Technology Reports

Studies on Spectrum Sharing Technology for Introduction of the Next-generation Mobile Communication Systems

We have been conducting a study on spectrum sharing technologies with a view to achieving more efficient use of radio spectrum resource for future mobile communication systems. Some of the results have also been submitted to the TES conducted by MIC of Japan; "studies on spectrum sharing for the next generation wireless communication" to which NTT DOCOMO have been actively contributed.

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1. Introduction

NTT DOCOMO is moving forward with R&D on IMT-Advanced toward achieving broadband mobile communication. A wide and continuous frequency band is indispensable to realize efficient broadband services using IMT-Advanced.

The International Telecommunication Union-Radiocommunication sector (ITU-R)[*1] World Radio communication Conference 2007 (WRC-07)[*2] also recognized the necessity of broadband mobile services, and decided to identify new spectrum bands with a total bandwidth of 428 MHz for the use of IMT (Third- and Fourth-Generation mobile communication systems)[1]. Those countries wishing to implement IMT are now preparing these frequencies for IMT use.

Among these new frequency bands, the band above 3 GHz (C band) is suitable for high-speed data communication. WRC-07, however, gave a green light only to a portion of the C band, the 200 MHz from 3.4 to 3.6 GHz, taking into account the extensive use by other existing services in some countries.

For those countries where the demand for IMT cannot be satisfied with the frequency band identified this time, the further use of a frequency band above 3.6 GHz is also being considered [2][3]. For that reason, use of the C band may differ from country to country and from region to region. Furthermore, the timing of introduction of IMT-Advanced may be different from country to country. Particularly at its initial introduction, there may be an issue of interference between IMT and existing radio systems at national borders, due to the different timeframes. This is also recognized by ITU-R as an important issue for smooth world-wide development of IMT systems. Another point is that the C band is already in use by existing services in some regions, so coexistence with incumbent services is an important issue in the introduction of IMT-Advanced. It is also important that IMT-Advanced system should maintain adequate service area and communication data rate, etc. so as to extract the full capabilities of IMT-Advanced as well as to protect existing services.

Against that background, the Association of Radio Industries and Businesses (ARIB)[*3] has conducted studies on spectrum sharing for the next generation wireless communication as a Min-

*1 **ITU-R**: A department of ITU, an organization that specializes in the field of telecommunications. It manages and coordinates international matters related to radio communication, such as radio regulations and spectrum use in various countries.

istry of Internal affairs and Communications (MIC) technical study based on the revenue from spectrum user fee in Japan. The objective of the study is to contribute to setting-up technical and/or regulatory conditions for the implementation of the IMT-Advanced systems.

NTT DOCOMO has been doing R&D on potential technologies for spectrum sharing with existing radio systems for smooth and early introduction of IMT-Advanced systems on the band identified by WRC-07. We contribute actively to the MIC's Technical Examination Service (TES) study group as well.

In this article, we describe an overview of the study group work on spectrum sharing technology and introduce the technical challenges being taken by NTT DOCOMO. These studies are being conducted together with Panasonic Mobile Communications Corporation in the study group.

2. TES: Studies on Spectrum Sharing for the Next Generation Wireless Communication

TES "Studies on spectrum sharing for the next generation wireless communication" began in FY 2006 and is planned to continue for four years until FY 2009. The TES study group consists of members from mobile communication operators, satellite communication operators, and major domestic and foreign equipment manufacturers. It discusses spectrum use by next generation wireless communication systems from various viewpoints.

This study group is studying next generation mobile communication system spectrum sharing technology mainly toward the efficient use of microwave band frequencies and to contribute to technical and regulatory conditions for the implementation of next generation wireless communication systems.

Specifically, we have studied the following three matters with respect to the C band that is being considered for the IMT-Advanced implementation.

- Validation of the propagation model to be used for sharing studies between IMT and other radio systems
- Investigation of the technical characteristics of the radio systems for which the spectrum sharing is to be conducted
- Feasibility tests of spectrum sharing techniques

3. Validation of the Propagation Model for Evaluating Interference between Systems

The model for evaluating interference between systems is specified in ITU-R Recommendation P.452 [4]. That model uses information on the topography between transceivers to judge whether the propagation path is Line Of Sight (LOS)[*4] or Non-Line Of Sight (NLOS)[*5]. That judgment is then used in estimating the propagation loss, taking into account free space propagation loss, diffraction, the ducting effect, troposphere reflection, clutter loss and other such factors (**Figure 1**). This model was also used in WRC-07 to calculate the Power Flux Density (PFD) limit[*6] that is a criterion for spectrum sharing between fixed satellite and mobile communication systems.

The model for evaluating inter-system interference should basically be designed not to overestimate the propagation loss in an actual environment. While that is important from the viewpoint of protecting existing systems from interference, excessive underestimation of propagation loss may result in undue constraint on a newly introduced system, e.g. its transmitting power. We are therefore conducting the following studies.

1) Studies on Expanding the Applicable Conditions

- Validation for short-distance propagation

The Recommendation ITU-R P.452 model emphasizes propagation loss mainly over long distances of several kilometers or more. However, future application of technology for preventing interference may reduce the distance between interfering stations and victim stations. We are therefore examining the applicability of Recommendation ITU-R P.452 to estimating such short distance propagation.

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*2 **WRC-07**: This conference is normally convened every three to four years with the goal of efficient use of the radio spectrum. It revises international Radio Regulation (RR) and other regulations that specify how each frequency band is used, how radio stations operate, technical standards and use of satellite orbits and so on.

*3 **ARIB**: An organization subordinate to the MIC that sets standards for systems that use the radio spectrum in the fields of communications and broadcasting in Japan.

*4 **LOS**: The state in which the transmitter and receiver are in a line of sight signal propagation relationship, with changes in the ground surface taken into consideration.

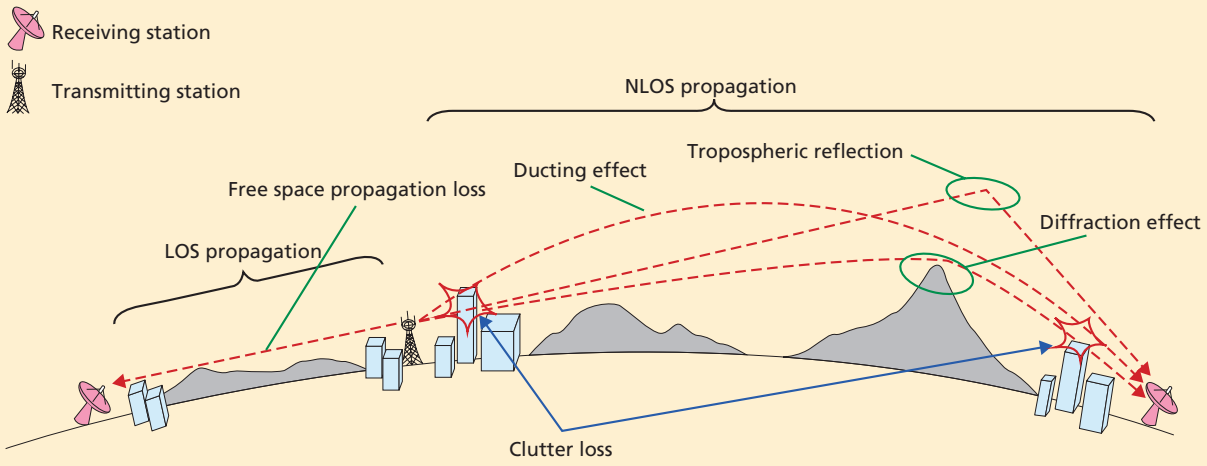


Figure 1 Main propagation loss factors considered in the ITU-R Recommendation P.452 model

- Validation for low antenna height assumption

ITU-R is currently studying revision of the propagation estimation method for when transmitters or receivers have low-height antennas (10 m or less). In this study, the validity of the revision currently proposed at ITU is to be investigated by data acquisition from field testing.

2) Verification of the Ducting Effect in Urban Areas

The ducting effect is a phenomenon in which radio waves propagate along the ground further than usual due to a temperature inversion layer that forms in the air because of night-time cooling or other reasons. The ducting effect is thought to be one factor that causes the underestimation of the propagation loss. To validate the ducting effect estimation method specified in Recommendation ITU-R P.452, experiments on medium- and long-distance propagation are in progress. The results will be input to ITU-R.

3) Verification of Clutter Loss Estimation

Clutter refers to the buildings and changes in topography around the transmitter and receiver that greatly affect signal propagation between them. An example of clutter loss evaluation is shown in **Figure 2**.

Last year, NTT DOCOMO proposed a method for validating the clutter loss estimation specified in Recommendation ITU-R P.452 by using 3-D map data and verified the clutter loss estimation for urban environments and where the local changes in topography are large. The results clarified the following two points [5].

- The clutter parameters assumed for urban environments do not provide a sufficient range of selection to cope with structural changes in continuously growing urban areas
- Local changes in topography that are not taken into account by the current model greatly affect the estimation results

We plan to propose a modified method to enable successive clutter loss estimation even in highly developed urban areas and undulating areas.

4. Study of System-specific Characteristics for Spectrum Sharing

For study of spectrum sharing conditions and sharing technology, the characteristics of the equipment used in the systems that will share spectrum

*5 **NLOS**: The state in which the transmitter and receiver are in a non-line of sight signal propagation relationship, with changes in the ground surface taken into consideration.
*6 **PFD limit**: The limit of power density per unit surface area.

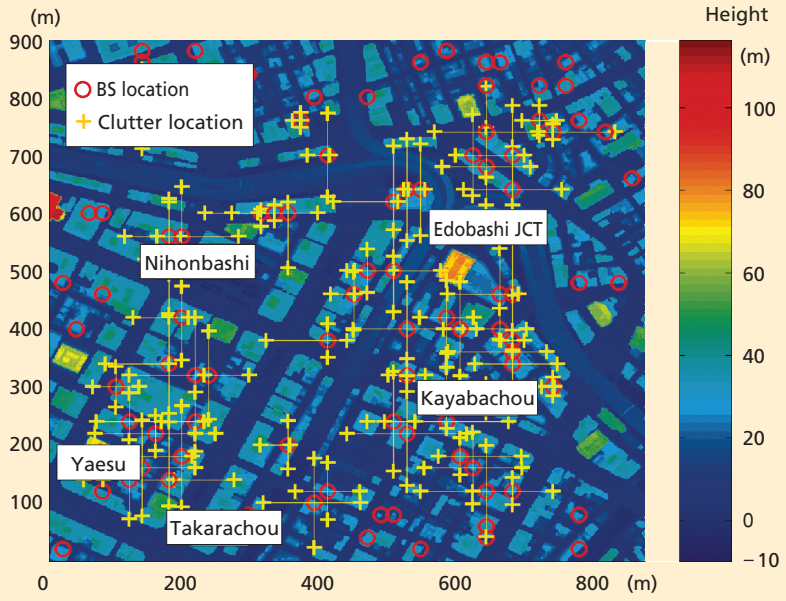
and the propagation characteristics for the circumstances in which that equipment is used (mobile/fixed, frequencies, antenna type, etc.) must be known. We are therefore studying the items listed below. The basic evaluation of systems for spectrum sharing is shown in **Figure 3**.

1) Obtaining Channel Characteristics

We are conducting field experiments using highly directional parabolic antennas designed for use with Fixed Satellite Services (FSS) to study the characteristics of radio wave propagation paths between IMT Base Station (BS) antennas to provide basic data for studying algorithms to prevent or suppress interference.

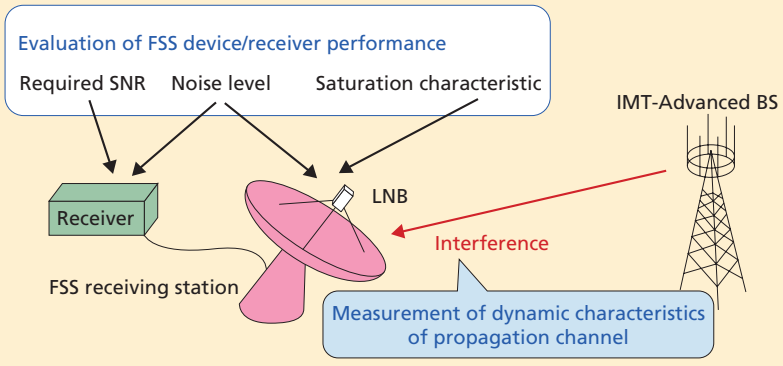
2) Evaluation of FSS Receiver Performance

These studies are intended to clarify the basic conditions for spectrum sharing between IMT systems and satellite systems, such as required guard band[*7] width. Specifically, basic data is being collected by measuring the performance of commercial receivers that are in actual use.



*The locations of the BSs in the figure show possible BS sites for clutter loss estimation, assuming that the BSs are installed on buildings from 25 to 30 m high, and do not shows actual BS sites in operation.

Figure 2 Example of clutter loss evaluation



LNB : Low Noise Block converter
SNR : Signal to Noise Ratio

Figure 3 Basic evaluation of systems subject to spectrum sharing

5. Validation of Spectrum Sharing Technologies

Report ITU-R M.2109[6] describes spectrum sharing techniques between IMT-Advanced and FSS. Our studies deal with the three interference mitigating techniques indicated in Report ITU-R M.2109, which are Multiple Input Multiple Output (MIMO), Sector Disabling, and Dynamic Spectrum Allocation (DSA) (**Figure 4**). Our studies also include technologies on the boundaries of those areas, and we are conducting computer simulations and field trial to study the effectiveness and issues of those technologies.

*7 **Guard band**: A frequency band set between the signal frequency bands of systems to prevent radio signal interference between systems.

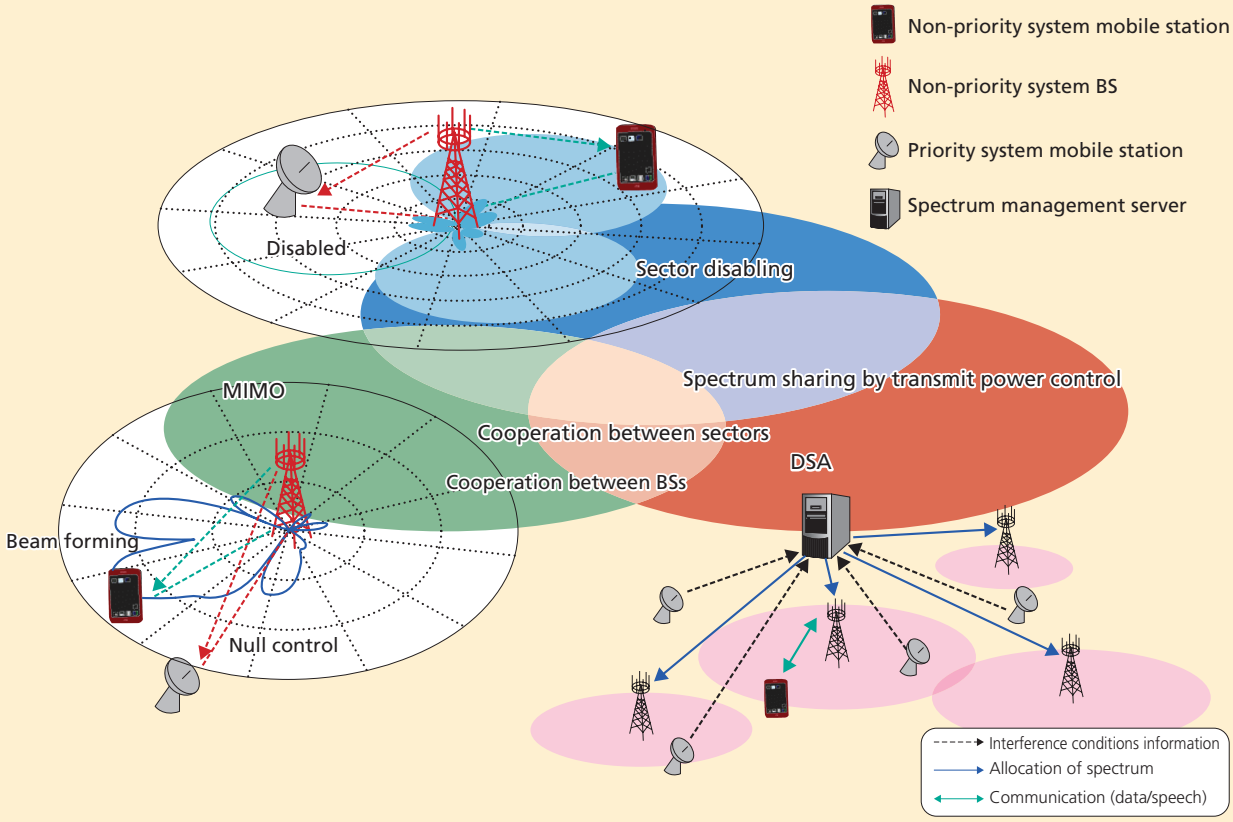


Figure 4 Spectrum sharing technology

5.1 Interference Reduction by MIMO Technology

Generally, MIMO refers to a radio communication technique that uses multiple antennas on the transmitting and receiving sides. Report ITU-R M. 2109, however, mainly refers to the use of multiple antennas on the transmitting side for beam forming as a means of avoiding harmful interference. Our studies seek to verify the effect of this beam forming on suppressing and reducing interference through field experiments.

In addition to the basic configuration in which one BS uses multiple antennas, we are also verifying configurations that involve cooperation between sectors and cooperation between BSs.

Even for system configurations in which the BS or sector has a single antenna, however, this technique can still be realized by cooperative transmission of multiple stations or sectors. With the sector cooperation technique, however, the main beam directions of the cooperating sectors differ; therefore the practical effect greatly differs from a MIMO scheme in which one sector has multiple antennas.

On the other hand, in the case of cooperative transmission among geographically separated BSs, it is possible to form a very sharp null due to the large antenna separation, although synchronization between BSs is a potential problem due to the use of different local oscillators at the different BSs.

5.2 Interference Mitigation or Avoidance by Sector Disabling

In sector disabling, when the transceiver of a newly deployed system

(non-priority system) is set up, its sectors that look in the direction of victim stations are not used.

This approach can be expected to greatly reduce interference without using advanced technology. In an actual propagation environment, however, there may be significant degradation caused by diffraction and reflection.

Moreover the interference mitigation effect should be also studied for the case in which various types of antenna (e.g. antenna beam width) and/or MIMO transmission scheme are applied to IMT-Advanced BS.

5.3 Interference Avoidance by DSA

DSA refers, in a broad sense, to a method of dynamically allocating frequencies. In Report ITU-R M.2109, it is introduced as a method for controlling the operation of an interfering station according to the usage of the spectrum by potential victim stations.

This DSA-based spectrum sharing method can be a paradigm shift from the conventional "static spectrum sharing approach" to a "dynamic spectrum sharing approach", where the "static spectrum sharing" is based on maintaining a separation distance with a sufficient margin from the interfering stations taking into account the noise level of victim receivers while the "dynamic spectrum sharing" is based on the actual permissible level of interference for the victim receiver at each point in time. This change in approach can reduce the large fixed interference margin that has previously been necessary to protect the victim stations.

To fully protect victim stations, however, there are many issues to be solved, such as accurate measurement of the interference level, tracking of the changes in the interference conditions, and processing complexity. We are therefore conducting laboratory and field experiments to clarify the basic performance and effectiveness of this technique, and the issues it entails.

NTT DOCOMO has made a proposal for spectrum sharing between priority and non-priority systems, which uses transmitting power control as a promising DSA approach [7]. The proposed technique is less affected by channel fluctuation than are beam forming methods. In addition, the method allows efficient spectrum sharing when victim system and interfering system use adjacent frequencies as well as the same frequency. The results of theoretical analysis show that capacity can be doubled compared to the conventional method.

6. Conclusion

In this article, we have introduced the research being done by NTT DOCOMO on spectrum sharing with existing services, which would be necessary for the global deployment of IMT-Advanced system.

The results of this work will be reported to the study group of the MIC TES "Studies on spectrum sharing for next generation wireless communication" to seek opinions and comments from experts in the relevant organizations. Taking these views into account, NTT DOCOMO will further proceed with this study in order to contribute to the study group and to facilitate the smooth introduction of IMT-Advanced system.

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