A GENERALIZED SPACE MAPPING TABLEAU APPROACH
TO MICROWAVE DEVICE MODELING

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A GENERALIZED SPACE MAPPING APPROACH TO MICROWAVE CIRCUITS AND DEVICE MODELING

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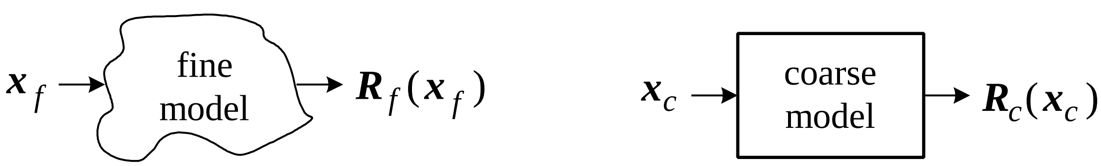
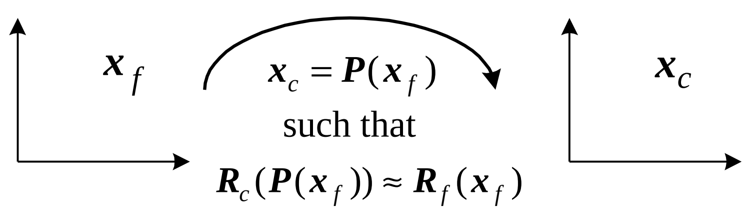
Basic Concepts

Space Mapping (SM) is a powerful tool for circuit design and optimization

two model types are usually defined in the SM: a “coarse” model, typically an empirical model, and a “fine” model, typically a full wave electromagnetic simulator





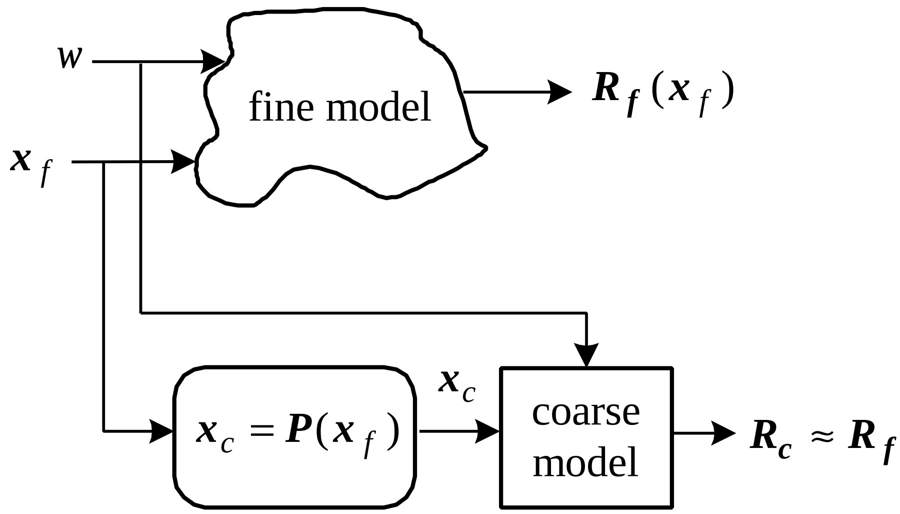
Generalized Space Mapping (GSM)

GSM is a comprehensive framework to engineering device modeling

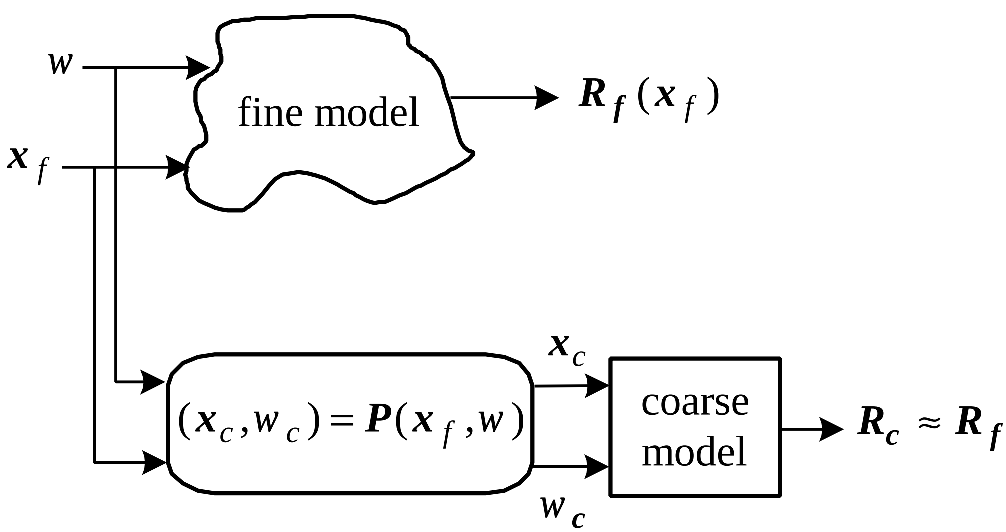
GSM exploits the Space Mapping (SM), the Frequency Space Mapping (FSM) and the Multiple Space Mapping (MSM) concepts to build a new engineering device modeling framework

two cases are considered: the basic Space Mapping Super Model (SMSM) concept and the Frequency-Space Mapping Super Model (FSMSM) concept

Space Mapping Super Model (SMSM)

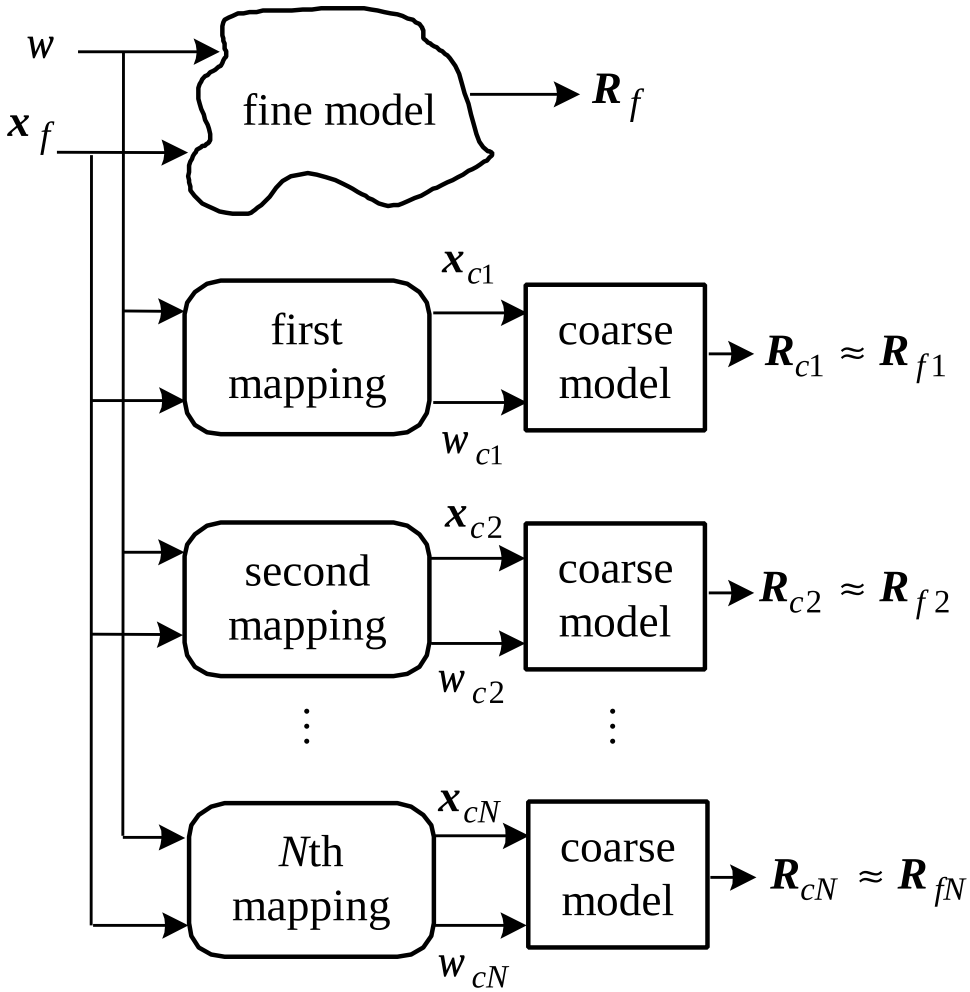


Frequency-Space Mapping Super Model (FSMSM)



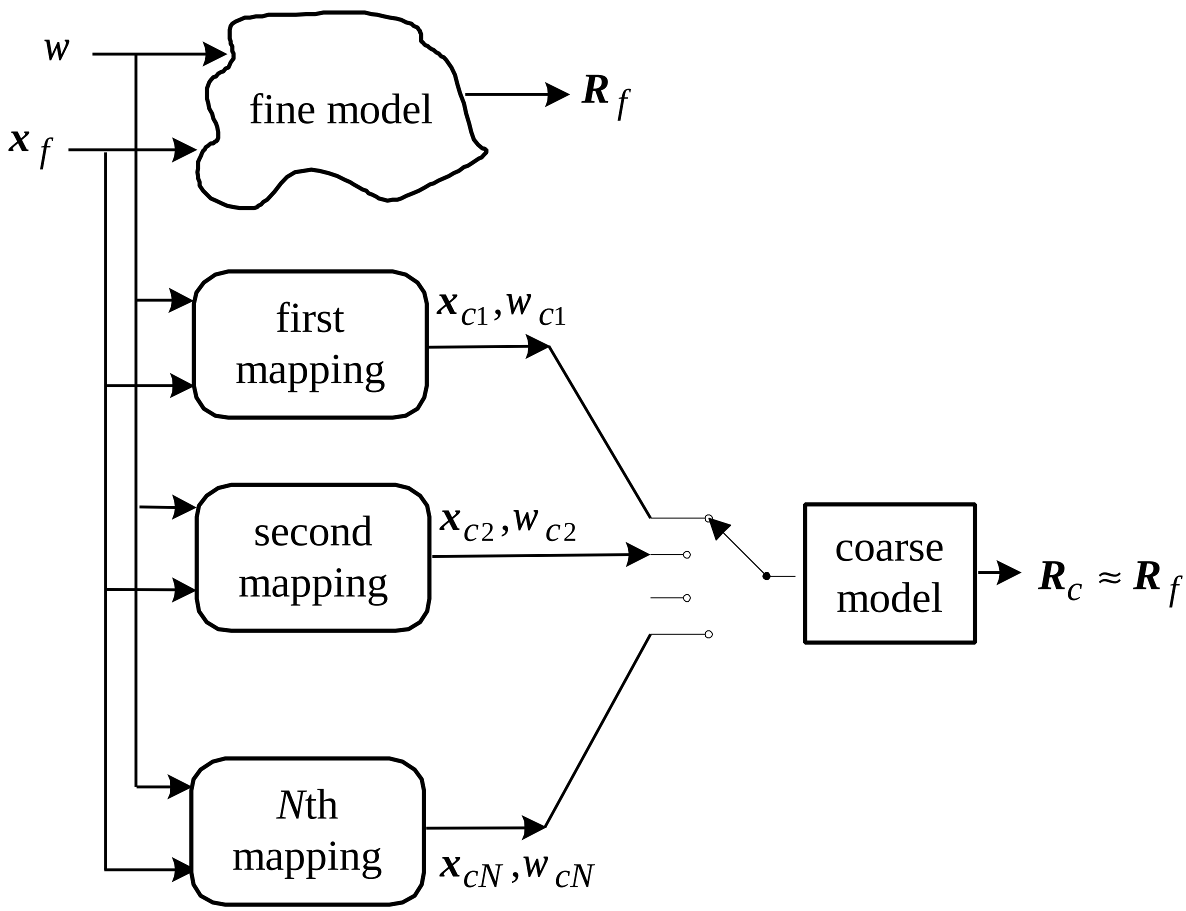
Multiple Space Mapping (MSM) Concept

MSM for different responses



Multiple Space Mapping (MSM) Concept

MSM for different frequency ranges



Mathematical Formulation for GSM

the kth mapping targeting the sub-response $\boldsymbol{R}_k$ or the response $\boldsymbol{R}$ in the kth frequency sub-range is given by

$$(\boldsymbol{x}_{ck}, w_{ck}) = \boldsymbol{P}_k(\boldsymbol{x}_f, w)$$

or, in matrix form, assuming a linear mapping,

$$\begin{bmatrix} \boldsymbol{x}_{ck} \\ w_{ck} \end{bmatrix} = \begin{bmatrix} \boldsymbol{c}_k \\ d_k \end{bmatrix} + \begin{bmatrix} \boldsymbol{B}_k & \boldsymbol{s}_k \\ \boldsymbol{t}_k^T & s_k \end{bmatrix} \begin{bmatrix} \boldsymbol{x}_f \\ w \end{bmatrix}$$

the mapping parameters $\{\boldsymbol{c}_k, \boldsymbol{B}_k, \boldsymbol{s}_k, \boldsymbol{t}_k\ s_k, d_k\}$ can be evaluated, directly or indirectly, by solving the optimization problem

$$\min_{\boldsymbol{c}_k, \boldsymbol{B}_k, \boldsymbol{s}_k, \boldsymbol{t}_k\ s_k, d_k} \left\| [\boldsymbol{e}_{k1}^T \quad \boldsymbol{e}_{k2}^T \quad \cdots \quad \boldsymbol{e}_{km}^T]^T \right\|$$

where m is the number of base points selected in the fine model space and $\boldsymbol{e}_{kj}$ is an error vector given by

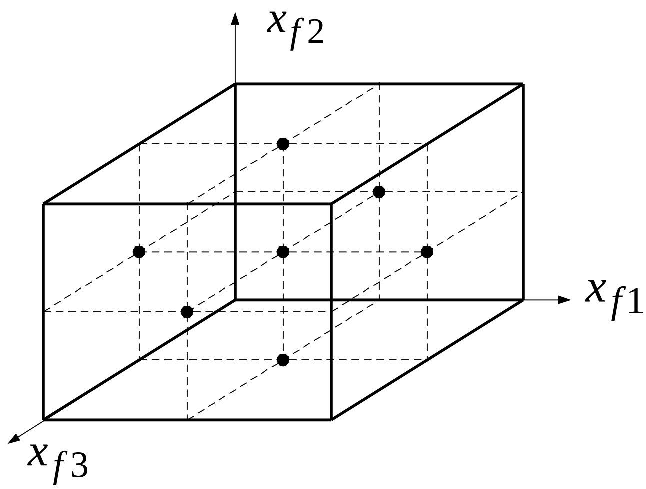
$$\boldsymbol{e}_{kj} = \boldsymbol{R}_f(\boldsymbol{x}_f^{(j)}, w) - \boldsymbol{R}_c(\boldsymbol{x}_{ck}^{(j)}, w_{ck}), \quad j = 1,2,\ldots,m$$

an important variation of the mapping is to use the inverse of the frequency variable (which is proportional to the wavelength) instead of the frequency itself

An Implementation of SMSM and FSMSM

the SMSM for the *k*th mapping can be evaluated through the following steps

choose a set of *m* base points $\{\boldsymbol{x}_f^{(j)},\ j=1,2,...,m\}$ in the fine model space



for each base point $\boldsymbol{x}_f^{(j)}$ the corresponding point $\boldsymbol{x}_c^{(j)}$ in the coarse model space can be obtained by solving a parameter extraction problem

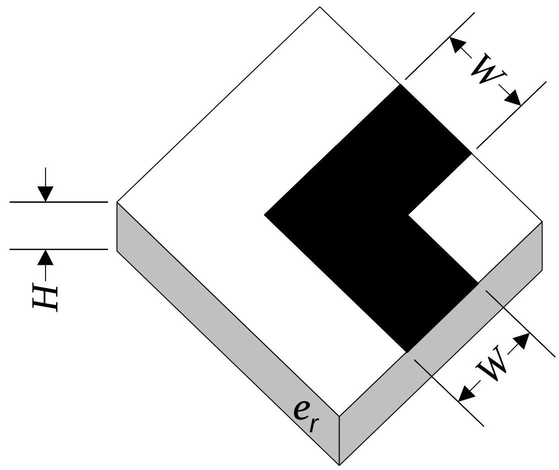
the *k*th mapping parameters $\boldsymbol{c}_k$, $\boldsymbol{B}_k$ can then be evaluated by least-squares

in FSMSM we evaluate $\boldsymbol{c}_k$, $\boldsymbol{B}_k$ as in SMSM and then obtain s_k, d_k by solving

$$\min_{\boldsymbol{s}_k, \boldsymbol{t}_k, s_k, d_k} \left\| \begin{bmatrix} \boldsymbol{e}_{k1}^T & \boldsymbol{e}_{k2}^T & \cdots & \boldsymbol{e}_{km}^T \end{bmatrix}^T \right\|$$

considering $\boldsymbol{c}_k$, $\boldsymbol{B}_k$ fixed

FSMSM for Microstrip Right Angle Bend



Parameter	Minimum	Maximum
W	20 mil	30 mil
H	8 mil	16 mil
e_r	8	10

the fine model is analyzed by Sonnet's ***em*** and the "coarse" model is Jansen empirical model

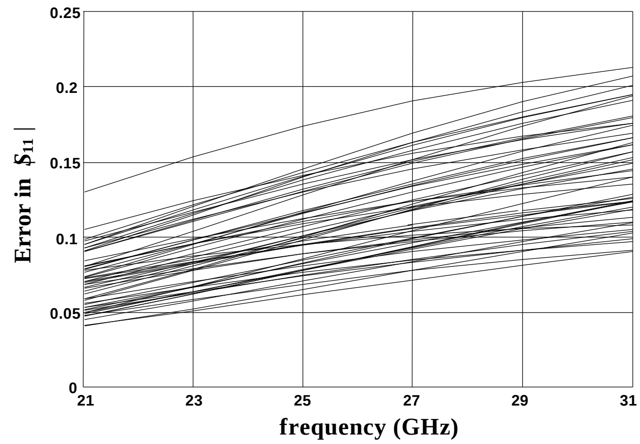
the fine model parameters are given by

$$\boldsymbol{x}_f = [W \quad H \quad e_r]^T$$

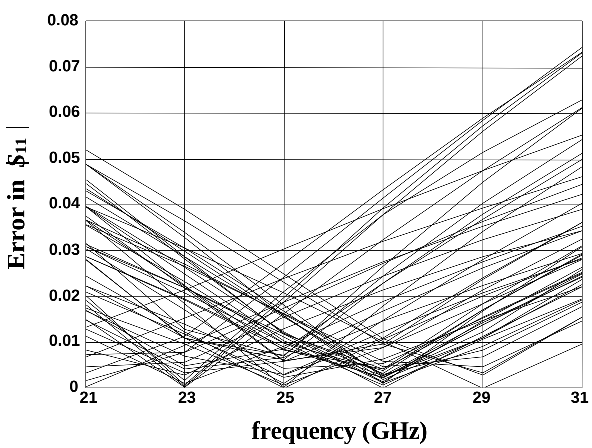
the coarse model parameters are given by

$$\boldsymbol{x}_c = [W_1 \quad H_1 \quad e_{r1}]^T$$

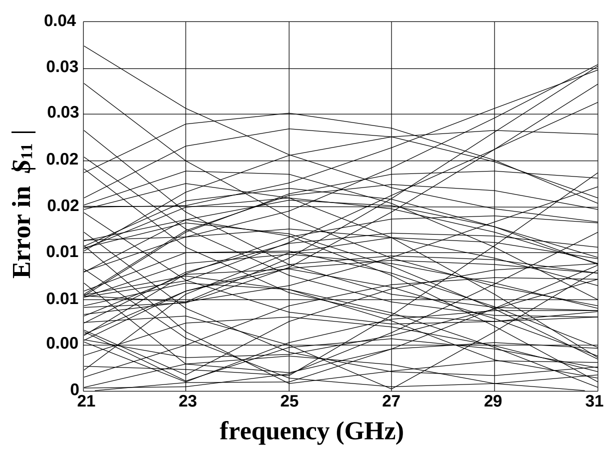
FSMSM for the Right Angle Bend



(before applying SMSM or FSMSM)



(after applying SMSM)



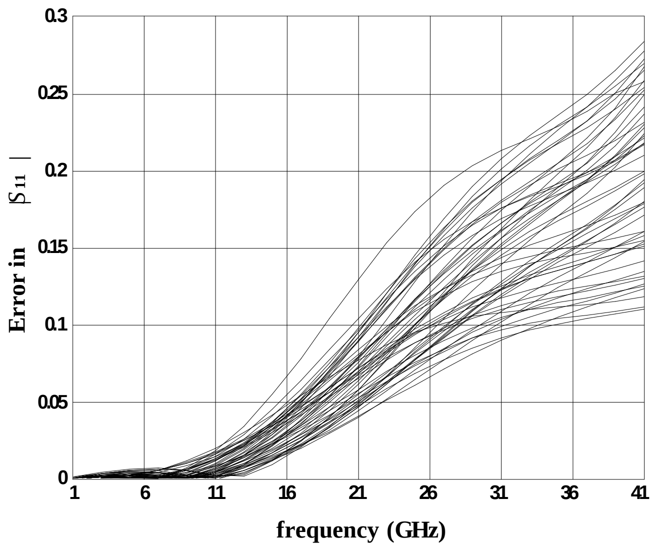
(after applying FSMSM)

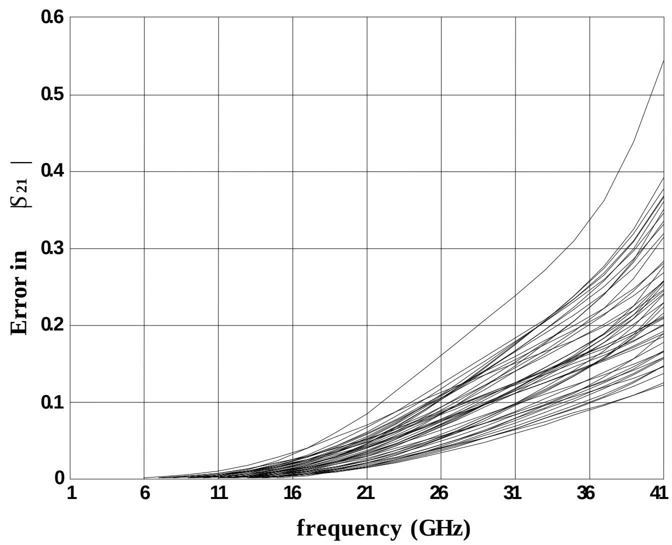
MSM-FSMSM for the Right Angle Bend

Frequency range	$\boldsymbol{B}_k$	$\boldsymbol{c}_k$	s_k	d_k
1 GHz to 11 GHz	**1**	**0**	1	0
11 GHz to 21 GHz	$\begin{bmatrix} 1.81627 & 0.81981 & 0.91555 \\ 0.44352 & 0.30230 & 0.02315 \\ 0.10138 & -0.27993 & 0.33187 \end{bmatrix}$	$\begin{bmatrix} -22.7 \\ -3.822 \\ 1.87 \end{bmatrix}$	1.297	-4.765
21 GHz to 31 GHz	$\begin{bmatrix} 2.33221 & 1.98365 & 2.17360 \\ 0.53802 & 0.54226 & 0.45435 \\ 0.09298 & -0.29729 & 0.28768 \end{bmatrix}$	$\begin{bmatrix} -49.41 \\ -9.324 \\ 2.49 \end{bmatrix}$	1.452	-10.964
31 GHz to 35 GHz	$\begin{bmatrix} 2.77533 & 3.06006 & 2.92395 \\ 0.69924 & 0.81860 & 0.59300 \\ 0.11844 & -0.31135 & 0.26187 \end{bmatrix}$	$\begin{bmatrix} -71.5 \\ -15.2 \\ 2.19 \end{bmatrix}$	1.446	-15.765
35 GHz to 41 GHz	$\begin{bmatrix} 3.94219 & 4.61833 & 4.95400 \\ 1.12763 & 1.33404 & 1.46545 \\ 0.11454 & -0.30212 & 0.26215 \end{bmatrix}$	$\begin{bmatrix} -125.4 \\ -36.13 \\ 1.87 \end{bmatrix}$	1.977	-36.335

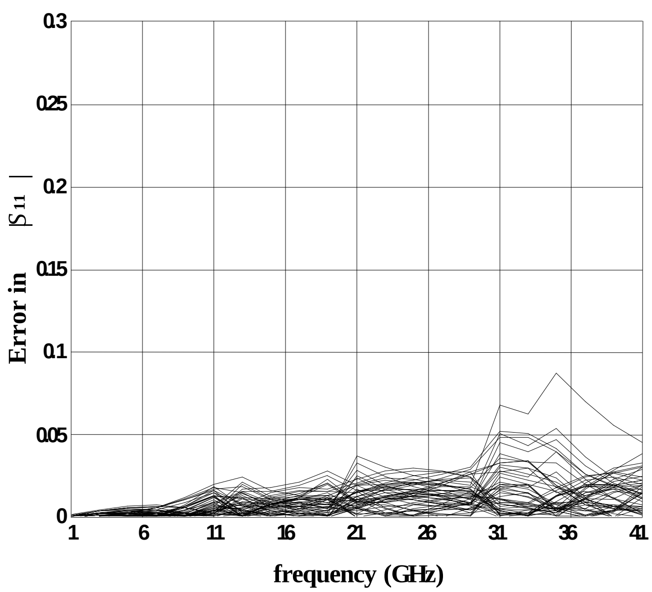
MSM-FSMSM for the Right Angle Bend

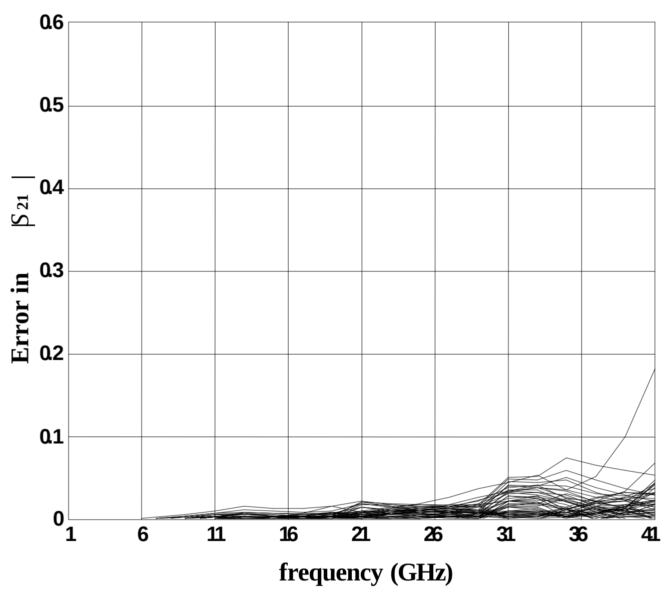
the error in $|S_{11}|$ and $|S_{21}|$ before applying MSM-FSMSM





the error in $|S_{11}|$ and $|S_{21}|$ after applying MSM-FSMSM





Conclusions

we introduce a comprehensive framework called Generalized Space Mapping (GSM) to engineering device modeling

In GSM we utilize a few relevant full-wave EM simulations to match the responses of the fine model and the coarse model over a designable region of parameters and frequency

GSM generalizes the Space Mapping (SM), the Frequency Space Mapping (FSM) and the Multiple Space Mapping (MSM) concepts to build a new engineering device modeling framework

two fundamental concepts are presented: one is a basic Space Mapping Super Model (SMSM) and the other is a basic Frequency-Space Mapping Super Model (FSMSM)

MSM can be combined with SMSM and FSMSM to provide a powerful and reliable modeling tool for microwave devices

more research is being carried out to efficiently evaluate the mappings defined in GSM and to apply the generic GSM concept to enhance the accuracy of microwave circuits