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MICROSTRIP TRANSFORMER
USING AGGRESSIVE SPACE MAPPING**

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DESIGN OF A THREE-SECTION 3:1 MICROSTRIP TRANSFORMER USING AGGRESSIVE SPACE MAPPING

M.H. Bakr, J.W. Bandler, R.M. Biernacki and S.H. Chen

Simulation Optimization Systems Research Laboratory
and Department of Electrical and Computer Engineering
McMaster University, Hamilton, Canada L8S 4L7

Abstract

The aggressive space mapping technique is used to obtain the optimal design of a three-section 3:1 microstrip transformer. Two different sets of models are used in the design process. Also, several aspects affecting the convergence of the technique are discussed. These aspects include the effect of interpolating electromagnetic simulator responses. It is shown that turning off the interpolation feature may result in divergence of the technique although there is a clear explanation for this phenomenon.. The effect of using different matching goals in the parameter extraction step is also investigated. It is shown that an improper selection of the matching goals is most likely to hinder the convergence of the technique. This work exemplifies the importance of these aspects for the convergence of the aggressive space mapping technique.

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J.W. Bandler, R.M. Biernacki and S.H. Chen are with Optimization Systems Associates Inc., P.O. Box 8083, Dundas, Ontario, Canada L9H 5E7, and with the Simulation Optimization Systems Research Laboratory, Department of Electrical and Computer Engineering, McMaster University, Hamilton, Ontario, Canada L8S 4L7.

M.H. Bakr is with the Simulation Optimization Systems Research Laboratory, Department of Electrical and Computer Engineering, McMaster University, Hamilton, Ontario, Canada L8S 4L7.

I. INTRODUCTION

In this work, design of a three section 3:1 microstrip impedance transformer [1], [2] using the aggressive space mapping technique [3] is presented. The technique enables the integration of electromagnetic (EM) simulators into an automated design process within a practical time frame. Previously, these simulators were mainly used to verify designs obtained using analytical/empirical circuit models. Using aggressive space mapping only a small number of EM simulations are required to obtain the required design.

The design procedure is carried out through two different sets of models. For the first set of models the coarse model uses ideal transmission-line models. The fine model utilizes the empirical model of the microstrip library supplied by OSA90/hope [4]. In the coarse model conversion between different types of parameters is carried out using a quasi-static model for the microstrip transmission line [5]. For the second set of models the fine model of the first case is considered as the coarse model while the fine model is obtained using Sonnet's *em* simulator [6]. The effect of using interpolation for the EM simulator responses and of using different matching goals in the parameter extraction step are discussed. Various results and comparisons are given.

II. THE FIRST SET OF MODELS

The three-section 3:1 microstrip filter is shown in Fig. 1. For this case, the coarse model is a cascade of 3 ideal transmission lines. The source and load impedances are 50 Ω and 150 Ω , respectively. The optimization variables are the characteristic impedance and the electrical length of each line at the frequency $f = 6$ GHz. The design specification is given by

$$|S_{11}| \leq 0.11 \quad \text{from 5 GHz to 15 GHz} \quad (1)$$

This specification ensures that the load is reasonably matched to the source over the given frequency band.

This continuous specification is converted into 21 discrete specifications using the frequency step $\Delta f = 0.5$ GHz.

First, using the user-friendly CAD system OSA90/hope [4], the coarse model is optimized to meet the design specifications. The minimax optimizer finds the final solution in 15 iterations. The starting and optimal values of the coarse model parameters are given in Table I.

The aggressive space mapping technique is then applied to this problem. The fine model is an empirical microstrip model supplied by OSA90/hope. The designable parameters for the fine model are the widths and physical lengths of the three microstrip lines. The thickness of the dielectric substrate is 0.635 mm and its relative permittivity is 9.7. The effect of nonideal dielectric is considered by setting the loss tangent to 0.002.

The implementation of aggressive space mapping in OSA90/hope requires the parameters of both models to be of the same type. For the coarse model a quasi-static microstrip model [5] is used to convert the width and the length of each of the microstrip lines to the corresponding characteristic impedance and the electrical length. The characteristic impedances and electrical lengths are then submitted as the input parameters to the TEM ideal transmission line models in OSA90/hope.

The number of required space mapping iterations is 9. The initial and final values of the designable parameters are shown in Table II. The responses of both models at the starting point and at the final solution are shown in Figs. 2 and 3, respectively.

An important step in the aggressive space mapping technique is parameter extraction. This step is crucial and, if it is not working properly, the process may not converge. A maximum of 30 iterations are allowed within the parameter extraction step to ensure the convergence of the technique. Fortunately, the parameter extraction step is not expensive in terms of CPU time because it involves fast coarse model simulations. It follows that increasing the number of iterations in this step does not affect significantly the time required by the technique. The Huber optimizer with different thresholds is used in the parameter extraction step. The convergence of the parameter extraction step is independent of the threshold for this well-behaving example. The OSA90/hope input file used is shown in Appendix A.

III. MONTE CARLO ANALYSIS

Once the mapping between the fine and coarse model parameter spaces is established it can be used for fast Monte Carlo simulations. This process involves the fine model parameters as statistical variables. They are assumed here to be uniformly distributed within a 2% tolerance. The mean is taken as the final solution of the aggressive space mapping technique. Fast Monte Carlo simulations are achieved by mapping each of the random outcomes of the fine model parameters to the corresponding coarse model parameters and then using the coarse model simulation to generate its responses. These responses are approximate in the sense of how good the coarse model is in emulating the fine model behaviour. The results are shown in Fig. 4.

To assess the usefulness of this “space-mapped” statistical analysis we have also performed Monte Carlo simulation using the fine model alone. The corresponding results are shown in Fig. 5. Indeed, the differences between the responses shown in Figs. 4 and 5 are acceptable. This is also confirmed by the yield estimates: when the fine model alone is used the yield estimated from 100 outcomes is 98% while the “space-mapped” yield is found to be 95%.

IV. THE SECOND SET OF MODELS

The fine model of the previous example is actually very fast. Furthermore, there exist simulation techniques leading to better accuracy than the empirical formulas used in that model. Therefore, we now consider that model as the coarse for another run of space mapping optimization. As the fine model we now want to apply very accurate EM simulations of the transformer using Sonnet’s *em* [6]. This time the fine model simulation is indeed slow - it takes about 1 hour on HP 700 machine to complete one frequency sweep.

First, the coarse model is directly optimized using the minimax optimizer of OSA90/hope. As before, the optimization variables are the lengths and widths of the microstrip sections. The starting point is the solution obtained from the aggressive space mapping technique in the first case. After 12 iterations, the

optimal solution for the coarse model is obtained. The starting and final values of the coarse model parameters are shown in Table III.

To parameterize the transformer for optimization we used the Geometry Capture [7] technique available in Empipe [4]. Using *xgeom* [6], 7 geometry files were produced. The first file contains the geometry of the three-section microstrip 3:1 transformer at the nominal parameter values. The other six files contain perturbed versions of the nominal geometry and each file represents a perturbation of one of the parameters. Empipe is then invoked to parameterize the structure.

The grid size used for the *em* simulator is 1.0 mil by 1.0 mil. The values of the dielectric thickness, dielectric permittivity and loss tangent are the same as in Section II.

The starting point for the aggressive space mapping is the optimal solution of the coarse model. Fig. 6 shows the responses of both models at the starting point. To ensure that the parameter extraction step is working properly 30 iterations are allowed per step. This does not add any overhead time because, as indicated before, the simulation time of the coarse model is negligible with respect to that of the fine model. The optimizer used for this step is the Huber optimizer. It is found that the best value of the Huber threshold for this problem is 0.15.

In order to save EM simulations one may be tempted to disable the interpolation feature available in Empipe. Then, when EM simulation is requested at an off-grid point no simulation at the neighbouring on-grid points are arranged by Empipe. The off-grid point is passed to *em*. It is important to realize that *em* will perform snapping of the structure to the closest on-grid geometry. Therefore the actual parameter values used for simulation are different from those submitted and considered as actual by the optimizer. As a consequence we expect difficulties in the convergence of the algorithm.

To verify the aforementioned expectations we run space mapping with the interpolation option disabled. The number of iterations required by the aggressive space mapping technique is 9. The initial and final values of the optimization variables are shown in Table IV. The responses of both models at the final point are shown in Fig. 7.

It is clear that the responses of both models at the final point are different. Although a sufficient number of iterations is allowed in the parameter extraction step the aggressive space mapping process did not converge. So, without using interpolation for off-grid points the technique may not work properly, unless we incorporate the snapping information into the space mapping algorithm. The OSA90/hope input file for this case is given in Appendix B.

The space mapping process for the second set of models is carried out again with the interpolation option of Empipe enabled. The same starting point is used. The number of iterations required by the technique is 9. The total number of needed fine model simulations is 54. The responses of both models at the final solution are shown in Fig. 8. The initial and final values of the parameters are given in Table V. It is clear from the results that the response of the fine model at the final point matches very well the optimal coarse model response. The final solution obtained using the aggressive space mapping technique is very close to the solution reported in [1].

The response selected to formulate matching goals for both models in the parameter extraction step was $|S_{11}|$, as can be seen from the OSA90/hope input file reported in Appendix C. The effect of using other types of matching goals for parameter extraction is investigated in the next section.

V. USING DIFFERENT MATCHING GOALS

Here we study the effect of the selection of circuit responses for the matching goals on the convergence of the technique. Several matching goals were tried and each time we restarted space mapping procedure from the same starting point. First, matching of $|S_{11}|^2$ is used. The aggressive space mapping is carried out using this new goal. The final solution is obtained only in 5 iterations. The initial and final values are shown in Table VI. The response of the fine model at the solution is shown in Fig. 9. This figure shows that a good match between the two models is obtained. The solution obtained using $|S_{11}|^2$ is very close to that obtained using $|S_{11}|$. However, the number of space mapping iterations, when $|S_{11}|^2$ is used, is reduced by almost 50%.

In the second experiment, matching of $|S_{11}|$ in dB is used. The technique terminated in only one iteration. Using this matching goal, the optimizer mistakenly considers the starting point as an optimal solution. The final response, which is the response at the starting point, is shown in Fig. 10. This response does not match the optimal response of the coarse model.

It is clear from this discussion that the selection of a proper matching goal is important to guarantee the convergence of the technique. Unfortunately, there are no general rules that could apply to all problems. Different matching goals might be tried and the one that gives the best result should be used. An automated selection of matching goals is a suggested area for further research.

VI. CONCLUSIONS

In this work, design of a three-section 3:1 microstrip transformer is carried out using aggressive space mapping. The technique is applied to two different sets of models. Using the first set of models, the aggressive space mapping managed to establish a mapping between the coarse model space and the fine model space. For the second set of models, the technique failed to establish the mapping when the interpolation feature of Empipe is disabled. However, using interpolation an excellent match between the two models is obtained. The effect of using different matching goals is discussed. It is pointed out that the convergence of the technique is highly dependent on the type of matching goal.

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TABLE I
COARSE MODEL OPTIMIZATION
(THE FIRST SET OF MODELS)

Parameter	Starting Value	Optimal Value
Z_1	50 Ω	62.513 Ω
E_1	90°	54.0°
Z_2	50 Ω	86.603 Ω
E_2	90°	54.0°
Z_3	50 Ω	119.975 Ω
E_3	90°	53.999°

TABLE II
SPACE MAPPING USING THE FIRST SET OF MODELS:
INITIAL AND FINAL PARAMETER VALUES

Parameter	Starting Value	Final Value
W_1	0.38100	0.38498
L_1	2.98820	2.71748
W_2	0.15240	0.15296
L_2	3.07176	2.98760
W_3	0.04480	0.04319
L_3	3.14610	3.14127

TABLE III
 COARSE MODEL OPTIMIZATION
 (THE SECOND SET OF MODELS)

Parameter	Initial Value (mm)	Final Value (mm)
W_1	0.38490	0.38145
L_1	2.71780	2.78208
W_2	0.15290	0.15126
L_2	2.98760	3.00255
W_3	0.04319	0.04227
L_3	3.14120	3.08801

TABLE IV
 SPACE MAPPING USING THE SECOND SET OF PARAMETERS
 WITH NO INTERPOLATION:
 INITIAL AND FINAL PARAMETER VALUES

Parameter	Initial Value (mm)	Final Value (mm)
W_1	0.38145	0.42740
L_1	2.78208	2.89632
W_2	0.15126	0.14534
L_2	3.00255	2.93280
W_3	0.04227	0.06367
L_3	3.08801	3.26402

TABLE V
SPACE MAPPING USING THE SECOND SET OF PARAMETERS
WITH INTERPOLATION:
INITIAL AND FINAL PARAMETER VALUES

Parameter	Initial Value (mm)	Final Value (mm)
W_1	0.38145	0.35760
L_1	2.78208	2.97243
W_2	0.15126	0.14241
L_2	3.00255	3.04148
W_3	0.04227	0.04215
L_3	3.08801	3.08122

TABLE VI
SPACE MAPPING USING THE SECOND SET OF PARAMETERS
WITH INTERPOLATION USING $|S_{11}|^2$:
INITIAL AND FINAL PARAMETER VALUES

Parameter	Initial Value (mm)	Final Value (mm)
W_1	0.38145	0.36268
L_1	2.78203	3.02509
W_2	0.15126	0.15235
L_2	3.00255	3.02779
W_3	0.04227	0.04271
L_3	3.08801	3.03413

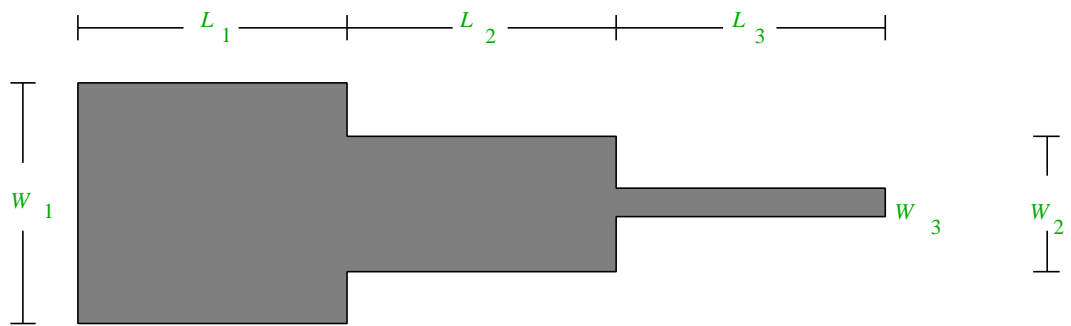


Fig. 1. Three-section 3:1 microstrip impedance transformer.

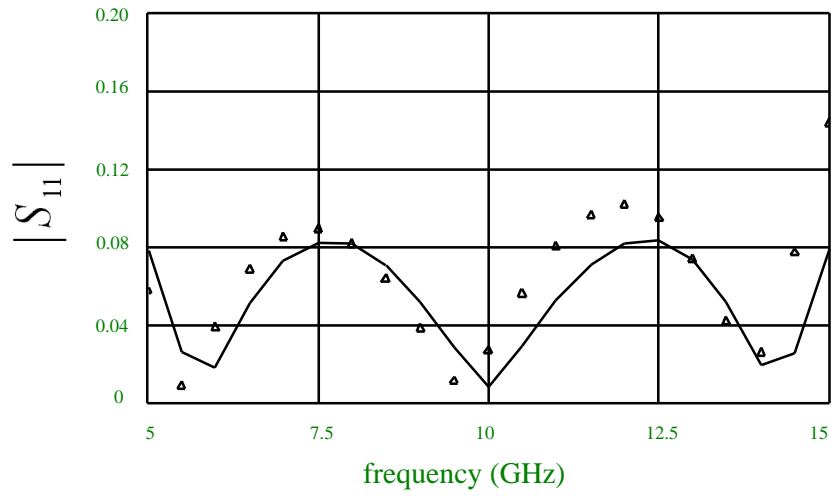


Fig. 2. The responses at the starting point of both the fine model (Δ) and the coarse model (---) using the first set of models.

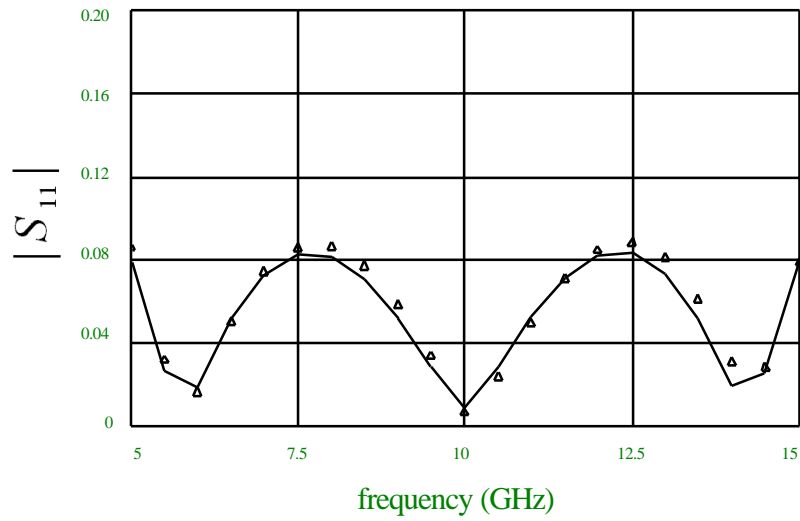


Fig. 3. The responses at the final point of both the fine model (Δ) and the coarse model (---) using the first set of models.

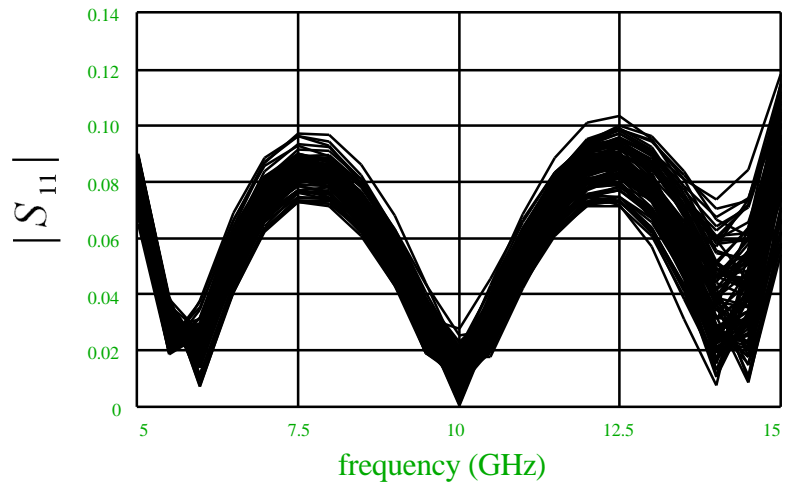


Fig. 4. Monte Carlo analysis using the space-mapped model.

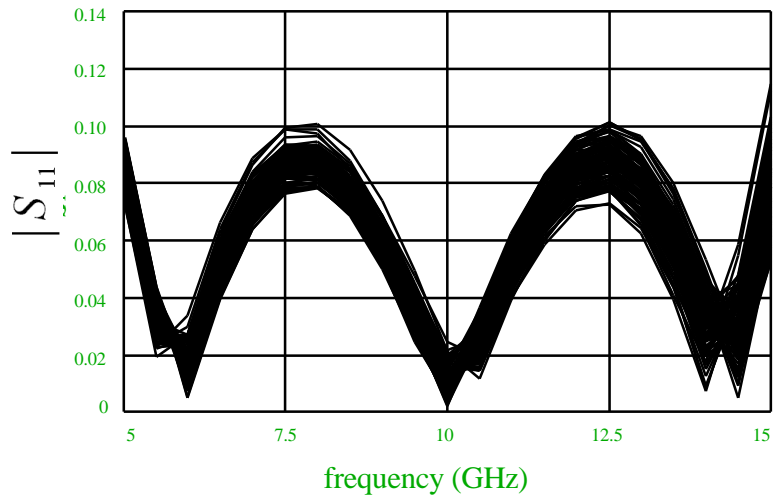


Fig. 5. Direct Monte Carlo analysis using the fine model.

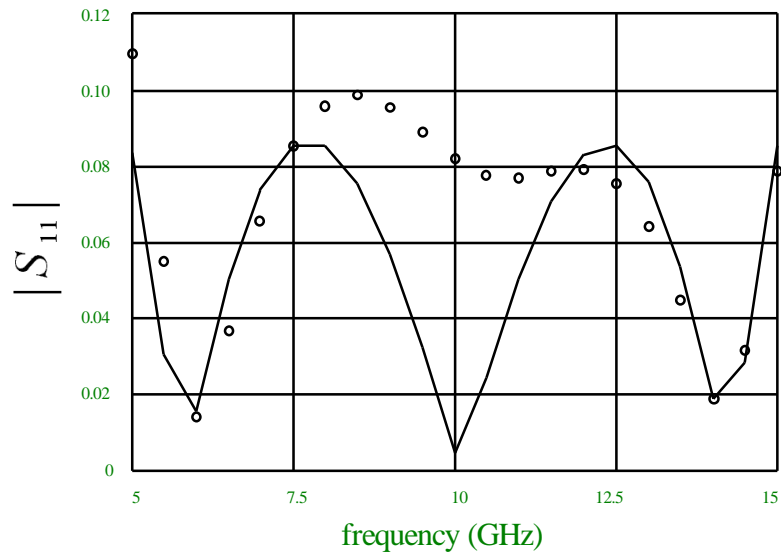


Fig. 6. The responses at the starting point of both the fine model (o) and the coarse model (—) using the second set of models.

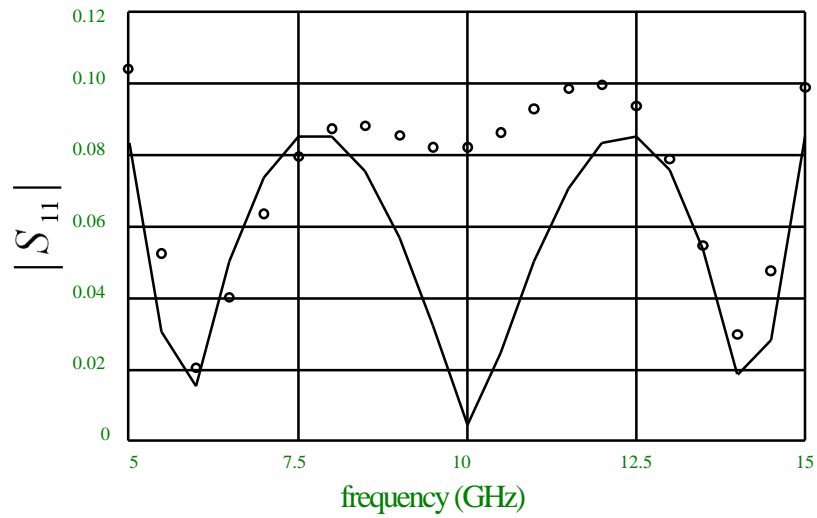


Fig. 7. The responses at the solution with no interpolation of both the fine model (o) and the coarse model (—) using the second set of models.

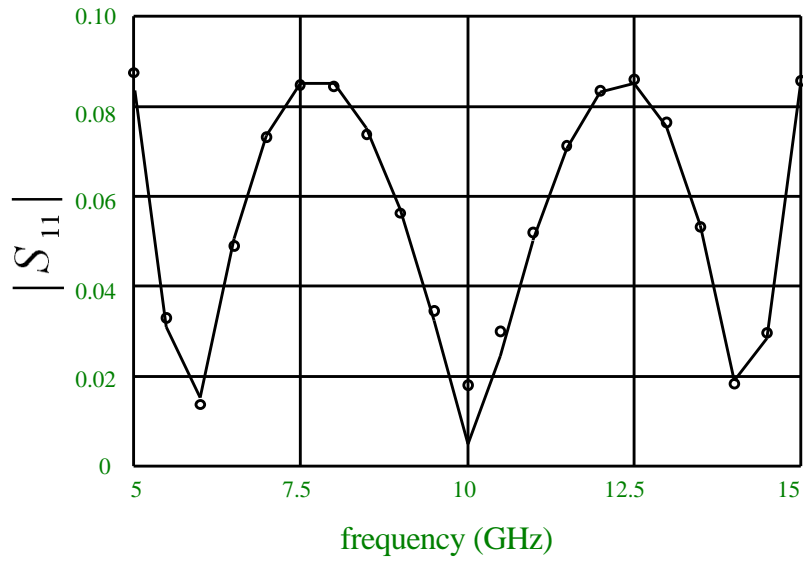


Fig. 8. The responses at the final point with interpolation of both the fine model (o) and the coarse model (—) using the second set of models.

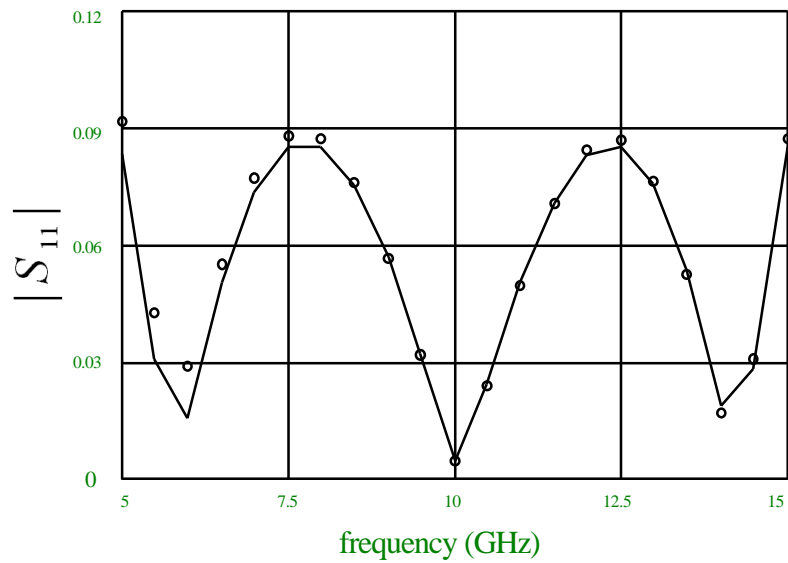


Fig. 9. The final responses of both the fine model (o) and the coarse model (—) using the matching goal $|S_{11}|^2$ and the second set of models.

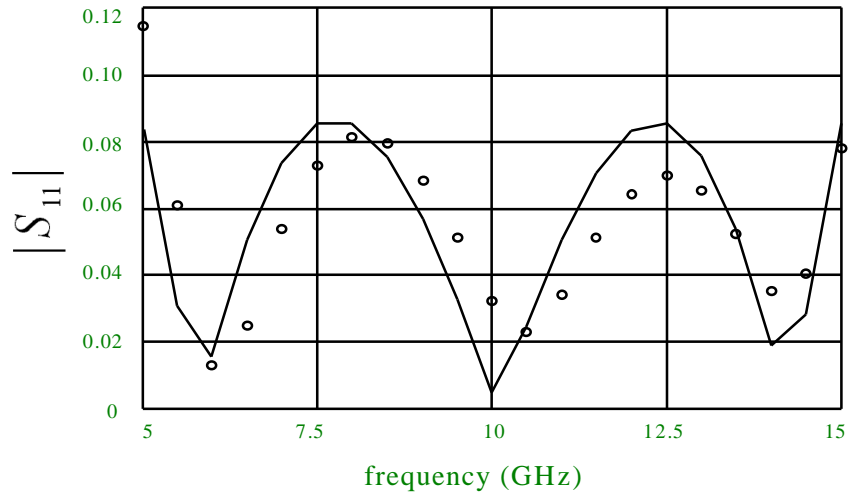


Fig. 10. The final responses of the fine model (o) and the coarse model (—) using $|S_{11}|$ in dB and the second set of models.

! This file explains the space mapping technique for a three section microstrip transformer
! The coarse model uses ideal transmission line. The fine model uses the built in library
! of microstrip transmission lines and microstrip steps.

```

Model
Xos_opt[6] = [0.381 2.9882 0.15240 3.07176 0.04480 3.1461 ];
X_fine[6] = [?0.384983? ?2.71748? ?0.152964? ?2.9876? ?0.0431972? ?3.14127? ];
Datapipe: com File="osa90 -pio"
           N_INPUT=15 INPUT=(4,ckt_file,macro,X_fine,Xos_opt)
           N_OUTPUT=6 OUTPUT=(Xos[6]);
end
spec
Xos=Xos_opt;
end
expression
Char ckt_file[]="
  Model
    X_fine[6]:* ;
    Xos_opt[6]:* ;
    Xos[6]=[?0.381? ?2.988? ?0.1524? ?3.07? ?0.0448? ?3.1469?];
    X_fine1[6]=X_fine*1mm;
    width=0.635;
    ! fine model follows
    MSUB Epsr=9.7 H=0.635mm TAND=0.002 ;
    MSL 1 2 W=X_fine1[1] L=X_fine1[2] ;
    MSTEP 2 3 W1=X_fine1[1] W2=X_fine1[3];
    MSL 3 4 W=X_fine1[3] L=X_fine1[4];
    MSTEP 4 5 W1=X_fine1[3] W2=X_fine1[5];
    MSL 5 6 W=X_fine1[5] L=X_fine1[6];
    Res 6 0 R=150;
    Port 1 0 R=50;
    ! transformation from W and L to Zo and E follows
    Epsre1=5.35+(4.35/sqrt(1+(12*width/Xos[1])));
    Epsre2=5.35+(4.35/sqrt(1+(12*width/Xos[3])));
    Epsre3=5.35+(4.35/sqrt(1+(12*width/Xos[5])));
    Ko=2*pi*20;
    Beta1=ko*sqrt(epsre1);
    Beta2=ko*sqrt(epsre2);
    Beta3=ko*sqrt(epsre3);
    E1=Beta1*Xos[2]*0.18/pi;
    E2=Beta2*Xos[4]*0.18/pi;
    E3=Beta3*Xos[6]*0.18/pi;
    Zo1=(60/sqrt(epsre1))*log((8*width/Xos[1])+(Xos[1]/(4*width)));
    Zo2=(60/sqrt(epsre2))*log((8*width/Xos[3])+(Xos[3]/(4*width)));
    Zo3=(60/sqrt(epsre3))*log((8*width/Xos[5])+(Xos[5]/(4*width)));
    !coarse model follows
    TEM 8 10 0 11 Z=Zo1 E=E1 F=6GHz;
    TEM 10 12 11 13 Z=Zo2 E=E2 F=6GHz;
    TEM 12 14 13 15 Z=Zo3 E=E3 F=6GHz;
    Res 14 15 R=150;
    Port 8 0 R=50;
    Circuit;
  end

  sweep
    Xos;
    Ac: freq: from 5GHz to 15GHz step=0.5GHz
        MS11 Ms22
        {XSWEEP Y= MS22.White & MS11.white.triangle
          Ymin=0 Ymax=0.2 NYticks=5 } ;
  end

  specification
    Ac:freq: from 3GHz to 17GHz step=0.5GHz
    Ms11=Ms22 ;
  end

  Control
    Optimizer=Huber;
    N_iterations=15;
    Display_N_digits=6;
    accuracy=1.0e-5;
  end

  trace
  end
" ;
Char macro[]="'f',message,'child osa90 for parameter extraction',pause,exit,'dxs',
right,enter,enter, message,'before extraction',pause,esc,'o',enter
'dxs',right,enter,up,right,enter,enter,message,'after extraction',

```

```
                esc,esc";
end
control
  optimizer=space_mapping;
  N_iterations=9;
end
Mapping
  1.00168 -0.0321446 -0.000738929 6.0593e-06 -0.000274923 0.0115213
  -0.146682 3.54245 0.0451281 0.140476 0.0247886 -0.315284
  0.00201035 -0.0486896 0.999117 0.00318837 -0.00032512 0.0377011
  -0.00716452 0.149926 0.00250962 1.00282 0.00122023 -0.0605317
  0.000307126 -0.00740569 -0.000110875 0.000631933 0.999955 0.00643235
  0.154408 -2.68051 -0.0455335 -0.154219 -0.0261712 1.3284
end
```

APPENDIX B

```

! This file optimizes the design of three-section 3:1 microstrip transformer using
! the aggressive space mapping technique with interpolation disabled.
! The fine model utilizes em simulator for the three section microstrip sections
! The coarse model makes use of the built in microstrip models in OSA90.
Model
Xos_opt[6]=[0.38145 2.78208 0.15126 3.00255 0.04227 3.08801];!coarse model optimal solution in
!mm
X_fine[6]=[?0.2 0.42740 0.9? ?1.5 2.89632 4? ?0.12 0.145347 0.36? ?1.5 2.93280 4?
?0.02 0.06367 0.313? ?2.0 3.26402 4?]; !fine model parameters
#include "tran.inc"
Xos1[6]=Xos_opt*1.0mm ;
X_fine1[6]=X_fine*39.37mil;! transform from mm to mil
Tran 1 2 0
W1=X_fine1[1] L1=X_fine1[2] W2=X_fine1[3]
L2=X_fine1[4] W3=X_fine1[5] L3=X_fine1[6];
Port 1 0 R=50 ;
Res 2 0 R=150;
!coarse model follows
MSUB Epsr=9.7 H=0.635mm TAND=0.002;
MSL 3 4 W=Xos1[1] L=Xos1[2] ;
MSTEP 4 5 W1=Xos1[1] W2=Xos1[3];
MSL 5 6 W=Xos1[3] L=Xos1[4];
MSTEP 6 7 W1=Xos1[3] W2=Xos1[5];
MSL 7 8 W=Xos1[5] L=Xos1[6];
Port 3 0 R=50;
Res 8 0 R=150;
Circuit;
Datapipe: Com File="osa90 -pio"
N_INPUT=9 INPUT=(4,ckt_file,macro,X_fine)
N_OUTPUT=6 OUTPUT=(Xos[6]);
end
spec
Xos=Xos_opt;
end
expression
Char ckt_file[]="
Model
X_fine[6]:* ;
#include ""tran.inc""
Xos[6]=[?0.38145? ?2.78208? ?0.15126? ?3.00255? ?0.04227? ?3.08801?];
Xos1[6]=Xos*1.0mm ;
X_fine1[6]=X_fine*39.37mil;! transform from mm to mil
Tran 1 2 0
W1=X_fine1[1] L1=X_fine1[2] W2=X_fine1[3]
L2=X_fine1[4] W3=X_fine1[5] L3=X_fine1[6];
Port 1 0 R=50 ;
Res 2 0 R=150;
!coarse model follows
MSUB Epsr=9.7 H=0.635mm TAND=0.002;
MSL 3 4 W=Xos1[1] L=Xos1[2] ;
MSTEP 4 5 W1=Xos1[1] W2=Xos1[3];
MSL 5 6 W=Xos1[3] L=Xos1[4];
MSTEP 6 7 W1=Xos1[3] W2=Xos1[5];
MSL 7 8 W=Xos1[5] L=Xos1[6];
Port 3 0 R=50;
Res 8 0 R=150;
Circuit;
end
sweep
Xos;
Ac: freq: from 5GHz to 15GHz step=0.5GHz
MS11 MS22
{XSWEEP Y= MS22.White.circle & MS11.white} ;
end
specification
Ac:freq: from 5GHz to 7.5GHz step=0.5GHz
Ms11=Ms22 W=50 ;
Ac:freq: from 8GHz to 12.5GHz step=0.5GHz
Ms11=Ms22 W=100;
Ac:freq:from 13GHz to 15GHz step=0.5GHz
Ms11=Ms22 W=50;
end
Control
Optimizer=Huber;

```

```

        N_iterations=30;
        Display_N_digits=6;
        accuracy=1.0e-5;
        Huber_threshold=0.15;
    end
    " ;
    Char macro[]='f',message,'child osa90 for parameter extraction',wait5,exit,
        'dxs', right,enter,enter, message,'before extraction',wait5,esc,
        'o',enter, 'dxs',right,enter,up,right,enter,enter,message,'after extraction',
        wait5,esc, esc";
end
control
    optimizer=space_mapping;
    N_iterations=9;
end
sweep
    Ac:freq:from 5.0GHz to 15GHz step=0.5GHz
        Ms11 Ms22
        {Xsweep Y=Ms11.white.circle& Ms22.white};
end

```

APPENDIX C

```

! This file optimizes the design of three-section 3:1 microstrip transformer using
! the aggressive space mapping technique with interpolation enabled.
! The fine model utilizes em simulator for the three section microstrip sections
! The coarse model makes use of the built in microstrip models in OSA90/hope.
Model
Xos_opt[6]=[0.38145 2.78208 0.15126 3.00255 0.04227 3.08801];!coarse model optimal solution in
!mm
X_fine[6]=[?0.2 0.3576 0.9? ?1.5 2.97243 4? ?0.12 0.142408 0.36? ?1.5 3.04148 4?
?0.02 0.0421529 0.313? ?2.0 3.08122 4?]; !fine model parameters
#include "tran.inc"
Xosl[6]=Xos_opt*1.0mm ;
X_finel[6]=X_fine*39.37mil;! transform from mm to mil
Tran 1 2 0
Wl=X_finel[1] L1=X_finel[2] W2=X_finel[3]
L2=X_finel[4] W3=X_finel[5] L3=X_finel[6];
Port 1 0 R=50 ;
Res 2 0 R=150;
!coarse model follows
MSUB Epsr=9.7 H=0.635mm TAND=0.002;
MSL 3 4 W=Xosl[1] L=Xosl[2] ;
MSTEP 4 5 Wl=Xosl[1] W2=Xosl[3];
MSL 5 6 W=Xosl[3] L=Xosl[4];
MSTEP 6 7 Wl=Xosl[3] W2=Xosl[5];
MSL 7 8 W=Xosl[5] L=Xosl[6];
Port 3 0 R=50;
Res 8 0 R=150;
Circuit;
Datapipe: Com File="osa90 -pio"
N_INPUT=9 INPUT=(4,ckt_file,macro,X_fine)
N_OUTPUT=6 OUTPUT=(Xos[6]);
end
spec
Xos=Xos_opt;
end
expression
Char ckt_file[]="
Model
X_fine[6]:* ;
#include ""tran.inc""
Xos[6]=[?0.38145? ?2.78208? ?0.15126? ?3.00255? ?0.04227? ?3.08801?];
Xosl[6]=Xos*1.0mm ;
X_finel[6]=X_fine*39.37mil;! transform from mm to mil
Tran 1 2 0
Wl=X_finel[1] L1=X_finel[2] W2=X_finel[3]
L2=X_finel[4] W3=X_finel[5] L3=X_finel[6];
Port 1 0 R=50 ;
Res 2 0 R=150;
!coarse model follows
MSUB Epsr=9.7 H=0.635mm TAND=0.002;
MSL 3 4 W=Xosl[1] L=Xosl[2] ;
MSTEP 4 5 Wl=Xosl[1] W2=Xosl[3];
MSL 5 6 W=Xosl[3] L=Xosl[4];
MSTEP 6 7 Wl=Xosl[3] W2=Xosl[5];
MSL 7 8 W=Xosl[5] L=Xosl[6];
Port 3 0 R=50;
Res 8 0 R=150;
Circuit;
responsel= MS11; ! when using +S11+2 as a matching goal this statement is changed to
! responsel= MS11 * MS11. Also, when using +S11+ in dB it is changed to
! responsel=20*log10(MS11)
response2= MS22; ! The same changes mentioned in the previous statement applies in this
statement
end
sweep
Xos;
Ac: freq: from 5GHz to 15GHz step=0.5GHz
MS11 MS22
{XSWEEP Y= MS22.White.circle & MS11.white} ;
end
specification
Ac:freq: from 5GHz to 15GHz step=0.5GHz
responsel=response2;
end
Control
Optimizer=Huber;

```

```

    N_iterations=30;
    Display_N_digits=6;
    accuracy=1.0e-5;
    Huber_threshold=0.15;
end
" ;
Char macro[]='f',message,'child osa90 for parameter extraction',wait5,exit,
             'dxs', right,enter,enter, message,'before extraction',wait5,esc,
             'o',enter, 'dxs',right,enter,up,right,enter,enter,message,'after extraction',
             wait5,esc, esc";
end
control
    optimizer=space_mapping;
    N_iterations=9;
end
sweep
    Ac:freq:from 5.0GHz to 15GHz step=0.5GHz
        Ms11 Ms22
        {Xsweep Y=Ms11.white.circle& Ms22.white};
end

```