MODELING OF MICROWAVE CIRCUITS EXPLOITING SPACE DERIVATIVE MAPPING

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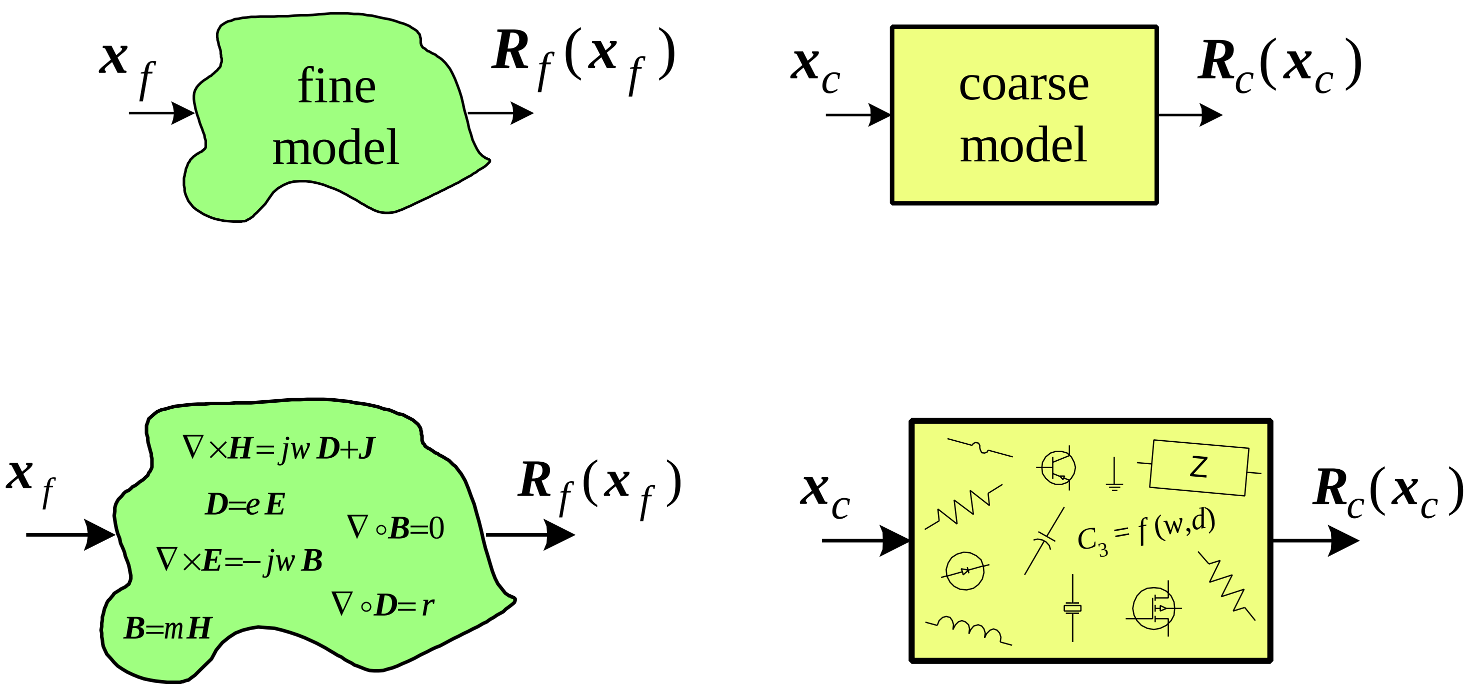
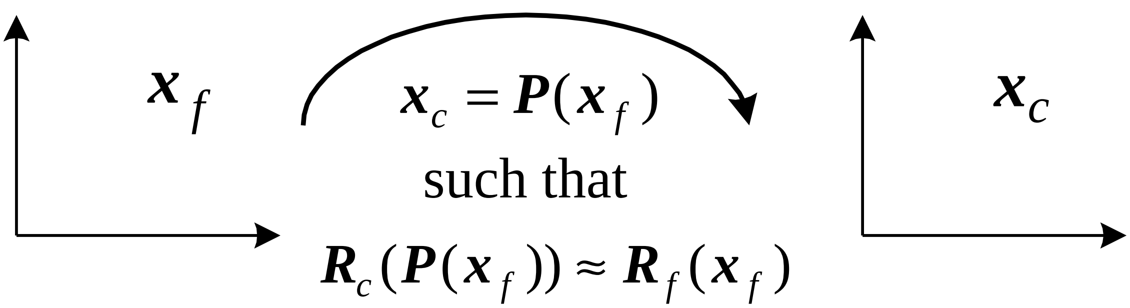
The Aim of Space Mapping

(Bandler et al., 1994-)





The Derivative Space Mapping

assume that $\boldsymbol{x}_c$ corresponds to $\boldsymbol{x}_f$ through a parameter extraction process

the Jacobian $\boldsymbol{J}_f$ of the fine model response at $\boldsymbol{x}_f$ and the Jacobian $\boldsymbol{J}_c$ of the coarse model response at $\boldsymbol{x}_c$ are related by

$$\boldsymbol{J}_f = \boldsymbol{J}_c \boldsymbol{B}$$

where $\boldsymbol{B}$ is a valid mapping at $\boldsymbol{x}_c$ and $\boldsymbol{x}_f$

consequently

$$\boldsymbol{B} = \left(\boldsymbol{J}_c^T \boldsymbol{J}_c\right)^{-1} \boldsymbol{J}_c^T \boldsymbol{J}_f$$

The Algorithm

suppose we need a fast and accurate approximation to the fine model response near a particular point $\boldsymbol{x}_{em}^{*}$

we denote by $\boldsymbol{J}_{em}^{*}$ the Jacobian of the fine model responses at $\boldsymbol{x}_{em}^{*}$ w.r.t. $\boldsymbol{x}_{em}$

the point $\bar{\boldsymbol{x}}_{os}$ corresponding to $\boldsymbol{x}_{em}^{*}$ is obtained through the parameter extraction step

$$\bar{\boldsymbol{x}}_{os} = arg\left\{ \min_{\boldsymbol{x}_{os}} \left\| \boldsymbol{R}_{em}(\boldsymbol{x}_{em}^{*}) - \boldsymbol{R}_{os}(\boldsymbol{x}_{os}) \right\| \right\}$$

the Jacobian $\bar{\boldsymbol{J}}_{os}$ of the coarse model responses at $\bar{\boldsymbol{x}}_{os}$ may be estimated by perturbation

the matrix $\boldsymbol{B}$ is then estimated by

$$\boldsymbol{B} = \left(\bar{\boldsymbol{J}}_{os}^{T} \bar{\boldsymbol{J}}_{os} \right)^{-1} \bar{\boldsymbol{J}}_{os}^{T} \boldsymbol{J}_{em}^{*}$$

the Space Derivative Mapping (SDM) model is simply given by

$$\boldsymbol{R}_{em}(\boldsymbol{x}_{em}) \approx \boldsymbol{R}_{os}(\bar{\boldsymbol{x}}_{os} + \boldsymbol{B}(\boldsymbol{x}_{em} - \boldsymbol{x}_{em}^{*}))$$

the SDM model should enjoy a wide region of validity as the two models are assumed to share the same physical structure

Two-Section WaveguideTransformer
(*Bandler, 1969*)

the coarse model is an “ideal” analytical model which neglects the junction discontinuity effects

the fine model is a more accurate “nonideal” analytical model which includes the junction discontinuity effects

optimizable parameters are the height and the length of each waveguide section.

the fine model is optimized using the OSA90/hope minimax optimizer

an estimate for the Jacobian of the fine model response is then obtained

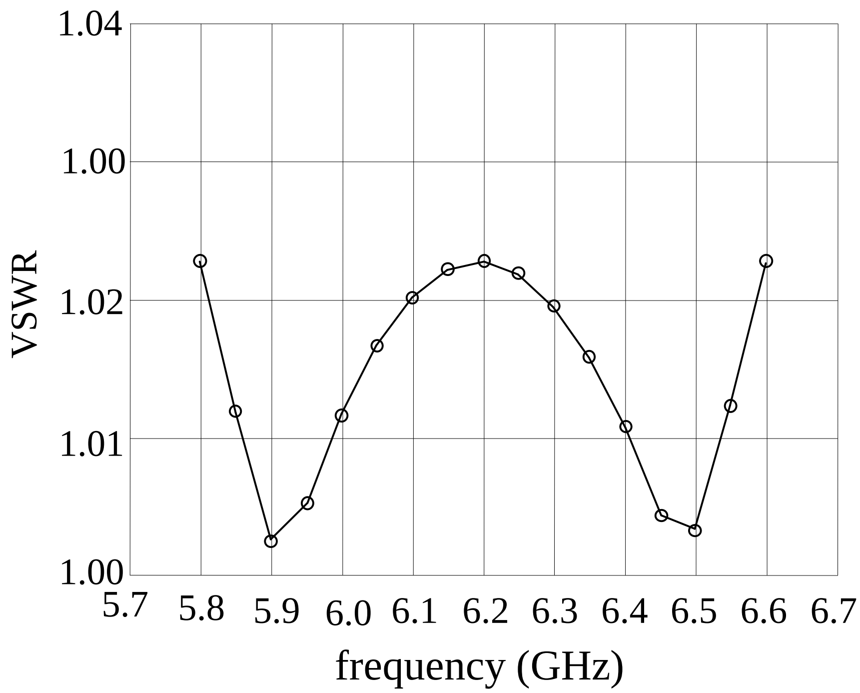
parameter extraction is applied to get $\bar{\boldsymbol{x}}_{os}$ and the Jacobian of the coarse model $\bar{\boldsymbol{J}}_{os}$ is obtained using perturbation

the matrix $\boldsymbol{B}$ is estimated using SDM

the established mapping can be utilized in SDM statistical analysis

Two-Section WaveguideTransformer

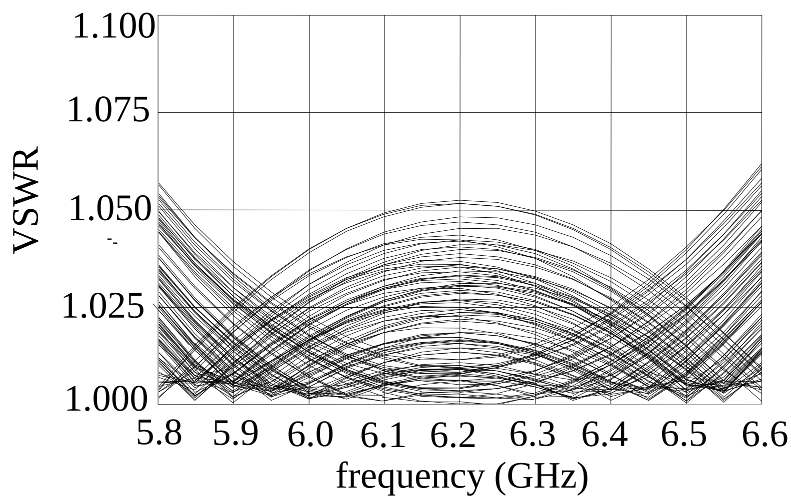
(*Bandler, 1969*)



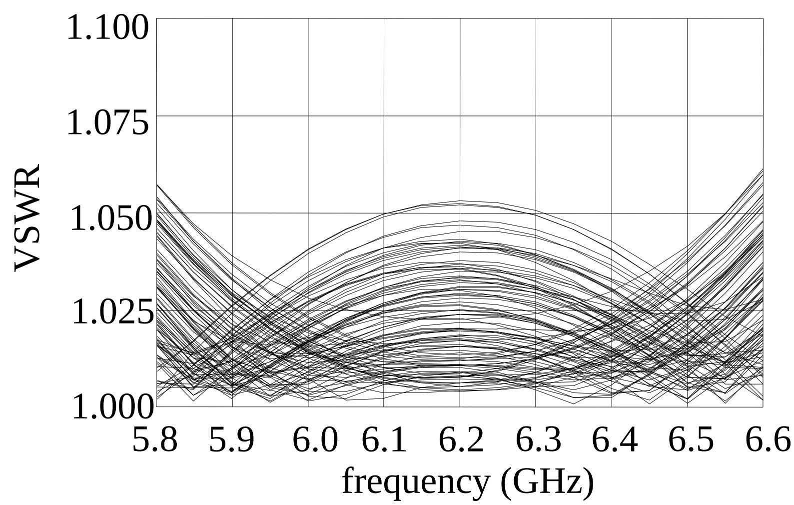
fine model response (o) and coarse model response (—) at the corresponding points

Statistical Analysis Using the SDM Model

1.0% tolerance



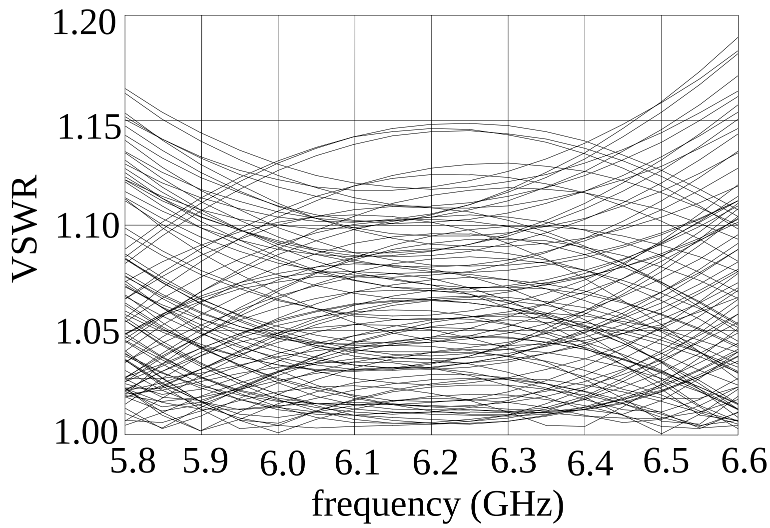
using Space Derivative Mapping



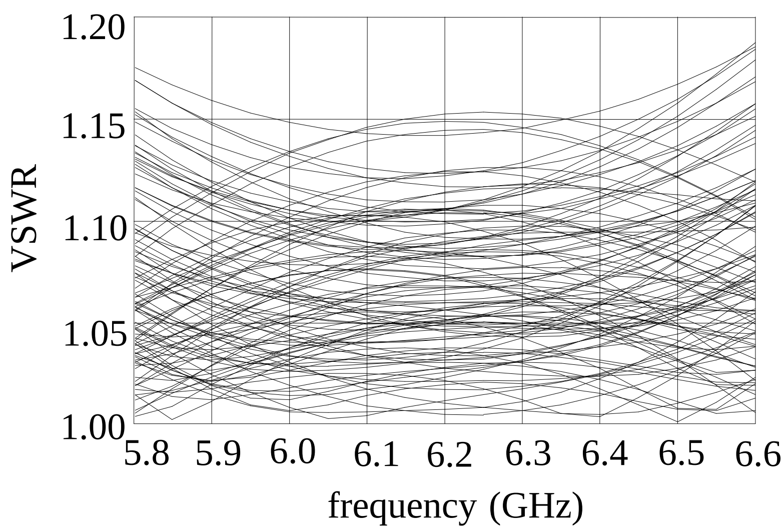
using fine model simulations

Statistical Analysis Using the SDM Model

4.0% tolerance



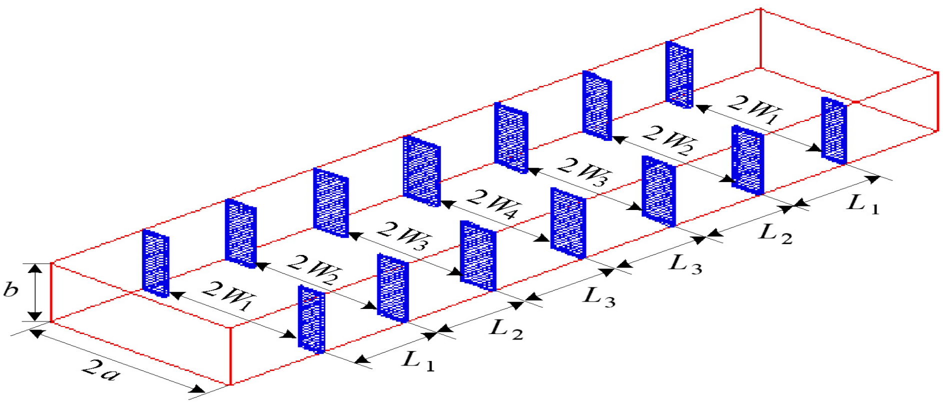
using Space Derivative Mapping



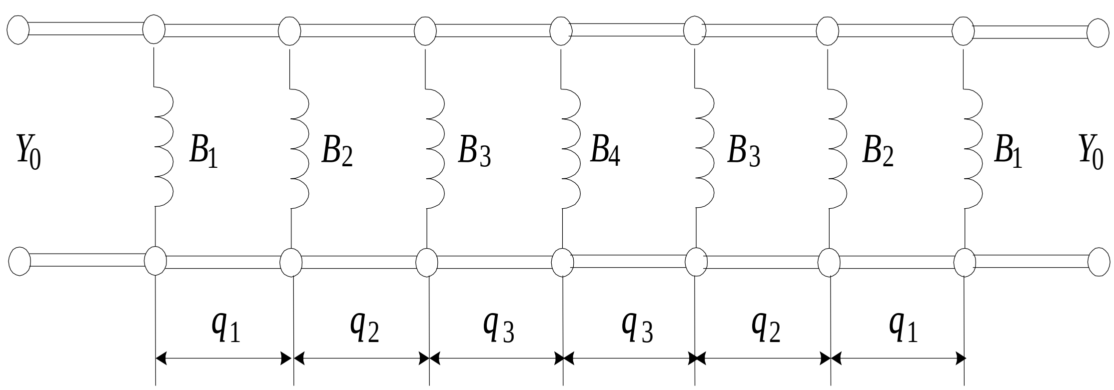
using fine model simulations

Six-Section H-Plane Filter

(*Matthaei et al., 1964, Bakr et al., 1999*)



the fine model



the coarse model

optimizable parameters are the septa widths W_1, W_2, W_3 and W_4 and lengths L_1, L_2 and L_3

the fine model exploits HP HFSS through HP Empipe3D

Six-Section H-Plane Filter

the H-plane speta have a finite thickness of 0.02 inches (0.508 mm)

the coarse model consists of lumped inductances and dispersive transmission line sections simulated by OSA90/hope

the equivalent inductances of the H-plane septa are calculated using formulas by *Marcuvitz* (*1951*)

the fine point of interest is the optimal fine model design

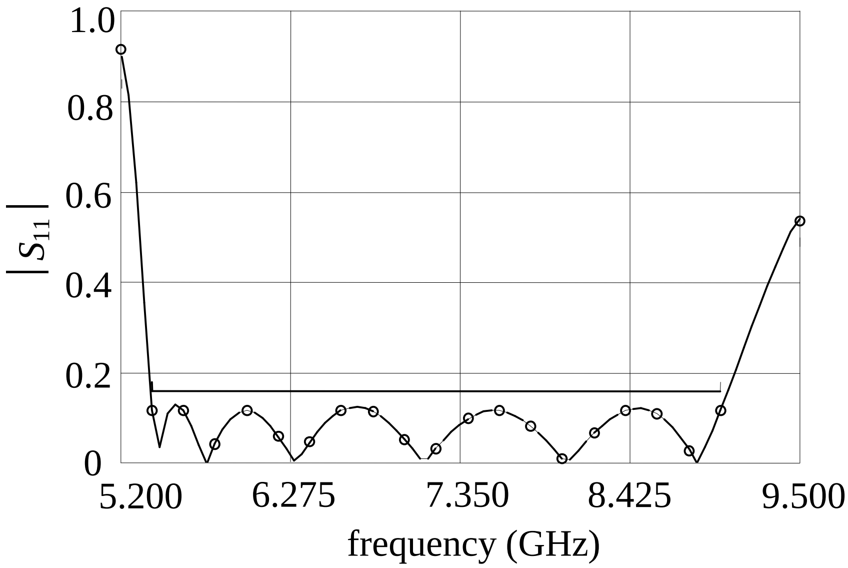
parameter extraction is then applied to obtain $\bar{\boldsymbol{x}}_{os}$

linear interpolation formulas (*Bandler et al*., *1997*) are utilized to estimate $\boldsymbol{J}^{*}_{em}$ using the database generated during optimization

$\bar{\boldsymbol{J}}_{os}$ is estimated by perturbation

the estimated matrix $\boldsymbol{B}$ is utilized in statistical analysis

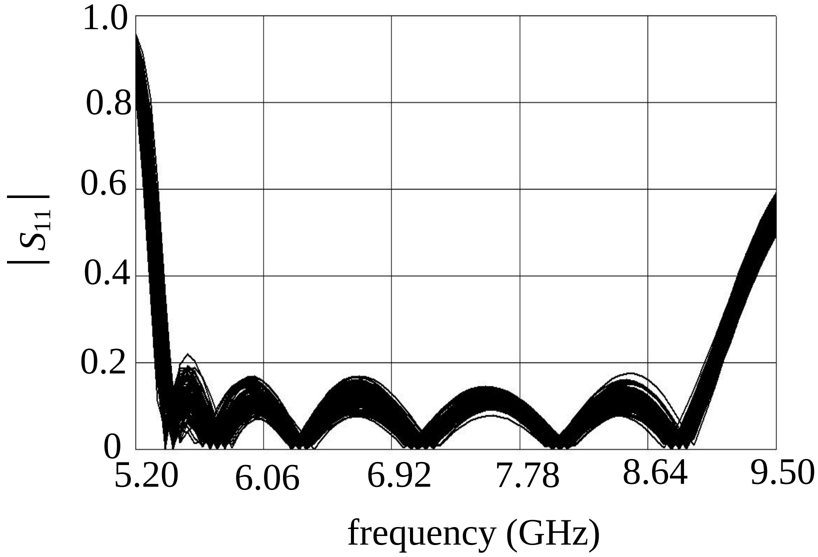
Six-Section H-Plane Filter



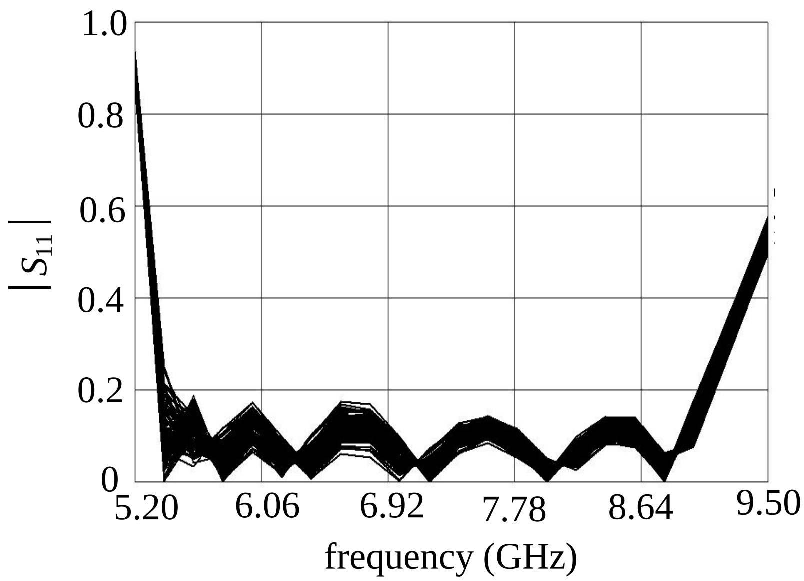
fine model response (o) and coarse model response (—) at the corresponding points

Statistical Analysis of the H-Plane Filter

1.0% tolerance



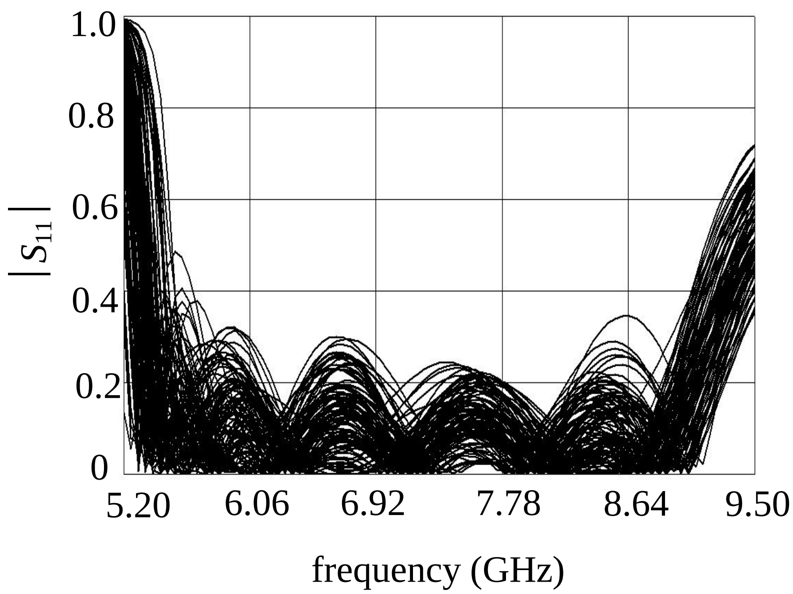
using Space Derivative Mapping



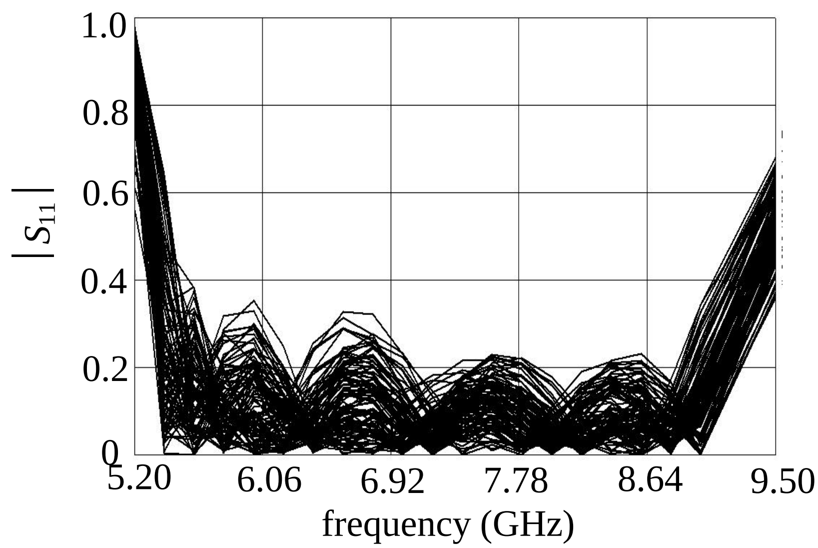
using fine model simulations

Statistical Analysis of the H-Plane Filter

4.0% tolerance

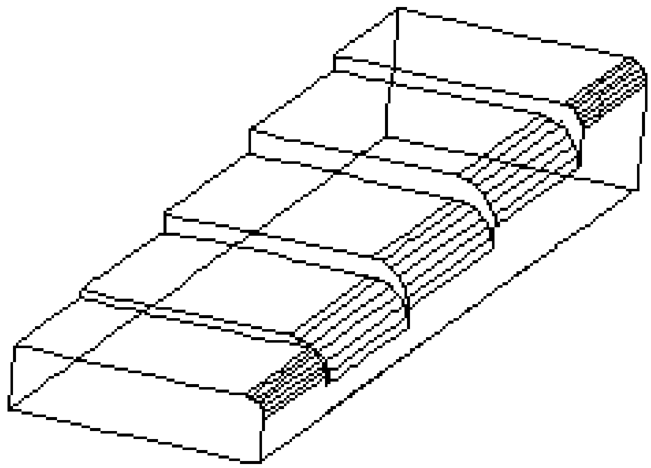


using Space Derivative Mapping



using fine model simulations

Three-section Rounded Edge Waveguide Transformer
(*HP Empipe3D Manual, 1998*)



the fine model of this circuit exploits HP HFSS through HP Empipe3D

the coarse model exploits an ideal empirical model that does not take into account the rounding of the corners

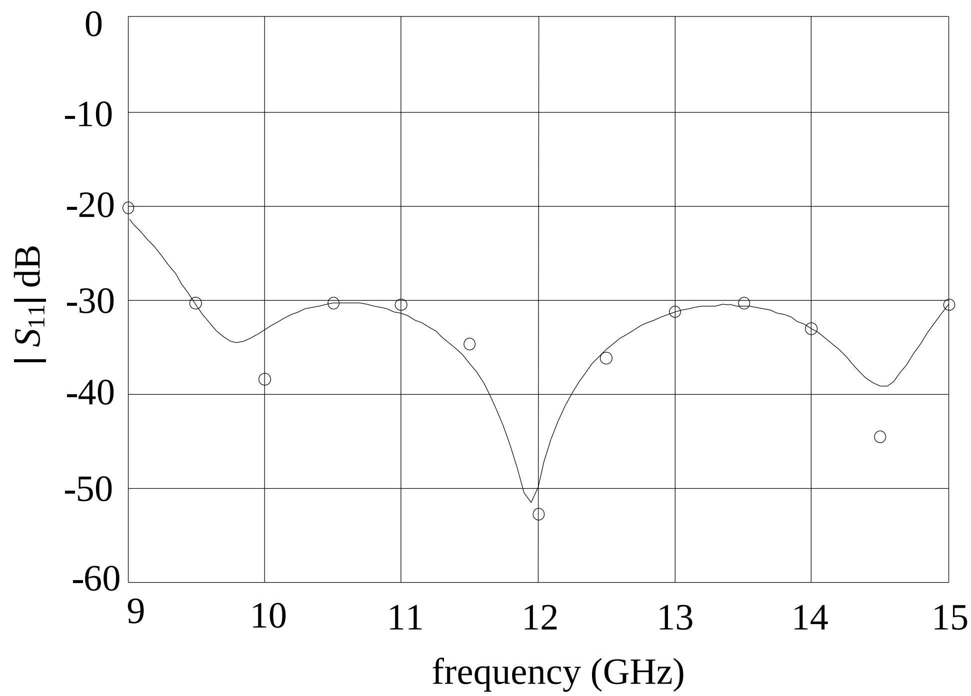
designable parameters for this problem are the height and length of each waveguide section

the fine point of interest is the optimal fine model design

linear interpolation formulas (*Bandler et al.*, *1997*) are utilized to estimate $\boldsymbol{J}_{em}^{*}$ using the database generated during optimization

$\overline{\boldsymbol{J}}_{os}$ is estimated by perturbation

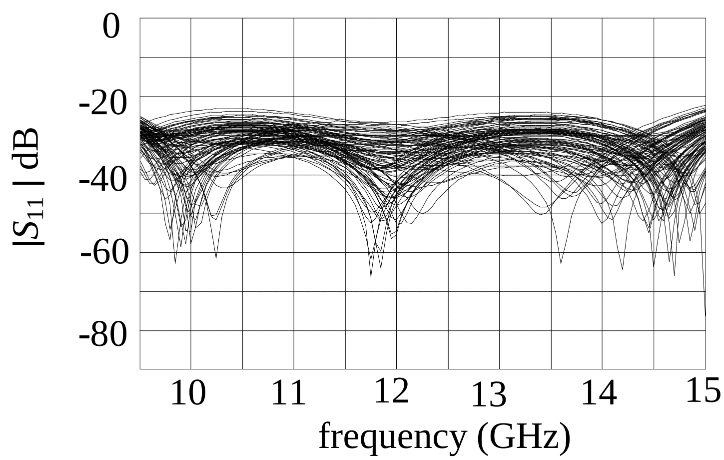
Three-section Rounded Edge Waveguide Transformer



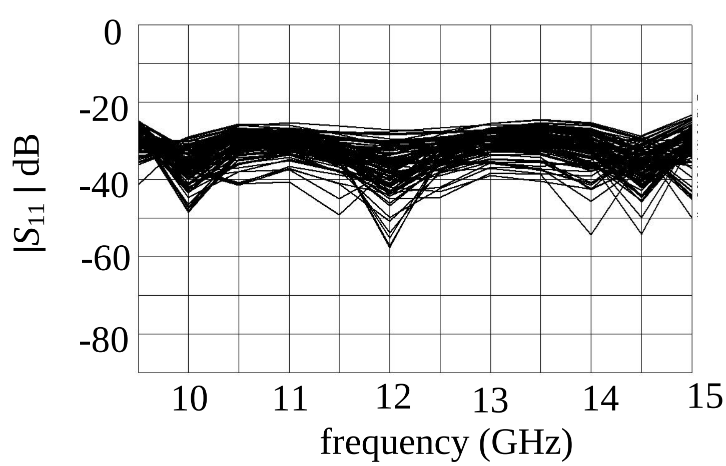
fine model response (o) and coarse model response (—) at the corresponding points

Three-section Rounded Edge Waveguide Transformer

2.0% tolerance



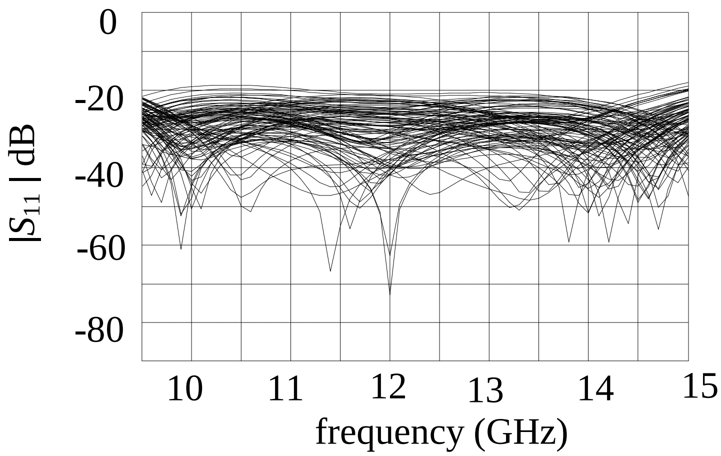
using Space Derivative Mapping



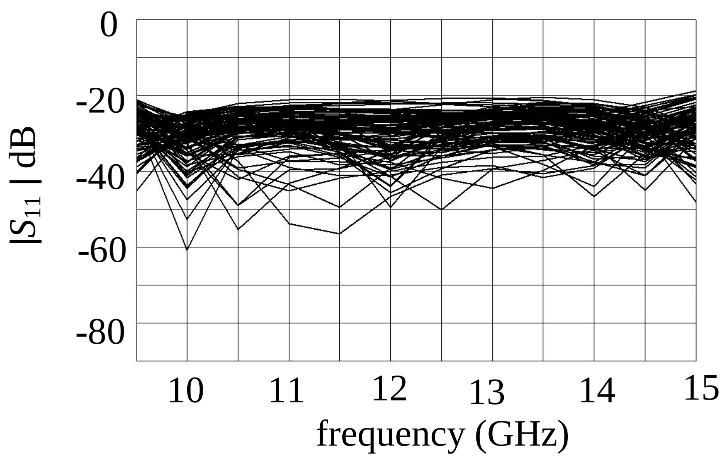
using fine model simulations

Three-section Rounded Edge Waveguide Transformer

4.0% tolerance



using Space Derivative Mapping



using fine model simulations

Conclusions

we present a novel technique for the fast and accurate modeling of microwave circuits

the technique exploits a Space Derivative Mapping (SDM) approach in the construction of a space-mapping based model

a novel lemma establishes the mapping between the input parameters to an EM model and the parameters of a corresponding empirical model with no additional overhead of EM simulations

SDM Modeling (SDMM) alleviates the extraction uniqueness problem involved in prior SM algorithms and the necessity of applying SM optimization in the ASM algorithm

statistical analysis of microwave circuits exemplifies our technique