Maas 16-way Wilkinson Divider Measurements

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Measurement and calibration

Steve Maas designed a 16-way Wilkinson power divider on a 1×1” alumina substrate that is 10 mils thick. For this prototype test, all but two of the divider arms have 50 Ω terminating resistors. Data were taken with an HP8722D network analyzer sweeping from 0.05 to 24 GHz. The unused output port on the coupler was terminated, but the coupling is not large, so small termination errors are unimportant. Calibration was a standard open-short-broadband match-through using the HP 85052D economy calibration kit and constants stored within the HP8722D network analyzer. These calibration standards are not specified above 18 GHz, so data at the highest frequencies may not be entirely accurate.

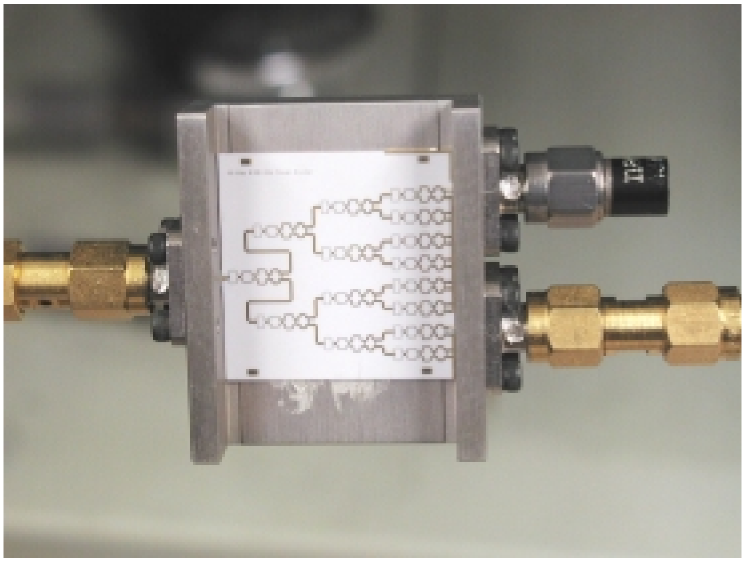

Figure 1: Divider in its test holder.

Assembly

The substrate slip-fits into an iridite-coated aluminum holder (Figure 1). A useful modification since the first test is to relieve the area near the walls with a 1/16” wide groove 0.01” deep. A thin layer of Bondline 2900 conducting epoxy, applied to the holder over an area approximately the same as the substrate, provides mechanical location and ground return. In an attempt to reduce stress from differential contraction, the substrate was allowed to cool slowly in the oven, with a partially open oven door, after the epoxy cure (150° C for 1 hour). A small crack still appeared (bottom center of Figure 2), but the cracking was overall much less than with the first attempt. The epoxy is high-modulus material designed for bonding chips, and a lower modulus epoxy might be better.

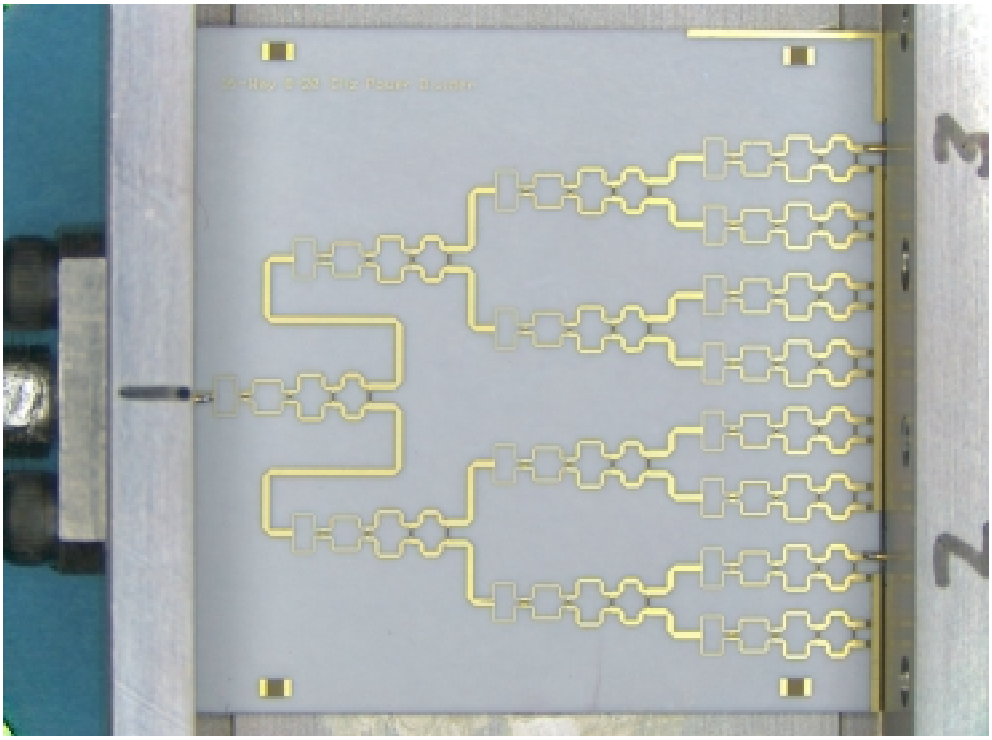

Figure 2: Image of substrate #3 in the test holder. Some cracking is visible at the bottom center of the substrate. The resistance of the four isolated resistors are measured during fabrication to set the divider resistance values.

The Amphenol 901-9804-1 SMA connector pins are in pressure contact with the traces only and have no solder or epoxy (the solder visible in Figure 2 is tinning). I bent each pin slightly to make contact – the bottom of the pin is otherwise a few mils above the substrate surface – so the contact is over a small area at the pin's end. These connectors have a 10 mil center conductor in an 85 mil dielectric.

Transmission
Figure 3 shows the transmission from the input to the two test ports, numbered 2 and 3. The typical loss is 14 dB and the 3 dB bandwidth is about 0.5 to 18.8 GHz. Overall, the splitter works well to 22 GHz.

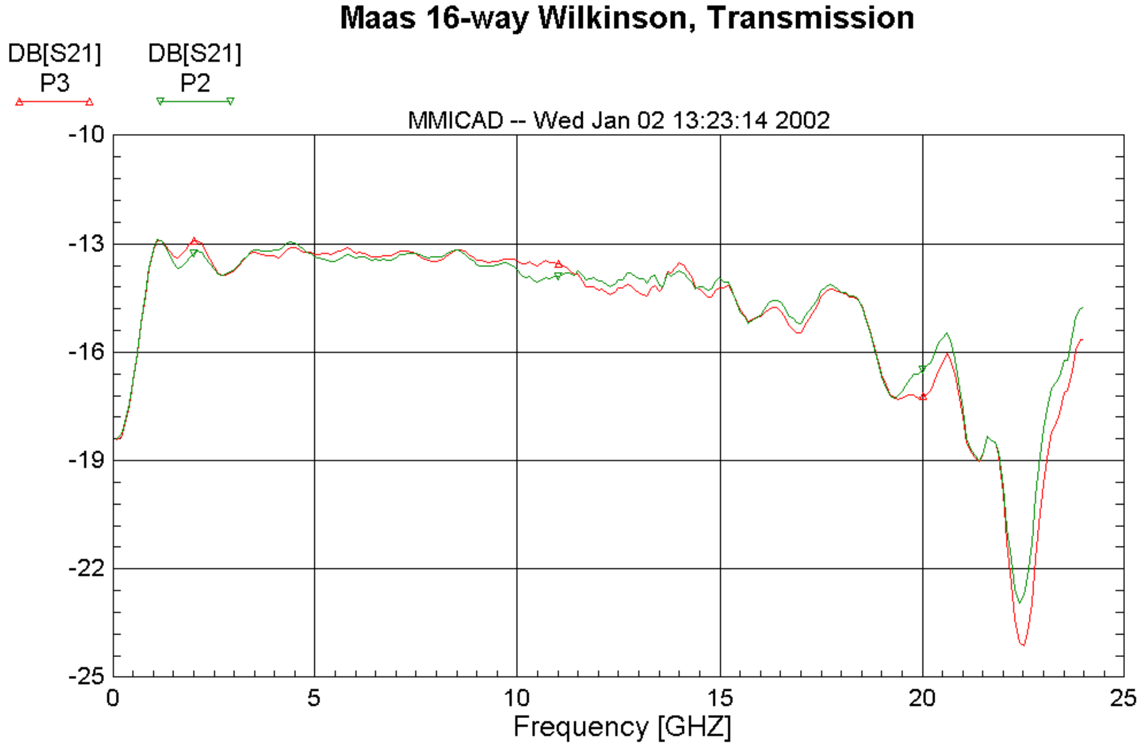

Figure 3: Transmission to ports 2 and 3.

The phase and delay differences between the two output ports are shown in Figure 4 and Figure 5. The phase match is flat within a few degrees. Much of the deviation from zero degrees comes from a linear term corresponding to a 1 ps delay difference. This delay is calculated from the phase differences with

$$\Delta t_{\mathrm{ns}} = \frac{\Delta\varphi_{\mathrm{deg}}}{360\, f_{\mathrm{GHz}}} \ .$$

A 1 ps delay corresponds to 0.3 mm in vacuum, so the measured delay difference could easily be a slight difference in connector pin length: I cut the pins to length by hand.

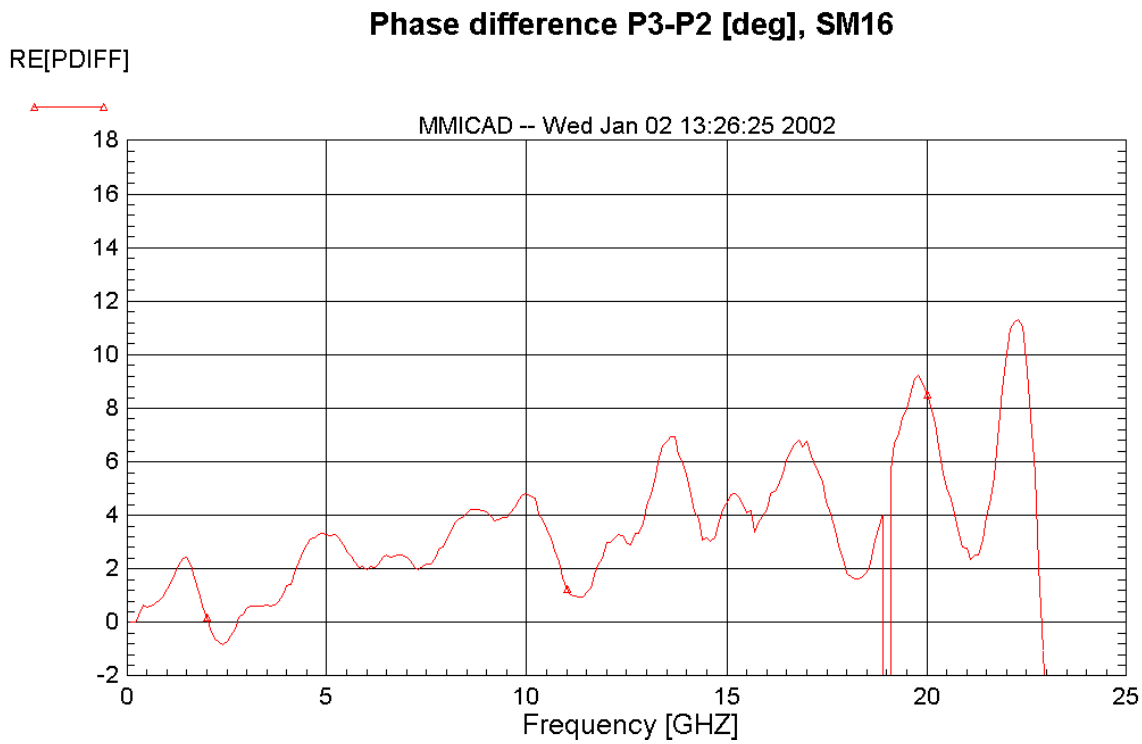

Figure 4: Phase difference between ports 3 and 2.

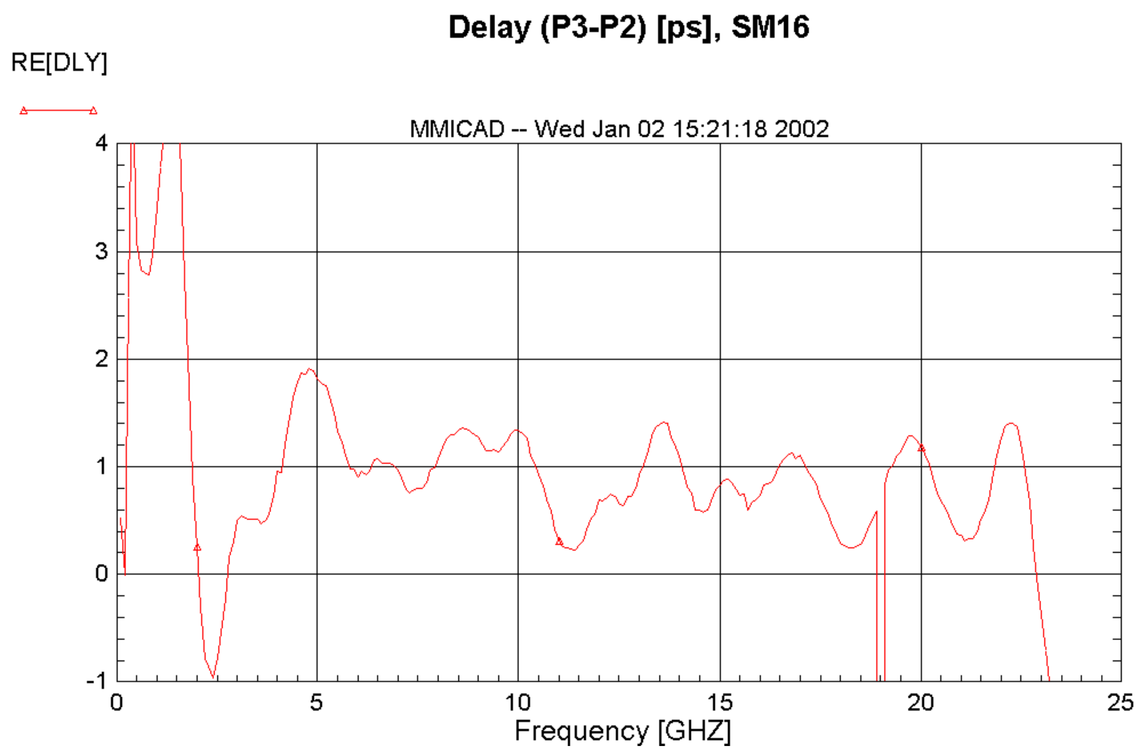

Figure 5: Delay difference between ports 3 and 2.

Port reflectivities

Figure 6 shows the return losses from the input and outputs. The outputs' return losses are generally -10 dB or lower, dipping close to -15 dB and below for frequencies below 10 GHz. Input return losses are less than -7.5 dB.

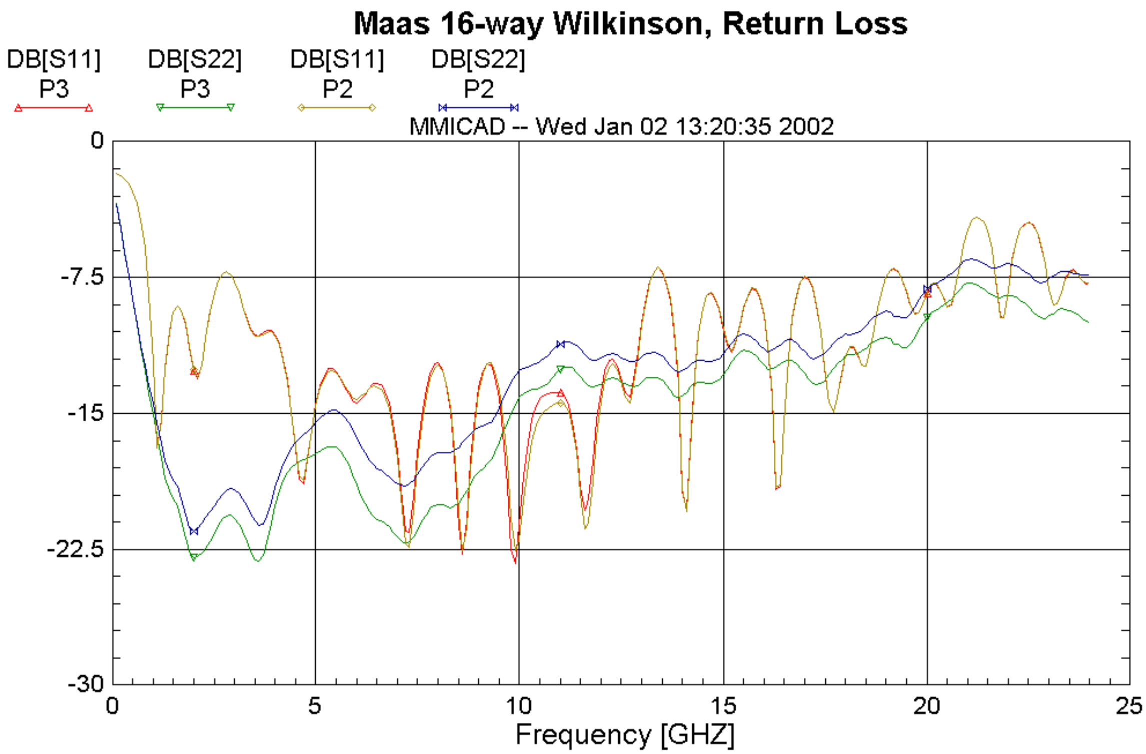

Figure 6: Input and output return losses

Surface Waves

I monitored S_{21} while poking around the larger areas of the substrate that are not metalized with my finger to check for surface waves. Other than some effect when my finger got very close to the lines, S_{21} was unaffected. Along with the reasonably flat coupling with frequency, this is a sign that there are no strong surface waves on the substrate.

Files

The network analyzer files are in Touchstone format with 201 points and are titled:

sm16b_2.s2p – port 2 data
sm16b_3.s2p – port 3 data