

Compact Tunable Diversity Antenna

Field of Invention

[0001] The present invention relates to compact yet tunable co-linear antennas. In particular, the invention relates to tunable antennas that are arranged both vertically and spatially as mobile diversity antenna.

Background

[0002] In urban and/or indoor environments, there is often not a clear line-of-sight between transmitter and receiver in a wireless link. Instead, some signals are being reflected along multiple paths before finally being received. Each of these reflections can introduce phase shifts, time delays, attenuations, and even distortions that can destructively interfere with one another at the aperture of a receiving antenna. As a result, performance problems, such as dropped connection, poor connection and even lost connection, are experienced. This is especially true in mobile communication when a wireless device and its antenna are on the move. Diversity antenna, a wireless scheme that utilizes two or more antennas, is effective at mitigating these multi-path reflections to improve the quality and reliability of a wireless link. This is because multiple antennas afford a receiver several observations of a signal from a transmitter. Each receiving antenna will experience a different interference environment. Thus, if one antenna is experiencing destructive interference and resulting in a deep fade, it is likely that another antenna is not experiencing destructive interference and has sufficient signal-to-noise ratio. Thus, a suitable combination of the outputs from two or more antennas can provide a robust link in a wireless network.

[0003] Inherently, a diversity antenna requires additional hardware and integration. Due to the commonality of the signal paths, a fair amount of circuitry can be shared. Also with multiple signals there is a greater processing demand placed on the receiver, which can lead to tighter design requirements. Usually, signal reliability is paramount and using a diversity antenna is an effective way to decrease the number of dropped and lost connections in a wireless link.

[0004] Despite development in diversity antenna, there exists a need for a spatial diversity antenna that is tunable yet compact.

Summary

[0005] The following presents a simplified summary to provide a basic understanding of the present invention. This summary is not an extensive overview of the invention, and is not intended to identify key features of the invention. Rather, it is to present some of the inventive concepts of this invention in a generalised form as a prelude to the detailed description that is to follow.

[0006] The present invention provides an elongate and cylindrically tunable antenna. The antenna is tunable manually and/or by a motor. Two or more antennas are arranged to form a spatial diversity antenna for improving quality and reliability of a link in wireless communication. An advantage of the antenna is that it is slender and compact. Another advantage is that the phase shift core is integrated and can be rotatable by a gear-motor unit.

[0007] In one embodiment of the present invention, the tunable cylindrical antenna comprises: an elongate substrate core; a bandwidth adjustment sleeve disposed concentrically with the substrate core; and an elongate phase shift core disposed coaxially below the substrate core; wherein a predetermined number of antenna patches are formed on a cylindrical surface of the substrate core and an equal number of parasitic antenna patches are formed on a cylindrical surface of the bandwidth adjustment sleeve such that the bandwidth adjustment sleeve and the substrate core are operable to be rotationally displaced so that the antenna characteristic is varied azimuthally during tuning.

[0008] In another embodiment, the substrate core comprises a core or sleeve and a support sleeve, said core or sleeve is made up of strips of two materials with different

dielectric constants, with the strips being arranged in an alternate manner to form a cylindrical core or sleeve and the antenna patches are formed on the support sleeve.

[0009] In another embodiment, the substrate core further comprises an outer sleeve disposed concentric with the support sleeve, said outer sleeve comprises strips of two materials with different dielectric constants, with the strips being arranged in an alternate manner. The substrate core/sleeve and outer sleeve may be rotatable in unison.

[0010] In another embodiment of the antenna of the present invention, the phase shift core comprises a meandering line associated with each patch antenna. In another embodiment, the phase shift core comprises a core or sleeve and a meandering line support sleeve disposed concentric with the core or sleeve, said core or sleeve is made up of alternate strips of two dielectric materials and the meandering lines are formed on the meandering line support sleeve, such that the core/sleeve and meandering line support sleeve are operable to be rotationally displaced so that the phase shift of the signal from the antenna is varied during tuning. The substrate outer sleeve or phase shift outer sleeve may be rotatably displaced by a gear-motor in relation to the relevant substrate core/sleeve or phase shift core/sleeve.

[0011] In another embodiment of the present invention, the tunable antenna comprises a series of antennas. In yet another embodiment, two or more of the tunable antenna is arranged as a spatial diversity antenna

Brief Description of the Drawings

[0012] This invention will be described by way of non-limiting embodiments of the present invention, with reference to the accompanying drawings, in which:

[0013] FIG. 1 illustrates component structures of a tunable antenna according to an embodiment of the present invention;

[0014] FIG. 2A illustrates patch antennas on the substrate core of the antenna shown in FIG. 1;

FIG. 2B illustrates a structure of the substrate core of the antenna shown in FIG. 1;

FIG. 2C illustrates another structure of the substrate core of the antenna shown in FIG. 1 according to another embodiment of the present invention;

[0015] FIG. 3 illustrates a structure of the substrate sleeve of the antenna core shown in FIG. 2A or 2B;

[0016] FIG. 4A illustrates a bandwidth adjustment sleeve of the antenna shown in FIG. 1;

FIG. 4B illustrates the bandwidth adjustment sleeve shown in FIG. 4A and a substrate core according to another embodiment of the present invention;

[0017] FIG. 5 illustrates a phase shift core of the antenna shown in FIG. 1;

[0018] FIG. 6A illustrates a structure of the phase shift core of the antenna shown in FIG. 1;

FIG. 6B illustrates another structure of the phase shift core according to another embodiment of the present invention;

[0019] FIG. 7 illustrates a series of antennas shown in FIG. 1 according to another embodiment of the present invention; and

[0020] FIG. 8 illustrates a diversity antenna according to yet another embodiment of the present invention.

Detailed Description

[0021] One or more specific and alternative embodiments of the present invention will now be described with reference to the attached drawings. It shall be apparent to one skilled in the art, however, that this invention may be practised without such specific details. Some of the details may not be described at length so as not to obscure the

invention. For ease of reference, common reference numerals or series of numerals will be used throughout the figures when referring to the same or similar features common to the figures.

[0022] FIG. 1 shows a tunable yet compact co-linear antenna 100 according to an embodiment of the present invention. As shown in FIG. 1, the co-linear antenna 100 is made up of three concentric structures: a substrate core 150; a bandwidth adjustment sleeve 180 disposed concentrically around the substrate core 150; and a phase shift core 110 disposed co-axially below the substrate core 150.

[0023] FIG. 2A shows a substrate core 150 according to one embodiment of the present invention. The substrate core 150 is made up of a dielectric core and three antenna patches 154 printed on the cylindrical surface.

[0024] FIG. 2B shows a substrate core 150a according to another embodiment of the present invention. The substrate core 150a is made up of a core or inner sleeve 152 and a support sleeve 153 surrounding the core/inner sleeve 152. As shown in FIG. 2B, the inner sleeve 152 is made up of strips of two dielectric materials ϵ_1, ϵ_2 that are alternately and axially disposed to form a cylindrical sleeve. Each inner sleeve 152 has three strips of each dielectric material ϵ_1, ϵ_2 , thus each strip is equally displaced at about 60 degree with respect to each other. The support sleeve 153 is a thin cylinder of a dielectric material ϵ_3 and has three equally spaced antenna patches 154 printed on its cylindrical surface. In one embodiment, the antenna patches 154 are printed on an inner cylindrical surface of the support sleeve 153; in another embodiment, the antenna patches 154 are printed on an outer cylindrical surface of the support sleeve 153. The support sleeve 153 is rotationally displaced about the inner sleeve 152, as shown by arrow R, so that the effective dielectric constant seen by the electromagnetic (EM) field around each antenna patch 154 is determined by the amount of overlap between each antenna patch 154 and the dielectric materials ϵ_1, ϵ_2 of the inner sleeve 152. In this way, the antenna's gain and radiation pattern characteristics are adjustable or tunable by turning the support sleeve 153 relative to the inner sleeve 152.

[0025] In one embodiment of the antenna patch, the antenna patch 154 is a simple patch antenna; in another, it is an array of patch antennas; in yet another, it is a dipole patch antenna.

[0026] FIG. 2C shows a substrate core 150b according to another embodiment of the present invention. The substrate core 150b is made up of the above substrate core 150a and an outer sleeve 155. The outer sleeve 155 is similar in construction as the inner sleeve 152. In one embodiment, the outer sleeve 155 is a radial projection of the inner sleeve 152. In an embodiment, the dielectric materials of the outer sleeve 155 are the same as those of the inner sleeve 152; in another embodiment, each dielectric material ϵ_4, ϵ_5 of the outer sleeve 155 is different from those of the inner sleeve 152. In one embodiment of the substrate core 150b, the inner and outer sleeves 152, 155 are rotatable in unison with respect to the support sleeve 153, which is disposed between the inner and outer sleeves 152, 155. As in the earlier embodiment, the effective dielectric constant seen by the EM field around each antenna patch 154 is adjustable by the amount of overlap between the antenna patch 154 and the dielectric materials $\epsilon_1, \epsilon_2, \epsilon_4, \epsilon_5$ of the inner/outer sleeve. In another embodiment, the inner sleeve 152 and the outer sleeve 155 are not rotatable in unison.

[0027] FIG. 3 shows an inner or outer substrate sleeve 152, 155 according to another embodiment of the present invention. As shown in FIG. 3, the inner/outer sleeve 152, 155 is made by forming apertures 156 in a cylindrical sleeve of a dielectric material ϵ_1, ϵ_4 where air in the apertures 156 has dielectric constant ϵ_2 or ϵ_5 .

[0028] FIG. 4A shows a bandwidth adjustment sleeve 180 according to another embodiment of the present invention. As shown in FIG. 4A, the cylindrical surface of the bandwidth adjustment sleeve 180 has three equally spaced parasitic antenna patches 184. When the bandwidth adjustment sleeve 180 is rotationally displaced with respect to the antenna patches 154, as shown by arrow R, characteristics of the EM field around each antenna patches 154 are adjusted by the amount of overlap between the antenna patches 154 and the parasitic antenna 184. These characteristics may be the antenna's bandwidth, gain and directivity.

[0029] FIG. 4B shows a tunable yet compact co-linear antenna 100b according to another embodiment of the present invention; in this embodiment, the substrate core 150 is a simple cylindrical core or sleeve of a dielectric material whilst the bandwidth adjustment sleeve 180 is made of the same or dissimilar dielectric material. Other embodiments of the co-linear antenna are made up of combinations of the bandwidth adjustment sleeve 180 and various embodiments of the substrate core 150a,150b.

[0030] FIG. 5 shows a phase shift core 110 according to another embodiment of the present invention. The phase shift core 110 is a simple cylindrical core or sleeve of a dielectric material. On the cylindrical surface of the phase shift core 110 are printed three equally spaced meandering lines 111. By forming meandering lines 111,111a of different numbers of meanders, the phase shift of a signal corresponding to an antenna patch 154 is made different from that of another. Accordingly, the phase shift of a signal received at or transmitted from the antenna 100 is varied azimuthally. Other embodiments of the co-linear antenna are made up of combinations of the phase shift core 110 and the above substrate core 150a,150b and/or bandwidth adjustment sleeve 180.

[0031] FIG. 6A shows a phase shift core 110a according to another embodiment of the present invention. As shown in FIG. 6A, the phase shift core 110a is made up of a cylindrical core or sleeve 112 formed from a composite of two dielectric materials and a meander line support sleeve 113. The structure of the phase shift core 110a is similar in construction to that of the substrate core 150a shown in FIG. 2B except that the meandering lines 111 are shown instead of the antenna patches 154. Thus, by rotationally overlapping the meandering lines 111 with respect to one of the dielectric material of the cylindrical core or sleeve 112, the phase shift of an antenna 100b is made adjustable.

[0032] FIG. 6B shows a phase shift core 110b according to yet another embodiment of the present invention. As shown in FIG. 6B, the phase shift core 110b is made up of the above phase shift core 110a and an outer sleeve 115. The structure of the phase shift core 110b is similar in construction to that of the substrate core 150b shown in FIG. 2C

except that the meandering lines 111 are shown instead of the antenna patches 154. Again, by rotationally overlapping the meandering lines 111 with respect to one of the dielectric materials of the phase shift sleeve 112,115, the phase shift of an antenna 100b is made adjustable.

[0033] In the above embodiments, by rotationally displacing the bandwidth adjustment sleeve 180 relative to the substrate core 150,150a,150b, etc. and/or phase shift core 110,110a,110b, etc., characteristics of the antenna 100,100a,100b, etc., such as gain, bandwidth, beam width, phase shift and directivity, are made adjustable. In addition, by placing two of the antennas spatially apart from each other and combining the outputs of the two antennas, a signal with high signal-to-noise ratio is obtainable.

[0034] FIG. 7 shows an antenna 200 according to another embodiment of the present invention. The antenna 200 is formed by connecting segments of antenna 100,100a,100b, etc. in series to form a slender antenna. In the centre of the antenna 200 is a feed member 210 for supporting transmission lines of the patch antennas and meandering lines. Each segment of the antenna 100,100a,100b has its own characteristic receiving or emitting pattern.

[0035] FIG. 8 shows a diversity antenna 300 formed by arranging two spatially spaced apart antennas 100,200 to improve quality and reliability of a link in wireless communication; the signals from separate antennas are summed up, for example, to maximize signal-to-noise ratio.

[0036] An advantage of the present invention is that the antennas are compact and disposed in a vertical and cylindrical manner. Another advantage is that the phase shift mechanism is integrated in the antenna 100,100a,100b, etc.. In contrast, the phase shift mechanism in a conventional system is located separate from the antenna; in addition, the phase shift mechanism of the present invention does not employ tuning diodes, selector networks or adaptive coding algorithms. Another advantage of the present invention is that each of the bandwidth adjustment sleeve, substrate core and phase shift core is rotationally displaced by a gear-motor drive 190 in relation to each other.

[0037] While specific embodiments have been described and illustrated, it is understood that many changes, modifications, variations and combinations thereof could be made to the present invention without departing from the scope of the invention. For example, three antenna patches have been illustrated and described. It is possible that four or more antenna patches be used in the diversity antenna of the present invention. In another example, the antenna patches are described as being printed; however, other methods of forming the antenna patches, such as by etching and depositing; laminating; and so on, are also feasible.

AMENDED CLAIMS

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1. A tunable cylindrical antenna comprising:
an elongate substrate core;
a bandwidth adjustment sleeve disposed concentrically with the substrate core;
and
an elongate phase shift core disposed co-axially below the substrate core;
wherein a predetermined number of antenna patches are formed on a cylindrical surface of the substrate core and an equal number of parasitic antenna patches are formed on a cylindrical surface of the bandwidth adjustment sleeve such that the bandwidth adjustment sleeve and the substrate core are operable to be rotationally displaced so that the antenna characteristic is varied azimuthally during tuning.
2. A tunable antenna according to claim 1, wherein the substrate core comprises a core or sleeve and a support sleeve, said core or sleeve is made up of strips of two materials with different dielectric constants, with the strips being arranged in an alternate manner to form a cylindrical core or sleeve and the antenna patches are formed on the support sleeve.
3. A tunable antenna according to claim 2, further comprising an outer sleeve disposed concentric with the support sleeve, said outer sleeve comprises strips of two materials with different dielectric constants, with the strips being arranged in an alternate manner.
4. A tunable antenna according to claim 3, wherein the substrate core/sleeve and outer sleeve are rotatable in unison.
5. A tunable antenna according to claim 2 or 3, wherein the number of pairs of strips of different dielectric materials is equal to the predetermined number of patch antennas.
6. A tunable antenna according to any one of the preceding claims, wherein the phase shift core comprises a meandering line associated with each patch antenna.

7. A tunable antenna according to claim 6, wherein the phase shift core comprises a core and a meandering line support sleeve disposed concentric with the core, said core is made up of alternate strips of two dielectric materials such that the dielectric core and meandering line support sleeve are operable to be rotationally displaced so that the phase shift of the signal from the antenna is varied during tuning.
8. A tunable antenna according to claim 7, further comprising an outer sleeve disposed concentric with the meandering line support sleeve, with said outer sleeve being made up of alternate strips of two dielectric materials.
9. A tunable antenna according to claim 8, wherein the phase shift core/sleeve and outer sleeve is rotatable in unison.
10. A tunable antenna according to any one of claims 4-9, wherein the substrate outer sleeve or phase shift outer sleeve is rotatably displaceable by a gear-motor in relation to the relevant substrate core/sleeve or phase shift core/sleeve.
11. A tunable antenna comprising a series of elongate antennas according to any one of the preceding claims.
12. A diversity antenna comprising two or more spaced apart antennas according to any one of the preceding claims.