AN INTRODUCTION TO NEUROMODELING OF MICROWAVE CIRCUITS EXPLOITING SPACE MAPPING TECHNOLOGY

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AN INTRODUCTION TO NEUROMODELING OF MICROWAVE CIRCUITS EXPLOITING SPACE MAPPING TECHNOLOGY

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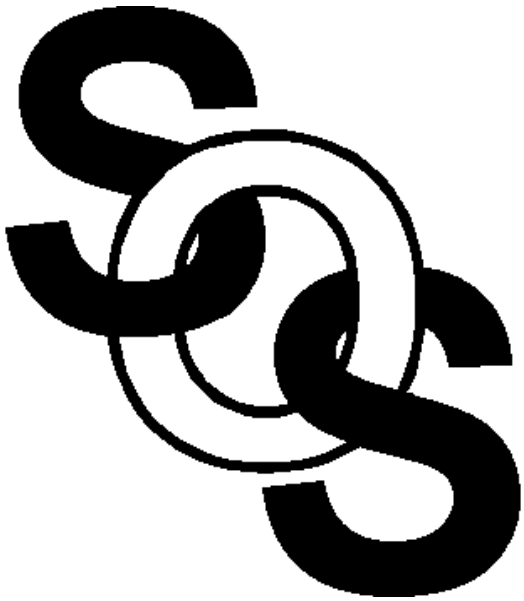
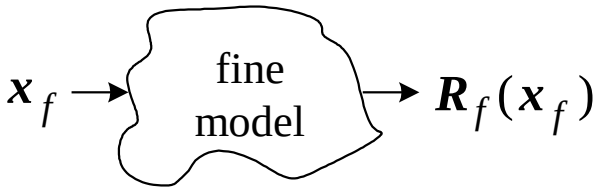
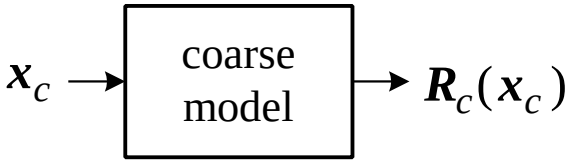


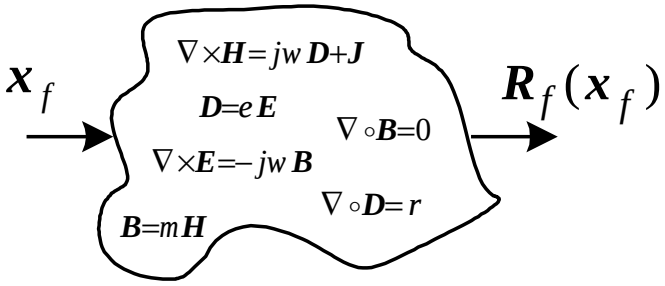
presented at

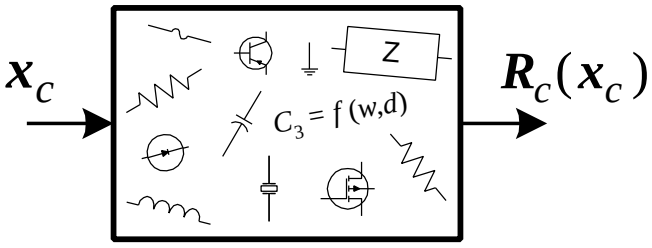
Supervisory Committee Meeting, Hamilton, December 1, 1998

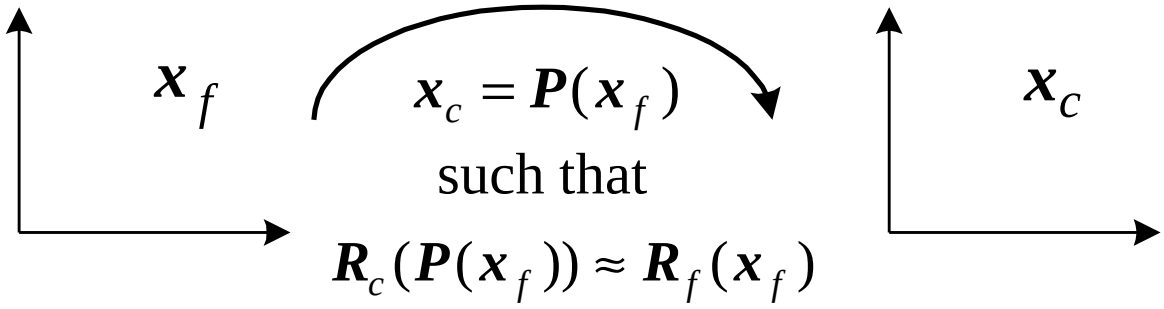
The Aim of Space Mapping (SM)





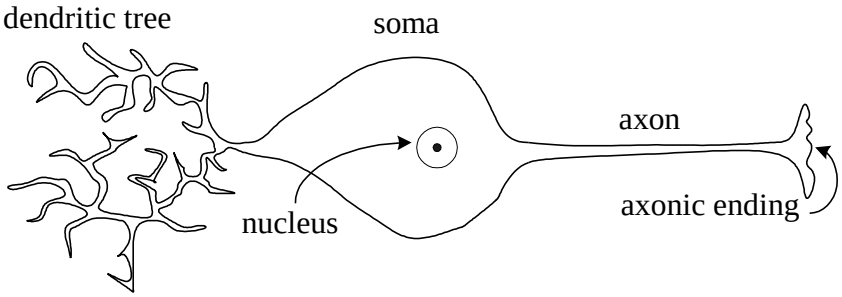




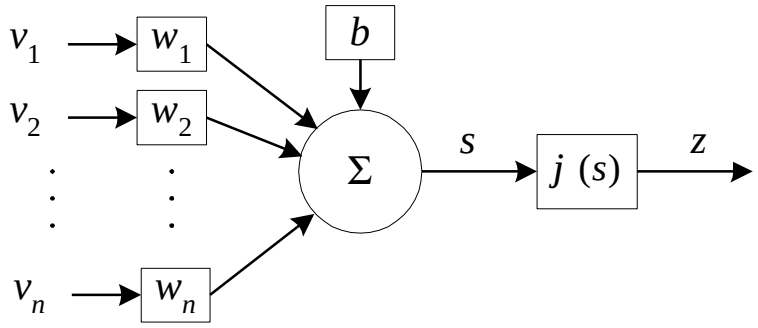


Artificial Neural Networks (ANN)

biological neuron



basic model of a neuron



$\boldsymbol{v} = \begin{bmatrix} v_1 \\ v_2 \\ \vdots \\ v_n \end{bmatrix}$ is the vector of inputs, which are signals coming from other neurons

$\boldsymbol{w} = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$ is the vector of weights to represent the corresponding synapse strength

b is the bias or offset term

$s = b + \boldsymbol{v}^T \boldsymbol{w}$ is the activation signal, and

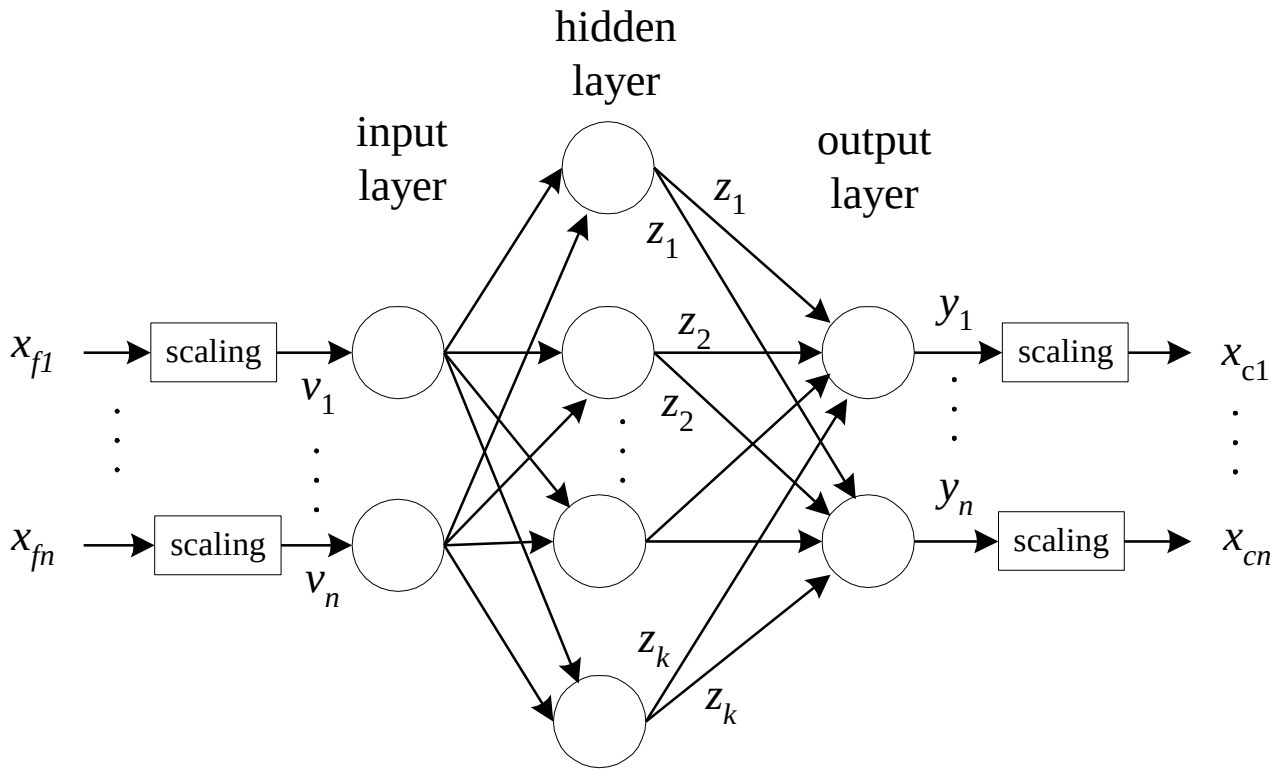
$z = j\ (s)$ is the output signal

if a sigmoid is used:

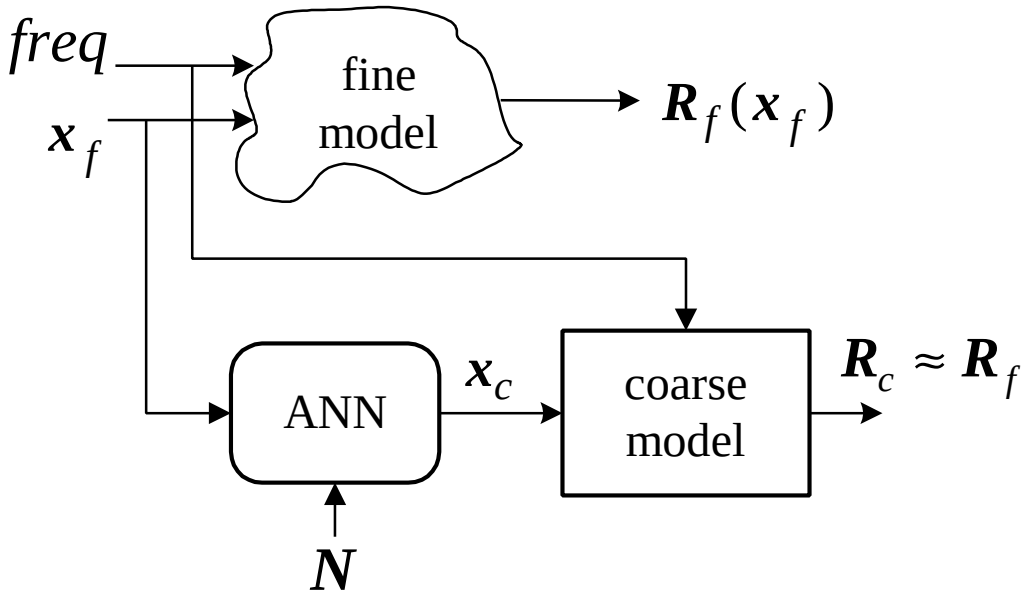
$$z = j\ (s) = \frac{1}{1 + e^{-s}}$$

Neural Space Mapping

using a three layer perceptron (3LP):



Space Mapping Neuromodeling (SMN) Concept



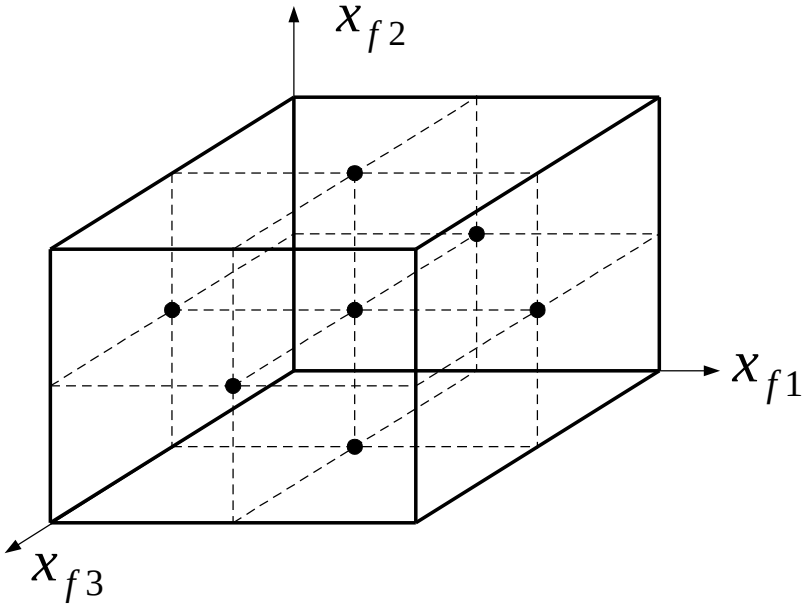
the neuromapping can be found by solving the optimization problem

$$\min_{N} \left\| [e_1^T \quad e_2^T \quad \cdots \quad e_l^T]^T \right\|$$

where N contains the internal parameters of the neural network (weights, bias, etc.) selected as optimization variables, l is the total number of learning samples, and e_j is the error vector given by

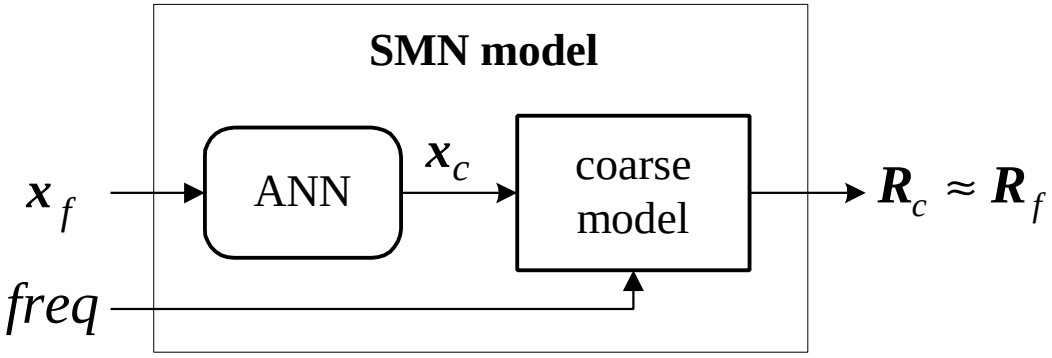
$$e_j = R_f(x_{f_j}) - R_c(x_{f_j}, N), \quad j = 1, 2, \ldots, l$$

Three-dimensional Star Distribution for the Learning Base Points

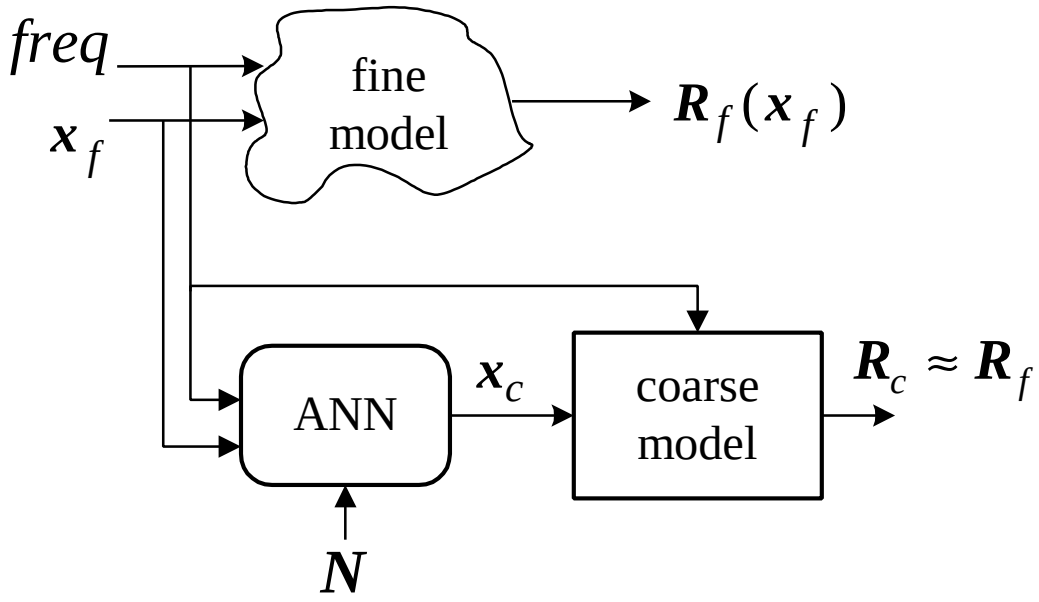


$$B_p = 2n + 1$$

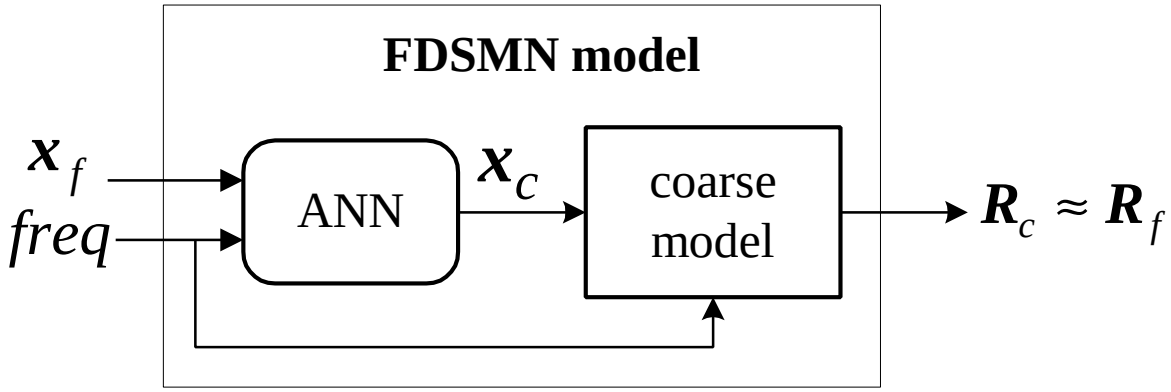
once the ANN is trained…



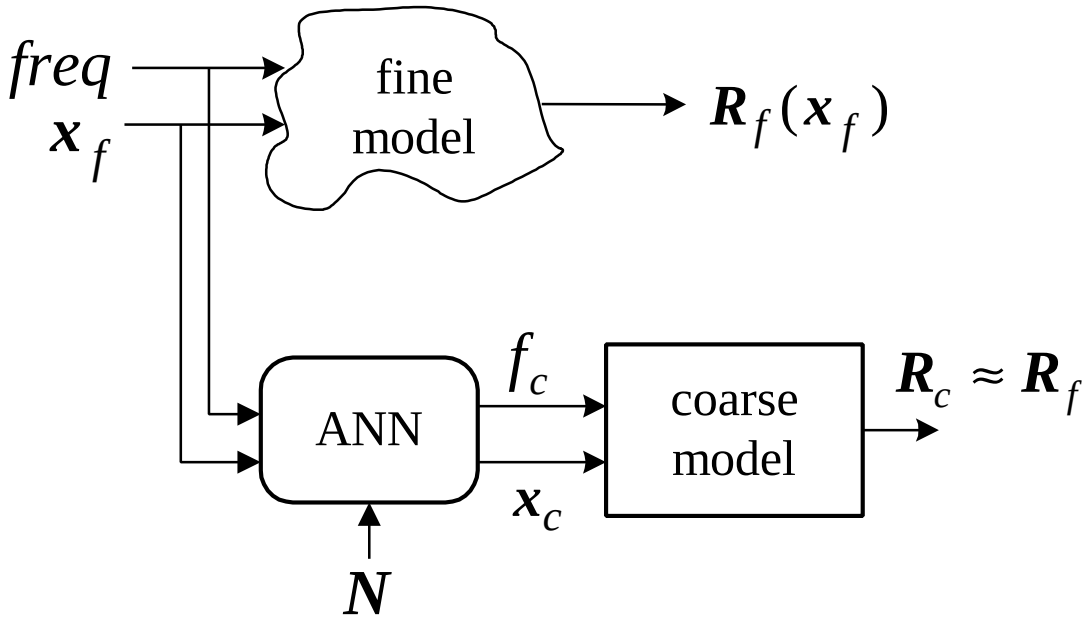
Frequency Dependent Space Mapping Neuromodeling (FDSMN) Concept



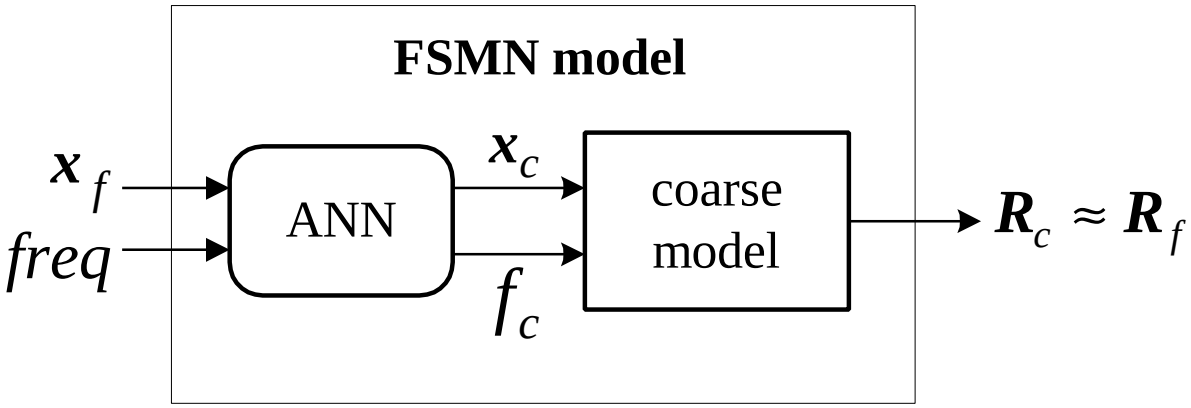
once the ANN is trained…



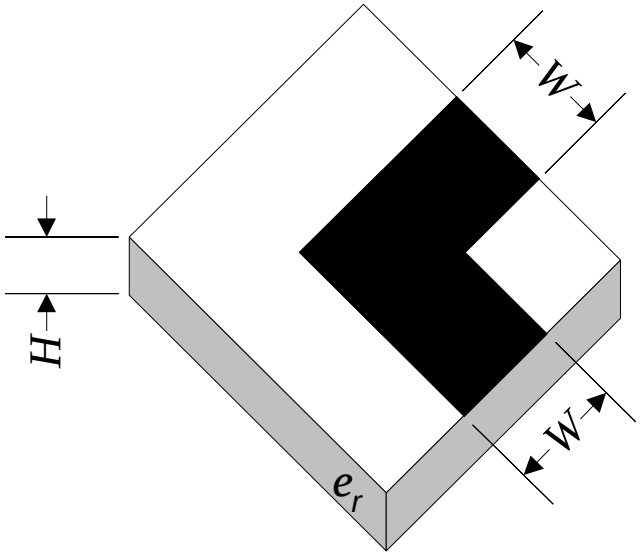
Frequency Space Mapping Neuromodeling (FSMN) Concept



once the ANN is trained…



SM Based Neuromodels of a Microstrip Right Angle Bend

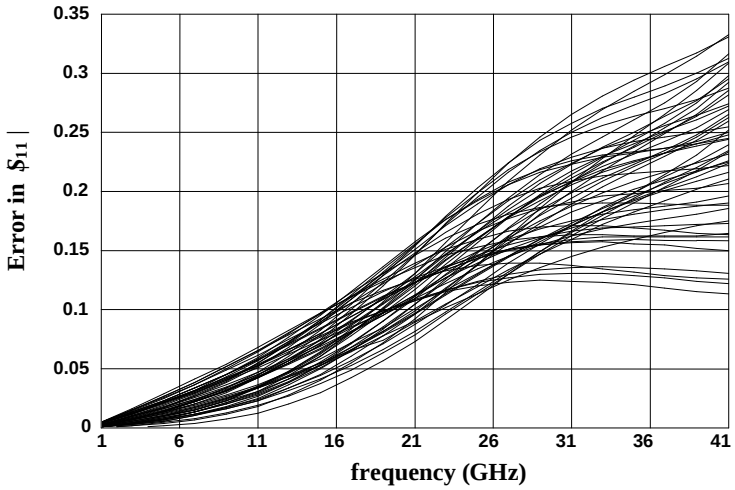


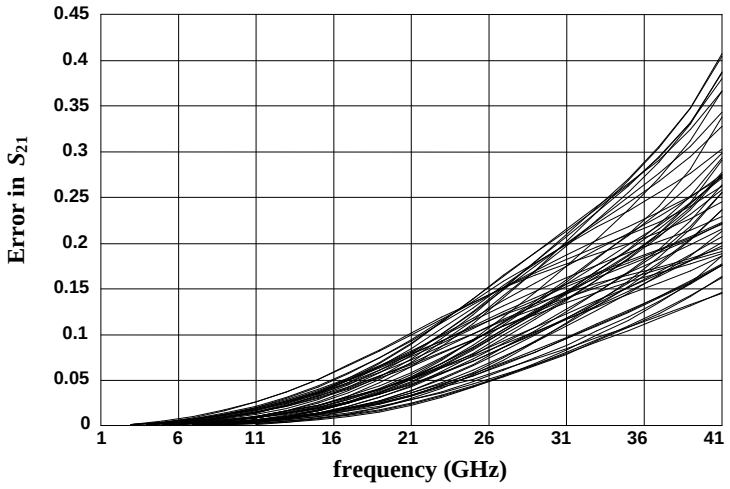
$20\text{mil} \le W \le 30\text{mil}$
$8\text{mil} \le H \le 16\text{mil}$
$8 \le e_r \le 10$
$1\text{GHz} \le freq \le 41\text{GHz}$

"coarse" model:
Gupta model

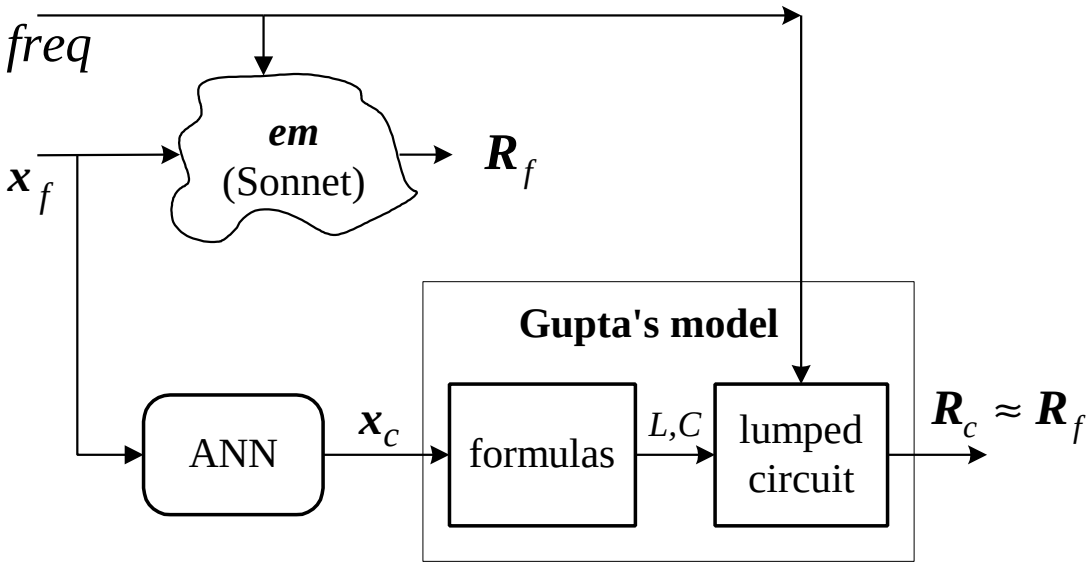
"fine" model:
Sonnet's ***em***™

comparison between ***em*** and Gupta model:

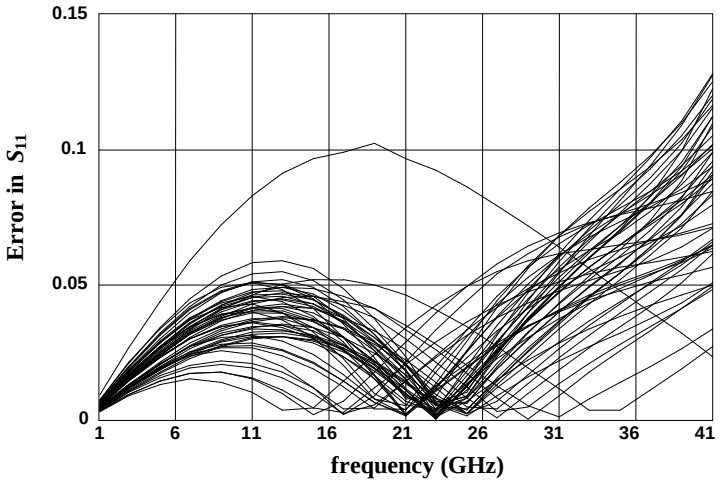


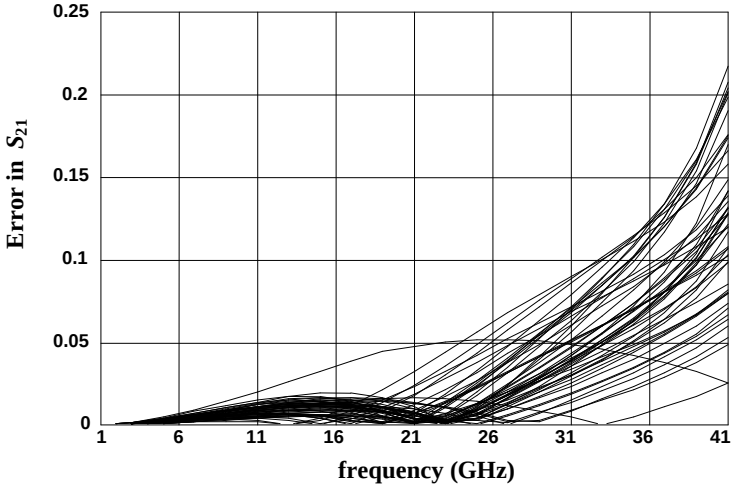


SMN Model for the Right Angle Bend (3LP:3-6-3)

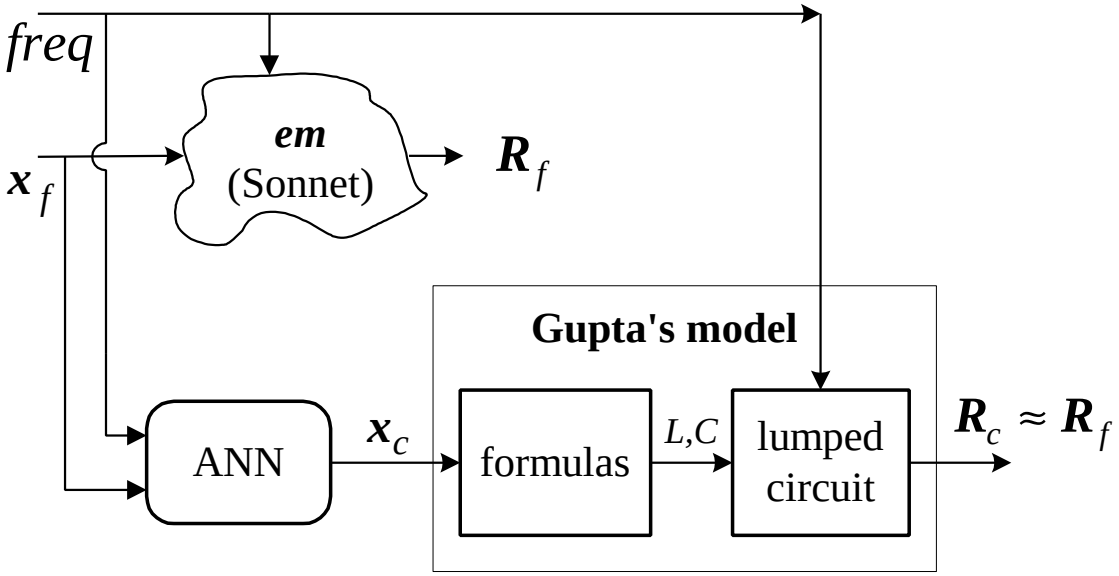


comparison between ***em*** and the SMN model:

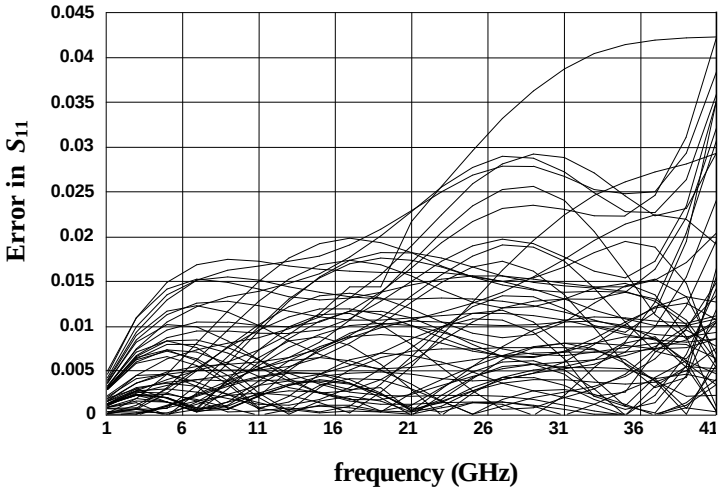


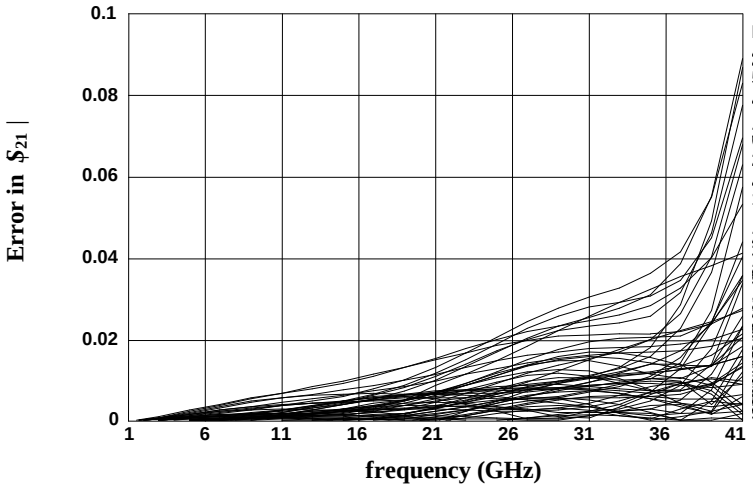


FDSMN Model for the Right Angle Bend (3LP:4-7-3)

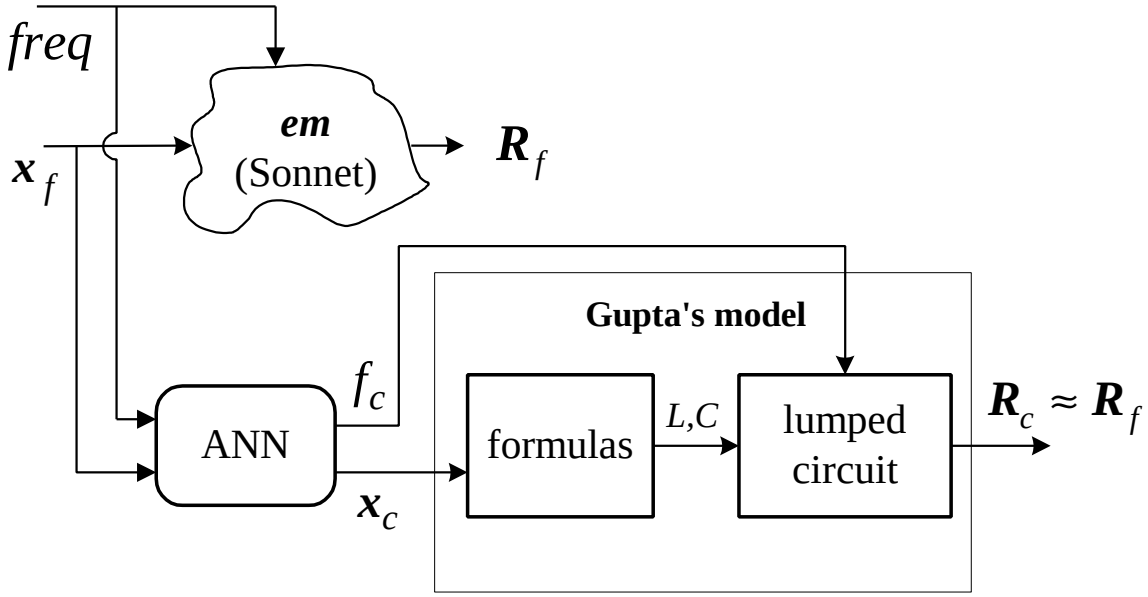


comparison between ***em*** and the FDSMN model:

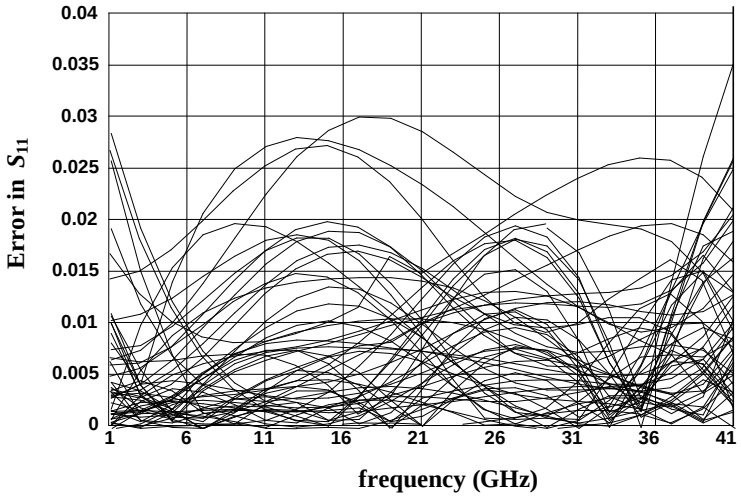


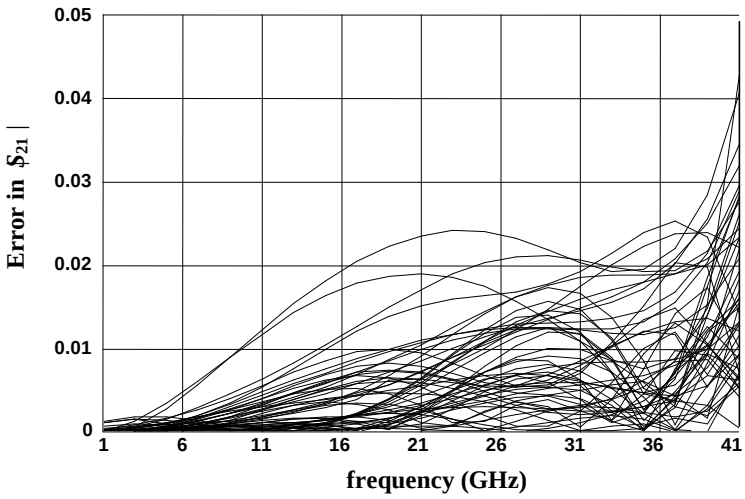


FSMN Model for the Right Angle Bend (3LP:4-8-4)

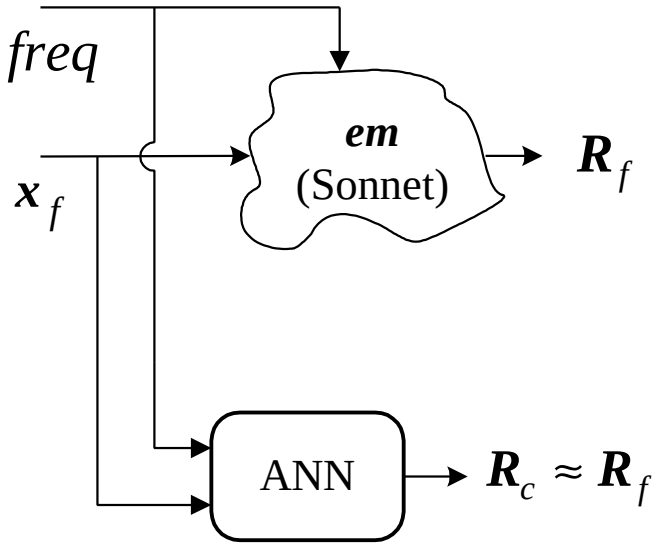


comparison between ***em*** and the FSMN model:

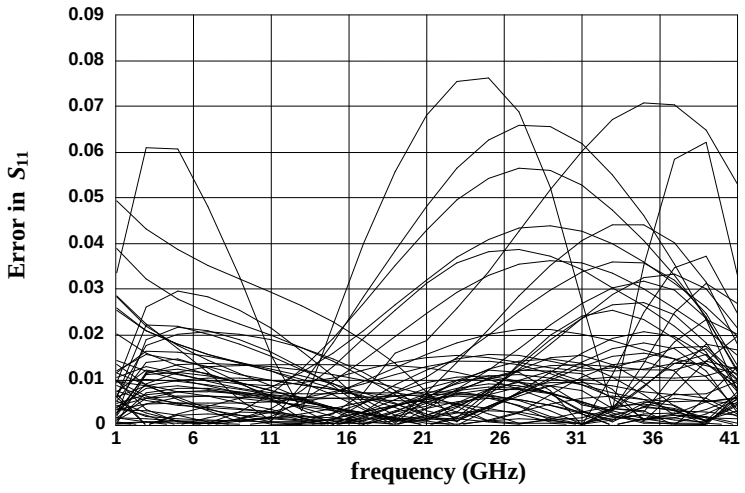


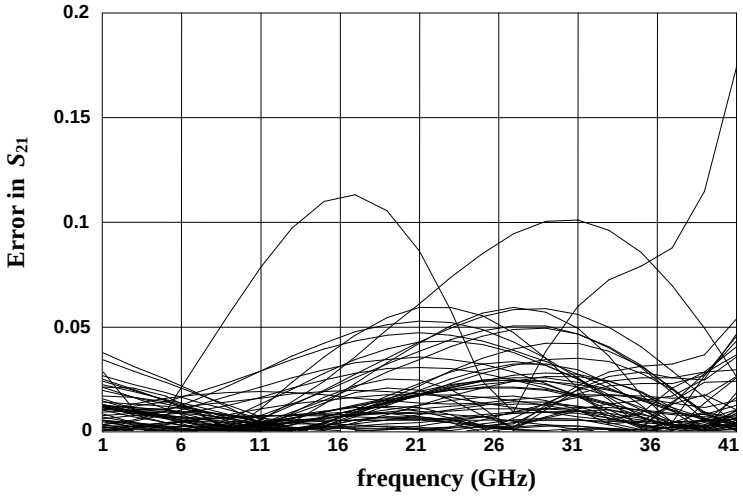


Classical Neuromodel for the Right Angle Bend (3LP:4-15-4)



comparison between ***em*** and classical neuromodel:





Conclusions

we present novel applications of Space Mapping technology to the neuromodeling of microwave circuits

three powerful techniques to generate SM based neuromodels are described and illustrated: Space-Mapped Neuromodeling (SMN), Frequency-Dependent Space-Mapped Neuromodeling (FDSMN) and Frequency Space-Mapped Neuromodeling (FSMN)

the SM based neuromodeling techniques exploit the vast set of empirical models already available, decrease the number of fine model evaluations needed for training, improve generalization ability and reduce the complexity of the ANN topology w.r.t. the classical neuromodeling approach

frequency-sensitive neuromapping (FDSMN and FSMN) is demonstrated to be a clever strategy to expand the usefulness of empirical models that were developed using quasi-static analysis

more research will be carried out to extend the SM based neuromodeling concepts to the iterative construction of the neuromapping for efficient electromagnetic optimization and statistical design of microwave circuits and components