Radio Equipment | Booster | Economization

Technology Reports

Outdoor Booster Equipment for 2 GHz FOMA

Outdoor booster (repeater) equipment was developed for 2 GHz FOMA in order to provide services to previously blind areas promptly and economically. Booster equipment cost is relatively lower than other BTS equipment. It can be applied at low operating cost because no wired transmission lines are needed. Outdoor booster system is a cost-effective way to provide service areas, particularly mountainous regions with low traffic where radio waves are received at a low power level.

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1. Introduction

The number of FOMA base stations installed for outdoor areas has increased up to around 35,000 as of the end of fiscal 2006, and service areas have been smoothly expanding. Booster equipment is considered a way of improving service areas economically even inside buildings, in underground malls, mountainous regions, and other locations with low traffic. Booster equipment receives, amplifies, and re-emits radio signals between a base station and mobile stations. The equipment can provide service areas at low cost because its size is small enough and no wired transmission lines are needed [1]-[3].

Outdoor booster equipment requires high-gain and high-output-power amplifier in order to provide a larger service area than that for indoor equipment. Moreover, it is necessary to prevent oscillation caused by feedback[*1] since the two antennas (one directed at the base station and the other directed at the mobile station) are located close to each other [2].

This article describes the newly developed outdoor booster equipment for 2 GHz FOMA and the antennas which have been designed to suit the booster equipment.

2. Equipment Design

2.1 FOMA Outdoor Solutions and Application Area

Figure 1 shows the relation between the radio network equipment used to construct outdoor FOMA service areas and its application area. In order to provide a service area with low traffic, a one-carrier/one-sector Base Transceiver Station (BTS), one-carrier Optical Feeder Transmitter and Receiver (OF-TRX), and outdoor booster equipment are applied [4]. The specific radio equipment to be introduced is determined by considering the coverage area, method of accommodating increases in traffic resulting from a larger service area, and the feasibility of installing optical transmission lines. Since booster equipment can expand a service area by directly amplifying and re-emit-

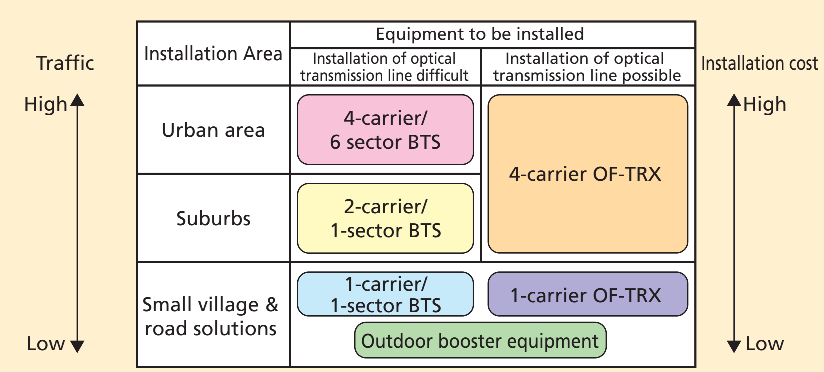


Figure 1 Relation between outdoor radio network equipment for FOMA and application area

*1 **Feedback**: Radio waves sent via the radio equipment's transmitting antenna and reflected back to its own receiving antenna.

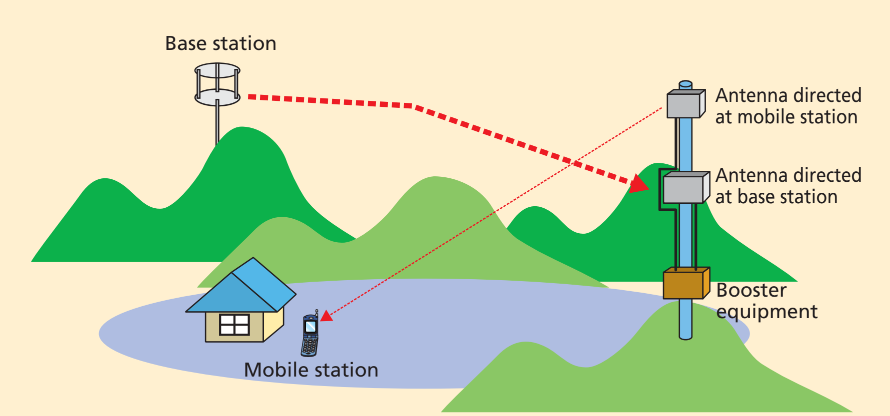


Figure 2 Overview of booster usage

ting radio waves from the BTS without a transmission line, its operating costs can be curtailed. Conversely, in a high traffic area, it is more suitable to use the BTS rather than a booster to provide a service area, since the capacity covered by the booster is partly shared with the capacity of the BTS.

2.2 Overview of Booster Usage

Figure 2 shows the overview of booster usage. The booster consists of an antenna directed at the base station, an antenna directed at the mobile station, and the booster main unit. In mountainous regions, basin-shaped valleys in the suburbs of cities, and other locations where downlink signal is received at low power level, the use of booster equipment is generally effective due to the small radius of the area covered and the low traffic.

2.3 Booster Transmission Noise and Uplink Capacity of Base Station

The installation of booster equipment degrades the uplink capacity of the base station. Equation (1) expresses the post-installation uplink capacity of base station C' relative to its pre-installation uplink capacity C as follows [5]:

$$C'/C = 1 - \frac{\sum N_{bk}}{(\eta - 1)N_{BTS}} \quad (1)$$

Here, N_{bk} denotes noise power from the booster equipment received at the base station, N_{BTS} the noise power of the base station's receiver, and η the base station's load margin[*2] [3].

Figure 3 shows the normalized uplink capacity and the radius of the area covered by the booster with respect to the propagation loss between the base station and booster equipment (hereinafter referred to as "propagation loss") according to the conditions shown in **Table 1**. Here, the propagation loss includes antenna gains. The radius of the area covered by the booster increases as the booster's gain increases and propagation loss decreases, but the degradation of capacity increases.

The newly developed booster equipment has a function to automatically control its gain according to propagation loss [1]. At propagation loss of 92 dB or more,

Table 1 Conditions for calculating capacity of the base station facing the booster

Item	Numerical value
Booster's downlink output power	30 dBm/carrier
Booster's maximum gain	80 dB
Gain of booster antenna directed at mobile station	11 dBi
Propagation model between booster and mobile station	Okumura -Hata model
Booster's noise figure	7 dB
Noise power of base station's receiver N_{BTS}	–103 dBm/3.84 MHz
Load margin of base station	1, 3, 6 dB

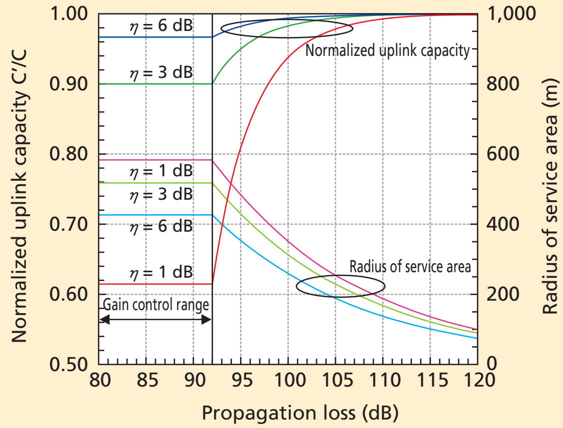


Figure 3 Relation between propagation loss and uplink capacity and radius of service area

*2 **Load margin**: In multiple access using CDMA technology, multiple users share the same frequency while tolerating interference. Load margin refers to the extent to which the increased interference caused by users is tolerated compared to thermal noise inherent in the receiver.

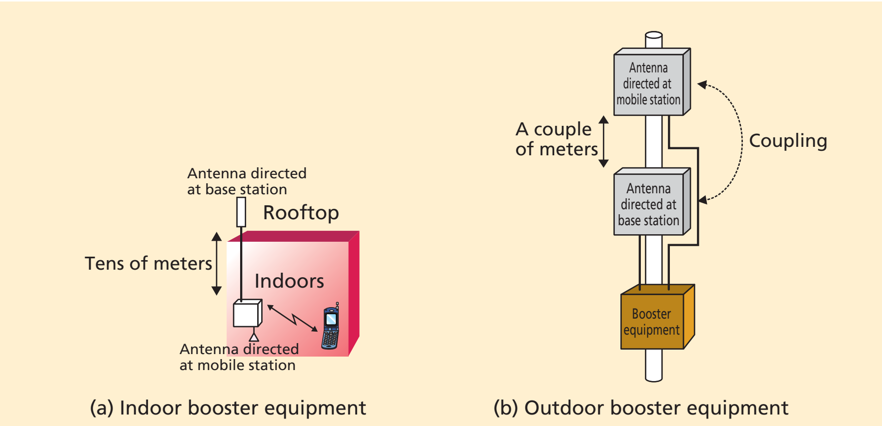


Figure 4 Feedback between booster antennas

Photo 1 External view of outdoor booster equipment

degradation of the capacity increases in proportion to the decrease in propagation loss. However, when propagation loss is within the control range from 80 dB to 92 dB, the booster can provide a service area while suppressing degradation of the capacity to a certain level. Fig. 3 shows that with a load margin of 3 dB, the booster can provide a service area with a radius of about 500 m when the booster operates within the gain control range.

2.4 Coupling Amount between Antennas

The required gain of indoor booster equipment is 60 dB or less [2] because the required radius of the service area is up to 100 m and generally the antenna directed at the base station and the antenna directed at the mobile station are located separately, resulting in large coupling amount[*3] between the antennas and consequently no feedback effects. However, gain of the outdoor booster equipment is up to 80 dB due to the required large radius of the service area, with the two antennas located only a couple of meters apart from each other on the same steel tower, thus it is difficult to achieve sufficient coupling amount between the antennas (**Figure 4**). Let L_c denote the coupling amount between two booster antennas, G_b the booster's gain, and M the margin to prevent oscillation. The required condition is expressed in equation (2) as follows:

$$L_C > G_b + M \tag{2}$$

Since the booster's gain must increase so as to increase the required radius of the service area, the required coupling amount between the antennas must be increased.

3. Equipment Overview

3.1 Outdoor Booster Equipment

Photo 1 shows the external view of the newly developed outdoor booster equipment and **Table 2** shows the basic specifications. Its maximum downlink power is 33 dBm and maximum gain is 80 dB. An automatic gain control function is applied to change the booster gain according to the propagation loss to minimize degradation in the uplink capacity of the base station [2]. The variable range of gain is 30 dB.

Table 2 Basic specifications of outdoor booster equipment

Item	Numerical value
Band	Downlink: 2,135 ~ 2,145 MHz Uplink: 1,945 ~ 1,955 MHz
Number of carriers	2 carriers
Output power	Downlink: 33 dBm Uplink: 15 dBm
Gain	50 ~ 80dB Automatic gain control
Max. radius of area covered	Approx. 500 m
Power supply voltage	AC100 V
Power consumption	No more than 250 VA
Size	No more than 450 (W) X 550 (H) X 250 (D) mm
Weight	No more than 35 kg

For the downlink, the Adjacent Channel Leakage power Ratio (ACLR)[*4], spurious[*5] and other radio characteristics are the same as those of the base station [6], whereas for the uplink, such characteristics are the same as those of the mobile station [7]. In addition, the booster has a function to decrease the booster's gain to prevent the oscillation when feedback increases due to changes in the external environment.

*3 **Coupling amount**: Loss (quantity) in one antenna and the other antenna between two antennas. Larger coupling amount is preferred to prevent oscillation when using a booster.

*4 **ACLR**: Ratio of one's signal power to that of unnecessary waves sent to an adjacent channel when a modulated signal is transmitted.

*5 **Spurious**: Undesired signal transmitted out of bands when a signal is sent.

3.2 Booster-dedicated Antennas

To achieve coupling amount even when two antennas are located closely to each other, booster-dedicated antennas were developed with a radiation pattern characterized by a high Front to Back (FB) ratio*6 and Front to Side (FS) ratio*7 [2][8]. **Photo 2** shows the external view of the booster-dedicated antennas and **Table 3** shows the basic specifications.

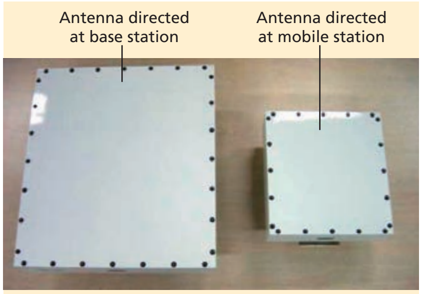


Photo 2 External view of booster-dedicated antennas

Figure 5 shows the horizontal beam pattern of the antennas directed at the base station and mobile station. The required gain of the antenna directed at the base station is 16 dBi or more to achieve higher received power with the booster equipment. A horizontal beam width*8 of the antenna directed at the mobile station is 40° to not only ensure the required gain but also to adequately shape the service area.

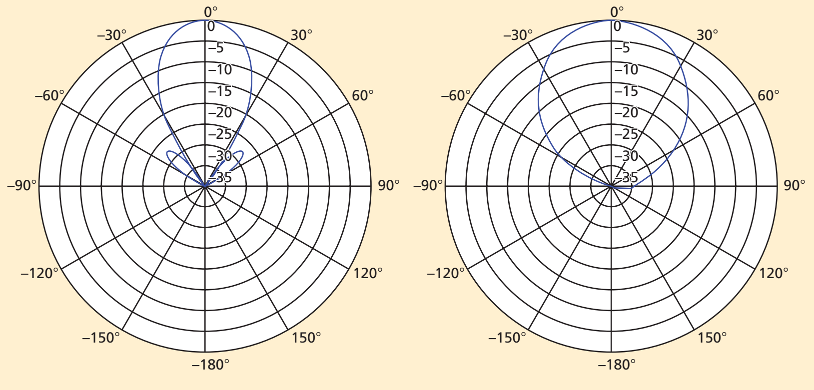
Figure 6 shows the measuring result of the coupling amount between the antenna directed at the base station and the antenna directed at the mobile station when both antennas radiate radio waves in the same direction. At a 6-meter distance between both antennas, coupling amount of approximately 90 dB was obtained, which is sufficient to operate the booster correctly (oscillation-free) with a maximum gain of 80 dB.

4. Conclusion

This article described newly developed outdoor booster equipment for 2 GHz FOMA and dedicated antennas for booster equipment. It explained how stable equipment operation is possible at a maximum gain of 80 dB by decreasing the degradation of the uplink capacity with automatic gain control and preventing oscillation caused by feedback using dedicated antennas. In the future, we plan to achieve further economical equipment and apply it to the 800 MHz band.

Table 3 Basic specifications of booster-dedicated antennas

Item	Antenna directed at base station	Antenna directed at mobile station
Antenna gain	16 dBi or more	11 dBi or more
Horizontal beam width	25°	40°
FB ratio	30 dB or more	30 dB or more
Size	No more than 500 (W) X 500 (H) X 100 (D) mm	No more than 320 (W) X 320 (H) X 100 (D) mm



(a) Antenna directed at base station (b) Antenna directed at mobile station

Figure 5 Horizontal beam pattern of booster-dedicated antennas

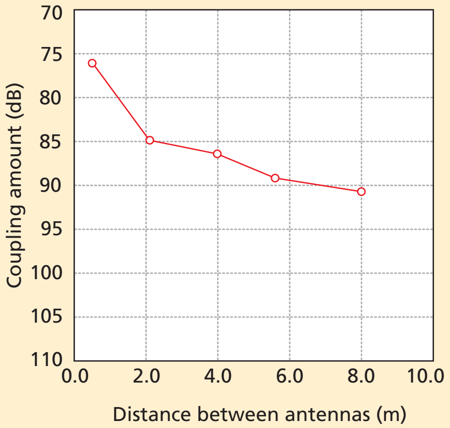


Figure 6 Results of measuring coupling amount between antennas

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*6 **FB ratio**: In this article, the ratio of the antenna gain at the main lobe (beam) and the antenna gain at the back lobe (approx. 180°, opposite direction of the main lobe).

*7 **FS ratio**: In this article, the ratio of the antenna gain at the main lobe (beam) and the antenna gain in the direction of approx. +90° and –90° from the main lobe.

*8 **Beam width**: Antenna's angle at which the beam is radiated with gain of –3dB or less from the maximum antenna gain.

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