A POWER FET OCTAVE BANDWIDTH TRAVELING WAVE COMBINER AMPLIFIER

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ABSTRACT

Theoretical and experimental performances of the traveling wave divider/combiner were presented at the 1980 MTT Symposium. Its application as a combiner circuit for wide bandwidth power amplifiers is experimented, resulting in a small dimensions, planar 2-stage 9 dB gain, 1.5 watts, 6-12 GHz MIC amplifier.

I - INTRODUCTION

Many applications require high RF power amplifiers over octave or multioctave bandwidths. The amount of power needed cannot be reached except with some sort of power combining scheme. The amplifier presented here uses the traveling wave divider-combiner concept [1].

Theoretical and experimental results are given for a 1 stage and a 2-stage FET - Traveling Wave Combiner Amplifier (TWCA). They demonstrate its capability for wide-bandwidth power combining and at the same time present a new way of connecting successive stages of an amplifier.

II - 4-WAY, 1-STAGE TRAVELING WAVE COMBINER AMPLIFIER

Fig. 1 shows a schematic of a 1-stage TWCA. Input power is equally divided in 4 waves reaching the individual FET amplifiers with different phase shifts. Each wave is separately amplified then recombined to each other, the phase lags in the input divider are recuperated in the output combiner. Equal mismatches in front of the individual amplifiers are mainly absorbed within the resistors of the divider circuit, the reflected waves inducing voltages which are out of phase at the terminals of the resistors. This results in a low overall input VSWR eventhough each FET may be poorly matched. This characteristic is of great interest for wide bandwidth transistor amplifiers because of their 6 dB/octave gain decrease.

Fig. 2 is a photograph of a first 1 stage, 4 way TWCA. Each 6-12 GHz divider/combiner circuit is fabricated on 0.635 mm thick alumina substrate. The phase-lag between individual FET's is $\frac{\pi}{2}$ at 9 GHz. The impedance match to the 50 ohm input and output impedances is achieved with 3-step quarter-wave impedance transformers.

Some modifications in the divider/combiner circuits were made to take into account the perturbations introduced at each power split. Then a second 1-stage, 4 way TWCA was realized.

The 6-12 GHz gain optimisation of the commercial FET's used in this amplifier has been obtained by means of the circuit of Fig. 3 where the capacitances are made by metal deposition over thin layers of high Q, high dielectric constant material. Small signal gain equalisation was not the objective here but rather to optimise it over all the 6-12 GHz bandwidth. This explains the hump in the gain curve around 8 GHz which could be avoided with another design for wider bandwidths.

Experimental results of the TWCA are given on Fig.4. Except for ohmic losses within the combining circuit (0.5 dB at 12 GHz, 0.25 dB at 6 GHz) the combining efficiency turns out to be almost 100 % over the whole octave bandwidth. The input reflexion coefficient is less than 0.3 for all frequencies, eventhough it reaches values as high as 0.85 around 6 GHz at the input of each FET. A 1 Watt minimum output power is obtained from 5.5 to 12 GHz with a minimum associated gain of 3.4 dB. The small signal maximum available gain of the FET's at 12 GHz is 6 dB.

III - 2-STAGE, TRAVELING WAVE COMBINER AMPLIFIER

Fig. 5 is a schematic of a 2-stage TWCA. Here, a 3-way feeds a 4-way TWCA stage of the type described above. However, a new traveling wave 3-way combiner/4-way divider has been introduced which presents the advantage that there is no need for a 50 ohm microstrip line between the two stages. Therefore, the dimensions of this connecting circuit are small even for wide bandwidths.

All dividing combining circuits are fabricated on 0.635 alumina substrates. The individual FET amplifiers have the same configuration as in the above 1-stage TWCA. For this experimental version, each FET has been individually biased and shielded from the others to prevent mutual coupling between adjacent bias wires. The experimental results show that all FET's of the same stage could be biased in parallel which would simplify the biasing circuits and enable the shields to be suppressed. The 2-stage amplifier worked as predicted for the first try without need for any kind of adjustment.

Experimental results are given on Fig. 6. The reason for the hump in the curves around 8 GHz has already been mentioned and is due to the cascading as all individual amplifiers are essentially the same. The bias conditions are 8^V, 200 mA for the second stage and 6^V, 150 mA for the first stage. At a 1 Watt minimum output power level the gain is greater than 9.1 dB from 5.5 to 12 GHz with a 1.5 W maximum output power around 8 GHz. From 6 to 12 GHz, 1.4 W minimum can be obtained with 6 dB minimum gain. The small signal gain is greater than 10 dB from 4.3 to 12.2 GHz.

The input reflection coefficient is lower than 0.3 from 4.5 to 11.5 GHz, reaching 0.35 around 12 GHz.

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Except for the ohmic losses which were measured separately, each individual amplifier being replaced by a portion of 50 ohms microstrip line, the efficiency of the total dividing/combining structure as far as gain and power are concerned is close to 100 % from 6 to 12 GHz.

IV - CONCLUSION

Experimental results confirm the interest for the traveling wave divider/combiner concept applied to wide bandwidth MIC power FET combiner amplifiers. For each individual FET and with the same type of matching circuit as those used here, 1 to 2 watts of RF power can be reached over X band octave bandwidths [2]. Over the same octave bandwidth a 2-stage 3 + 6 FET TWCA could then deliver 10 Watts with 10 dB associated gain. Medium power stages can also be designed in the same way leading to an amplifier chain, composed of stackable TWCA stages, having performances competitive with traveling wave tubes.

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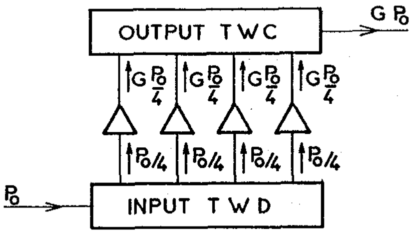
[1] A.G. BERT and D. KAMINSKY, "The Traveling Wave Divider/Combiner", IEEE Trans. Microwave Theory Tech., 1980 Symposium Issue, vol. MTT-28, p 1468 - 1473, Dec. 1980.

[2] H.Q. TSERNG, H.M. MACKSEY, S.R. NELSON, "2 W, 8 - 12 GHz Ga As F.E.T. Amplifier", Electr. Lett. 14th August 1980, vol. 16, n° 17, p 680 - 681.



TWD: TRAVELING WAVE DIVIDER

TWC: TRAVELING WAVE COMBINER

FIG.1: SCHEMATIC OF A 4_WAY 1 STAGE TWCA

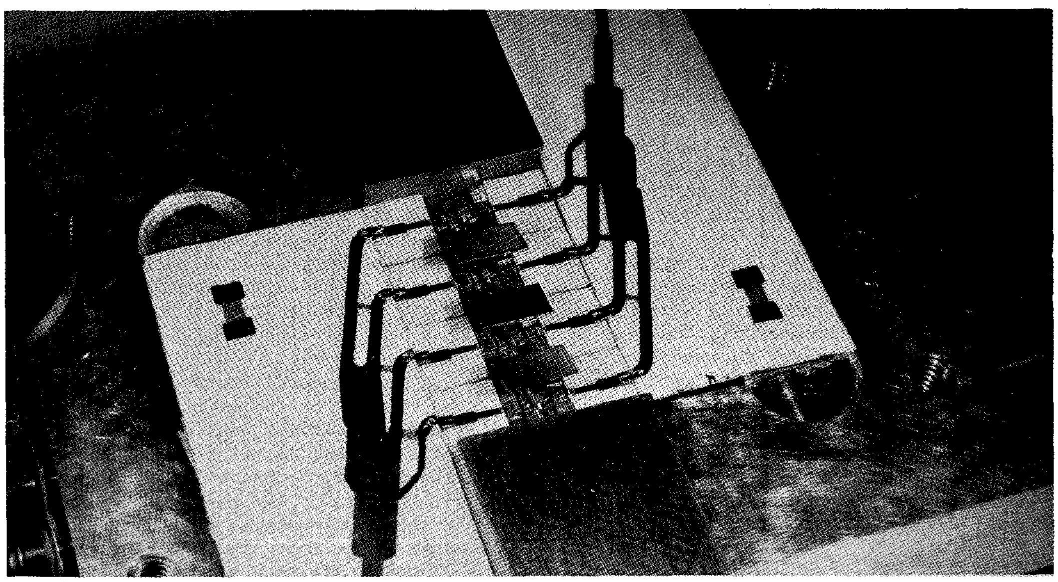
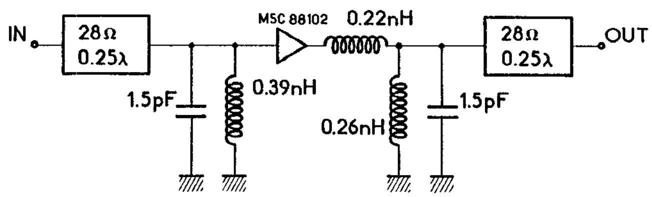


FIG.2 - 1 STAGE, 4-WAY TRAVELING WAVE COMBINER AMPLIFIER



REFERENCE FREQUENCY 9GHz, 0.25mm ALUMINA

FIG.3: F.E.T AMPLIFIER CIRCUIT TOPOLOGY

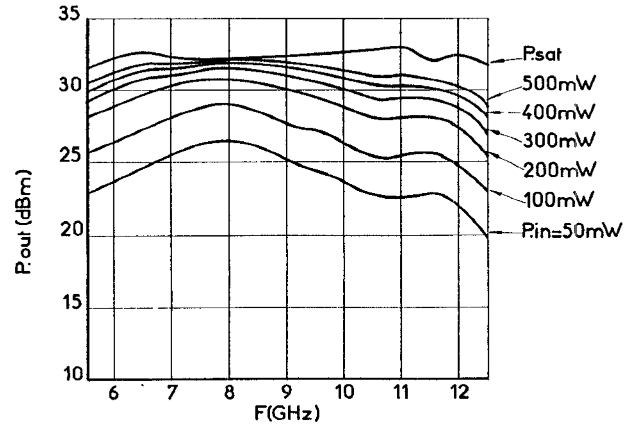


FIG.4: OUTPUT POWER OF THE 4_WAY, 1_STAGE TWCA VS. FREQUENCY

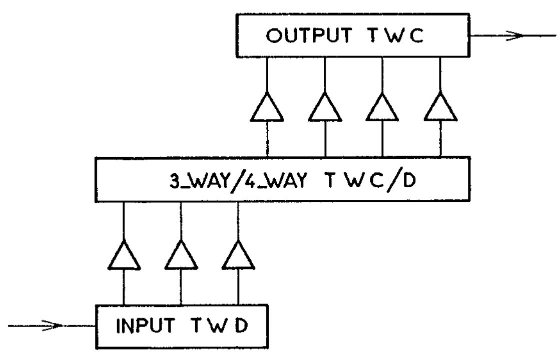


FIG.5: SCHEMATIC OF A 2_STAGE 3_WAY/4_WAY TWCA

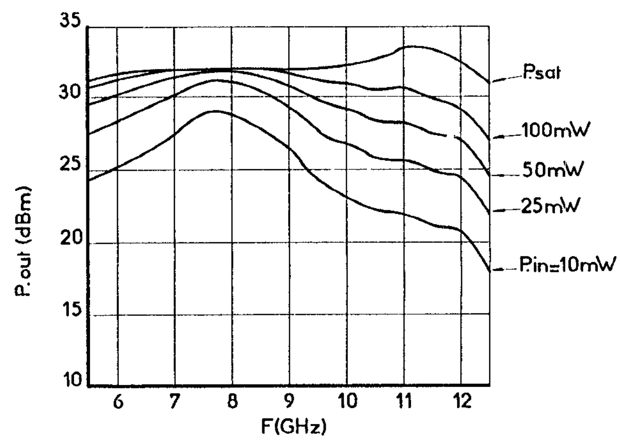


FIG.6: OUTPUT POWER OF THE TWO_STAGE TWCA VS. FREQUENCY