A Broadband Circular Combiner/Divider for Planar Gunn Oscillators

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Abstract
In this paper, a circular power combiner/divider using coplanar strip-lines operating at the centre frequency of 30 GHz is demonstrated. The combiner/divider has a coplanar strip-line (CPS) crossover phase inverter and it shows good isolation (<-22 dB) up to 55 GHz. The combiner/divider is suitable for combining planar Gunn oscillators that operate in a wide frequency range.

Introduction and device design
Planar Gunn diodes operating at over 100 GHz have been demonstrated and shows potential in the terahertz frequency range [1], [2]. Such devices show many advantages over traditional Gunn diodes since they are MMIC-compatible and have lithographically controlled oscillation frequency that allows multiple frequency sources on a single chip. These devices are also easier to make than HEMT-based oscillators since they have no gate. In this summary, a circular power combiner/divider using coplanar strip-lines to combine planar Gunn diodes is proposed. The device has broadband operating frequency range and excellent isolation that will enable high power sources to be made.

Figure 1 (a) shows the layout of the new combiner/divider. The combiner/divider is a modified version of Wilkinson combiner/divider. The isolation resistor between port 2 and port 3 in the conventional Wilkinson combiner/divider is replaced by two quarter-wavelength waveguides, a phase inverter [2] and two resistors that allow broadband operation and good port isolation [3]. Transition from coplanar strip-lines to coplanar waveguide (CPW) is made at the test ports to allow on-wafer GSG (40 µm/60 µm/40 µm) test. Air bridges are used to avoid coplanar strip-line mode propagation on CPW. The coplanar strip-lines have characteristic impedance $Z_0$ of 70.7 Ω and the resistor $R_0$ has resistance of 100 Ω. The quarter-wave guided wavelength at 30 GHz is 942 µm. All design parameters are listed in Table I.

The circuit was simulated using the 3D EM simulator HFSS. In the simulation, the resistors were assigned a material having bulk conductivity of 606 kS/m that gives a sheet resistance of 50 Ω/□. Since the resistors are very thin (33 nm), the simulator must be set to solve the fields inside the resistors. The simulation results are plotted against experimental results in Figure 2.

Fabrication and Results
The device was fabricated on a 620 µm semi-insulating GaAs substrate using electron beam lithography. Air-bridges were developed using a dry-etch process. NiCr thin film resistor has a thickness of 33 nm which gives a sheet resistance of 50 Ω/□. The device was tested using on-wafer probes and a VNA system (Agilent N5250 C). The system was calibrated from 10 MHz to 60 GHz using the short-open-load-thru (SOLT) method.

It can be seen in Figure 2 that simulation results and experimental results show good agreement. The device has a lowest insertion loss of 3.5 dB at 30 GHz and a bandwidth of 15 GHz for $S_{21}$<-4 dB. The device has excellent isolation (<-22 dB) up-to 55 GHz. The matching on the two coupling ports is better than -16 dB between 15 GHz and 35 GHz. These may be further improved by introducing curved CPW to CPS transitions to avoid sudden change of fields at the right angles.

This broadband circular combiner/divider shows great potentials for combining power devices with broadband frequency tuning range. Meanwhile the excellent port isolation permits reduction of mutual frequency interferences in antenna array systems and other balanced circuits.
Figure 1 (a) The proposed circular combiner/divider, (b) geometry of coplanar strips and (c) the coplanar stripline crossover phase inverter.

Table I Parameters used in the simulation and fabrication

<table>
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<tr>
<th>Width of CPS (w)</th>
<th>Separation of CPS (s)</th>
<th>Height of Substrate (h)</th>
<th>Dielectric constant ($\varepsilon_r$)</th>
<th>$\lambda/4$ at 30 GHz</th>
<th>Outer ring radius (R)</th>
<th>Inner ring radius (r)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60 µm</td>
<td>24 µm</td>
<td>620 µm</td>
<td>12.9</td>
<td>942 µm</td>
<td>684 µm</td>
<td>600 µm</td>
</tr>
</tbody>
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Figure 2 S-parameters of measured and simulated circular combiner/divider.

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References