed transmission line and the printed transmission line is connected to a signal input via a first cable and the plurality of receiving antenna elements in the sub-array are connected to each other via a second printed transmission line and the second printed transmission line is connected to a signal output via a second cable.

12. An antenna array comprising a plurality of antenna elements for transmitting radio frequency signals and/ or receiving radio frequency signals, the plurality of antenna elements being distributed on a base, wherein the base is made from a plurality of base modules connected together to form the base.

13. An antenna array according to claim 12, wherein each of the plurality of base modules has some of the plurality of antenna elements.

14. An antenna array according to claim 12, wherein the some of the plurality of antenna elements disposed on a single base module are interconnected by way of a printed transmission lines.

15. An antenna array according to claim 12, wherein the plurality of base modules are connected to a signal input or output by way of cables.

16. An antenna array according to claim 12, wherein the plurality of antenna elements include a plurality of transmitting antenna elements for transmitting radio frequency signals, and a plurality of receiving antenna elements for receiving radio frequency signals.

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17. An antenna array according to claim 12, wherein each of the plurality of base modules has some of the plurality of transmitting antenna elements and some of the plurality of receiving antenna elements.

10 18. An antenna array according to claim 12, wherein the some of the plurality of transmitting antenna elements disposed on a single base module are interconnected by a first printed transmission line and the some of the plurality of receiving antenna elements are interconnected by a second printed transmission line.

15 19. An antenna array according to claim 12, wherein the plurality of base modules are connected to a signal input or output by way of cables.

20. An antenna array according to claim 12, wherein the first printed transmission line on the single base module is connected to a signal input by a first cable and the
20 second printed transmission line is connected to a signal output by a second cable.

21. An antenna array according to claim 12, wherein the base forms a common ground plane for the plurality of antenna elements.

22. A module for a base for an antenna array, the module comprising:

a port for receiving at least one antenna element for radiating or receiving radio frequency signals;

5 a printed transmission line for conducting signals to or from the at least one antenna element; and

a connector for connecting the printed transmission line to a cable for electrical connection to an input or an output of the signals.

23. A module for a base for an antenna array according to claim 22, wherein the
10 module further comprises a second port for receiving a second antenna element.

24. A module for a base for an antenna array according to claim 22, wherein the at least one antenna element is a transmitting antenna element and the second antenna element is a receiving antenna element.

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25. A module for a base for an antenna array according to claim 22, wherein the transmission line is for connection to the transmitting antenna element and the module further comprises a second printed transmission line for connection to the receiving antenna element.

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26. A module for a base for an antenna array according to claim 22, wherein the connector is for connecting the transmission line to the signal input and the module further comprises a second connector for connecting the second transmission line to the signal output.

27. An antenna array comprising a plurality of antenna elements for transmitting and/ or receiving radio frequency signals, wherein the plurality of antenna elements are arranged in sub-arrays.

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28. An antenna array according to claim 27, wherein the antenna elements arranged in a single array are connected to each other by a printed transmission line.

29. An antenna array according to claim 27, wherein the printed transmission line is
10 connected to a signal input or a signal output by a cable.

30. An antenna array according to claim 27, wherein each sub-array has at least one transmitting antenna element and at least one receiving antenna element.

15 31. An antenna array according to claim 27, wherein each sub-array has a plurality of transmitting antenna elements and a plurality of receiving antenna elements.

32. An antenna array according to claim 27, wherein the at least one transmitting antenna element is connected to a signal input via a first cable and the receiving antenna
20 element is connected to a signal output via a second cable.

33. An antenna array according to claim 27, wherein the plurality of transmitting antenna elements in one of the sub-arrays are connected to each other via a printed transmission line and the printed transmission line is connected to a signal input via a first

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cable and the plurality of transmitting antenna elements in the sub-array are connected to each other via a second printed transmission line and the second printed transmission line is connected to a signal output via a second cable.