## 1.2.1 Broadcast-wave Relay Technology

### Coupling Loop Interference Canceller

Improvements were made on an algorithm for a coupling loop interference (CLI) canceller to achieve the cancellation of coupling waves with a delay time longer than possible with the conventional scheme. Field trials using the Himeji relay station of the Telecommunication Advancement Organization of Japan (TAO) Digital Terrestrial Broadcasting R&D Collaboration Facility, verified the positive effects of the improvements made. In preparation for the start of SFN broadcast-wave relay stations, we collected data related to coupling loop interference at 13 TAO experimental relay stations nationwide to determine CLI canceller set up conditions in an actual environment. In addition to the knowledge gained about SFN multi-stage relay broadcasting characteristics from a fiscal 2001 investigation, further information was gained through analysis and evaluation of the coupling between transmitting and receiving antennas, and its fluctuation and delay spread, to establish the basic performance required in a CLI canceller.

### Diversity Reception

With the employment of a prototype diversity reception system, receiving experiments using experimental radio-waves emitted from the TAO Digital Terrestrial Broadcasting R&D Collaboration Facility were conducted using three broadcast-wave relay links, between the Niigata[1]-Takada relay stations (Niigata prefecture), the Osaka Ikoma[1]-Hokudan Tarumi relay station (Hyogo prefecture), and the Haseyama[1]-Ise relay stations (Mie prefecture). All three relay links include overseas propagation in their path, making it possible to confirm a prototype system's capability to adequately reduce the signal characteristic degradation caused by fading interference or multipath interference during such propagation. This improved characteristic meets the standard of an equivalent CN ratio of 38.2dB or greater, which an Association of Radio Industries and Businesses (ARIB) standard indicates as an example for a broadcast-wave relay link budget. The experiments also analyzed the measured fading time probability and relationship between multipath DU ratio and delay time, by which the operating conditions for this receiving system were examined.

[1] transmitting station

### Relay System with Equalization and Symbol Decision Techniques

A relay system with equalization and symbol decision techniques was developed for use in a multi-stage broadcast-wave relay network. This relay system is capable of removing signal degradation caused by propagation channel multipath interference and noise at each relay station, over a relay link from a master station to terminal stations. This newly developed system, as shown in Figure 1, reduces multipath interference through equalization, and after determining the signal point, re-transmits the signals at a CN radio of 40dB or greater, which satisfies a standard link budget. This decision-making function prevents the accumulation of signal degradation during transmission, making a multi-stage broadcast-wave relay feasible. Signal delay for this system is approximately 6ms in excess of one symbol duration (approx.1ms), which allows application to an MFN broadcast-wave relay with frequency conversion. It is also equipped with a diversity reception function for 1 to 4 branches, making the system applicable to a relay link with significant fading, such as occurs during overseas propagation.

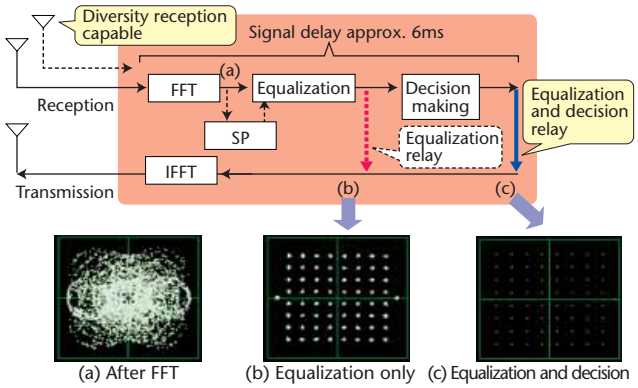



**Figure 1: Configuration of a relay system with equalization and symbol decision techniques for digital terrestrial broadcasting (red box) and a 64QAM constellation after signal processing**

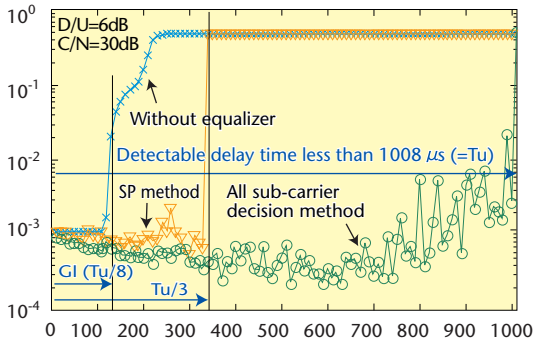



**Figure 2: Indoor experiment results (delay time versus BER)**

### Equalizing System for Multipath Beyond Guard Interval

With the aim of securing the digital terrestrial broadcasting SFN service area, studies progressed on equalization technology that can maintain good reception characteristics even against multipath interference with a delay time beyond the OFDM signal Guard Interval (GI). During fiscal 2002, a prototype system was constructed and used for an investigation of the differences between the conventional method that employs a Scattered Pilot (SP) as a multipath estimation technique and a new method that utilizes the values determined for all OFDM sub-carriers. The results from an indoor experiment are shown in Figure 2. The application of the values determined for all sub-carriers enables an expansion of the multipath delay time range for estimation and equalization, to the extent that approximately equals the useful symbol duration. Advances were also made in construction of an experimental receiver incorporating this equalization algorithm.

### Co-channel Interference Elimination Technology

The interference factors for a broadcast-wave relay include interference from other stations using the same channel, in addition to that generated from the relay signal itself, such as from multipath fading and coupling loop interference in an SFN relay. In fiscal 2002, in cooperation with the Engineering Administration Department, we studied the conditions needed to eliminate such interference using interference estimations for a relay station in the Tohoku region, based on the Channel Plan. Examination was made of an adaptive array algorithm that forms a void in the direction of incoming interference waves, through adaptively composing the output signals from multiple receiving antennas for each OFDM signal sub-carrier. This permitted progress in the development of an interference elimination system for a relay station .

## 1.2.2 Digital Terrestrial Data Broadcasting

We pursued studies that will contribute to the implementation of digital terrestrial broadcasting, including the development of suitable data broadcasting services and receivers, and conducted experiments on effective multiplexing and transmission schemes to reduce reception-response time.

We continued with research, started in fiscal 2001, on a location-aware data service and examined a data broadcasting read-out service. (Refer to 1.1.2)

We also furthered the studies on network-linked data broadcasting services. These are new services that will enable a single receiver to receive both digital terrestrial data broadcasting services (1 segment reception) and Internet service via wireless communication. This receiver will be suitable for use as a mobile receiver, such as a cellular phone, in Personal Digital Assistance (PDA), and in car navigation systems. During fiscal 2002, a simulator for network-linked data broadcasting services was constructed to verify the feasibility, effectiveness, benefits, and convenience of these services. Transmission systems capable of responding to actual broadcast signals were established, for which an experimental receiver was also fabricated on a PC as the receiving device. With the employment of these systems, we verified receiver implementability and system operability.

As for effective multiplexing and transmission schemes for services designed for portable receivers, we developed a data-multiplexing scheme that incorporated packet number information, which can improve digital terrestrial broadcasting mobile reception performance in areas with reception difficulty, as well as reduce the acquisition time for data contents. Field trials using radio waves emitted from the Kinuta experimental station (STRL) proved the effectiveness of this multiplexing scheme containing packet number information.

(1) Cellular phone type (2) PDA type (3) Car navigation system type

**Receiver display examples for network-linked data broadcasting services**

## 1.2.3 Digital Terrestrial Broadcasting Mobile Reception Technology

### Mobile Experiment for Car Reception

Aiming to improve mobile reception performance for digital terrestrial broadcasting, advances were made on a diversity reception system that combines FFT output signals from individual antennas. The performance against Doppler shift using a prototype system was measured in indoor experiments. Mobile reception experiments conducted in Tokyo, Sendai, and Nagoya, using receivers installed in a car, confirmed an improvement in reception accuracy. These experiments permitted examination of mobile reception service areas. It was determined that an area with a high electrical field has potential for HDTV mobile reception, and that SDTV signals can be received while traveling in over 90% of home reception service areas.

### Leaky Coaxial Cable

Research was launched on the re-transmission of digital terrestrial broadcasting to enclosed spaces, such as indoor or underground shopping centers, via a leaky coaxial cable. During fiscal 2002, 1-segment transmission experiments using VHF channel 7 were conducted in various locations, such as the STRL building, to investigate the relationship between electrical field intensity and bit error rate. Regarding the standing waves generated when radio waves are reflected from interior walls and other surfaces, quantitative knowledge was obtained on the degree of electrical field intensity fluctuation by location, and on the influence of electrical field intensity and noise on the bit error rate.

### Gap Filler (GF)

Studies continued on Gap Filler (GF), as a countermeasure to the viewing problem observed in urban areas in the shadow of buildings. With the purpose of examining the influence of transmitted GF waves, which interfere with master station wave reception, in fiscal 2002, we conducted a reception experiment by constructing an area with identical electrical field reception characteristics for both waves in Izumi-ku, Sendai-city. The results from the experiment showed that a coding ratio of 3/4 enabled reception, not one of 7/8, with a lower margin in comparison with a reception state without GF interference. It also revealed that adjustment of GF transmission polarization could further reduce the margin.

### ITS

**Roadside ITS field trial**

As for studies on software defined radio technology for Intelligent Transport Systems (ITS), we exhibited, at the STRL open house, a prototype digital terrestrial broadcasting software receiver that was developed jointly with the Telecommunications Advancement Organization of Japan. Advances were also made in reducing the receiver size and improving downloading speed for ISDB-T demodulation software. SFN field trials using the TAO's experimental facility were also carried out (figure).

## 1.2.4 Digital Terrestrial Broadcasting Implementation

### Cooperation with Testing Center

The Terrestrial Digital Receiver Testing Center was established in April 2002 with the aim of diffusing high-performance, low-cost receivers in preparation for the commencement of digital terrestrial broadcasting. STRL devised specifications for transmission experiments based on accumulated reception data from past experiments at various locations, to secure RF and demodulation performance for a receiver, in addition to carrying out actual testing (figure). Receiver manufacturers participated in the tests, which covered analog TV interference and digital TV interference in relation to the ratio of protection from interference, multipath interference, SFN, and mobile reception.

**Transmission system used for testing**

### Auxiliary Channel Standardization

With regard to the Auxiliary Channel (AC), which had been an ISDB-T provisional standard, the Association of Radio Industries and Businesses (ARIB) conducted verification experiments using an STRL system to confirm its functions and characteristics. The interface between AC data and the OFDM transmission carrier was also standardized, to be reflected in the ARIB standard B31. As a part of studies on the construction of relay facilities at less cost, work progressed on development of an ISDB-T LSI for demodulation equipped with an AC demodulation function, in collaboration with the Engineering Administration Department of NHK.

### Overseas Development and International Collaboration

We participated in activities to promote the Japanese digital terrestrial broadcasting system (ISDB-T) abroad in cooperation with the Digital Broadcasting Expert Group (DiBEG) at ARIB. DiBEG operations included the dispatch of instructors overseas, translation of digital terrestrial broadcasting standards into English, presentations on the current state of Japanese digital terrestrial broadcasting via a homepage designed for overseas users, and the introduction of Japanese digital terrestrial broadcasting to visitors from Brazil, who are now selecting a broadcasting system for their country.

## 1.2.5 Cable TV Transmission Technology

Research continued, from fiscal 2001, on transmission schemes to improve digital broadcasting's re-transmission capability on cable TV networks. Based on the algorithm verification result, using software, we constructed a prototype 1024 QAM receiver during fiscal 2002. We conducted transmission experiments using this receiver and obtained a transmission speed of approximately 50Mbps on a bandwidth equivalent to a single cable TV channel.

This prototype receiver equalizes the waveform with the use of a known training sequence multiplexed in the transmitted signal. In an indoor experiment, a bit-error rate (BER) before error correction of $10^{-4}$ was obtained with a reception CN ratio of 37dB (Figure 1). Implementation loss is 1dB or less. Using this prototype system, examination was made of the effects from interference waves and on the transmission characteristic degradation caused by nonlinear amplification. Transmission experiments on the television system verified 50Mbps transmission on the 6MHz-bandwidth, indicating the prospect of realizing large-capacity transmission compared with digital cable TV systems (Figure 2). A 1024 QAM signal received at each reception point was A/D converted for recording, to perform a detailed analysis of cable TV transmission channel characteristics. A computer simulation of a demodulator, using the measured data, helped with the examination of algorithms for a waveform equalization scheme and a carrier recovery scheme to improve receiver performance.

Regarding a scheme to increase transmission capacity without a training sequence, we developed an algorithm using the above received data, and incorporated the results in a prototype 1024 QAM receiver.

This research was carried out jointly with the Yokohama Advanced Cable TV Research Center of the Telecommunications Advancement Organization of Japan.

We also contributed to discussions on a measurement method for OFDM signal transmission systems at the Japan Cable Television Engineering Association.

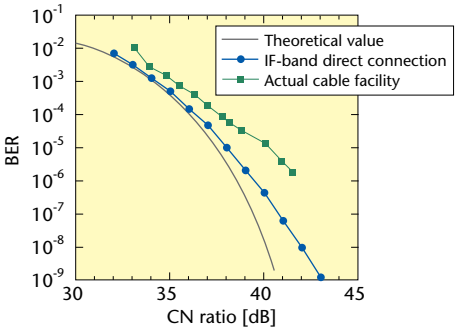



**Figure 1: 1024 QAM signal transmission characteristics**

**Figure 2: Experiment using actual facility**

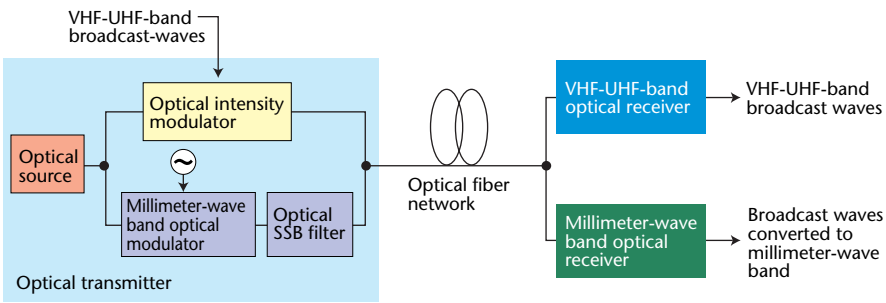
## 1.2.6 Optical Transmission Technology

Research progressed on optical transmission technology with the purpose of delivering future broadcasting services such as digital satellite and terrestrial broadcast-waves via optical fiber networks, including Fiber To The Home (FTTH). This research aims to realize a transmission scheme that will multiplex millimeter carrier waves into regular broadcast-wave signals to enable a receiver to convert transmitted digital broadcast-waves into millimeter-waves (figure), in order to accommodate homes where the installation of fiber optic cable proves difficult.

In fiscal 2001, basic examinations of optical signal generation using an optical modulator for millimeter-wave bands and simulations were conducted. These also allowed transmission characteristics to be analyzed. During fiscal 2002, we progressed to the detailed examination of optical Single Side Band (SSB) carrier generation for millimeter-wave bands, and studies on an entire transmission system for multi-channel broadcast-waves.

The generation of an optical SSB carrier employs a millimeter-wave band optical modulator and an optical SSB filter. Concerning an optical intensity modulator and optical phase modulator for millimeter-wave band driving, we determined the conditions under which the optical sideband power reaches a maximum by analyzing and evaluating optical modulation characteristics under various operating conditions. As a parameter evaluation, we analyzed millimeter-wave power fluctuation values after optical reception, and obtained a design guideline for an optical SSB filter that will minimize the power fluctuations.

Based on the abovementioned results, operation was confirmed with a prototype millimeter-wave optical multiplexing system. This revealed that the system is capable of multiplexing optical intensity modulation signals and a 40GHz band optical SSB carrier on eight UHF-band broadcast-wave channels, and receiving broadcast-waves converted to the 40GHz-band by optical self-heterodyne detection and UHF-band broadcast waves.




**Millimeter-wave wavelength division multiplexing (WDM) transmission system**