New Cross-T Junction for CPW Stub-Filters on MMIC's

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Abstract—**This letter reports on a new Cross-T junction for CPW stub-type filters. We analyzed the structure by full 3D structure simulations and corrected its equivalent circuit based on measurement data. Using the equivalent circuit of the Cross-T we optimized filters by compensating for their discontinuities. We found good agreement between the measured and simulated characteristics, which confirms the validity of the equivalent circuit.**

I. Introduction

Currently we can see an increasing interest in creating filters on MMICs. Stub-filters are an important group of traditional microwave filter structures, containing open-ended and/or short-ended stubs [1], [2]. Discontinuities such as T-junctions and open/short ends at CPW lines have been thoroughly investigated by a number of numerical methods [3]–[5]. Previous publications have investigated geometry suitable to be analyzed by the actual numerical method, so the structures usually have had a "systematic" geometry (usually formed only by parallel and perpendicular planes) which is not possible to follow by the real process exactly. In our experiment we analyzed Cross-T geometry which closely follows the real result of the process. We worked with a 3D structure simulator (HP-HFSS) to find the suitable equivalent circuit. We analyzed Cross-T because the impedance of the stubs at our filters should be extremely low, which can be realized by two parallel connected stubs.

II. The Proposed Cross-T

A. Geometry

We investigated three different structures shown on Fig. 1. Fig. 2 shows the details of the one we found the most advantageous, because of its simple equivalent circuit. The CPW grounds are connected by X-shaped 30-μm-wide strips on the first metal layer, while the center conductors are connected by other X-shaped 30-μm-wide strips rotated by 45 degrees on the second metal layer. The ground-to-ground spacing on all CPW lines was fixed to 150 μm. The metal layers were separated by a polyimide layer of 2 and 5 μm thickness. The GaAs substrate was 450 μm thick, with $Er = 13$ permittivity and $tg(d) = 0.0016$ dielectric loss. The metallization was 1-μm-thick evaporated gold on both layers, with about 10^{+7} S/m conductivity.

Manuscript received October 26, 1994.
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IEEE Log Number 9410015.

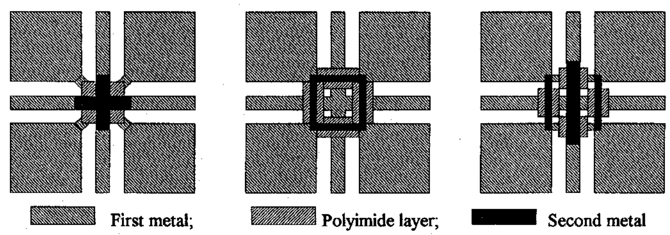

Fig. 1. The three investigated CPW Cross-T junctions.

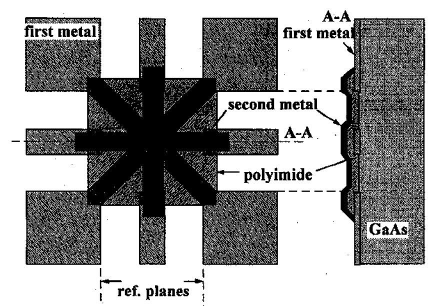

Fig. 2. CPW Cross-T junction, top and side view.

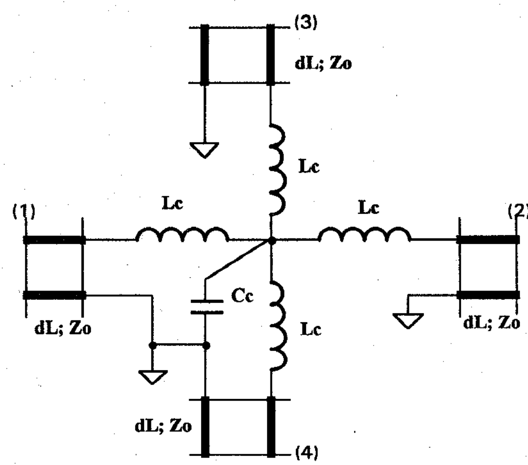

Fig. 3. Equivalent circuit for the CPW Cross-T junction (Lc, Cc: Cross-T inductance and capacitance; Zo: characteristic impedance; dL: length of the transmission line section).

B. Equivalent Circuit

To find the equivalent circuit for the CPW Cross-T junction we defined one in a circuit simulator (HP MDS) and fitted its S-parameters to the results of the structure simulator. The equivalent circuit is shown on Fig. 3. For the simulations the connecting CPW lines with 50-μm-wide center lines and 150

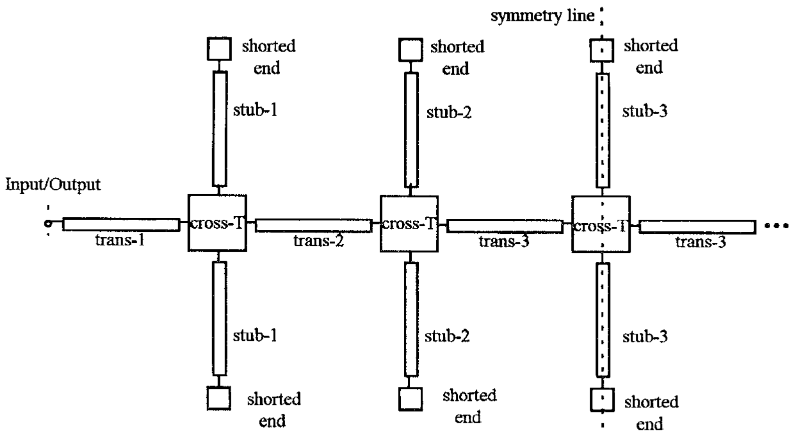

Fig. 4. Equivalent circuit of the filter (only the symmetry half is shown).

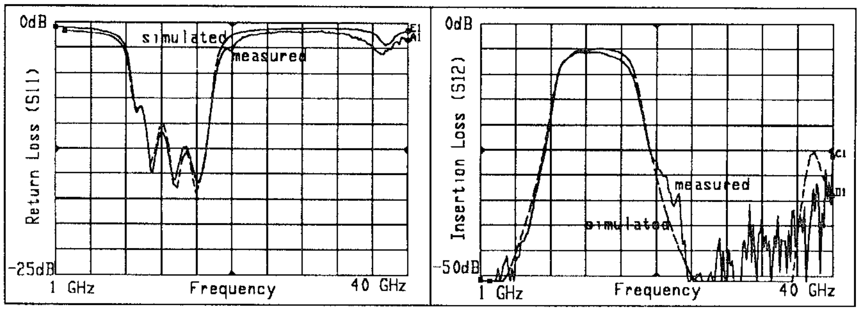

Fig 5 Measured and simulated filter characteristics (thin line: simulated; thick line: measured).

μm ground-to-ground spacing were taken into account. We corrected the parameters of the equivalent circuit ($Lc; Cc; dL$) based on the test element measurements. Using the corrected circuit parameters we achieved a very good agreement between the measured and simulated filter characteristics up to 40 GHz. Table I shows the equivalent circuit parameters for the Cross-T junction; dataset-A refers to the structure simulation results, dataset-B to the corrected values, both for 5 μm polyimide thickness, while dataset-C gives the measurement-based equivalent circuit parameters for 2 μm polyimide thickness. The capacitance was very large at 2 μm polyimide thickness, possibly because the high fringing capacitance caused by the employed "lift-off" technique which was used to create the second metal layer.

III. Application at Filters

For the filters we used short-ended CPW stubs, taking their end-discontinuities into account as well. We extracted an equivalent end-inductance from EEsof-Academy and substituted it as a user-defined structure into our simulator (where this model is missing from the library). With the actual substrate and line parameters the following equivalent end-inductance (L_{eq}) was found for the short-end on the CPW line

$$L_{\text{eq}}\,[\text{pH}] = 56.213 - 24.344\log(w_{\mu\text{m}}).$$

Losses on the lines were taken into account by RHO = 2; RHG = 0.0. The CPW center line width ($W_{\mu\text{m}}$) should be substituted into the above equation in μm's to get correct values for the inductance in pH's.

TABLE I
Equivalent Circuit Parameters of the CPW Cross-T Junction

	Cc[fF]	Lc[pH]	dL[µm]	Zo[Ω]
Dataset-A	80	0	20	50
Dataset-B	38	29	20	Z_{lines}
Dataset-C	423	10	0	-

The initial filter design was based on the traditional Richard's transformation [6]. Because we employed short-ended parallel connected stubs, first the low pass prototype had to be transformed into a high-pass one. Then we transformed this by Richard's transformation into a series of serial connected open-ended and parallel connected short-ended stubs. As a third step, the serial connected open-ended stubs were transformed into parallel connected short-ended stubs, according to Kuroda's identities with impedance inverters. This last step also separated the stubs. Because the losses of MMIC's are high, we tried to compensate for the transmission line losses, which cause "pass-band corner degradation," by optimizing the geometry of the lossy filter with the circuit simulator. Our goal was to achieve minimal losses with flat insertion loss characteristic in the entire pass-band. Fig. 4. shows the equivalent circuit for the filter, while Table II. gives the geometrical data of the CPW lines for the 2 μm version.

TABLE II
CENTERLINE WIDTHS AND LINE LENGTH AT THE CPW LINES FORMING THE FILTER

	Cc[fF]	Lc[pH]	dL[μm]	Zo[Ω]
Dataset-A	80	0	20	50
Dataset-B	38	29	20	Z_{lines}
Dataset-C	423	10	0	-

B. Measurement Results

Fig. 5. compares the measured and the simulated filter characteristics at the filter realized with 2 μm polyimide thickness. Besides the good agreement, we observe relatively high losses in the pass-band, which is common with passive MMIC circuits and can be compensated for by employing amplifiers.

IV. CONCLUSION

We designed a new Cross-T junction for CPW lines and defined its equivalent circuit based on structure simulations verified by measurements. We designed CPW stub filters taking the discontinuities into account by using the equivalent circuit for the Cross-T junctions and by using a simple end-inductance model for the short-ended stubs. Measured and simulated characteristics were in a good agreement. These results suggest that when there are no proper equivalent circuits in commercial circuit simulators, we can take the discontinuities into account successfully by simulating them with 3D structure simulators or extracting their parameters from test element measurements.

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