A GUIDED MILLIMETER-WAVE TRANSMISSION SYSTEM USING HIGH-SPEED PSK REPEATERS

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Abstract

This paper presents system features and some hardware performances of the "W-40G" guided millimeter-wave transmission system, which is under development at the Electrical Communication Laboratories, NTT, Japan.

Introduction

A guided millimeter-wave transmission system, "W-40G", is presently under development at the ECL's. The main features of this system are:

(1) It transmits about 300,000 PCM telephone signals or 200 coded color TV signals in both directions through a single circular waveguide line.
(2) A high-speed digital transmission of 0.8 Gb/s is used for each millimeter-wave channel.

This paper briefly presents system construction and hardware performances.

W-40G System Construction and Repeater Circuitry

Overall frequency band of the W-40G system is about 43 GHz, from 43.40 to 86.74 GHz, and millimeter-wave channel spacing is about 0.8 GHz. It is assumed that the standard circuit of 2,500 km is composed of 9 multiplexing sections. Each multiplexing section includes 2 multiplexing-supervisory stations and 13 relay stations. In one relay station, 52 repeaters are installed.

Standard repeater spacing is 20 km. The waveguide line is 51 mm I.D. hybrid-tandem type (4 dielectric and 1 helix), and it is protected by steel conduit pipes welded together.[1]

The repeater employed in this system is all solid state. Its transmission capacity is about 0.8 Gb/s. FIG. 1 shows a block diagram of the repeater. Signal format is 400 MB 4-phase PSK, and the intermediate frequency is chosen as 1.7 GHz. Approximate zero-crossing waveform equalization is adopted in the system.[2]

Millimeter-Wave and Intermediate Frequency Circuits

The high-frequency portion of the repeater is composed of receiving and transmitting frequency converters, a common local wave supply, 1.7 GHz IF (intermediate frequency) amplifiers, etc. These frequency converters and IF amplifiers employ GaAs Schottky-barrier diodes and Si transistors, respectively.

Transmission bandwidth of these circuits is more than 0.8 GHz. A typical characteristic of transmitting frequency converter is shown in FIG. 2.[3] The local oscillator frequency stability is within $\pm 7 \times 10^{-5}$.

To separate and combine millimeter-wave channels, semicircular type, figure-8 type and ring type filters are used in 3-stage hierarchical networks.[4]

High-Speed MODEM

A newly developed 1.7 GHz ring type 4-phase modulator is used in the MODEM panel. It is composed of two trifilar transformers with ferrite cores and Si Schottky-barrier diodes. FIG. 3 shows examples of modulated waveform and Lissajous figure.[5] Demodulation and regeneration are accomplished by coherent detection and baseband decision.

In the carrier recovery circuit shown in FIG. 4, an external digital memory is added to the loop, which reduces the phase error caused by frequency variation of millimeter-wave carrier and extends the pull-in range. FIG. 5 shows examples of characteristics of the carrier recovery circuit.[6]

The timing circuit employs an envelope detector and a frequency conversion type PLO.[7]

Code Converter

Transmitting and receiving code converters are installed at the multiplexing-supervisory stations corresponding to every millimeter-wave channel. Their main functions are:

(1) Modulo-4 addition or subtraction for 4-phase PSK format.
(2) Parity check to detect the channel error-rate.
(3) Data scrambling or de-scrambling for stable timing.
(4) Sending some particular code patterns to the repeatered line for fault location.

FIG. 6 shows a block diagram of the transmitting code converter. A time-sharing technique has been adopted in design of the code converters; i.e. two 400 Mb/s baseband signals are divided into four 200 Mb/s signals and are recombined after being code-converted. Monolithic IC's are used in the 200 Mb/s circuits.[8]

Supervision and Control

Main supervision and control functions at the multiplexing-supervisory stations are:

(1) Supervision of repeaters and relay stations.
(2) Supervision of channel error-rate.
(3) Fault location of repeaters in trouble.
(4) Protection switching (12 working versus 1 protection channels).

A millimeter-wave carrier frequency for each direction is allocated to carry telemetry and command signals.

Conclusion

A new waveguide line about 23 km in length has been constructed between Ibaraki ECL and Mito Telephone Office. Its transmission characteristics are presently under test. Repeaters, terminal equipment, channel separating- and combining-networks and measurement sets have almost been completed and are now under installation in the terminal and relay stations, in order to start the W-40G system field trial.

Acknowledgment

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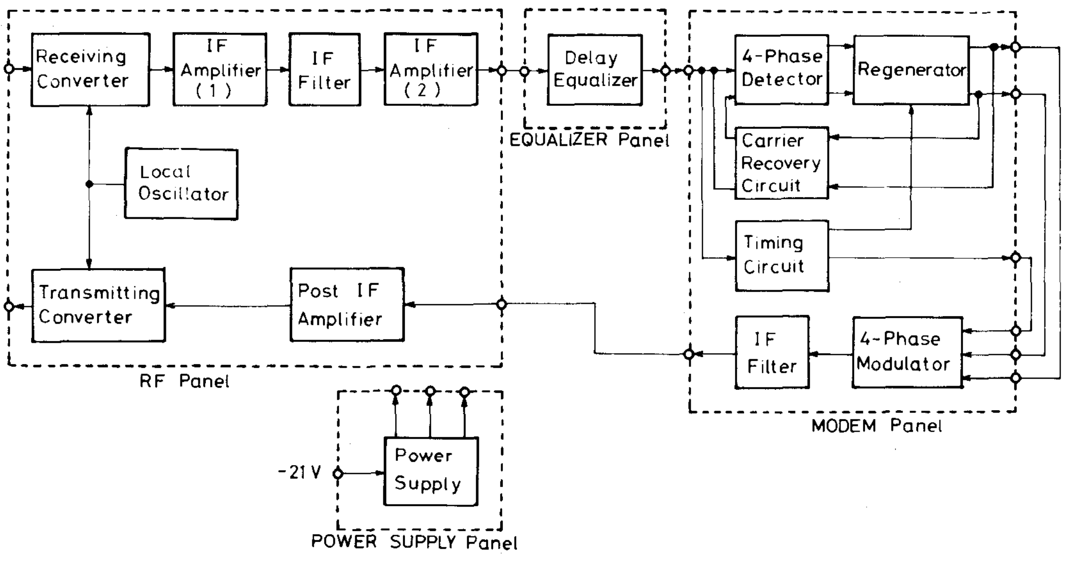

FIG. 1. BLOCK DIAGRAM OF THE REPEATER FOR THE W-40G SYSTEM.

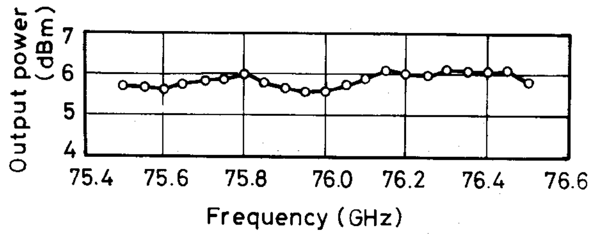

FIG. 2. AN EXAMPLE OF FREQUENCY CHARACTERISTIC OF THE TRANSMITTING FREQUENCY CONVERTER. LOCAL SIGNAL; 14.6 dBm, 74.3 GHz. INPUT IF SIGNAL; 14 dBm, 1.7 GHz.

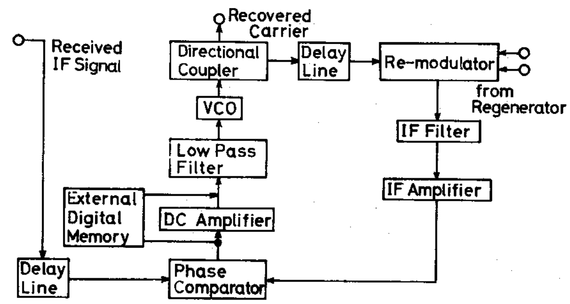

FIG. 4. BLOCK DIAGRAM OF THE RE-MODULATION TYPE CARRIER RECOVERY CIRCUIT.

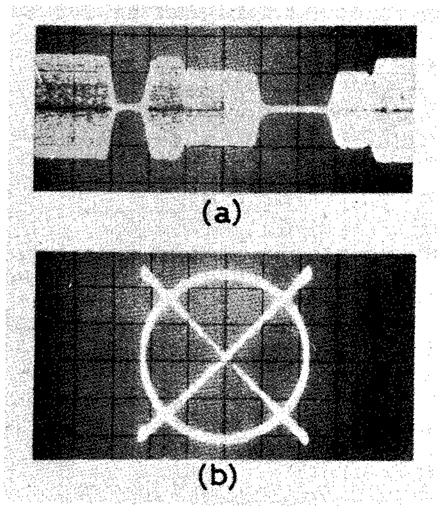

FIG. 3. EXAMPLES OF CHARACTERISTICS OF THE RING TYPE 4-PHASE MODULATOR. (a) MODULATED PHASE WAVEFORM (2.5 ns/div.). (b) LISSAJOUS FIGURE OF A MODULATED SIGNAL.

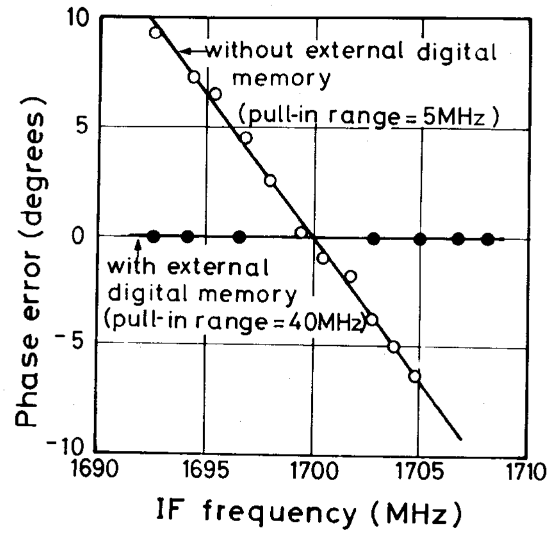

FIG. 5. PHASE ERROR CHARACTERISTICS OF THE RE-MODULATION TYPE CARRIER RECOVERY CIRCUIT.

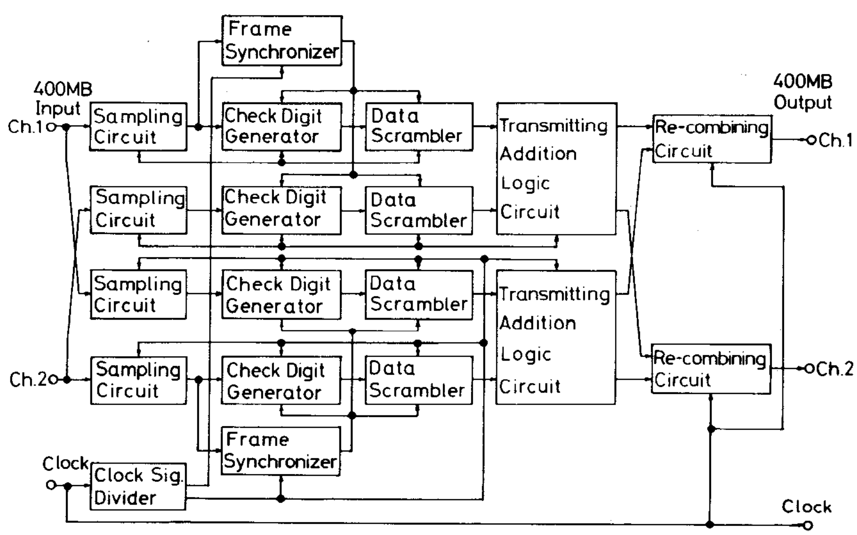

FIG. 6. BLOCK DIAGRAM OF THE TRANSMITTING CODE CONVERTER.