# Special Article on Link Systems
## Development of New Microwave Radio-Relay Systems

Microwave Radio-Relay Systems have been mainly applied for constructing DoCoMo's transmission networks. Then, the construction of network infrastructure will be made progress with increased the trunk transmission capacity and lower initial cost.

In this paper, the newly developed transit system, microwave radio-relay systems are explained.

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## Introduction

As for the applied area and the applied microwave radio-relay systems in the transmission networks of DoCoMo group, in the most case, the 4/5/6G-150M systems have been applied for long-haul links and the 11/15G-150M systems and the 11/15G-50M systems have been applied for short-haul links, as shown in Figure 1.

In the circumstances around these microwave radio-relay systems, the situation is all the more pressed for securing transmission capacity and strengthening competitive power (transmission cost reduction) to serve IMT-2000 (International Mobile Telecommunications-2000) slated to commence its services in 2001, in addition to the demand increase due to the growth of overall mobile communication businesses. Furthermore, the existing systems are the inherited specification systems that have been developed and put into practical use by the main body of NTT in 1989 with a view to serving NNI (Network Node Interface). Hence, the equipment design itself is about 10 years old. In order to address this point, it has been required to establish the company equipment specification and to improve maintenance function by application of the latest design technology.

In response to these requests, new microwave radio-relay systems have been developed by DoCoMo in order to realize transmission capacity increase, economizing, and improvement in maintenance. These systems are described in this

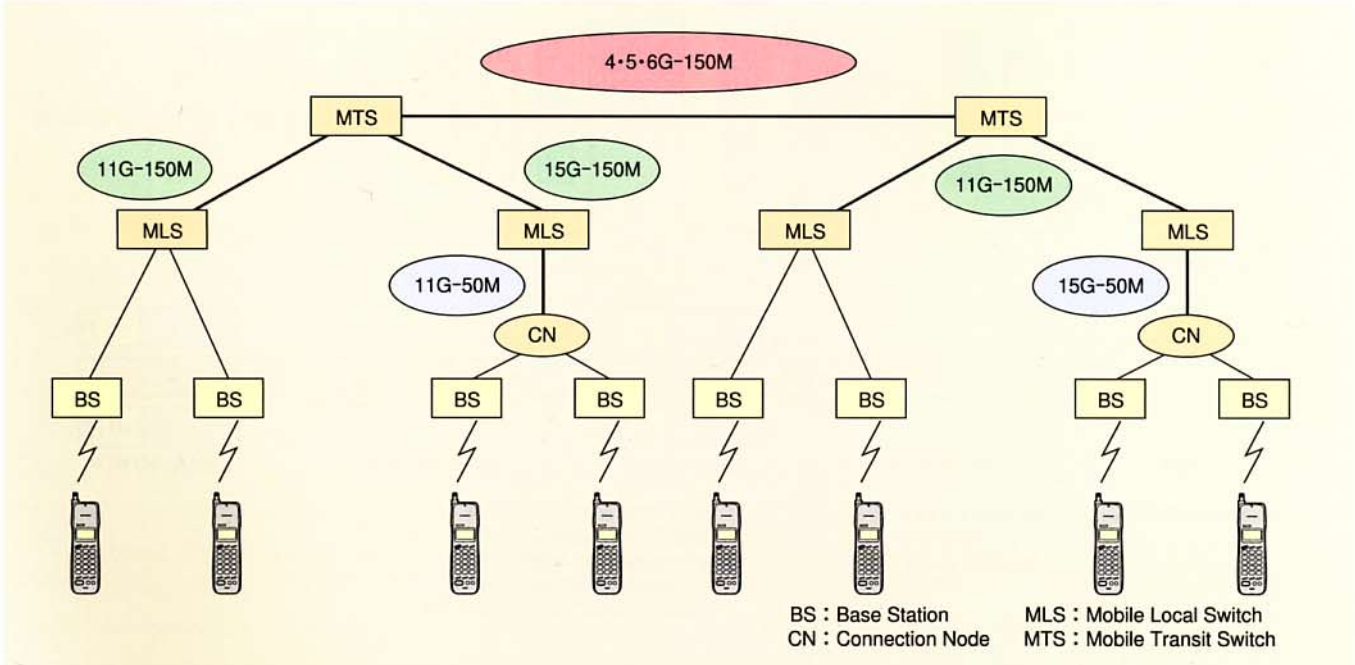


Figure 1 Application of Fixed Radio-Relay Systems in the Mobile Communication Network

paper.

## Development Concept

Keywords in the development of new microwave radio-relay systems are "Transmission capacity increase", "Economizing", and "Improvement in maintenance". Major realization schemes are as follows.

At first, as for the 150M systems, "Transmission capacity increase" is planned by adoption of high-level modulation technique for the exiting 11/15G-150M (8PSK*1) and 4/5/6G-150M (16QAM*2) systems as well as reconsideration of frequency channel arrangement. In particular, "Remarkable economizing" including reduction of modulation and demodulation unit is planned for 4/5/6GHz-band systems by the change from 3 multi-carrier transmission to single carrier transmission. Moreover, along with raising the monitoring and telemeter functions of the 11/15GHz-band systems to the level of the existing long-haul systems, the monitoring telemeter for 4/5/6GHz-band systems are similarly planned to be studied in optimal reconsideration.

Next, as for the 50M systems, "Saving equipment space" and "Improvement in maintenance" are mainly planned for the existing 11/15G-50M systems. Although the latest circuit design is adopted and panel functions are integrated, radio system main parameters such as modulation scheme, radio clock frequency, and transmission power are not changed.

The above-mentioned matters have been determined as the basic development concept. It is illustrated in Figure 2.

## 11/15G-150MD Systems

These systems are the microwave radio-relay systems that have been newly developed with a view to increasing transmission capacity, strengthening the monitoring/telemeter

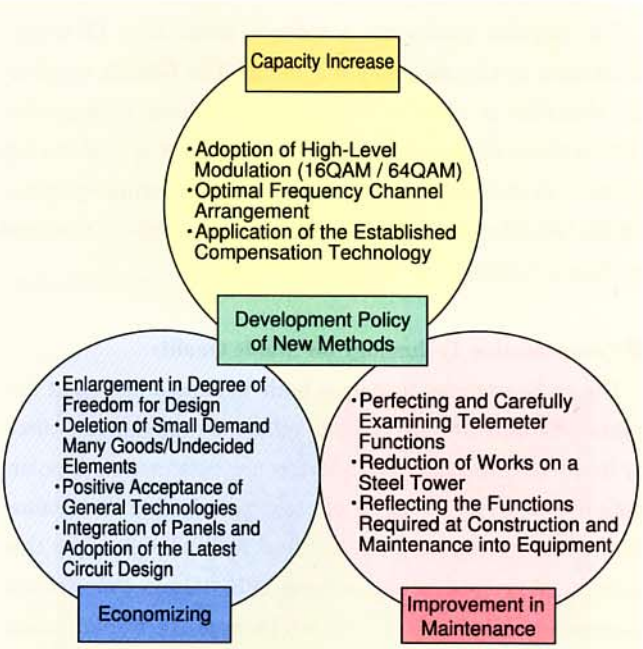


Figure 2 Concept of Development

Table 1 Main Parameters of 11/15G-150MD Systems

| | 11/15G-150MD Systems | | Existing Systems | |
|---|---|---|---|---|
| | 11G-150MD | 15G-150MD | 11G-150M | 15G-150M |
| Frequency Band | 10.7~11.7GHz | 14.4~15.23GHz | 10.7~11.7GHz | 14.4~15.23GHz |
| Transmission Rate | 155.52Mbit/s/system | | 155.52Mbit/s/system | |
| Number of Systems Working+Back up | 15+1S | 11+1S | 10+1S | 7+1S |
| Modulation Scheme | 16 quadrature amplitude modulation (Radio clock frequency : Approx. 41.8329MHz) | | 8 phase shift keying (Radio clock frequency : Approx. 55.7772MHz) | |
| Transmission Power | 33dBm/35dBm | 30dBm | 33dBm/37dBm | 24dBm/30dBm |
| Noise Figure | 4.0dB or less | 5.0dB or less | 4.0dB or less | 5.0dB or less |
| Fundamental Degradation | 2.5dB or less | | 3.0dB or less | |
| Standard Repeater Spacing | 25km | 10km | 30km | 10km |
| Compensation Device | Transversal equalizer (DFE) Cross polarization Interference Canceller (XPIC) Error correction (Double error correcting BCH code) | | Transversal equalizer (DFE) Error correction (Double error correcting BCH code) | |
| Interface Type | 150M, 50M/intraoffice, interoffice | | 150M, 50M/intraoffice, interoffice | |
| Frequency Allocation | 60MHz co-channel allocation | | 40MHz co-channel allocation | |
| Power Supply Type | DC−48V | | DC−48V, −21V | |
| Facility Form | Indoor installment | | Indoor installment | |

functions, and reducing the cost, as the successor systems for the existing 11/15G-150M systems. The main parameters of the systems are listed in Table 1, as a comparison against the existing systems. The features are described for the systems as follows. Additionally, Figure 3 shows the features.

### ■ Transmission Capacity Increase by Adoption of High-Level Modulation Scheme and Reconsideration of Frequency Channel Arrangement

The 16-point quadrature amplitude modulation (16QAM) is adopted as the modulation scheme. The 60MHz co-channel allocation is adopted for frequency channel arrangment. Due to these measures, one and half capacity is realized for route transmission compared with the existing systems (8PSK/40MHz interleave allocation). An example of frequency channel arrangment is shown in Figure 4.

### ■ Compensation Technology for Stable Quality

The radio systems that uses both V/H polarization at frequency band of 10GHz or over suffers on rain severe effect by frequency interference (Interference between cross polarization) due to degradation of cross polarization discrimination, along with decrease in received power level. As for this system, adoption of a digital-type XPIC (Cross Polarization Interference Canceller)[*4] allows to improve transmission quality. Furthermore, a digital-type Transversal equalizer[*5] is adopted to realize stable quality of equipment, in response to increase in the equivalent CN degradation volume due to Inter Simbol Interference accompanied with the high-level modulation scheme.

### ■ Strengthening the Monitoring / Telemeter Functions

Transmission power level, received power level and BER (Bit Error Rate) of radio equipment as well as circuit quality of radio section can be measured at the front of the equipment using monitor goods or PC. Moreover, various kinds of telemeters are enabled remotely from an operation center.

When a failure occurs, multiple equipment alarms may occur at the following systems. A function has been realized to collect these alarms to the main monitor equipment, and arrange and judge them to announce a failure alarm "The highest class alarm", which has the highest possibility for the factor of failure occurrence, to an operator.

In addition, auto monitoring is always conducted on quality of radio section. It contains a function that announces "Radio section degradation alarm" to an operation center and sums them if errors before error correction exceeds a certain threshold value. These monitoring and telemeter functions are decided to be common functions for the 4/5/6G-150MD systems described later.

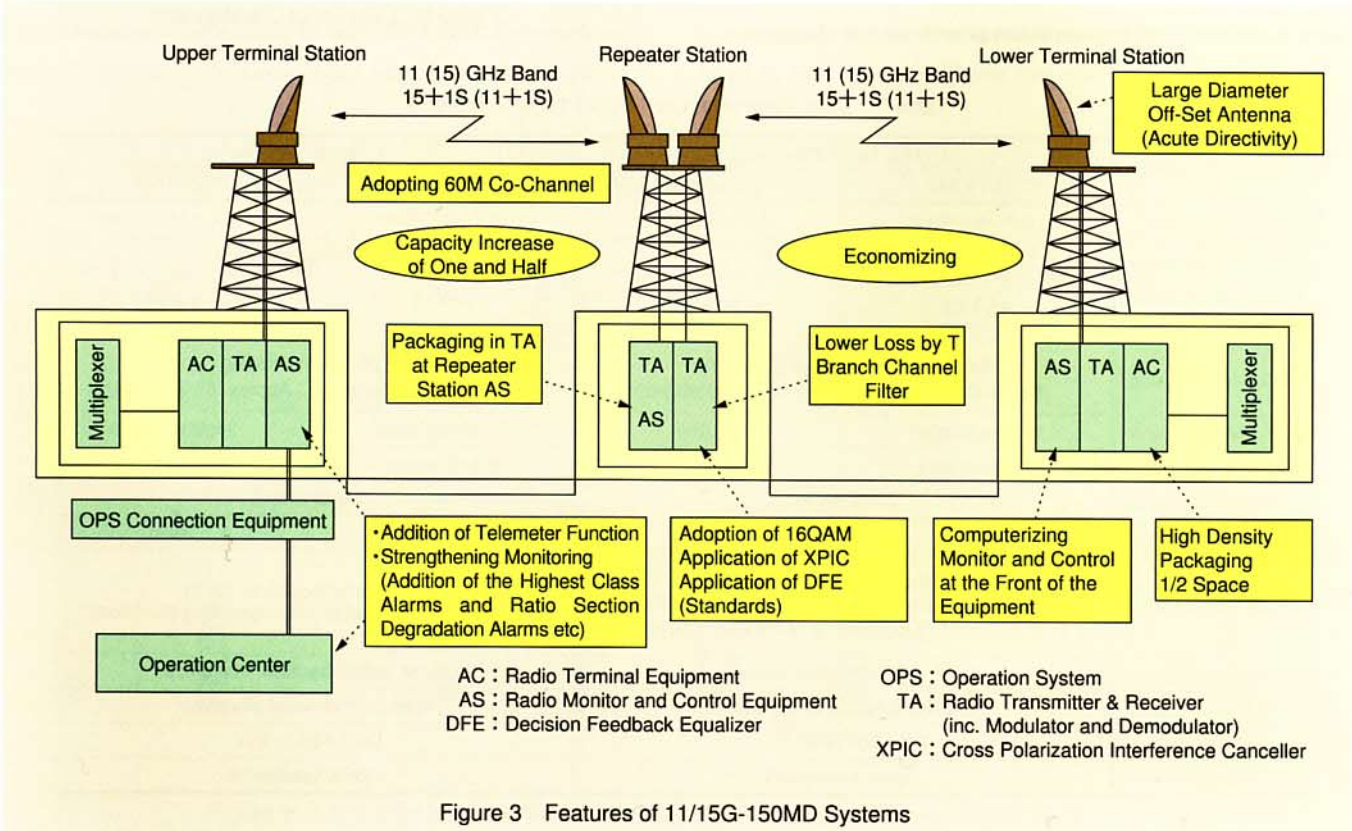


Figure 3 Features of 11/15G-150MD Systems

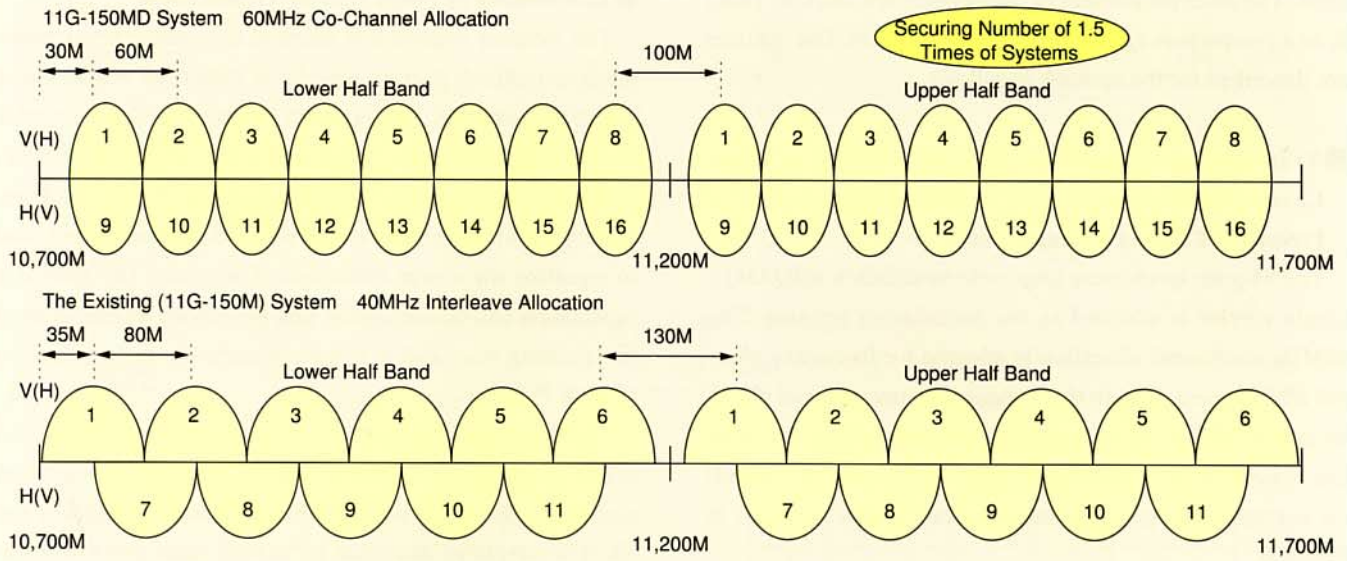


Figure 4 Frequency Channel Arrangement (11GHz Band)

### ■ Equipment Packaging for Realization of Saving Floor Space

As for the radio transmission/reception equipment, 4systems of the transmission/reception unit, the modulation and demodulation unit and the channel branch filter can be packaged into one rack (600 mm wide) for 11GHz band. 6systems can be packaged into one rack (800 mm wide) for 15GHz band.

As for radio the terminal station equipment, 4systems of signal processing unit, the line switching unit, and the interface unit the existing systems. According to panel function integration and the latest circuit design, 8 systems can be packaged into the same one rack for this system. Hence, the floor space is saved remarkably.

As for the radio monitor and control equipment, the line monitor and control unit, the device monitor unit, and the telemeter function unit are packaged into one rack (600 mm wide). The Monitor and control equipment for the repeater station is packaged into radio transmission/reception equipment to save the floor space of the repeater station.

### ■ Smaller and Lighter Channel Branch Filter with Lower Loss

Since the number of systems becomes one and half for the system compared with the existing one, channel branch filter insertion loss is required to have smaller difference between systems and to be lower loss. Consequently, a T branch type (branch line + Band Pass Filter (BPF)) channel branch filter is adopted. At the same time, the equipment becomes remarkably smaller and lighter, compared with a hybrid type channel branch filter in the existing systems (Figure 5).

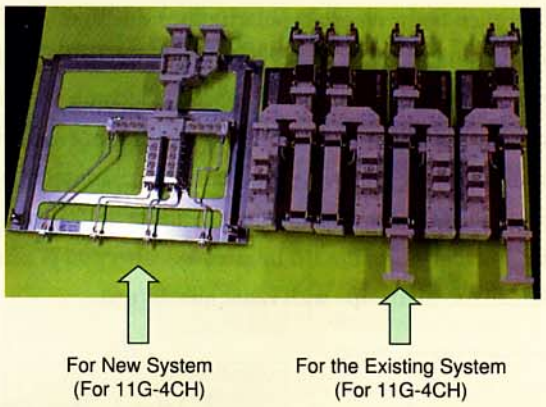


Figure 5 Outlook of Channel Branch Filter (for 11GHz Band)

### ■ Offset Antenna that Lightens Interference Condition

Along with adoption of high-level modulation scheme, interference condition becomes severe inevitably. Offset antennas of 2.4m diameter and 3.4m diameter with sharp antenna directivity have been newly put to practical use for this system. They allow us to secure an applied plane area equivalent to the existing systems.

## 4/5/6G-150MD Systems

These systems are the microwave radio-relay systems that have been newly developed with a view to increasing capacity, strengthening the monitor telemeter functions, and reducing the cost, in contrast to the existing 4·5·6G-150M sys-

tems. The main parameters of the systems are listed in Table 2, as a comparison against the existing systems. The features are described for the systems as follows.

### ■ Transmission Capacity Increase by Adoption of High-Level Modulation Scheme and Reconsideration of Frequency Channel Arrangement

The 64-point quadrature amplitude modulation (64QAM) / single carrier is adopted as the modulation scheme. The 40MHz co-channel allocation is adopted for frequency channel arrangement. Due to these measures, one and half capacity is realized for route transmission compared with the existing systems (16QAM-52M/20MHz co-channel allocation). An example of frequency channel arrangement is shown in Figure 6.

### ■ Higher Quality by Compensation Technology

At the time of fading, the effect by frequency interference (Interference between cross polarization) due to degradation of cross polarization discrimination or Inter Simbol Interference due to waveform distortion becomes severe. A digital-type XPIC (Cross Polarization Interference Canceller) and a digital-type Transversal equalizer are adopted as the standard package for this systems to improve transmission quality. Furthermore, the Bit Interleave [*6] function is adopted in optional menu to cope with radar interference.

### ■ Economizing by Single Carrier Transmission

The existing system has adopted the multi-carrier transmission method, putting waveform distortion resilience at the main purpose. This system adopts the single carrier transmission method, by adopting the standard of DEF, which has high ability to suppress increase of radio clock frequency (28MHz or less) occurred by the many-valued, and to equalize waveform distortion. Therefore, the size of a modulation and demodulation unit is reduced by one third of the existing one, and it brings remarkable economization (Figure 7).

Additionally, as for a radio section where propagation condition is severe, a menu of 2 multi-carrier transmission method in the radio section can be applied. It lightens the effect of waveform distortion by halving radio clock frequency.

### ■ Equipment Packaging for Realization of Saving Space

As for radio transmission/reception equipment, 7systems of transmission/reception unit, modulation and demodulation unit and channel branch filter can be packaged into one rack (800 mm wide). Although the modulation and demodulation unit and the 3SD [*7] unit of the existing systems have been placed respectively in separate racks, this system can be packaged into one rack even for 3SD reception, According to panel function integration and the latest circuit design (Figure 8).

Table 2 Main Parameters of 4/5/6G-150MD Systems

| | 4/5/6G-150MD Radio Systems | Existing Systems |
|---|---|---|
| Frequency Band | 3.4～4.0GHz(4G-150MD)<br>4.4～5.0GHz(5G-150MD)<br>5.925～6.425GHz(6G-150M) | 3.4～4.0GHz (4G-150M)<br>4.4～5.0GHz (5G-150M)<br>5.925～6.425GHz (6G-150M) |
| Transmission Rate | 155.52Mbit/s/system | 155.52Mbit/s/system, 52Mbit/s×2/system |
| Number of Systems Working+Back up | 13+1S (4G, 5G), 11+1S (6G) | 9+1S (4G, 5G), 7+1S (6G) |
| Route Capacity (52Mbits Conversion) | 51.84Mbit/s×39 (4G, 5G)<br>51.84Mbit/s×33 (6G) | 51.84Mbit/s×25 (4G, 5G)<br>51.84Mbit/s×21 (6G) |
| Modulation Scheme | 64QAM (Radio clock frequency : Approx. 27.8886MHz) | 16QAM (Radio clock frequency : Approx. 13.9443MHz) |
| Transmission Power | 26dBm/32dBm | 19dBm/25dBm/31dBm (3 Multi primary carriers) |
| Noise Figure | 5.0dB or less | 5.0dB or less |
| Standard Repeater Spacing | 50km | 50km |
| Compensation Device | Transversal equalizer (DFE)<br>Cross Polarization Interference Canceller (XPIC)<br>Forward error correction (Double error correcting BCH code)<br>Bit Interleave | Transversal equalizer (LE, DFE)<br>Cross Polarization Interference Canceller (XPIC)<br>Forward error correction (Double error correcting BCH code)<br>Bit Interleave |
| Interface Type | 150M, 50M/intraoffice, interoffice | 150M, 50M/intraoffice, interoffice |
| Frequency Allocation | 40MHz co-channel allocation※ | 20MHz co-channel allocation |
| Power Supply Type | DC−48V | DC−48V, −21V |
| Facility Form | Indoor installment | Indoor installment |

※ : There is a menu that applies 2 multi-carrier transmision method to marine areas etc.

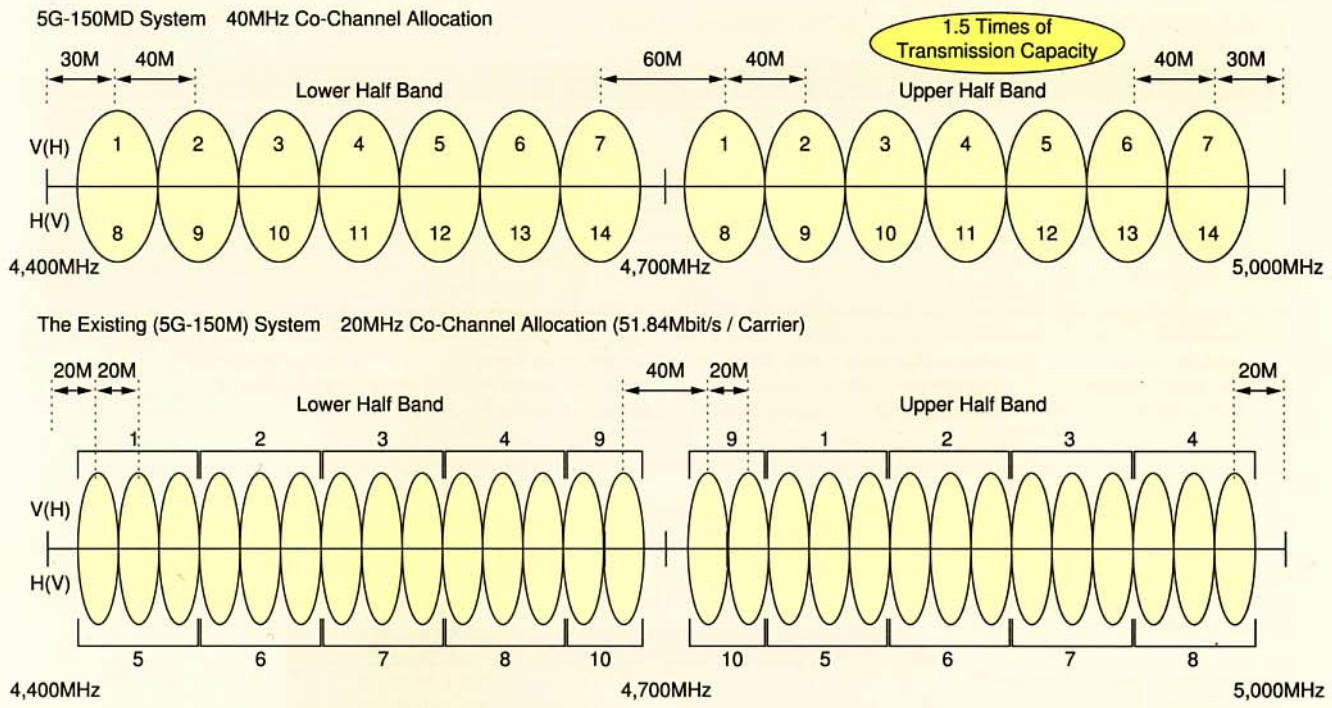


Figure 6 Frequency Channel Arrangement (5GHz Band)

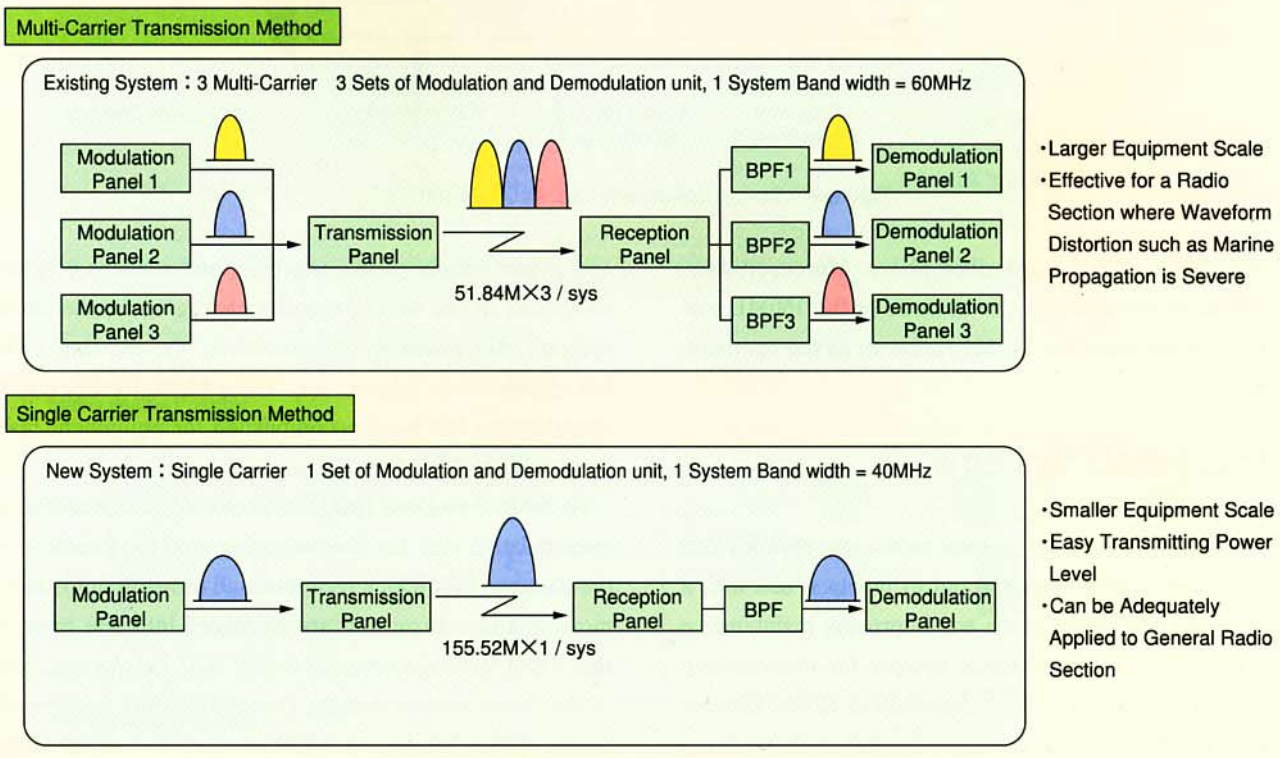


Figure 7 Feature of Single / Multi Carrier Transmission

The radio terminal equipment and the radio monitor and control equipment are common specification with the 11/15G-150MD systems. The floor space is saved to 50% compared with the existing systems.

### ■Strengthening the Monitoring and Telemeter Functions

The monitoring and telemeter functions are common functions with the 11/15G-150MD systems. The functions are strengthened by "The highest class alarm" and "Radio sec-

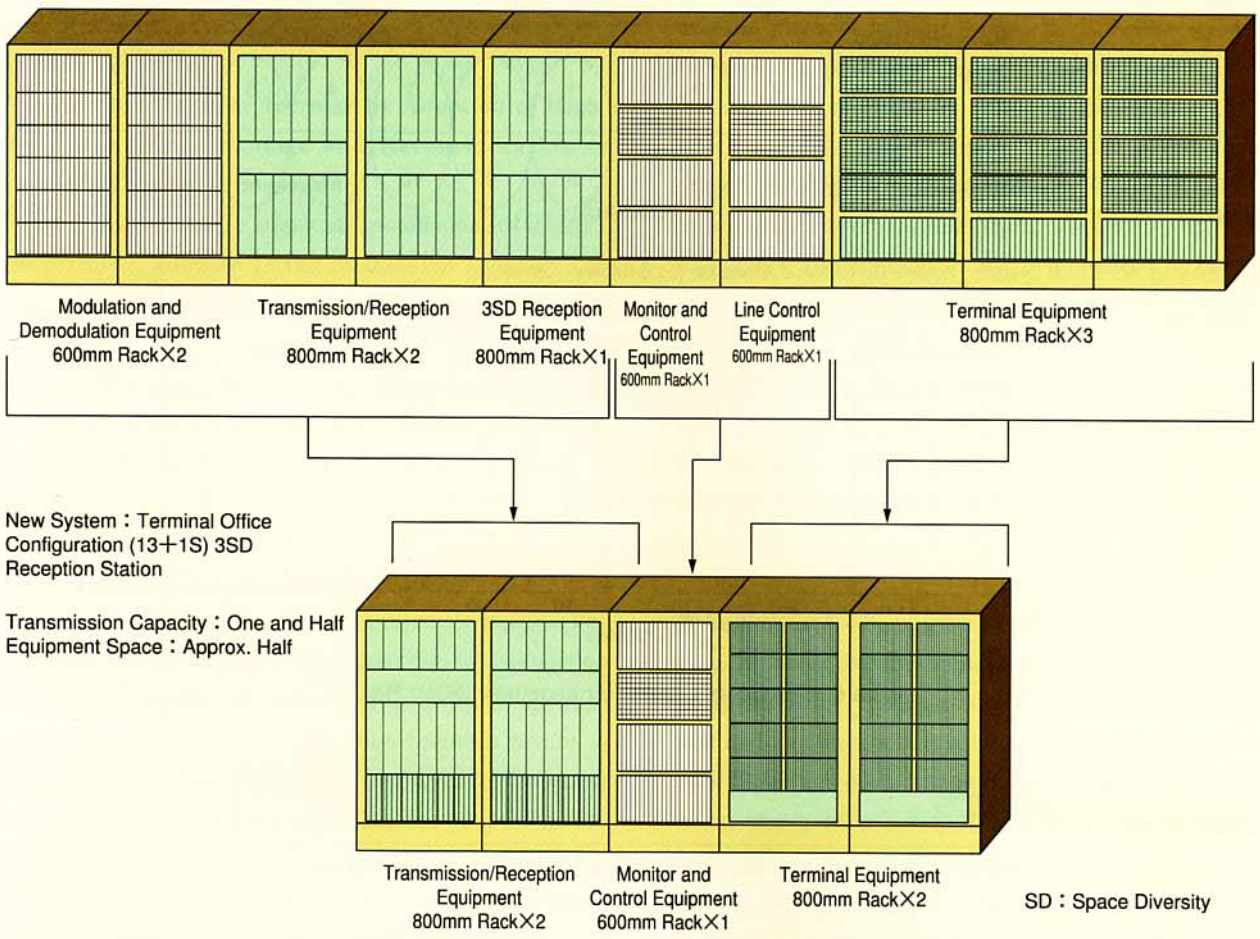


Figure 8 Saving Equipment Space (5G-150MD)

tion degradation alarm", described above. Moreover, common operation management can be done as the 150MD systems (4/5/6GHz-band and 11/15GHz-band) as the operation side.

## 11/15G-50MD Systems

These systems are the microwave radio-relay systems that have been newly developed and put to practical use with a view to saving equipment space and improving maintenance ability functions, as a successor system for the existing 11/15G-50M systems. The main parameters of the systems are listed in Table 3, as a comparison against the existing systems. The features are described for the systems as follows. Additionally, Figure 9 shows the features.

### ■ Realization of Saving Equipment Space

ODU (OutDoor Unit) of this system adopts a monoblock type panel containing the existing transmission, reception, and power supply panels together, and realizes 6 systems packaging in one box (3 systems packaging for the existing system). According to this measures, the existing 4 ODU boxes reduces to 2 boxes for 11GHz band. Hence, effective space saving has been accomplished for equipment installment on a steel tower.

As for IDU (InDoor Unit), 6systems of the modulation and demodulation unit, the line switching unit, the interface unit, the common unit (clock reception and transmission), and the monitor and control unit are packaged into one rack (600 mm wide) for Radio terminal station IDU, thanks to adoption of the latest circuit design. In addition, the regenerative repeat station has one rack (800 mm wide) configuration in place of the existing two rack (600 mm wide) configuration to attain floor space saving.

### ■ Improvement in Maintenance Ability Functions

This system is composed of IDU and ODU. Basically outdoor maintenance is accompanied. Under consideration of

Table 3 Main Parameters of 11/15G-50MD Systems

| | 11/15G-50MD Systems | | Existing Systems | |
|---|---|---|---|---|
| | 11G-50MD | 15G-50MD | 11G-50M | 15G-50M |
| Frequency Band | 10.7～11.7GHz | 14.4～15.23GHz | 10.7～11.7GHz | 14.4～15.23GHz |
| Transmission Rate | 51.84Mbit/s/system | | 51.84Mbit/s/system | |
| Number of Systems | 10+1S | 7+1S | 10+1S | 7+1S |
| Modulation Scheme Working+Back up | 4 phase shift keying (Radio clock frequency : Approx. 27.8888MHz) | | 4 phase shift keying (Radio clock frequency : Approx. 27.8888MHz) | |
| Transmission Power | 28dBm | 26dBm | 28dBm | 26dBm |
| Noise Figure | 4.0dB or less | 4.5dB or less | 4.0dB or less | 4.5dB or less |
| Standard Repeater Spacing | 15km | 7.5km | 15km | 7.5km |
| Compensation Device | Transversal equalizer, Bit Interleave, Forward Error correction (Double error correcting BCH code) | | Transversal equalizer, Forward Error correction (Double error correcting BCH code) | |
| Interface Type | 50M/intraoffice, interoffice, 6.3M (Electrical) | | 50M/intraoffice, interoffice, 6.3M (Electrical) | |
| Frequency Allocation | 40MHz interleave allocation | | 40MHz interleave allocation | |
| Repeat Scheme | Regenerative repeat/Non-regenerative repeat | | Regenerative repeat/Non-regenerative repeat | |
| Power Supply Type | DC−48V | | DC−48V, −21V | |
| Facility Form | Outdoor unit+Indoor unit | | Outdoor unit+Indoor unit | |

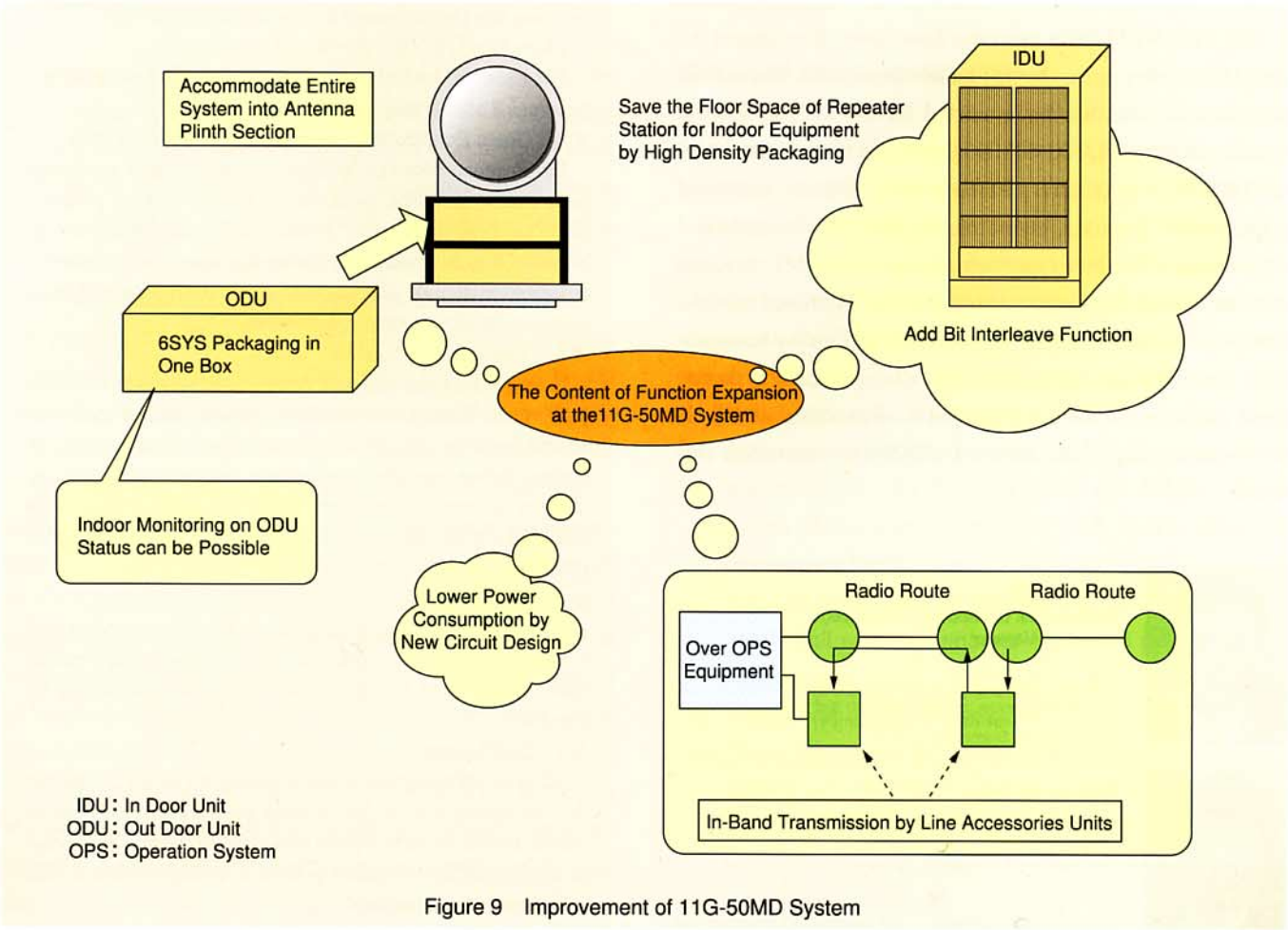


Figure 9 Improvement of 11G-50MD System

maintenance ability, ODU operation status (transmission output, reception output, and power supply) can be monitored from indoors, towards abolishing primary confirmation works on a steel tower.

### ■ Compensation Technology, Taking Usage at 4GHz Band into Consideration

IDU of this system is used as the 4G-50M system using 4GHz band. Therefore, compensation is fulfilled by the Bit

Interleave function as an optional menu, in response to possible radar interference.

### ■ Line Attached Goods as Effective Utilization of Transmission Routes

Business-commission type lines have been used for transmission of information for operation system of radio route, regardless of leased lines or public network lines. As for measures to decrease dependency on business-commission type lines, it can be considered to utilize radio system in-band effectively. In order to enable it, "Line accessory unit" is added in the menu. It is to transfer various information of 9600bit/s, 2400 bit/s, and 1200bit/s etc using 64kbit/s or 32kbit/s vacant channels of digital service channels in radio signal frame structure.

## Conclusion

The 11/15G-150MD systems have been introduced all over the country since the last half of fiscal 1998. The nationwide introduction has been started for the 4/5/6G-150MD systems and the 11/15G-50MD systems on the last half of fiscal 1999. By way of each 150MD system with the increased transmission capacity, economizing, and the strengthened monitoring/telemeter functions, along with 50MD systems with the saved equipment space and the improved maintenance ability, as well as by combination with other transmission multiplexing equipment and radio entrance systems, great contribution can be expected to economical and flexible constructing of the future DoCoMo transmission networks.

Glossary

＊1 4PSK and 8PSK

PSK is an abbreviation of Phase Shift Keying. It is a modulation scheme that carrier waves are changed for 4 phases by 2-bit information in the case of 4PSK and 8 phases by 3-bit information in the case of 8PSK.

＊2 16QAM and 64QAM

QAM is an abbreviation of Quadrature Amplitude Modulation. It is a modulation scheme that changes both phase and amplitude. It is called as Quadrature Amplitude Modulation because two amplitude modulation waves are synthesized with phase difference of 90 degree. 16QAM has 16 code points and 64QAM has 64 code points. QAM is a highly efficient modulation scheme that 4-bit information can be transmitted at one code point for 16QAM and 6-bit information for 64QAM.

＊3 BCH

Bose-Chaudhuri-Hocquenghem code. It is a cyclic code that acquires high error correction capability with comparably simple circuit scale. The relationship between block length N, information bit K, and the number of correction possible bits t is expressed by the following equation.

$[ N = 2I - 1 ( I > 2 ), N - K \leq It ]$

For each method, the number of correction possible bits becomes 2 as $N = 255$ and $K = 239$.

＊4 Cross Polarization Interference Canceller (XPIC)

Interference between vertical polarization and horizontal polarization is called interference between cross polarization.The XPIC applies the Transversal equalizer technology between signals of vertical polarization signals and horizontal polarization signals and negates automatically mutual inter-polarization interference components.

＊5 Transversal equalizer / DFE

It suppresses interference between bits caused by multipath effect. Transversal equalizer extracts interference component from the adjacent bit by comparison of signal level difference before and after interference compensation, and suppresses automatically interference by control of each bit amplitude to the direction of suppressing the extracted component.

＊6 Bit Interleave

It is a way that acquires error correction capability possessed, changing burst-like interference effect into randomized interference effect by the scheme of interlacing bit strings.

＊7 3SD reception

SD is an abbreviation of Space Diversity. Based on the fact that the fading impact differs when antenna is apart to some extent, two or more reception antennas are arranged in order to synthesize the reception powers in better condition. 3SD uses 3 reception antennas.