PROCEEDINGS OF ISAP2000, FUKUOKA, JAPAN

BASIC CHARACTERISTICS OF PLANAR RADIATING OSCILLATOR USING BUTTERFLY-SHAPED PATCH

Masami Murata*, Akiko Kishi*, Shingo Ohmori** and Toshiaki Matsui**

*University of Electro-Communications,
1-5-1, Choufugaoka, Choufu-shi, Tokyo 182-8585, Japan.
**Communications Research Laboratory
Yokosuka Research Center
Ministry of Posts and Telecommunications, 4-2-1
Nukui-Kitamachi, Koganei-shi, Tokyo 184-8795, Japan.
Phone: +81-423-27-7527, Fax: +81-423-27-6669
E-mail: murata@net.is.uec.ac.jp

I. INTRODUCTION

Recently, new millimeter-wave techniques have received much attention for the realization of high performance millimeter-wave communication system[1]. Such system usually requires high efficiency, compact, light weight, reliability, and low cost. One of techniques satisfies the demands is active integrated antenna technique, which have been intensively studied in recent years [2-4].

Several groups reported a simple active integrated antenna consists of a patch and single/double FET, in the literature [5-7]. We also reported planar radiating oscillator using a butterfly-shaped patch (in the case of symmetrical triangle-shaped patch) and its spatial power-combining array [8-9].

Here we report basic characteristics of planar radiating oscillator using a butterfly-shaped patch (symmetrical fan-shaped patch and symmetrical triangle-shaped patch). The stable oscillation can be selected by adjusting the substrate thickness. By using the butterfly-shaped patch, we have observed both low cross-polarization and changeable injection locking range at the same time. The changeable injection locking range especially is key characteristic for many applications using injection locking.

II. DESIGN OF PLANAR RADIATING OSCILLATOR

A configuration of the planar radiating oscillator using a butterfly-shaped patch (B-PRO) is shown in Fig. 1. The span L (about $\lambda_0/2$) of the butterfly-shaped patch determines the oscillation frequency. The geometrical structure of the resonator can be designed by selecting parameters such as substrate thickness h, flare angle θ and curvature R. DC bias lines are soldered to connect each choke filter and are electrically isolated from the ground plane. The gate of HEMT needs no external biasing, and the transmission lines for circuit do not exist, except for the butterfly-shaped patch and two high impedance bias lines. A commercial packaged HEMT, Mitsubishi MGF4314D, was used, which has a 0.15μm gate and an fmax of approximately 20GHz. The circuit was fabricated on RT/Duroid 5870 substrates ($\varepsilon_r = 2.17$) with thickness of 3.2mm.

III. EXPERIMENTAL RESULTS

Measurement was done by using a spectrum analyzer (HP8565) followed a receiving horn antenna, which was located 1 m distant from the B-PRO under test. The efficient oscillation with very low spurious were observed when the substrate thickness versus wavelength was roughly 0.05 <$\sqrt{\varepsilon_r} \cdot h/\lambda_0$<0.2. High output power also mainly obtained in this range, and these hold true for some slight different gain HEMT we tried. An EIRP (effective isotropic radiated power) 254.7mW at 8.4GHz was obtained under Ids=22.85mA and Vds=3.4V, where$\theta = 60^\circ$, R>>L and $\sqrt{\varepsilon_r} \cdot h/\lambda_0$= 0.13.

The selection of locking range and radiation pattern with low cross-polarization is important characteristics, for example, for spatial power combining through mutual coupling. Fig. 2-(a) and Fig2-(b) show the radiation patterns at $\theta = 60^\circ$, $R \cong L/2$ where $\sqrt{\varepsilon_r} \cdot h/\lambda_0$= 0.13 (symmetrical fan-shaped patch) and $\theta = 60^\circ$, R>>L where $\sqrt{\varepsilon_r} \cdot h/\lambda_0$ =0.13 (symmetrical triangle-shaped patch), respectively. The cross-polarization level was suppressed approximately 20 dB down from the maximum power, respectively. This is due to the single resonant mode operation of the butterfly-shape patch. The difference of these patterns was observed in E-plane of horizontal direction.

Fig. 3 shows typical injection-locking range versus locking gain. The locking signal was injected through a pyramidal horn, which illuminated the B-PRO at a distance of 1 m. Injection-locking range and locking gain can calculated from [10]. We fabricated and measured two cases, where $R \cong L/2$ and R>>L under $\theta = 60^\circ$, $\sqrt{\varepsilon_r} \cdot h/\lambda_0$= 0.13. We observed significant differences in these two cases. For examples, a locking gain of 35.5 dB with maximum locking bandwidth of 33MHz was obtained for R>>L type, while 9.7MHz was obtained for $R \cong L/2$ type.

IV. CONCLUSION

Basic characteristics in planar radiating oscillator using a butterfly-shaped patch and a HEMT, have been presented in this paper. We have attained the cross-polarization level approximately 20 dB down from the maximum power, and observed that variation of the curvature makes differences of the locking range. The changeable injection locking range especially is key characteristic for many applications such as spatial power combining, phased array antenna, and systems using injection locking.

ACKNOWLEDGEMENT

We would like to thank Dr. Keren Li for reviewing the manuscript.

REFERENCES

[1] T. Teshirogi and T. Yoneyama, Eds. Modern Millimeter-Wave Techniques. Japan: Ohmsha. Inc., 1999. (in Japanese)

[2] J. A. Navarro and K. Chang, Eds. Integrated Active Antennas and Spatial Power Combining. New York: Wiley. Inc., 1996.

[3] R. A. York and Z. B. Popovic, Eds. Active and Quasi Optical Arrays for Solid-State Power Combining. New York: Wiley. Inc., 1997.

[4] K. C. Gupta and P. S. Hall, Eds. Analysis and Design of Integrated Antenna Modules. New York: Wiley. Inc., 2000.

[5] R. A. York et. al., "Active patch antenna element for array application, " Electron. Lett., vol. 26, pp. 494-495, Mar. 1990.

[6] X. D. Wu and K. Chang, "Dual FET Active Patch Elements for Spatial Power Combiners," IEEE Trans. Microwave Theory Tech., vol. MTT-43, pp. 1810-1815, January. 1995.

[7] J. Navarro, L. Fan and K. Chang, "Novel FET integrated inverted stripline patch," Electron Lett., vol. 30, pp. 655-657, April. 1994.

[8] M. Murata and T. Matsui, "2x2 spatial power combining of planar radiating oscillator using butterfly-shaped patch element, " in Proc. 29 European Microwave Conference, Munich, Germany, vol. 2, pp. 201-204, October, 1999.

[9] T. Matsui and M. Murata, "Radiating Oscillator Apparatus for Micro- and Millimeter-waves", U. S. Patent 5982245. 1999.

[10] R. Adler, "A study of locking phenomena in oscillators, " Proc. IRE, vol. 34, pp. 351-357, June. 1946.

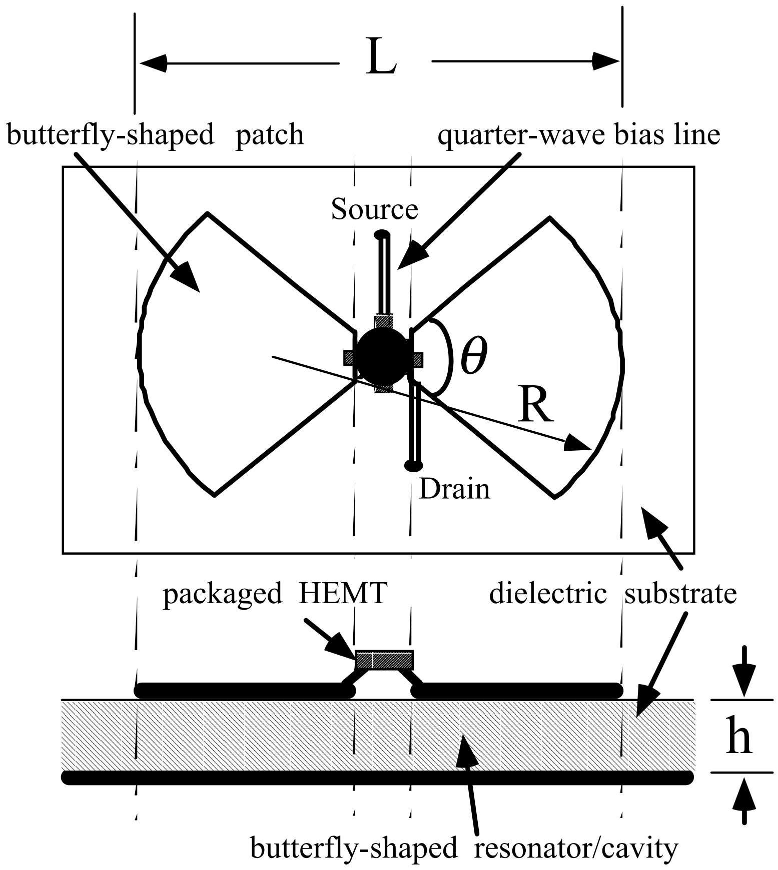
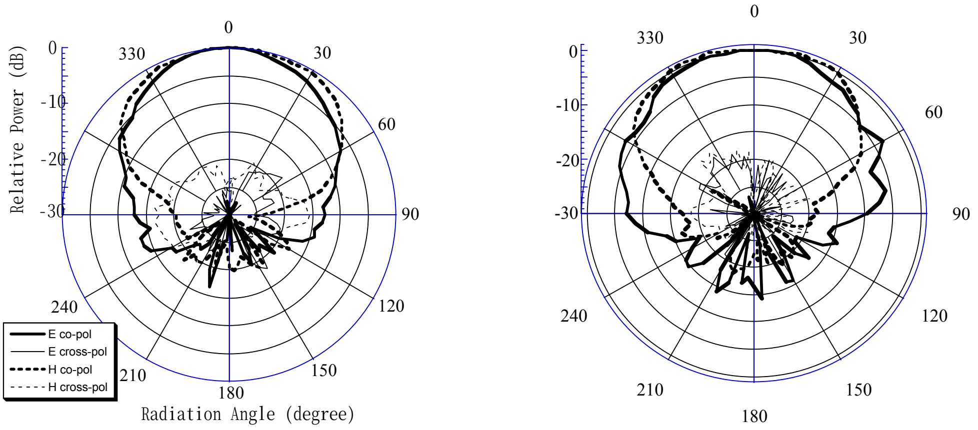


Fig. 1 Planar Radiating Oscillator using a Butterfly-Shaped Patch and a HEMT



(a) θ=60 ° , $R \cong \frac{L}{2}$ (b) θ=60 ° , R>>L

Fig. 2 Radiation Patterns of B-PRO

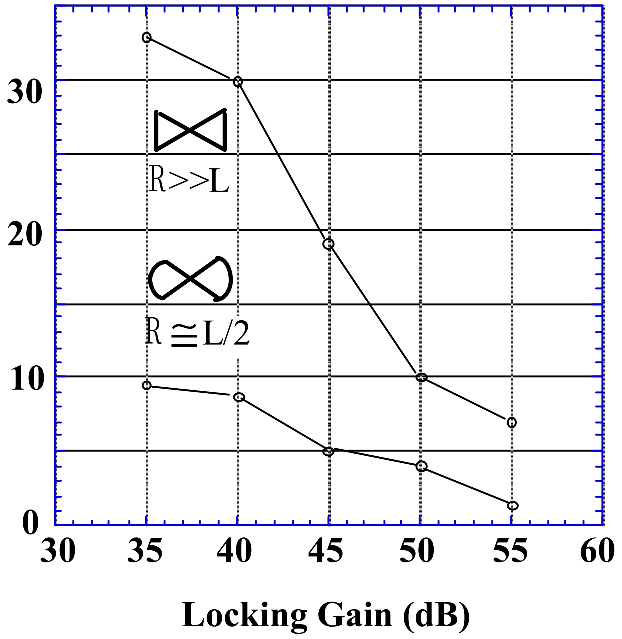


Fig. 3 Injection Locking Range versus Locking Gain