Conclusions: This Letter has presented original practical results for a suboptimal, heterodyne detection, digital PPM system. It has been shown that, even when operating 8-6 dB away from the shot-noise limit, this system gives a 16-8 dB improvement in receiver sensitivity over an equivalent sub-optimal direct detection system, employing the same optical preamplifier. We have also shown that the suboptimal filtering technique can be applied to a digital PPM heterodyne system, yielding a significant reduction in receiver complexity from that of the optimal predetection filter.

Acknowledgments: The authors wish to thank the UK SERC for the CASE award studentship. We also wish to thank BTL, the collaborating body.

20th January 1992
A. J. Massarella and M. N. Sibey (Division of Electronics and Communications, School of Engineering, The Polytechnic, Queensgate, Huddersfield, W. Yorkshire HD1 3DJ, United Kingdom)

References
4 Garrett, T.: 'Digital pulse-position modulation over dispersive optical fibre channels'. Int. workshop on Digital Communications, Terni, Italy, 15th-19th August 1983

IMPROVED 3dB MULTISECTION HYBRID COUPLER USING MMC CENTRE SECTION

S. Lucyszyn, S. A. Ausat and I. D. Robertson

Indexing terms: Microwave Couplers, Microwave devices, Microwave integrated circuits

To improve the performance of the recently introduced three-section hybrid coupler, a new design for the centre section is introduced. Instead of using a broadside coupler, a multilayer MMC coupler is employed for the centre section. The very significant improvements to the measured results of the new compact three-section hybrid coupler are presented.

Introduction: A three-section hybrid coupler, which employed a long straight broadside coupler for the centre section and microstrip edge-coupled lines for the other two sections, was introduced by Izadi1 [1]. This coupler achieved a two-octave bandwidth (centred at 17 GHz); however, the measured insertion loss, equal power balance and return loss performance were poor. To improve the performance, a new design for the centre section was developed, using a multilayer MMC coupler [2, 3].

Centre section MMC coupler: A small three-section hybrid coupler was required to provide an equal power split between the coupled and direct ports, while maintaining a good phase quadrature performance, across a two-octave bandwidth (centred at 6 GHz). The GEC-Macdon (Cardwell) foundry was used to fabricate the GaAs MMC coupler, using their Standard F20 process. Here, the lower underpass metal is much thinner than the upper bulk metal. As a result, a broadside coupler would be too lossy. Instead, a unique off-set multilayer coupler was employed. With the lower metal offset from the upper metal and a suitable dielectric via, the insertion loss of the coupler can be significantly reduced by plating up the lower metal with upper bulk metal.

For low frequency MMIC couplers, straight coupled lines would result in an inconvenient aspect ratio, which may impose unnecessary restrictions on the wafer array dimensions and make the MMC too fragile to handle. To reduce the aspect ratio, the MMC coupled transmission lines were meandered, using four equidistantly spaced right-angled bends. This effectively resulted in an 80% reduction in the longitudinal length of the MMC coupled lines. The total length of the MMC coupled lines was 3-3 mm, corresponding to a frequency of maximum coupling of 7.7 GHz, and the active area taken up by the complete MMC coupler was only 1-1 x 0.8 mm².

The design, fabrication, direct two-port automatic network analyser measurements and subsequent modelling strategies of this multilayer MMC directional coupler have been described in detail [2]. Here, very accurate modelling was achieved by crude conformal mapping from a microstrip structure to a stripline structure. However, the resulting four-port model included the significant effects of the test fixture.

To characterise the MMC coupler itself, accurate measurements for the coupler had to be determined. The techniques adopted were test fixture de-embedding (using accurate equivalent circuit models) and matrix renormalisation. These techniques and the resulting four-port measurements for this MMIC coupler have been described in detail [4].

From these four-port measurements, a new four-port model for the de-embedded MMC coupler was obtained. The measured and the new modelled performances for the direct and coupled power responses are given in Fig. 1. It can be seen from Fig. 1 that the four-port model accurately characterises the multilayer MMC coupler. This model was successfully used in the modelling of the complete three-section hybrid coupler.

Fig. 1 Measured and modelled performances of coupled and direct power responses of centre section MMC coupler

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>□</td>
<td>measured coupled</td>
</tr>
<tr>
<td>△</td>
<td>modelled coupled</td>
</tr>
<tr>
<td>+</td>
<td>measured direct</td>
</tr>
<tr>
<td>x</td>
<td>modelled direct</td>
</tr>
</tbody>
</table>

Measured results: The layout of the complete hybrid coupler is illustrated in Fig. 2. Here, stepped tapers are used to match the low impedance outer couplers to the centre section MMC coupler. Using an HP8510B automatic network analyser, the same measurement techniques of test fixture de-embedded and matrix renormalisation were used to produce the accurate four-port measurements of the hybrid coupler. The measured power responses are shown in Fig. 3, and the relative phase difference between the direct and the coupled signals is shown in Fig. 4. A comparison of the measured performances of the hybrid coupler presented here and that presented by Izadi are given in Table 1.

From the measured results given in Table 1, a significant improvement in the insertion loss and a very significant improvement in the equal power balance and input return loss performances have been achieved with the new hybrid coupler design. In addition, a very good phase quadrature balance was achieved. A small degradation in the isolation was found, however, it is still within very acceptable levels.

The level of insertion loss in both designs can be attributed to the centre section couplers, because lossy polyimide dielec-
trics were used. With the previous design, the polyimide is more lossy at the higher frequencies of operation, whereas with the new design, there is more length of less lossy coupled phase quadrature balance responses were achieved. The folded layout of the MMIC coupler demonstrated that a compact low frequency multisection hybrid coupler can be realised.

Table 1: COMPARISON OF BEST RESULTS REPORTED BETWEEN PREVIOUS AND NEW THREE-SECTION HYBRID COUPLER DESIGNS

<table>
<thead>
<tr>
<th></th>
<th>Previous</th>
<th>New</th>
</tr>
</thead>
<tbody>
<tr>
<td>Centre frequency $f_c$</td>
<td>12 GHz</td>
<td>6 GHz</td>
</tr>
<tr>
<td>Insertion loss*</td>
<td>1.5 dB</td>
<td>0 dB</td>
</tr>
<tr>
<td>Equal power imbalance†</td>
<td>±0.79 dB</td>
<td>±0.45 dB</td>
</tr>
<tr>
<td>Isolation‡</td>
<td>15 dB</td>
<td>13.5 dB</td>
</tr>
<tr>
<td>Return Loss‡</td>
<td>10 dB</td>
<td>15.9 dB</td>
</tr>
<tr>
<td>Phase quadrature imbalance‡</td>
<td>not specified</td>
<td>±3 †</td>
</tr>
</tbody>
</table>

* as $f_c$; † within normalised frequency range of 0.6 < $f/f_c$ < 1.5; ‡ up to 1.4$f_c$.

Moreover, an even lower frequency multisection hybrid coupler can be realised. Moreover, an even lower frequency multisection hybrid coupler can be realised without having to increase the longitudinal length of the MMIC. Finally, with the emerging developments in flip-chip technology [5, 6], very high yield and low cost production of hybrid couplers can be achieved by replacing the traditionally low yield and high cost techniques used with wire bonding.

31st January 1992

S. Lucyszyn, S. A. Ainsa and I. D. Robertson (Communications Research Group, Department of Electronic and Electrical Engineering, King’s College, University of London, Strand, London WC2R 2LS, United Kingdom)

References

KINK-RELATED NOISE OVEESHTOE IN SOI n-MOSFET OPERATING AT 4.2K

E. Simoen, B. Dierickx and C. Claes

Indexing terms: Field-effect transistors, Transistors, Semiconductor devices and materials

The low frequency noise behaviour of SOI n-MOSFETs operated at 4.2K is reported for the first time and compared with room temperature behaviour. It is shown that the noise level increases by a factor of 3-5, and the kink-related noise overshoot becomes much more pronounced on cooling. These results are compared with the noise overshoot observed in bulk devices operating at 4.2K and a similar explanation for the phenomenon is proposed.

Introduction: Partially-depleted (PD) SOI n-MOSFETs exhibit the well known kink behaviour, if operated floating. Apart from deteriorating the output characteristics, another