A phase shifter element for adjusting a transmission phase of a signal travelling through a transmission line has a conductive track (4) disposed in a parallel relationship with at least one ground plane (2). The phase shifter element has a phase shifting member (10) movable in a space between the conductive track (4) and the at least one ground plane (2). The phase shifting member (10) has at least a first section (12) comprising a first material having a first dielectric constant, the first section (12) being arranged such that, if the phase shifting member (10) is moved in relation to the conductive track (4) along a predetermined axis, an amount of the first material in a zone directly between the conductive track (4) and the ground plane (2) is varied. The width of the zone is defined by a predetermined arrangement of the first material in the phase shifting member (10) and the position of the phase shifting member (10) relative to the conductive track (4).
Phase Shifter Element

Field of the Invention

The present invention relates generally to a phase shifter element, and more specifically, but not exclusively, to a phase shifter element for use in a wireless antenna structure.

Background of the Invention

A phase shifter element may be required for use in many applications in which control of transmission phase of a radio frequency signal is required. For example, it may be required to adjust a transmitted, or received, beam pattern, and in particular the direction of a beam, of a phased array antenna by adjustment of the relative transmission phase of each of an array of antenna elements.

Many techniques are available to adjust transmission phase using active components, that is to say components requiring a supply of power to operate. Examples include devices based on the control of a reflection from a variable impedance device such as a PIN (P-type Intrinsic N-type) diode, in which a bias current of the PIN diode is controlled. Such phase shifting devices may offer convenient electronic control capable of rapid changes of phase, but are typically limited in power handling capability, which is an especially important characteristic at a wireless transmitter.

Many applications involving phase shifters do not require rapid adjustment of phase, and a passive phase shifter that may be mechanically adjusted is preferred. In particular, antennas at cellular wireless base stations are required to produce a carefully tailored radiation pattern with a defined beamwidth in azimuth and a precisely defined beam pattern in elevation; in fact the elevation beam is generally required to be narrower than the azimuth beam.

It is conventional to construct such antennas as an array of antenna elements to form the required beam patterns. Such arrays require a feed network in order to energise the antenna elements: on transmission, the feed
network splits signals into components with whichever phase relationship is required to drive the antenna elements, and on reception, the feed network functions as a combiner. An array consisting of a single vertical column of antenna elements is commonly used at cellular radio base stations. The feed network of such an array antenna may require one or more phase shifting elements in order to adjust the relative transmission phase of the antenna elements, and so steer a beam. It is particularly important to be able to steer a beam in elevation, in order to adjust the coverage pattern of a cell of a cellular wireless system; typically antennas at a cellular wireless base station are deployed with a down-tilt in the beam direction, and by adjusting the down-tilt the range of distances covered in a cell may be adjusted, and so potential interference with other cells may be avoided. Such an adjustment may be carried out infrequently by an operator, and a mechanically adjusted phase shifting element may be appropriate.

Mechanically adjusted phase shifting elements are known, but may suffer from poor return loss, that is to say poor impedance match, and excessive insertion loss.

It is also desirable for a phase shifting element to be cheap to construct, and to use construction techniques compatible with the design of an array antenna.

Summary of the Invention

In accordance with a first aspect of the present invention, there is provided a phase shifter element for adjusting a transmission phase of a signal travelling through a transmission line, the phase shifter comprising the transmission line and the transmission line comprising a conductive track and at least one ground plane, the conductive track being disposed in a parallel relationship with the at least one ground plane, the transmission line being for connection to a terminating impedance, and the phase shifter element further comprising a phase shifting member movable in a space between the conductive track and the at least one ground plane,
wherein the phase shifting member comprises at least a first section comprising a first material having a first dielectric constant, the first section being arranged such that, if the phase shifting member is moved in relation to the conductive track along a predetermined axis, an amount of the first material in a zone directly between the conductive track and the ground plane is varied, the width of the zone being defined by a predetermined arrangement of said first material in the phase shifting member and the position of the phase shifting member relative to the conductive track, and

wherein the phase shifter element is arranged such that a section of the conductive track, when not overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, has a first characteristic impedance greater than the terminating impedance.

An advantage of arranging for a section of the conductive track to have a characteristic impedance greater than the terminating impedance when not overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant is that the return loss, which is related to the impedance match of the phase shifter element over the control range of phase shifts may be optimised. In particular, a worst case impedance match over a control range may be optimised. A benefit is that unwanted reflections from the phase shifter element may be reduced and transmission loss of the phase shifter element may also be reduced.

In an embodiment of the invention, the conductive track comprises first, second and third parts, the second part being situated between the first and third parts, and the second part of the conductive track is wider than the first and third parts.

This has an advantage that an improved impedance match may be achieved.

In an embodiment of the invention the conductive track comprises first, second and third parts, the second part being situated between the first and third parts, and the phase shifter element is arranged such that the first and third parts
of the conductive track, when not overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, have the first characteristic impedance, and the second part, when not overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, has a characteristic impedance less than the first characteristic impedance.

This has an advantage that an improved impedance match may be achieved. The first characteristic impedance may be achieved, for example, by increasing the spacing of the ground plane from the conductive track.

In an embodiment of the invention at least a section of the first part of the conductive track is arranged to direct signals in a first direction and at least a section of the third part of the conductive track is arranged to direct signals in a second direction, different from the first direction.

This has an advantage that the width of the phase shifter element may be reduced.

In an embodiment of the invention the first direction is substantially opposite to the second direction.

This has an advantage that space may be saved.

In an embodiment of the invention, both ends of the conductive track are arranged to be on an opposite side of the phase shifting member in the plane of the ground plane to the third part of the conductive track.

This has an advantage that the two ends of the conductive track may be on the same side of a phase shifter element which may be advantageous when a number of phase shifter elements are concatenated.

In an embodiment of the invention, the phase shifting member comprises at least a first section and a second section, each section comprising the first material, each section having a respective width in a direction perpendicular to the predetermined axis in the plane of the ground plane which is dependent on a distance along the predetermined axis,

wherein the respective width decreases with the distance along the predetermined axis in a first direction.
This has an advantage that the spacing of the two fingers may be adjusted so that the interaction of reflections from the two fingers may be arranged to reduce impedance mis-match at the input of the phase shifting element.

In an embodiment of the invention at least part of the first section of the phase shifting member is arranged to move between the first part of the conductive track and the ground plane, and at least part of the second section of the phase shifting member is arranged to move between the third part of the conductive track and the ground plane.

In an embodiment of the invention the first section of the phase shifting member is offset in relation to the second section of the phase shifting member in a direction along the predetermined axis by at least the length of the first section, the length being measured along the predetermined axis.

In an embodiment of the invention the first section of the phase shifting member is aligned in relation to the second section of the phase shifting member in a direction perpendicular to the predetermined axis in the plane of the ground plane.

This has an advantage that the phase shifter element may be made narrower in a direction perpendicular to the predetermined axis, which may be advantageous for installation in an antenna array assembly.

In embodiments of the invention, the width of the first section is substantially the same as the width of the second section for a given distance within a first range of distances along the predetermined axis.

Preferably, the distance between a mid-point of a width of the first section and a mid-point of a width of the second section is dependent on the distance along the predetermined axis. This has an advantage that the distance may be adjusted for each distance along the axis, that is to say for each value of phase shift, to optimise impedance match of the phase shifting element.

Preferably, the distance between a mid-point of a width of the first section and a mid-point of a width of the second section increases with increasing distance along the predetermined axis from a narrower end of each
section, within a first range of distances along the predetermined axis. It has been found that this may be advantageous in optimising impedance match of the phase shifting element.

In an embodiment of the invention, the first range comprises at least a third of the length of the first and second sections.

In an embodiment of the invention the first range comprises at least a half of the length of the first and second sections.

In an embodiment of the invention, the first and second sections meet at the narrower end of each section.

In an embodiment of the invention, a distance between a mid-point of a width of the first section and the mid-point of a width of the second section in a region towards the widest end of the first and second sections is equivalent to between 0.2 and 0.3 wavelengths of the signal, a distance between a mid-point of a width of the first section and the mid-point of a width of the second section in a region towards the mid-point of the length of the first and second sections is equivalent to between 0.15 and 0.25 wavelengths of the signal, and a distance between a mid-point of a width of the first section and the mid-point of a width of the second section in a region towards the narrowest end of the first and second sections is equivalent to between 0 and 0.15 wavelengths of the signal.

Preferably, the first characteristic impedance is achieved by reducing the width of the conductive track. This has an advantage that a spacing between the ground plane and the conductive track need not be varied in order to achieve the impedance.

Preferably, the element is arranged such that a section of the conductive track, when overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, has a second characteristic impedance less than the terminating impedance. It has been found that this may be advantageous in optimising impedance match of the phase shifting element.
Preferably, the second characteristic impedance is achieved by maintaining the reduced track width across substantially the entire width of the phase shifter element.

Preferably, the conductive track is arranged to have a width such that a return loss at the input to the phase shifter is optimised for a range of values of phase shift encompassing a value of phase shift mid-way between a maximum and a minimum phase shift of the phase shifter.

In an embodiment of the invention the predetermined axis is perpendicular to at least part of the conductive track.

Further features and advantages of the invention will be apparent form the following description of preferred embodiments of the invention, which are given by way of example only.

**Brief Description of the Drawings**

Figure 1 is a schematic diagram showing an oblique view of a phase shifter element in an embodiment of the invention;

Figure 2 is a schematic diagram showing an oblique view of a phase shifter element in a second embodiment of the invention;

Figure 3 is a schematic diagram showing an oblique view of a phase shifter element in third embodiment of the invention;

Figure 4 is a schematic diagram illustrating a principle of operation of an embodiment of the invention;

Figure 5 is a schematic diagram showing a plan view of a phase shifter element in an embodiment of the invention at a first phase shift setting;

Figure 6 is a schematic diagram showing a plan view of a phase shifter element in an embodiment of the invention at a second phase shift setting;

Figure 7 is a schematic diagram showing a plan view of a phase shifter element in an embodiment of the invention at a third phase shift setting;

Figure 8 is a schematic diagram showing a plan view of a phase shifter element according to second embodiment of the invention;
Figure 9 is a schematic diagram showing a plan view of a phase shifter element showing an alternative shape of the dielectric blocks according to an embodiment of the invention;

Figure 10 is a schematic diagram showing a plan view of a phase shifter element showing an alternative shape of the conductive track according to an embodiment of the invention;

Figure 11 is a schematic diagram showing a plan view of a phase shifter element showing an alternative arrangement of the dielectric blocks and conductive track according to an embodiment of the invention;

Figure 12 is a schematic diagram showing a plan view of a phase shifter element showing a further variation of the dielectric blocks and conductive track according to an embodiment of the invention;

Figure 13 is a schematic diagram showing a plan view of a phase shifter element showing a single dielectric block and a folded track arrangement according to an embodiment of the invention;

Figure 14 is a schematic diagram showing a plan view of a phase shifter element showing a rectangular dielectric block and a meandered conductive track according to an embodiment of the invention; and

Figure 15 is a schematic diagram showing a plan view of a phase shifter element showing a variant of the arrangement of Figure 13.

Detailed Description of the Invention

By way of example, embodiments of the invention will now be described in the context of a phase shifter element, for use in a cellular wireless system base station antenna at carrier frequencies typically in the range 800 MHz to 3 GHz, and in a particular within bands at approximately 2 GHz. However, it will be understood that this is by way of example only and that other embodiments may involve other frequency ranges either higher or lower in frequency and embodiments are not limited to use with a particular type of antenna. The phase shifter element is not limited for use with an antenna system; it may find
application in any radio frequency system requiring control of transmission phase.

Figure 1 shows a phase shifter element for adjusting a transmission phase of a signal travelling through a transmission line in oblique view. A transmission line is formed comprising a conductive track 4 and at least one ground plane 2. As shown in Figure 1, the conductive track 4 is disposed in a parallel relationship with the at least one ground plane 2. The transmission line is for connection to a terminating impedance; typically a radio transmission system is designed for a standard terminating impedance of 50 Ohms, although some systems may be designed for other terminating impedance values such as 75 Ohms. The terminating impedance is thus a standard impedance value which is connected to a component to measure return loss, that is to say reflected signals, and other measures related to impedance match. The term impedance match thus may relate to the degree to which an impedance of a terminal of a device conforms to a specified terminating impedance. For best performance in terms of minimum loss and optimum return loss, it is advantageous that devices should have an impedance at a terminal that conforms as closely as possible to the terminating impedance. An impedance mismatch typically results in reflection of signal from the mismatch.

Referring to Figure 1, it can be seen that the phase shifter element further comprises a phase shifting member 10 movable in a space between the conductive track 4 and the at least one ground plane 2 at least in a direction perpendicular to the conductive track. One direction of possible motion is indicated in Figure 1 by the arrow: movement of the phase shifting member in this direction may result in a reduction in transmission phase through the transmission line. Transmission of signals through a transmission line introduces a delay to this signal dependent on the dielectric constant of a dielectric material disposed between the conductive track and the ground plane forming the transmission line; a higher dielectric constant gives a greater delay. A change in delay will typically result in a phase shift. Therefore, a change in the proportion of the length of conductive track that forms a transmission line
having dielectric material with a higher dielectric constant to the length of conductive track that forms a transmission line having dielectric material with a lower dielectric constant, such as air, will produce a phase shift in the transmission of the signal.

It can be seen from Figure 1 that the phase shifting member 10 comprises at least a first section 12. In the embodiment of Figure 1, a second section 14 is shown. A particularly suitable material for the first and second sections is polycarbonate, which may typically have a dielectric constant, that is to say relative permittivity, of approximately 3. Polycarbonate may have properties that are a good tradeoff between high dielectric constant, which is desirable to increase a phase shift in a transmission line, and transmission loss. Other materials that may be used include Teflon-based dielectric materials, typically exhibiting a lower loss than polycarbonate but having a lower dielectric constant of typically approximately 2. Alternatively epoxy-glass material may be used for the first and second sections; this material is cheap and has a high dielectric constant of typically approximately 4, but a relatively high transmission loss. The embodiment shown in Figure 4 uses a polycarbonate material for the first and second sections.

In the embodiment of Figure 1, the first and second sections are arranged such that, if the phase shifting member 10 is moved in relation to the conductive track 4 in a direction perpendicular to the conductive track, that is to say in the direction of the arrow or in the opposite direction, an amount of the first material in a zone directly between the conductive track and the ground plane is varied, the width of the zone being defined by the arrangement of the first material in the first 12 and second 14 sections of the phase shifting member as illustrated in Figure 1 and by the position of the phase shifting member 10 relative to the conductive track 4. In the embodiment of Figure 1, the area of the phase shifting member 10 that is not in the first 12 or second 14 sections, shown as sections 16a, 16b and 16c, is composed of a second material having a dielectric constant lower than that of the material of the first and second sections. Conveniently, the second material is a foam material, preferably a non-
conductive polymer foam material, which is composed mostly of air, so that the
dielectric constant is approximately 1. Alternatively, the areas 16a, 16b and 16c
may simply be voids in which the dielectric material is air, as illustrated by
Figure 2. The phase shifting member 10 may have a frame around the boarder
to contain the foam material and to support the first and second sections 12, 14.
Alternatively, as illustrated by Figure 3, the phase shifting member 10 may be
defined by the shape the first and second areas 12 and 14.

The phase shifter element may be arranged such that a section of the
conductive track 4, when not overlying a zone directly between the conductive
track and the ground plane comprising the first material having the first
dielectric constant, has a first characteristic impedance greater than the input
impedance of the phase shifter. This may be achieved by reducing the width of
the track compared to a width that would produce a characteristic impedance
equal to the terminating impedance of the system for which the phase shifter
element is designed. So, for example in an embodiment of the invention, the
track width of the conductive track is such that the transmission line has an
impedance of approximately 65 Ohms in sections where the transmission line
formed by the conductive track 4 and the ground plane 2 has an air dielectric,
whereas the terminating impedance is 50 Ohms. In this example, the impedance
of sections where the transmission line formed by the conductive track 4 and the
ground plane 2 has a polycarbonate material dielectric is approximately 42
Ohms. It may be advantageous to design the width of the conductive track to
be such that a return loss at the input to the phase shifter is optimised for phase
shift approximately mid-way between a maximum and a minimum phase shift of
the phase shifter. Alternative methods of changing a track impedance include
changing the spacing between the track and the ground plane, for example by
arranging for the ground plane to have a well under the track.

It can be seen in Figure 1 that the distance between a mid-point of a
width of the first section 12 and a mid-point of a width of the second section 14
is dependent on the distance along an axis perpendicular to the conductive track.
In the embodiment illustrated in Figure 1, the distance between a midpoint of a width of the first section 12 and a midpoint of a width of the second section 14 increases with increasing distance along the axis perpendicular to the conductive track from the narrower end of each section for at least the first third or in some embodiments the first half of the length of the sections starting from the narrow end of the sections. This shape, as shown in Figure 1 and a similar shape shown in Figure 5 for the first and second sections 12, 14, has the beneficial property that an impedance match of the phase shifter element is optimised for each position of the phase shifting member 10, that is to say for each phase shift value.

As shown in Figure 1 and Figure 5, the first 12 and second 14 sections may meet at the narrower end of each section. This may be advantageous for mechanical strength, and may also optimise the impedance match of the phase shifter element when the narrow ends of the first and second sections are between the conductive track 4 and the ground plane. Reflections from an impedance mismatch between the section of the conductive track over an air dielectric and the section of conductive track over first and second sections at their narrower ends may to an extent cancel reflections from the transitions between the conducting track 4 and sections of track 6, 8 having the terminating impedance, thus improving the return loss of the phase shifting element.

Particularly advantageous embodiments of the invention may have the following parameters: a distance between a midpoint of a width of the first section and the midpoint of a width of the second section in a region towards the widest end of the first and second sections is equivalent to between 0.2 and 0.3 wavelengths of the signal, a distance between a midpoint of a width of the first section and the midpoint of a width of the second section in a region towards the mid-point of the length of the first and second sections is equivalent to between 0.15 and 0.25 wavelengths of the signal, and a distance between a mid-point of a width of the first section and the mid-point of a width of the second section in a region towards the narrowest end of the first and second sections is equivalent to between 0 and 0.15 wavelengths of the signal. The
length of the conductive track 4 may be typically 0.3 – 0.5 wavelengths. In this example, the wavelength is expressed as a wavelength expected at each part of the transmission line in view of the dielectric material present at that part.

It should be noted that embodiments have been described with respect to a single ground plane, so that the transmission line acts as a microstrip transmission line. However, it should be understood that embodiments of the invention may comprise two ground planes forming a tri-plate structure, in which the conductive track is disposed between the two ground planes, and the transmission line is a stripline transmission line. In this case, the second ground plane may simply overlay the microstrip structure already described, although adjustments to track widths to take account of the characteristic impedance of the stripline rather than microstrip transmission line may be necessary. An air or foam dielectric may typically be used between the conductive track and the second ground plane. Alternatively, a second phase shifting member may be employed between the conductive track and the second ground plane, that may be arranged to move in conjunction with the phase shifting member 10.

Figure 4 illustrates a principle of operation of the phase shifter element, showing track impedance at various parts of the conductive track 4. The solid line in Figure 4 relates to a system in which, unlike in embodiments of the invention, the conductive track 4 has a width such that the track impedance is equal to the terminating impedance in a section having an air dielectric. The value of impedance of the line at point 20 is the terminating impedance, typically 50 Ohms. At sections between points 22 and 24 and points 26 and 28, the conductive track has a material with a higher dielectric constant than air as a dielectric, for example polycarbonate. In these sections, it can be seen from Figure 4 that the track impedance, that is to say the characteristic impedance of a transmission line formed by the conductive track and the ground plane, is significantly lower than the terminating impedance. This may result in strong reflections from the mis-match at the transition points between the impedances.

By contrast, the broken line of Figure 4 shows track impedance at various parts of the conductive track 4 according to embodiments of the
invention. Point 20 corresponds with the end of the conductive track 4, as shown in Figure 2 as the transition between track 6 having the terminating impedance and the conductive track 4. It can be seen for example by reference to Figure 2 that between point 20 and point 22, the track has an air dielectric corresponding to area 16c, and it can be seen from Figure 4 that the track impedance of this section is greater than the terminating impedance. Between points 22 and 24, the conductive track crosses the first section 12 of the phase shifting member, having a dielectric constant greater than does air, and in this section the track impedance is less than the terminating impedance. The section between points 24 and 26 corresponds to another section in which the dielectric is air, and the track impedance is again higher than the characteristic impedance. The section between points 26 and 28 corresponds to second section 14, of the phase shifting member having a dielectric constant greater than does air, and in this section the track impedance is again less than the terminating impedance. The section between 28 and 30 is again a section with an air dielectric, and the end of the conducting track is at point 30, at which there is a transition to a width of track having the terminating impedance. It is found that the impedance match of the phase shifter element may be optimised, at least at the mid point of the travel of the phase shifting member, by adjusting the track impedance of the conductive track to follow an impedance profile similar to that illustrated by the broken line of Figure 4; this may be achieved by adjusting the width of the conductive track. The shape of the first 12 section and second 14 section of the phase shifting member may then be optimised at each setting of the phase shifter to optimise return loss.

Figure 5, Figure 6 and Figure 7 shows a phase shifter element according to an embodiment of the invention set to produce increasingly large amounts of phase shift. Figure 8 shows a phase shifter according to a second embodiment of the invention in which the regions 16a, 16b and 16c have an air dielectric, rather than the foam dielectric shown in Figures 5 to 7.

Figure 9 illustrates a variant of phase shifter element of Figure 8, in which the thin ends of the first and second sections of the phase shifting member
are not joined; this may be advantageous in term of impedance match in some configurations.

Figure 10 illustrates a phase shifter element in which the conductive track comprises a first part 4a, a second part 4b and a third part 4c. As may be seen from Figure 10, and the second part 4b of the conductive track is wider than the first 4a and third 4c parts. As a result, the impedance of the second part, in air, may be lower than that of the first and third parts. The impedance of the second part may be set to the characteristic impedance of the device. This may give flexibility in setting the length of the conductive track and the spacing of the sections of the phase shifting member, which may have a form similar to that illustrated by Figure 9. An improved impedance match may also be achieved using this arrangement of the conductive track. As an alternative to changing the width of the track, the characteristic impedance of the parts of the conductive track may be changed by local adjustment of the spacing between the conductive track and the ground plane, as has already been described.

Figure 11 illustrates a phase shifter element in which the conductive track 4a, 4b, 4c is arranged to turn back on itself, so that the first section 4a and the third section 4c direct signals in substantially opposite directions, and the two ends of the conductive track are on the same side of a phase shifter element. This may be advantageous when a number of phase shifter elements are concatenated, in connecting together successive elements, and also makes the element narrower. It can be seen from Figure 11 that the first section of the phase shifting member is offset in relation to the second section of the phase shifting member in a direction along the predetermined axis by at least the length of the first section, the length being measured along the predetermined axis. Also, the first section of the phase shifting member is aligned in relation to the second section of the phase shifting member in a direction perpendicular to the predetermined axis in the plane of the ground plane. As a result, the phase shifter element may be made narrower in a direction perpendicular to the predetermined axis, which may be advantageous for installation in an antenna array assembly.
Figure 12 illustrates an alternative embodiment of the phase shifter element, in which the first 4a and third 4c parts of the conductive track are arranged at an angle to each other. As a result, the phase shifter element may be made narrower than would be required if the conductive track were straight. The shape of the dielectric part of the phase shifting member, 12, shown in Figure 12 has been found to give good performance in terms of impedance match in conjunction with this shape of conducting track.

Figure 13 shows a variant of the phase shifter element of Figure 10, in which the phase shifting member has a single section, and the conducting track turns back on itself as shown over the single section. This may have space saving advantages. Figure 15 illustrates a variant of the phase shifter element of Figure 13.

Figure 14 illustrates a variant of the phase shifter in which the dielectric section 12 of the phase shifter member has a rectangular shape, and the conductive track 4a, 4b, 4c is meandered as shown.

The above embodiments are to be understood as illustrative examples of the invention. It is to be understood that any feature described in relation to any one embodiment may be used alone, or in combination with other features described, and may also be used in combination with one or more features of any other of the embodiments, or any combination of any other of the embodiments. Furthermore, equivalents and modifications not described above may also be employed without departing from the scope of the invention, which is defined in the accompanying claims.
Claims

1. A phase shifter element for adjusting a transmission phase of a signal travelling through a transmission line, the phase shifter comprising the transmission line and the transmission line comprising a conductive track and at least one ground plane, the conductive track being disposed in a parallel relationship with the at least one ground plane, the transmission line being for connection to a terminating impedance, and the phase shifter element further comprising a phase shifting member movable in a space between the conductive track and the at least one ground plane,

   wherein the phase shifting member comprises at least a first section comprising a first material having a first dielectric constant, the first section being arranged such that, if the phase shifting member is moved in relation to the conductive track along a predetermined axis, an amount of the first material in a zone directly between the conductive track and the ground plane is varied, the width of the zone being defined by a predetermined arrangement of said first material in the phase shifting member and the position of the phase shifting member relative to the conductive track, and

   wherein the phase shifter element is arranged such that a section of the conductive track, when not overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, has a first characteristic impedance greater than the terminating impedance.

2. A phase shifter element according to any preceding claim, wherein the conductive track comprises first, second and third parts, the second part being situated between the first and third parts, and the second part of the conductive track being wider than the first and third parts.

3. A phase shifter element according to claim 1 or claim 2, wherein the conductive track comprises first, second and third parts, the second part
being situated between the first and third parts, and the phase shifter element is arranged such that the first and third parts of the conductive track, when not overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, have the first characteristic impedance, and the second part, when not overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, has a characteristic impedance less than the first characteristic impedance.

4. A phase shifter element according to claim 2 or claim 3, wherein at least a section of the first part of the conductive track is arranged to direct signals in a first direction and at least a section of the third part of the conductive track is arranged to direct signals in a second direction, different from the first direction.

5. A phase shifter element according to claim 4, wherein the first direction is substantially opposite to the second direction.

6. A phase shifter element according to any of claims 2 to 5, wherein both ends of the conductive track are arranged to be on an opposite side of the phase shifting member in the plane of the ground plane to the third part of the conductive track.

7. A phase shifter element according to any preceding claim, wherein the phase shifting member comprises at least a first section and a second section, each section comprising the first material, each section having a respective width in a direction perpendicular to the predetermined axis in the plane of the ground plane which is dependent on a distance along the predetermined axis, wherein the respective width decreases with the distance along the predetermined axis in a first direction.
8. A phase shifter element according to claim 7 and any of claims 2 to 6, wherein at least part of the first section of the phase shifting member is arranged to move between the first part of the conductive track and the ground plane, and at least part of the second section of the phase shifting member is arranged to move between the third part of the conductive track and the ground plane.

9. A phase shifting member according to claim 8, wherein the first section of the phase shifting member is offset in relation to the second section of the phase shifting member in a direction along the predetermined axis by at least the length of the first section, the length being measured along the predetermined axis.

10. A phase shifting member according to claim 9, wherein the first section of the phase shifting member is aligned in relation to the second section of the phase shifting member in a direction perpendicular to the predetermined axis in the plane of the ground plane.

11. A phase shifter element according to any of claim 7 to 10, wherein the width of the first section is substantially the same as the width of the second section for a given distance within a first range of distances along the predetermined axis.

12. A phase shifter element according to any of claim 7 to 11, wherein the distance between a mid-point of a width of the first section and a mid-point of a width of the second section is dependent on the distance along the predetermined axis.

13. A phase shifter element according to claim 12, wherein the distance between a mid-point of a width of the first section and a mid-point of a
width of the second section increases with increasing distance along the predetermined axis from a narrower end of each section, within a first range of distances along the predetermined axis.

14. A phase shifter element according to claim 13, wherein the first range comprises at least a third of the length of the first and second sections.

15. A phase shifter element according to claim 14, wherein the first range comprises at least a half of the length of the first and second sections.

16. A phase shifter element according to claim 13, claim 14 or claim 15, wherein the first and second sections meet at the narrower end of each section.

17. A phase shifter element according to any one of claim 11 to claim 16, wherein a distance between a mid-point of a width of the first section and the mid-point of a width of the second section in a region towards the widest end of the first and second sections is equivalent to between 0.2 and 0.3 wavelengths of the signal, a distance between a mid-point of a width of the first section and the mid-point of a width of the second section in a region towards the mid-point of the length of the first and second sections is equivalent to between 0.15 and 0.25 wavelengths of the signal, and a distance between a mid-point of a width of the first section and the mid-point of a width of the second section in a region towards the narrowest end of the first and second sections is equivalent to between 0 and 0.15 wavelengths of the signal.

18. A phase shifter element according to any preceding claim wherein the first characteristic impedance is achieved by reducing the width of the conductive track.
19. A phase shifter element according to any preceding claim, wherein the element is arranged such that a section of the conductive track, when overlying a zone directly between the conductive track and the ground plane comprising the first material having the first dielectric constant, has a second characteristic impedance less than the terminating impedance.

20. A phase shifter element according to any preceding claim, wherein the conductive track is arranged to have a width such that a return loss at the input to the phase shifter is optimised for a range of values of phase shift encompassing a value of phase shift mid-way between a maximum and a minimum phase shift of the phase shifter.

21. A phase shifter element according to any preceding claim, wherein the predetermined axis is perpendicular to at least part of the conductive track.
Patents Act 1977: Search Report under Section 17

Documents considered to be relevant:

<table>
<thead>
<tr>
<th>Category</th>
<th>Relevant to claims</th>
<th>Identity of document and passage or figure of particular relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>1, 2 at least</td>
<td>US6075424 A (HAMPEL ET AL): Whole document relevant, esp Figs 1A, Fig 2A-2C and related passages.</td>
</tr>
<tr>
<td>X</td>
<td>1 at least</td>
<td>GB767067 A (STANDARD TELEPHONES AND CABLES LTD): Whole document relevant, esp Figs 2 and 3 and related passages.</td>
</tr>
<tr>
<td>X</td>
<td>1 at least</td>
<td>US7283015 B1 (US NATIONAL SECURITY AGENCY): Whole document relevant, esp Fig 4 and col 4 lines 9-26.</td>
</tr>
<tr>
<td>X</td>
<td>1 at least</td>
<td>JP2005130333 A (MATSUSHITA ELECTRIC INC CO LTD): Whole document relevant, esp translated abstract.</td>
</tr>
</tbody>
</table>

Categories:

| X | Document indicating lack of novelty or inventive step |
| Y | Document indicating lack of inventive step if combined with one or more other documents of same category. |
| & | Member of the same patent family |

A | Document indicating technological background and/or state of the art. |

P | Document published on or after the declared priority date but before the filing date of this invention. |

E | Patent document published on or after, but with priority date earlier than, the filing date of this application. |

Field of Search:

Search of GB, EP, WO & US patent documents classified in the following areas of the UKC:

Worldwide search of patent documents classified in the following areas of the IPC:
H01P; H01Q

The following online and other databases have been used in the preparation of this search report:
EPODOC, WPI

International Classification:

<table>
<thead>
<tr>
<th>Subclass</th>
<th>Subgroup</th>
<th>Valid From</th>
</tr>
</thead>
<tbody>
<tr>
<td>H01P</td>
<td>0001/18</td>
<td>01/01/2006</td>
</tr>
<tr>
<td>H01Q</td>
<td>0003/26</td>
<td>01/01/2006</td>
</tr>
</tbody>
</table>