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(54) **Antenna apparatus**

(57) Antenna apparatus and a method of providing antenna apparatus. The apparatus comprising: a parabolic dish operable to collect and direct a satellite spectrum electromagnetic signal towards a focal point of the parabolic dish; a converter located at the focal point operable to convert the satellite spectrum electromagnetic signal to an electrical signal, the converter being coupleable to cabling for carrying the electrical signal; wherein the antenna apparatus further comprises: a white space electromagnetic signal radiating element arranged to use the parabolic dish as a white space electromagnetic signal reflector and coupleable to cabling for carrying elec-

trical signals to and from the white space electromagnetic signal radiating element. Aspects recognise that a typical satellite antenna apparatus comprising a parabolic dish and converter, can also act as a part of a white spectrum antenna. In particular, providing a white space spectrum radiating element and positioning it such that the parabolic dish of the satellite antenna can be used as a reflector, a highly directional, high gain white space antenna may be formed. Allowing the combined antenna apparatus to be connectable to suitable feed lines can allow a signal to be fed to, and taken from, each of the two antenna provided as a single piece of antenna apparatus.

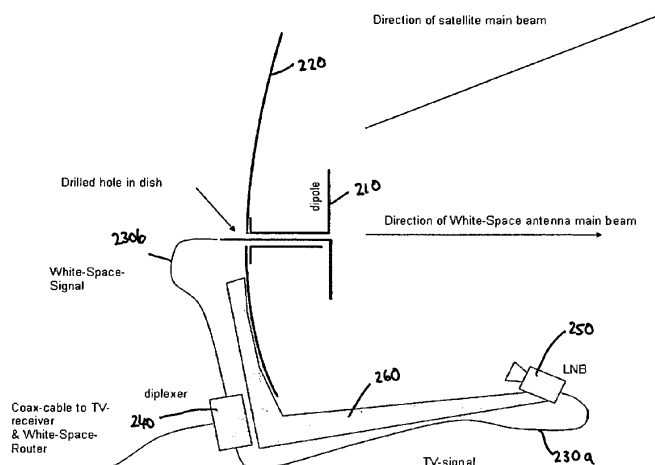


Figure 7a: Satellite dish with added White-Space Dipole. Mounted through a hole in dish with coaxial feed

Description

FIELD OF THE INVENTION

[0001] The present invention relates to antenna apparatus, a method of providing antenna apparatus, a white space frequency spectrum antenna module and a method of installing such a white space frequency spectrum antenna module.

BACKGROUND

[0002] Internet use is increasing, resulting in a need to provide data carrying capability to an increasing number of geographical locations.

[0003] It has been recognized that it is possible to provide fixed wireless high capacity internet connections by providing a data carrying network in unused portions of a radio frequency spectrum. In many countries, for example: USA, GB, Continental Europe, unused bands are available in the radio frequency spectrum, those unused bands formerly being used for analog TV signals. Those unused bands have been allocated by regulatory bodies, for example, the FCC, as available spectrum for wireless high speed data (internet) access. This part of the spectrum, which becomes available by the decommissioning of former terrestrial broadcast TV signalling, is called "White-Space-Spectrum" and typically lies within the so-called UHF spectrum, specifically within the frequency band between 350MHz and 700MHz.

[0004] To make use of this white-space-spectrum, new receiver and transmitter end user equipment is required, to allow an end user to connect to the internet wirelessly. That wireless internet connection is provided via dedicated base-stations which allow access to a high-speed data backbone network, for example, the internet.

[0005] It is desired to provide a cost effective means to provide high-capacity internet connections to allow fixed wireless data access.

SUMMARY

[0006] Accordingly, a first aspect provides antenna apparatus comprising: a parabolic dish operable to collect and direct a satellite spectrum electromagnetic signal towards a focal point of the parabolic dish; a converter located at the focal point operable to convert the satellite spectrum electromagnetic signal to an electrical signal, the converter being coupleable to cabling for carrying the electrical signal; wherein the antenna apparatus further comprises: a white space electromagnetic signal radiating element arranged to use the parabolic dish as a white space electromagnetic signal reflector and coupleable to cabling for carrying electrical signals to and from the white space electromagnetic signal radiating element.

[0007] The first aspect recognizes that to make use of so-called "white-space-spectrum", new receiver and transmitter end user equipment is required, to allow an

end user to connect to the internet wirelessly. That wireless internet connection is provided via dedicated base-stations which allow access to a high-speed data backbone network, for example, the internet.

[0008] As part of such new receiver and transmitter equipment, new dedicated antenna equipment might have to be installed in locations where fixed wireless internet connections are desired. Such installations may be labour intensive and may significantly increase the total cost of commissioning necessary end-user equipment.

[0009] The first aspect provides apparatus which may allow for satellite receiver antennas to be improved or adapted such that they also can be used as antenna installations for white-space communications. The proposed antenna apparatus may be particularly helpful in deployment scenarios in which a satellite service provider and white-space connectivity provider are the same entity

[0010] The first aspect recognises that a typical satellite antenna apparatus comprising a parabolic dish and converter, can also act as a part of a white spectrum antenna. In particular, providing a white space spectrum radiating element and positioning it such that the parabolic dish of the satellite antenna can be used as a reflector, a highly directional, high gain white space antenna may be formed. Allowing the combined antenna apparatus to be connectable to suitable feed lines can allow a signal to be fed to, and taken from, each of the two antenna provided as a single piece of antenna apparatus.

[0011] The parabolic dish forms a section of a parabolic curve. That section is chosen such that appropriate satellite frequency spectrum can be directed to the focal point by the dish. It will be appreciated that the alignment, diameter and curvature of the parabolic dish may be chosen to be best suited to satellite signalling. Furthermore, in order for the dish to offer use as a reflector for a white space radiating element, the diameter of the dish may be chosen to be optimised for the white space frequency to be used by the particular radiating element chosen.

[0012] It will be appreciated that the satellite antenna will be arranged to typically operate within a narrow range of frequency within the satellite band and that the white space radiator and reflector will be chosen to operate optimally within a narrow frequency band of all available white space spectrum. The particular dimensions of components may be chosen as appropriate in dependence upon the particular satellite and white space frequencies of interest in a particular implementation.

[0013] In one embodiment, the apparatus further comprises signal manipulation apparatus arranged to be coupleable to the white space electromagnetic signal radiating element and the converter, the signal manipulation apparatus being arranged to multiplex signalling for the white space electromagnetic signal radiating element and the converter.

[0014] Accordingly, signals from each of the white space and satellite antenna may be multiplexed into a

single electrical signal which may be carried on appropriate cabling, for example, coaxial cabling. Accordingly, signals from each of the antenna may be carried on a single cable, thus minimising the need to provide separate cabling for each of the satellite antenna and the white space antenna.

[0015] In one embodiment, the apparatus further comprises signal manipulation apparatus arranged to be coupleable to the white space electromagnetic signal radiating element and the converter, the signal manipulation apparatus being arranged to demultiplex signalling for the white space electromagnetic signal radiating element and the converter.

[0016] Accordingly, signals to each of the white space and satellite antenna may be multiplexed into a single electrical signal which may be carried on appropriate cabling, for example, coaxial cabling. Accordingly, signals to each of the antennae may be carried on a single cable, thus minimising the need to provide separate cabling for each of the satellite antenna and the white space antenna.

[0017] In one embodiment, the signal manipulation apparatus comprises a parallel combination of a low pass filter and a high pass filter. In one embodiment, the signal manipulation apparatus further comprises dedicated digital circuitry operable to bypass the high pass filter.

[0018] A key component of some aspects and embodiments described is the RF-combiner/splitter also known as a signal manipulator. Such a 'Splitter-Combiner' module is operable to provide multiplexing of the two signals: (i) a signal emerging from the LNB of the satellite dish and (ii) a signal emerging from the white space radiating element. It will be appreciated that such multiplexing functionality is possible for most commercial satellite systems (C-band and Ku-band), given that the LNB output signal of such systems (IF signal of the satellite link) is modulated on a carrier frequency that varies from 950 MHz to 2150 MHz, whilst the white spectrum signal carrier frequency would typically always be less than 700MHz. There is therefore no spectral overlap between the two applications, and the aforementioned 'splitter-combiner' or 'diplexer' can be implemented as a parallel combination of a lowpass (LP) filter connected to the white space spectrum dipole and a high-pass (HP) filter connected to the satellite LNB. It will be appreciated that it is necessary to ensure that a DC power supply and baseband control signals of the LNB of the satellite antenna, which are also typically multiplexed onto the same cabling, for example, a coaxial cable, are not suppressed by the HP filter that is connected to the LNB. For that purpose, dedicated digital circuitry supply may be required to allow for bypassing of the HP filter. Furthermore, a bypass in the kHz-range may be required in order to let signalling from a satellite-receiver towards the LNB pass through (for band-selection of the LNB).

[0019] In one embodiment, the antenna apparatus further comprises a mount, operable to support the radiating element in position to use the parabolic dish as a white

space electromagnetic signal reflector.

[0020] Accordingly, the radiating element may be supported in position within the parabolic dish such that the radiating element can use the dish as a reflector. Various mounting positions and forms of mount may be available. According to one arrangement, a hole is drilled into dish to allow placement of a radiating element coupleable to, for example, a coaxial feed, within the centre of the dish. Such a mount arrangement may have a low impact on the satellite frequency antenna pattern. According to some arrangements, an add-on arm may be used to mount the radiating element on a component of the satellite antenna. Depending on the material of the arm, which may be chosen, for example, to comprise a plastic material with low dielectric value, the impact on the satellite-antenna pattern is low. Such an arrangement may also allow for particularly easy retro-fit installation. According some arrangements, a spider-shaped arrangement of several arms may be provided to hold the radiating element in place within the dish.

[0021] In order to minimize impact on the satellite antenna pattern, such arms may be formed or constructed from metal or a low-dielectric plastic material. In one embodiment, the mount comprises an arm supported on the parabolic dish. In one embodiment, the mount comprises a plurality of support legs, attachable to the parabolic dish. In one embodiment, the mount is formed from a material having a low dielectric value.

[0022] In one embodiment, the white space electromagnetic signal radiating element comprises a dipole. It will be appreciated that the used cross-section of, for example, an added dipole, is low and the shadowing-effect of dipole installation on a satellite dish may be arranged such that it is negligible.

[0023] In one embodiment, white-space electromagnetic spectrum extends within UHF spectrum, between 350MHz and 700MHz. In one embodiment, satellite electromagnetic spectrum extends between around 10GHz and 12GHz. Typical satellite RF spectrum operates in the order of 10-12GHz, white-space RF spectrum operates in the region of 350-700MHz.

[0024] A second aspect provides a method of providing antenna apparatus comprising: arranging a parabolic dish to collect and direct a satellite spectrum electromagnetic signal towards a focal point of the parabolic dish; locating a converter operable to convert the satellite spectrum electromagnetic signal to an electrical signal at the focal point, the converter being coupleable to cabling for carrying the electrical signal; arranging a white space electromagnetic signal radiating element to use the parabolic dish as a white space electromagnetic signal reflector, the radiating element being coupleable to cabling for carrying electrical signals to and from the white space electromagnetic signal radiating element.

[0025] In one embodiment, the method further comprises arranging signal manipulation apparatus to be coupleable to the white space electromagnetic signal radiating element and the converter, the signal manipula-

tion apparatus being arranged to multiplex signalling for the white space electromagnetic signal radiating element and the converter.

[0026] In one embodiment, the method further comprises arranging signal manipulation apparatus to be coupleable to the white space electromagnetic signal radiating element and the converter, the signal manipulation apparatus being arranged to demultiplex signalling for the white space electromagnetic signal radiating element and the converter.

[0027] In one embodiment, the signal manipulation apparatus comprises a parallel combination of a low pass filter and a high pass filter.

[0028] In one embodiment, the signal manipulation apparatus further comprises dedicated digital circuitry operable to bypass the high pass filter.

[0029] In one embodiment, the antenna apparatus further comprises a mount, operable to support the radiating element in position to use the parabolic dish as a white space electromagnetic signal reflector.

[0030] In one embodiment, the mount comprises an arm supported on the parabolic dish.

[0031] In one embodiment, the mount comprises a plurality of support legs, attachable to the parabolic dish.

[0032] In one embodiment, the mount is formed from a material having a low dielectric value.

[0033] In one embodiment, the white space electromagnetic signal radiating element comprises a dipole.

[0034] In one embodiment, white-space electromagnetic spectrum extends within UHF spectrum, between 350MHz and 700MHz.

[0035] In one embodiment, satellite electromagnetic spectrum extends between around 10GHz and 12GHz.

[0036] A third aspect provides a white space frequency spectrum antenna module installable on a satellite antenna, the module comprising: a white space radio electromagnetic spectrum radiating element arranged to be mountable on a satellite antenna, and signal manipulation apparatus arranged to be coupleable to the white space electromagnetic signal radiating element and the satellite antenna, the signal manipulation apparatus being arranged to multiplex signalling for the white space electromagnetic signal radiating element and the satellite antenna.

[0037] The third aspect recognises that rather than provide a satellite antenna and white space antenna as a unitary apparatus, or integrally formed together, it is possible to retro-fit a white space transceiver module to an existing satellite antenna. In particular, the third aspect recognises that it is possible to re-use cabling provided for said satellite antenna apparatus for white space spectrum antenna use provided an appropriate diplexer unit is provided to manipulate signals for each antenna into a form suitable for a single cable to carry.

[0038] In one embodiment, the signal manipulation apparatus is arranged to be coupleable to the white space electromagnetic signal radiating element and the satellite antenna, the signal manipulation apparatus being ar-

ranged to demultiplex signalling for the white space electromagnetic signal radiating element and the satellite antenna.

[0039] In one embodiment, the signal manipulation apparatus comprises a parallel combination of a low pass filter and a high pass filter.

[0040] In one embodiment, the signal manipulation apparatus further comprises dedicated digital circuitry operable to bypass said high pass filter.

[0041] In one embodiment, the module further comprises a mount, operable to support the radiating element in position to use a parabolic dish of the satellite antenna as a white space electromagnetic signal reflector.

[0042] In one embodiment, the mount comprises an arm mountable on the parabolic dish.

[0043] In one embodiment, the mount comprises a plurality of support legs, attachable to the parabolic dish.

[0044] In one embodiment, the mount is formed from a material having a low dielectric value.

[0045] In one embodiment, the white space electromagnetic signal radiating element comprises a dipole.

[0046] In one embodiment, the white-space electromagnetic spectrum extends within UHF spectrum, between 350MHz and 700MHz.

[0047] In one embodiment, the satellite electromagnetic spectrum extends between around 10GHz and 12GHz.

[0048] A fourth aspect provides a method of installing a white space frequency spectrum antenna module on a satellite antenna, comprising: mounting a white space radio electromagnetic spectrum radiating element on a satellite antenna, and arranging signal manipulation apparatus to be coupleable to the white space electromagnetic signal radiating element and the satellite antenna, such that the signal manipulation apparatus is operable to multiplex signalling for the white space electromagnetic signal radiating element and the satellite antenna.

[0049] In one embodiment, the method comprises arranging the signal manipulation apparatus to be coupleable to the white space electromagnetic signal radiating element and the satellite antenna, the signal manipulation apparatus being arranged to demultiplex signalling for the white space electromagnetic signal radiating element and the satellite antenna.

[0050] In one embodiment, the signal manipulation apparatus comprises a parallel combination of a low pass filter and a high pass filter.

[0051] In one embodiment, the signal manipulation apparatus further comprises dedicated digital circuitry operable to bypass said high pass filter.

[0052] In one embodiment, the method further comprises supporting the radiating element in position on a mount to use a parabolic dish of the satellite antenna as a white space electromagnetic signal reflector.

[0053] In one embodiment, the mount comprises an arm mountable on the parabolic dish.

[0054] In one embodiment, the mount comprises a plurality of support legs, attachable to the parabolic dish.

[0055] In one embodiment, the mount is formed from

a material having a low dielectric value.

[0056] In one embodiment, the white space electromagnetic signal radiating element comprises a dipole.

[0057] In one embodiment, the white-space electromagnetic spectrum extends within UHF spectrum, between 350MHz and 700MHz.

[0058] In one embodiment, the satellite electromagnetic spectrum extends between around 10GHz and 12GHz.

[0059] It will be appreciated that features and embodiments described in relation to the first and second embodiments may be incorporated with features and embodiments of the third and fourth aspects as appropriate.

[0060] Further particular and preferred aspects are set out in the accompanying independent and dependent claims. Features of the dependent claims may be combined with features of the independent claims as appropriate, and in combinations other than those explicitly set out in the claims.

[0061] Where an apparatus feature is described as being operable to provide a function, it will be appreciated that this includes an apparatus feature which provides that function or which is adapted or configured to provide that function.

BRIEF DESCRIPTION OF THE DRAWINGS

[0062] Embodiments of the present invention will now be described further, with reference to the accompanying drawings, in which:

Figure 1 illustrates schematically a building having satellite and white space connections in accordance with one embodiment;

Figure 2 illustrates schematically a region across which combined beam-forming functionality of a dipole and dish arrangement may be provided according to embodiments;

Figure 3 illustrates schematically geometry of an offset feed parabolic satellite dish provided at a latitude of 51 degrees;

Figure 4 illustrates schematically geometry of an offset feed parabolic satellite dish provided at a latitude of 51 degrees comprising a dipole in accordance with one embodiment;

Figure 5 illustrates schematically a deployment of white space base stations according to one embodiment;

Figure 6 illustrates schematically main components of a satellite and white space diplexer unit according to one embodiment;

Figures 7a to 7d illustrate schematically a typical satellite antenna including a white space antenna according to embodiments.

DESCRIPTION OF THE EMBODIMENTS

[0063] It has been recognized that it is possible to provide fixed wireless high capacity internet connections by

providing a data carrying network in unused portions of a radio frequency spectrum. In many countries, for example: USA, GB, Continental Europe, unused bands are available in the radio frequency spectrum, those unused bands formerly being used for analog TV signals. Those unused bands have been allocated by regulatory bodies, for example, the FCC, as available spectrum for wireless high speed data (internet) access. This part of the spectrum, which becomes available by the decommissioning of former terrestrial broadcast TV signalling, is called "White-Space-Spectrum" and typically lies within the so-called UHF spectrum, specifically within the frequency band between 350MHz and 700MHz.

[0064] To make use of this white-space-spectrum, new receiver and transmitter end user equipment is required, to allow an end user to connect to the internet wirelessly. That wireless internet connection is provided via dedicated base-stations which allow access to a high-speed data backbone network, for example, the internet.

[0065] As part of such new receiver and transmitter equipment, new dedicated antenna equipment might have to be installed in locations where fixed wireless internet connections are desired. Such installations may be labour intensive and may significantly increase the total cost of commissioning necessary end-user equipment.

[0066] Aspects and embodiments described provide a method of upgrading existing satellite receiver antennas such that they can be used as antenna installations for white-space communications. The proposed method can minimize the installation and equipment costs, and may allow service providers to offer required end-user equipment at a reasonable cost. The proposed method may be particularly helpful in deployment scenarios in which a satellite service provider and white-space connectivity provider are the same entity, for example, BSkyB in the UK.

[0067] In general, in order to use white-space spectrum a dedicated white-space antenna must be provided together with a cable-connection to the location of interest. Such an installation may be complex and costly, especially in relation to wiring, since a cabled connection between an antenna mounted outside and a router, typically provided inside a building, is required. Such cabling may require drilling through walls or a roof and installation may therefore be inconvenient and costly.

Overview

[0068] Before discussing the embodiments in any more detail, first an overview will be provided. Aspects and embodiments make use of: an existing satellite antenna to create a high-gain antenna installation for the white-space spectrum and an existing coaxial cable which connects a satellite low-noise-block (LNB) with a satellite receiver/decoder.

[0069] Figure 1 illustrates schematically a building having satellite and white space connections in accordance

with one embodiment. In the arrangement shown in Figure 1 a building 10 is provided with antenna equipment 20 arranged to allow a signal from a satellite 30 and a white space spectrum base station 40 to be simultaneously received. Cabling 50 is arranged to couple the antenna equipment 20 to signal decoding apparatus 60.

[0070] Antenna equipment 20 acts as signal reception apparatus and comprises, in the schematic of Figure 1, a dipole 210 for the white-space spectrum (WS-spectrum) arranged in front of a satellite dish 220. The satellite dish 220 is operable to act as a reflector for the dipole 210, and thus the combination of dipole and dish creates an effective high-gain antenna setup. The resulting dipole antenna is operable to create a reliable high speed fixed wireless access link between building 10 and WS-base station 40.

[0071] The satellite dish 220 and low noise block (LNB) (not shown in Figure 1) provides a satellite antenna which is still operable to receive a TV-signal from satellite 30. That is to say, the original purpose of the satellite antenna is not impacted by the provision of dipole 210.

[0072] Both received signals: white space signal from base station 40 and TV signal from satellite 30, can be multiplexed onto radio frequency coaxial cabling 230 which couples the satellite antenna comprising the dish 220 and low noise block (LNB) and the dipole 210 to a splitter/combiner and/or duplexer 240.

[0073] That reception duplexer 240 is coupled, via cabling 50, to a decoding splitter/combiner/duplexer 610 associated with decoding apparatus 60. The decoding duplexer 610 is provided inside the building 10 and is operable to separate the two signals carried on cabling 50. The satellite signal is coupled to a TV-Sat-receiver, and the WS-signal is coupled to a WS-transceiver and router 630. The router is used, for example, to provide a connection to a computer via wifi or ethernet to the internet.

[0074] It will be appreciated that embodiments typically require: a RF-combiner/splitter 240; 610 inside and outside the building 10, that combiner being operable to multiplex a high RF signal and a low RF signal onto suitable RF cabling; and provision of a WS-dipole 210 arrangeable in front of satellite dish 220.

[0075] Figure 2 illustrates schematically a region across which combined beam-forming functionality of a dipole and dish arrangement may be provided according to embodiments. For a typical central-European location, for example, London (latitude = 51deg), the elevation aspect angle of a geostationary satellite provided above the equator is approximately 32deg.

[0076] Figure 3 illustrates schematically geometry of an offset feed parabolic satellite dish provided at a latitude of 51 degrees. For a typical offset-fed parabolic satellite dish having a 600mm-700mm diameter, such an aspect angle results in a nearly upright position of the dish, and the main beam direction of such dish points at around 32deg to the satellite, as illustrated schematically in Figure 3.

[0077] Aspects and embodiments described herein allow for use of reflective properties of a satellite dish at lower frequencies than that of a satellite band (10GHz). Satellite TV signals at high frequency RF, used in a satellite link, see the dish as a parabolic surface several orders larger than the used wavelength. The dish therefore acts to receive and to form a narrow, high-gain, beam. At rather low RF frequencies typical in the White-Space spectrum, the surface of the satellite dish acts as a 'flat' reflective surface. Such a flat reflective surface can be used to significantly increase directivity of any used White-Space radiator and thus a very simple radiator, for example, a dipole, can be used to provide a White-Space spectrum link, rather than a more complex installation comprising additional reflectors or directive antennas like Yagi- or Log-per-antennas.

[0078] Figure 4 illustrates schematically geometry of an offset feed parabolic satellite dish provided at a latitude of 51 degrees comprising a dipole in accordance with one embodiment. In the arrangement shown in Figure 4, a WS-dipole, or other suitable radiator operable to radiate in the WS-spectrum to provide a signal suitable for a WS data access link, is provided in front of a satellite dish which acts as a reflector. Figure 4 illustrates an arrangement suited to a dipole operating at 600MHz. The resulting WS-radiation pattern has the following characteristics:

- high gain (8 to 9dB)
- a horizontal 3dB beam width of approximately 90 degrees
- a vertical 3dB beam width of approximately 60 degrees

[0079] It will be appreciated that such a relatively broad radiation angle allows use of such an arrangement in a range of locations having different latitudes, for example across Europe or the US, those locations having different elevation aspect angles towards the satellite, as illustrated in Figure 2. For example, for Oslo the aspect angle is 22 deg, so 10degrees less than in London, which results in a more downwardly pointing dish, but the elevation radiation pattern of the WS-dipole is still broad enough to cover such a different aspect angle. The same is true for a more southerly location than London, for example, Miami, where the aspect angle is 60 degrees. In this instance the WS-pattern will point about (60-32=28deg) higher towards the sky than in London, with the result that at such an angle, the elevation diagram of the WS-antenna is only reduced by about 3dB. As a result, the link between the WS-antenna and the WS-base-station is not significantly impacted.

[0080] It will be appreciated that other appropriate white space frequency radiators, for example, a longer dipole having higher vertical gain, may also be used. It will be appreciated that adding, for example, a dipole, to a satellite dish can provide a highly directive and cost effective solution for a white-space antenna to provide

fixed wireless access. Such implementations may avoid the need for additional cabling or additional antenna installations. The visual impact of providing white space functionality to an existing satellite installation is minimal and no significant structural alterations to a building are required. According to some embodiments, the form of the radiating element may be such that a more appropriate radiative pattern may be generated. For example, it may be possible for the radiating to comprise two or more dipole elements.

[0081] Provision of a white space antenna on a satellite dish may be arranged such that the impact on an existing satellite antenna is minimal since difference between the used frequency spectrums of the two applications is large. Typical satellite RF spectrum operates in the order of 10-12GHz, white-space RF spectrum operates in the region of 350-700MHz. It will be appreciated that the used cross-section of, for example, an added dipole, is low and the shadowing-effect of dipole installation on a satellite dish may be arranged such that it is negligible.

[0082] Figure 5 illustrates schematically a deployment of white space base stations according to one embodiment. In a given geographical area, all end-user white space antennas will be arranged to face in the same general direction. That direction is defined by TV-satellite functionality. Such a feature may be beneficial for determining white space base-station (BS) deployment locations selected by a service provider. By placing base station infrastructure in appropriate locations with an appropriate orientation, facing against the end-user satellite dishes, it is possible to achieve optimized coverage with minimal interference between users and also between adjacent cells. Figure 5 illustrates a deployment in which end-user reception and transmission equipment 20 is south-facing and, as a result, white space base stations 40a, 40b are deployed to be substantially north-facing. In the particular deployment illustrated in Figure 5, white space base station 40b is deployed to be substantially north east facing. In the deployment illustrated, all satellite dishes 220 are arranged to point in a southerly direction, as a result all white space antennas provided on transception equipment 20 in accordance with aspects and embodiments are also provided pointing in a generally southerly direction. As a result of a high front-back-ratio interference between users is likely to be minimized. Since white space transception equipment 20 is provided to point in a generally southerly direction, any white-space base stations 40a, 40b are arranged to point in a generally northerly direction, but due to the wide 3dB-width of a combined satellite-white-space-antenna, deviation from due north can be accommodated. Network planning is possible such that a choice of possible locations for white space base stations remains available.

[0083] Figure 6 illustrates schematically main components of a satellite and white space diplexer unit according to one embodiment. A key component of aspects and embodiments described is the RF-combiner/splitter 240; 610 shown in Figure 1. Such a 'Splitter-Combiner' mod-

ule is operable to provide multiplexing of the two signals: (i) the signal emerging from the LNB of the satellite dish and (ii) the signal emerging from the white space dipole. It will be appreciated that such multiplexing functionality is possible for most commercial satellite systems (C-band and Ku-band), given that the LNB output signal of such systems (IF signal of the satellite link) is modulated on a carrier frequency that varies from 950 MHz to 2150 MHz, whilst the white spectrum signal carrier frequency would typically always be less than 700MHz. There is therefore no spectral overlap between the two applications, and the aforementioned 'splitter-combiner' or 'diplexer' can be implemented as a parallel combination of a lowpass (LP) filter connected to the white space spectrum dipole and a high-pass (HP) filter connected to the satellite LNB. It will be appreciated that it is necessary to ensure that a DC power supply and baseband control signals of the LNB, which are also typically multiplexed onto the same coaxial cable, are not suppressed by the HP filter that is connected to the LNB. For that purpose, dedicated digital circuitry (DC) may be required to allow for bypassing of the HP filter. Furthermore, a bypass in the kHz-range may be required in order to let signalling from a satellite-receiver towards the LNB pass through (for band-selection of the LNB).

[0084] Figures 7a to 7d illustrate schematically a typical satellite antenna including a white space antenna according to embodiments. A typical satellite antenna comprises a dish 220, having a low-noise-block (LNB) receiver 250 arranged to be held at the focal point of the dish 220 by a mechanical arm 260. The LNB 250 is coupled, by coaxial cable 230a to a diplexer 240. Figures 7a to 7d illustrate schematically various possibilities regarding physical placement of a WS-spectrum dipole in front of the satellite dish 220. In each case a dipole 210, coupled to diplexer 240 by coaxial cable 230b is provided.

[0085] According to the arrangement shown in Figure 7a, a hole is drilled into dish 220 to allow placement of a dipole 210 with a coaxial feed 230b within the dish. Such a mount arrangement has a low impact on the satellite frequency antenna pattern.

[0086] According to the arrangement shown in Figure 7b, an add-on arm 270 is used to mount the dipole 210 on mechanical arm 260. Depending on the material of the arm, which may be chosen, for example, to comprise a plastic material with low dielectric value, the impact on the satellite-antenna pattern is low. Such an arrangement may also allow for particularly easy retro-fit installation.

[0087] According to the arrangement shown in Figure 7c, an add-on arm 280 is used to mount the dipole 210 on the dish 220. As shown in Figure 7c, the arm reaches in to the dish from top of the dish.

[0088] According to the arrangement shown in Figure 7a, a spider-shaped arrangement of several arms 290 is provided to hold the dipole 210 in place. In order to minimize impact on the satellite antenna pattern, such arms may be formed or constructed from metal or a low-die-

lectric plastic material.

[0089] Aspects and embodiments described allow re-use of existing installations with minimal impact on their performance, whilst creating a highly directive antenna configuration in the white-space spectrum. Use of a satellite dish as a reflector for a dipole allows for optimized combined antenna operation. Combining a satellite region of spectrum antenna with a white space region of spectrum antenna allows for installation cost and effort to be minimized. Furthermore, embodiments can allow for substantial re-use of existing cabling from outside a building to inside.

[0090] As a result of uniform orientation in a given geographical location of satellite antennas and the good front-to-back ratio of a white space antenna arrangement which uses a satellite dish as a reflector, locations of white space base stations can be optimized and the likely interference level within the system is reduced, therefore enabling higher data rates. Aspects allow for the minimization of visual impact of a new white space spectrum installation by re-using existing infrastructure. By providing a high-gain white space antenna at a user location, the system can tolerate a relatively large link distance between white space base station and an end user.

[0091] A person of skill in the art would readily recognize that steps of various above-described methods can be performed by programmed computers. Herein, some embodiments are also intended to cover program storage devices, e.g., digital data storage media, which are machine or computer readable and encode machine-executable or computer-executable programs of instructions, wherein said instructions perform some or all of the steps of said above-described methods. The program storage devices may be, e.g., digital memories, magnetic storage media such as a magnetic disks and magnetic tapes, hard drives, or optically readable digital data storage media. The embodiments are also intended to cover computers programmed to perform said steps of the above-described methods.

[0092] The functions of the various elements shown in the Figures, including any functional blocks labelled as "processors" or "logic", may be provided through the use of dedicated hardware as well as hardware capable of executing software in association with appropriate software. When provided by a processor, the functions may be provided by a single dedicated processor, by a single shared processor, or by a plurality of individual processors, some of which may be shared. Moreover, explicit use of the term "processor" or "controller" or "logic" should not be construed to refer exclusively to hardware capable of executing software, and may implicitly include, without limitation, digital signal processor (DSP) hardware, network processor, application specific integrated circuit (ASIC), field programmable gate array (FPGA), read only memory (ROM) for storing software, random access memory (RAM), and non volatile storage. Other hardware, conventional and/or custom, may also be included. Similarly, any switches shown in the Figures are

conceptual only. Their function may be carried out through the operation of program logic, through dedicated logic, through the interaction of program control and dedicated logic, or even manually, the particular technique being selectable by the implementer as more specifically understood from the context.

[0093] It should be appreciated by those skilled in the art that any block diagrams herein represent conceptual views of illustrative circuitry embodying the principles of the invention. Similarly, it will be appreciated that any flow charts, flow diagrams, state transition diagrams, pseudo code, and the like represent various processes which may be substantially represented in computer readable medium and so executed by a computer or processor, whether or not such computer or processor is explicitly shown.

[0094] The description and drawings merely illustrate the principles of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within its spirit and scope. Furthermore, all examples recited herein are principally intended expressly to be only for pedagogical purposes to aid the reader in understanding the principles of the invention and the concepts contributed by the inventor(s) to furthering the art, and are to be construed as being without limitation to such specifically recited examples and conditions. Moreover, all statements herein reciting principles, aspects, and embodiments of the invention, as well as specific examples thereof, are intended to encompass equivalents thereof.

Claims

1. Antenna apparatus comprising:

a parabolic dish operable to collect and direct a satellite spectrum electromagnetic signal towards a focal point of said parabolic dish;
a converter located at said focal point operable to convert said satellite spectrum electromagnetic signal to an electrical signal, said converter being coupleable to cabling for carrying said electrical signal;

wherein said antenna apparatus further comprises:

a white space electromagnetic signal radiating element arranged to use said parabolic dish as a white space electromagnetic signal reflector and coupleable to cabling for carrying electrical signals to and from said white space electromagnetic signal radiating element.

2. Apparatus according to claim 1, further comprising: signal manipulation apparatus arranged to be cou-

- pleable to said white space electromagnetic signal radiating element and said converter, said signal manipulation apparatus being arranged to multiplex signalling for said white space electromagnetic signal radiating element and said converter. 5
3. Apparatus according to claim 1 or claim 2, further comprising: signal manipulation apparatus arranged to be coupleable to said white space electromagnetic signal radiating element and said converter, said signal manipulation apparatus being arranged to demultiplex signalling for said white space electromagnetic signal radiating element and said converter. 10 15
4. Apparatus according to claim 2 or claim 3, wherein said signal manipulation apparatus comprises a parallel combination of a low pass filter and a high pass filter. 20
5. Apparatus according to claim 4, wherein said signal manipulation apparatus further comprises dedicated digital circuitry operable to bypass said high pass filter. 25
6. Apparatus according to any preceding claim, wherein said antenna apparatus further comprises a mount, operable to support said radiating element in position to use said parabolic dish as a white space electromagnetic signal reflector. 30
7. Apparatus according to claim 6, wherein said mount comprises an arm supported on said parabolic dish. 35
8. Apparatus according to claim 6, wherein said mount comprises a plurality of support legs, attachable to said parabolic dish.
9. Apparatus according to any one of claims 6 to 8, wherein said mount is formed from a material having a low dielectric value. 40
10. Apparatus according to any preceding claim, wherein said white space electromagnetic signal radiating element comprises a dipole. 45
11. Apparatus according to any preceding claim, wherein white-space electromagnetic spectrum extends within UHF spectrum, between 350MHz and 700MHz. 50
12. Apparatus according to any preceding claim, wherein satellite electromagnetic spectrum extends between around 10GHz and 12GHz. 55
13. A method of providing antenna apparatus comprising:
- arranging a parabolic dish to collect and direct a satellite spectrum electromagnetic signal towards a focal point of said parabolic dish; locating a converter operable to convert the satellite spectrum electromagnetic signal to an electrical signal at the focal point, the converter being coupleable to cabling for carrying said electrical signal;
- arranging a white space electromagnetic signal radiating element to use said parabolic dish as a white space electromagnetic signal reflector, said radiating element being coupleable to cabling for carrying electrical signals to and from said white space electromagnetic signal radiating element.
14. A white space frequency spectrum antenna module installable on a satellite antenna, said module comprising:
- a white space radio electromagnetic spectrum radiating element arranged to be mountable on a satellite antenna, and
- signal manipulation apparatus arranged to be coupleable to said white space electromagnetic signal radiating element and said satellite antenna,
- said signal manipulation apparatus being arranged to multiplex signalling for said white space electromagnetic signal radiating element and said satellite antenna.
15. A method of installing a white space frequency spectrum antenna module on a satellite antenna, said method comprising:
- mounting a white space radio electromagnetic spectrum radiating element on a satellite antenna; and
- arranging signal manipulation apparatus to be coupleable to said white space electromagnetic signal radiating element and said satellite antenna, such that the signal manipulation apparatus is operable to multiplex signalling for said white space electromagnetic signal radiating element and said satellite antenna.

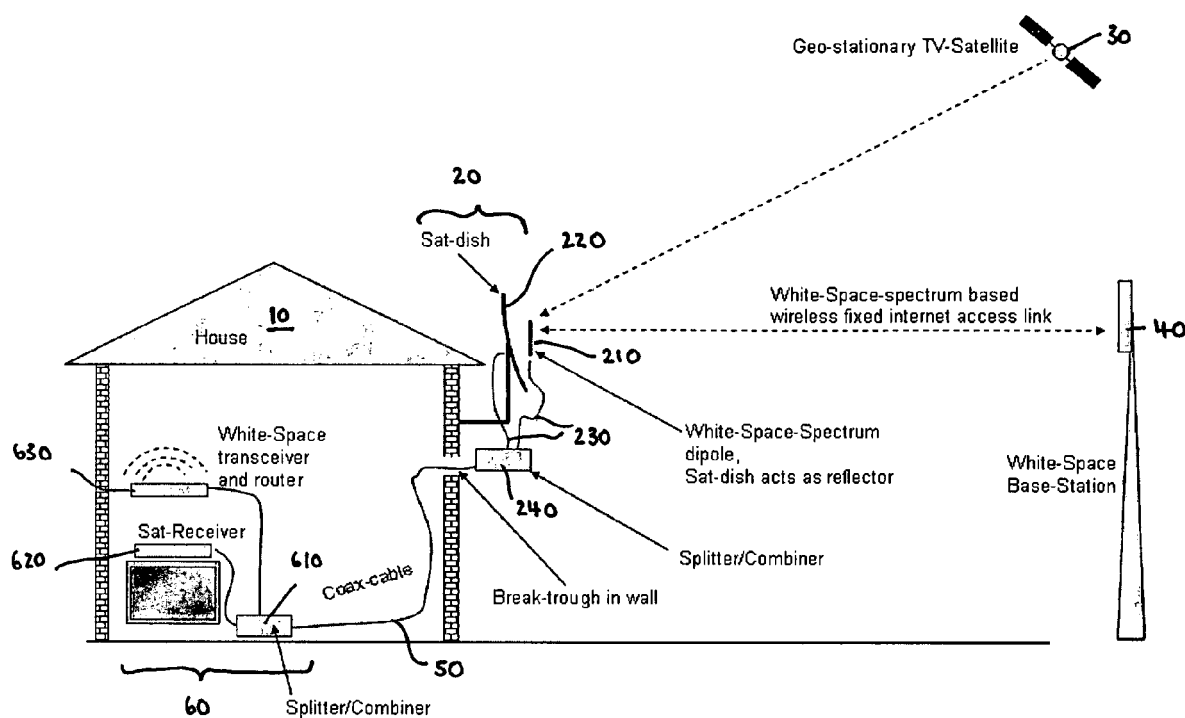


Figure 1: Setup of satellite dish on House and setup of White-Space-Spectrum dipole antenna

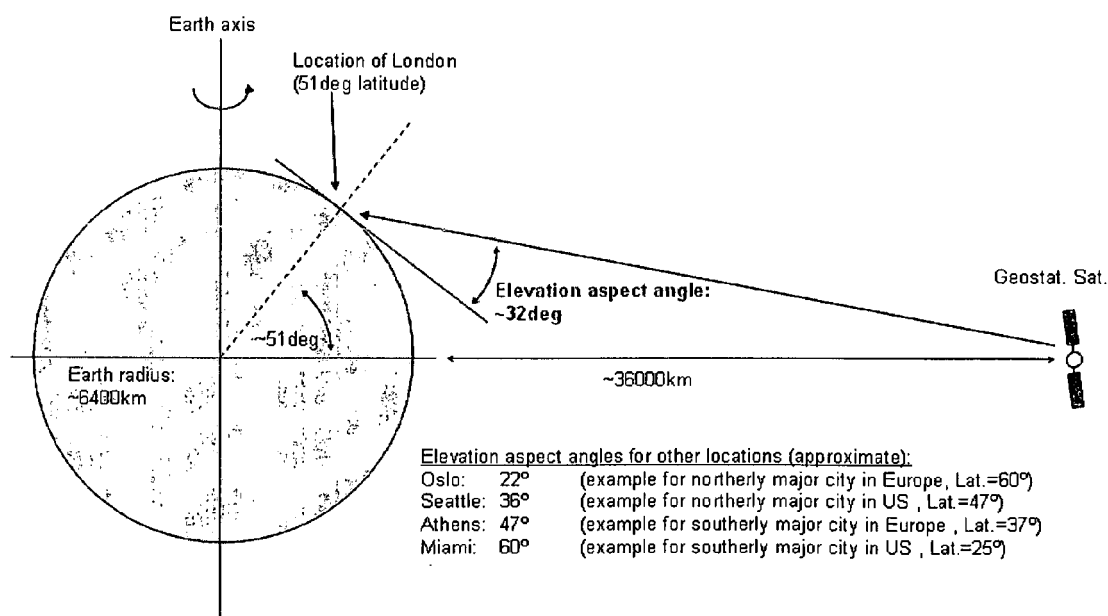


Figure 2: geometry of satellite towards Earth in geostationary orbit at latitude = 51 deg (London)

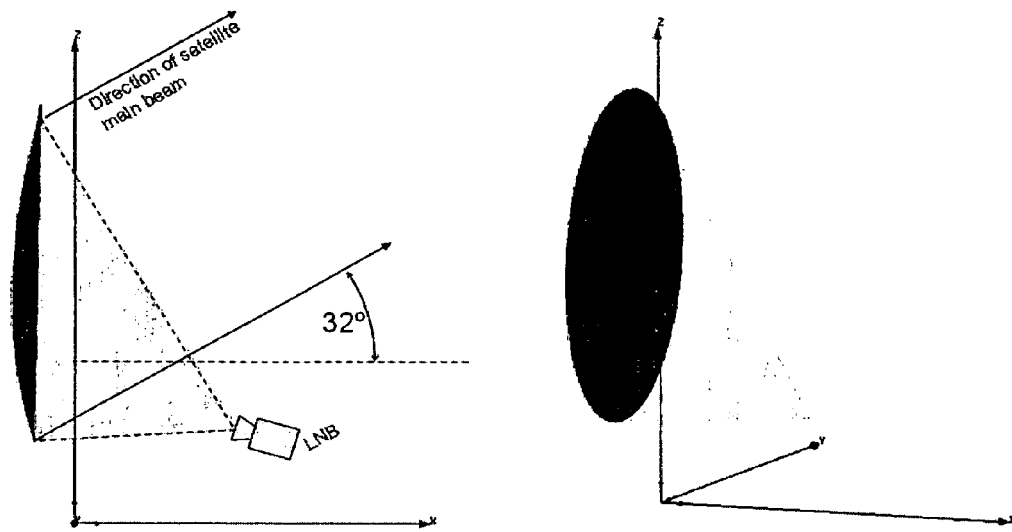


Figure 3: Geometry of offset-feed parabolic satellite dish in Latitude = 51deg (London, UK) with LNB.

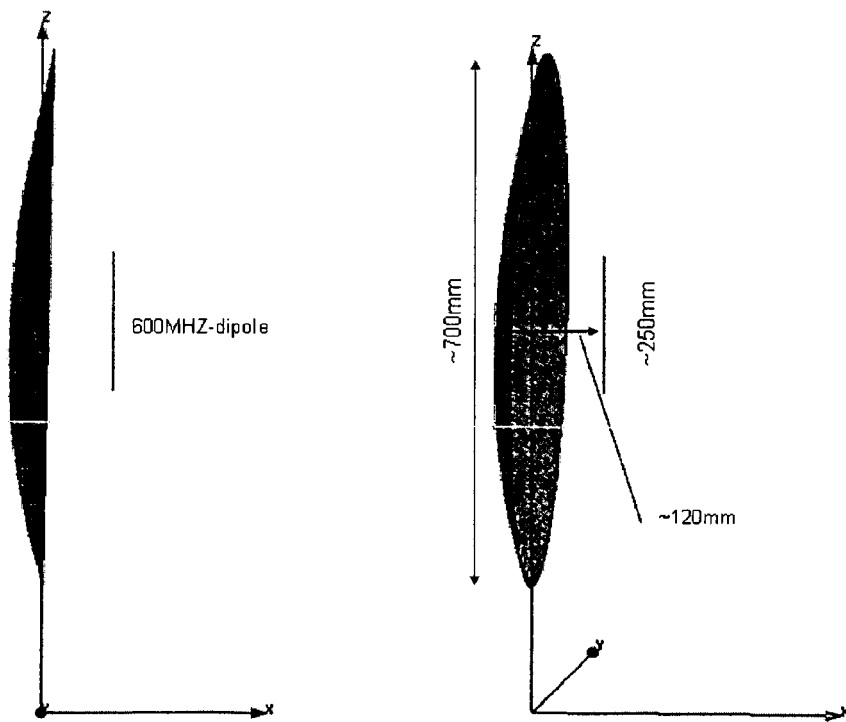


Figure 4: 32deg-uptilt dish for Latitude of London (51deg-North), with 600MHZ-dipole located in front of reflector.

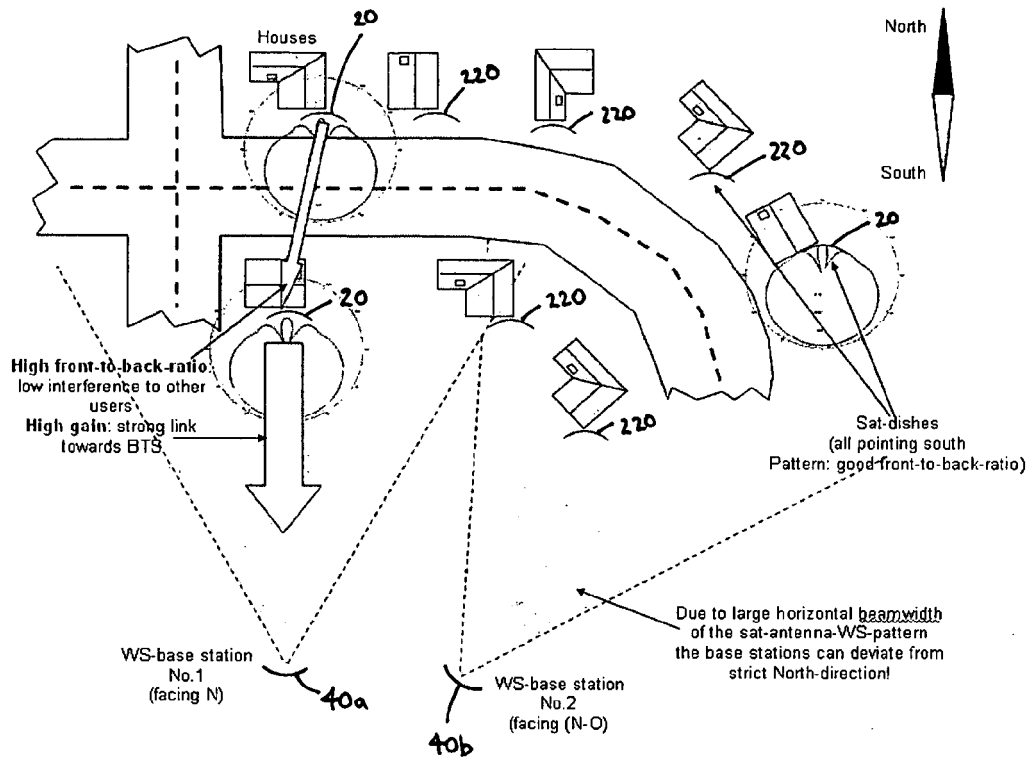


Figure 5: Network planning with North-facing base stations and all south-facing sat-antennas.

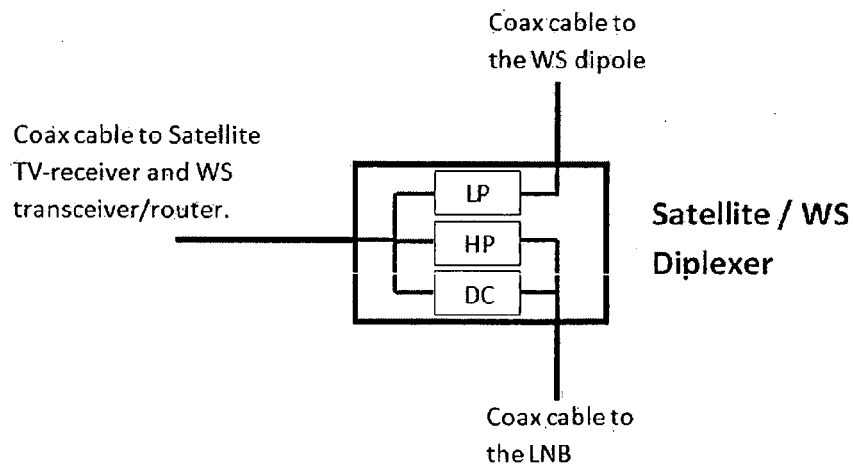


Figure 6: Satellite / WS diplexer functionalities

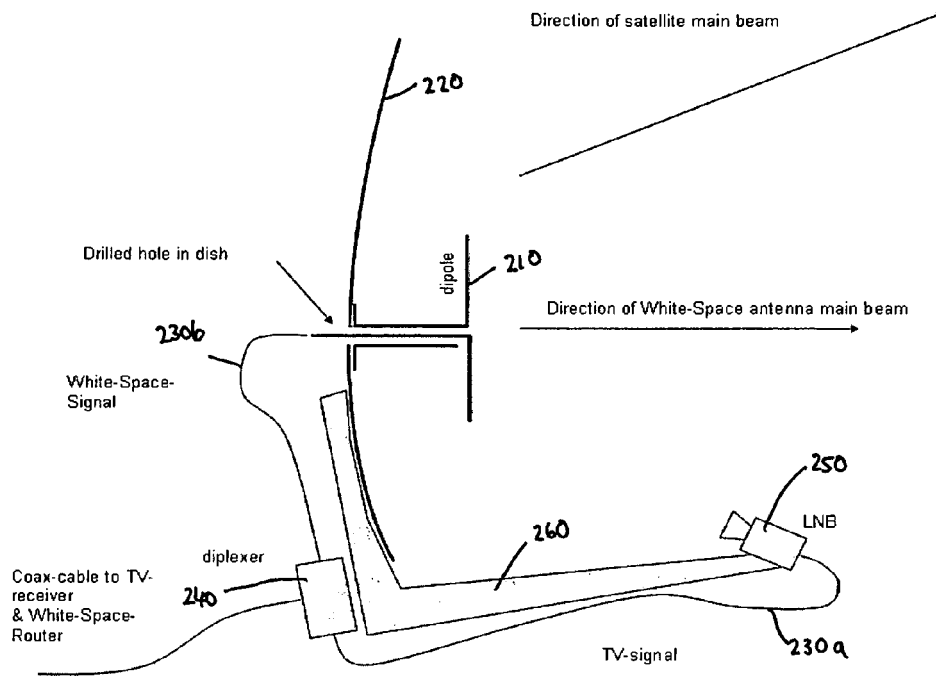


Figure 7a: Satellite dish with added White-Space Dipole. Mounted through a hole in dish with coaxial feed

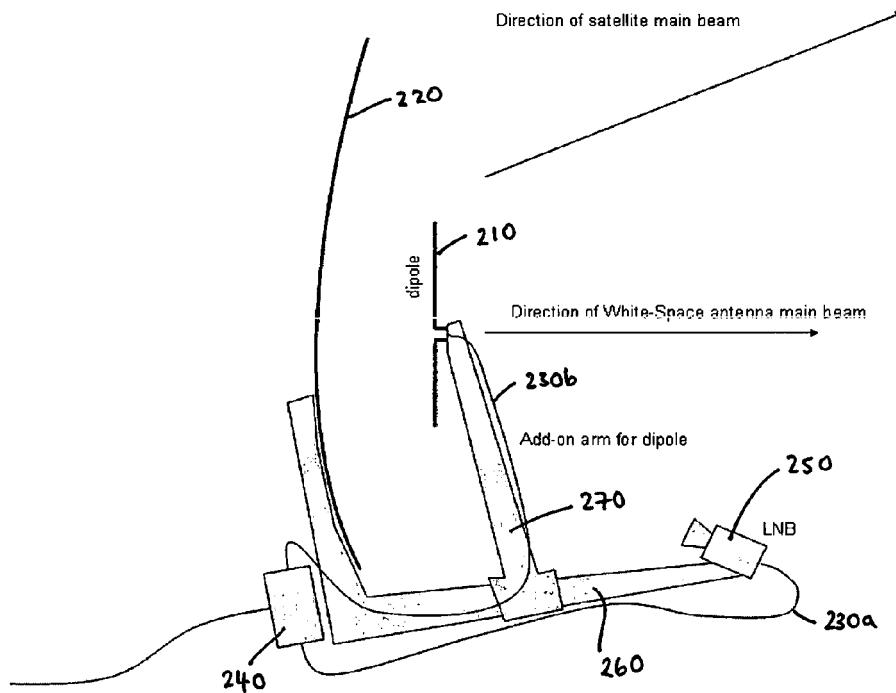


Figure 7b: Satellite dish with added White-Space Dipole. Mounted with extra arm from below.

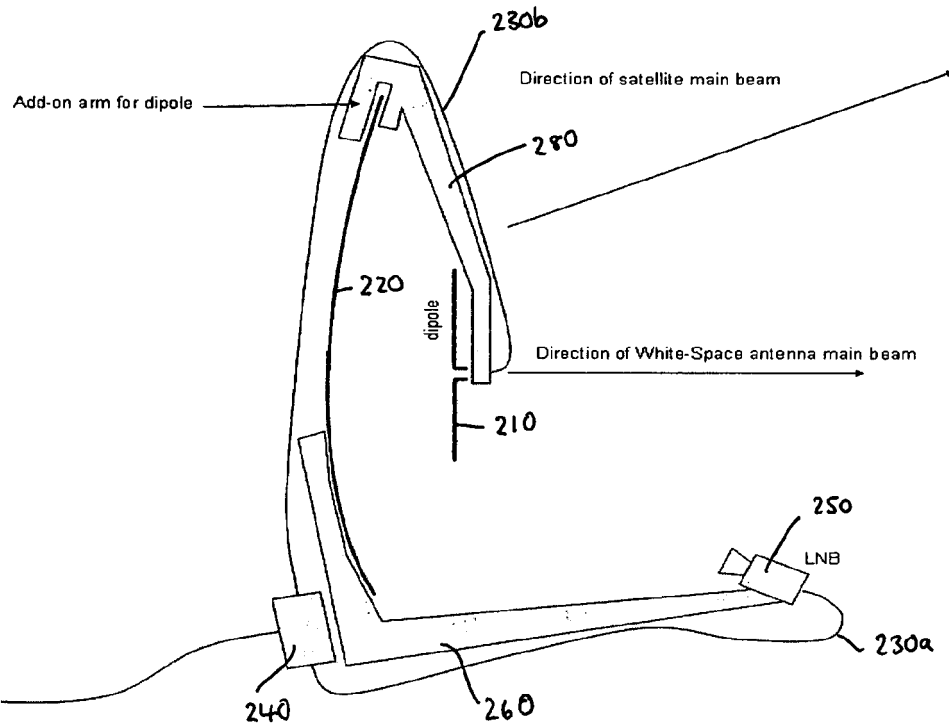


Figure 7c: Satellite dish with added White-Space Dipole. Mounted with arm from above.

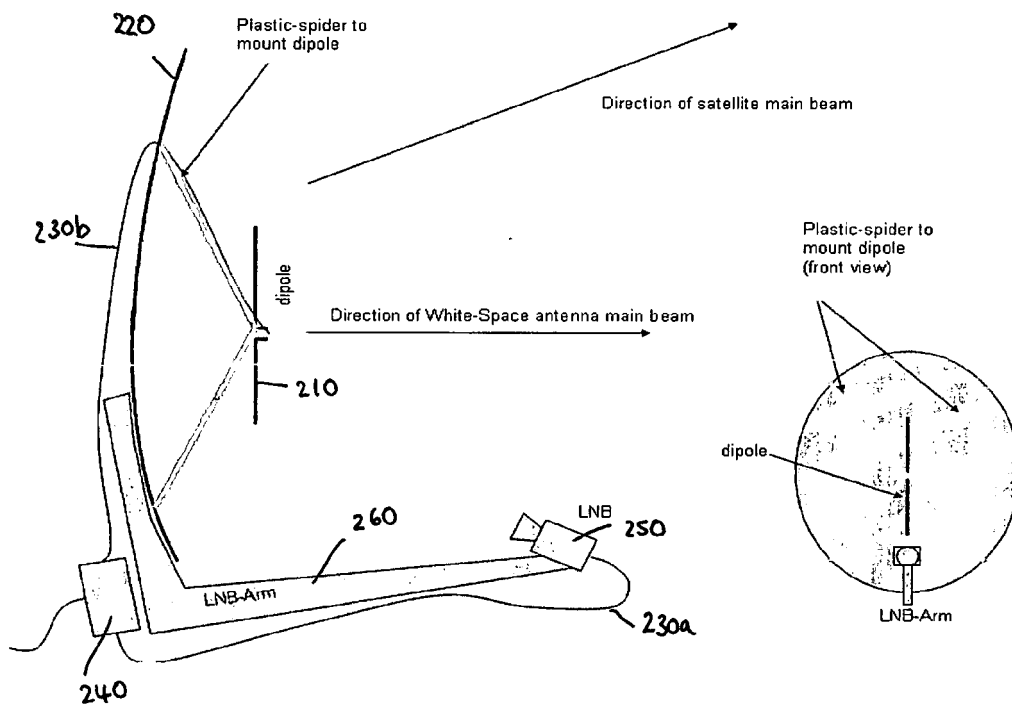


Figure 7d: Satellite dish with added White-Space Dipole. Mounted with spider (metal or dielectric arms).



EUROPEAN SEARCH REPORT

Application Number
EP 12 36 0053

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The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 21 January 2013	Examiner Marot-Lassauzaie, J
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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**ANNEX TO THE EUROPEAN SEARCH REPORT
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