A BALANCED UNIPLANAR ACTIVE MMIC COMBINER/DIVIDER WITH IMPROVED POWER CAPABILITY

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ABSTRACT

Present paper deals with a new active uniplanar power combiner/divider which presents major interest for MMICs future applications. Its design takes advantages on uniplanar interconnection technology based on coplanar strips and waveguides (CPS and CPW). Moreover, this circuit allows to realise either a 180° out of phase power combiner or a 180° out of phase power divider. Finally, it offers new potentialities compared to the early published basic circuits, featuring superior electrical performances such as an improved gain value (about 9 dB) and a suitability for an integration in more complete functions as balanced mixers.

INTRODUCTION

The development of high performance and low cost microwave integrated circuits is required for new telecommunication systems. Therefore, uniplanar technology becomes increasingly attractive for MMICs applications [1] because the use of via holes is avoided and a significant reduction of the circuit dimensions is achieved.

Furthermore, some of these interconnections, i.e. coplanar strips (CPS) and coplanar waveguides (CPW), are less dispersive than microstrip counterparts and can be very useful for millimetre wave designs. As another benefit, CPS structures are particularly suited for differential applications since a CPS transmission line doesn't require a physical ground for the signal propagation. A unique CPS line then allows to convey simultaneously two 180° out of phase signals.

In order to demonstrate all these uniplanar interconnect potentialities, we present in this paper the design and performances of an active 180° CPS/CPW power combiner easily integrable in a balanced mixer.

CIRCUIT DESCRIPTION

Passive or active couplers usually require large areas in MMIC chips since they use respectively quarter-wavelength transmission lines or active components combined with inductive lines and lumped elements. To overcome this drawback, we propose the design of an active 180° power combiner with an operation principle based on the LUFET concept [2-4] : the FET finger electrodes, well suited for uniplanar technology, are unified to access lines. Then, a single active device featuring dedicated finger electrodes is able to realise a full function (isolator, power divider,

power combiner, ...). Since this principle allows a significant size reduction, cost is reduced, distributed parasitic effects are minimised and wide band operation is achieved.
Compared to LUFET functions previously published [3], the design presented in this paper takes benefit of CPS access lines and, based on multi-fingers FETs implementation, exhibits improved gain and power capabilities. The layout of a medium power proposed active LUFET coupler is presented in Figure 1.
In power combiner configuration, two opposite phase signals are applied through CPWs and drive two pairs of FET devices with gate and source electrodes as input terminals. Since the two pairs of transistors are 180° out of phase driven, two amplified output signals are recovered between source and drain electrodes and are in phase recombined by way of a CPS tee junction. It can also be noticed that the FET devices set up the required isolation.
To improve the 180° power combiner electrical performances (gain and power capabilities), the topology of Figure 1 can be duplicated, by adding firstly a CPW/CPS transition [5] and secondly a CPS tee junction at each input terminal. This technique is illustrated by the circuit layout of Figure 2.
For a further implementation of this coupler in inputs or outputs, in a balanced mixer for example, care must be taken on ground reference localisation since input and output accesses can't be simultaneously referred to ground. Moreover, for improved operations, by a judicious ground location, the same circuit can realise 180° power combiner (figure 3 where input terminals are floating and output terminal is referred to ground) or 180° power divider functions (figure 4 where input terminal is referred to ground and output terminals are floating).
Finally, we can notice in Figures 3 and 4 that the use of a CPW/CPS transition enables a unique line to convey simultaneously two opposite phase signals (-Sin and +Sin for power combiner operation, -Sout and +Sout for power divider operation).

DESIGN METHODOLOGY

The design of this circuit is performed on the basis of electromagnetic simulations and involves the separation of circuit active section from passive one. Thus, the synthesis methodology considers the active section (i.e. the FET intrinsic region) as a lumped element. This assumption is fulfilled because of the FET finger small dimensions with respect to the wavelength.
The optimised design of the circuit passive part has been achieved by the electromagnetic simulation software "Sonnet" (@ Sonnet Software Inc.) and final electrical performances have been performed with the software "MDS" (Microwave Design System @ Hewlett-Packard).
The design methodology accuracy has been checked through the realisation and the characterisation of a two single gate finger FETs out of phase coupler (as described in [3]). Results of simulations and measurements performed from 1 GHz to 41 GHz are presented on Figure 5. A good agreement between predicted and experimental results (i.e. forward transmission S31, input reflection S11 and input isolation S21) can be observed.

ELECTRICAL PERFORMANCES

Main simulations results relative to the circuit of Figure 1, from 1 to 21 GHz, are presented on Figure 6 : very good transmission (close to +4 dB) and reverse transmission (less than -20 dB) between one input signal and the output signal, and a correct isolation (less than -10 dB) between the two input signals are obtained on a large frequency range up to 21 GHz.
We have to notice that this combiner exhibits a power gain close to 10 dB when its two branches are driven with 180° signals.
The comparison of the predicted output power versus input power characteristics for medium and high power combiner is presented on Figure 7. By duplicating the structure of Figure 1 as proposed, we notice an enhancement of 3 dB on the power gain and of 6 dB on the output saturation power.

Since the circuits are still under process at the Philips Microwave Limeil foundry (the test is expected for August), we will be able to present a comparison with measurements at the conference time.

The process main features are a GaAs substrate thickness H = 600 μm, a dielectric constant $\varepsilon_r \approx 12.3$, and a metal thickness t = 1.25 μm. The active devices are PHEMTs with one 0.2 x 50 μm^2 gate finger and their biasing current is about Idss / 2.

CONCLUSION

A new active 180° power Combiner/Divider has been designed taking benefits from potentialities offered by CPS and CPW uniplanar structures. Its main predicted characteristics are a very compact size (circuit dimensions are only 330 x 240 μm^2) and a significant gain value (about 10 dB). Another key point consists in the unique circuit ground reference location which makes possible a further integration of this type of circuit in numerous MMICs applications. Therefore, this new structure is promising for the development of millimetre wave MMIC designs based on CPS/CPW interconnections which are now being widely addressed for advanced applications in satellite communication systems (in up or down-converters based on balanced mixers for example) or millimetre wave wireless applications, involving size and cost reduction.

REFERENCES

[1] I. Wolff : "Design rules and realization of coplanar circuits for communication applications", *Proc.23rd European Microwave Conf., September1993, pp.36-41.*

[2] T. Tokumitsu et al. : "Active isolator, combiner, divide r, and magic-T as miniaturized function blocks", *1988 IEEE, GaAs IC Symposium, pp. 273-276.*

[3] T. Tokumitsu et al. : "Divider and Combiner Line-Unified FET's as basic circuit function modules-Part I", *IEEE MTT, Vol.38, n°9, Sept. 1990, pp. 1210-1217.*

[4] M Aikawa et al. : "MMIC technology for communication systems", *Ann. Telecom., 47, n° 11-12, 1992, pp. 469-477.*

[5] D.Prieto et al. : "CPS structure potentialities for MMICs : a CPS/CPW transition and a bias network", *1998 IEEE MTT-S Digest, TU2E-4, pp. 111-114.*

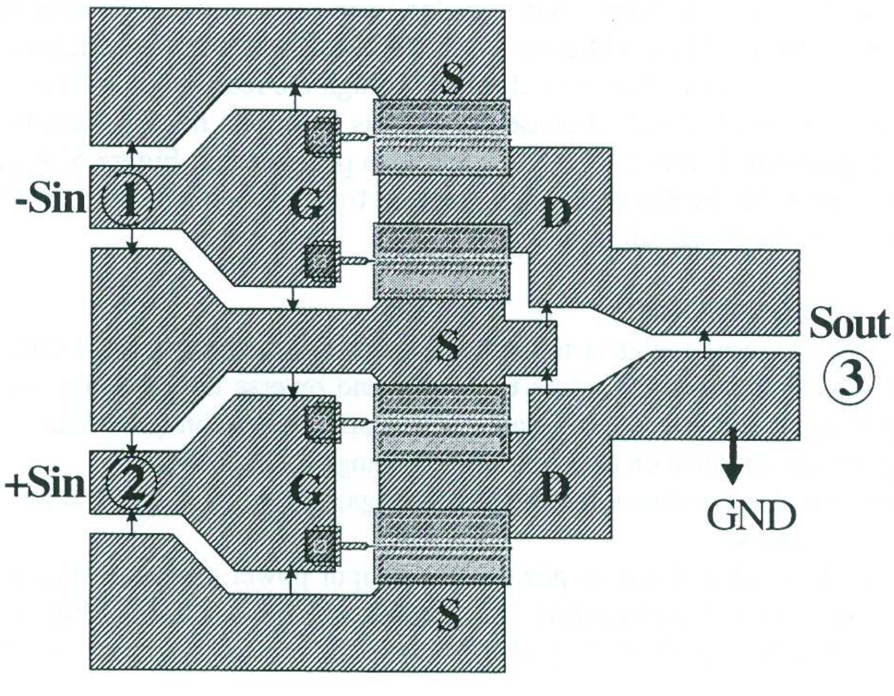

Fig.1 : 180° medium power combiner layout.

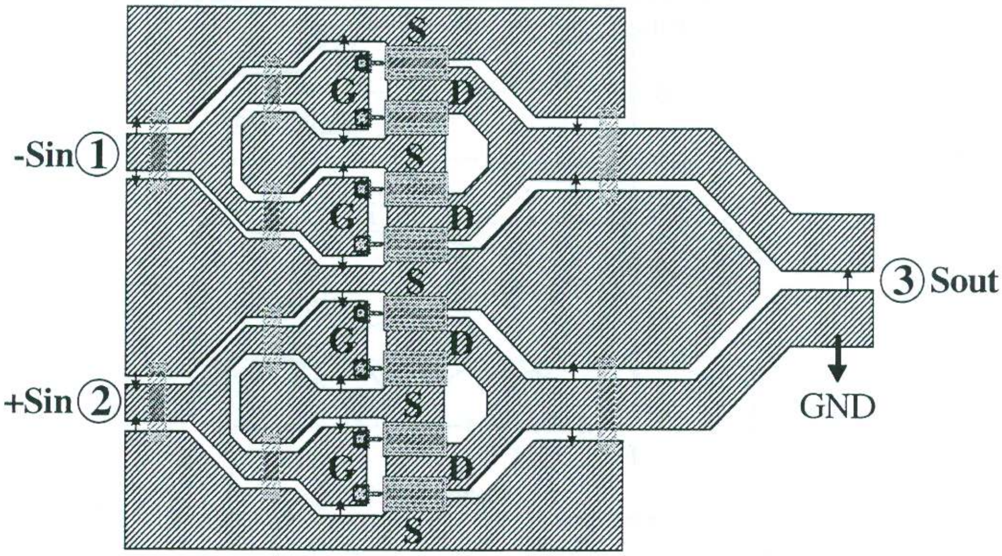

Fig.2 : 180° higher power combiner layout.

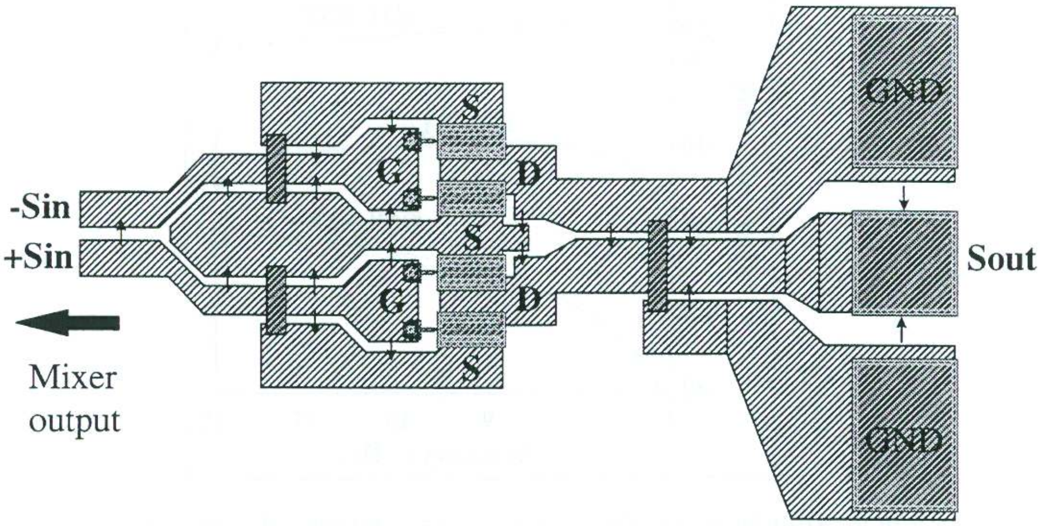

Fig.3 : 180° power combiner layout (with access lines as a frequency converter output circuit).

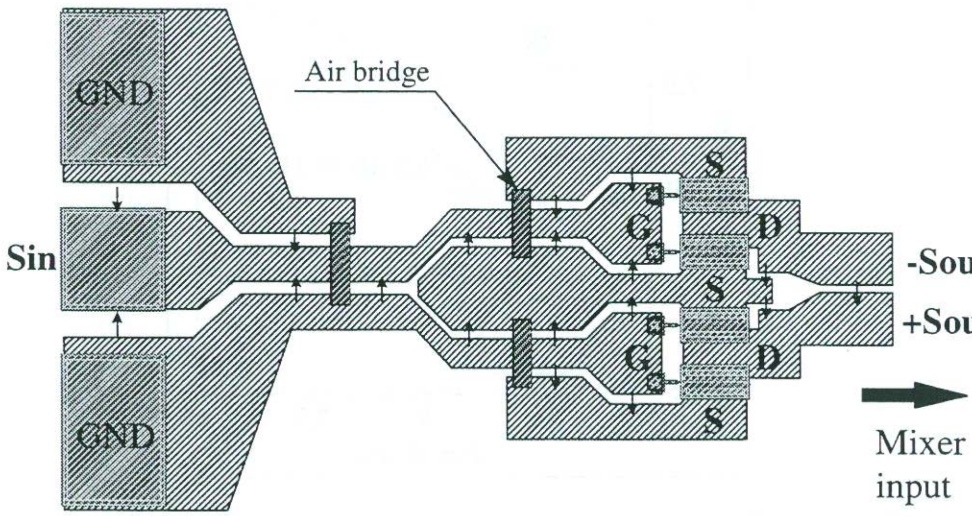

Fig.4 : 180° power divider layout (with access lines as a balanced frequency converter input circuit).

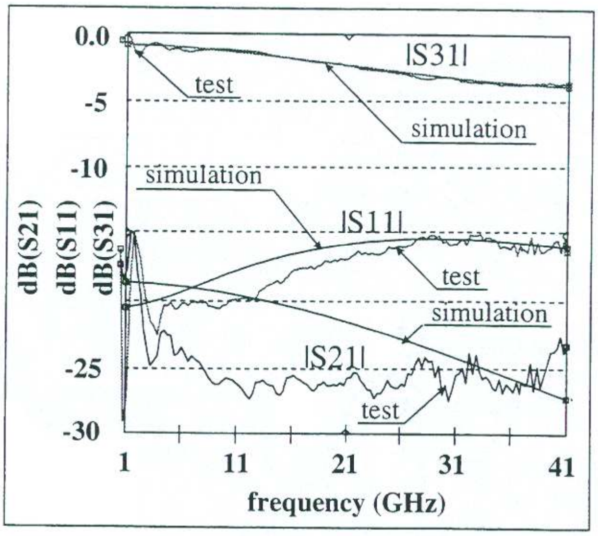

Fig.5 : electrical performances of a basic power combiner (test/simulation comparison).

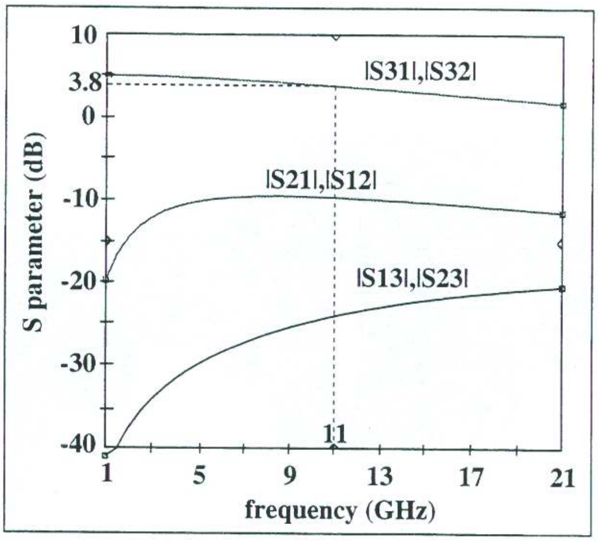

Fig.6 : simulation results for the power combiner of Figure 1.

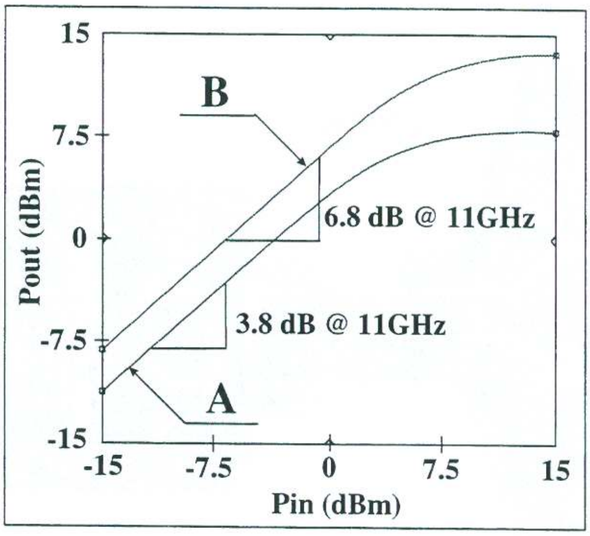

Fig.7 : predicted output power versus input power characteristics of :
A : medium power combiner (fig.1) / **B** : higher power combiner (fig.2).