CC-4

Microstrip Fed Planar Frequency-Multiplying Space Combiner

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ABSTRACT

A frequency-multiplying power combining array has been made of slots in the ground plane on a substrate with a microstrip feed line on the back side. The second harmonic generated by a diode in each slot is combined in free space. A design procedure and experimantal results are presented.

INTRODUCTION

The frequency multiplying slot array is a unique structure that contains (1) a slot antenna array, (2)frequency multipliers, and (3) a power combiner in a single component. The implementation of such a structure using waveguide has been reported previously[1]. The structure has a simple configuration and requires no bias and no post-production tuning. In this paper, a new printed circuit configuration is presented in which, unlike the work in [1], no waveguide is used for feeding. In the new structure, the array of slots on the substrate is fed by a microstrip line or a coplanar waveguide fabricated on the back side of the substrate. The new structure has more desirable features such as (1)planar structure, (2)large coupling, (3)controllable coupling and (4)flexibility in arrangement of slots on a planar circuit.

Fig.1 shows a typical configuration of the planar multiplier/combiner. On the front side of the substrate, there is an array of slots, in each of which a diode is placed for frequency multiplication. A microstrip line feed on the back side is used in this example. The incident signal at the frequency fo is successively fed to these slots which are typically a quarter wavelength long. The diode in each slot generates a second harmonics of 2fo. Then, the slot behaves as a half wave slot dipole and an efficient radiation of 2fo signal takes place. The radiated powers from all the slots are combined in free space.

DESIGN PROCEDURE

In order to design the proposed structure, it is necessary to know the characteristics of the microstrip-to-slot transition. Based on the approximate equivalent circuit shown in Fig.2 [2], these coupling characteristics have been studied. Measurement of microstrip-to-slot transition has been carried out with the conventional coaxial-to-slotline transition as a probe for picking up the signal over slot in place of the diode. The results are shown in Fig.3. The dotted lines show the calculated results under the assumption of $n = 1$ in Fig. 2.

By using the measured results in Fig. 3, we designed an equally excited, broadside multiplying slot array. First, from the power requirement of the diode in the first slot, we evaluate the location of the microstrip-to-slot transition. We can then find out the amount of the power left over on the microstrip line. Next, we find the location of the transition of the second slot so that the power provided to the second diode is equal to that for the first diode. Then, we determine the length of the microstrip to the second slot to obtain an appropriate phase shift between slots. This process is repeated until all the slots are taken care of. Notice from Fig. 1 that the location of the transition moves inward as the feed signal progresses along the microstrip line. The decreasing power available from the feed line is compensated for by an increasing degree of coupling so that all the diodes are given an equal excitation power.

EXPERIMENTAL RESULTS

For frequency multiplication, nonlinear reactive elements such as varactor diodes are desirable to achieve good performance. However, only the schottky-barrier diodes designed for X-band mixers have been available to the authors. The conversion gain G_c of the diodes used for frequency multiplication has been calculated with the values obtained from the measurement set-up shown in Fig. 4 by the equation:

$$G_c = R_d - R_r - P_d + P_r + C_d - C_r$$

where R_i; receving power (dBm)

P_i; incident power (dBm)

C_i; coupling (dB)

$i = d$; DUT, and $i = r$; reference antenna

The value of G_c obtained with the diode ND5051(NEC) has been -16.2 dB. Fig. 5 shows the photograph of a 2 x 4 slot array. Fig.6 shows the measured radiation pattern of the 2x4 slots array with the incident power of 26 dBm at 5.4 GHz. The power fed to each diode is estimated to be 11 dBm.

CONCLUSIONS

By using experimental data which characterize the transition from microstrip to slot, we designed the planar multiplier/combiner in the form of a slot array fed by a microstrip on the back side of the substrate. The results show the feasibility of the practical use of the proposed structure. The new structure has desirable features such as controllable power coupling and flexibility in array geometry on a planar substrate in addition to the features of general multiplying slot array [1]. The present structure is more suited for microwave and millimeter-wave integrated circuit applications.

REFERENCES

1. N. Camilleri and T. Itoh, "A quasi-optical multiplying slot array", IEEE Trans. Microwave Theory and Techniques, Vol. MTT-33, No. 11, pp.1189-1195, November 1985.
2. K. C. Gupta, R. Garg and I. J. Bahl, Microstrip Lines and Slotlines, Artech, 1979.

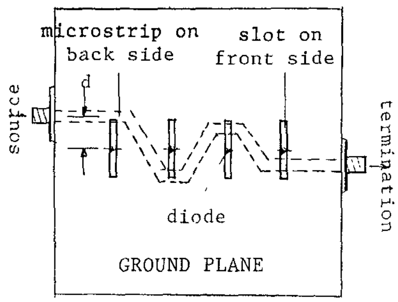


Fig.1 Structure of multiplying slot array antenna fed by microstrip

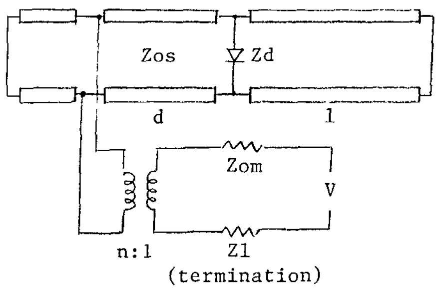
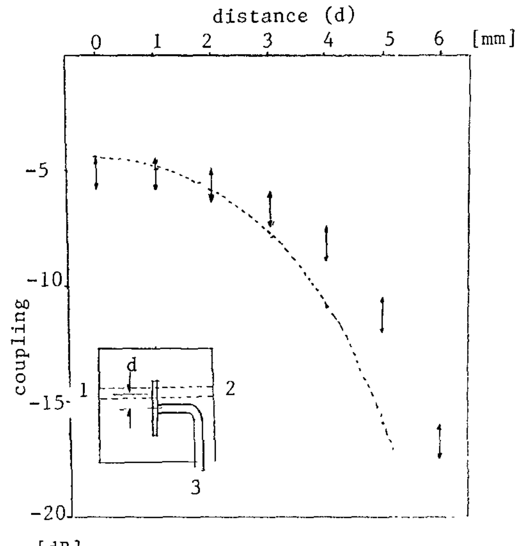
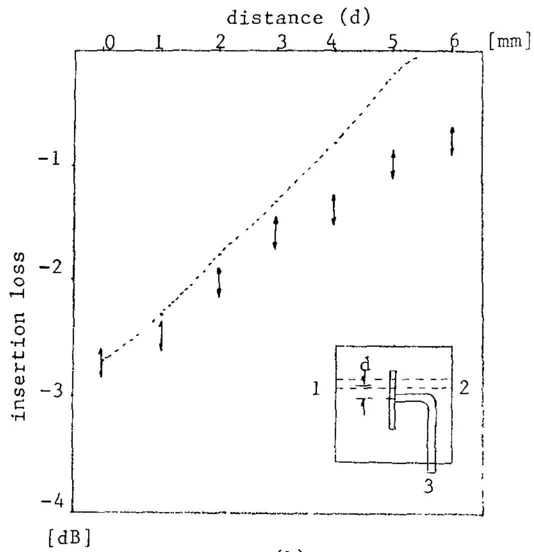


Fig.2 Equivalent circuit for one slot(l= /8)



(a)



(b)

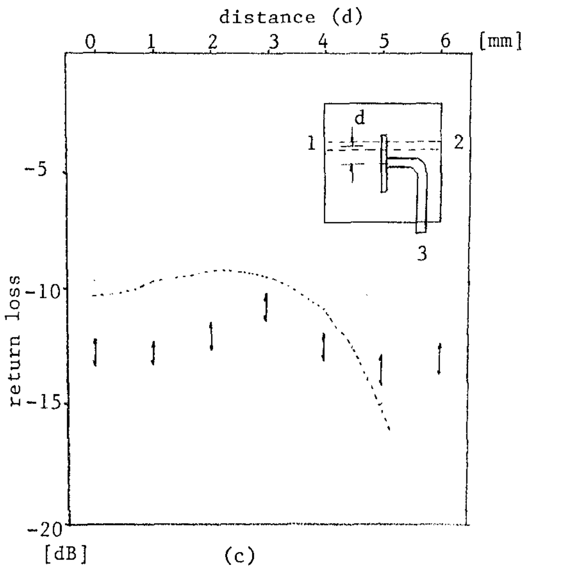


Fig.3 Transition characteristics from microstrip to slot line
(a) coupling (S_{31}) (b) insertion loss (S_{21})
(c) return loss (S_{11})

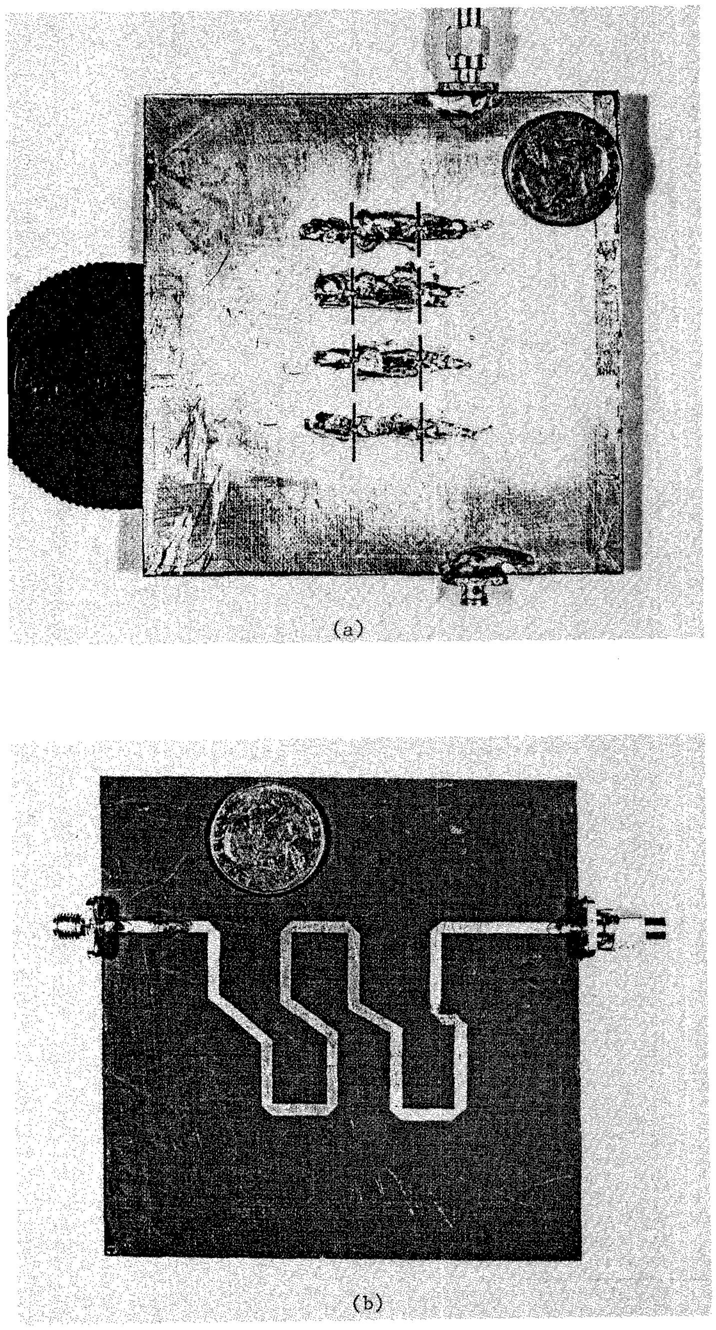


Fig.5 Photographs of a 2x4 slot array antenna
(a) slot array pattern
(b) microstrip feed pattern

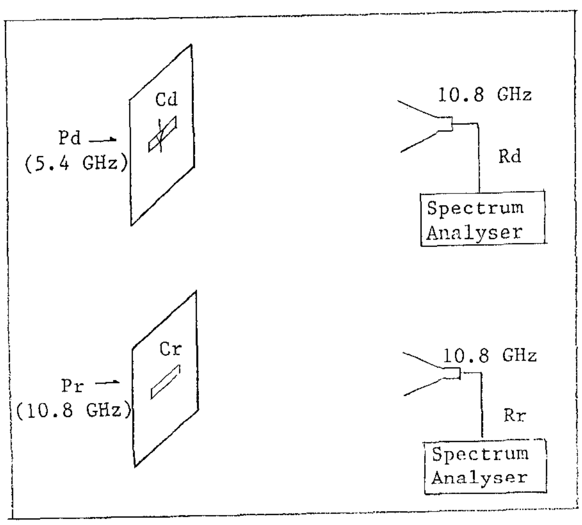


Fig. 4 Test set-up for measuring multiplication conversion gain

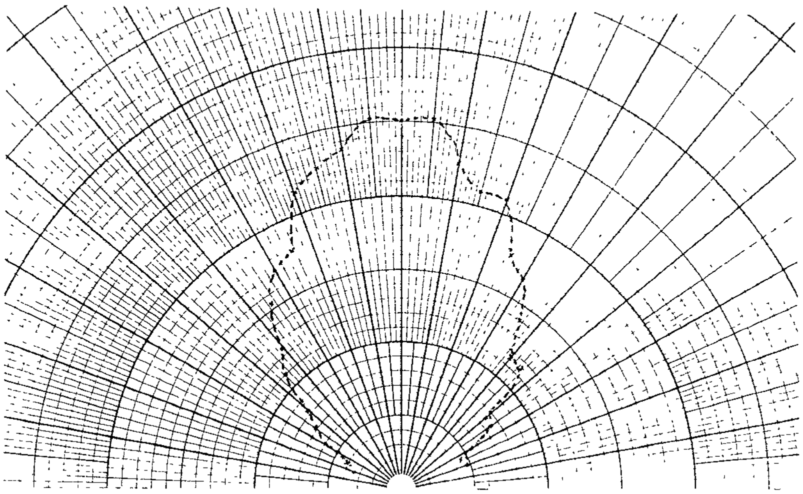


Fig.6 E-plane radiation pattern of the 2x4 slot array shown in Fig.5