A NEW CAVITY POWER COMBINING TECHNIQUE FOR PLANAR CIRCUIT SOURCES

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New power combining technique which uses the cavity with planar circuit sources is proposed. Planar circuit is placed outside the cavity and coupled through the slot. All the possible modes are checked from the extracted Z-parameters and the efficiency is calculated to be 95% by simulation. The measurement shows that power combining works well in the desired mode without spurious oscillation at other frequency.

1. Introduction

To make high power source or amplifier with solid state device, there have been many studies on the efficient power combining techniques. In 1970s, common cavity combining technique with 2-terminal device(IMPATT diode) was used [1], but it has complicated structure and IMPATT diode has low efficiency. Along with the development of 3-terminal device on the planar circuit, quasi-optical or spatial power combining method take advantage of its easy fabrication and high efficiency. It uses large 2-dimensional arrangement of many sources orthogonal to power flow direction [2]. Therefore it needs 3-dimensional bulky structure to combine power of large 2-dimesional plane of sources. Recently, compact size using 'tray' architecture to lie within normal waveguide was reported [3].

In this paper, a simple cavity power combining technique is proposed using microstrip line to waveguide transition [4]. Planar circuit lies on WR90 waveguide which has no top side and the ground of substrate replaces that as shown Fig. 1. Through the slot on the ground of the circuit, power flows to the waveguide loaded cavity from the planar circuit. Z-parameter of passive part viewed at the microstrip line ports on the planar circuit is extracted by HFSS simulation, which results in the calculation of oscillation modes and required source impedances. The equivalent circuit of the combining structure and the active source impedance are checked so that only desired mode can exists. Combining efficiency is 95% by simulation at 10 GHz.

2. Theory

Common cavity power combining source is a kind of multi-device oscillator [1]. To verify the steady state of this system, in other words, mode, one can use Equation (1) using Z-parameter of multi-port passive part(Z) and active part($\overline{Z}$) representing combining structure and source respectively(Fig. 2). If active part is composed of independent and identical sources, then Equation (1) becomes eigen mode problem of Equation (2). Its solution, eigen value and eigen vector means input impedance of all ports and current in each mode. Power combining efficiency can be calculated by Equation (3) using extended Z-parameter(Z^{EX}) which has additional (N+1)th port excluding waveguide load.

$$(Z+\overline{Z})i=0 \quad (1)$$

$$(Z-\lambda I)i=0\ , \qquad \text{where } \overline{Z}=\begin{bmatrix}-\lambda & 0 & 0\\ 0 & -\lambda & 0\\ 0 & 0 & \ddots\end{bmatrix} \quad (2)$$

$$i_{LOAD} = -i_{N+1} = \frac{\left[Z^{EX}_{(N+1)1} \quad Z^{EX}_{(N+1)2} \quad \cdots \quad Z^{EX}_{(N+1)N} \right]}{(Z^{EX}_{N+1,N+1} + z_{LOAD})} \begin{bmatrix} i_1 \\ i_2 \\ \vdots \\ i_N \end{bmatrix}$$

$$Power\ \ Combining\ \ Efficiency\ = \frac{P_{LOAD}}{Pin} = \frac{z_{LOAD}\,|\,i_{LOAD}\,|^2}{\mathrm{Re}\{(Zi)^T\, i^*\}} \qquad (3)$$

3. Implementation

WR90 waveguide is made of aluminium and substrate is Teflon of ε_r=2.6, thickness=0.5mm, and tan δ=0.002. Iris inside of the waveguide makes load-coupled cavity and the gap between iris and top side is adjusted to get 50 ohm of input impedance seen at all the microstrip line port on the substrate. Fig. 3 is the layout of 2 sources for 2-port combining. NE32584c HEMT is used as source device. Fig. 4 is simulated input impedances(eigen values) of 8-port combinin g circuit at all modes and source impedance against the frequency, 8~12GHz. Fig. 4 shows that only one mode has 50 ohm of input impedance at 10 GHz, and there is no possible mode at other frequencies. Fig. 5 is the equivalent circuit around 10 GHz in each mode. Fig. 6 is calculated power efficiency of 8-port combining structure at all modes and it shows 95% in the desired mode at 10 GHz.

4. Measurement

Measured output power of one source to direct 50 ohm load is 10.3 dBm. However output power of one source on waveguide cavity is 7.5 dBm. It's because of loss of the microstrip line to waveguide transition as shown in Fig 7. It is thought that the difference is due to the leakage through the contact between substrate and coarsely manufactured waveguide. Fig. 8 is measured output power of 1, 2, 4 and 8 sources power combining. It shows well behavior of power combining in the desired mode.

5. Conclusion

Simple cavity power combining technique for planar circuit sources was proposed. Mode establishment was verified from the extracted Z-parameters and simulated efficiency was 95%. Although there was some loss due to the leakage in the coarsely manufactured waveguide cavity, The measurement shows that power combining works well in the desired mode. With more investigation on the leakage suppression, this combining technique will be applicable to the simple high power source with planar circuit.

References

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[4] Rizwan Bashirullah and Amir Mortazawi, " A Slotted-Waveguide Power Amplifier for Spatial Power-Combining Applications", IEEE Trans. Microwave Theory Tech., vol 48, pp. 1142-1147, Dec. 1999.

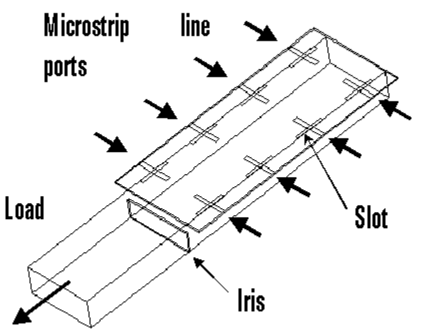

Fig. 1. Waveguide cavity power combining structure with planar circuit outside the cavity

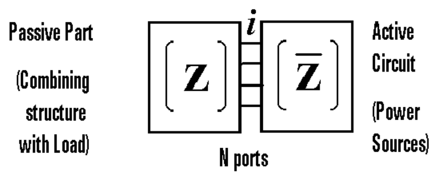

Fig. 2. Z-parameter representation of power combining system

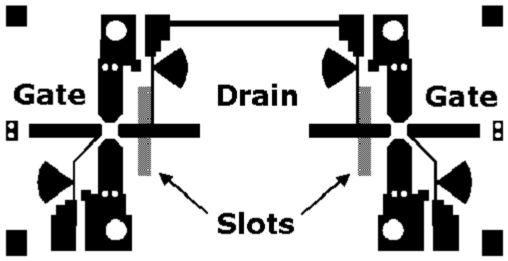

Fig. 3. Layout of 2 sources

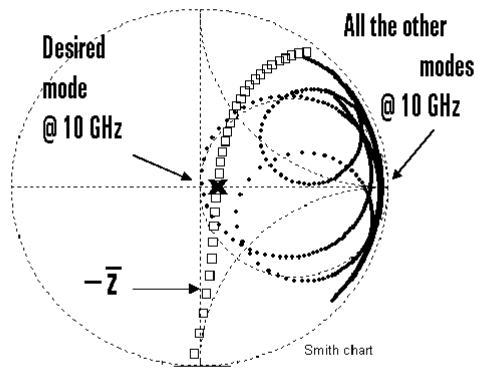

Fig. 4. Simulated input impedance of 8 ports power combining system (dot) and negative source impedance (square, 'x' at 10GHz) in frequency of 8~12GHz

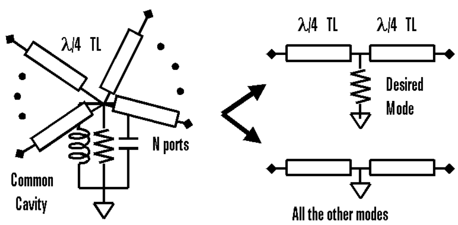

Fig. 5. Equivalent circuit of passive part around 10GHz in each mode

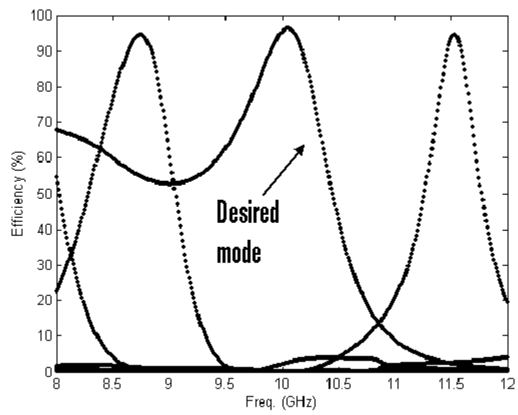

Fig. 6. 8-port power combining efficiency at all modes (Simulation)

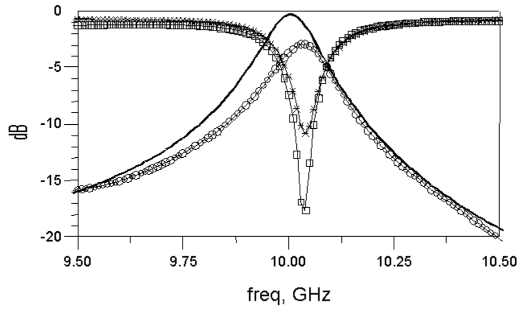

Fig. 7. Simulation(solid) and measurement(S21-circle, S11-star, S22-square) of microstrip line(port 1) to waveguide(port 2) transition

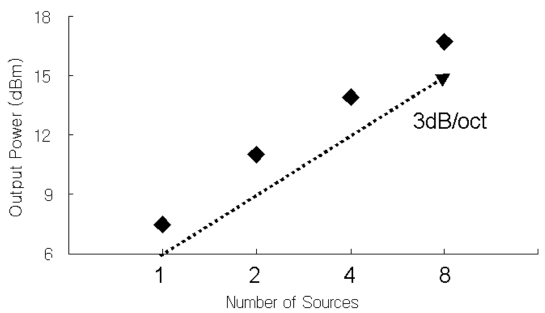

Fig. 8. Measured output power