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A 3x3 STRONG COUPLING QUASI-OPTICAL ARRAY WITH THE STABLE IN-PHASE MODE BY DIELECTRIC RESONATORS

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Introduction

In the microwave and millimeter-wave engineering, a personal communication system and a multi-media system are growing interest[1]. In order to realize these systems, technologies for multi-function, high performance, small size, light weight and low cost are requested. Among many technologies, the quasi-optical technique is one of the most suitable ones for coping with these requirements.

Essentially, the quasi-optical and active integrated antenna techniques are demonstrated for high power generation from solid state devices which only have small capability of generation of millimeter-waves[2-4]. Recent research works seem to be focused on this topic on behalf of military-use oriented applications[5],[6]. However, for civil-use oriented applications such as an indoor wireless LAN system or an automobile collision avoidance radar, relatively small output power is requested. From the view point of these applications, instead of high power generation, the quasi-optical and active antenna techniques are strongly required to realize a high power combining efficiency and high stability of operation.

For the high power combining efficiency, adjacent oscillator circuits in the quasi-optical power combining array should be in-phase. To obtain this situation, the strong coupling method for the design of the quasi-optical array is suitable for selection of the in-phase mode from many undesired modes which are created from the combination with many active devices[7]. When the strong coupling method is used, the in-phase mode is enforced by a field maximum point (a high impedance point) settled at the middle point of the coupling line connected between the adjacent oscillator circuits.

However, when the medium power of several watts is requested and then the number of the active devices reduces, effect of additional reactances due to the termination of the periodic structure at the edge of the array becomes relatively strong. Therefore, the reactance affects the operation of the in-phase mode. In order to avoid such a unstable operation and to keep the in-phase mode between the adjacent oscillator circuits, the coupling can be carried out through the edge of the row of the array to minimize the edge effect due to the termination of the periodicity. Further, to enhance the the strong coupling method of settling the field maximum point at the middle point of the coupling line, a dielectric resonator can be placed there.

In this paper, the design method to realize a 3x3 quasi-optical power combining array with the strong coupling is demonstrated and the effect of the dielectric resonator for the in-phase mode stabilization in the 3x3 quasi-optical array is examined. The experimental results of the operating spectrum and antenna patterns are discussed.

Design and configurations

In a design procedure, the quasi-optical array with periodic structure and strong coupling is reduced into each unit cell due to its periodicity. Further, a coupling line for the direct connection between adjacent oscillators is replaced with the open stub for the in-phase mode. As a result, at the middle of the coupling line, the field maximum point is created for the in-phase mode. The unit cell of the quasi-optical array consists of a solid state active device circuit and a planar antenna. In this paper, a MESFET and a slot antenna were selected as the components of the quasi-optical array, and a microstrip line was used as a transmission line.

A simulator used for the circuit design is a commercial available CAD (MDS by HP-EEsof). Small signal S-parameters were used when the FET oscillator was designed with an input impedance of -50 Ω at 10 GHz. For the simple circuit, the oscillator was configured with series feedback. For the design of the unit cell of the array with the in-phase mode, two open stubs with a half length of the coupling line were incorporated into the FET oscillator.

A configuration of the unit cell of the quasi-optical array is shown in Fig. 1. The circuit pattern shown in Fig. 1 was also used to fabricate the 3x3 quasi-optical array shown in Fig. 2. A dimension of each slot is 1.00λg long and 0.081λg wide at 10 GHz (λg is a guided wavelength). The length of the strong coupling line is 2.0λg for row connection. For the connection between the upper and lower rows, the coupling line is formed as a letter "S" to minimize the additional reactance effect at the edge. The length of the strong coupling line at the edge is 4.0λg to keep the in-phase mode between the upper and lower rows. The distance between centers of the adjacent slot antennas is 1.1λo (λo is a wavelength in free-space).

Experimental Results

The circuits were made in the hybrid integrated circuit technology with a package-type MESFET (MGF4314D by Mitsubishi Electric Corp.) and a dielectric substrate with copper sheets (RT-Duroid 5780 by Rodger). The antenna pattern was measured with a distance of 1.8 m between the 3x3 quasi-optical power combining array and a receiving standard gain horn antenna.

The 3x3 array was made by periodically connecting the stub of the unit cell of the 3x3 array mentioned above. In order to settle the field maximum point stable, the dielectric resonators were placed at the middle point of the coupling line. It operated at 9.85 GHz with Vds=4.86 [V], Ids=110.6 [mA] and Vgs=-0.79 [V]. An observed spectrum was shown in Fig. 3 and its operation was very stable.

The measured H-plane antenna pattern from the 3x3 array loading dielectric resonators is shown in Fig. 4. It is obvious that, since the antenna pattern shown in Fig. 4 is a sum pattern, all FET oscillators are in-phase. In Fig. 4, a theoretical antenna pattern calculated by the moment method was also indicated. Although sidelobes increased due to unexpected radiation from the edge of the array substrate, agreement between two antenna patterns are very good. The effective radiated power was estimated as 34.16 dBm.

Conclusions

In this paper, mode control for a 3x3 quasi-optical power combining array with strong coupling loading dielectric resonators was demonstrated. From observation of the antenna patterns, all FET oscillators operated in the in-phase mode and its operation became very stable. The method described here can be applied to design a monolithic quasi-optical power combining array.

References

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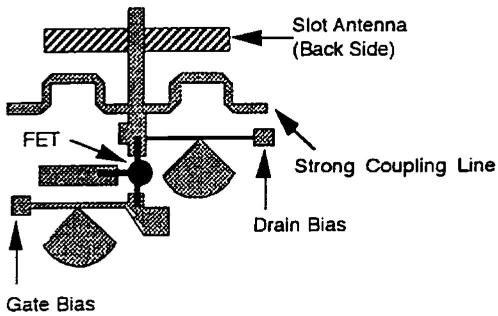

Fig.1 Configuration of Unit Cell

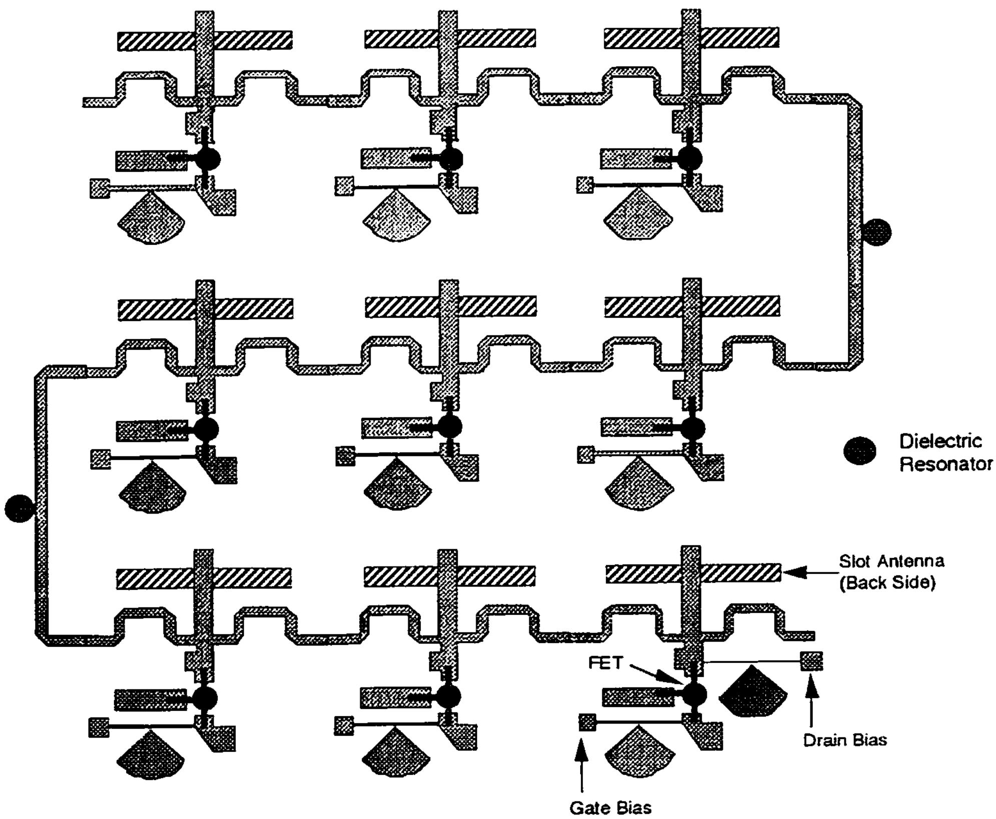

Fig.2 Configuration of 3x3 Array

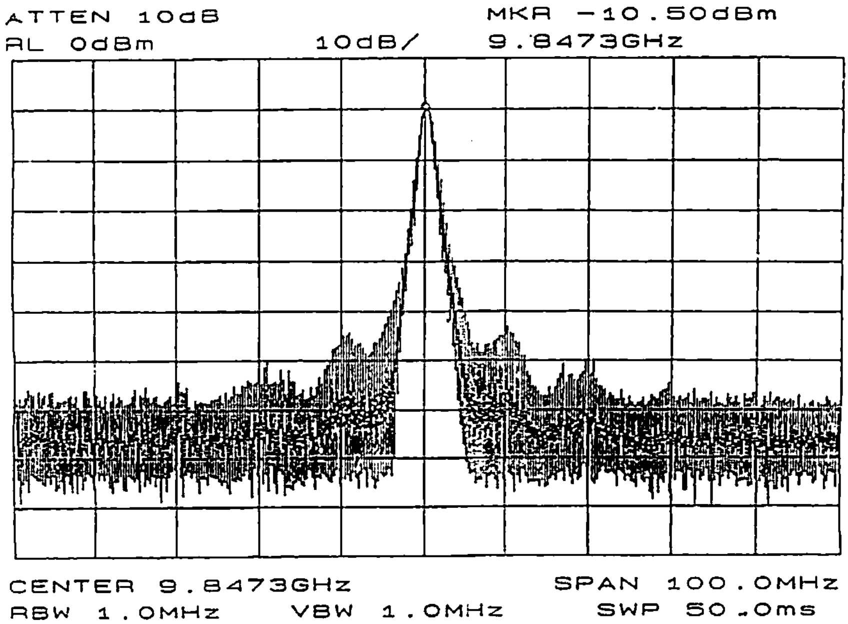

Fig. 3 Operating Spectrum

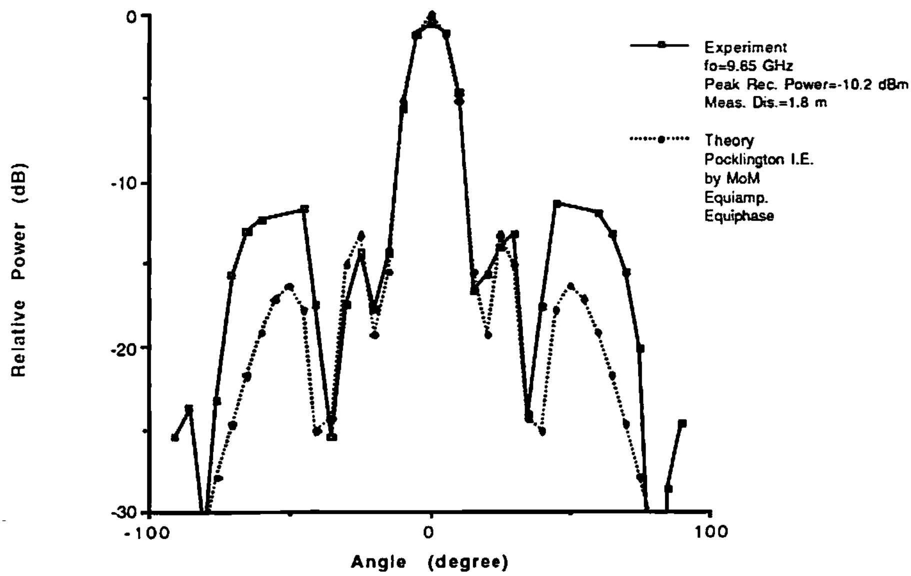

Fig. 4 Antenna Pattern Comparison of 3x3 Array in H-Plane