Service Area Expansion and Deployment Acceleration Technology for Quasi-millimeter-wave-band Wireless Access System

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Abstract

To expand the service areas of wireless access systems using the quasi-millimeter wave band and accelerate their deployment, we have developed antenna beamforming technology, radio zone design technology, and subscriber station construction technology.

1. Introduction

The increasing demand for high-speed and high-capacity communications has recently led to the utilization of the quasi-millimeter wave band, which can guarantee a wide bandwidth. In particular, wireless access systems using the quasi-millimeter wave band are being applied to solve the regional-based digital divide by bringing high-speed access to sparsely populated rural regions and to provide services to apartments in metropolitan areas where optical fiber installation is difficult. These systems provide access lines that complement optical fiber.

To expand the applicability and service provisioning area of the quasi-millimeter-wave-band wireless access system and accelerate system deployment, NTT Access Service System Laboratories has developed antenna beamforming technology, radio zone design technology, and subscriber station construction technology to enhance WIPAS (wireless IP access system), which is a 26-GHz fixed wireless access system providing a radio transmission rate of up to 80 Mbit/s [1].

2. New technologies

2.1 Antenna beamforming technology

To serve customers in a large area, the base station antenna of the quasi-millimeter-wave-band wireless access system has a non-directional (omnidirectional) antenna. However, this can lead to communication quality degradation caused by waves reflected from mountains (bedrock) and large buildings (concrete or wood) around the base station, as shown in **Fig. 1**. One countermeasure against such interference is to adjust the directivity of the subscriber station antenna to eliminate reflected waves arriving in directions other than that of the main direct antenna beam. However, waves reflected from objects behind the base station, from the viewpoint of the subscriber station, have the same angle of incidence as the main antenna beam, and they still have a significant influence on the communications quality. To reduce the strength of the reflected waves, we have developed a technique for controlling the directivity of the base station antenna. This is done by attaching a radio wave absorber inside the radome (radar dome) of a base station antenna. This approach enables the antenna directivity to be controlled to suit the service area. It also has a simple construction.

An overview of the antenna beamforming technology is shown in **Fig. 2**. By suppressing the strength of the waves transmitted toward reflectors, we can reduce the interference from reflected waves and prevent communications quality degradation for subscribers in the service area. This is done by attaching a radio wave absorber over the angular range corresponding to the direction of a reflector (in this example, a large building). This reduces the signal strength in that direction, so reflected waves are weaker. This

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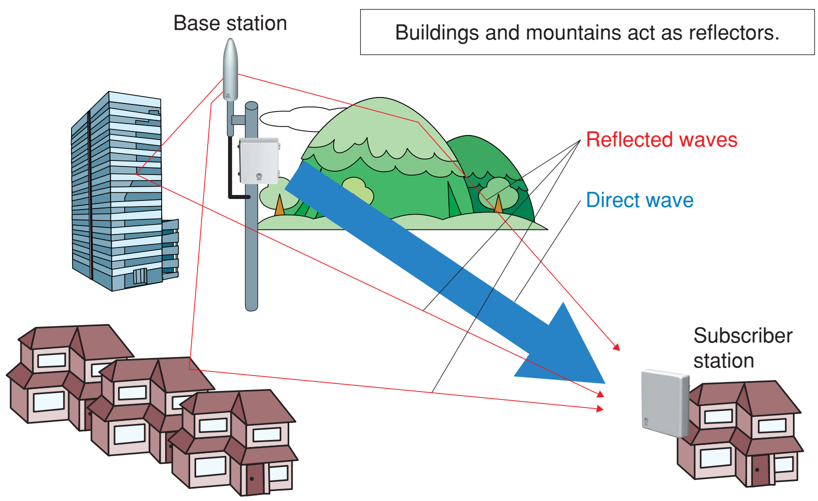


Fig. 1. Direct and reflected waves.

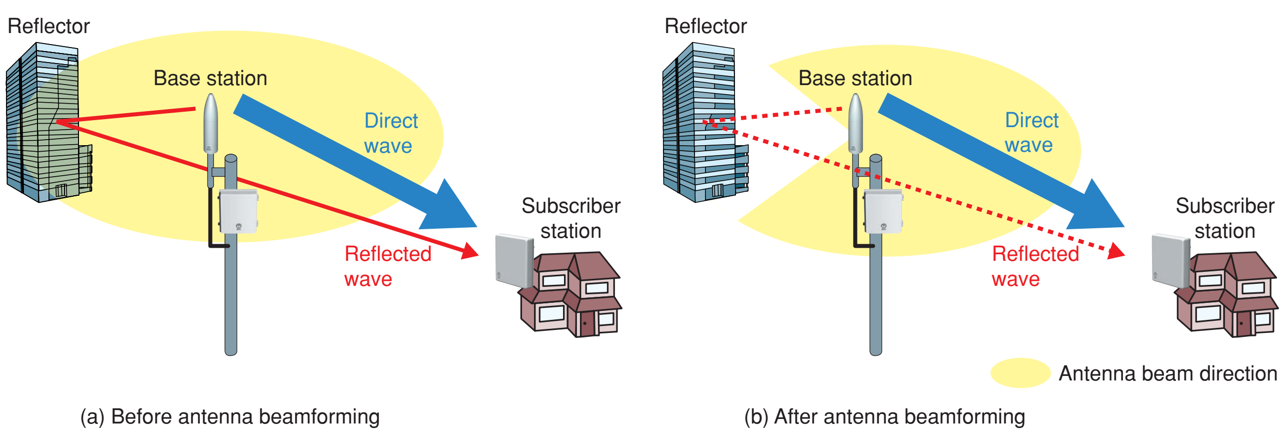


Fig. 2. Application of antenna beamforming.

method provides flexible control of the antenna's directivity. To provide an access service to customers in an area degraded by reflected waves, we need to install another base station. Thus, instead of using one non-directional antenna to cover a 360° service area, and having some subscribers suffer from reflection-degraded signal quality, we apply this beamforming technology to the non-directional antennas and ensure that all subscribers receive high-quality signals.

Installation of the radio wave absorber is very simple, as shown in **Fig. 3**. A sheet of absorber material is cut into long narrow tapering strips and attached vertically to the inside of the radome. This can be done to existing base stations. Since the only material required is an inexpensive radio wave absorber, the implementation cost is low. Moreover, when new building are constructed or demolished, the coverage provided by the absorber strips can be quickly and simply adjusted by a service engineer. This technique provides a countermeasure not only against interference from reflected waves, but also against interference caused by overreach*1 in the area expansion of quasi-millimeter-wave-band wireless access systems. As a result, the frequency efficiency of the area expansion can be improved. Field trials of this technique have confirmed that communication quality is

*1 Overreach: In this context, overreach means that electromagnetic waves used in one area reach other areas where the same frequency is used. As a result, the transmission quality may be reduced by interference.

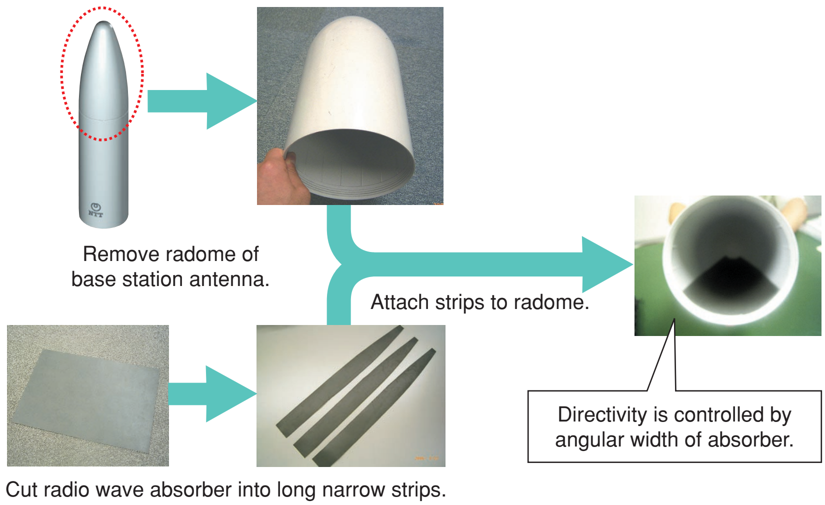


Fig. 3. Attachment of radio wave absorber.

improved.

2.2 Radio zone design technology

One of the conditions for providing services using quasi-millimeter-wave-band wireless access systems is line-of-sight (LOS) transmission between a base station and subscriber stations. Computer systems used for designing radio zones usually have a three-dimensional (3D) database compiled from various kinds of data such as geographical data, house map data, and tree shape data. Using the database, such a system estimates the LOS probability between various candidate base station positions and the surrounding houses. This enables optimum positioning of the base stations before actual construction.

As geographical data for the 3D database, "Digital Map 50 m Grid (Elevation)" provided by the Geographical Survey Institute may be used. Fundamentally, the geographical data should correspond to the actual elevation at each mesh lattice point. However, some newly developed residential areas involve large-scale earthworks that can change the local topography, leading to inconsistencies between the geographical data on file and current reality. Therefore, it is necessary to update elevation data at mesh lattice points spaced 50 m apart with the latest elevation data derived from elevation data at points obtained from municipal planning maps.

Among the methods available for estimating elevation data at mesh lattice points using data measured at other points, the nearest-neighbor method and the inverse distance weighting method are widely used. The former uses measured values that are closest to the mesh lattice point to be updated. The latter uses weighted coefficients that depend on the distances between the lattice point to be updated and some nearby measurement points. These methods are effective in areas where the elevation is almost equal in all directions or varies slowly. However, in newly developed residential areas where mountains have been deeply cut into, the elevation changes so rapidly in a specific direction that the estimation error can become large.

To reduce the estimation error and estimate the elevation data more accurately in terrain of this type, we considered the variogram*2, which has been used in geostatistics as a parameter indicating the spatial dependency between points. As an example, **Fig. 4** shows the updated results of elevation data at each 50-m mesh lattice point based on measured elevation data at some points on a municipal planning map. The updated results are closer to the real terrain. The calculated LOS ratios (number of LOS objects divided by the total number of objects) are shown in **Fig. 5**. In areas such as residential districts where the 50-m mesh elevation data and the actual geographical data differ, this method can increase the precision of the LOS ratio evaluation. A radio zone design system that uses this method should increase the opportunities to provide quasi-millimeter-wave-band wireless access service.

*2 Variogram: A variogram is a function that shows the ratio of variation in spatially separated data. It is used for estimating the degree of spatial dependence between two locations.

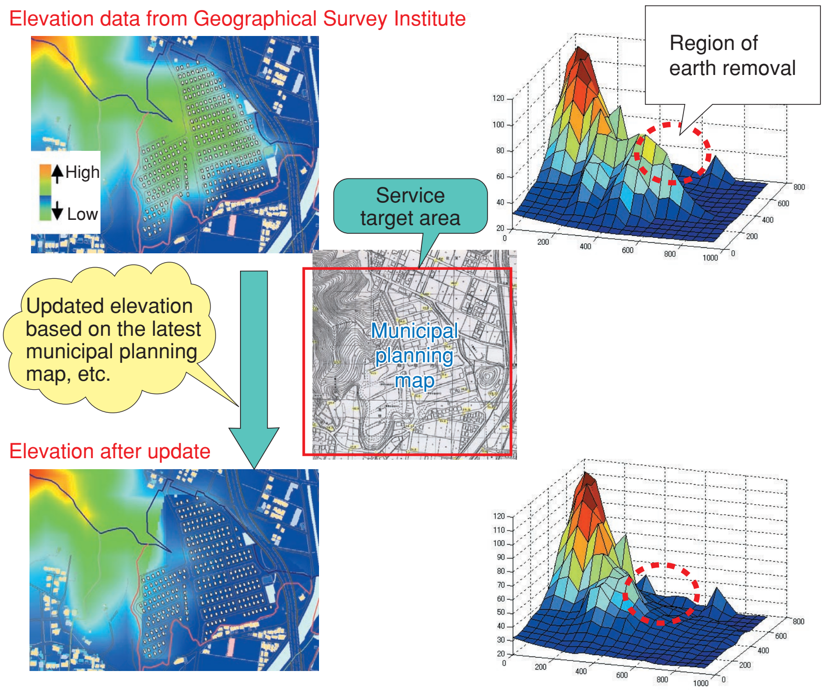
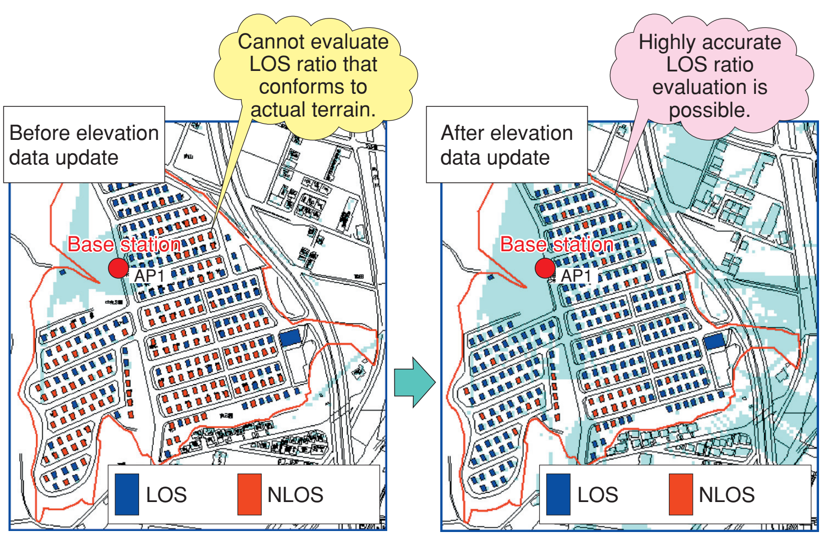


Fig. 4. Updated elevation results.



	Buildings	Homes	Families
Total number of designated objects	277	275	275
Number of objects in LOS	133	131	131
LOS ratio	48.0%	47.6%	47.6%

	Buildings	Homes	Families
Total number of designated objects	277	275	275
Number of objects in LOS	234	232	232
LOS ratio	84.5%	84.4%	84.4%

NLOS: non-line-of-sight; AP: access point

Fig. 5. Example of LOS ratio evaluation results.

2.3 Subscriber station construction technology

2.3.1 New construction methods for rooftops

Up to now, a roof-mounted base structure (typically a framework having four legs) has been used to install a subscriber station on the roof of a house. Installations of this type have been aimed only at ordinary residential homes (including houses with Japanese-style tile roofs) in Honshu, Shikoku, and Kyushu. Since there is demand for roof installations in rural areas of Okinawa, where many houses have eaves with insufficient strength to support antenna anchor points, and in Hokkaido, which experiences heavy snowfall, we adapted the roof installation method to make it applicable to those areas.

(1) For houses with weak eaves

The base structure mounted on the roof is held in place by stay lines (usually 2 or 4). In the usual method, each stay line is fixed to one anchor point on the fascia of the roof, which puts a heavy load on the fascia. In some rural areas of Okinawa, for example, there are many houses with eaves that are comparatively weak as a result of salt-air damage and deterioration. The new construction method we designed fixes each stay line to two anchor points on the fascia, as shown in **Fig. 6**. As a result, the tensile force is distributed, enabling an antenna to be mounted even on a house with weak eaves. We verified through actual experiments that antennas mounted using this method met the NTT specifications. Furthermore, since this construction method reduces the load on the anchor points, it should also be effective in areas that have strong winds.

(2) For areas with heavy snowfall

When a TV antenna is installed

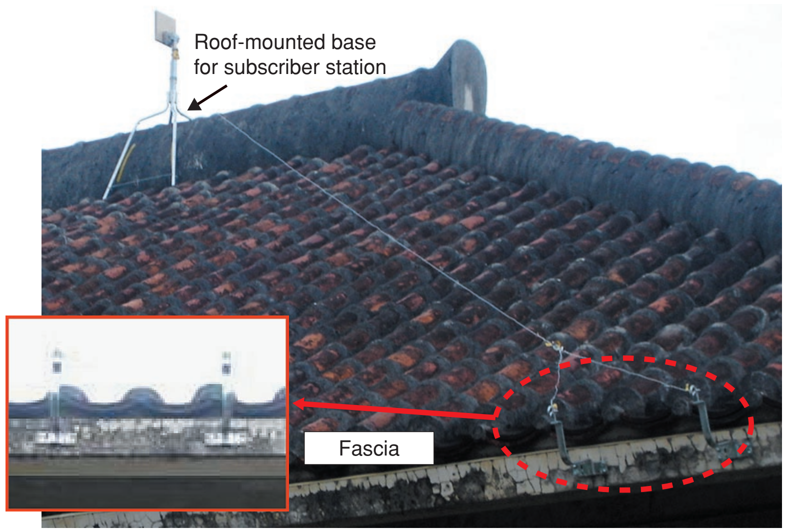


Fig. 6.   Construction method using two anchors on the fascia.

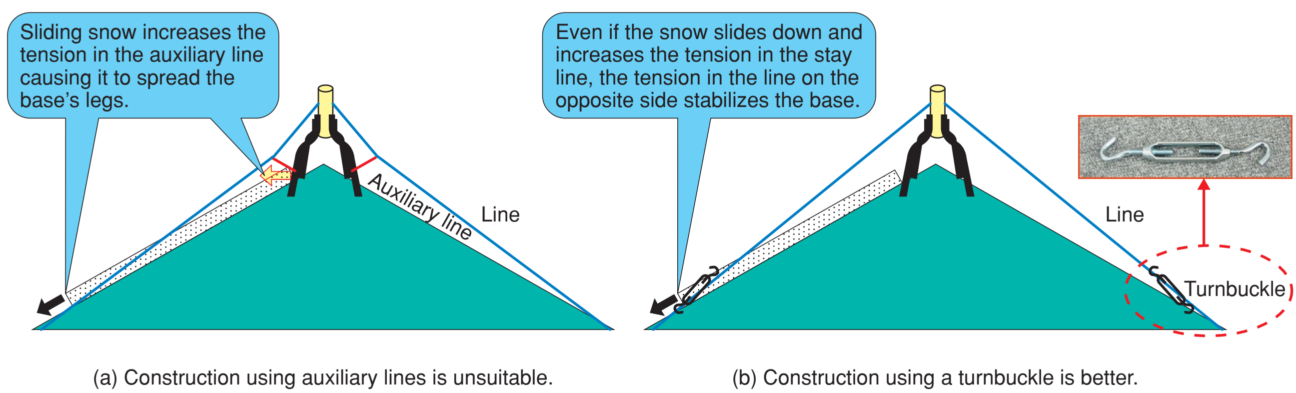


Fig. 7.   Construction method for areas with snowfall.

on a roof, an auxiliary line is placed between the stay line and the legs of the roof-mounted base to increase the tension in the stay line. With this construction method, however, when accumulated snow slides off the roof, its weight increases the tension in the auxiliary line, which causes the legs of the base to spread, which makes the base unstable, as shown in **Fig. 7(a)**. We devised a new method in which the base is fixed to the roof without an auxiliary line. Instead, a turnbuckle is used to maintain the tension in the stay line, as shown in **Fig. 7(b)**. When accumulated snow slides off the roof, even if it increases the tension in the stay line, the line on the opposite side resists the force and the base remains stable. We verified this method in actual experiments.

2.3.2 Construction method using extension pole under the eaves of a house

There have been cases where roof-installation of the subscriber station was the only option to guarantee LOS between the base station and the subscriber station, but the installation was prevented by the shape of the roof or was unacceptable to customers. We have developed and evaluated a construction method in which an extension pole is installed under the eaves of a house. This puts the subscriber station at the same height as a roof-mounted one. An installation example is shown in **Fig. 8**. The extension should be mounted where it can ensure that the subscriber station is in LOS of the base station and should not be in contact with the edge of the roof or with the roof tiles. After installation, diagonal lines

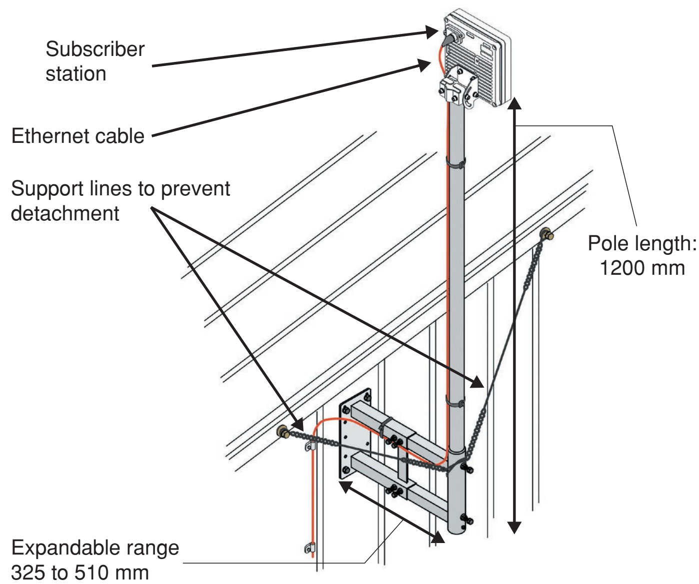


Fig. 8. Example of extension pole.

are connected to the upper part of the fixed brace-bolts on both sides of the fixture to support it. Since the installation and the directional adjustment are performed high above the ground, the use of access equipment such as a boom lift is recommended for safety.

3. Future plans

Quasi-millimeter-wave-band wireless access systems that provide access for services such as B FLET's in areas where optical fiber is difficult to lay are being introduced nationwide. To provide even more enhanced services in future, we plan to develop new fixed wireless access systems.

Reference

[1] S. Ueno, T. Tanaka, K. Usui, Y. Yasui, Y. Shindo, and H. Maruyama, "Development of Service-area Expansion Technologies for Wireless IP Access System," NTT Technical Review, Vol. 3, No. 8, pp. 52-56, 2005.

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