20G-400M DIGITAL RADIO-RELAY SYSTEM

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Abstract

A 20-GHz high-speed digital radio-relay system, with 400-Mb/s transmission capacity, is under development for long-haul transmission. This paper describes the design and characteristics of this system. Results of field evaluation tests are also presented.

The hypothetical reference circuit is 2,500 km long, and the standard repeater spacing is 3km. The circuit specification for the hypothetical reference circuit is then determined as follows: (1) The percentage of time, bit error rate exceeded 10^{-6} during rainfall, is less than 0.1% per 2,500 km. (2) The steady state bit error rate is less than 10^{-7} per 2,500km or 10^{-10} per hop.

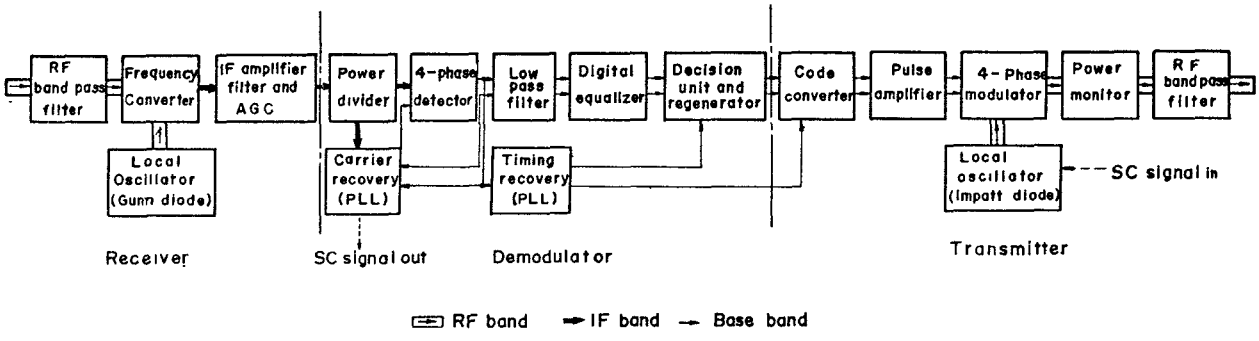

Fig. 1 20-GHz digital radio-repeater block diagram

Introduction

In 1969, the research on the 20-GHz digital radio-relay system started in Electrical Communication Laboratories of Nippon Telegraph and Telephone Public Corporation.[1] The theoretical and experimental research, including the development of the system equipment[2] and the evaluation of the cross polarized co-channel interference at heavy rainfall[3] and multi-hop transmission characteriatics[4], has been carried out.

This paper describes the recent improvements of the system. Results of field evaluation tests are also presented.

System Performances

The system is designed to have seven working radio frequency channels with one protection channel in the 3.5GHz band between 17.7~21.2GHz. Each channel has a 400-Mb/s (200MB, QPSK) transmission capacity.

Interleaved frequency arrangement can offer large rainfall attenuation margin of 46 dB. Therefore, the system can operate with Japan's usual repeater spacing of 3km even when the point rainfall rate exceeds 150 mm/hr.

Repeater Performance

Repeaters are all solid state. Microwave ICs and monolithic ICs are extensively used in IF amplifier circuits, demodulator circuits, etc. Figure 1 shows the repeater layout.

The main feature of repeaters are summarized as follows:

(1) The local oscillators are stabilized by the band rejection circuits[5]. A diamond heat sink is used for Si IMPATT diodes, resulting in increased output power of the transmitter. The improved Gunn diodes provide high reliability for the receivers.

(2) The quadriphase modulator implemented by the PIN diodes is of the pass length switching type, capable of direct phase modulation of the 20-GHz band. The diodes are driven by newly developed pulse amplifiers. The amplifier is designed to reduce the pulse rise time and jitter due to the PIN diodes by depleting the accumulated diode charge, at the instance of switching from forward to reverse bias.[6]

(3) A main IF (1.7GHz) amplifier is constructed by cascading unit amplifiers. This unit amplifier combined with the bridged T type BPF has good performances over the wide frequency band. [7]

(4) Coherent detection is employed for the signal demodulation format. For reference carrier extraction, a reverse-modulation technique[8] is used. The 3-dB directional coupler is the major element of the quadriphase detector. This coupler is composed of microstrip lines, and thus very high directivity has been achieved as shown in Figure 2. This high directivity resulted in the reduction of distortion and interference due to echos from detector diodes and others.

To economize the radio frequency, a new digital equalizer has been developed that reduces intersymbol interference from adjacent pulses.[9]

(5) A timing recovery circuit uses the phase locked loop (PLL) with a crystal-multiplized 20-MHz voltage controlled oscillator. In order to suppress the jitter accumulation, the PLL damping factor is selected as about 50.

(6) A service channel (SC) with 180-kb/s is transmitted by a double modulation technique. The SC signal is applied to the varactor diode of a local oscillator tank circuit and is detected by the PLL of a carrier recovery circuit in the repeater.

The repeaters are assembled from four units; transmitters, receivers, demodulators and DC-DC converters. Each is designed to be a plug-in uint, whose overall size is 198 x 110 x 400 mm^3. Table 1 shows the performances of each circuit.

Repeater Specification

Table 2 shows the equivalent carrier to noise ratio (C/N) degradation factors of the trial repeaters,[10] where the equivalent C/N degradation means the C/N (dB) difference between the theoretical value without band limitation and the experimental one to achieve the same error rate. The overall bandwidth of the transmission system is 170MHz. Also Table 2 shows that the sum of each equivalent C/N degradation at 10^{-6} error rate is equal to or less than 4.1dB. Figure 3 shows the overall error rate of the repeater (Branching filters are included.). The equivalent C/N degradation is about 2.6dB at 25°C and the additional degradation is less than 1.0dB, due to the temperature variation from -10°C to +45°C.

Field Evaluation Tests

The two-hop experiment (about 9km long) was conducted between Yokosuka ECL and Miura in April, 1974, in order to evaluate the overall system performance.

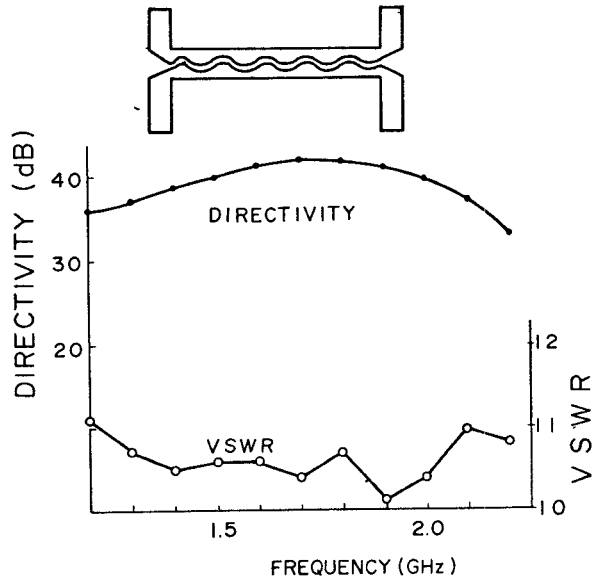

Fig. 2 Characteristics of a high directivity microstrip coupler

TRANSMITTER	Transmitting power		+ 22 dBm	
	Frequency variation		2.4 MHz	#
	Modulation loss		2.0 dB	
	Modulated phase-error		2.8°	#
	Switching time		1.0 nS	
RECEIVER	Noise figure		8.6 dB	
	3-dB band width		445 MHz	
	Receiver output		11.5 dBm	
	Maximum AGC range		58 dB	
	Delay (± 200 MHz)		0.41 nS	
	Local frequency variation		1.8 MHz	#
DEMODULATOR	Quadriphase demodulator	Isolation between two inputs	36 dB	
		1.5 dB band width	1.7 ± 0.23 GHz	
	Carrier recovery circuit	Pull in freq. range	-12 ~ +16 MHz	
		Output S/N	32 dB	
	Timing recovery circuit	Steady phase error	9.8°	#
		Pull-in freq. range	-22 ~ +30 kHz	

- 10°C ~ + 45°C

Table 1. Repeater Components Performance

Figure 4 shows experimental results on the relation between interference and thermal noise to achieve 10^{-6} error rate. Experimental interference is less than that calculated by the assumption of Gaussian distribution.

Figure 5 shows an accumulation of jitter. It was measured by chaining repeaters. The result of multi-

hop trial radio circuits [8] is also shown in this figure. The results of experiments agree with theoretical predictions[11] and it was found that the jitter is less than 10° rms up to 1,000 hops, provided that a damping-factor of 50 is employed for the timing recovery circuit.

Conclusion

Technical and economical viabilities of the 20GHz radio relay long-haul transmission system have been confirmed through the manufacturing of high-speed repeaters and through their field evaluation tests. Commercial tests are planned in 1975.

Acknowledgement

The authors wish to express their thanks to members of the Electrical Communication Laboratories of NTT for their guidance and encouragment through this research. They also extend their thanks to the members of Nippon Electric Company for their endeavors in producing trial repeaters.

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Intersymbol interference	≦22%	≦1.9 dB
Carrier phase error	≦8°	≦1.2 dB
Decision level variation	≦5.5%	≦0.3 dB
Clock phase error	≦10°	≦0.1 dB
Noise factor D/U	≦30 dB	≦0.1 dB
Other factors		≦0.5 dB
TOTAL		≦4.1 dB

Table 2. Error Rate Characteristics Degradation Factor and Theoretical Value

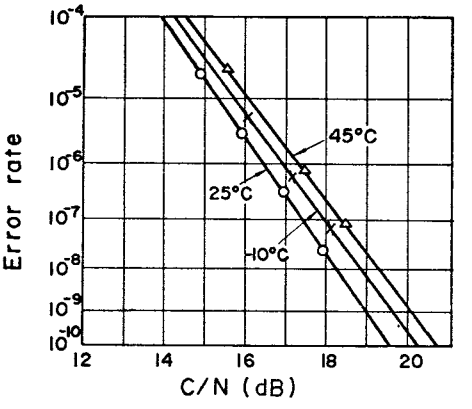

Fig. 3 Error rate performance of experimental digital radio-repeater

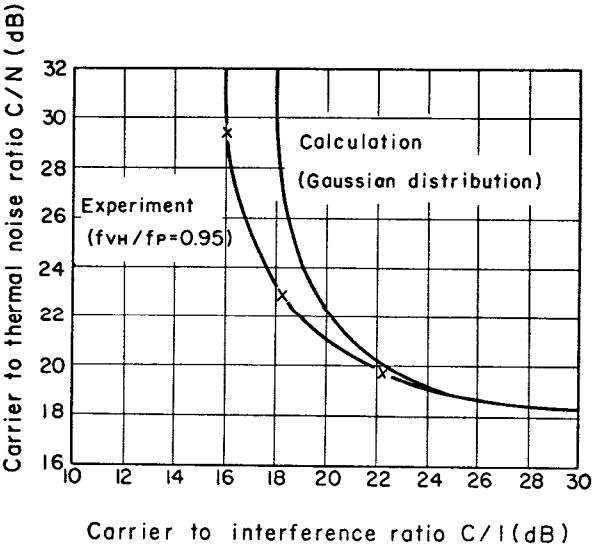

Fig. 4 Relation between interference noise and thermal noise to achieve 10^{-6} error rates

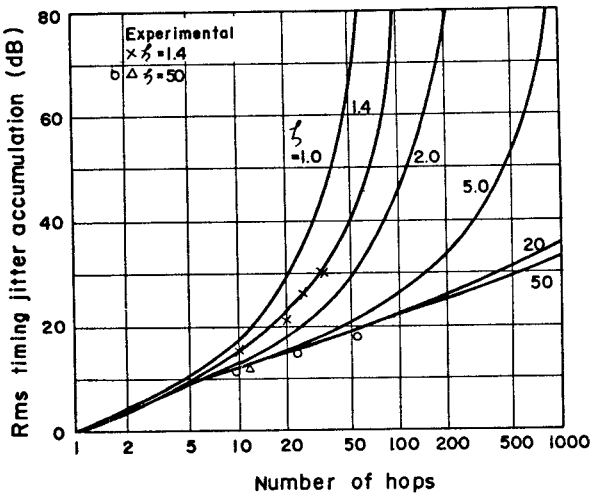

Fig. 5 Timing jitter accumulation characteristic
ζ : Damping factor