1.2.1 Broadcast-wave Relay Technology

Experiments on element technology were conducted at eight locations of the Telecommunication Advancement Organization of Japan (TAO) Digital Terrestrial Broadcasting R&D Collaboration Facility as a part of regional council experiments. The TAO facilities completed their operations in fiscal 2003.

Coupling Loop Interference (CLI) Canceller

For implementation of the Coupling Loop Interference (CLI) canceller, a series of field trials using the TAO facilities were performed to examine the performance requirements and application conditions. At the Nakijin relay station (Okinawa Prefecture), we measured the fluctuations of feedback wave properties during a typhoon for a study of system operation speed using simulations based on the obtained data. A Single Frequency Network (SFN) broadcast-wave relay experiment using a canceller was conducted to gauge the equivalent degradation of the carrier to noise (CN) ratio against the desired to undesired (DU) ratio of the feedback waves. The results are shown in Figure 1.

SFN broadcast-wave relay experiments at the Mitoyama relay station (Nagano Prefecture) and the Sue relay station (Fukuoka Prefecture) employed a canceller that utilizes all OFDM carriers in the estimation of feedback wave properties. The results clarified that a significant improvement could be obtained even at the Mitoyama relay station with extremely severe feedback wave delay spread. The measurements of the canceller operation limit at these three relay stations indicated that the DU ratio at which a canceller's protective circuit turns on was in the range of -14dB to -13dB.

Diversity Reception System

To study the fading characteristics of overland propagation of broadcast-wave relay networks and verify the effectiveness of the diversity reception system, we conducted reception experiments using the TAO facilities at the Kanazawa transmitting station, Hakui relay station (Ishikawa Prefecture), and other facilities in Fukuoka and Miyazaki Prefectures. During the Hakui relay station experiment, master station waves were received with two antennas differing in above ground height by approximately 30m. The reception power of both antennas and waveforms of the diversity reception system's input/output signals were obtained at given intervals. The diversity effect was evaluated using the Modulation Error Ratio (MER) based on analysis of the obtained signal waveforms.

Equalizing System for Multipath Beyond the Guard Interval

Research and development progressed on an equalizer that can reduce the reception characteristic degradation generated by multipath interference with a delay time beyond the signal's Guard Interval (GI). During fiscal 2003, the equalization function in the time domain was investigated through a reception experiment using TAO facilities in Fukuoka Prefecture. In this study, the prototype receiver's performance was assessed by receiving SFN broadcast-waves transmitted from the Kusenbu transmitting station and Sue relay station. As shown in Figure 2, the results confirmed by mapping CN ratio against BER (Bit Error Rate) that the performance was equivalent to reception with delay time within the GI even when the multipath delay time reached 450μ sec, or more than 1/3 of the OFDM signal's effective symbol duration.

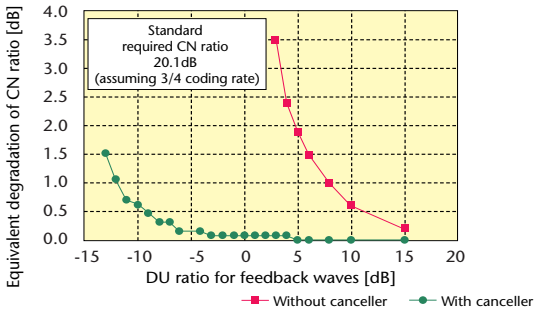


Figure 1: Results from SFN broadcast-wave relay experiment at the Nakijin relay station

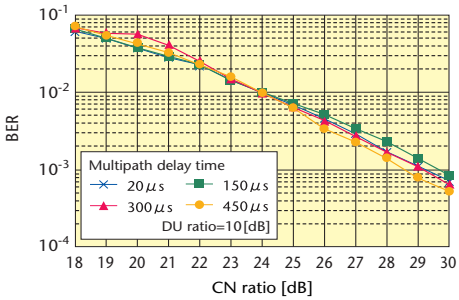


Figure 2: Equalization experiment result for multipath beyond GI outside Fukuoka city

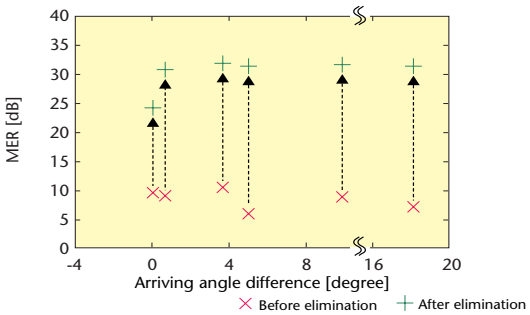


Figure 3: Co-channel interference elimination experiment at the Sue relay station

-Arrival angle difference and MER before and after interference elimination process-

Co-Channel Interference Elimination System

As a countermeasure against co-channel interference at a broadcast-wave relay station, progress is being made on the development of a system that eliminates interference waves in the frequency domain with the use of an adaptive array antenna. Field trials using a prototype system were conducted in fiscal 2003. The field trial using the Motoyoshi relay station (Miyagi Prefecture) verified the basic system operation, and that at the Haseyama relay station (Mie Prefecture) confirmed that a total of three waves for one analog wave and two SFN waves beyond the GI could be eliminated simultaneously. An experiment at the Sue relay station (Fukuoka prefecture) using a TAO outside broadcasting van showed the relationship between the arrival angle difference of interference wave and the desired wave and the amount of interference removal, by adjusting the arrival angle of the interference wave.

A system for an SFN to remove interference waves in the time domain, with the use of an FIR filter, was tested at the Nakijin relay station (Okinawa Prefecture), with the purpose of comparing performance with an interference elimination method in the frequency domain.

1.2.2 Digital Terrestrial Data Broadcasts

Network-linked Data Broadcast Services

We focused on two kinds of services for network-linked broadcasting. One is the mobile service of terrestrial digital broadcasting, and the other is to add recording functions to a network-linked service.

We constructed a prototype mobile terminal (Figure 1) to study the technical feasibility of mobile network-linked data broadcasting services. This terminal accepts the actual transport stream format and provides a browser for data broadcasting contents. The terminal can transmit and retrieve data related to broadcasting contents through its data communication capability. The browser installed in the terminal to realize network-linked broadcasting services handles such communication.

Figure 1: Prototype mobile receiver

Regarding the development of mobile network-linked broadcasting services, we implemented experimental contents on the service simulator developed in fiscal 2002 to study both effectiveness and feasibility (Figure 2). They combine data broadcasting contents and the Internet contents.

We have developed a prototype terminal system to add recording functions toward the new network-linked services. A home receiver chooses the same broadcasting channel as that of the mobile terminal at the command of the mobile terminal received through the communication network. The home receiver constantly records received streams for a certain duration on a temporary memory. Combination of these functions allows the user to store currently viewing video scenes or music from the beginning onto the home receiver while outside the home, by placing a "record" command on the mobile terminal.

Figure 2: Receiver and display example on a service simulator

Multiplexing Scheme

We continued to study on an efficient multiplex and transmission scheme that shortens acquisition time for data broadcasting. We evaluated the scheme developed in fiscal 2002 to shorten acquisition time even in an environment where packet error occurs, such as portable and mobile reception. As a result, the relationship between packet error rate and travel speed of the receiver was obtained in addition to other quantitative characteristics and performance of our scheme. It was also found that the forming of related content elements into a group on a data carousel reduces the acquisition time.

1.2.3 Mobile Reception Technology for Digital Terrestrial Broadcasting

High Capacity Mobile Reception

For the realization of mobile reception for digital terrestrial broadcasting, field trials were conducted using a prototype diversity receiver (Figure). This confirmed that stable mobile reception of a Hi-Vision (HDTV) program in an urban area can be obtained with the use of four receiving antennas. These findings were reported at the Asia-Pacific Broadcasting Union (ABU) General Meeting in Istanbul.

Outside mobile HDTV reception experiment

Regarding reception services designed for hand-held receivers, studies on error occurrence conditions and coverage area were conducted by means of reception tests using a prototype hand-held receiver in the vicinity of Tokyo Tower.

A contributing document related to planning criteria for digital terrestrial broadcasting was submitted to the International Telecommunication Union - Radiocommunication Sector (ITU-R), and is now being considered for adoption as a recommendation.

Closed Space Re-transmission Technology

We studied the re-transmission technology for digital terrestrial broadcasting in closed spaces, such as indoors or in underground shopping centers, via a leaky coaxial cable (LCX). We developed equipment that causes the electrical field to fluctuate in a space. Experiments found that reception coverage was improved because the device prevents the minimum field level retention of the standing wave at a specific point.

Gap Filler

Studies continued on a micro-power re-transmission system, called a Gap Filler (GF), as a countermeasure to receiving errors observed in the shadow of buildings in urban areas. To reduce costs, we developed a gap filler system that amplifies and re-transmits eight received broadcast-waves over an RF-band without frequency conversion. This new system is equipped with a wide range multi-path equalizer by an analog circuit, which can equalize short delay waves. It also features AGC and Squelch functions by channel unit.

ITS Software Defined Radio Technology

As a joint research project with the Telecommunications Advancement Organization of Japan (TAO), we developed a software defined radio receiver for digital terrestrial broadcasting which is relatively small and has a high speed clock. We also developed a software defined radio receiver for communications media such as Dedicated Short Range Communication (DSRC), (a transmission medium developed for ITS), wireless LAN, and W-CDMA (adopted for the third-generation cellular phone system). We proceeded with the development of a software defined radio receiver that can be used in digital terrestrial broadcasting and communications.

1.2.4 Cable TV Transmission Technology

Following the construction of the 1024QAM scheme, which multiplexes a training sequence for equalization, research in fiscal 2003 proceeded with the development of a transmission scheme that is capable of transmitting information for one digital BS broadcasting transponder using a single cable TV channel. We developed a scheme that employs no training sequence with the goal of increasing the capacity, and such parameters as the roll-off filter were examined on this.

A prototype demodulator (Figure 1) realizes a capacity of approximately 53Mbps through the adoption of an equalization process without a training sequence, a 4% roll-off rate, and shortened Reed-Solomon code (204,188). Its reception CN ratio at a BER before error correction of 10^{-4} is 38dB, indicating hardware with a degradation from the theoretical value of approximately 2dB. Computer simulation confirmed that increasing the 129 Tap count of the prototype roll-off filter to 257 would reduce implementation loss to 1dB or less.

Figure 1: Prototype 1024QAM demodulator

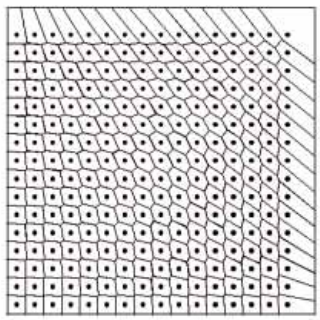


Figure 2: 1024QAM symbol decision region example (first quadrant)

Using this prototype system, a transmission experiment was conducted at an actual cable TV transmission facility. It proved that digital BS broadcasting signals from one transponder can be transmitted in a 6MHz-bandwidth. This system promises high capacity transmission on a digital cable TV system.

Examination was also made of a technique to reduce the influence of the phase noise of the tuner. It was shown that adjusting the shape of the symbol decision region for a QAM demodulation circuit, from the conventional square to a polygon elongated in the circumferal direction (Figure 2) has potential for reducing the error rate degradation caused by phase noise.

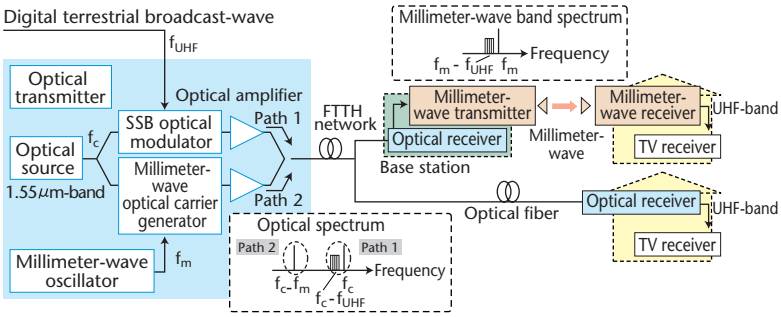
We also contributed to a discussion on specifications for the operation of digital terrestrial television broadcasting transmodulation at the Japan Cable Laboratories.

1.2.5 Optical Transmission Technology

As a means to supplement radio wave broadcasting services, such as those of digital terrestrial broadcasting, research progressed on optical transmission technology with the purpose of delivering not only communications, such as those of the Internet, but also digital broadcasting services to homes via Fiber To The Home (FTTH) networks, using optical wavelength division multiplexing. One of the related studies concerns a transmission scheme that will multiplex millimeter carrier waves into regular broadcast-wave signals to enable frequency conversion of digital broadcast-waves transmitted over an optical fiber cable into millimeter-waves, thereby accommodating homes where the installation of fiber optic cable proves difficult.

In fiscal 2003, we constructed a prototype optical transmission system for 8 channels of digital terrestrial broadcast-waves in the UHF-band, with the employment of 1.55μm-band recommended by ITU-T for broadcast distribution purposes. We should at the Open House of the Science & Technical Research Laboratories that an optical receiver can generate broadcast-waves in both the millimeter-band (40GHz) and the UHF-band.

Another advance was the construction of a Single Side Band (SSB) optical modulator with suppressed carrier, in place of the optical intensity modulator, with the aim of obtaining deeper broadcast-wave optical modulation at the optical transmitter. Suppression of the optical carrier by 10dB to prevent saturation at the optical amplifier, connected at a later stage, resulted in an improvement of the reception CN ratio after millimeter-wave band optical transmission of 7dB, attaining a 40dB reception CN ratio. The high frequency of the millimeter-wave band makes it difficult to fabricate an inexpensive local oscillator with superior phase noise performance that can down-convert digital terrestrial broadcasting signals. To overcome this problem, we conducted a verification experiment on self heterodyne operation, which down-converts digital terrestrial broadcast-waves in the millimeter-wave band with the use of an optically multiplexed carrier transmitted along with the broadcast-waves (Figure). The experiment produced phase noise and bit error rate performance nearly equivalent to those of digital terrestrial broadcasting signals transmitted optically in the UHF-band.



Millimeter-wave wavelength division multiplexing (WDM) broadcasting distribution system over FTTH network