(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
17 July 2003 (17.07.2003)

PCT

(10) International Publication Number
WO 03/058850 A2

(51) International Patent Classification[7]: H04B 7/155

(21) International Application Number: PCT/BE03/00002

(22) International Filing Date: 6 January 2003 (06.01.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
0200238.4 7 January 2002 (07.01.2002) GB

(71) Applicants *(for all designated States except US)*: **LORANET NV** [BE/BE]; Kapeldreef 75, B-3001 Leuven (BE). **INTERUNIVERSITAIR MICROELEKTRONICA CENTRUM VZW** [BE/BE]; Kapeldreef 75, B-3001 Leuven (BE).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **ENGELS, Marc** [BE/BE]; Rotselaarsesteenweg 118, B-3018 Wijgmaal (BE). **ERREYGERS, Jan, Jozef, Julia, Maria** [BE/BE]; Optielt 15, B-3390 Tielt-Winge (BE). **HASPESLAGH, Johan, Joseph, Gustaaf** [BE/BE]; Bovenstraat 16, B-3210 Lubbeek (BE). **OP'T EYNDE, Frank** [BE/BE]; Berg-Bogaertlaan 6, B-3012 Wilsele (BE).

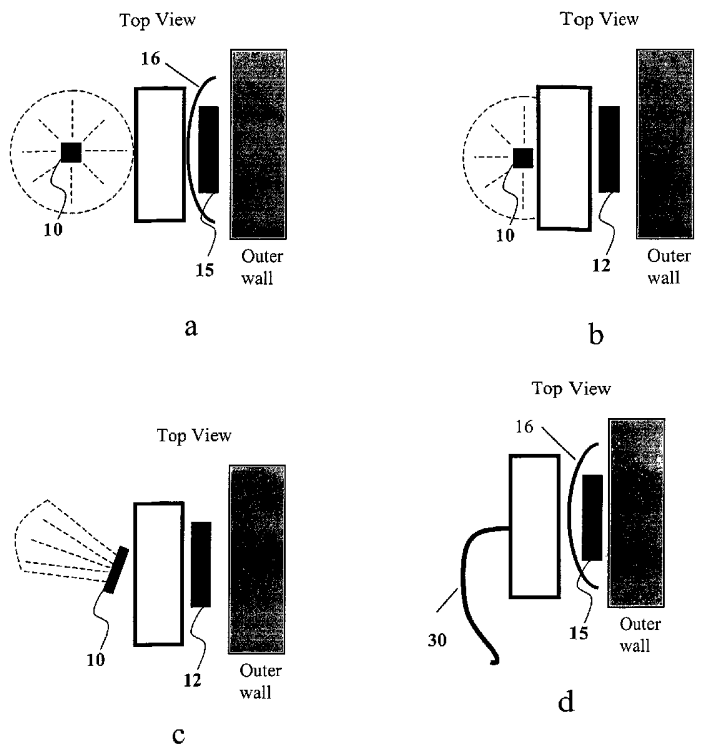
(74) Agents: **BIRD, William, E.** et al.; Bird Goën & Co, Klein Dalenstraat 42A, B-3020 Winksele (BE).

(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

[Continued on next page]

(54) Title: DEVICE AND METHOD FOR IMPROVING WIRELESS OUTDOOR-TO-INDOOR DIGITAL COMMUNICATION



(57) Abstract: An indoor to outdoor unit is described for placement outside of a building and adjacent to a structural part of the building. The unit has first antenna means (12) for communication with at least one indoor antenna (13) placed inside said building, the first antenna means having a reflector for reflecting radio signals towards the inside of the building. For instance, the first antenna means may be adapted to be located with respect to a wall of the building in such a way that a part of the wall is situated in the near-field region of the first antenna means. The first antenna means may be adapted for connection to a cable network. Alternatively; the unit may also have a second antenna means (10) for communication with at least one outdoor antenna (9) located outside the building. The first and second antenna means are adapted for attachment to or located in a housing. In operation some signals received by the second antenna means (10) from the one outdoor antenna (9) are transmitted to the first antenna means (12) and some signals transmitted from the second antenna means (10) to the one outdoor antenna (9) are received from the first antenna means (12) so that the unit acts as a repeater.

WO 03/058850 A2

Declaration under Rule 4.17:
— *of inventorship (Rule 4.17(iv)) for US only*

Published:
— *without international search report and to be republished upon receipt of that report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

DEVICE AND METHOD FOR IMPROVING WIRELESS OUTDOOR-TO-INDOOR DIGITAL COMMUNICATION

The present invention is related to communications via a radio channel, in particular to a wireless radio telecommunications system, an indoor-outdoor coupling device for coupling between a telecommunications network, such as a wireless or cable network and an indoor wireless network, especially a LAN, and a method for providing improved communications between the inside and outside of a building.

Technical Background

With reference to Fig. 1 electromagnetic signals transmitted by a transmitting antenna (1) suffer from severe attenuation, before arriving at the receiving antenna (2). As a result, the Signal Power received by the receiving antenna is much less than the Signal Power transmitted by the transmitting antenna. The greater the distance between the two antennas, the larger this attenuation. When the radio signal has to pass through obstacles such as walls, tree leaves, rain drops, fog or snow, or enter enclosures such as buildings the signal attenuation can be even larger.

When the direct line-of-sight between transmitting antenna and receiving antenna is obstructed, e.g. by buildings (see Fig. 2), radio communication might still be possible because reflected electromagnetic signals (3) might still arrive at the receiving antenna. However, under such circumstances, the signal attenuation will be considerably larger and may be delayed, compared with the case of a direct line-of-sight.

This signal attenuation has an impact on the capacity of the communication: the smaller the signal arriving at the receiving antenna, the less information bits can be sent over the communication link. This can be expressed with the following equations:

$$R \le BW \cdot \log_2\left(1 + \frac{Received\_Signal\_Power}{Received\_Noise\_Power}\right) \qquad \text{Eq. 1}$$

$$R \le BW \cdot \log_2\left(1 + \frac{Transmitted\_Signal\_Power / Attenuation}{Received\_Noise\_Power}\right) \qquad \text{Eq. 2}$$

where R is the bitrate (number of transmitted information bits per second) capacity of the radio link (measured in "bits/sec"), and BW is the bandwidth of the radio signal (measured in "Hz"). For a given bandwidth BW, R increases with the *Received Signal Power*, or, in other words, R decreases with the signal attenuation between transmitting and receiving antenna. Therefore the capacity of the radio link is negatively impacted by the distance between the transmitting and receiving antennas. This relationship between distance and capacity becomes worse when the radio signal has to pass through obstacles such as walls, tree leafs, rain drops, fog or snow, or when the direct line-of-sight between the two antennas is obstructed. In other words, for a given R, BW and *Transmitted Signal Power*, equation 2 yields a maximum signal attenuation, and hence a maximum distance between the two antennas.

A known solution to this problem is the insertion of a repeater in the radio link, as depicted in Fig. 3: the information is first transmitted from the transmitting antenna (1) to an auxiliary receiving antenna (4) associated with the repeater. In a second step, the repeater amplifies the received signal and re-transmits it from an auxiliary transmitting antenna (5) associated with the repeater, to the receiving antenna (2). The resulting capacity of the link is then given by expression 3:

$$R \leq BW \cdot \log_2\left(1+\frac{Transmitted\_Signal\_Power * gain \big/ Attenuation1 * Attenuation2}{\mathrm{Re}ceived\_Noise\_Power1 * gain + \mathrm{Re}ceived\_Noise\_Power2}\right)$$

Eq. 3

where *gain* is the signal gain of the repeater, and *Attenuation 1* and *Attenuation 2* are the signal attenuations over the two radio links, respectively.

The goal of the repeater is to satisfy expression 3 for those cases where a direct communication from (1) to (2) would suffer from too large a signal attenuation. A potential problem of the repeater is the fact that it generates a delayed and amplified version of the original signal. This signal might interfere with the original signal, causing fading and inter-symbol interference (ISI).

An indoor-to-outdoor communication (or vice-versa), is depicted in Fig. 4. In this situation, the radio signal is impacted by the attenuation due to the distance (6) between the outdoor antenna and the outer wall of a building, by the attenuation due to the passage through the outer wall of the building (7), and by the attenuation due to the signal propagation inside the building (8). US 5,604,789 and UWO 01/30003 both propose communicating between an outside antenna, e.g. of a base station or a repeater and an indoor antenna unit. However, these suffer from the wall antenuation of the signal thus requiring high power outdoor transmitters and/or arranging the repeater to be close to buildings. In the article "A new radio access strategy using a repeater in the DECT radio local loop application" by Bonzano L., De-Benedittis R., Palestini V., Rosina G., Proceedings of 1994 3rd IEEE International Conference on Universal Personal Communications, San Diego, CA, USA, 27 Sept.-1 Oct. 1994 various simulations are described to compare performance of radio communications between outdoor and indoor environments in a radio local loop application. To overcome the propagation problems due to additional wall attenuation and to offer a suitable indoor coverage, a repeater function is presented as a viable solution. For this purpose a non-wireless through-the-wall repeater is proposed. Similar designs are proposed in US 5,912,641 and US 5,765,099. However, such a design requires providing a non-wireless link through a wall or other part of the building structure.

Summary of the Invention

It is an objective of the present invention to provide improved wireless communications devices and methods for communicating between an indoor and an outdoor environment.

In one aspect of the present invention an indoor to outdoor unit is provided for placement adjacent to a structural part of the building such as a wall, comprising: first antenna means being for wireless communication with at least one indoor antenna placed inside said building, the first antenna means preferably having a reflector for reflecting radio signals towards the inside of the building.

The present invention also provides a wireless or radio signal indoor to outdoor unit wherein second antenna means is for communication with at least one outdoor antenna placed outside the building, and that the first antenna means is for communicating with the at least one indoor antenna placed inside said building. The first and second antenna means are preferably contained in or attached to a housing which may be fixed to a wall of the building or otherwise attached close thereto. The main communication between the first and second antenna means is preferably not by a wireless path. The second antenna means may also be a directional antenna. The direction to which the second antenna means transmits and receives radio signals may be determined by various means, e.g. by means for selection between *n* antenna elements, pointed to different directions, by moving an antenna or by beamforming. The second antenna means may also be automatically pointed by means of a mechanical moving device (e.g. a motor). The second antenna means may be substantially a flat antenna (e.g. a patch antenna) or a combination of substantially flat antenna elements. The indoor-outdoor unit is preferably placed outside the building, near the outer wall, e.g. attached to an outer wall. Different protocols may be used for the indoor and outdoor communications. For example, the indoor radio communication may be a Wireless LAN protocol. The outdoor radio communication may use a Wireless MAN protocol or a BFWA protocol, for example. The indoor and outdoor communication paths may be parts of different communications networks.

It is also within the scope of the present invention that the indoor and outdoor communication paths are part of identical networks.

In another aspect, the present invention provides a method of communicating over an extended distance by transmitting signals in a multipath tolerant format to a repeater that amplifies the signal and re-transmits it in the same format. The repeater preferably has a first and a second antenna, there being a cross-coupling path between the first and second antenna, whereby a gain of the amplification is such that the loop gain of the communication path formed by the first antenna, an amplifier and the second antenna and the cross-coupling path is lower than one. The repeater may also comprise means for cancelling a signal received at the first or second antenna over a cross-coupling path from a signal transmitted from the second or first antenna, respectively, such that that a loop gain of the communication path formed by the first antenna, the means for cancelling, the amplifier and the second antenna and the cross-coupling path is lower than one. Examples of a multipath tolerant format are OFDM or DMT signal with a cyclic prefix and a time modulated signal with a cyclic prefix. The use of a multipath tolerant format allows a repeater having a lower gain than would otherwise be required to reduce cross-coupling problems at the repeater. If a transmission is not in a multipath tolerant format, a remote terminal receiving the original signal may consider this as noise compared to the received amplified signal from the repeater. Thus, a higher level of amplification is required at the repeater to maintain a particular signal to noise ratio. By using a multipath tolerant format for the radio signals the remote terminal can combine both the original signal and the amplified signal and thus obtain a better received signal quality. Accordingly, the amplification at the repeater may be reduced to obtain a certain signal quality at the remote terminal. The reduction in amplification required, reduces the cost of the indoor-outdoor unit. The indoor antenna may be included in a handheld mobile device, for example, although the present invention is not limited thereto, e.g. it may be a fixed indoor antenna, e.g. an access point or bridge of a wireless LAN.

In another aspect of the present invention an antenna is provided, aimed at establishing a wireless communication with devices placed inside a building, whereby the antenna is placed close to the outer wall on the outside of the building, in such a way that a part of this wall is situated in the near-field region of the antenna. Since the global effect of all three attenuations (6) to (8) has to satisfy equation 2, the isolated effect of attenuation (6) can be reduced by the location of the antenna with a maximum distance between the outdoor antenna and the outer wall being small. This antenna is placed substantially parallel to the wall. The antenna preferably has a reflector to reflect radio signals towards the inside of the building.

In another aspect of the present invention the indoor-outdoor unit is adapted to automatically switch to another outdoor antenna when communications with the first outdoor antenna are impaired.

The present invention will now be described with reference to the following drawings.

Brief Description of the Drawings

In the figures, the same reference numbers in different figures refer to components having similar function unless otherwise stated.

Fig. 1 shows a radio communications channel in side view.

Fig. 2 shows a radio communications channel with obstruction in side view.

Fig. 3 shows a radio communications channel with repeater in side view.

Fig. 4 shows an indoor-outdoor radio communications channel in side view.

Fig. 5 shows an indoor-outdoor radio communications channel with an indoor-outdoor unit in accordance with one embodiment of the present invention in side view.

Figs. 6a to d show schematic top views further embodiments of an indoor-outdoor unit according to the present invention.

Fig. 7 shows a schematic top view of a further embodiment of the present invention comprising an antenna directed away from a building consisting of *n* (here: 6) directive elements.

Fig. 8 shows a schematic top view of a further embodiment of the present invention comprising an antenna directed towards the inside of a building having a beamwidth covering a half-sphere.

Fig. 9 shows schematic top and side views of a single unit housing for an indoor-outdoor unit in accordance with an embodiment of the present invention.

Fig. 10 shows a multipath tolerant modulation format for radio signals.

Fig. 11 shows an embodiment of an indoor-outdoor unit in accordance with an embodiment of the present invention.

Definitions

Multi-path tolerant format: refers to the use of a digital data stream with guard gaps. When a digital radio signal is sent through a dispersive channel the digital signals are spread/delayed such as to cause inter-symbol interference (ISI). By using guard gaps between digital data blocks the spread or delay of the signal is into the guard gap and less into neighbouring data blocks. Thus, ISI is reduced. The disadvantage is that the data rate is lowered. A preferred type of guard gap is a cyclic prefix, i.e. a copy of the end of a digital data block is added before the data block

Antenna gain: G generally refers to the power gain which is the ratio of the radiation intensity of an antenna compared with that of an isotropic antenna. Manufacturers usually refer to a single value of G which is then the maximum value. The gain is the product of the directivity and the efficiency.

Directional antenna has antenna gain in the azimuth plane, i.e. there is one or more gain maxima in one or more directions in the azimuth plane. The 3dB beam width in the azimuth plane is less than 180°.

Variable direction antenna is an antenna in which the direction of maximum gain can be changed during operation. An adaptive antenna is a form of variable direction antenna.

For further details on antennas for wireless communications reference is made to

"Antennas and Propagation for wireless communication systems", S. R. Saunders, Wiley, 1999. For further details on methods of operating cellular wireless systems and the use of repeaters to extend wireless networks, reference is made to "The Cellular Radio Handbook", third edition, N. J. Boucher, Quantum Publishing, 1995, especially, chapters 10, 11 and 12.

Description of the Illustrated Embodiments

The present invention will be described with reference to certain drawings and embodiments but these are provided by way of example only. The present invention may have wide application as indicated by the attached claims. The present invention relates to communication between indoor and outdoor environments, especially making use of wireless radio telecommunication networks. The access method for the telecommunications networks is not considered a limitation on the present invention, e.g. whether CDMA, FDMA, TDMA, CDMA-FDMA, CDMA-FDMA-TDMA, FDMA-TDMA or whether spread spectrum techniques are used such as frequency hopping or direct sequence spread spectrum.

A first aspect of the present invention provides a solution for indoor coverage for a wireless radio communications network by placing an indoor to outdoor coupling unit (10, 12) outside a structural part of a building such as the outer wall of the building, as shown in Fig. 5. To place the unit it is preferably portable, e.g. has a housing to which the antennas are attached or wherein they are included, as well as any electronics placed within the housing in a suitable sealed compartment required to control the environment inside the unit. The portable unit may be brought to site as a kit of parts that are there assembled and installed at the appropriate location. The unit may be battery powered or may have a suitable power connection, e.g. for connection to the mains or an optional solar cell battery charging system for keeping the batteries charged up. The indoor-outdoor device is preferably in the form of a self-contained unit that does not require an opening in the wall of the building, i.e. does not have two parts: an indoor antenna and an outdoor antenna with a connection there between which must pass through the wall.

A first communication (11) is established between a first antenna means (12) associated with the indoor to outdoor unit and an indoor antenna means (13). A second radio communication (6) is established between an outdoor antenna means (9) and a second antenna means (10) associated with the indoor to outdoor unit. The radiation of the first antenna means (12) should reach as much as possible the inside of the building. When the radiation of the first antenna means (12) that reaches the wall a fraction of the radiation will be transmitted through the wall, another fraction of the radiation will be absorbed by the material of the wall and the rest of the radiation will be reflected by the wall. Literature data typically cite an attenuation of 10-15 dB for microwave radiation that passes through a wall. However, experiments have shown that only a small fraction of the radiation is actually absorbed by the material of the wall. The largest part of the radiation is reflected and does not enter the building. In accordance with an embodiment of the present invention this problem can be overcome by adding a reflector to the first antenna means. The radiation transmitted by the first antenna means either reaches the wall or the reflector. The radiation that reaches the reflector will be reflected towards the wall. Radiation that is reflected by the wall, reaches the reflector and is reflected back towards the wall. Each time the radiation reaches the wall, a fraction will be transmitted through the wall. After multiple reflections of the radiation between the reflector and the wall, a large fraction of the radiation will have been transmitted through the wall because the absorption of the radiation by the wall is limited. In one embodiment the first antenna means (12) is a combination of an omnidirectional or directional antenna (15) with a reflector (16) that reflects the radiation from the antenna towards the house (see Fig. 6a, 6d as well as item 17 of Fig. 9). In another embodiment the first antenna means (12) is an antenna having a 3dB bandwidth over less than a certain angle in the azimuth plane, e.g. of 180° (half-sphere) or less, radiating towards the inside the building (see Fig. 8) combined with a reflector. In a particular embodiment of the invention this first antenna means (12) is a flat antenna (e.g. a patch antenna), placed parallel to the outer wall combined with a reflector.

It is of importance that the first antenna means are placed sufficiently close to the outside wall of the building. If the first antenna means are too far away from the wall, radiation reflected by the wall may escape between the wall and the reflector. This would reduce the fraction of the radiation that reaches the inside of the building. Preferably the distance between the first antenna means and the wall is less than a few wavelengths of the radiation such that the wall is in the near field region of the first antenna means. For example, the distance may be less than five wavelengths.

Another aspect of the invention is that the first antenna means (12) improves the coverage of a wireless network in a building over different floors. It is known e.g. for wireless LAN systems that when the access point is installed in a building, the coverage is generally limited to the floor on which the access point is installed. The reason is that the materials between different floors often consist of reinforced concrete such that the reinforcement of the concrete acts as an efficient reflector of electromagnetic radiation. When the first antenna means is installed outside the building, close to the outer wall, the radiation that enters the wall is also internally reflected in the wall. In this way the radiation effectively travels inside the wall. At each reflection a fraction of the radiation also leaves the wall. The wall acts in this way as a spreader of the radiation. This spreading effect is even more pronounced when the outside wall is a cavity wall because the fraction of the radiation absorbed in the cavity is very low. Therefore in a particular embodiment, the indoor-outdoor unit does not contain the second antenna means and the sole purpose of the unit is to act as a relay for wireless communications between different floors of a building.

Generally the second antenna means (10) of the indoor to outdoor coupling unit can be a) an omnidirectional antenna (10, Fig. 6a), b) a directive antenna (10) having a 3dB bandwidth over a limited angle in the azimuth plane, e.g. a half-sphere, and directed towards the outside of the building (Fig. 6b), or c) a directional antenna (10) having a 3dB bandwidth angle less than 180°, e.g. 60° or 90°, pointed to the outdoor antenna (Fig. 6c). In the latter case, due to the larger antenna gain, a higher signal attenuation can be accommodated and the length of the transmission path (6) can be larger. However, such a directional antenna needs usually to be pointed towards the outdoor antenna (9), e.g. manually. Alternatively, the second antenna means may be replaced by connection (30) to a cable network such as an optical fibre cable, a coax cable, a twisted pair cable or similar (Fig. 6d).

Another aspect of the present invention is a solution to eliminate manual pointing requirement for the second antenna means. In an embodiment the second antenna means (10) consists of n directional antenna elements with fixed positions, each pointed to a different direction. This is shown in Fig. 7. With a selection device, the antenna element yielding the best performance can be selected. In another embodiment the second antenna means is pointed by electronic means such as e.g. beamforming. In another embodiment the second antenna means (10) is comprised of a moveable antenna, that is being pointed automatically toward the outdoor antenna (9) by means of a mechanical moving device, such as a motor. When the indoor-outdoor device is being installed by the customer at his house, there is a large probability that there is no direct Line-of-Sight between the second antenna means (10) of the indoor-outdoor unit and the outdoor antenna (9). Therefore the signals receive from the outdoor antenna are very likely to contain a significant portion of multipath radiation components. Therefore the *n* sectors covered by the *n* antenna elements should be sufficiently overlapping in order to be optimized for the reception of signals that contain a significant portion of multipath radiation components. In order to receive signals with significant multipath, the second antenna means should have preferably a beam width of at least 30 degrees with the main lobe of the antenna pattern oriented towards the transmitting antenna (9). Therefore the 3 dB beamwidth of the directional antenna element should preferably extend at least 15 degrees further than the maximum pointing error. As this is required for each directional antenna element, it follows that the overlap of the 3 dB beamwidth coverage angles of two directional antenna elements that cover adjacent angles, has to be at least 30 degrees. An advantage is that the indoor-outdoor unit can be installed by the customer without having to pay a lot of attention to the exact orientation of the antennas. The indoor-outdoor unit has to be installed against a wall from which it has a 180 degree "viewing" angle. The transmitting station has to be within the 180 degree angle. In a particular embodiment of the invention, the first second means (10), or its *n* elements, are flat antennas (e.g. patch antennas). Alternatively, it can be a beamformer.

Another aspect of the invention covers the integration of parts of the first and second antenna means. As described above in a particular embodiment the second antenna means consists of n directional patch antennas. A patch antenna is an at least two layered structure with a ground plane and a particularly shaped patch. In a particular embodiment the ground plane 17(Fig. 9) of the n directional patch antenna elements serves as the reflector part of the first antenna means. This integration step has several advantages. Firstly less material is used because no extra material is required to construct the reflector of the first antenna means. Secondly the physical dimensions of the indoor-outdoor unit are reduced because of the physical integration of the two antenna means.

For large scale deployments of wireless networks to be economically feasible, it is required that the customer premise equipment, e.g. an indoor-outdoor unit, is installed by the customer. Therefore, the unit is preferably not complex and preferably should not have different elements which require careful assembly. Therefore, another aspect of the present invention is the integration of the first antenna means and the second antenna means into one single housing (Fig. 9). The indoor-outdoor communication device becomes one physical unit (14) that is easy to install by the customer at the customer's premises.

The indoor-outdoor coupling unit can be used for coupling an indoor network with a different outdoor network or for overcoming the transmission impairments introduced by walls in networks where equipment inside buildings belongs to the same network as outdoor equipment. In a preferred first aspect the indoor and outdoor communication channels (6, 11) are part of different networks or use different protocols or are otherwise so arranged that they are not mutually interfering. The indoor to outdoor unit then translates, for example, the indoor communication protocol to the outdoor communication protocol and vice versa. In particular embodiments of the invention the indoor communication channel (11) is part of a Wireless Local Area Network (WLAN), or uses a WLAN protocol such as e.g. IEEE 802.11a, IEEE 802.11b, IEEE 802.11g, HIPERLAN1 or HIPERLAN2. The outdoor communication channel (6) is part of a Wireless Metropolitan Area Network (WMAN), a Wireless Wide Area Network (WWAN) or a Broadband Fixed Wireless Access (BFWA) network, or uses a WMAN, WWAN or BFWA protocol such as IEEE 802.16, IEEE 802.16a, HIPERACCESS or HIPERMAN.

In a second aspect the indoor and outdoor communication channels (6, 11) are part of the same network (e.g. WLAN, WMAN, WWAN or BFWA) or use the same protocol. The indoor to outdoor unit then acts as a repeater that amplifies the received signal and re-transmits it. In particular embodiments of the repeater, the amplification can be combined with a frequency shift and/or a demodulation and re-modulation operation. An example of such a unit is shown schematically in Fig. 11, in which the second antenna means 10 is connected to a first radio unit 1. Details of filters and other radio components are not shown. Similarly, the first antenna means 12 is connected to a second radio unit 2. Modulator/demodulator units 21, 23, respectively modulate/demodulate the respective signals. A processing unit 22 is provided to carry out processing on the signal, e.g. to change format, protocol or similar.

Another aspect of the invention solves fading and inter-symbol inference caused by the indoor-outdoor unit operating as a repeater that preferably provides only pure amplification of the signal. It does so by combining the repeater with a multipath tolerant modulation format (see Fig. 10). Such a modulation format consists, for example, of blocks of data for which the last L values (14) are identical to the first L values (13). Various embodiments of such multipath tolerant modulation formats exist. When a repeater is amplifying signals that are not in a multipath tolerant modulation format, the receiving device will receive the original signal, transmitted e.g. by a base station as interference. Therefore, such a repeater has to provide sufficient gain such that the amplified signal is strong enough compared to the original signal in order to have a sufficient signal-to-interference-and-noise ratio at the receiving device. A high gain may cause stability problems because of cross-coupling between the transmitting and receiving antenna of the repeater. When a multipath tolerant modulation format is used, the receiving device will treat the original signal as multipath components of the amplified signal. The use of the mulitpath tolerant modulation format provides at least two advantages. Firstly, the repeater is not required to have a high gain because the original signal is not received as noise. This makes even repeaters with gains of 5, 10 or 15 dB useful. Secondly, the energy of the radiation of the original signal is still useful for the receiving device. A particular embodiment of a multipath tolerant modulation format is an OFDM or a DMT signal with cyclic prefix. OFDM systems are described in "OFDM for Wireless Multimedia Communications", by R. van Nee and R. Prasad, Artech House 2000, and in “Wireless OFDM Systems”, by M. Engels [Ed.], Kluwer Academic Publishers, 2002. In such a system a block of data inputs is modulated and distributed over various carriers in the frequency domain. Next the frequency domain signal is transformed by a block of samples in the time domain. And finally, the last L samples of this time domain block are copied and prepended to the time domain block. Another embodiment of a multipath tolerant modulation format is a time domain signal with cyclic prefix. In this embodiment, a block of data is first modulated in the time domain, Next, the last L samples of this time domain block are copied and prepended to the block

When the indoor-outdoor unit has been installed, it generally sets up a connection with the outdoor network, preferably automatically. At that moment the exact direction of the transmitting station is not yet known. The indoor-outdoor unit will perform signal detection on the different antenna elements of second antenna means 10 and usually in a variety of different frequency bands. Typically, a complete scan will be performed over the complete range of antenna elements and frequency bands or over a sub-set of these. The indoor-outdoor unit will store the information obtained during the scan. The selection can be embodied by an appropriate algorithm like but not limited to the selection on the base of maximal received power. After the complete scan, the indoor-outdoor unit will first try to set up a connection using the antenna element and frequency band where the best signal has been detected. If this would not be successful, it will try to connect to the second strongest signal, and so on.

. In another aspect of the invention the usage of multiple antenna techniques with antenna means (10) may result in a communication with antenna's at multiple outdoor nodes located at different locations. This feature is particularly useful for providing redundancy in the outdoor connection. Multiple antenna techniques include beamforming, spatial division multiple access (SDMA), multiple input multiple output (MIMO) systems.

If the connection with the outdoor transmitter is lost, the indoor-outdoor unit can restart its initialization procedure and perform again a complete scanning of the frequency bands and the antenna elements. Alternatively, the indoor-outdoor unit can look up in a database, e.g. located in a memory to which it has access, in which frequency band and on which antenna element the second strongest signal was received during the previous initialisation. Then it attempts to establish connection with this transceiver without reinitialisation. If it does not succeed, it tries with the third strongest signal found in the previous initialisation, and so on. If no connection can be made, a complete initialisation procedure with complete scanning is started again.

Such an indoor-outdoor unit could, for instance, be used for transmitting digital data information between an outdoor antenna (e.g. a base station or an outdoor cell extending repeater) and one or more in-door computers. Alternatively, the indoor-outdoor coupling unit could be used for transmitting digital voice information between an outdoor antenna (e.g. a base station or an outdoor cell extending repeater) and an in-door telephony device or telephony network. Alternatively, the indoor-outdoor coupling unit could be used to communicate other forms of speech information, e.g.

VOIP, or video information, such as e.g. Video-on-Demand or to provide connection to the Internet.

The present invention has been described for applications where an indoor wireless network is coupled to an outdoor wireless network. It will be clear to those skilled in the art that the invention is not limited thereto. The invention also applies to the coupling of indoor networks to a variety of outdoor networks. In such coupling devices the second antenna means are replaced by appropriate termination means for other networks. These means can be e.g.:

- Means for termination of an xDSL network, wherein xDSL stands for any of the DSL technologies such as ADSL, SDSL, SHDSL, VDSL
- Means for termination of a cable network such as broadband cable network, e.g. a CATV network such as a cablemodem for DOCSIS or EURODOCSIS protocols.

Claims:

1. An indoor to outdoor unit for placement adjacent to a structural part of a building, comprising:
first antenna means (12) being for communication with at least one indoor antenna (13) placed inside said building, the first antenna means having a reflector (16) for reflecting radio signals towards the inside of the building.

2. The unit according to claim 1 wherein the first antenna means is adapted to be located with respect to a wall of the building in such a way that a part of the wall is situated in the near-field region of the first antenna means.

3. The unit according to claim 2, wherein the first antenna means (12) is for placement at a distance from the wall which is equal to or less than five times the wavelength of radio signals to be transmitted by the first antenna means (12).

4. The unit according to any of claims 1 to 3, wherein the first antenna means (12) is adapted for operation at at least one frequency less than or equal to 10GHz.

5. The unit according to any previous claim wherein the unit comprises means for connection to a cable network.

6. The unit according to any of the claims 1 to 4 further comprising:
second antenna means (10) for communication with at least one outdoor antenna (9) located outside the building;
the first and second antenna means both being for attachment to or located in a housing, so that in operation some signals received by the second antenna means (10) from the one outdoor antenna (9) are transmitted to the first antenna means (12) and some signals transmitted from the second antenna means (10) to the one outdoor antenna (9) are received from the first antenna means (12).

7. The unit according to claim 6, wherein a ground plane of the second antenna means is part of the reflector of the first antenna means.

8. The unit according to any previous claim, wherein the reflector is shaped to direct radio signals into the building.

9. The unit according to claim 6 or 7, wherein the first antenna means (12) is a directional antenna and the housing is adapted for attachment to the outside of the building such that when mounted, the first antenna means (12) points to the inside of the building.

10. The unit according to any of claims 6 to 9, wherein the second antenna means (10) is a directional antenna.

11. The unit according to claim 10, wherein the second antenna means (10) comprises means for changing the direction from where radio signals may be received by the second antenna means (10).

12. The unit according to claim 11, wherein the second antenna means (10) is automatically pointable by one of the following: means for selection between *n* antenna elements, pointing to different directions, beamforming means and a mechanical moving device which determines the direction to which the second antenna means (10) transmits.

13. The unit according to claim 12, wherein the *n* antenna elements are directional antenna elements and the 3dB beamwidths of at least two of the antenna elements overlap each other.

14. The unit according to claim 13, wherein the overlap is at least 10, 20, or 30°.

15. The unit, according to any of the claims 6 to 14, wherein the second antenna means (10) comprises at least a patch antenna.

16. The unit according to any of the claims 6 to 15, wherein different protocols are used for communication between the indoor-outdoor unit and the indoor antenna for communication between the indoor-outdoor unit and the outdoor antenna.

17. The unit according to claim 16, wherein communication between the indoor-outdoor unit and the indoor antenna uses a Wireless LAN protocol.

18. The unit according to claim 16 or 17, wherein communication between the indoor-outdoor unit and the outdoor radio (6) uses a Wireless MAN protocol or a BFWA protocol.

19. The unit according to any of claims 6 to 18, wherein the indoor and outdoor communication paths are part of different networks.

20. The unit according to claim 19, wherein the indoor radio communication (11) is part of a Wireless LAN network.

21. The unit according to claim 19 or 20, wherein the outdoor radio communication (6) is part of a Wireless MAN network or a BFWA network.

22. The unit according to any of the claims 6 to 15, wherein identical protocols are used for communication between the indoor-outdoor unit and the indoor and outdoor antenna.

23. The unit according to claim 22, wherein the indoor-outdoor unit performs a frequency shift between the indoor and outdoor communication.

24. The unit according to claim 22, where the indoor-outdoor unit performs a demodulation and remodulation operation.

25. The unit according to any of the claims 5 to 18, wherein the indoor and outdoor communication paths are part of identical networks.

26. The unit according to claim 25, wherein the indoor-outdoor unit performs a carrier frequency shift between the indoor and outdoor communication.

27. The unit according to claim 25, wherein the indoor-outdoor unit performs a demodulation and remodulation operation.

28. The unit, according to any of the previous claims, used for communicating digital data information.

29. The unit according to any of the previous claims, used for communicating voice or other audible information, coded in a digital format.

30. The unit according to any of the above mentioned claims, wherein the indoor antenna is included in a handheld mobile device.

31. The unit according to any of the above mentioned claims, where the indoor antenna is included in a stationary device.

32. The unit according to any of the claims 6 to 31, wherein the indoor-outdoor unit is adapted to automatically make connection with a second outdoor antenna when the connection (6) with a first outdoor antenna (9) is impaired.

33. The unit according to claim 32, wherein the indoor-outdoor unit has stored data identifying at least one second outdoor antenna.

34. A method of wireless communication over an extended distance by transmitting signals in a multipath tolerant format to a repeater having a first and second antenna, the repeater receiving a signal at the first antenna, amplifying the signal with an amplifier and re-transmitting the amplified signal in the same multipath resistant format from the second antenna.

35. A method according to claim 34 wherein a gain of the amplified signal is less than 20, 15 or10 dB.

36. A method according to claim 34 or 35, wherein the repeater is an indoor-outdoor unit in accordance with any of the claims 6 to 33.

37. A method according to any of the claims 34 to 36, wherein the multipath tolerant

format consists of an OFDM or DMT signal with a cyclic prefix.

38. A method according to any of the claims 34 to 36, wherein the multipath tolerant format consists of a time modulated signal with a cyclic prefix.

39. An indoor-outdoor unit having antenna means comprising a plurality of directional antennas for communication with one of a plurality of outdoor antennas, wherein the unit is adapted to automatically select one of the directional antennas to make connection between this directional antenna and one of the outdoor antennas.

40. The unit according to claim 39, wherein the unit is adapted to automatically switch to another outdoor antenna when communications with the one outdoor antenna are impaired.

41. The unit according to claim 40, wherein the unit is adapted to switch to another outdoor antenna without reinitialisation.

42. The unit according to claim 40 or 41, further comprising a memory for storing information as to which another outdoor antenna the unit is to switch to.

43. The unit according to any of claims 39 to 42 wherein the 3dB beamwidths of at least two of the plurality of directional antennas overlap each other.

44. The unit according to claim 43, wherein the overlap is at least 10, 20, or 30°.

45. A method of indoor to outdoor wireless communication comprising:

transmitting from a first antenna means (12) to at least one indoor antenna (13) placed inside a building through a structural element of the building, and reflecting radio signals towards the inside of the building from a reflector on the first antenna means.

46. The method according to claim 45, further comprising locating the first antenna means with respect to the structural element of the building in such a way that a part of the structural element is situated in the near-field region of the first antenna means.

47. The method according to claim 46, wherein the first antenna means (12) is located at a distance from the structural element which is equal to or less than five times the wavelength of radio signals to be transmitted by the first antenna means (12).

48. The method according to any of the claims 45 to 47, further comprising:

providing second antenna means (10) for communication with an outdoor antenna, receiving some signals at the second antenna means (10) from the one outdoor antenna (9) and transmitting them to the first antenna means (12) and receiving some signals from the first antenna means (12) and transmitting them from the second antenna means (10) to the one outdoor antenna (9)..

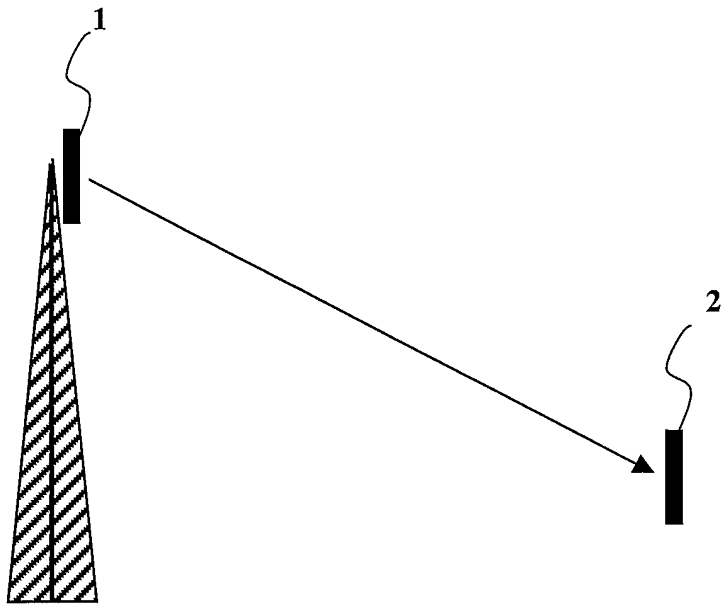


Fig. 1

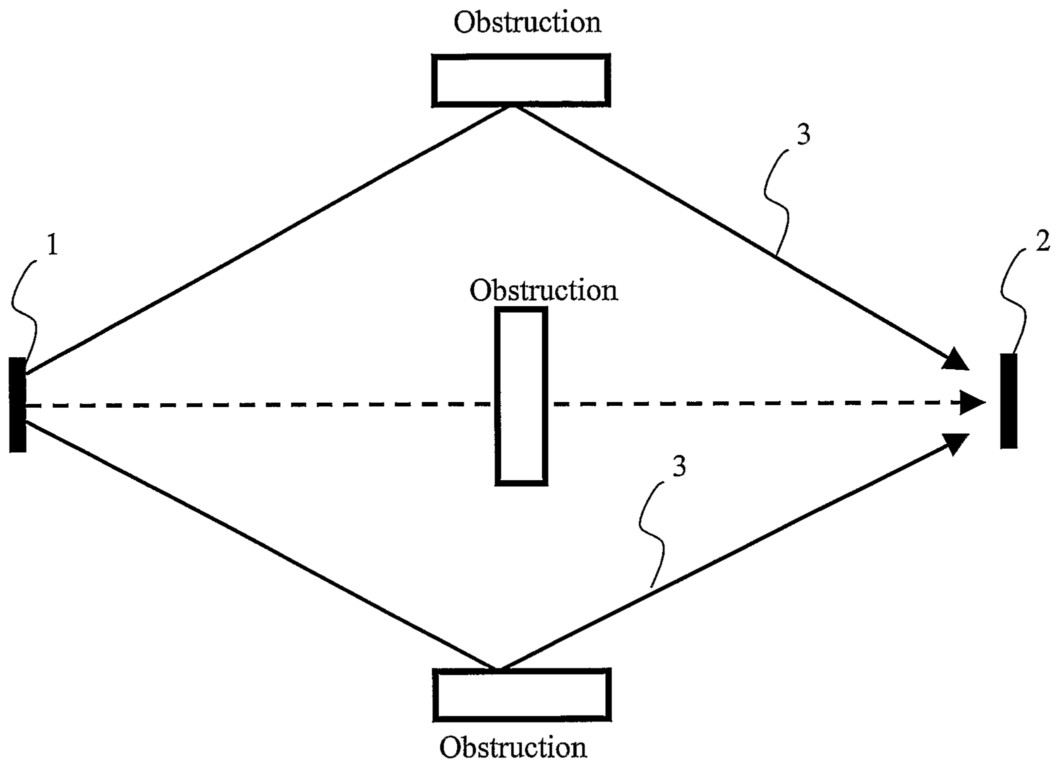


Fig. 2

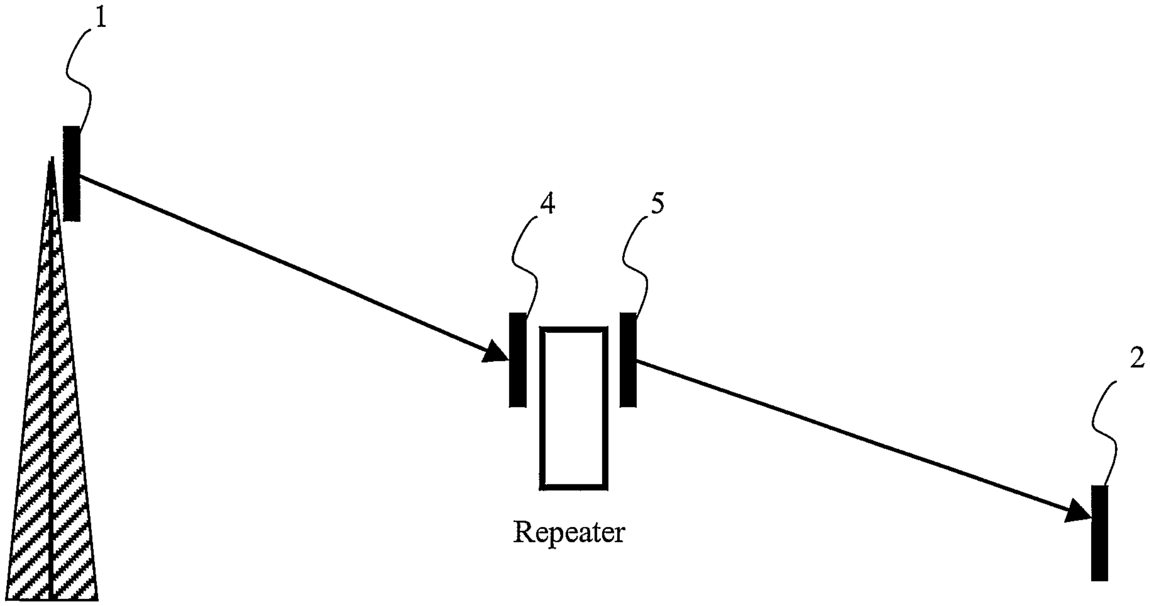


Fig. 3

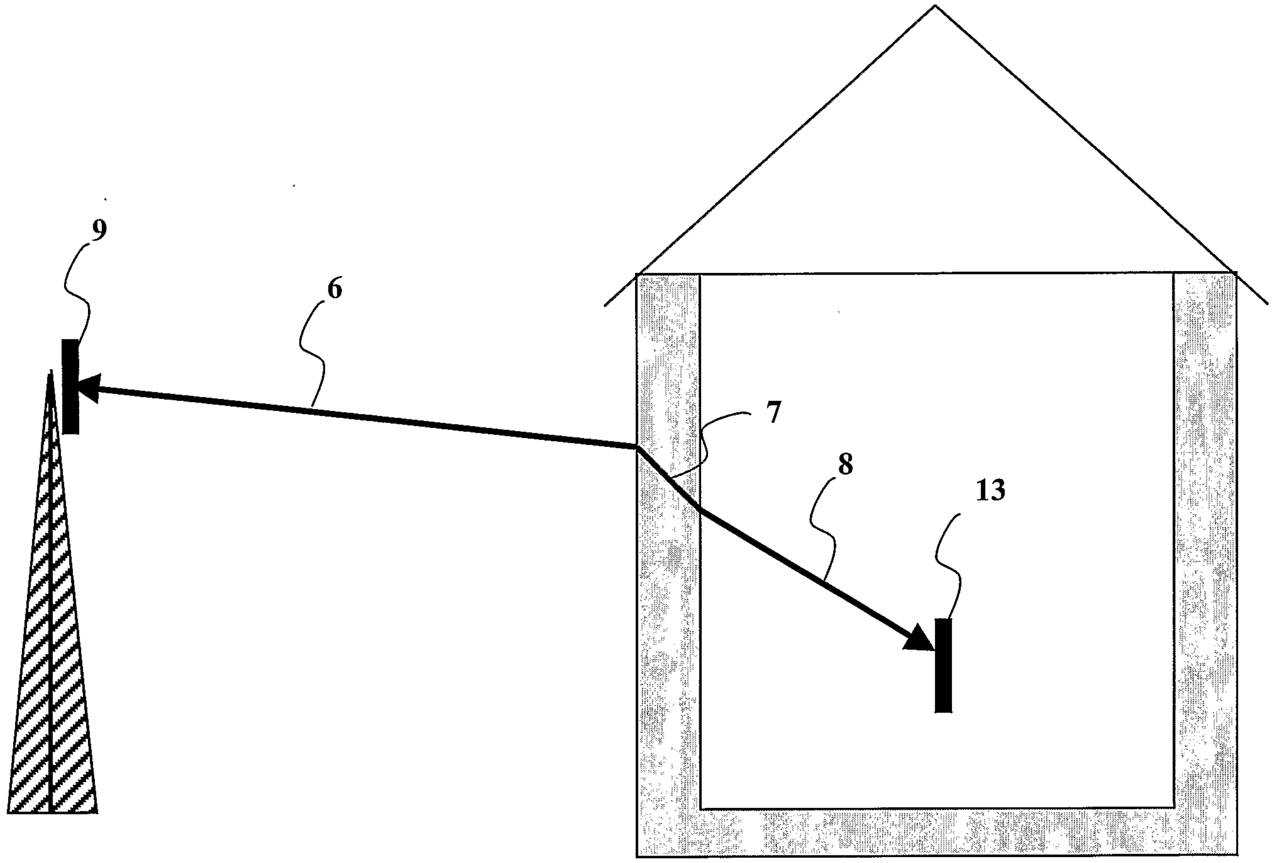


Fig. 4

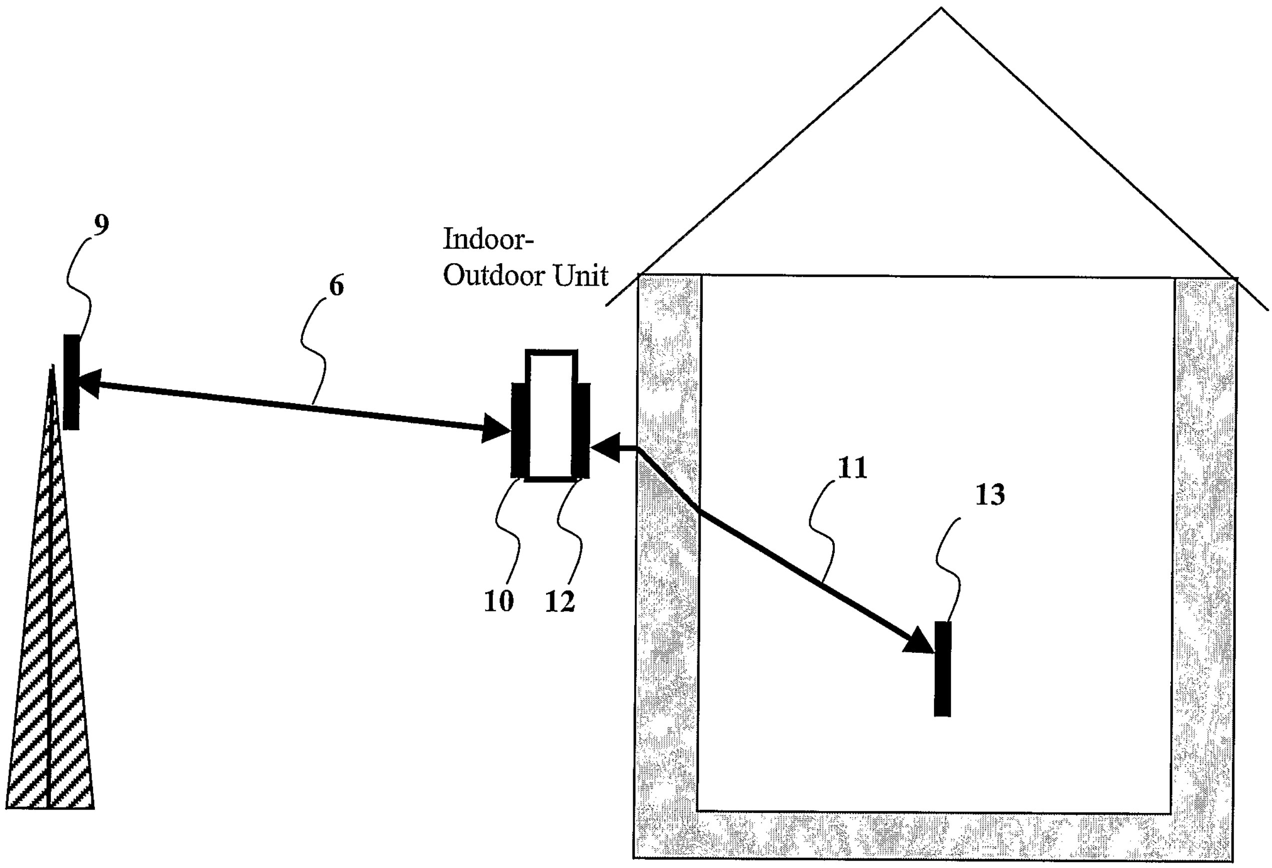


Fig. 5

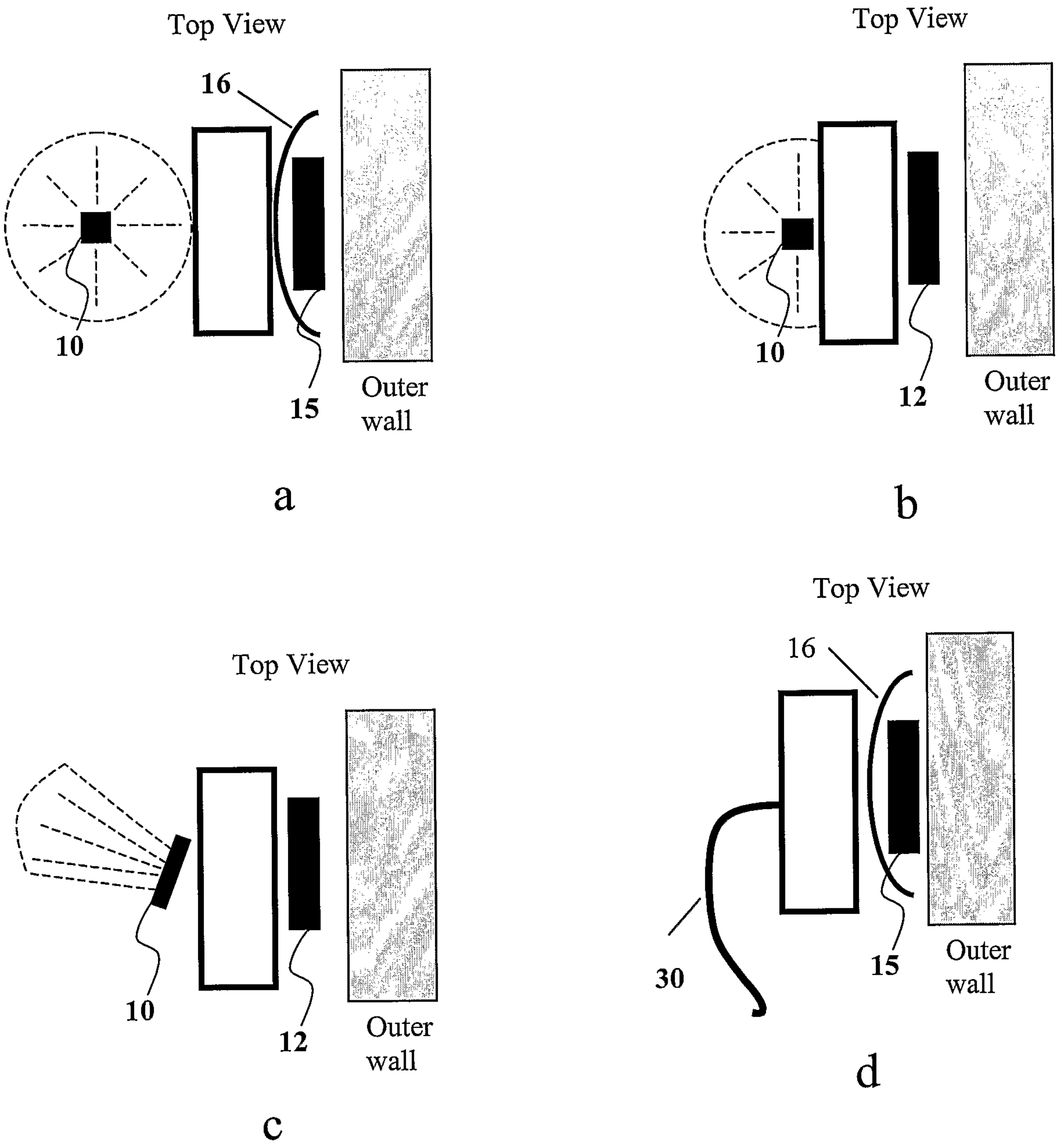

Top View
16
10
15
Outer wall
a
Top View
10
12
Outer wall
b
Top View
10
12
Outer wall
c
Top View
16
30
15
Outer wall
d

Fig. 6

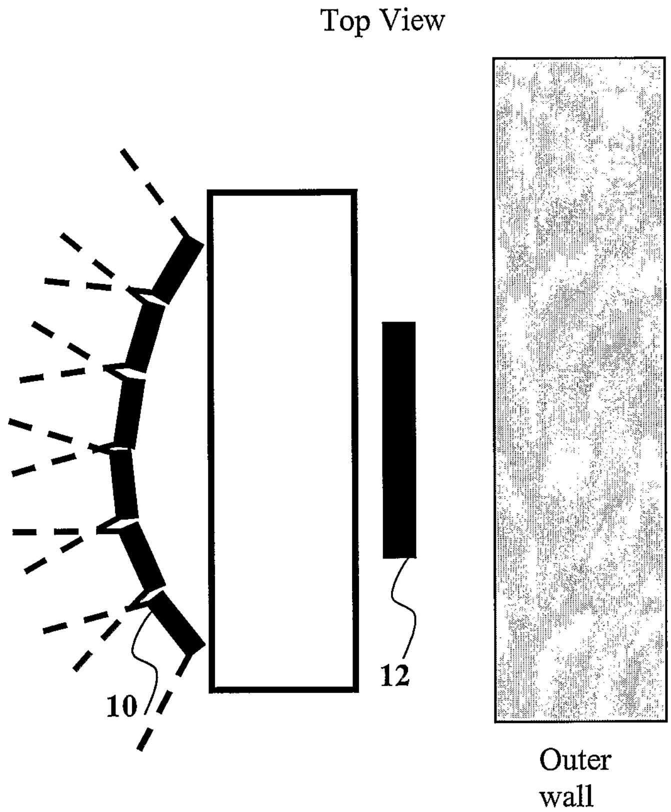


Fig. 7

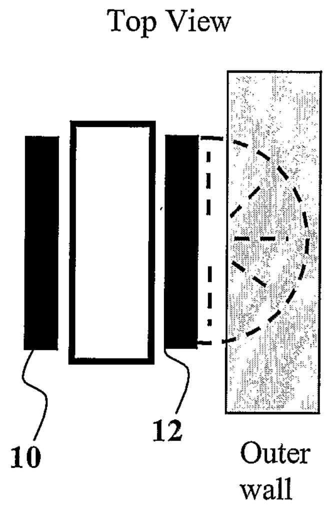


Fig. 8

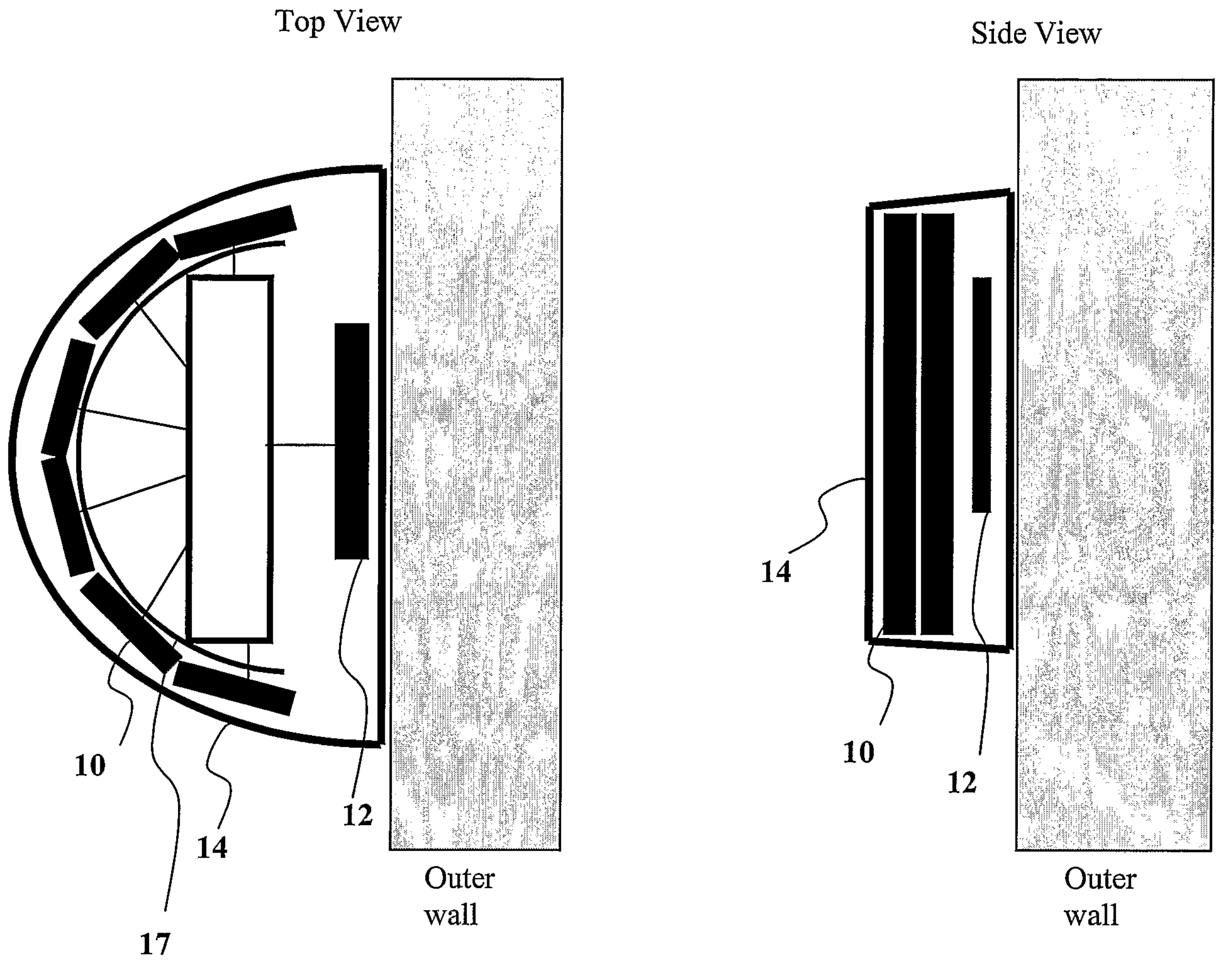


Fig. 9


13
14

Fig. 10

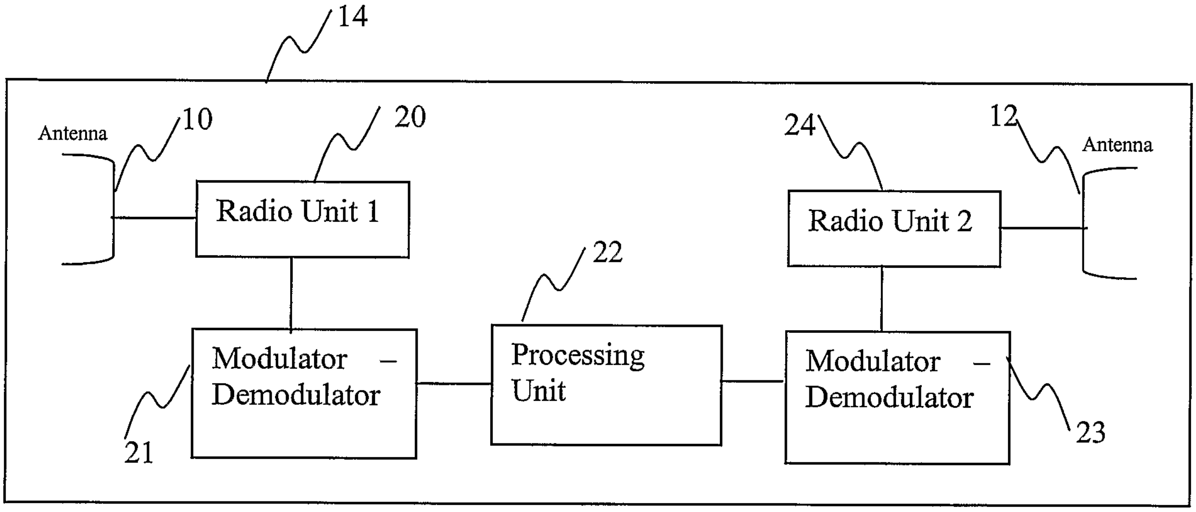

14
Antenna
10
20
Radio Unit 1
24
12
Antenna
Radio Unit 2
22
Modulator – Demodulator
Processing Unit
Modulator – Demodulator
21
23

Fig. 11