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B. Kyrysha
National Technical University of Ukraine “KPI”

THE ADVANCED MICROSTRIP X-JUNCTION BROADBAND RF MODEL FOR CIRCUIT CAD/CAM SOFTWARE

This article describes an RF microstrip X-junction model enhancement technique for circuit CAD/CAM software. An example of EM-field modeling results usage for schematic model accuracy improvement was shown. The new model usage boundaries where calculated and tested.

Key words: circuit model, RF, EM-model, X-Junction, microstrip.

Описано спосіб покращення мікросмугової радіочастотної моделі з X-подібним з’єднанням для програмного забезпечення CAD/CAM плат. Показано приклад використання результатів моделювання електромагнітного поля для підвищення точності схематичної моделі. Обчислено та випробувано межі використання нової моделі.

Ключові слова: модель схеми, радіочастоти, електромагнітна модель, X-подібне з’єднання, мікросмуга.

Introduction

Recent RF engineering using CAD/CAM software is often based on three iterations: project description, model, optimization [1]. The automated iterative design process generates a lot of different solutions for manual selection. All models for such CAD/CAM software must be modular with high computational rate and adjustable precision. Most of the broadband RF models with high precision are based on EM-modeling (numerical computational method of Maxwell equations in three dimensions). EM-based models have high precision but computationally heavy and badly parameterized. In contrary to EM-models, circuit models are not computationally demanding and can be programmed for wide range of parameters usage. The main disadvantage of circuit models is low accuracy for signals and parameters which different from predefined models values. The parameters limitations are not suitable for optimization procedures.

Analysis

Selection of coupled transmission structures models is critical in passive circuits design software. Most of such libraries are technology dependent and distributed by manufacturers. Usage of manufacturer depended library is not effective than primary goal is best quality or price/quality value.

The main advantage of the manufacturer’s libraries is high accuracy for supported components models: lines, junctions, passive elements. The accuracy of the manufacturers coupled transmission structures models are based on empirical data tables and their approximations. Such models are tightly connected with equivalent circuit. This is the main reason why models libraries from different manufacturers are often incompatible with each other.

In the contrary, most of RF CAD/CAM software has abstract transmission structures libraries. Such libraries are based on hybrid analytic/empirical models design approaches [2]. Universal models can be really fast but have no possibilities to take into account additional coupling effects on higher frequencies. The abstract models are usable for frequencies up to 5-7 GHz. The resources of lower RF frequencies are highly limited because of wide range of standardized solutions for these frequencies. The coupling effects at higher frequencies require better models independent from manufacturer’s predefined components limitations.

The simplified semi-three-dimensional EM-models (2.5d models) are fast and accurate in comparison to classic EM-models [3]. The accuracy of such models are usually is 10 % or less for S-parameters. The main problem of 2.5d EM-models is complexity of variable parameters implementation: materials properties, geometry. Each geometry value change in EM model requires new volume decomposition and model synthesis, which is time consuming process.

The most effective solution in selection between EM-models and circuit models is old EM-model data usage improvement. The EM-model data can be used for the circuit model accuracy improvement by circuit model elements values approximations (which are similar to manufacturer-dependent library). The equivalent circuit with topology parameter-dependent elements values can be used for the optimization procedures and synthesis tasks more effectively than table-based models. The main limitation of EM-optimized transmission structures models is the equivalent circuit flexibility.

Most of equivalent circuits for RF transmission line structures are simplified versions of analytic descriptions or simplified wave equations. Thus basic equivalent circuits are quite simple and hard to adopt. For higher frequencies better circuit models are required. There are a lot of basic microstrip structures which can be used by designers. In this article only one of them is described: X-junction. The other coupled transition line structures models are published before this article [1].

The advanced equivalent circuit design is a compromise between computationally efficiency and accuracy. For better results few new approximations of elements parameters where made. The advanced version of X-junction circuit model has new approximations for elements values. These approximations utilize possibility of EM-models usage and lesser sensitivity to basic high-frequencies coupling effects analytics.

Original microstrip X-junction structure and circuit model

One of the most popular RF CAD/CAM software is AWR Microwave office [3]. This software utilizes three kinds of models: EM-models, semi-analytic models, tables of S-parameters. These models can be used for test data synthesis and EM models S-parameters calculation. The X-junction structure is shown on Fig. 1. The semi-analytical equivalent circuit is shown on Fig. 2. This model is an improved version of classic analytical model from [2].

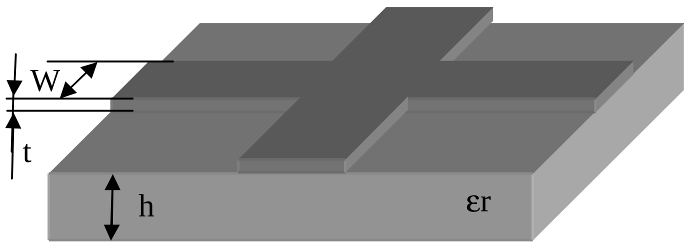

Fig. 1. The microstrip X-junction geometry and parameters list

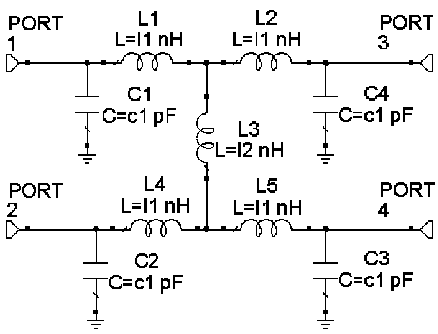

Fig. 2. The basic equivalent circuit of X-junction transmission line

The basic circuit model of X-junction elements values can be calculated by these formulas [2]:

$$\frac{C}{W}=\frac{1}{4}\left[\left(37.61\frac{W}{h}-13.42\left(\frac{W}{h}\right)^{1/2}+159.38\right)\ln\frac{W}{h}+\left(\frac{W}{h}\right)^{3}+74\frac{W}{h}+130\right]\left(\frac{W}{h}\right)^{-1/3}-60\frac{0.5}{W/h}-0.375\frac{W}{h}\left(1-\frac{W}{h}\right), \quad (1)$$

$$\frac{L_1}{h}=\left[\left(165.6\frac{W}{h}+31.2\sqrt{\frac{W}{h}}-11.8\left(\frac{W}{h}\right)^2\right)\frac{W}{h}-32\frac{W}{h}+3\right]\left(\frac{W}{h}\right)^{-3/2}, \quad (2)$$

$$\frac{L_2}{h}=337.5+\frac{1+7/(W/h)}{W/h}-5\frac{W}{h}\cos\left[\frac{p}{2}(1.5-W/h)\right], \quad (3)$$

The relative error of this model is less then 5 % for frequencies up to 7 GHz. The relative error was calculated for the test set of S-parameters in comparison with EM-model results (Fig. 3). The error level of this model is exponentially dependent from W/h. The model parameters are limited by impedances from 25 to 80 Om.

Advanced circuit model

The circuit improvement was based on two assumptions:

- the X-junction model can be improved by better microstrip line model usage[1];
- the more complicated energies distribution given by EM-models requires more elements for equivalent signals dependencies approximations [3].

These assumptions where implemented by multiply inductive connections to the nodes on the corner positions (Fig. 4).

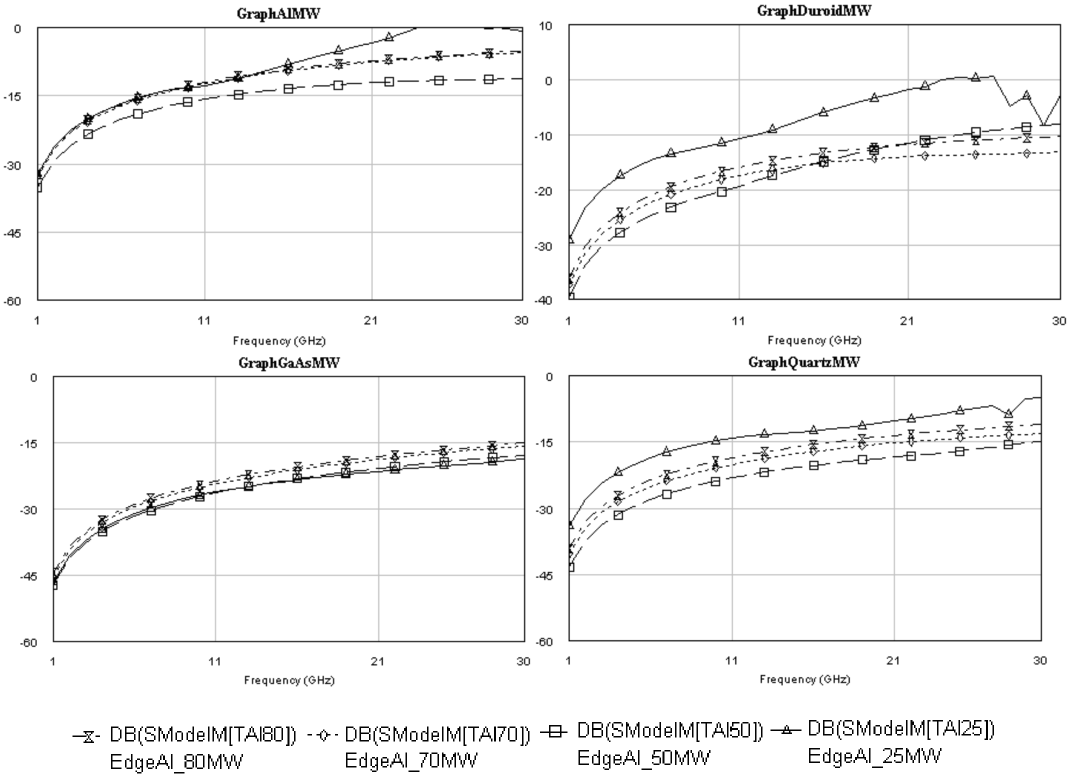

Fig. 3. The relative error to frequency dependencies for the basic X-junction equivalent circuit

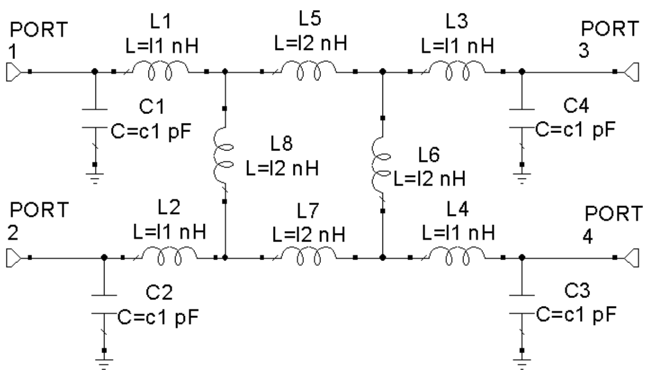

Fig. 4. The improved equivalent circuit of microstrip X-junction

The S-parameters of EM models and the optimized elements values for advanced equivalent circuit are presented in Table 1.

Table 1

Material	Z1	W1	Er	H	C1	L1	L2	Fmax
Al	25	1650	9.8	500	0.154210771	0.49712	-0.12	13
Al	50	475	9.8	500	0.0214	0.5465	-0.1972	23
Al	70	228.8	9.8	500	0	0.643	-0.26	30
Al	80	150	9.8	500	0	0.53	-0.22458	30
Duroid	25	3800	2.5	504	0.1952579	0.448748	-0.0632884	14
Duroid	50	1600	2.5	504	0.0358739	0.47925	-0.112898	24
Duroid	70	850	2.5	504	0.0087	0.5634636	-0.17984729	30
Duroid	80	700	2.5	504	0.005	0.57226	-0.1913749	30
GaAs	25	260	13	100	0.02247	0.116597	-0.0345688	30
GaAs	50	71.3	13	100	-0.000589	0.12828	-0.0507	30
GaAs	70	28.85	13	100	-0.001	0.13779	-0.0606	30
GaAs	80	18	13	100	-0.00159	0.13853	-0.06286	30
Quartz	25	1950	3.3	300	0.11736	0.295	-0.05525	20
Quartz	50	750	3.3	300	0.014	0.314795	-0.0882	30
Quartz	70	400	3.3	300	0.00143	0.339148	-0.11674	30
Quartz	80	300	3.3	300	0.0013	0.3486336	-0.12784	30

For the better equivalent circuit usability the number custom parameters and equations complexity must be limited to minimum. The additional advantage of such approximations simplification is its lesser sensitivity to input parameters deviations. The result approximated elements values can be calculated by:

$$C = \frac{-1.8042 * e_{\mathrm{r}}^{3} + 42.2607 * e_{\mathrm{r}}^{2} + -296.676 * e_{r} + 701.0091}{1000 * e^{2}} e^{-Z/12.5}, \tag{4}$$

$$L_1 = \left(121 - 50.1 \cdot e_r + 8.02 \cdot e_r^2 + -0.365 \cdot e_r^3 + Z \cdot \left(1.14 - 0.513 \cdot e_r + 0.07 \cdot e_r^2 - 0.0028 \cdot e_r^3\right)\right) \cdot 0.01, \tag{5}$$

$$L_{21} = \left(979 - 460.3 \cdot e_r + 31.1 \cdot e_r^2 + -0.21 \cdot e_r^3 + Z \cdot \left(-98 + 43.3 \cdot e_r - 6.23 \cdot e_r^2 + 0.265 \cdot e_r^3\right)\right) \cdot 0.0001. \tag{6}$$

The result model accuracy analysis is shown on Fig. 5.

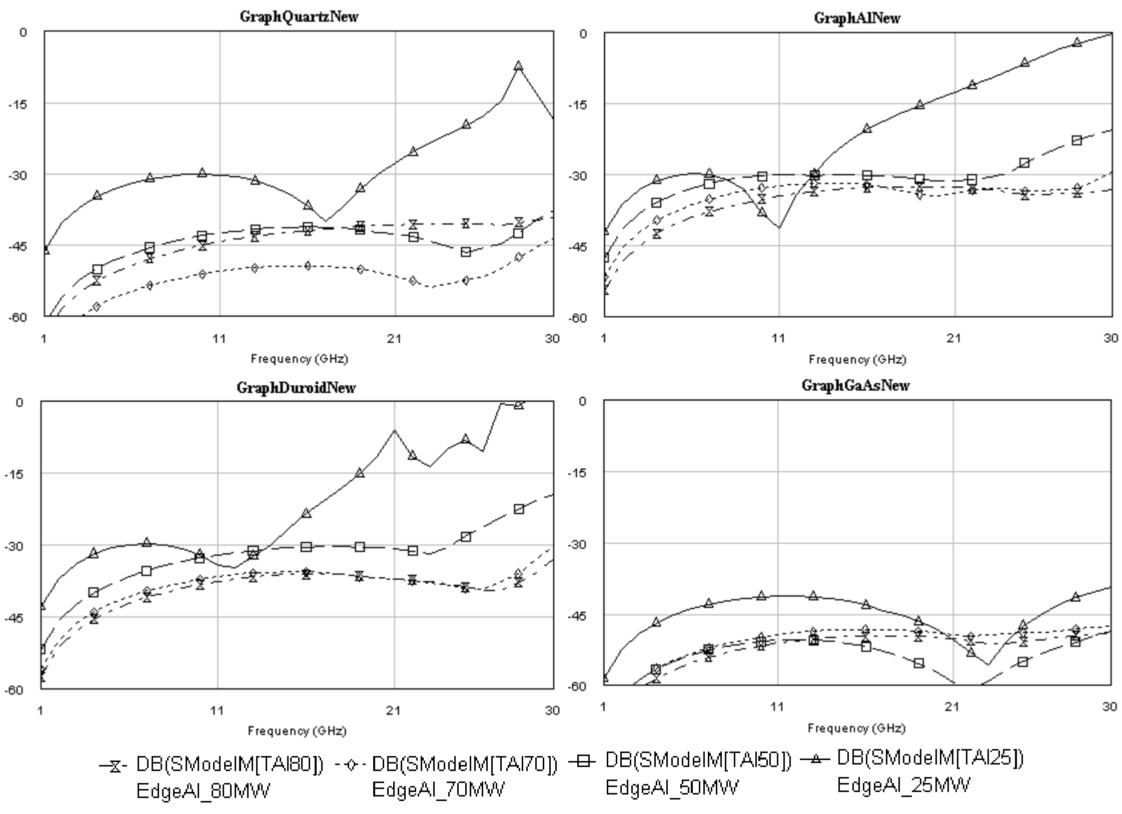

Fig. 5. The relative error to frequency dependency for advanced microstrip X-junction circuit model Conclusion

The hypothesis of better accuracy than basic equivalent circuit by new microstrip model usage was proven. The possibility of large table models numerical and circuit approximation was demonstrated. The advanced microstrip X-junction transmission equivalent circuit was designed and tested. The advanced X-junction circuit model is simple enough to be implemented in regular modern circuit CAD/CAM software.

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V. Bondarchuk, S. Tkachenko
Lviv Polytechnic National University,
Computer-Aided Design Department

DEVELOPMENT OF THE SUBSYSTEM OF THE AUTOMATED GENERATION FOR THE PUBLIC TRANSPORT ALTERNATIVE ROUTES WITH CHANGES

In this paper made the survey modern subsystems of the generation for the public transport routes with changes. Own created subsystem is more functionality and most useful. Geographical coordinates of points on the map are the input information for own subsystem. This coordinates for user input. User should input two or more points on the map. If user will input two points – it will be the start and the end of way and if input more points – it will be way with intermediate points. Public transport routes are model for input data. Model saves in data base. Subsystem result of work shows on the map. If the route goes along the street it is highlighted.

Key words: transport routes, subsystem, Dijkstra's algorithm.

Розглянуто існуючі картографічні підсистеми для генерування маршрутів з пересадками для громадського транспорту. Створено власну підсистему, що має більші функціональні можливості, а тому зручніша для користувача. Вхідною інформацією для підсистеми є географічні координати точок на карті, які задає користувач. Можна або задати дві точки – початок руху та кінець, або вказати проміжні точки, через які має пролягати маршрут. Моделлю для вхідних даних є маршрути громадського транспорту, що зберігаються в базі даних. Результати роботи підсистеми показують в графічному вигляді на карті. Вулиці, якими проходитиме маршрут, підсвічуються.

Ключові слова: транспортні шляхи, пісистема, алгоритм Дейкстри.

Introduction

Several years ago, to replace paper maps and atlases came electronic or interactive maps that allow you to find any objects in seconds – just type the name of the object, click on the appropriate button, and will appear snippets cards. But not only speed refers to the benefits of interactive maps, they have implemented an interactive viewing information. In general, there are three types of maps – maps created