PROCEEDINGS OF ISAP '92, SAPPORO, JAPAN

ELECTRONICALLY AND OPTICALLY CONTROLLED ACTIVE INTEGRATED ANTENNA

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ABSTRACT

This paper describes active integrated antennas using negative resistance MESFET oscillators controlled by illuminating with a fiber illuminator as well as by changing applied DC voltages. For the active integrated antenna with two oscillators, the electronic tuning range of 250 MHz and the optical tuning range of 50 MHz were obtained at 12 GHz. The antenna radiation patterns are also discussed.

INTRODUCTION

Recently, active integrated antennas made of quasi-optical components have been of growing interest for microwave and millimeter-wave systems which require compact and simple circuits[1]. This active integrated antenna consists of an antenna and one or more active devices. However, the active antenna is not a simple combination of an antenna and solid state devices but forms a single entity in which the antenna not only acts as a radiator but behaves as a potion of the active device circuit.

We have already reported several active antennas for quasi-optical oscillators based on the slot in a layered structure to demonstrate topology useful for the MMIC technology[2-4]. The active antenna based on the slot takes advantage of two sides of the substrate. Since the slot is in the ground plane and the active device is on the other side of the substrate, the circuit size can be reduced.

However, as the circuit density increases, interaction between lines in a chip can create trouble. In order to avoid such problems and enhance design flexibility and simplification, as one possible breakthrough, an optical control method is applicable. The FET is found as a useful device for optical control of microwave circuits such as the HEMT oscillator by illumination with a laser[5]. For the reduction of interference between the RF and control circuit in an active integrated antenna, the optically controlled MESFET oscillator is very promising.

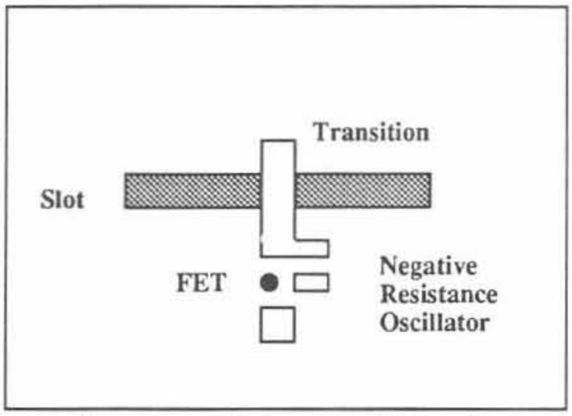
In this paper, we report on the experimental results of two types of the active integrated antennas with electronic and optical control. One of them consists of a single slot and a negative resistance MESFET oscillator. Another circuit has two MESFET oscillators connected in parallel to the single slot to increase radiation power. The comparison on antenna patterns with and without illumination is also reported.

DESIGN

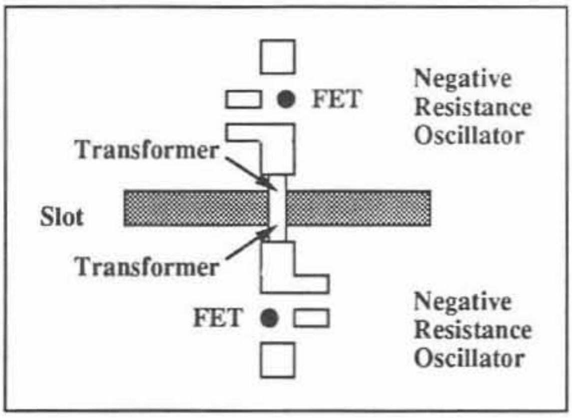
Two types of active integrated antennas have been demonstrated. Fig. 1 shows their configurations. In both cases, the slot length, designed for 1λ at 10 GHz (the slot width is 0.08λ), is electromagnetically coupled to the microstrip feed on the other side of the substrate to construct a layered structure. The case of all MESFETs were removed in order to illuminate them with an optical source.

The circuit part of Structure A consists of the negative resistance oscillator and a microstrip-to-slotline transition. Impedance of the oscillator is designed for -50 Ω and the length of the transition is designed for $\lambda/4$ at 10 GHz. The purpose of Structure A is to confirm how valid the reactance variation due to illumination with the optical source is under the simple configuration of a single quasi-optical oscillator.

In Structure B, the designed impedance of each oscillator is also -50 Ω. These two oscillators were connected in parallel with the slot antenna through a $\lambda/4$ transformer to match the input impedance of the slot which provide a 50 Ω load to the circuit at 10 GHz. Through this configuration, it is expected that the radiation energy from the slot increases. Further, the increase of the reactance variation is expected when its variation from the double-oscillator illumination is compared with that from the single-oscillator illumination under Structure B configuration. Note that the tuning range in Structure B by illuminating only one MESFET oscillator is not the same as the tuning range in Structure A. This is because the input impedance seen from the slot to the circuit in Structure A is different from that in Structure A.



Structure A (one oscillator)



Structure B (two oscillators)

Fig. 1 Active Antenna Configuration

EXPERIMENTAL RESULTS

i) Structure A

The oscillation frequency of 12.5 GHz was obtained. The electronic tuning range was 145 MHz by changing both Vds and Vgs. By illuminating with a fiber illuminator (a quartz halogen lamp with optical fibers), the optical tuning range of 50 MHz was obtained through tuning only Vgs (1.5 V to 1.9 V) (Vds=4.0 V constant). In addition, due to illumination, the receiving power at the broadside direction increased about 2.5 dB.

ii) Structure B

The operation frequency was 12.1 GHz. The increase of receiving power at the broadside direction was 1.4 dB compared to that of Structure A. The electronic tuning range due to changing V_{ds} and V_{gs} of 250 MHz was obtained. In the case of the optical control, Vds was fixed at 4.0 V and V_{gs} was tuned from 1.5 V to 1.9 V. In order to compare the difference of the amount of illumination on the MESFETs, both cases of the single-oscillator illumination and the double-oscillator illumination were investigated under Structure B configuration. Fig. 2 shows their results. The maximum tuning range was 38 MHz for the single-oscillator illumination and 47.5 MHz for the double-oscillator illumination. Apparently, an optimum voltage for the maximum sensitivity exists. Under the same V_{gs}, the tuning range of the double-oscillator illumination increased 146 % compared to that of the single-oscillator illumination. The increase of receiving power due to illumination at the broadside direction was 1.5 dB for the single-oscillator illumination and 3.0 dB for the double-oscillator illumination. Note that, due to the difference of the configuration between Structure A and Structure B, the reactance variation is different.

Further, the obtained antenna patterns were compared with theoretical pattern in Fig.3. The theoretical values were obtained through the moment method using a Pocklington type integral equation. These antenna patterns reflect the radiation not from a 1λ slot (designed frequency) but from the 1.25λ slot (circuit operation frequency). Although, due to the deficiency of the experiment set-up, the antenna pattern was distorted in the observation angle of more than 45^{o}, the agreement between the theoretical values and the experimental data within 40^{o} is good. In addition, there was no significant difference between the no-illumination pattern and illumination pattern.

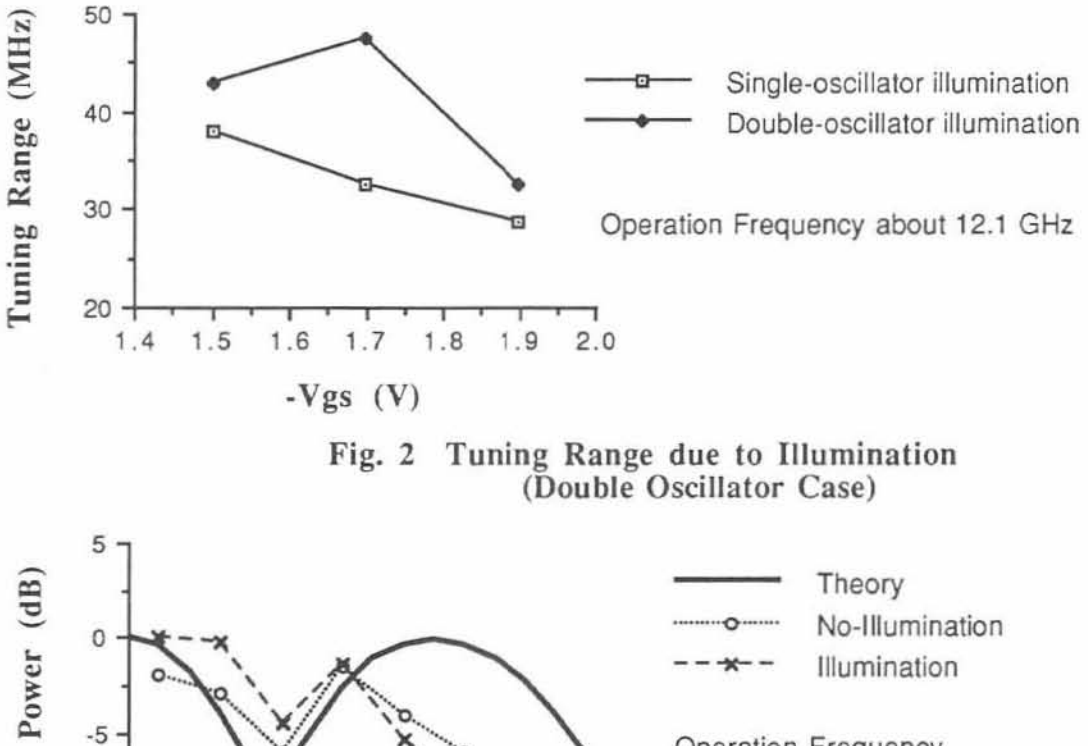


Fig. 2 Tuning Range due to Illumination (Double Oscillator Case)

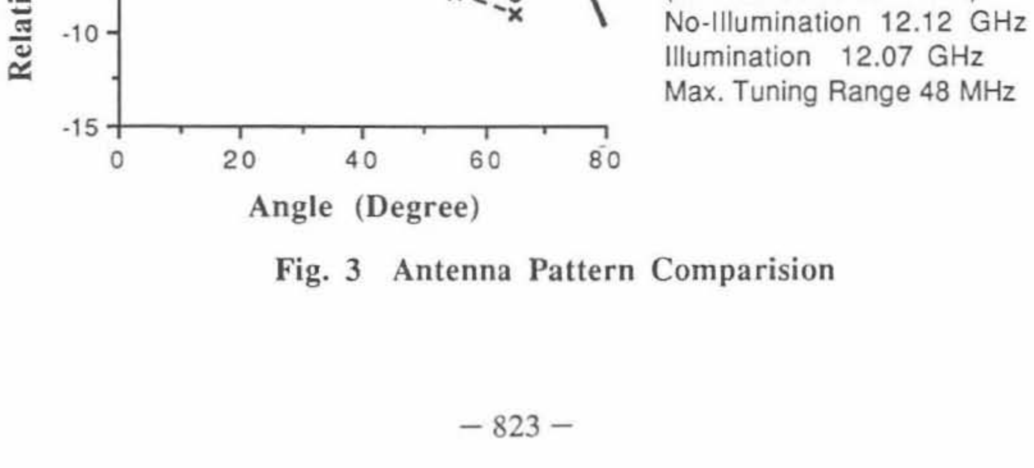


Fig. 3 Antenna Pattern Comparision

CONCLUSION

An approach for the active integrated antenna controlled optically as well as electronically using a slot and MESFETs was reported. The operation frequency was changed by tuning the applied DC voltage and by illuminating with an optical source. By adopting the optical control method, the active integrated antenna without interference between the RF and the control circuit is envisioned. It is believed that the advantages of optical illumination for the active integrated antenna in MMIC form include low cost and simplification of circuits.

ACKNOWLEDGEMENT

This work was supported by US Army Research Office under contract DAAL 03-88-K-0005.

REFERENCES

[1] T. Itoh, "Active Antennas", Journees In't De Nice Sur Les Antennes, France, Nov. 1990, pp 435-438

[2] S. Kawasaki and T. Itoh, "A Layered Negative Resistance Amplifier and Oscillator Using a FET and a Slot Antenna", 1991 IEEE MTT-S Int'l Microwave Symposium Dig. vol. 3, Boston, MA, June 1991, pp 1261-1264

[3] S. Kawasaki and T. Itoh, "24 GHz FET Oscillator with Slot Antenna for Quasi-Optical Transmitter", 16th In't Conf. on IR & MMW, Switzerland, Aug. 1991, pp 286-287

[4] S. Kawasaki and T. Itoh, "40 GHz Quasi-Optical Second Harmonic Spatial Power Combiner Using FETs and Slots", to be published in the 1992 IEEE MTT-S Int'l Microwave Symposium Dig.

[5] M.A. Romero, A.L.A. Cunha and A.A.A. de Salles, "Theory and experiment for ther HEMTs under optical illumination", 1991 IEEE MTT-S Int'l Microwave Symposium Dig. vol. 2, Boston, MA, June 1991, pp 495-498