SPACE MAPPING SUPER MODEL CONCEPT

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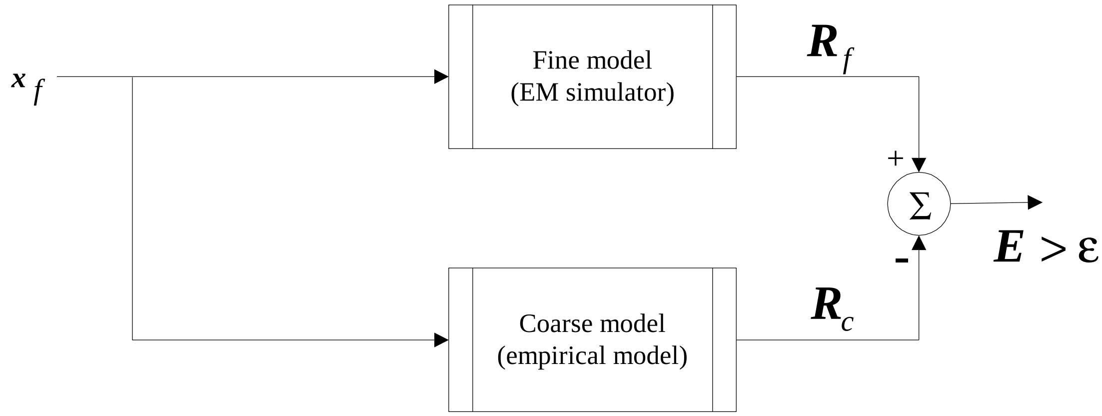
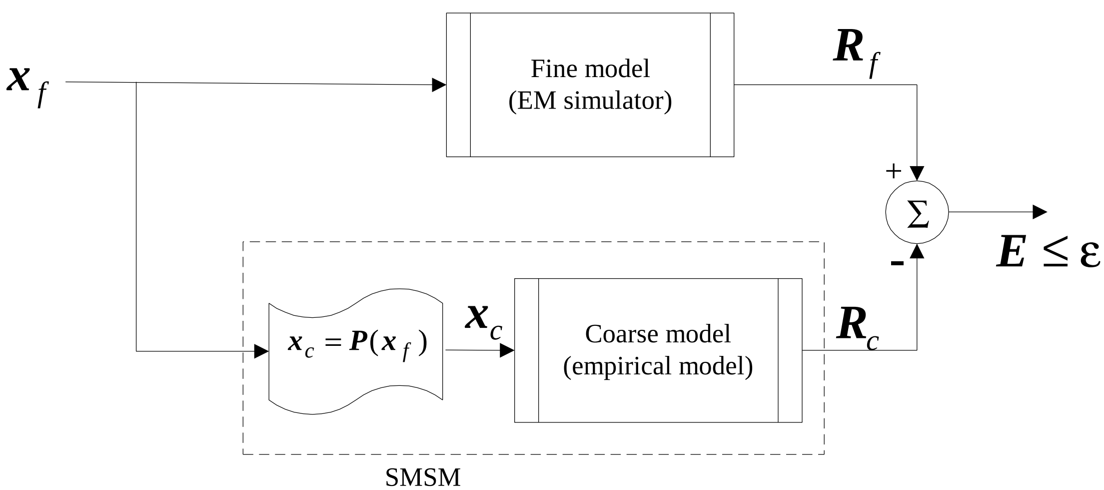
Introduction

EM simulators versus analytical models



how can we improve the accuracy of empirical models?



Introduction

$\boldsymbol{x}_f$: is a vector representing the fine model parameters (the physical parameters)

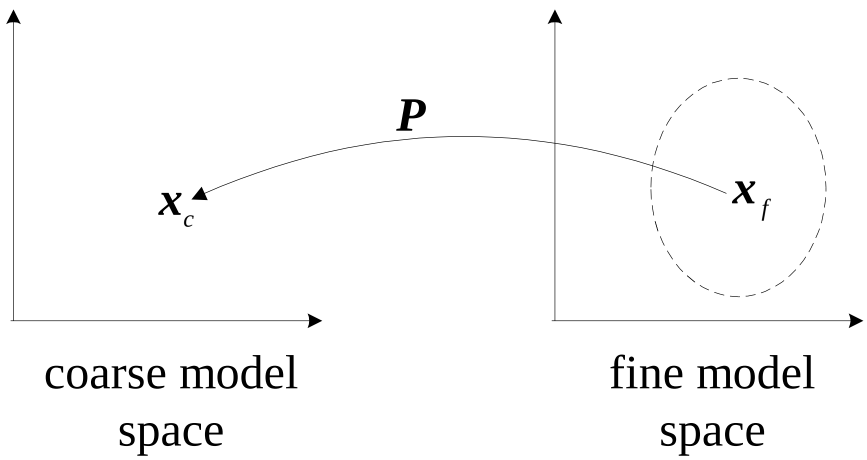
$\boldsymbol{x}_c$: is a vector representing the coarse model parameters

$\boldsymbol{R}_f$: the fine model (EM simulator) response

$\boldsymbol{R}_c$: the coarse model (empirical model) response

the mapping $\boldsymbol{P}$ is established over a region of parameters in the fine model space and in a predefined frequency range

Space Mapping Super Model (SMSM)



$$\boldsymbol{x}_c = \boldsymbol{P}(\boldsymbol{x}_f)$$

such that

$$\left\| \boldsymbol{R}_f(\boldsymbol{x}_f) - \boldsymbol{R}_c(\boldsymbol{x}_c) \right\| \leq \varepsilon$$

in a predefined frequency range $f_{\min} \leq f \leq f_{\max}$

the numerical values given by the mapping $\boldsymbol{P}$ can be obtained by solving the parameter extraction problem (*Bandler et al.*, 1994-1997)

$$\min_{\boldsymbol{x}_c} \left\| \boldsymbol{R}_f(\boldsymbol{x}_f) - \boldsymbol{R}_c(\boldsymbol{x}_c) \right\|$$

Space Mapping Super Model (SMSM)

the mapping $\boldsymbol{P}$ is assumed to be linear, that is

$$\boldsymbol{x}_c = \boldsymbol{P}(\boldsymbol{x}_f) = \boldsymbol{B}\,\boldsymbol{x}_f + \boldsymbol{C}$$

where

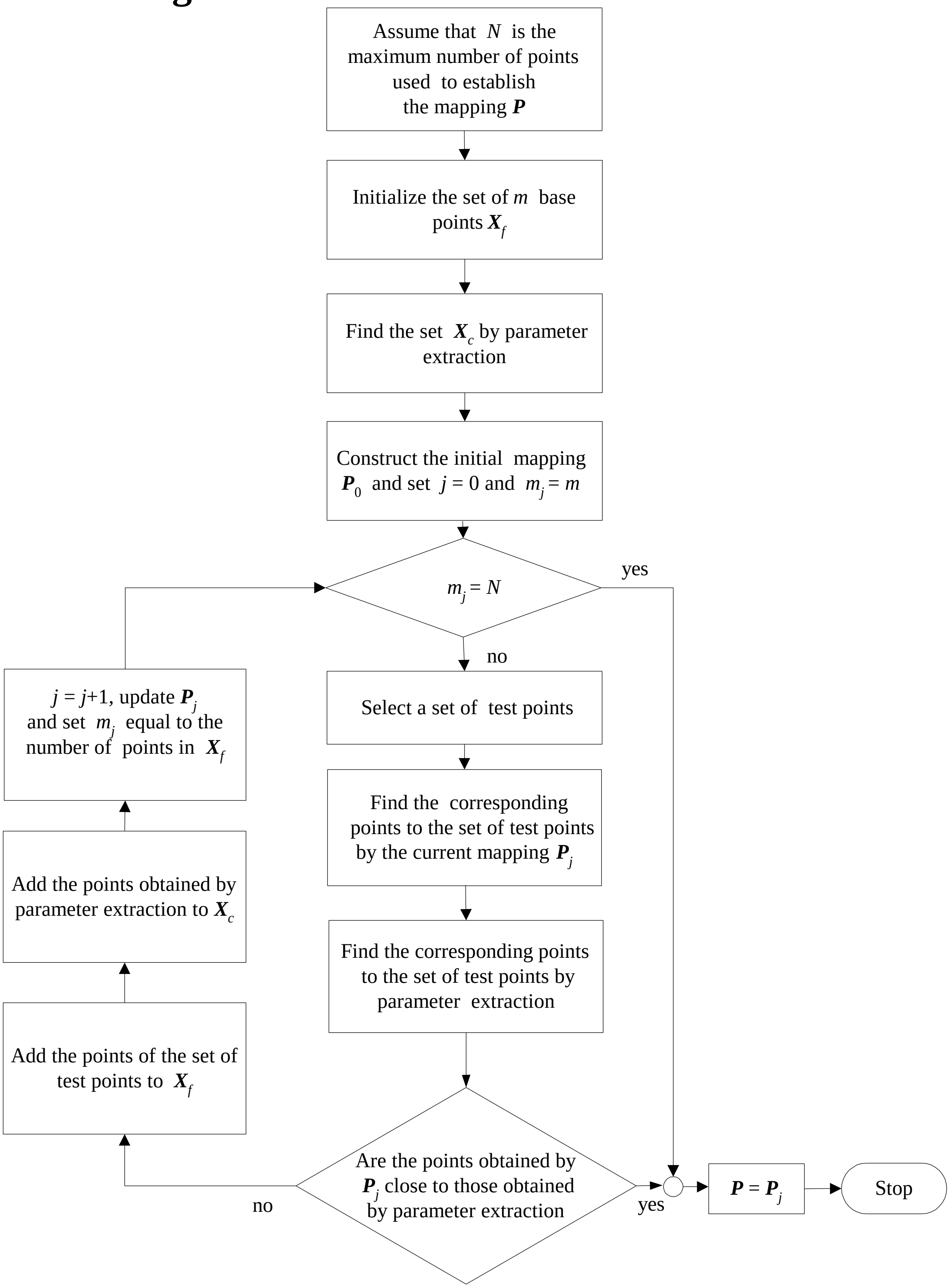
$\boldsymbol{x}_f$: a vector of dimension n_1

$\boldsymbol{x}_c$: a vector of dimension n_2

$\boldsymbol{B}$: an n_2xn_1 matrix of constant coefficients

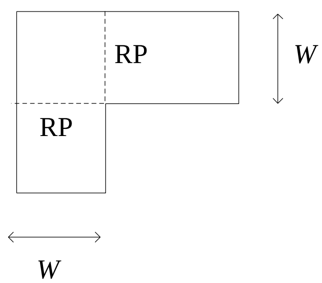
$\boldsymbol{C}$: a constant vector of dimension n_2

SMSM Algorithm

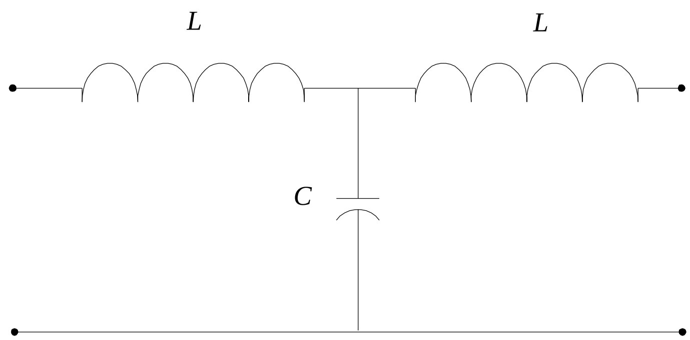


Example 1

Right Angle Bend



(a)
right angle bend
(W, H, e_r)



(b)
the equivalent circuit of the right

the capacitance C and the inductance L are computed from (*Gupta et al.*, 1979)

the range of the parameters W, H, and e_r are

Parameter	Minimum value	Maximum value
W	20 mil	30 mil
H	8 mil	16 mil
ε_r	8	10

Right Angle Bend

the mapping $\boldsymbol{P}$ is defined by

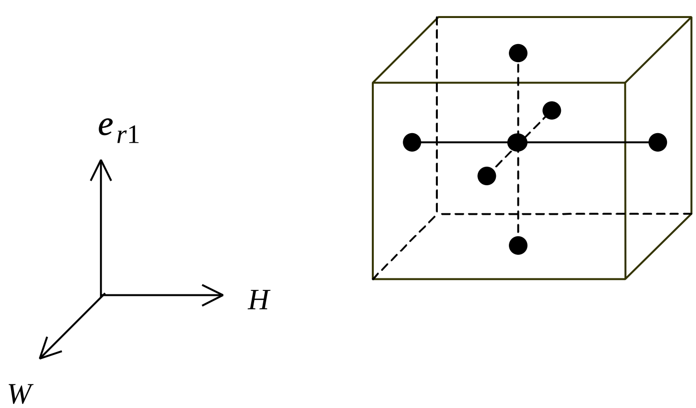
$$\boldsymbol{x}_c = \boldsymbol{P}(\boldsymbol{x}_f) = \boldsymbol{B}\,\boldsymbol{x}_f + \boldsymbol{C}$$

where

$$\boldsymbol{x}_f = \begin{bmatrix} W \\ H \\ \varepsilon_r \end{bmatrix}, \quad \boldsymbol{x}_c = \begin{bmatrix} W_1 \\ H_1 \\ \varepsilon_{r1} \end{bmatrix}$$

where W_1, H_1 and ε_{r1} are the parameters to be used by the empirical model in order to match its response with that obtained by Sonnet ***em*** simulator

only 7 simulation sweeps at 7 points in the space were used



Right Angle Bend

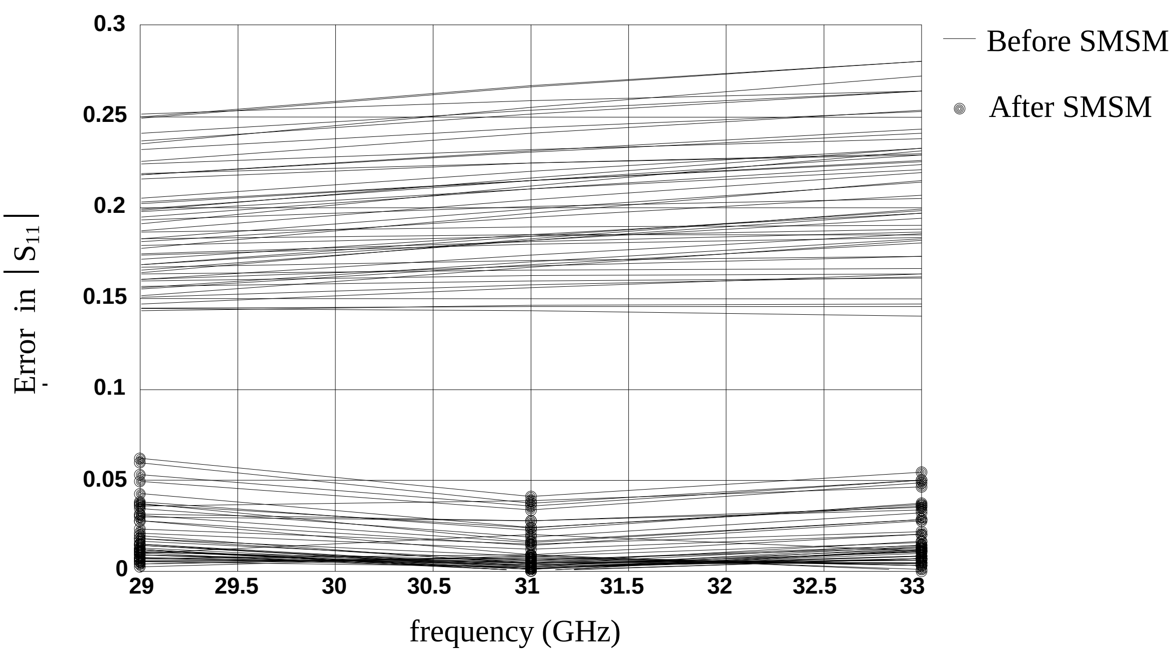
The mapping parameters $\boldsymbol{B}$ and $\boldsymbol{C}$ in the frequency range from 29 GHz to 33 GHz are

$$\boldsymbol{B} = \begin{bmatrix} 0.4600 & 1.6788 & 0.4442 \\ -0.1808 & 1.1474 & -0.1997 \\ 0.4484 & -1.0337 & 1.2115 \end{bmatrix}, \quad \boldsymbol{C} = \begin{bmatrix} -11.45 \\ 3.58 \\ 4.64 \end{bmatrix}$$

Right Angle Bend

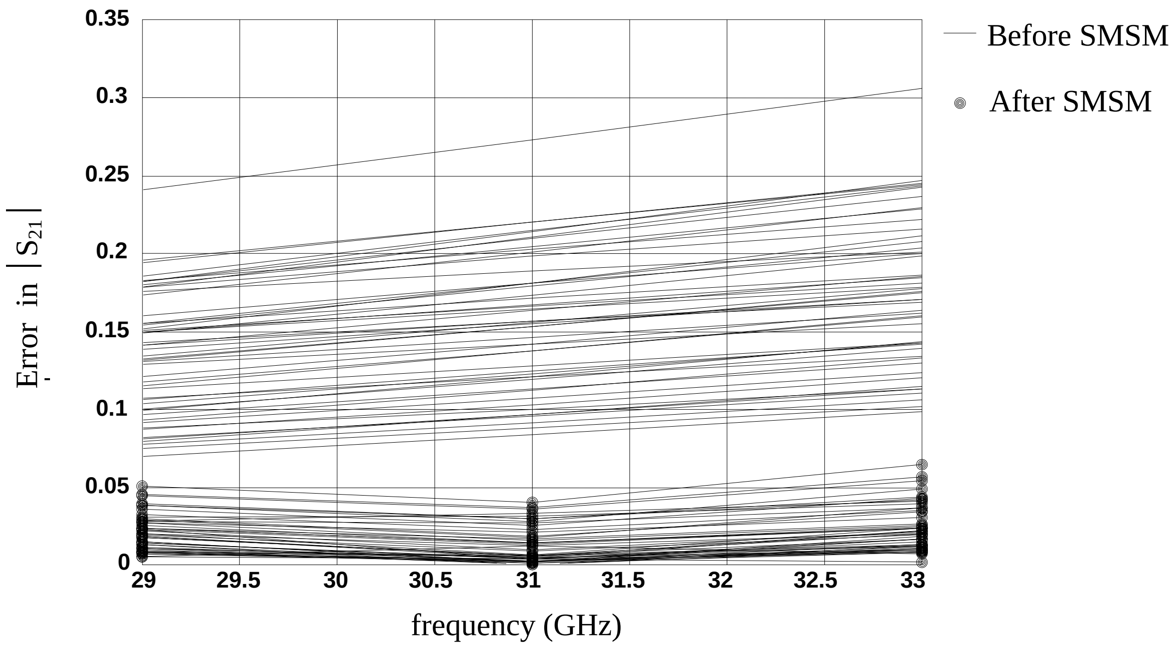
the SMSM was tested at 50 uniformly distributed random points in the region of the fine model parameters.

the difference in $|S_{11}|$ computed by Sonnet ***em*** simulator and by (*Gupta et al.*, 1979) empirical model before and after applying SMSM



Right Angle Bend

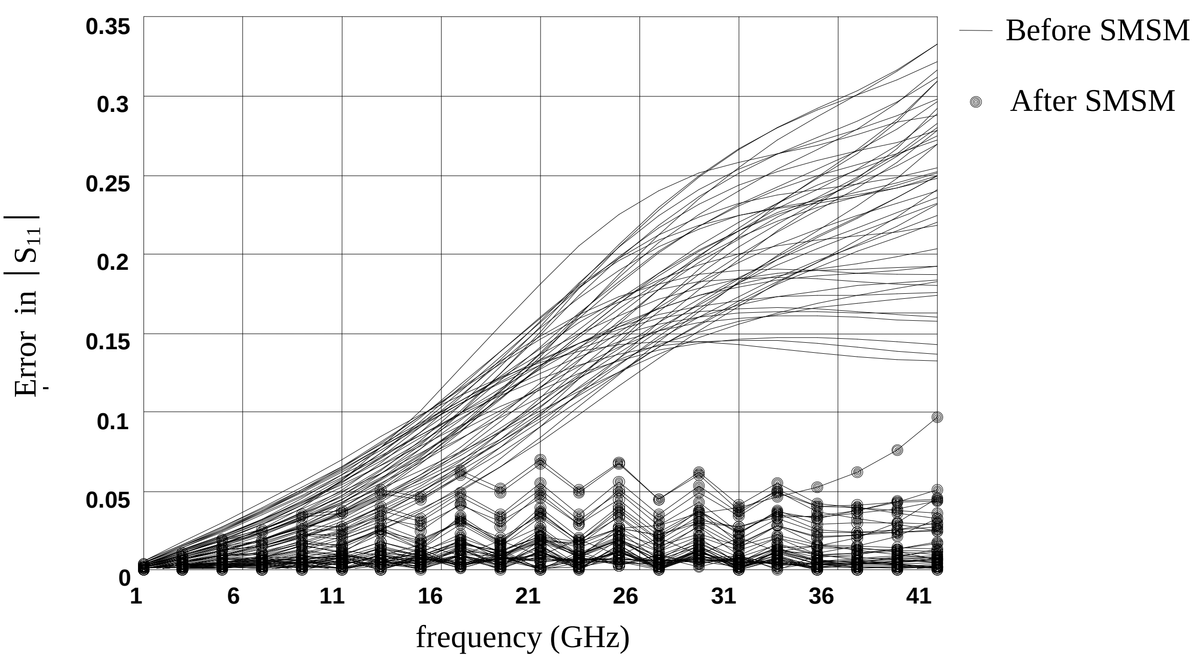
the difference in $|S_{21}|$ computed by Sonnet ***em*** simulator and by (*Gupta et al.*, 1979) empirical model before and after applying SMSM



Right Angle Bend

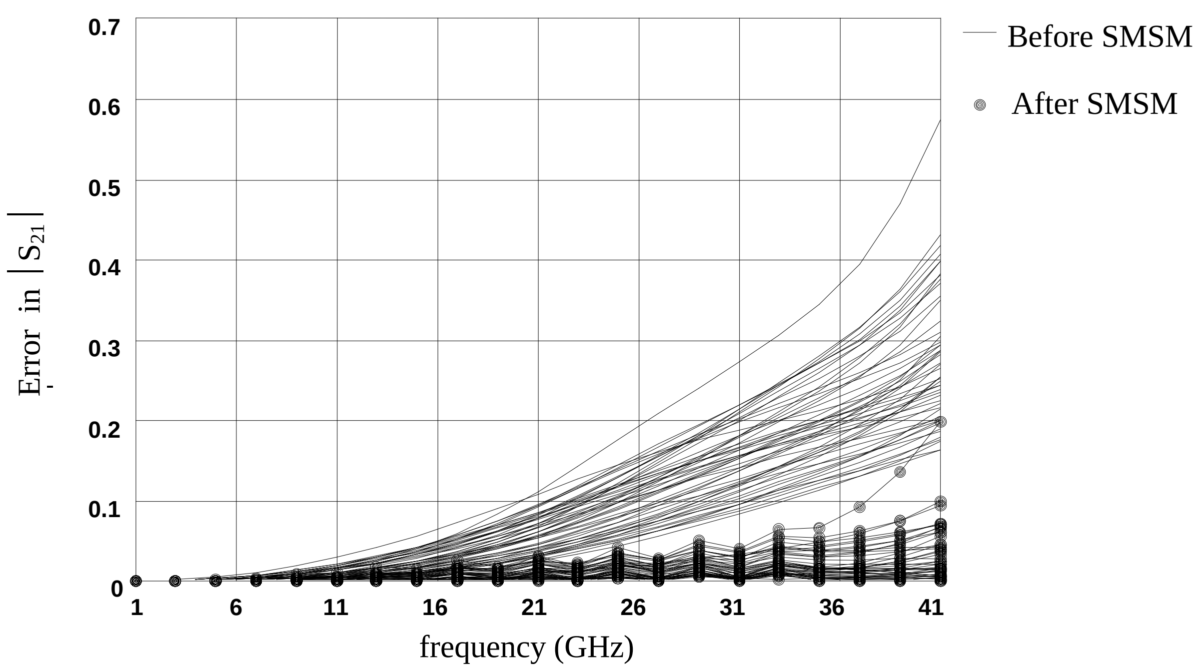
the results of applying SMSM in the frequency range 1 GHz to 41 Ghz

the difference in $|S_{11}|$ computed by Sonnet ***em*** simulator and by (*Gupta et al.*, 1979) empirical model before and after applying SMSM



Right Angle Bend

the difference in $|S_{21}|$ computed by Sonnet ***em*** simulator and by (*Gupta et al.*, 1979) empirical model before and after applying SMSM



Example 2

Microstrip Line with High Dielectric Constant

the fine model is the Sonnet ***em*** simulator with parameters given by

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

the coarse model is Jansen empirical model with parameters given by

$$\boldsymbol{x}_c = [W_1 \quad L_1 \quad H_1 \quad \varepsilon_{r1}]^T$$

the frequency range

$$3.7\,\text{GHz} \le f \le 4.1\,\text{GHz}, \quad \Delta f = 0.05\,\text{GHz}$$

the region of parameters in the fine model space is defined in the following table

Parameter	Minimum value	Maximum value
W	5 mil	9 mil
L	15 mil	25 mil
H	40 mil	60 mil
ε_r	20	25

the mapping ***P*** is defined by

$$\boldsymbol{x}_c = \boldsymbol{P}(\boldsymbol{x}_f) = \boldsymbol{B}\ \boldsymbol{x}_f + \boldsymbol{C}$$

Microstrip Line with High Dielectric Constant

where

$$\boldsymbol{x}_f = \begin{bmatrix} W \\ L \\ H \\ \varepsilon_r \end{bmatrix}, \quad \boldsymbol{x}_c = \begin{bmatrix} W_1 \\ L_1 \\ H_1 \\ \varepsilon_{r1} \end{bmatrix}$$

only 9 simulation sweeps at 9 points in the space were used

The matrix $\boldsymbol{B}$ and the vector $\boldsymbol{C}$ are given by

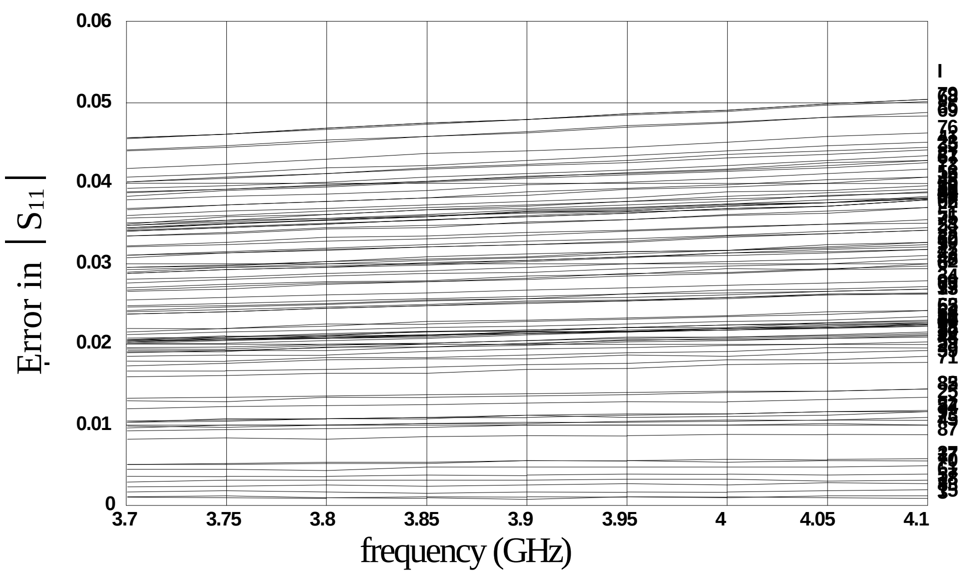
$$\boldsymbol{B} = \begin{bmatrix} 1.11322 & -0.00521 & 0.05229 & -0.00088 \\ -0.13860 & 0.89951 & -0.23090 & -0.01242 \\ -0.07667 & 0.01254 & 0.79066 & 0.00074 \\ -0.02085 & -0.02777 & 0.21448 & 1.07136 \end{bmatrix},$$

$$\boldsymbol{C} = \begin{bmatrix} -0.96425 \\ 6.91249 \\ 2.47249 \\ -2.58961 \end{bmatrix}$$

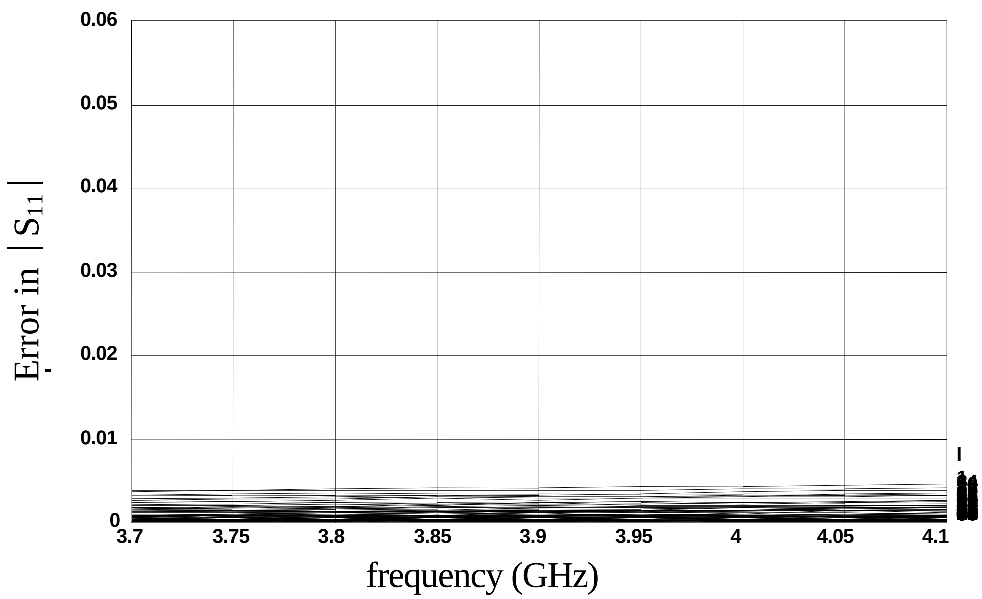
the SMSM was tested at 100 uniformly distributed random points in the region of interest

Microstrip Line with High Dielectric Constant

the difference in $|S_{11}|$ computed by Sonnet ***em*** simulator and by Jansen empirical model before applying SMSM

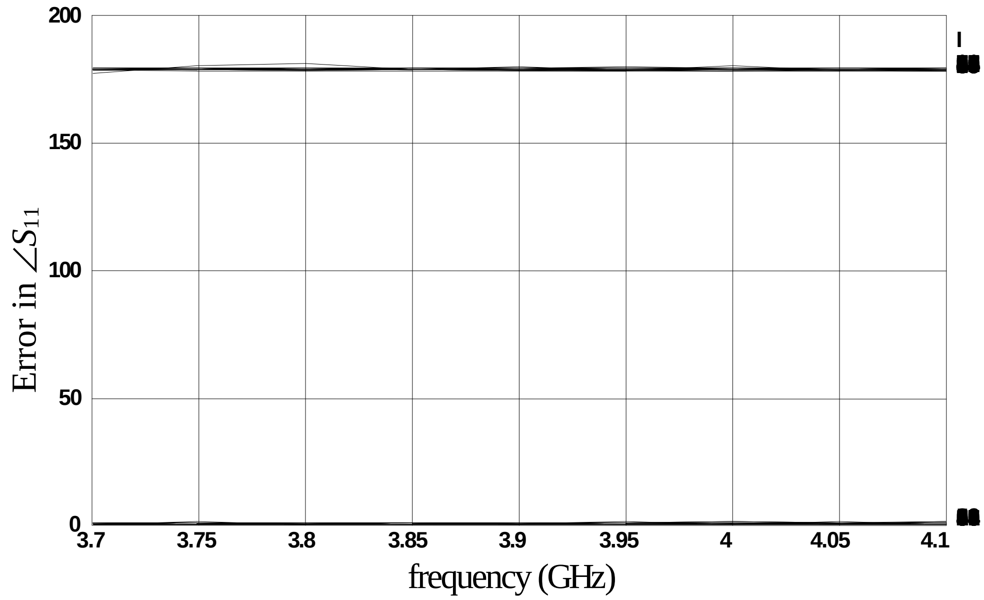


the difference in $|S_{11}|$ computed by Sonnet ***em*** simulator and by Jansen empirical model after applying SMSM



Microstrip Line with High Dielectric Constant

the difference in the phase of S_{11} computed by Sonnet ***em*** simulator and by Jansen empirical model before applying SMSM



the difference in the phase of S_{11} computed by Sonnet ***em*** simulator and by Jansen empirical model after applying SMSM