DESIGN AND PERFORMANCE OF GaAs MMIC CPW BALUNS USING OVERLAID AND SPIRAL COUPLERS

T. Gokdemir, S. B. Economides, A. Khalid, A. A. Rezazadeh and I. D. Robertson

Department of Electronic and Electrical Engineering
King's College, Strand, London WC2R 2LS

ABSTRACT

The design and performance of microwave and mm-wave baluns using multilayer GaAs MMIC technology is presented. For mm-wave designs a compact overlaid coupler is employed. For lower frequencies it is shown that novel spiral couplers can be used. Results for baluns operating at 30-40 GHz and 5-15 GHz are presented.

INTRODUCTION

Baluns are extremely important components for mixers and push-pull amplifiers. However, MMIC baluns have received far less attention in the literature than other passive components such as couplers and filters. Surprisingly, the problem is more severe at lower frequencies, because of size restrictions, and as a result many commercial MMIC products require off-chip baluns. Active baluns have been reported, but often these cannot be used because of their noise figure, DC power requirement, and limited power handling.

Recent works have addressed the general problem of passive monolithic balun design. Of particular note are the results for baluns based on the Marchand technique [1,2,3]. Alternatively, in 1993, M. C. Tsai presented a balun technique employing a pair of Lange couplers [4]. Since many techniques have been reported for miniaturisation of couplers, this coupler-based balun is well suited for the development of miniaturised baluns. In this paper, two novel coupler geometries have been used to realise miniature baluns with this technique.

BALUNS USING QUADRATURE COUPLERS

The balun can be connected in two configurations: the schematic diagrams of each balun circuit are shown in Fig. 1(a,b). Method (a) uses open circuit terminations and the outputs are taken at the outer ends of the couplers. Method (b) uses short-circuit terminations and the outputs are taken from the centre. For a well-matched coupler with good amplitude and phase balance, method (a) gives excellent results if high value load resistors are used instead of the open circuits. With a mediocre coupler, however, the performance of balun (a) collapses. With a non-ideal coupler it is found that type (b) successfully compensates for coupling imbalance and gives good results.

The first balun uses a multilayer coupler with overlaid tracks [5] in configuration (a), the second uses a novel spiral coupler, derived from the planar spiral transformer [6,7], in configuration (b).

BALUN USING OVERLAID COUPLERS

Balun with spiral transformers has high parasitics above 15 GHz. The most serious parasitic is usually the capacitance between the two spirals since this makes the transformer resonate as the capacitive coupling becomes dominant at higher frequencies. To minimise this the turns need to be as small as 5um. The solution for is to use overlaid directional coupler. This kind of balun is made up of a half wavelength resonator with two quarter wavelength long coupled transmission lines. To obtain tight coupling and to improve losses due to current crowding effects combination of both edge coupling and offset broadside coupling has been used as seen in Fig.2. The coupling balance has been improved either using high value load resistors or controlling the length of the overlapping metal layer. The use of resistors also enhances the matching. The coupled length for each coupler is 800 um. The fabrication was performed at GEC-Marconi with F40 foundry. The measured results in Fig. 3 show low insertion loss and good matching over the frequency range 30 to 40 GHz. The power balance between the two outputs and the phase is very good and the layout can be made more compact with meandering.

0-7803-4603-6/97/$5.00 (c) IEEE

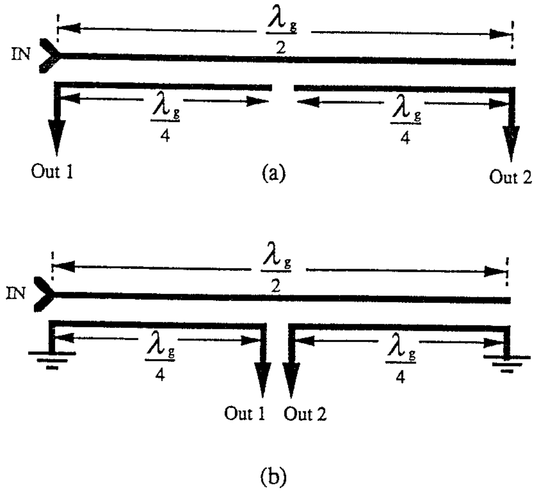

Fig. 1. Two types of balun configuration,
a) With o/c terminations, b) With s/c terminations

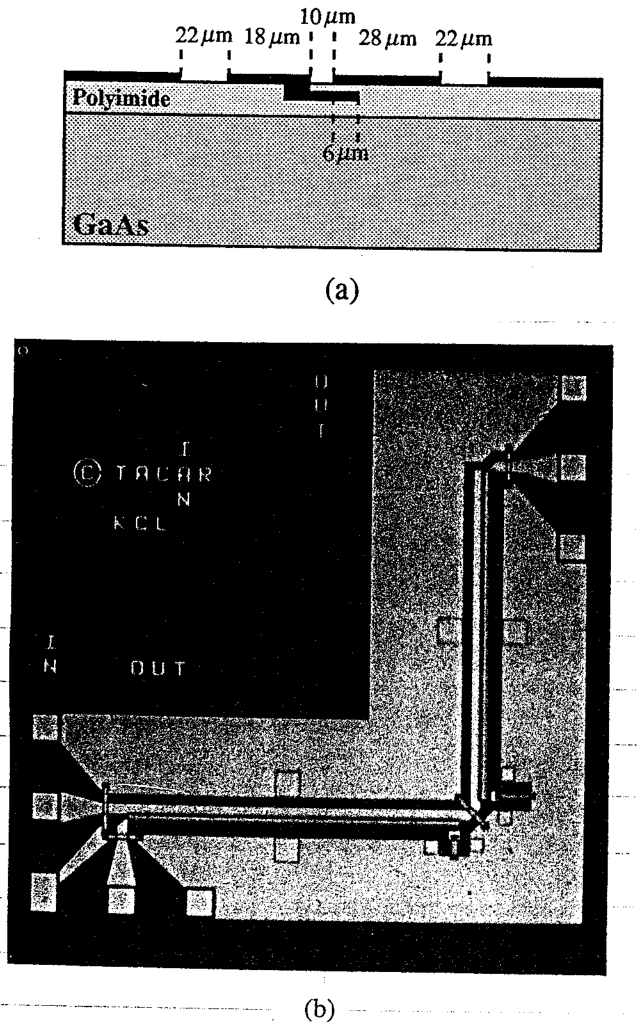

Fig. 2. Balun using overlaid coupler.
(a) Cross section of the coupler, (b) Balun photograph.

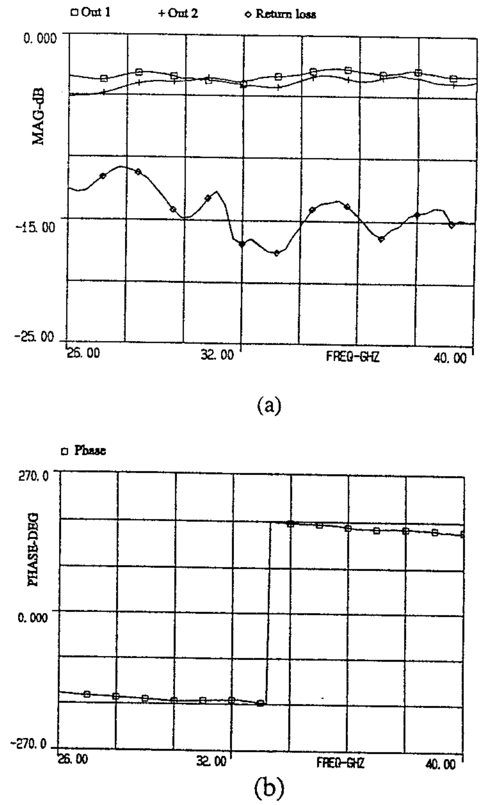

Fig. 3. Measured overlaid balun response.
(a) Magnitude and matching,
(b) Phase.

BALUN USING SPIRAL COUPLERS

Studies of planar spiral transformers have illustrated that they can be effectively modelled as coupled-line elements [8]. This leads to the conclusion that a transformer could act as a quadrature coupler if connected as a four-port, with a centre frequency very approximately equivalent to the unwound length. Fig. 4 shows such a coupler: the track widths are 12um, the gaps 10um and the unwound length 5mm. The fabrication was performed at King's College London using an experimental multilayer MMIC process [9]. Characterisation of the coupler reveals significant overcoupling and poor match, attributed to the fact that the Zo of the coupler is too high. By widening the tracks and optimising the gaps, the spiral coupler can be improved, but the area increases very considerably. Fortunately, though, balun type (b) can compensate for the non-ideal coupler. Thus, the size does not need to be increased, and the balun layout is shown in Fig. 5. The measured response, in Fig. 6, shows excellent performance. The insertion loss is mostly due to the DC resistance of the long tracks and can be improved by plating up the tracks.

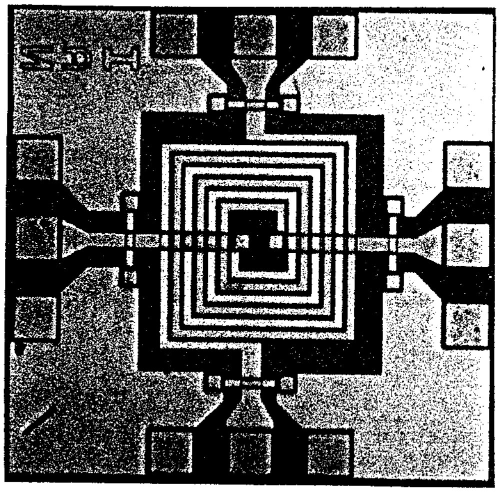

Fig. 4. Photograph of the spiral coupler.

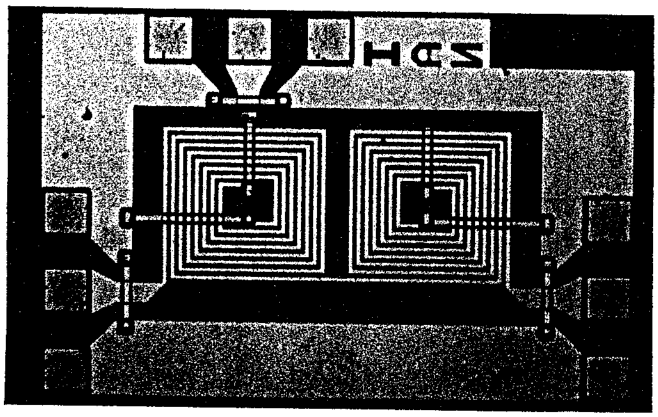

Fig. 5. Spiral balun photograph.

CONCLUSIONS

The design of microwave and mm-wave baluns using novel multilayer and spiral couplers has been described. The dual coupler balun technique has proved flexible and offers high performance. Many other miniature overlaid couplers can also be used, including microstrip types.

The spiral coupler is less than perfect, but the balun can compensate for coupling imbalance. Note that the layout of this spiral-coupler balun is, surprisingly, almost identical to the multilayer Marchand balun of Ref. 2. Yet, the two designs have been developed from different approaches. This indicates that this is a robust balun topology which could be widely adopted.

The spiral coupler does not actually need multilayer processing, so the balun can be fabricated on standard foundry processes.

The balun using overlaid couplers can be used at higher frequency where spiral-coupler balun severely effected by the parasitics. This type gives good coupling balance and the overlaid couplers can be meandered to obtain more compact layout.

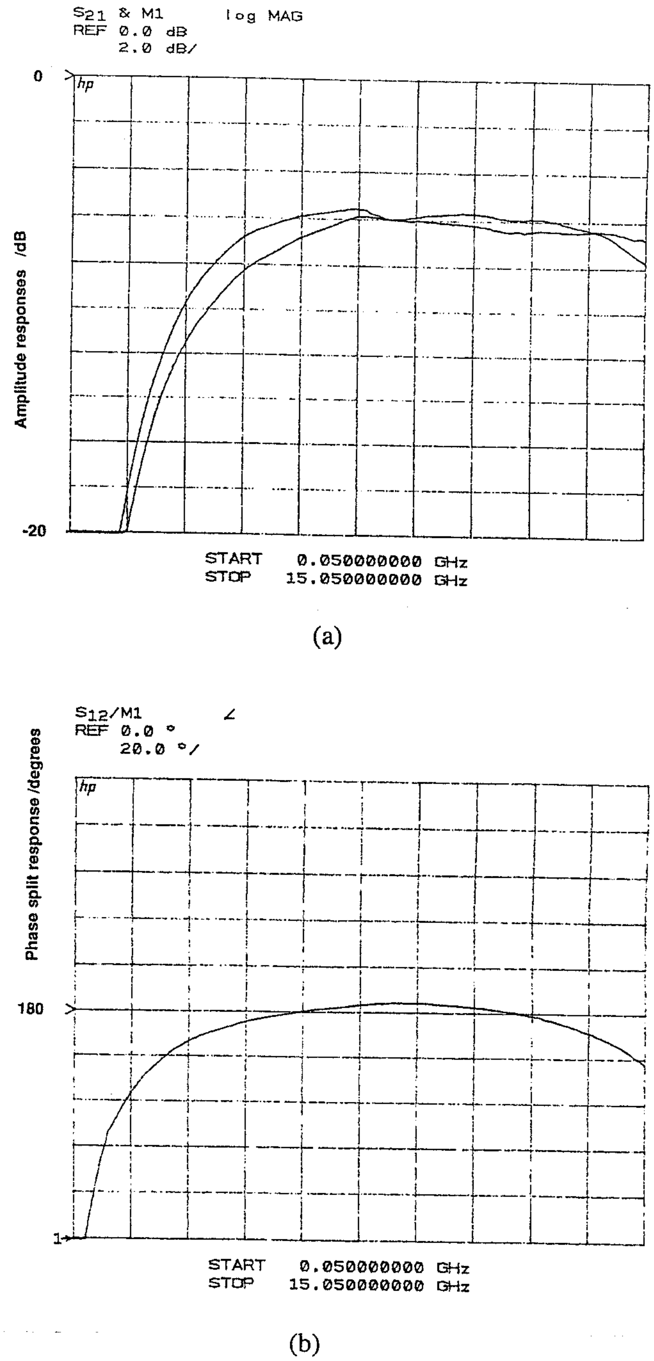

Fig. 6. Measured spiral balun response.
a) Magnitude,
b) Phase.

REFERENCES

1. T. Chen, K. W. Chang, S. B. Bui et al, "Broadband monolithic passive baluns and monolithic double balanced mixer", IEEE Trans. Microwave Theory Tech., Vol. 39, No. 12, pp. 1980-1986, 1991.
2. M. Engels and R. H. Jansen, "A novel compact balun structures for multilayer MMICs", 26 European Microwave Conference Proc., Vol. 2, pp. 692-696, 1996.
3. A. M. Pavio and A. Kikel, "A monolithic or hybrid broadband compensated balun", IEEE MMT-s Dig., pp. 483-486, 1990.
4. M. C. Tsai, "A new compact wideband balun", IEEE Microwave and millimetre Wave Monolithic Circuit Symp., pp. 123-125, 1993.
5. T. Gokdemir, I. D. Robertson, Q. H. Wang et al, "K/Ka band coplanar waveguide directional couplers using a three metal level MMIC process", IEEE Microwave and Guided Wave Letters, Vol. 2, pp. 76-78, 1996.
6. S. B. Economides, A. Khalid, A. A. Rezazadeh et al, " A study of cpw spiral transformers using multilayer GaAs MMIC technology", Microwaves and RF Conference Proc., pp. 420-425, 1996.
7. S. A.Jamison, A. Podel, M. Helix et al, "Inductive coupled push-pull amplifiers for low cost monolithic microwave ICs", IEEE GaAs IC Symp. Dig., pp. 91-93, 1982.
8. L. Wiemer, H. R. Jansen, I. D. Robertson et al, "Computer simulation and experimental investigation of square spiral transformers for MMIC applications", IEE Colloquium on computer aided design of microwave circuits, Digest no. 99, pp. V1-5, 1985.
9. Q. H. Wang, T. Gokdemir, D. Budimir et al, "Fabrication and Microwave characteristic of multilayer circuits for MMIC application", IEE Proc. Microwaves, Antenna and Propagation, Vol. 143, No. 3, pp. 225-232, 1996.