W-40G GUIDED MILLIMETER-WAVE TRANSMISSION SYSTEM

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ABSTRACT

System structure, repeater equipments and transmission characteristics of a guided millimeter-wave transmission system "W-40G" are reported. It can transmit 300,000 telephone channels in the frequency band from 43 to 87 GHz.

Introduction

A guided millimeter-wave transmission system called W-40G[1] has been developed to offer a large capacity long haul transmission line. It can transmit about 300,000 coded telephone channels employing the frequency band from 43 to 87 GHz.

The system performance was confirmed with a 22.7 km waveguide line as well as with trial millimeter-wave and high-speed digital equipments installed at two terminal stations and a repeater station. Some system parameters and equipment performance have been improved during the field evaluation test to completecthis system.

Circuit Structure and Main Parameters

A hypothetical reference circuit of W-40G is illustrated in Fig. 1. Millimeter-wave transmitters and receivers. branching filter networks, code converters and protection switches are installed at terminal stations and supervisory-switching stations.

Regenerative repeaters transmit an 800 Mb/s millimeter-wave signal and maintain the error rate at less than 10^{-7} for the 2,500 km circuit. The average repeater spacing is 15 km when the waveguide route has a similar radius of curvature to the existing coaxial cable routes in Japan. Table 1 shows the main parameters of this system.

Waveguide Transmission Line

The waveguide line consists of dielectric-coated and helix waveguides with an inner diameter of 51 mm. They are connected with a ratio of four dielectric-coated pieces to one helix piece and pulled into a 150 mm bore steel conduit.

Frequency Allocation, Branching Filter Network and Interferences

The total frequency band is divided into 8 groups; each group is subdivided into 7 channels with a center-to-center separation of 740 MHz. The branching filter network consists of a transmit-receive filter, band-splitting filters, channel-dropping filters and mode transducers. The total loss of the network is less than 6.9 dB in the 80 GHz region.

The interchannel and intersymbol interferences are maintained as small as -30 dB by employing filters and equalizers at IF stages of the repeater. The transmit-receive and spurious interferences are suppressed by inserting filters in the millimeter-wave stages in the repeater.

Regenerative Repeaters

The repeater consists of five panels: a transmitter-receiver, a delay equalizer, a MODEM and two auxiliary panels.[2] The allowable loss between transmitter and receiver is more than 60 dB in the 80 GHz region at an error rate of 3×10^{-10}. Tape meanderline delay equalizers are equipped to equalize linear delay of the channel within ±0.5 ns/GHz. An intermediate frequency of 1.7 GHz is used in this repeater.

Up and down frequency converters, local oscillators, circulators and filters have been developed for the transmitter-receiver panel. Noise figure and output power of the transmitter-receiver panel in the 80 GHz region are about 13 dB and 8 dBm, respectively. The frequency stability of local oscillators is within $\pm 7\times10^{-5}$ in an ambient temperature range from 0 to 40° C.

The MODEM panel employs a parallel type 4-phase modulator, a coherent demodulator, a pair of transistor decision circuits and a timing recovery circuit. A digital integrator is added to the carrier recovery PLL to get a pull-in range of more than 40 MHz and a substantially zero steady-state phase error. Required carrier to noise ratio to achieve an error rate of 10^{-9} is as small as 16 dB in the above mentioned temperature range.

Code Converters, Supervisory, and Measuring Equipments

Transmitting and receiving code converters have such functions as modulo-4 addition and subtraction for the 4-phase PSK, parity check to monitor the channel error rate, scrambling for stable synchronizations and generation of fault location pattern.

A supervisory and control equipments, a 1.544 Mb/s transmitter-receiver in the 60 GHz region and a protection switch for 400 Mb/s have been developed for supervisory and control purposes.

Error rate measuring equipment, carrier to noise ratio measuring equipment, amplitude and delay measuring equipment and timing jitter measuring equipment have also been developed.

Field Trial Link

The block diagram and the route map of W-40G field trial link are illustrated in Figs. 2 and 3, respectively. The minimum bending radius of curvature of the waveguide route is as small as 30 m. At a sharper bend a single or a pair of corner waveguides is employed. Fig. 4 is a photograph of repeater equipments installed at the field trial terminal station.

Transmission characteristics such as level diagram, amplitude and delay, eye pattern, error rate, interferences and timing jitter have been measured and analyzed. The results were satisfactory to confirm the feasibility of the W-40G system and equipment design. Fig. 5 shows some measured results of the field evaluation test.

Conclusion

Feasibility of the large capacity guided millimeter-wave transmission system has been confirmed with the trial manufacturing and installation of waveguides and equipments as well as with the operation

test of the field trial link. The estimated cost per telephone channel of W-40G is about half that of the most economical existing large capacity analog system.

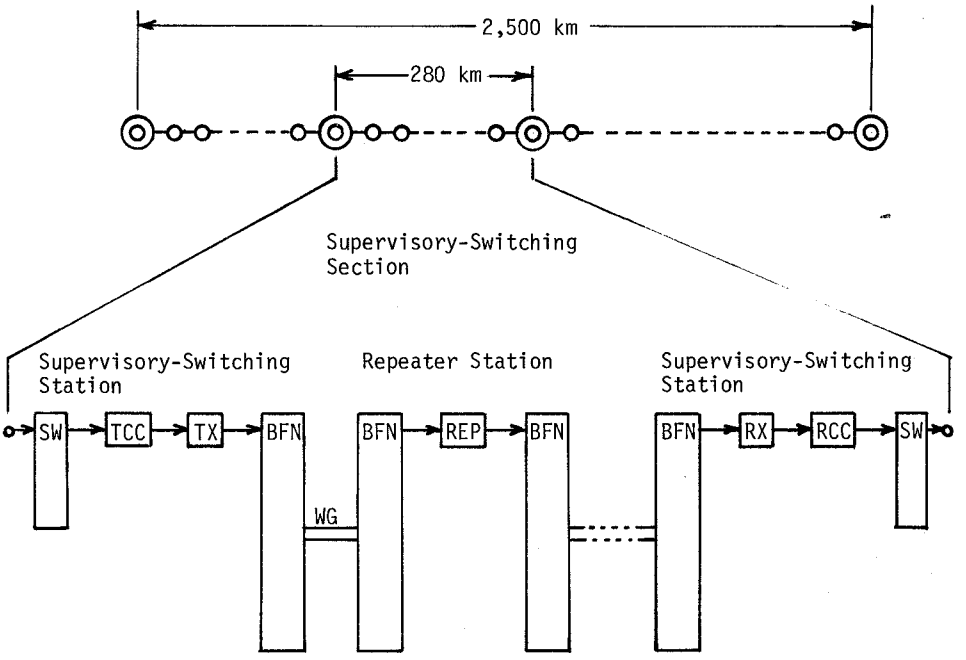
It is considered that the guided millimeter-wave transmission system will be one of the most important trunk transmission lines in the near future because of its capacity, quality and cost.

References

1. K. Miyauchi et al: "A Guided Millimeter-Wave Transmission System using High-Speed PSK Repeaters", 1972 IEEE-GMTT Microwave Symp.
2. K. Miyauchi et al: "Transmitter-Receiver for the Millimeter-Wave Transmission System in the 43 - 87 GHz Range", 4th European Microwave Conf., C9-2, Montreux, Sept. 1974.

Table 1 Main system parameters of W-40G

Hypothetical reference circuit (tentative)	2,500km, 9 supervisory-switching sections
Number of mm-wave channels	28 sys. (both E-W and W-E)
Overall transmission band	43-87GHz
Transmission capacity	about 21Gb/s, two-way 800Mb/s per mm-wave channel
Transmission line	
Standard waveguide	hybrid-tandem (4 dielectric and 1 helix), 51mm I.D.
Conduit	150mm bore steel pipe
Transmitting method	up-converter
Intermediate frequency	1.7GHz
Modulation and demodulation	4-phase PSK, coherent detection
Error rate	less than 10^{-7} per 2,500km
Average repeater spacing	15km



SW: protection switch BFN: branching filter network
TCC: transmitting code converter TX: transmitter
WG: waveguide line REP: regenerative repeater
RCC: receiving code converter RX: receiver

Fig. 1 Circuit Structure of W-40G

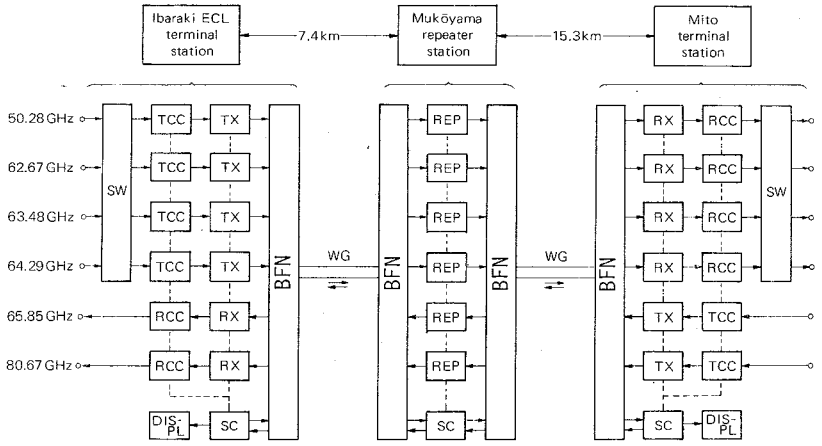


Fig. 2 Block Diagram of W-40G Field Trial Link

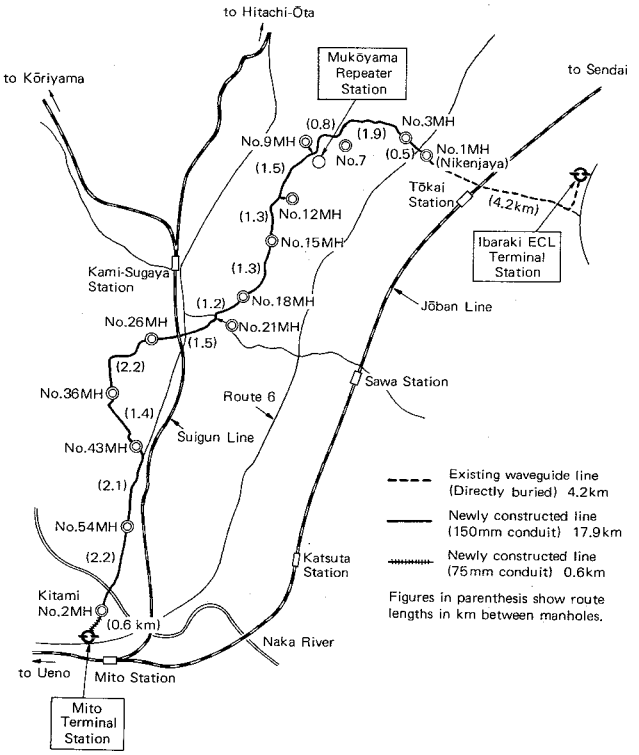


Fig. 3 Route Map of W-40G Field Trial Link

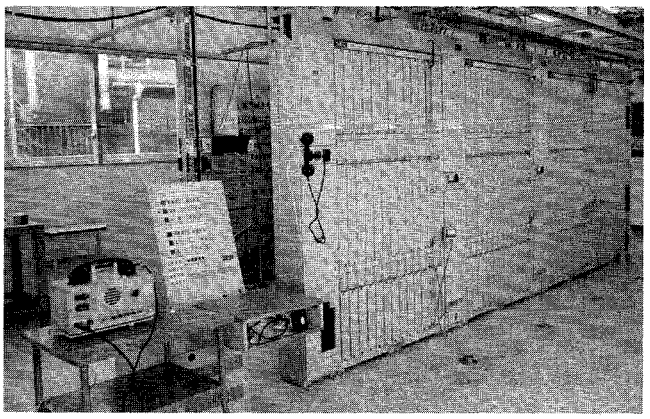
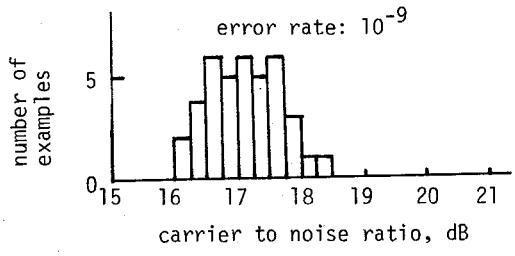
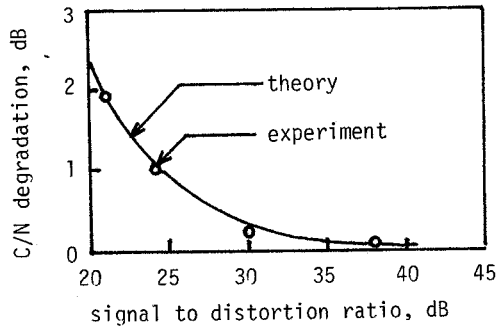


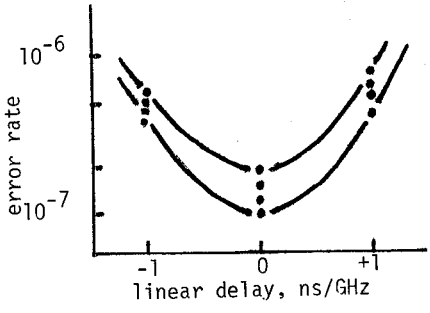
Fig. 4 Repeater Equipments Installed in the Ibaraki ECL Terminal Station



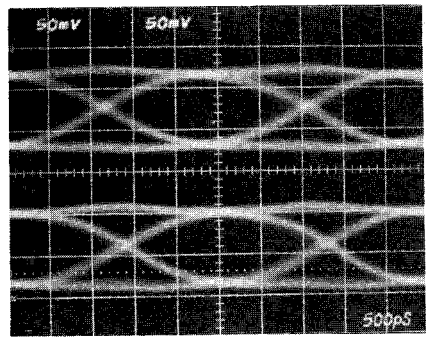
(a) Measured distribution of carrier to noise ratio



(b) Measured C/N degradation due to interchannel interference



(c) Measured error rate vs. channel linear delay



(d) Observed eye pattern at the demodulator output

Fig. 5 Characteristics of W-40G Field Trial Link