A 156 Mbps Compact FSK Modulator Module for 38 GHz Wireless LANs

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Abstract – **The results on the development of a 156 Mbps modulator module for 38 GHz wireless LANs are presented. The modulator module employing a dielectric resonator and MMICs has a compact structure. The frequency stability is less than 5.7 ppm/degree and suitable to a direct modulation of FSK. The spectrum of 38 GHz RF signals shows a wide frequency deviation of 75 MHz for 156 Mbps modulation. The 2^{31}-1 random data of 156 Mbps demodulated in a testing system exhibits a clear eye pattern. Error free in the data transmission process between the modulation and the demodulation is also confirmed.**

I. INTRODUCTION

There are increasing demands for microwave and millimeter wave short-range communication systems, such as wireless LANs, in high speed digital data transmission applications. The systems make possible layout flexibly and can be used as mobile terminals, as they are expected to be low cost, simple configuration.

One of the ways of achieving these high performances is the use of a direct carrier modulation technology. Several development results on modulation for the short-range communication systems have been reported in the past few years [1-5]. For DPSK modulation [1], the modulation speed reaches 156 Mbps, but it makes the system more complex due to the indirect modulation procedures. A 60 GHz direct vector modulator is reported [2], and the data speed is 1 Mbps. FSK, including quasi-MSK, allows sources to have a reasonable stability. Y. Takimoto et al also reported a 10 Mbps FSK system [1]. Very recently, K. Takahashi et al reported a 156 Mbps quasi-MSK LAN [5]. In this system, a free-running oscillator is used as a modulation source. The source has a larger RF drift, which degrades the base band data duty and communication quality.

In order to realize 156 Mbps direct modulation of FSK in high quality, more stable frequency and wider frequency deviation are requested for compact LANs. Therefore, we have tried to utilize a dielectric resonator (DR) oscillator as a source, and prepare a matching circuit for data input to develop the modulator module. The frequency stability is less than 5.7 ppm/degree in the temperature range of 25-85 degrees. A frequency deviation of about 75 MHz is obtained under 156 Mbps data modulation. The demodulated data shows a clear eye pattern and no error has been detected for over 12 hours in a testing LAN.

II. MODULATOR MODULE

The modulator module is developed for a 38GHz RF wireless LAN, which is not only for indoors but also for outdoors, and is linked to optical fiber network at an access point. The system provides the multimedia traffic at

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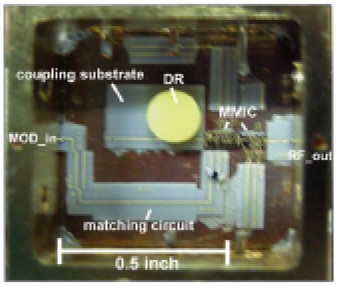

Fig. 1 A photograph of the modulator module.

a speed of up to 156 Mbps in each direction and supports multicasting/broadcasting by using reservation-based slotted idle signal multiple access (RS-ISMA) [6].

It is desired to fabricate the system with low cost and compact configuration. The DR oscillators advantage in cost and simplicity in comparison with RF sources of phase loop lock circuits. Therefore, the DR is a strong candidate for direct FSK modulation at high speed if a wide frequency deviation can be obtained. For the system, the modulation index close to 0.5 is necessary.

Fig. 1 shows a photograph of the fabricated modulator module, which consists of a DR, a coupling substrate, a matching circuit and GaAs MMIC chips. The quality factor and the frequency temperature coefficient of the DR are about 15000 and +/-1 ppm/degree, respectively. A microstrip line with a terminal of 50-ohm film-resistor is formed on the coupling substrate of alumina material. The matching circuit is prepared between the terminal of data input and the tuning-pad of the oscillating MMIC chip. The micro-connections between MMIC chips and the substrates are Au wires. The module has a compact size. The volume inside the package is about 2 cm x 2 cm x 0.75 cm. The terminals of data input and RF output are assembled to SMA and K connectors, respectively.

The voltage of the tuning pad can control the negative impedance of the oscillating MMIC at the input port, which is connected to the coupling substrate and the DR. The control sensitivity depends on not only the oscillating frequency and the tuning voltage, but also the position of

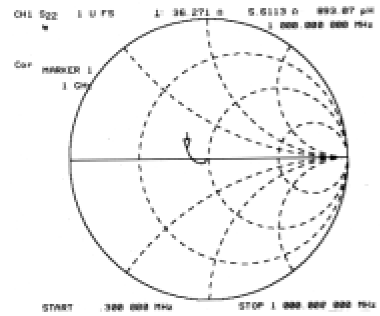

Fig. 2 Typical reflection of the modulator module at data input.

the DR on the coupling substrate. We apply the 156 Mbps data to the tuning pad through the matching circuit and modulate directly the oscillating frequency of 19 GHz. The 19 GHz modulated signal is duplexed to the 38 GHz RF signal and is amplified for RF output. The frequency duplexer also provides 2 times frequency deviation for the FSK modulation.

III. MEASURED RESULTS

The matching circuit of the fabricated modulator module was measured first. Fig. 2 shows an S_{22} parameter at the data input terminal, which suggests a low reflection in the frequency range from 0.3 MHz to 1 GHz for the matching circuit. DC resistance at the data input is also about 50 ohm.

Fig. 3 shows a power spectrum of the carrier signal without data modulation. The frequency drifts from 38.7426 GHz to 38.7558 GHz with the temperature change of 25-85

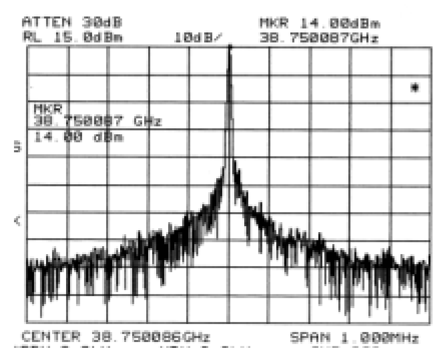

Fig. 3 Spectrum of the modulator module without modulation at RF output.

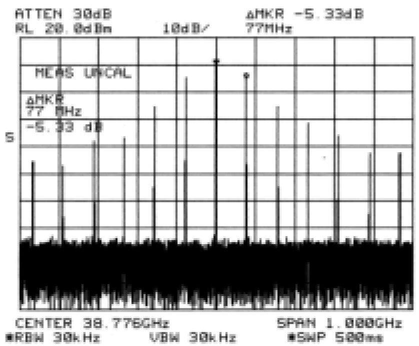

Fig. 4 Spectrum of RF output signal modulated by a sine wave of 78 MHz.

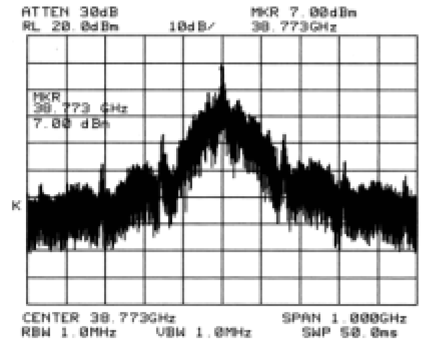

Fig. 5 Spectrum of RF output signal modulated by 156 Mbps digital random data.

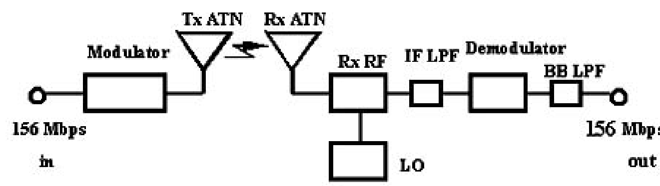

Fig. 6 Block diagram of a testing system used for measuring the modulator module.

Celsius, indicating the frequency stability less than about 5.7 ppm/degree. The phase noise is about -99 dBc/Hz at 100 kHz frequency offset from the center frequency.

In general, the center frequency of the stable DR oscillator has a narrow tunable range. We have obtained a wide tuning range of about 75 MHz for the requested RF frequency deviation by adjusting the coupling condition of the DR. The spectrum of RF signal modulated by a sine wave of 78 MHz is shown in Fig. 4. The result suggests that this module is able to provide a FSK modulation with the frequency index of about 0.5 at 156 Mbps data speed for the LAN.

Fig. 5 shows the RF spectrum modulated by the156 Mbps random digital data. From Fig.5 it is understood that the RF power was concentrated within the main-lope of about 250 MHz and decreased quickly in the sidelopes. We also know the frequency distribution is almost independent of the modulation index except the center frequency.

To investigate the modulated signals in time reign, we made up the testing system shown in Fig. 6. The modulated RF signal is transmitted to air by a Tx antenna, and is received by an Rx antenna and an Rx RF module. Then, the signal is converted down to an IF signal of 500 MHz, and is returned to 156 Mbps base band data by a demodulator in the IF board. The base band LPF at output is a Bessell low pass filter with a cutoff frequency of 117 MHz and removes the IF signal mixed in base band data.

The received demodulated 156 Mbps 2^{31}-1 random base band data is shown in the bottom trace of Fig7. For comparison the input data is also shown in the upper one. It is seen that the demodulated data exhibits clear eye patterns, indicating that the modulator module operates very well. The delay time between the input data and the output data is caused from the distance of data transmission.

We also have measured the bit error rate (BER) as a function of the RF received power in the data transmission process. As measurement conditions, the gain of Rx antenna is 8.1dB, the gain of Tx antenna is 21.5 dB, the transmission distance between the antennas is 0.8 m. The received power is changed by attenuating the Tx output power. The received power measured directly is equal to the value estimated roughly from the air loss of the transmission distance and antenna gains of the Tx and the Rx. The

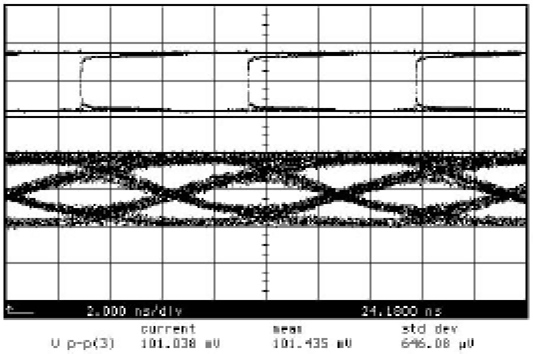

Fig. 7 Eye patterns of 156 Mbps 2^{31}-1 random base band data at the input and the output of the testing system.

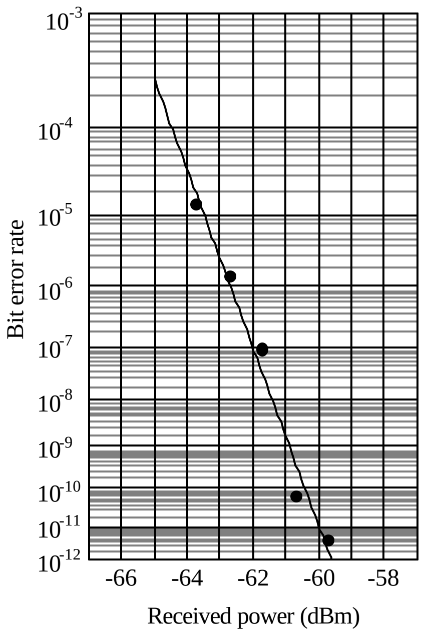

Fig. 8 BER as a function of received power.

measured result is shown in Fig. 8. No bit error is detected for over 12 hours when the received power is –58 dBm. It is not difficult in making the received power larger than –61.7 dBm to meet the required BER less than $1x10^{-7}$ for the wireless LANs. Therefore, it is confirmed that our FSK modulator module provides excellent characteristics for 156 Mbps 38 GHz wireless LANs.

IV. CONCLUSION

In conclusion, we have fabricated a 156 Mbps FSK modulator module employing a DR and MMICs for 38 GHz wireless LANs. The fabricated modulator module has a compact structure, a high frequency stability less than 5.7 ppm/degree, and a wide frequency deviation of 75 MHz. The clear eye pattern of the demodulated 156 Mbps 2^{31}-1 random base band data and the error free characteristic in the data transmission process for 12 hours demonstrate that the fabricated modulator module operates very well.

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