60-GHz-Band Ultracompact Transmitter for HDTV

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ABSTRACT

We have developed a 60-GHz-band ultracompact transmitter for short-range transmission of High Definition TV (HDTV) program material. This transmitter utilizes microwave direct-frequency modulators with simplified temperature-compensation circuits and millimeter-wave modules involving MMIC multipliers and power amplifiers incorporated with integrated planar antennas. This structure has enabled the development of a pocket-sized transmitter ($120 \times 90 \times 30$ mm^3) with a low power consumption of 2.2 W. With this transmitter, HDTV signals have been successfully transmitted on an experimental video link with this transmitter.

INTRODUCTION

In outside live productions of HDTV programs, such as sports events, there is a growing need for a small battery-powered transmitter that can be used to send signals from a compact video camera within a short range, for example in a gymnasium. 42-GHz-band HDTV field pick-up (FPU) systems [1][2][3] which are used to transmit program materials from an outside location to a broadcasting station have already been developed. However, the transmitters are still large and heavy. They also require signal processing units that have large power consumption.

We have tried another approach to transmitting HDTV program materials. A 42-GHz-band wireless HDTV camera system [4] has been developed. The system uses three RF carriers frequency-modulated by each HDTV component signal, and a pair of orthogonal circularly-polarized waves, which can use the narrow bandwidth efficiently without a signal processing unit.

As a new transmission system for HDTV, we have now developed an ultracompact transmitter using the 60-GHz band because of the availability of devices already developed for consumer use such as in wireless LAN systems and in automotive radar, and because of the physical characteristics of high propagation loss in this band [5], which is suitable for short-range transmission. In order to make a transmitter that is small, light, and low power consumption, we used microwave-band direct frequency modulators [6], MMIC multipliers and amplifiers, and integrated-microstrip-planar antennas. This paper describes an outline of the transmitter 's design, performance, and applications.

TRANSMISSION SCHEME

To meet the requirements of downsizing and low power consumption, we adopt a transmission scheme involving the use of three RF carriers, individually frequency-modulated by the output analog component signals (Y, P_B, P_R) from the HDTV camera, as shown in Figure 1. Frequency modulation allows equipment to be much smaller and lighter than it would be if it used a digital signal processing system. As a result an ultracompact transmitter can be developed.

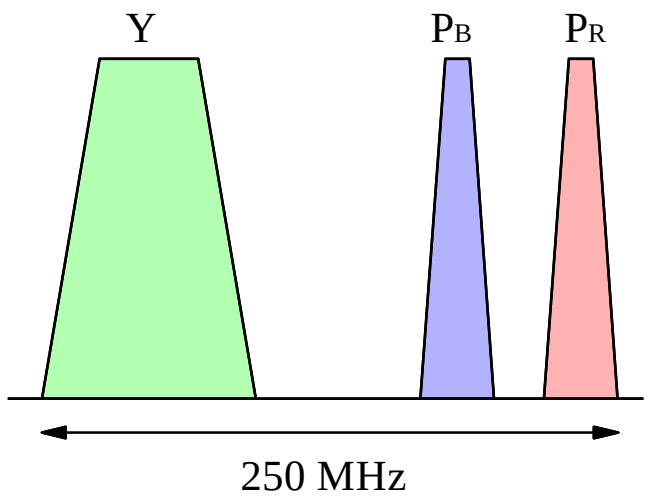

Fig.1. Frequency allocation.

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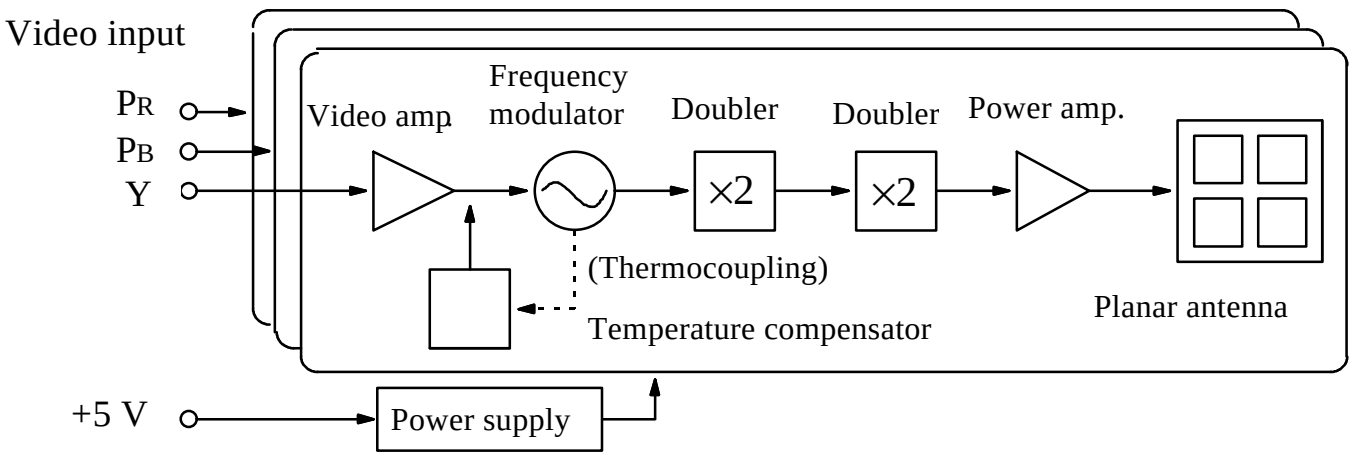

Fig. 2. Black diagram of the transmitter.

CONFIGURATION OF TRANSMITTER

Figure 2 shows the block diagram of the transmitter. For simplicity and compactness, the Y, P_B, and P_R signals from the video camera are individually frequency-modulated at the 15-GHz band by GaAs FET direct-frequency modulators stabilized by dielectric resonators. Figure 3 shows the schematic diagram of the modulator. To obtain high-modulation sensitivity, we used two hyper-abrupt-junction-varactor diodes on both ends of a microstrip line, which is magnetically coupled to the dielectric resonator [6]. Figure 4 shows the modulation characteristics of the modulator. A modulation sensitivity of greater than 4 MHz/V in the 15-GHz band is obtained. The modulators are temperature-compensated by CMOS temperature sensors attached to the modulator housings. Figure 5 shows the temperature-compensation circuit. The compensation

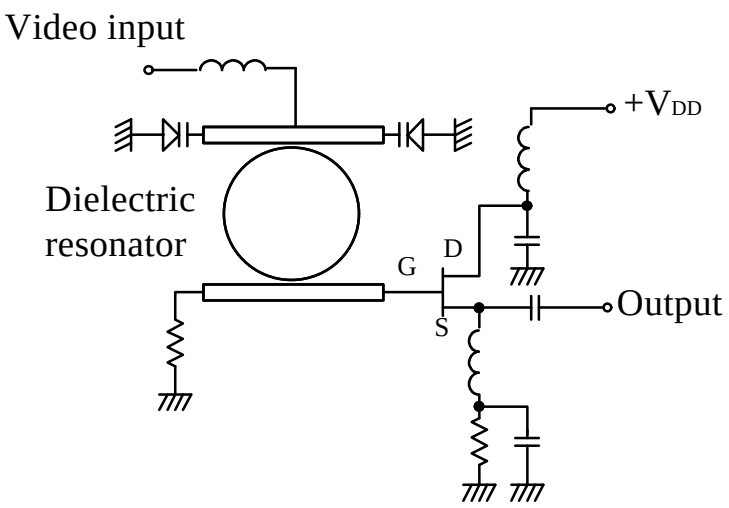

Fig. 3. Schematic diagram of the microwave direct-frequency modulator.

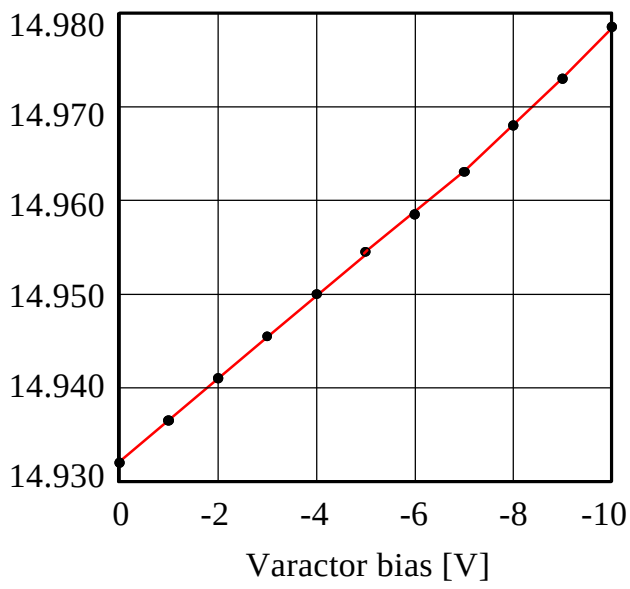

Fig. 4. Modulation characteristics.

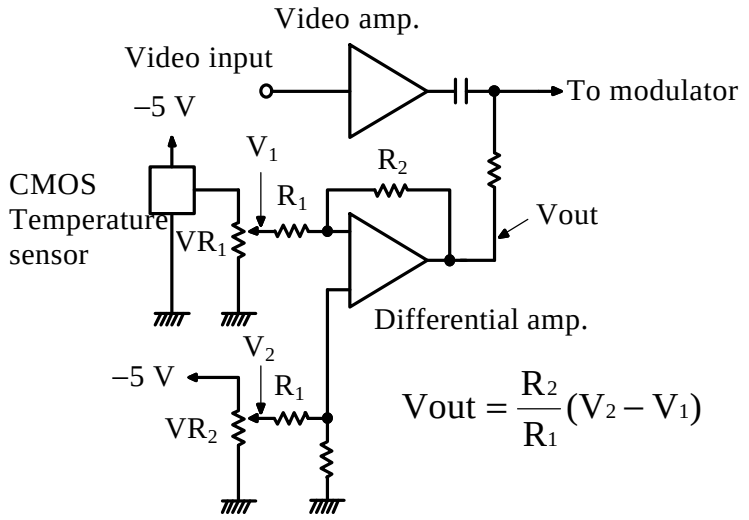

Fig. 5. Temperature compensation circuit.

characteristics of the circuit can be easily adjusted by changing the gain or the offset level of the differential amplifier. The temperature dependencies of the oscillation frequency of the modulator are shown in Figure 6. The frequency drift

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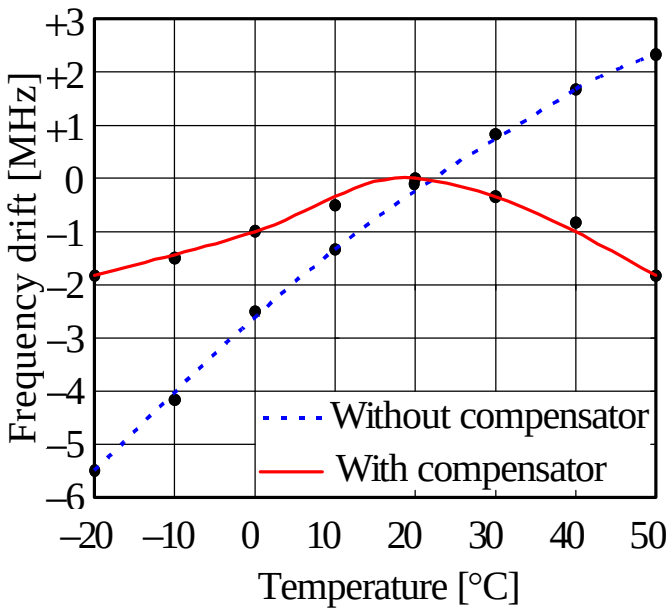

Fig. 6. Temperature dependencies of the oscillation frequency of the modulator.

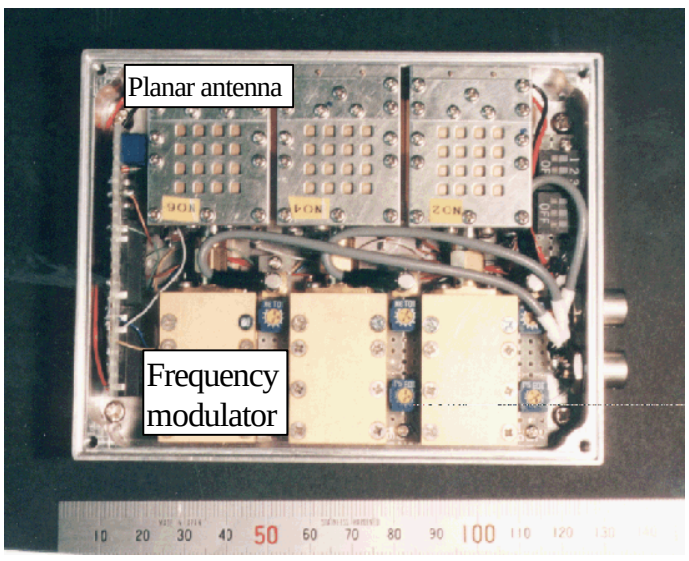

Fig. 7. Top view of the transmitter with top cover removed.

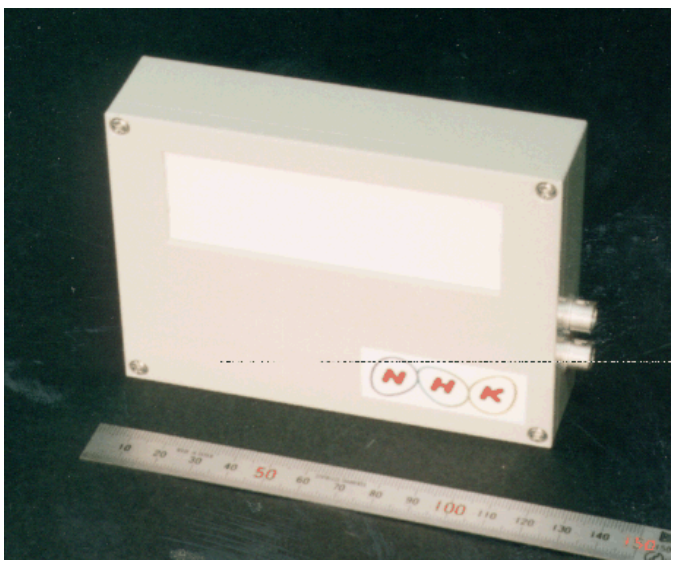

Fig. 8. Outside view of the transmitter.

is reduced from 8 MHzp-p to 2 MHzp-p by using the temperature-compensation circuit. The outputs of each modulator are multiplied to the 60-GHz band by cascaded MMIC doublers. The MMIC amplifiers amplify these outputs to 5 mW. These MMICs are developed for wireless LAN systems or automotive radar. Sixteen-element microstrip planar antennas are attached to the housing of the millimeter-wave circuits involving multipliers and power amplifiers. The polarization of the antennas is right-handed circular polarization (RHCP).

Photographs of the transmitter are shown in Figure 7 and 8.

PERFORMANCE OF TRANSMITTER

Table 1 lists the characteristics of the transmitter. An ultracompact size ($120 \times 90 \times 30$ mm^3) and low a power consumption of 2.2 W are achieved by applying the simple configuration of the transmitter. The operating time of the transmitter is about two hours using four AA-sized NiMH rechargeable batteries. Table 2 shows the link budget of the transmission system having a receiver with a noise figure of 8 dB and a parabolic antenna 10 cm in diameter. The picture S/N of the received Y signal is 50 dB or more at the transmission distance of 50 m. We checked that high-quality pictures could be transmitted by using the transmitter on an experimental link.

Table 1. Characteristics of the 60-GHz-band ultracompact transmitter

Radio frequency	60 GHz
Output power	5 mW minimum
Modulation method	Frequency modulation
Frequency stability	less than 2 MHzp-p (–20 to +50 °C)
Polarization	RHCP
Antenna	Planar antenna
Size	$120 \times 90 \times 30$ mm^3
Weight	700 g
Power consumption	2.2 W

Table 2. Link budget.

		Y	P_B, P_R
Frequency	(GHz)	59.8	59.9
Baseband bandwidth	(MHz)	24.0	8.0
Maximum frequency deviation	($MHz_{p\text{-}p}$)	40.0	10.0
Transmitter power	(dBm)	7.0	7.0
Transmitter antenna gain	(dB)	19.0	19.0
EIRP	(dBw)	26.0	26.0
Propagation loss (50m)	(dB)	–102.0	–102.0
Rain attenuation (6dB/km)	(dB)	–0.3	–0.3
Attenuation by atmospheric gases (20dB/km)	(dB)	–1.0	–1.0
Receiver antenna gain	(dB)	32.9	32.9
Pointing loss	(dB)	–1.0	–1.0
Received power	(dBm)	–45.4	–45.4
Noise figure	(dB)	8.0	8.0
Equivalent noise power	(dBm)	–86.5	–91.8
C/N	(dB)	40.2	45.4
FM improvement	(dB)	11.8	11.8
Emphasis improvement	(dB)	–0.8	–0.8
Unweighted S/N	(dB)	52.2	57.5

CONCLUSION

A 60-GHz-band ultracompact transmitter for short-range transmission of HDTV program material has been developed. It is expected that dynamic and attractive pictures will be obtained in outside live-productions of HDTV programs by using this transmitter.

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REFERENCES

[1] H. Nakakita, F. Suginoshita, and H. Tanaka, "Millimeter-Wave Field Pick-up Links for HDTV, " MWE'96 Microwave Workshop Dig., pp. 358-363.

[2] K. Takano, "42 GHz-band experimental station for High-Definition Television transmission, " NHK Technical Report, vol. 28, No. 12. pp. 468-473, 1985.; In Japanese.

[3] H. Tanaka, F. Suginoshita, H. Nakakita, and H. Fujio, "42 GHz Digital FPU for HDTV, " International Workshop on HDTV 94.

[4] H. Mizuno, H. Nakakita, H. Mitsumoto, N. Yazawa, and Y. Fujita, "42 GHz Wireless HDTV (Hi-Vision) Camera, " NAB HDTV World Conf. Proc., pp.79-86, 1993.

[5] CCIR Rep. 719-3, "Attenuation by atmospheric gases," Report of the CCIR, pp. 189-204, 1990.

[6] H. Mitsumoto and K. Imai, "GaAs Direct Frequency-modulator for 42-GHz-band HDTV Radio Cameras and 7-GHz-band Field Pick-up Transmitters, " 1993 IEEE MTT-S Int. Microwave Symp. Dig., pp. 633-666.