

Crossing Transmission Line Modeling Using Two-port Measurements

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Abstract

A four-port device, namely crossing transmission line, is measured within a two-port structure. The structures for characterization and verification are manufactured in 65 nm CMOS process. The lumped equivalent model and measured results are matched up to 110 GHz.

1. Introduction

CMOS technology is the best candidate for the unlicensed band at 60 GHz frequency, also considering the cost [1]. A CMOS transceiver to work thoroughly at mm-Wave frequencies, one should have well-known device models beforehand, some of which have more than two-ports. Furthermore, to accurately characterize these devices a manufacturing and measurement cycle is required. During measurements, network analyzers are used commonly, having several specifications, one of which is the dynamic range related with the measurement accuracy. Typical values for two- and four-port measurements up to 67 GHz are around 120 dB. Values are still good for frequencies higher than 67 GHz two-port measurements. Unfortunately, four-port measurements up to 110 GHz, values go down to 80 dB, which considerably affects the accuracies [2]; thus four-port device modeling would be a hard task. Having in mind on these issues, in this work, a crossing transmission line (TL) is modeled using two-port measurement data.

2. Structure and Method

The details of crossing TL, having two different orientations are shown in Fig. 1(a), and (b). The structure is too small for measurement without crosstalk, as probe-to-probe distance should be more than 100 μm , at least [3]. Hence, four Test Element Groups (TEGs) are constructed each of which having six crossing TLs with two different orientations (Fig. 1), and TLs added between them to achieve 200 μm length (Fig. 2). Furthermore, the introduced effect by a single crossing would be too small. Having six of them is also helpful to acquire accurate models.

To model the crossing TL with two-port measurements, ports 3 and 4 for Fig. 1(a), and ports 1 and 2 for Fig. 1(b) orientations, terminated with known loads as open circuited and short circuited TLs with lengths of 104 μm , and 14 μm , respectively. It is important to note that all TLs other than crossing TL have already been characterized [3], in advance. TEGs are manufactured with 65 nm CMOS process. The implemented and measured TEGs are illustrated in Fig. 2 together with the flow of model extraction and verifica-

tion, and a chip micrograph is provided in Fig. 3. For the model construction, two measurement results are used at the same time from two different TEGs which are crossing TL orientation in Fig. 1(a) with ports 3 and 4 are terminated with 104 μm length open circuited TLs, and in the other, crossing TL orientation in Fig. 1(b) with ports 1 and 2 are terminated with 104 μm length open circuited TLs, shown in Fig. 2(a), and (b), respectively. For validation, measurements of TEGs, in which open circuited TLs are replaced with short circuited 14 μm length TLs, shown in Fig. 2(c), and (d), are compared with the extracted model.

3. Results and Lumped Equivalent Model

Model construction is done using the two measurement data as mentioned above. Fig. 4 represents the lumped equivalent model of crossings. Note that subscripts “UP” is for the upper layer lumped components, and “LW” is for the lower layer lumped components. Although the dimensions of crossing TL are small, one should not neglect the parasitic shunt capacitances to ground, and hence C_1 and C_2 are added for upper and lower layers, accordingly. Moreover, C_{COUP} models for the capacitive coupling between the crossing TLs. Using this model the values of the lumped components are optimized using the measurement results of Fig. 2(a), (b); and the results are given in Table I. The S-parameter comparison plots of these measurements and their model equivalents are presented in Fig. 5, in terms of S_{11} and S_{21} , in magnitude (dB) and phase (Degrees). For verification of the model, measurement and model equivalent results of TEGs, presented in Fig. 2(c), (d), are compared in Fig. 6. From both model extraction (Fig. 5) and verification (Fig. 6), one can observe that the model results are well matched up to 110 GHz.

4. Conclusion

In this work, an approach to model a four-port device with two-port measurements is presented. A lumped equivalent model for the crossing TL is constructed using the measurement results of two TEGs. Also, validation of the model is done by comparing the measurement results of unused two TEGs with their modeled versions. The results for both cases are well matched up to 110 GHz.

Acknowledgements

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References

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- [3] N. Li, *et al.*, *IEICE*, 2010, p. 431

Table I. Lumped component values for model

L_{UP}	2.86 pH	L_{LW}	2.13 pH	C_1	2.05 fF
R_{UP}	0.18 Ω	R_{LW}	0.27 Ω	C_2	0.05 fF
C_{UP}	105 fF	C_{LW}	175 fF	C_{COUP}	1.64 fF

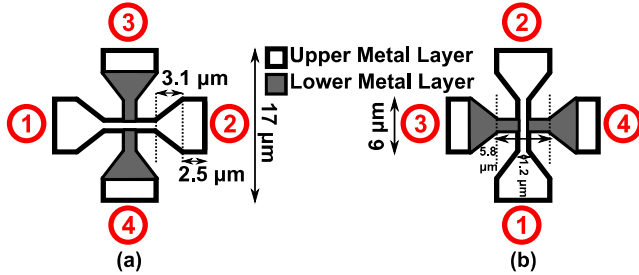


Fig. 1. Detailed structure of crossing TL, and orientations of (a) upper layer thru connected, (b) lower layer thru connected.

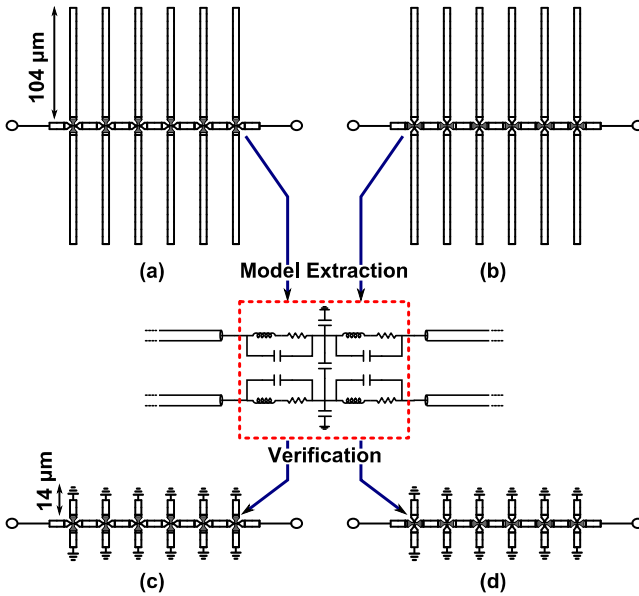


Fig. 2. An illustration of the manufactured TEGs (a)-(d), and crossing TL model extraction and validation flow (middle). (a) Crossing TL orientation as in Fig. 1(a), ports 3 and 4 connected to open circuited TLs, (b) crossing TL orientation as in Fig. 1(b), ports 1 and 2 connected to open circuited TLs, (c) crossing TL orientation as in Fig. 1(a), ports 3 and 4 connected to short circuited TLs, (d) crossing TL orientation as in Fig. 1(b), ports 1 and 2 connected to short circuited TLs.

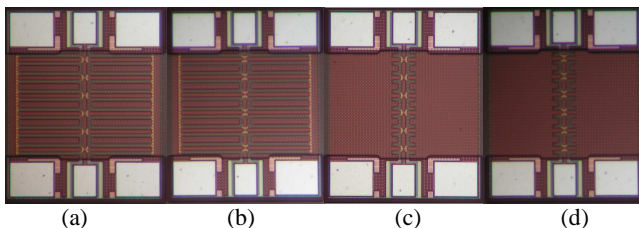


Fig. 3. Chip Micrograph

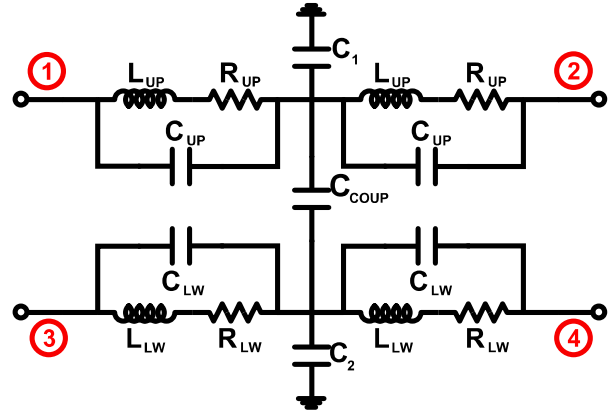


Fig. 4. Lumped equivalent circuit model for crossing TL.

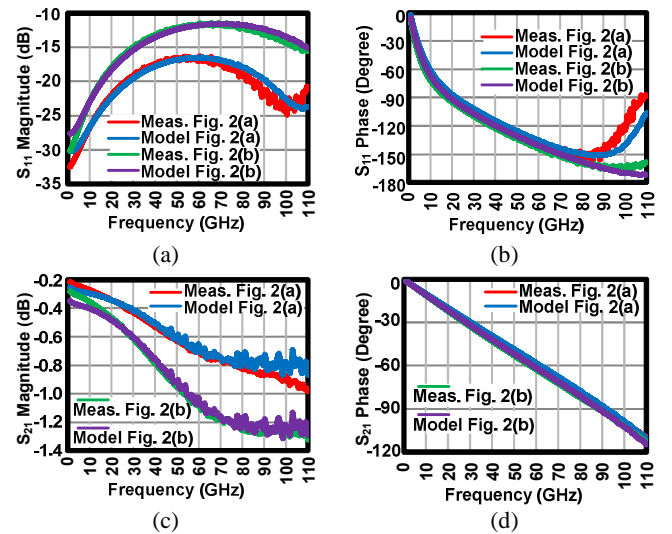


Fig. 5. S-parameter comparison between measurements and extracted models of Fig. 2(a), (b). Plots are given as: (a) Magnitude of S_{11} in dB, (b) Phase of S_{11} in degrees, (c) Magnitude of S_{21} in dB, and (d) Phase S_{21} in degrees.

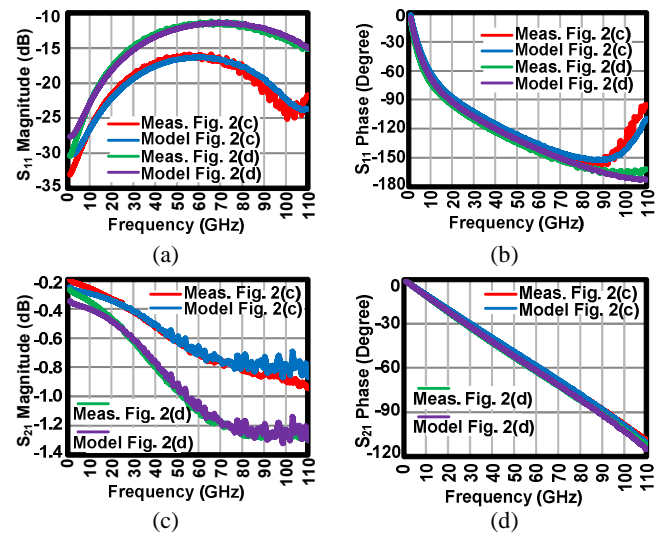


Fig. 6. S-parameter comparison for verification between measurements and extracted models of Fig. 2(c), (d). Plots are given as: (a) Magnitude of S_{11} in dB, (b) Phase of S_{11} in degrees, (c) Magnitude of S_{21} in dB, and (d) Phase S_{21} in degrees.