# A 60GHz MMIC STABILIZED FREQUENCY SOURCE COMPOSED OF A 30GHz DRO AND A DOUBLER

M.Funabashi*, T.Inoue*, K.Ohata*, K.Maruhashi**, K.Hosoya**, M.Kuzuhara**
K.Kanekawa*** and Y.Kobayashi***

*Advanced Millimeter Wave Technologies Co. Ltd.
c/o NEC Corporation, 2-9-1 Seiran, Otsu, Shiga 520, Japan

**Kansai Electronics Research Laboratory, NEC Corporation
2-9-1 Seiran, Otsu, Shiga 520, Japan

***Saitama University
255 Shimookubo, Urawa, Saitama 338, Japan



**Abstract**

This paper presents a 60GHz highly stabilized frequency source, which is composed of a 30GHz DRO and a doubler based on 0.15μm gate AlGaAs/InGaAs HJFET MMIC technologies. The 30GHz DRO exhibited low phase noise of -102dBc/Hz at 100kHz off-carrier with the maximum output power of 7.7dBm. The 30-to-60GHz doubler showed high conversion gain of -1.5dB at the input power of 7dBm. For the 60GHz frequency source, markedly low phase noise of -93dBc/Hz at 100kHz off-carrier and better than 1.9ppm/°C frequency stability has been achieved.

## Introduction

Millimeter wave communication systems, especially at 60GHz band, are attracting much attention for high speed wireless LANs, image data transmissions, contactless ID cards[1]. In these systems, monolithically integrated stabilized frequency sources with low phase noise and high stability are required for high quality communications. The oscillation frequency stabilization with a dielectric resonator (DR) is the most possible solution for these requirements. To date, a 38GHz MMIC dielectric resonator oscillator (DRO) with -68dBc/Hz phase noise at 100kHz off-carrier and -2.1ppm/°C frequency stability[2], a 62GHz MMIC DRO with -78dBc/Hz phase noise, a 36GHz MMIC DRO with -97dBc/Hz and -1.7ppm/°C frequency stability[3] were reported. The authors also reported a 55GHz MMIC DRO with -88dBc/Hz phase noise and -3.9ppm/°C frequency stability[4]. However, further spectrum purity is required for various practical applications, for example, highly reliable high speed data transmission systems.

The purpose of this work is to develop a 60GHz highly stabilized frequency source with a dielectric resonator based on MMIC technologies. In this work, an approach to construct the frequency source with a 30GHz DRO and a frequency doubler has been made due to higher performance and better design accuracy for the 30GHz oscillator than those for the 60GHz one. State of the art low phase noise performance of -93dBc/Hz at 100kHz off-carrier with high stability has been realized.

## MMIC Design

The MMIC DRO and doubler were designed and fabricated using a microstrip line circuit configuration. As the active element, a 0.15μm long, 100μm (50μm×2) wide T-shaped gate N-AlGaAs/InGaAs/N-AlGaAs double doped double heterojunction FET(HJFET)[5], whose fmax is higher than 240GHz, is adopted.

The oscillator circuit has a series feedback topology as shown in Fig.1. A shorted stub is connected to the source of the active FET as the series feedback element for negative resistance generation. The resonance circuit composed of a microstrip line coupled to a dielectric resonator and a termination is placed at the gate side. The bias network consists of a quarter wavelength line and a bypass capacitor. The fabricated MMIC DRO chip is shown in Fig.2. The chip size is 3.37×3.37mm$^2$

The circuit schematic of the 30-to-60GHz frequency doubler is shown in Fig.3. The doubler consists of an active device, a 30GHz input matching circuit, a 60GHz output matching circuit and a 30GHz shorted circuit made with a quarter wavelength open stub. The fabricated MMIC doubler is shown in Fig.4. The chip size is 1.07×2.22mm$^2$. The substrate thickness is 40μm and the plated heat sink (PHS) is adopted. All groundings are made through via-

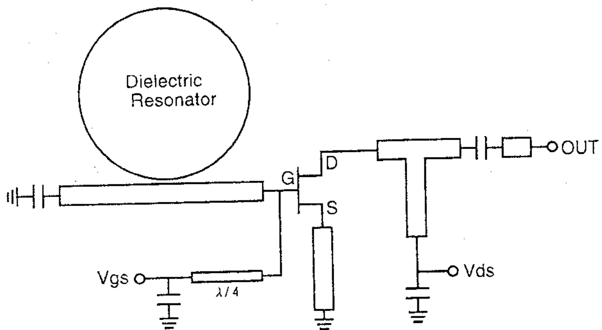


Fig.1 Circuit schematic of the 30GHz DRO.

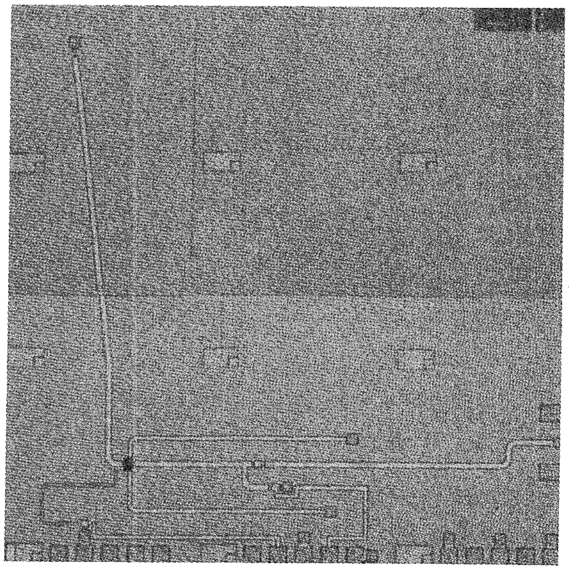

Fig.2 Chip photograph of 30GHz MMIC DRO.
(The DR is not placed.)

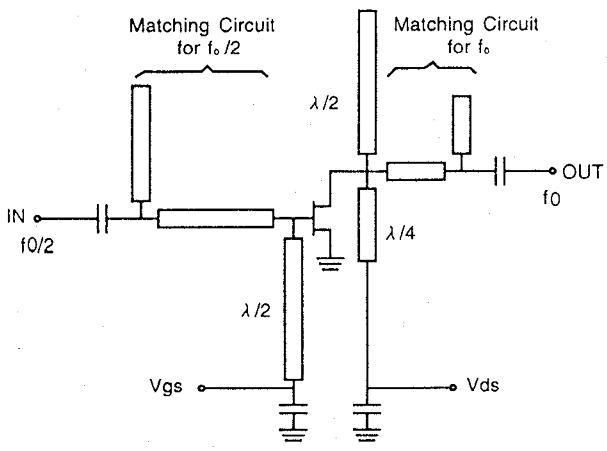


Fig.3 Circuit schematic of frequency doubler.

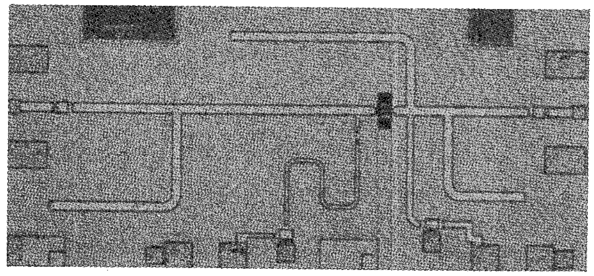

Fig.4 Chip photograph of the MMIC doubler.

holes of 30μm square.

## MMIC PERFORMANCE

The fabricated 30GHz DRO was evaluated using a test jig which is composed of a chip carrier so as to evaluate MMIC by an RF probe and of a metal screw above the carrier for a mechanical tuning element. A rod shaped TE01δ mode DR made from Ba(Mg,Ta)$O_3$, whose relative dielectric constant and temperature coefficient are 23.8 and 0.5ppm/°C, respectively, was placed directly on the MMIC chip. The diameter and height of the DR is 2.2mm and 1.4mm, respectively. When the DR was coupled to the oscillator, highly stabilized oscillation was achieved around 30GHz as shown in Fig.5. Markedly low phase noise of -102dBc/Hz at 100kHz off-carrier has been obtained. At 1MHz off-carrier, the phase noise is -117dBc/Hz. Figure 6 shows the oscillation frequency and output power dependences on gate bias of the MMIC DRO. The oscillation frequency variation is less than 1MHz, and the maximum output power of 7.7dBm is obtained. Figure 7 shows the temperature dependence of the DRO performance. The oscillation frequency stability is high of 1.7ppm/°C.

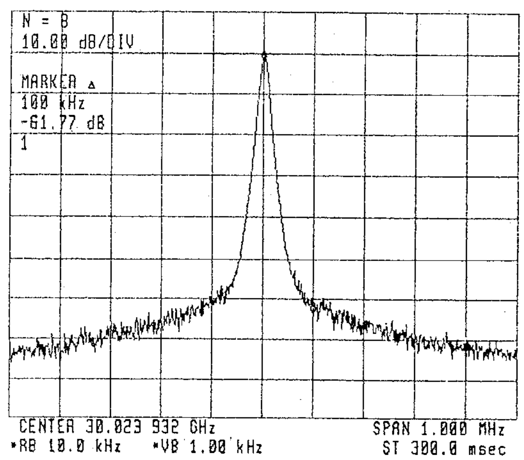


Fig.5 Output spectrum of the 30GHz DRO.

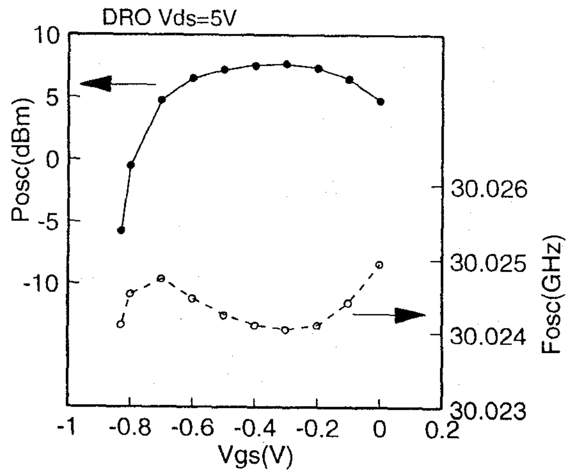


Fig.6 Gate bias dependence of the frequency and output power of the 30GHz DRO.

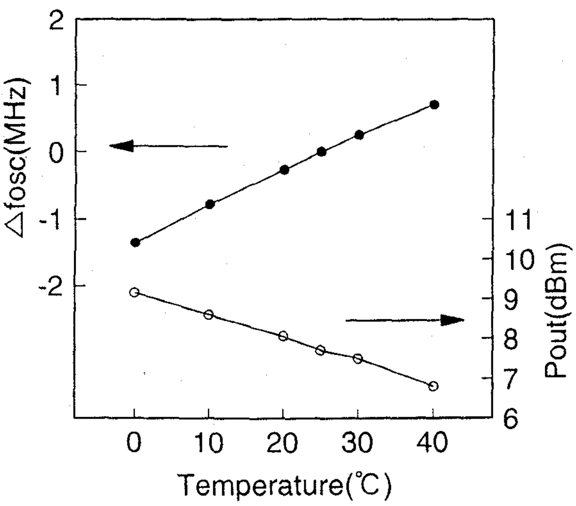


Fig.7 Temperature stability of the 30GHz DRO.

Figure 8 shows the input to output power characteristics at 30GHz input. Figure 9 shows frequency responses for the 60GHz output and 30GHz output at the input power of 7dBm. High conversion gains of 0.3dB at the input frequency of 30.5GHz, -1.5dB at 30GHz and -4.5dB at 29.5GHz were obtained. The suppression of the 30GHz input signal at the output is more than 20dB.

As a 60GHz frequency source, the 30GHz DRO and the doubler were combined in the same jig as used for 30GHz DRO, and output performance was evaluated. Figure 10 shows the output spectrum of 60GHz frequency source. Low phase noise of -93dBc/Hz at 100kHz off-carrier with -0.8dBm output power was obtained. Figure 11 shows the output frequency and power dependences on drain bias. The frequency pushing for the drain bias is smaller than 4.3MHz/V. The mechanical tuning range for the

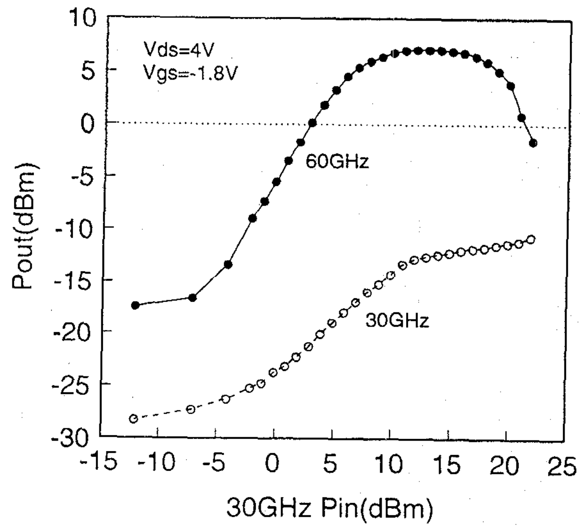


Fig.8 Power performance of the doubler.

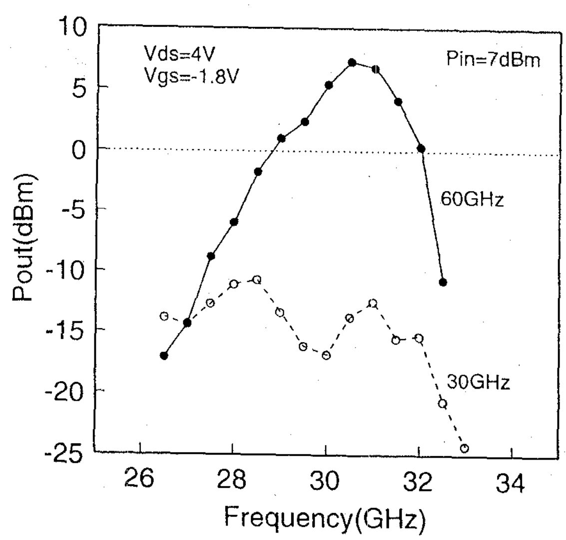


Fig.9 Frequency response of the doubler.

output frequency is from 58.97GHz to 60.23GHz within ±1.5dB output power deviation. The maximum output power is 1.1dBm. The 60GHz output power level is somewhat smaller than that expected. This is due to some mismatch between the DRO output and the doubler input. The 30GHz output power is well suppressed down to less than -25dBm. Figure 12 shows the temperature dependence of the 60GHz source. The oscillation frequency stability is better than 1.9ppm/°C.

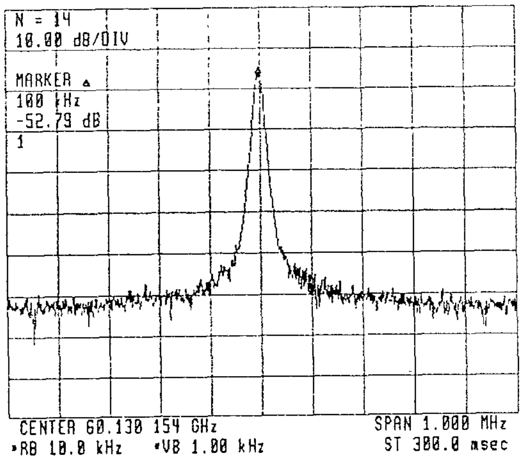


Fig.10 Output spectrum of the 60GHz source.

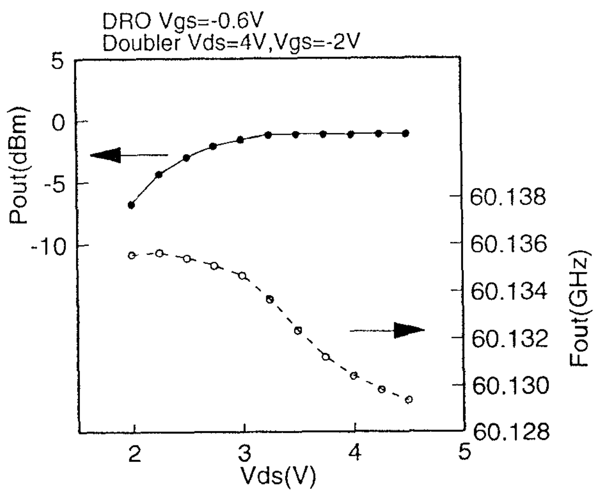


Fig.11 Output frequency and power of the 60GHz source vs. drain bias of the 30GHz DRO.

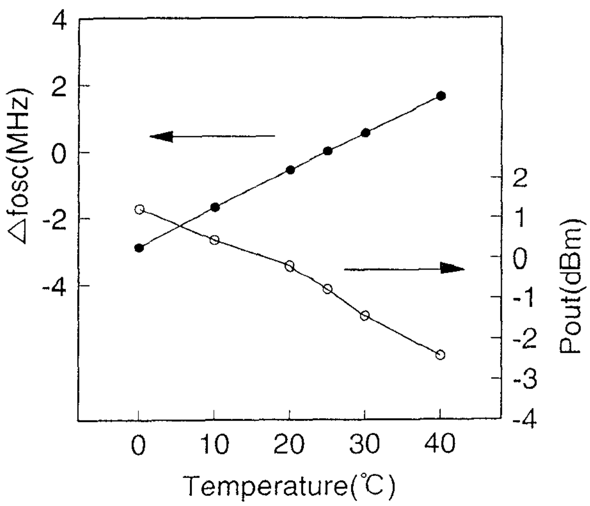


Fig.12 Temperature stability of the 30GHz DRO.

## Conclusion

A 60GHz stabilized frequency source composed of a 30GHz MMIC DRO and a 30-to-60GHz MMIC doubler has been developed utilizing 0.15μm gate AlGaAs/InGaAs heterojunction FETs. The 30GHz DRO exhibited markedly low phase noise of -102dBc/Hz at 100kHz off-carrier. The frequency doubler showed maximum conversion gain of -1.5dB at the input frequency of 30GHz. For the 60GHz source, state of the art low phase noise of -93dBc/Hz at 100kHz off-carrier and better than 1.9ppm/˚C frequency stability with 1.2GHz mechanical tuning range has been achieved.

## Acknowledgment

The authors wish to thank to Drs. T. Ishimine, Y. Takimoto and H. Abe for useful discussions and encouragements.

## References

[1] Y.Takimoto and T.ihara, "Research activities on millimeter wave indoor communication systems in Japan," 1993 IEEE MTT-S Microwave Symp. Dig., pp.673-676.

[2] P.G.Wilson, "Monolithic 38GHz dielectric resonator oscillator," 1991 IEEE MTT-S Microwave Symp. Dig., pp.831-834.

[3] U.Guttich and J.Wenger, "Design, Fabrication, and Performance of Monolithic Dielectrically Stabilized PM-HFET Oscillators up to 60GHz," 1994 European Microwave Conf. Proc., pp.361-365.

[4] M.Funabashi et al., "A V-band AlGaAs/InGaAs heterojunction FET MMIC dielectric resonator oscillator," 1994 IEEE GaAs IC Symp. Dig., pp.30-33.

[5] M.Funabashi et al., "High gain V-band heterojunction FET MMIC power amplifiers," 1993 IEEE GaAs IC Symp. Dig., pp.667-670.