

OMNIDIRECTIONAL ANTENNA UTILIZING AN ASYMMETRICAL BICONE AS A PASSIVE FEED FOR A RADIATING ELEMENT

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TECHNICAL FIELD OF THE INVENTION

10 The present invention is directed to an omnidirectional antenna having a radiating element that is passively fed with electromagnetic signals by an asymmetrical-shaped pair of cones or discs. The invention is particularly well suited for low-profile antenna applications involving the transmission and reception of data in wireless local area networks.

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BACKGROUND OF THE INVENTION

Low profile antennas are desirable for use in in-building wireless local area network (WLAN) applications. However, it has been technically difficult to balance the requirements for high gain and
20 desirable antenna patterns for in-building communication applications when the antenna is limited to a physically small structure.

Antenna designers appreciate that antenna gain can be improved by placing the radiating element above a large, conductive surface, such as a ground plane. A large ground plane also can support
25 the desired shaping of an antenna pattern. Common design requirements for a ground plane of a low-profile antenna are a conductive material comprising a relatively large surface, typically greater than 5 wavelengths. This conductive material can comprise either a solid surface or a grid having holes of a diameter less than 0.1 wavelength.
30 Although an infinitely large ground plate provides a theoretically ideal conductive surface, conventional low-profile antenna designs often face "real estate" constraints. Consequently, low-profile antennas are often limited in their performance by a reduced ground plane size and the limited physical size of a radiating element within the practical
35 constraints of an indoor, workplace environment. For example, a dipole

antenna having a direct, active signal feed and constrained by a low-profile configuration can lack sufficient gain to support effective wireless communications in the high multipath environment of a typical indoor WLAN application.

In prior antenna designs, designers have achieved additional gain and desirable radiation patterns by the incorporation of stacked cone and/or disk elements as part of the antenna assembly. Conventional antenna designs have employed cone- or disk-shaped elements that operate in tandem to reflect electromagnetic energy in a manner similar to that of a horn antenna. Other prior antenna designs have used stacked biconical elements to form an array of radiating elements, typically fed by a central coaxial feed or a waveguide distribution network. For example, a discone antenna design has been implemented with stacked vertical, hollow conical elements to eliminate signal reflections and to improve antenna bandwidth. However, these prior antenna designs have not exhibited the physical characteristics required of a low-profile antenna application involving minimal available real estate.

In view of the foregoing, a need exists for a low-profile antenna system for WLAN applications that provides increased gain and more desirable radiation patterns than is possible with existing antenna designs.

SUMMARY OF THE INVENTION

In accordance with a first aspect of the present invention, there is provided an antenna assembly, comprising: a cone assembly comprising at least two structures of conductive material separated by a dielectric substance for generating electromagnetic signals, the cone assembly operative to passively feed the electromagnetic signals of the antenna assembly to an antenna element, the antenna element mounted to the cone assembly and operative to radiate the electromagnetic signals in response to passive feeding of the electromagnetic signals by the cone assembly; and a ground plane for increasing passive feeding of electromagnetic signals with the antenna.

In accordance with a second aspect of the present invention, there is provided an antenna system comprising: a network; a central computer linked to the network; a client computer linked to the network; and an access point for linking the client computer to the network, the access point comprising: an antenna assembly comprising: a cone assembly

comprising at least two structures of conductive material separated by a dielectric substance for generating electromagnetic signals, the cone assembly operative to passively feed the electromagnetic signals of the antenna assembly to an antenna element, the antenna element mounted to the cone assembly and operative to radiate the electromagnetic signals in response to passive feeding of the electromagnetic signals by the cone assembly; and a ground plane for increasing passive feeding of electromagnetic signals with the antenna.

Embodiments of the present invention seek to provide significant advantages over the prior art by providing a low-profile antenna to transmit radio frequency (RF) energy with high gain and desirable output patterns, typically for data transmission in an in-building, wireless local area network (WLAN). In general, embodiments of the present invention are directed to an antenna having an emitter element, such as a dipole, which passively receives a signal feed from a vertically stacked pair of asymmetrically-shaped cone elements. The cone elements or discs form a bicone assembly that is centrally fed by a coaxial cable input at a junction formed by an indirect coupling of the apex of each cone. This inventive antenna assembly can be mounted with a standard wall or ceiling-mounted

enclosure, with the low-profile antenna typically extending beneath a metallic enclosure cover that serves as a ground plane.

Embodiments of the present invention generally seek to provide a low-profile, omnidirectional antenna system, employing an asymmetrical bicone design with a passive feed for an emitter element, such as a dipole element. A feed signal can be delivered via a conventional coaxial cable, which centrally feeds a pair of stacked, conductive bicone elements mounted below the dipole element. The coaxial cable may be used to distribute electromagnetic energy from a source to the bicone elements, with the center conductor connected to the upper cone and the outer conductive sheath or mesh connected to the lower cone. The bicone elements, which are stacked within the vertical plane of the antenna, may be indirectly coupled at a common junction formed by an insulator mounted to the apex of each cone. One or more insulators also can be used to separate the combination of upper and lower stacked cones and a vertically-mounted dipole element. The dipole element may be supported within the vertical plane of the antenna by the upper cone. This configuration may result in a passive coupling of electromagnetic energy within the vertical plane of the antenna assembly and to the dipole element.

The bicone insulator, which is mounted between the upper and lower cones, can provide the sole mechanical support of the upper cone for one aspect of the present invention. In example embodiments of the present invention, the bicone insulator can comprise a threaded insulator of non-conductive material having an internal UNF 4-40 thread and an UNC 10-24 external thread. The female contact receptacle of the bicone insulator may accept the bottom tip of the upper cone and the male contact member may fit within an opening of the lower cone to form the common junction between the upper and lower cone elements. The bicone insulator may control the dielectric capacitance between the upper and lower cones. Because the center conductor of the coaxial feed cable passes through an opening in the bicone insulator and into the upper cone, this insulator may provide the dielectric loading of a low impedance coaxial transmission line. It will be appreciated that this combination of components for the inventive antenna can be assembled without tools and in the absence of any soldering of the central conductor of the feed

coaxial cable to the antenna itself. This may support a low cost implementation of a lower profile antenna for wireless communication applications, such as indoor applications.

In example embodiments of the present invention, the antenna can be used in connection with a ceiling-mounted enclosure housing a communications device. In this operating environment, the emitter element of the antenna is typically mounted perpendicular to a conductive enclosure cover operating as a conductive ground plane. Because the enclosure and its cover are typically mounted along the ceiling of an interior location, the mounted antenna may point downward toward the interior. The ground plane, which can be provided by a solid or grid-like surface of a metallic ceiling tile, is useful for increasing antenna gain and shaping the beam width within the elevation plane. In particular, the combination of a ceiling-mounted ground plane with the inventive passive feed network for an emitter or radiating element may result in an antenna exhibiting a decreased beam width within the elevation plane while exhibiting desirable downtilt beam characteristics. The resulting downtilt radiation pattern is particularly desirable in a ceiling-mounted WLAN application.

That embodiments of the invention seek to provide an antenna having a bicone assembly for passively coupling electromagnetic energy to and from a dipole element will become apparent from the following detailed description of the exemplary embodiments and the appended drawings and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustration showing an exploded representation of an assembly of an antenna for an exemplary embodiment of the present invention.

FIG. 2 is an illustration showing a side view of an assembled representation of the exemplary antenna shown in FIG. 1.

FIG. 3 is an illustration showing a cross-sectional view of an assembled representation of the exemplary antenna shown in FIG. 1.

FIG. 4 is an illustration showing an enlarged detail of a cross sectional-view of the exemplary antenna shown in FIG. 1.

FIG. 5A is an illustration showing an enlarged detail of a cross sectional-view of an antenna constructed in accordance with an alternative embodiment of the present invention.

5 FIG. 5B is an illustration showing an exploded view of an assembly of a pair of cones separated by a bicone insulator in accordance with an alternative embodiment of the present invention.

10 FIG. 6A is an illustration showing a cross sectional-view of a ceiling- or wall-mounted enclosure for a computing device connected to an antenna in accordance with a representative operating environment for an exemplary embodiment of the present invention.

FIG. 6B is an illustration showing a planar view of the representative antenna mounted for use in the operating environment shown in FIG. 6A.

15 FIG. 7 is an illustration showing a cross sectional-view of an antenna covered by a radome in accordance with an alternative operating environment of an exemplary embodiment of the present invention.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

20 The antenna of the present invention is primarily useful for transmitting and/or receiving radio frequency (RF) signals in applications, such as wireless local area computer networks (WLAN), where efficient, unobtrusive operation is desired. Although the inventive antenna can operate as a monopole without a ground plane, the preferred operating environment comprises the combination of an exemplary embodiment of
25 the antenna with a conductive ground plane. In its preferred application, the antenna assembly can be mounted on a conductive ground plane, such as a ceiling tile or grid. For a typical wall or ceiling-mounted antenna application, the conductive surface of the ground plane is typically provided by a custom or existing enclosure cover, such as the type
30 covering an HVAC vent or a speaker for an audio or paging system.

It will be appreciated that a ground plane is useful for increasing antenna gain or shaping the beam width within the elevation plane. In particular, the combination of the ground plane with the inventive antenna results in an antenna exhibiting a decreased beam width
35 within the elevation plane while exhibiting desirable downtilt beam

characteristics. When combined with a ground plane implemented by a conductive ceiling tile, the antenna is typically connected to a communications device mounted with the ceiling enclosure to support a WLAN. Consequently, the emitter element of the antenna typically
5 points downward toward the interior of a room when the antenna is mounted perpendicular to a ceiling tile operating as a conductive ground plane.

Exemplary embodiments of the invention will now be described with reference to the drawings, in which like numerals refer to
10 like elements throughout the several figures. FIG. 1 is an exploded view illustration showing the primary components of an exemplary embodiment of the antenna. FIGs. 2 and 3 show side and cross-sectional views of an assembled version of the antenna illustrated in FIG. 1. FIG. 4 shows a detailed view of a coaxial interface to the exemplary antenna,
15 including a coaxial cable input, a nonconductive adapter, a basal cone, an insulator, a receptacle pin, and an upper cone. Although transmission operations of the antenna are primarily explained below in connection with FIGs. 1-4, those skilled in the art will appreciate that the antenna is also capable of supporting receive operations based on the reciprocal flow
20 of electromagnetic signals for the antenna design. Consequently, the reference to a radiating or emitter element for the inventive antenna operating in support of transmission applications is also applicable to receive applications involving reception of electromagnetic signals by this antenna element.

As shown in FIGs. 1-2, an exemplary antenna 20 comprises
25 a basal cone 1, an upper cone 3, and a dipole element 5. The basal cone 1 and the upper cone 3 form a bicone element having a central junction formed by the apex of each cone and is fed electromagnetic energy by a transmission medium, such as a coaxial cable. An insulator 2 can be
30 placed at this central junction to physically separate each of the cones 1 and 3, thereby electrically isolating the conductive surfaces of the cones. An insulator provided by an adapter 4 connects the upper cone 3 to a vertically-mounted radiating element provided by the dipole element 5. The basal cone 1 preferably has a wide cone shape, whereas the upper
35 cone 3 preferably has a narrow cone shape. This preferred asymmetrical

configuration for the pair of cones 1 and 3 supports the passive coupling of electromagnetic energy to and from the dipole element 5 within the vertical plane of the antenna 20. The asymmetrical shape for the cone pair affects the input impedance at the central feed point located at the cone junction, while further supporting a relatively broad operational frequency range for the antenna 20, and increasing coupling to the dipole element 5.

The basal cone 1 is preferably implemented as a truncated, wide-based cone comprising aluminum or a similarly conductive material. A representative implementation of the basal cone 1 is hollow, with an open base and a flattened upper face which contains a central aperture. The insulator 2, also described as a bicone insulator, can be mounted to the exterior portion of the basal cone 1, typically at the central aperture of the cone. The basal cone 1 can be supported by a base insulator 7, which is useful for mounting the antenna 20 to the desired substrate structure.

The upper cone 3 is preferably an inverted, narrow-angled cone of solid aluminum, or similarly conductive metal. At the narrower, basal end of the upper cone 3 is a central recess sized to accommodate a pin receptacle 9. At the broader, opposite end of the upper cone 3 is a central recess sized to accommodate the formed base of a nonconductive, cylindrical adapter 4. The cylindrical adapter 4 connects the upper cone 3 to the rod-like, dipole element 5 within the vertical plane of the antenna 20. The dipole element 5 terminates with a plastic end cap 6, which is typically employed for safety reasons.

An electromagnetic signal can be carried by a transmission medium and delivered to a central junction located between the basal cone 1 and the upper cone 3. The insulator 2, which preferably has a low dielectric permittivity, is mounted at this junction between both the lower cone 1 and the upper cone 3. For the preferred embodiment, the transmission medium is implemented by a coaxial cable 8 comprising a center conductor 8a and an outer sheath 8b. A cylindrical adapter 10, which includes an opening extending throughout its length, is positioned within the hollow portion of the basal cone 1 and receives the coaxial cable 8. The adapter 10 establishes an electrical connection between the

outer conductive sheath 8b and the conductive interior surface of the basal cone 1. The coaxial cable conductor 8a extends through the length-wise opening of the cylindrical adapter 10 and protrudes through the central aperture in the upper surface of the basal cone 1. The central coaxial conductor 8a passes through a central opening in the insulator 2, which is positioned adjacent to the exterior portion of the aperture of the basal cone 1, and terminates at the conductive pin receptacle 9 positioned within a recess of the upper cone 3.

The basal cone 1 and the upper cone 3, which are separated by the insulator 2, operate in tandem to create an electromagnetic field within the vertical plane of the antenna assembly when a signal is actively fed to the bicone assembly. Specifically, electromagnetic energy is typically supplied to the upper cone 3 through the coaxial cable conductor 8a, which terminates in the pin receptacle 9 at the upper cone 3. The electromagnetic field created by the vertically-stacked array of the basal cone 1 and the upper cone 3 passively feeds the dipole element 5, which is vertically mounted above the cone array with the interposition of the insulating adapter 4. The central nature of the feed by the coaxial cable into a pair of cones, each having a symmetrical shape about their respective central axes, results in the coupling of electromagnetic energy to the dipole element 5 and the generation of an omnidirectional radiation pattern. This passive coupling of electromagnetic energy to (and from) the dipole element 5 ultimately yields a transmitted (received) signal by the dipole with significantly increased gain characteristics.

As shown in FIGs. 3 and 4, the coupling of the coaxial outer conductor or sheath to the interior portion of the basal cone 1 is accomplished by an interconnection with the adapter 10. In contrast, the central coaxial conductor 8a actively feeds the upper cone 3 by extending through openings in both the basal cone 1 and the insulator 2 to terminate in the pin receptacle 9, which is mounted within a recess of the apex of the upper cone 3. The insulator 2 isolates the conductive surface of the coaxial cable conductor 8a from the conductive surface of the basal cone 1. Similarly, the insulator 2 also physically separates the apex of the basal cone 1 from the apex of the upper cone 3, thereby isolating the conductive surfaces of this cone pair. A signal that is transmitted through

the coaxial cable conductor 8a to the antenna 20 provides a direct feed, exciting the upper cone 3 and creating a desirable electromagnetic field in the vertical plane of the upper cone 3 and the grounded basal cone 1. The insulator 2, which is interposed between the basal cone 1 and the upper cone 3, allows this electromagnetic field to build between the conical elements in a manner defined by the relative asymmetry of the basal cone 1 and the upper cone 3.

The insulator 2, alternatively described as the bicone insulator, preferably provides the sole mechanical support of the upper cone 3. For an exemplary embodiment, the insulator 2 comprises a shaped non-conductive material having an internal UNF 4-40 thread and an UNC 10-24 external thread. The top portion of the insulator 2 comprises a female contact receptacle that accepts the bottom tip of the upper cone 3 (and the pin receptacle 9). The bottom portion of the insulator 2 comprises a male contact member that can be inserted within the opening within the top flat surface of the basal cone 1. An opening extending along the length of the insulator 2 can accept the center conductor of the coaxial cable 8. This configuration for the insulator 2 controls the dielectric capacitance between the bicone elements 1 and 3 and forms a dielectric loading of a low impedance coaxial transmission line.

FIG. 5A shows an alternate embodiment of the antenna assembly for low-profile antenna applications. Referring to FIG. 5A, an antenna assembly 20' comprises a dipole element 5' having an open coil or spring-type configuration, instead of the linear rod configuration for the dipole element 5 shown in FIGs. 1-4. This open coil design provides more durability for certain exposed antenna applications, while satisfying the requirement for conserving available "real estate" for an antenna in a low-profile operating environment. Similar to the antenna 20, the dipole element 5' is coupled to the upper cone 3 via the insulating adapter 4 and can include the plastic end cap 6 at the opposite end, the terminating point of the coil. The opposite end of the upper cone 3 is indirectly connected to the apex of the base cone 1 via the insulator 2. The insulator 2 electrically isolates the conductive surfaces of the cones while supporting the stacking of these cones within the vertical plane of the antenna

assembly 20'. The pair of asymmetrical-shaped cones 1 and 3 can passively couple electromagnetic energy to and from the dipole element 5' in a manner similar to that described above with respect to the antenna 20. In this manner, the dipole element 5' can support both transmission and reception operations for the antenna assembly 20'.

FIG. 5B provides an illustration of an exploded view of an assembly of bicone elements separated by an insulator in accordance with an alternative exemplary embodiment of the inventive antenna. Focusing upon the junction formed by the insulator 2' placed between the lower and upper cones 1' and 3', the center conductor 8a passes through the lower cone 1', the insulator 2', and into a receptacle of the upper cone 3'. The center conductor 8a can be connected to the upper cone 3' by adjusting a set screw 16 located along one side of the upper cone 3' and proximate to the cone receptacle that accepts the center conductor. In this manner, the center conductor 8a is connected to the upper cone 3' without the use of a solder connection. The set screw is inserted within a threader receptacle along a side of the upper cone 3' and can be adjusted by manually turning the set screw within the threaded receptacle. This solderless section of the center conductor 8a to the upper cone 3' supports a low cost assembly of the antenna without a need for tools.

FIGs. 6A and 6B show an antenna assembly mounted for operation in a typical operating environment of a WLAN, *i.e.*, a ceiling tile (or wall) mounting within the interior of a facility having one or more wireless network access points that communicate with a central computer via the wireless communications network. This operating environment and the ceiling/wall tile mounting and associated enclosure for a communication device, such as a wireless network access point, is described in detail in U.S. Patent Application Serial No. 09/092,621, filed on June 5, 1998, which is assigned to the assignee of the present application and is fully incorporated herein by reference. For example, a wireless network access point can be enclosed within an ceiling- or wall-mounted enclosure in an interior building structure. The antenna for this wireless network access point can be provided by the antenna assembly 20 shown in FIGs. 1-4 or the antenna assembly 20' of FIG. 5A. This antenna can be mounted to a receptacle, located in either the cover of the

enclosure or within the enclosure itself, and typically extends into the room environment. Consequently, the low-profile characteristics of the antenna assemblies 20 and 20' are particularly well suited for this wireless communication application.

5 Referring to FIGs. 6A and 6B, for a representative ceiling-mount configuration, the stacked antenna assembly is centrally mounted over the conductive surface of a ceiling tile 14, which is welded to a mounting frame 13 of an enclosure that fits within a conventional ceiling tile grid 12. This enclosure typically houses a computing device, such as
10 a wireless network access point, connected to an antenna to support wireless communications, such as WLAN applications. An antenna assembly 11, which can be implemented by either the antenna assembly 20 shown in FIGs. 1-4 or the antenna assembly 20' in FIG. 5, is mounted vertically, pointing down from its ceiling location along the ceiling tile
15 14. The antenna assembly 20 can be mounted directly to the exterior portion of the ceiling tile 14 or, in the alternative, this antenna can be mounted within the enclosure and extend through an aperture within the ceiling tile 14. For example, a coaxial cable, connected to the computing device mounted within the enclosure, can enter through an aperture in the
20 ceiling tile 14 to centrally feed the antenna assembly 11.

When the antenna assembly 11 is mounted over the conductive surface of the ceiling tile 14, the larger ground plane afforded by the metal tile surface produces a stronger electromagnetic field. This results in a stronger passive coupling of electromagnetic energy within
25 the vertical plane to the dipole element 5 (or the dipole element 5'). The enhanced signal quality which ultimately results, along with the unobtrusive nature of the ceiling mounting in an indoor workplace setting, provide significant advantages for exemplary embodiments of the present invention over existing antenna alternatives in WLAN applications.

30 FIG. 7 shows an alternative embodiment of a ceiling-mounted antenna installed within a protective radome. As shown in FIG. 7, the antenna assembly 20 (or the antenna assembly 20') can be housed within a radome 15 to protect the antenna components from exposure to the operating environment. The shape of the non-conductive surface of
35 the radome 15 may be varied to best fit the shape of the antenna 20 and

the aesthetic considerations of the particular application. The radome 15 preferably comprises a material that is substantially transparent to radio frequency signals that are transmitted and received by the antenna assembly housed within the radome.

- 5 In view of the foregoing, it will be appreciated that the invention provides an antenna assembly including a cone assembly for passively coupling electromagnetic signals to and from an antenna element. It should be understood that the foregoing relates only to the exemplary embodiments of the present invention, and that numerous
10 changes may be made therein without departing from the spirit and scope of the invention as defined by the following claims.

CLAIMS

The invention claimed is:

- 5 1. An antenna assembly, comprising:
 a cone assembly comprising at least two structures of conductive
 material separated by a dielectric substance for generating electromagnetic
 signals, the cone assembly operative to passively feed the electromagnetic
10 signals of the antenna assembly to an antenna element, the antenna element
 mounted to the cone assembly and operative to radiate the electromagnetic
 signals in response to passive feeding of the electromagnetic signals by the cone
 assembly; and
 a ground plane for increasing passive feeding of electromagnetic signals
 with the antenna.
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2. The antenna assembly of claim 1, wherein the two structures form a bicone
 having a basal cone of conductive material and an upper cone of conductive material.
3. The antenna assembly of claim 1, wherein the ground plane comprises a
20 conductive surface of a ceiling tile.
4. The antenna assembly of claim 1, wherein the ground plane comprises a
 conductive surface of a wall.
- 25 5. The antenna assembly of claim 1, wherein the ground plane comprises a grid.
6. The antenna assembly of claim 5, wherein one of the conductive structures
 further comprises a set screw.

7. The antenna assembly of claim 5, wherein the antenna assembly is mounted within a ceiling enclosure.
8. The antenna assembly of claim 5, wherein the antenna assembly is mounted within a wall enclosure.
9. The antenna assembly of claim 1, wherein the ground plane comprises an enclosure cover.
10. The antenna assembly of claim 9, wherein the enclosure cover comprises an HVAC enclosure cover.
11. The antenna assembly of claim 9, wherein the enclosure cover comprises a cover for a speaker of an audio system.
12. An antenna system comprising:
a network;
a central computer linked to the network;
a client computer linked to the network; and an access point for linking the client computer to the network, the access point comprising:
an antenna assembly comprising:
a cone assembly comprising at least two structures of conductive material separated by a dielectric substance for generating electromagnetic signals, the cone assembly operative to passively feed the electromagnetic signals of the antenna assembly to an antenna element, the antenna element mounted to the cone assembly and operative to radiate the electromagnetic signals in response to passive feeding of the electromagnetic signals by the cone assembly; and

a ground plane for increasing passive feeding of
electromagnetic signals with the antenna.

13. The antenna system of claim 12, wherein the access point further comprises a
5 communications device.

14. The antenna system of claim 12, wherein the two structures of the antenna
assembly form a bicone having a basal cone of conductive material and an upper cone
of conductive material.

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15. The antenna system of claim 12, wherein the ground plane comprises a
conductive surface of a ceiling tile.

16. The antenna system of claim 12, wherein the ground plane comprises a
15 conductive surface of a wall.

17. The antenna system of claim 12, wherein the ground plane comprises a grid.

18. The antenna system of claim 12, wherein the network comprises a local area
20 network.

OMNIDIRECTIONAL ANTENNA UTILIZING AN ASYMMETRICAL BICONE AS A PASSIVE FEED FOR A RADIATING ELEMENT

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Abstract

10 An antenna assembly comprising a radiating element which passively receives a signal fed by a vertically-stacked pair of asymmetrically-shaped, conductive cone elements mounted below the radiating element. The cone elements are centrally fed by a coaxial cable input at a common junction formed the apex of each cone element. This antenna assembly provides a low-profile antenna to transmit and receive radio frequency (RF) energy with high gain and desirable antenna patterns for data transmission in an in-building, wireless local area network.

15 The antenna assembly can be mounted in a standard ceiling or wall-mounted enclosure, with the low-profile antenna extending beneath the surface of a conductive enclosure cover that serves as the ground plane for the antenna element. This configuration achieves high antenna gain with a downtilt-beam, omnidirectional radiation pattern, which is highly desirable in an in-building

20 wireless local area network (WLAN) application.

Figure 1