TABLE I
REGION OF INTEREST FOR THE
MICROSTRIP LINE EXAMPLE

Parameter	Minimum value	Maximum value
W	10 mil	30 mil
L	40 mil	60 mil
H	10 mil	20 mil
e_r	8	10

TABLE II
THE SMSM AND FSMSM MAPPING PARAMETERS
FOR THE MICROSTRIP TRANSMISSION LINE

	SMSM	FSMSM
$\boldsymbol{B}$	$\begin{bmatrix} 1.015 & -0.002 & -0.007 & -0.022 \\ -0.001 & 0.992 & 0.020 & 0.023 \\ -0.008 & 0.001 & 0.985 & 0.027 \\ 0.009 & -0.004 & 0.044 & 1.028 \end{bmatrix}$	$\begin{bmatrix} 1.026 & -0.005 & 0.006 & -0.021 \\ -0.009 & 0.965 & -0.011 & 0.017 \\ -0.002 & 0.004 & 0.979 & 0.022 \\ 0.019 & -0.001 & 0.020 & 1.025 \end{bmatrix}$
$\boldsymbol{c}$	$[-0.011 \;\; -0.008 \;\; 0.012 \;\; -0.036]^T$	$[-0.013 \;\; 0.001 \;\; 0.011 \;\; -0.010]^T$
$\boldsymbol{s}$	$\mathbf{0}$ (fixed)	$[-0.006 \;\; 0 \;\; 0.002 \;\; -0.002]^T$
$\boldsymbol{t}$	$\mathbf{0}$ (fixed)	$\mathbf{0}$
s	1 (fixed)	1.035
d	0 (fixed)	0.001

TABLE III
REGION OF INTEREST FOR THE
MICROSTRIP RIGHT ANGLE BEND

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

TABLE IV
THE FSMSM MAPPING PARAMETERS FOR
THE MICROSTRIP RIGHT ANGLE BEND

	Gupta's model [11]	Jansen's model [12]
$\boldsymbol{B}$	$\begin{bmatrix} 1.291 & 0.207 & 0.189 \\ 0.067 & 0.613 & -0.094 \\ 0.092 & -0.066 & 0.918 \end{bmatrix}$	$\begin{bmatrix} 2.768 & 0.314 & 0.276 \\ -0.042 & 1.282 & 0.318 \\ -0.018 & -0.013 & 0.421 \end{bmatrix}$
$\boldsymbol{c}$	$[0.094 \ \ -0.174 \ \ 0.123]^T$	$[0.048 \ \ -0.012 \ \ 0.031]^T$
$\boldsymbol{s}$	$[0.109 \ \ -0.296 \ \ 0.183]^T$	$[0.001 \ \ -0.053 \ \ 0.250]^T$
$\boldsymbol{t}$	$[-0.001 \ \ -0.002 \ \ -0.002]^T$	$[-0.001 \ \ -0.002 \ \ -0.001]^T$
s	3.269	2.343
d	0.019	0.015

TABLE V
REGION OF INTEREST FOR THE
MICROSTRIP STEP JUNCTION

Parameter	Minimum value	Maximum value
W_1	20 mil	40 mil
W_2	10 mil	20 mil
H	10 mil	20 mil
e_r	8	10

TABLE VI
THE MSMDR MAPPING PARAMETERS FOR THE
MICROSTRIP STEP JUNCTION

	Target responses are {Im[S_{11}], Im[S_{21}], Im[S_{22}], Re[S_{21}])}	Target responses are {Re[S_{11}], Re[S_{22}]}
$\boldsymbol{B}$	$\begin{bmatrix} 0.764 & 0.033 & -0.062 & 0.074 \\ 0.191 & 0.632 & 0.255 & -0.502 \\ -0.023 & 0.116 & 1.485 & 0.018 \\ 0.676 & -0.365 & -0.111 & 0.177 \end{bmatrix}$	$\begin{bmatrix} 3.071 & -0.008 & -0.010 & -0.004 \\ 0.008 & 0.202 & 0.032 & 0.004 \\ -0.001 & 0.001 & 1.152 & 0.000 \\ -0.077 & -0.118 & -0.002 & 1.241 \end{bmatrix}$
$\boldsymbol{c}$	$[0.002 \quad -0.002 \quad 0.002 \quad -0.006]^T$	$[-0.001 \quad 0.001 \quad 0.000 \quad -0.003]^T$
$\boldsymbol{s}$	$[-0.003 \quad 0.004 \quad -0.001 \quad -0.002]^T$	$\mathbf{0}$
$\boldsymbol{t}$	$[-0.001 \quad 0.000 \quad -0.005 \quad 0.000]^T$	$[-0.001 \quad 0.000 \quad -0.007 \quad 0.003]^T$
s	1.546	5.729
d	0.113	0.065

TABLE VII
REGION OF INTEREST FOR THE
MICROSTRIP SHAPED T-JUNCTION

Parameter	Minimum value	Maximum value
h	15 mil	25 mil
x	5 mil	15 mil
y	5 mil	15 mil
e_r	8	10

TABLE VIII
THE MSMFI MAPPING PARAMETERS
FOR THE MICROSTRIP SHAPED T-JUNCTION

	2 GHz to 16 GHz	16 GHz to 20 GHz
$\boldsymbol{B}$	$\begin{bmatrix} 1.04 & 0.07 & 0.01 & 0.08 & -0.06 & 0.00 & 0.22 \\ 0.00 & 0.89 & 0.00 & -0.07 & -0.20 & 0.06 & -0.03 \\ -0.00 & 0.07 & 0.99 & 0.04 & -0.12 & 0.01 & -0.06 \\ -0.04 & 0.00 & -0.01 & 0.97 & 0.10 & -0.06 & -0.27 \\ 0.01 & 0.04 & 0.00 & 0.03 & 0.99 & -0.05 & -0.03 \\ -0.13 & -0.05 & -0.04 & -0.16 & 0.12 & 0.99 & 0.62 \\ -0.08 & 0.12 & -0.03 & 0.00 & -0.07 & 0.03 & 0.83 \end{bmatrix}$	$\begin{bmatrix} 0.99 & 0.02 & -0.00 & 0.01 & -0.09 & -0.01 & 0.13 \\ 0.05 & 0.85 & 0.01 & -0.07 & -0.28 & 0.01 & -0.01 \\ -0.06 & 0.15 & 0.98 & 0.04 & -0.25 & 0.00 & 0.02 \\ -0.10 & -0.06 & -0.03 & 0.88 & 0.13 & -0.09 & -0.27 \\ 0.08 & 0.04 & 0.03 & 0.11 & 1.07 & -0.04 & -0.12 \\ -0.14 & -0.02 & -0.05 & -0.15 & 0.23 & 1.03 & 0.51 \\ -0.13 & 0.22 & -0.04 & 0.02 & -0.07 & 0.03 & 0.87 \end{bmatrix}$
$\boldsymbol{c}$	$[0.02 \quad 0.01 \quad -0.01 \quad -0.03 \quad -0.01 \quad 0.07 \quad -0.03]^T$	$[0.01 \quad 0.01 \quad -0.01 \quad -0.03 \quad -0.01 \quad 0.05 \quad -0.03]^T$
$\boldsymbol{s}$	$[-0.01 \quad 0.09 \quad -0.10 \quad -0.02 \quad 0.00 \quad -0.02 \quad -0.20]^T$	$[0.00 \quad 0.01 \quad -0.01 \quad 0.00 \quad 0.00 \quad 0.00 \quad -0.02]^T$
$\boldsymbol{t}$	$\mathbf{0}$	$[0.01 \quad 0.00 \quad -0.02 \quad 0.00 \quad 0.00 \quad 0.00 \quad 0.00]^T$
s	0.851	0.957
d	–0.003	0.008

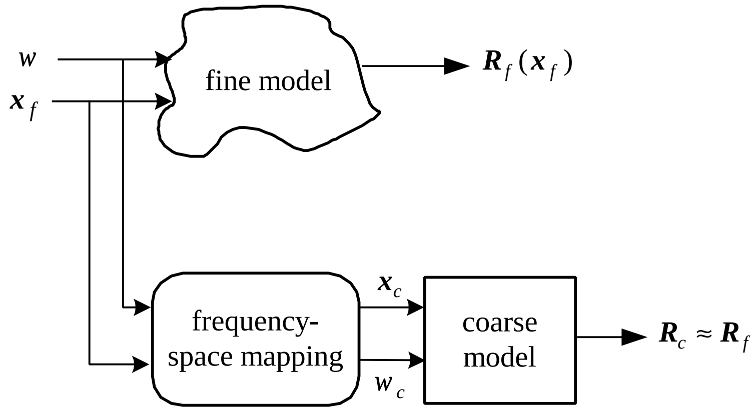


Fig. 1. The Frequency-Space Mapping Super Model (FSMSM) concept.

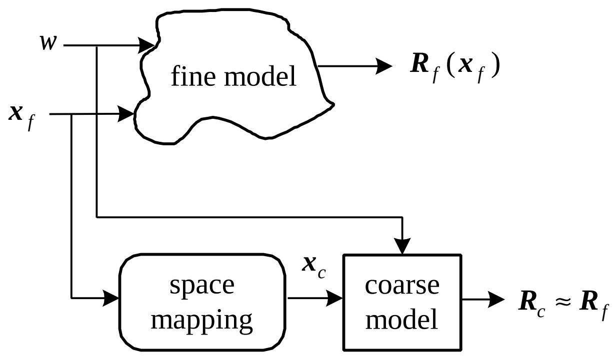


Fig. 2. The Space Mapping Super Model (SMSM) concept.

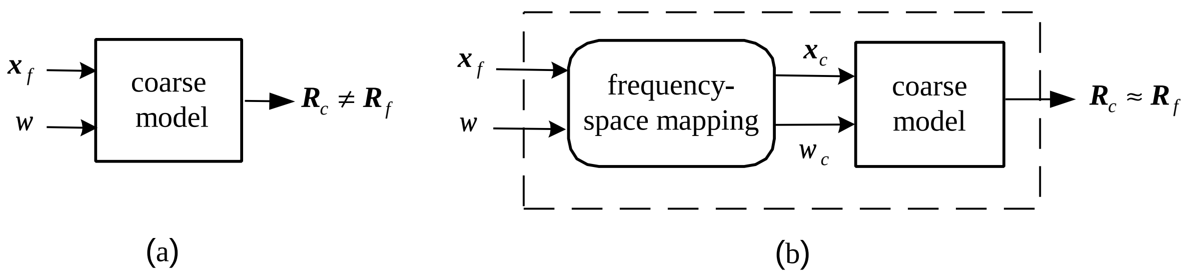


Fig. 3. The coarse model (a) and the enhanced coarse model (b).

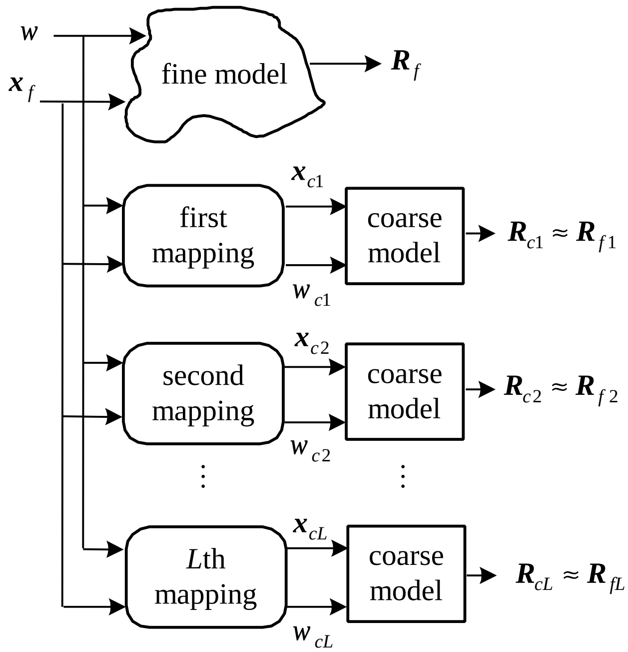


Fig. 4. The Multiple Space Mapping for Device Responses (MSMDR).

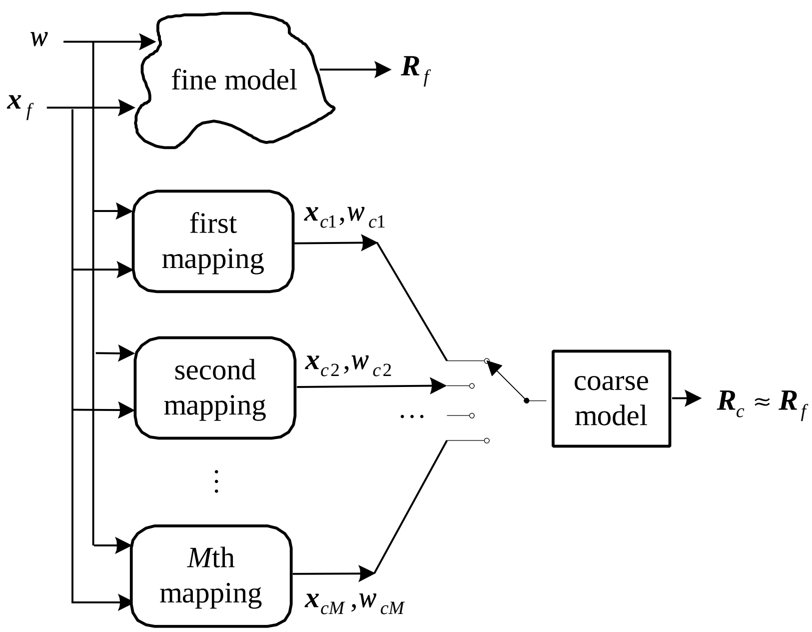


Fig. 5. The Multiple Space Mapping for Frequency Intervals (MSMFI).

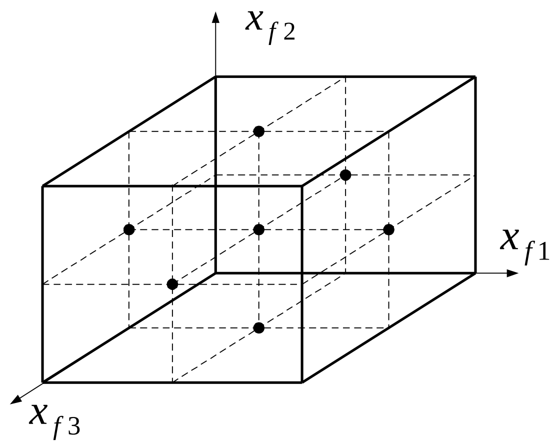


Fig. 6. Distribution of the base points in the region of interest for a 3-dimensional space [6].

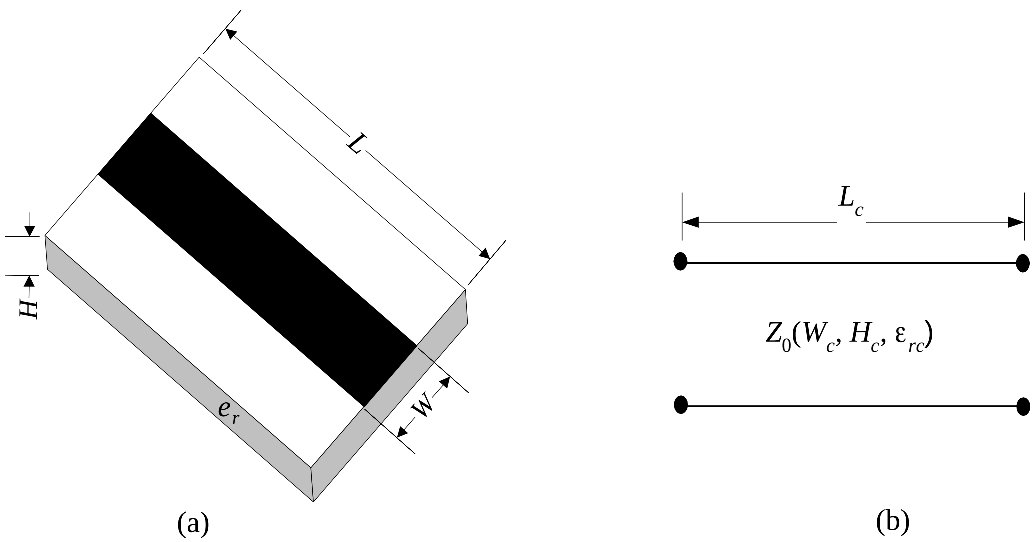
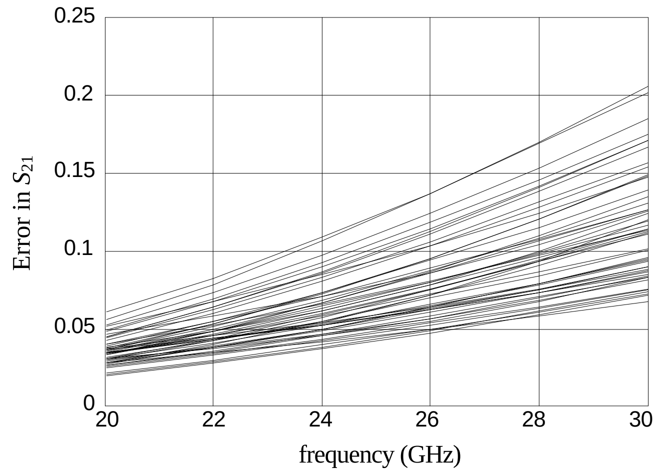
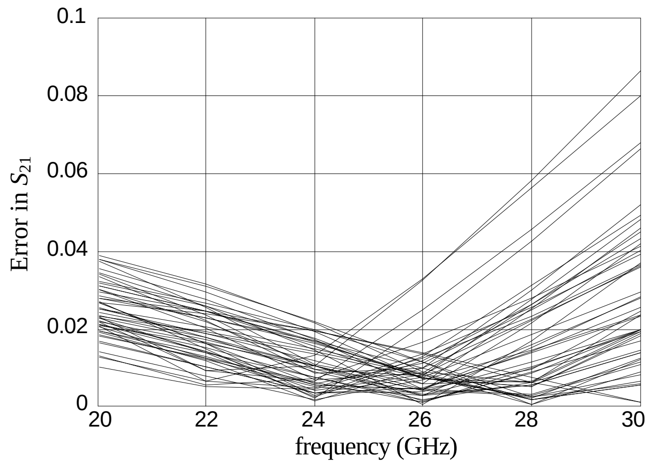


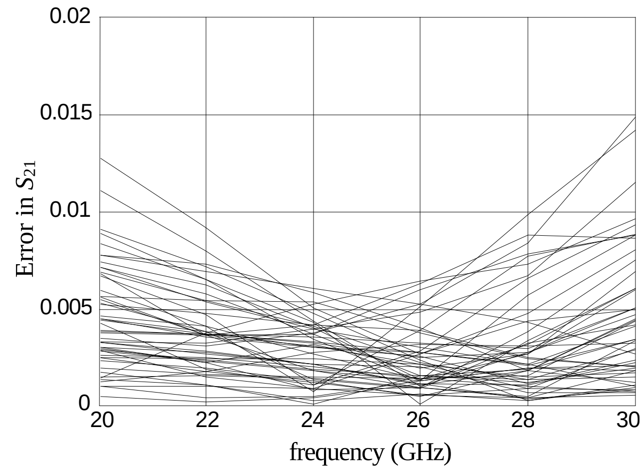
Fig. 7. Microstrip line models: (a) the fine model; (b) the coarse model.



(a)

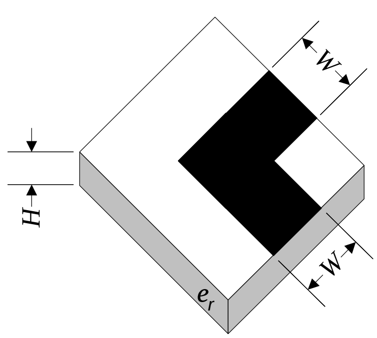


(b)

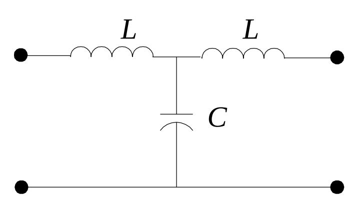


(c)

Fig. 8. Error in S_{21} with respect to ***em***™: (a) by the microstrip transmission line model; (b) by the microstrip transmission line SMSM; (c) by the microstrip transmission line FSMSM.



(a)



(b)

Fig. 9. Microstrip right angle bend: (a) the fine model; (b) the coarse model.

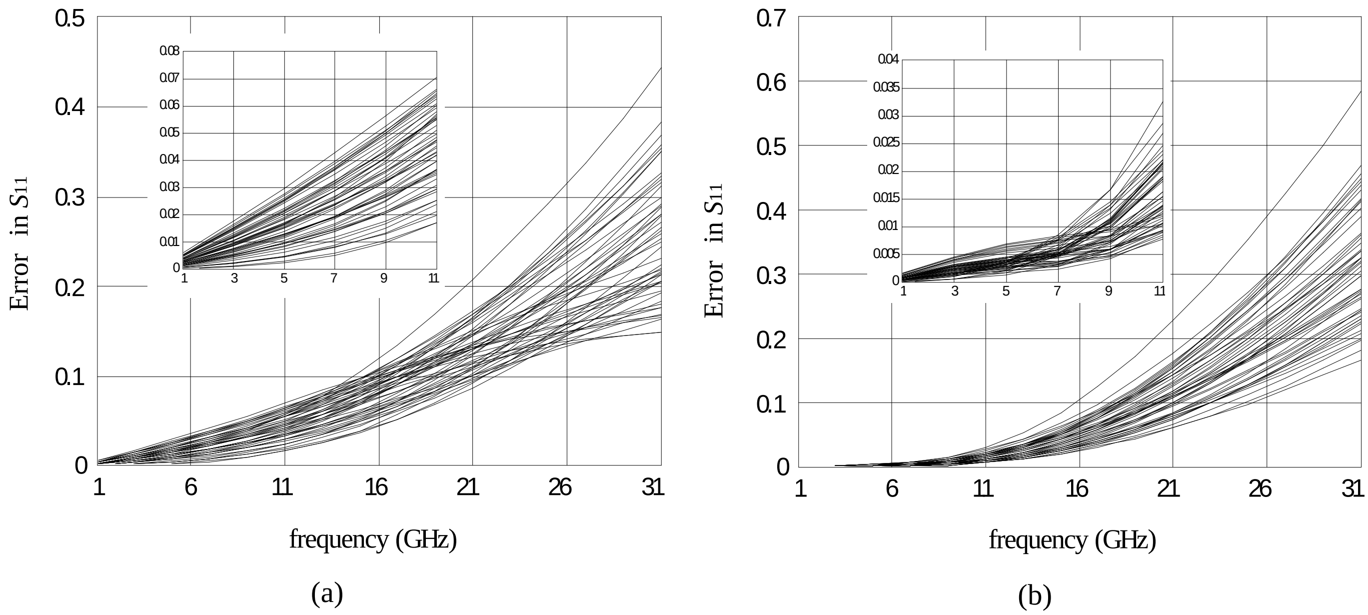


Fig. 10. Error in S_{11} of the microstrip right angle bend with respect to ***em***^{TM}: (a) by Gupta's model [11]; (b) by Jansen's model [12].

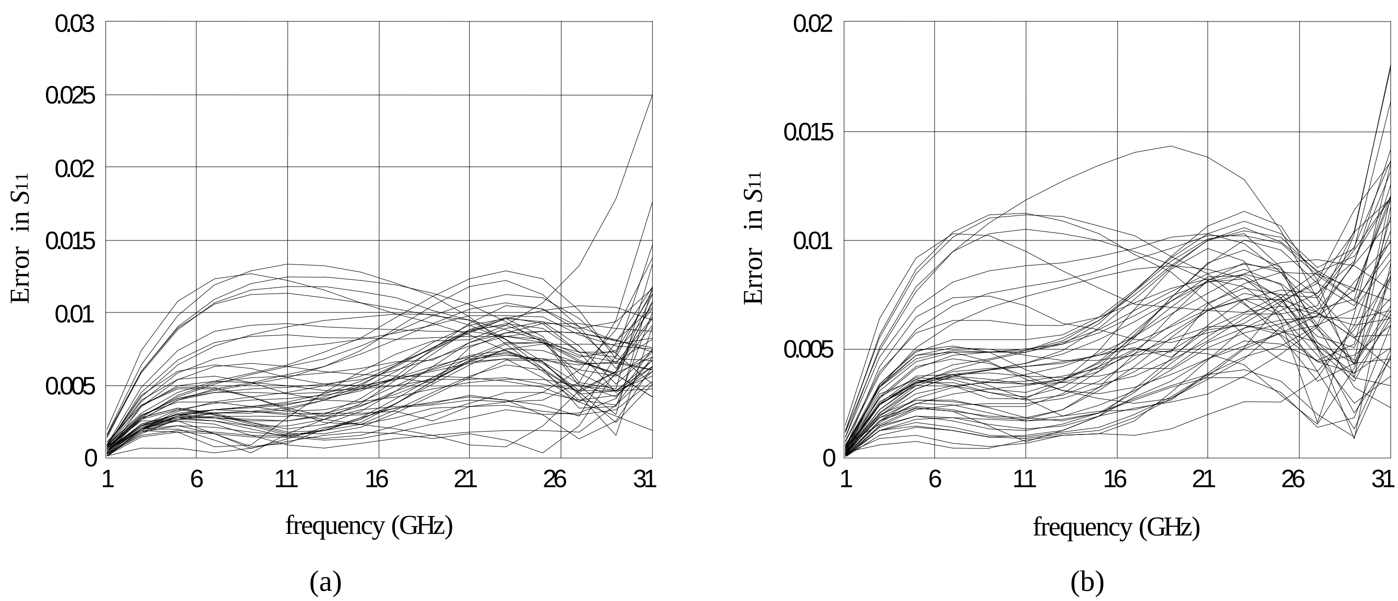


Fig. 11. Error in S_{11} of the microstrip right angle bend with respect to ***em***^{TM}: (a) by the enhanced Gupta's model [11]; (b) by the enhanced Jansen's model [12].

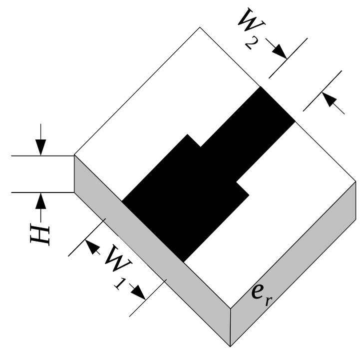


Fig. 12. Microstrip step junction.

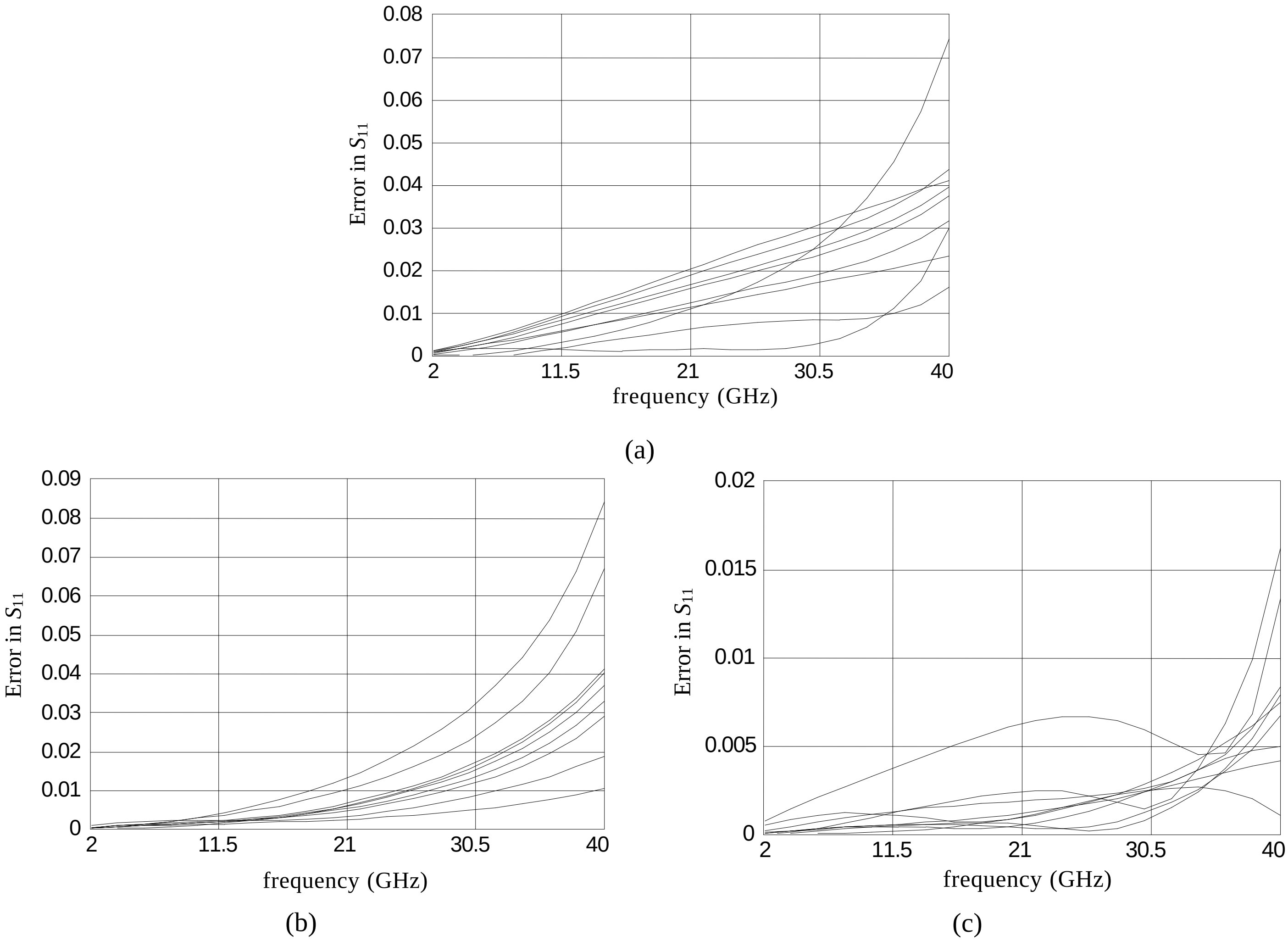


Fig. 13. Error in S_{11} of the microstrip step junction with respect to ***em***^{TM}: (a) before applying any modeling technique; (b) after applying FSMSM; (c) after applying the MSMDR algorithm.

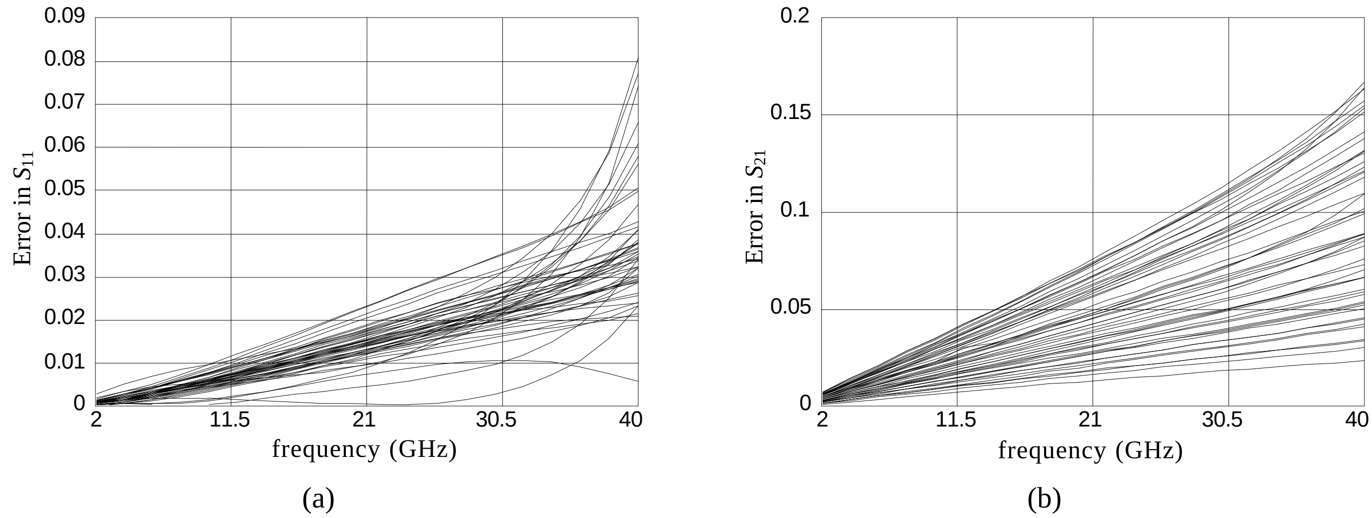


Fig. 14. Error of the microstrip step junction coarse model with respect to ***em***™: (a) in S_{11}; (b) in S_{21}.

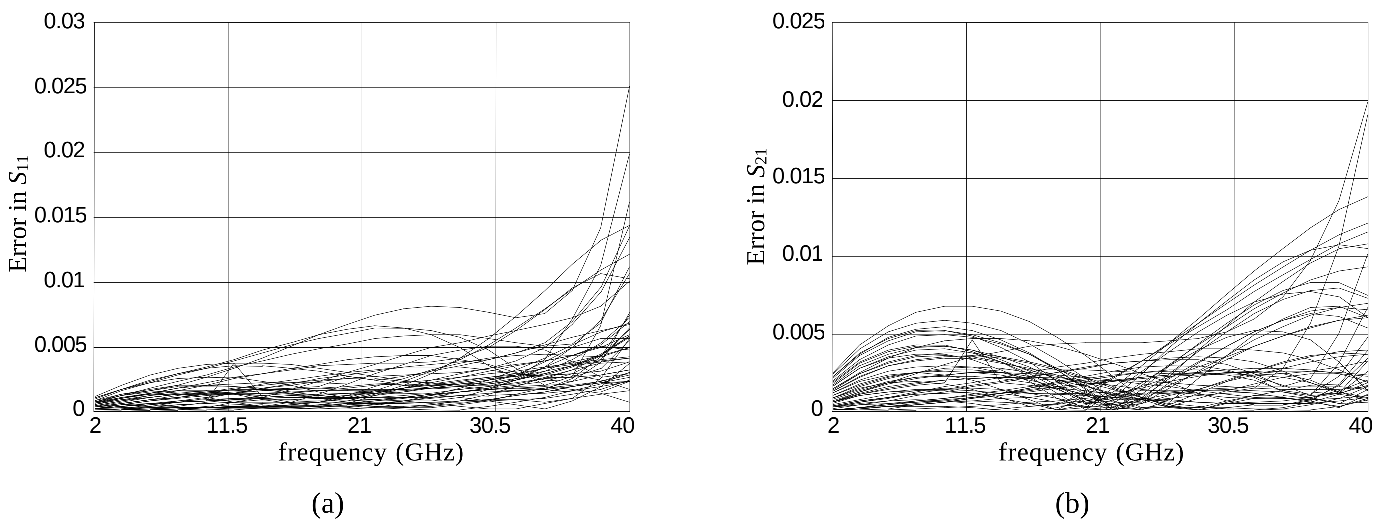
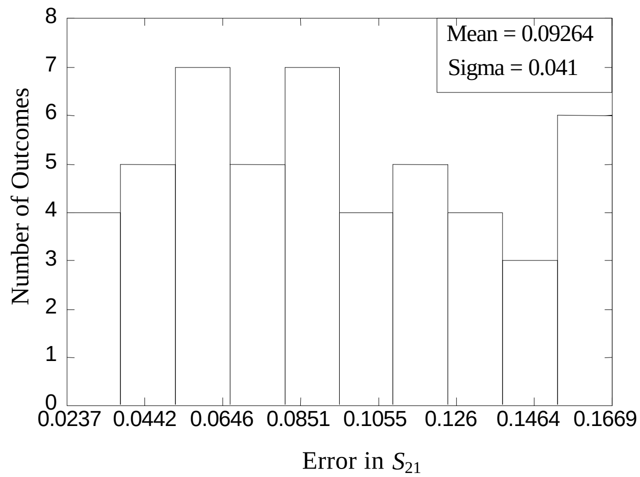
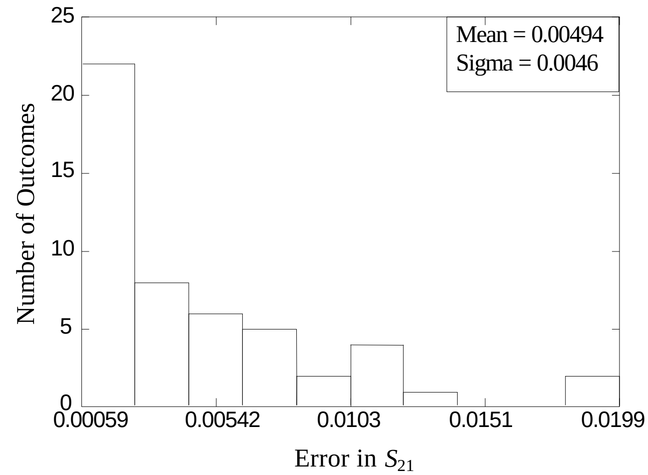


Fig. 15. Error of the microstrip step junction enhanced coarse model with respect to ***em***™: (a) in S_{11}; (b) in S_{21}.

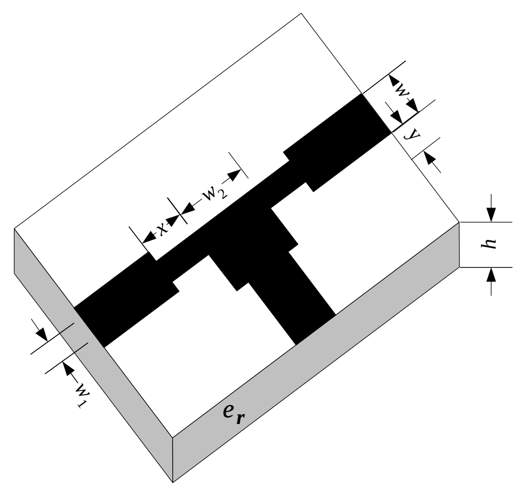


(a)

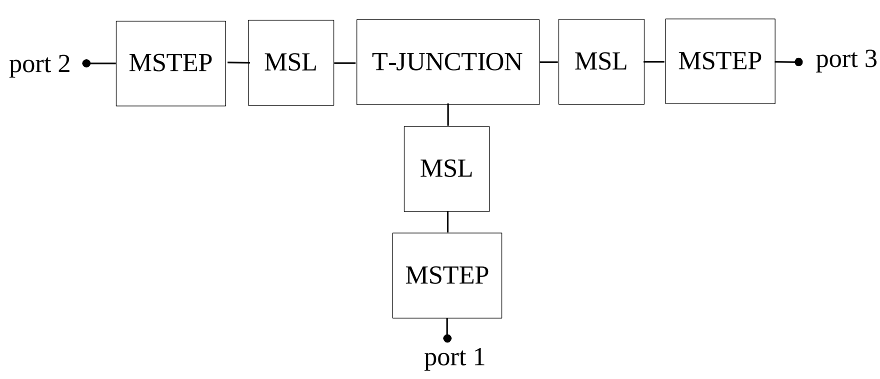


(b)

Fig. 16. Histogram of the error in S_{21} of the microstrip step junction for 50 points in the region of interest at 40 GHz: (a) by the coarse model; (b) by the enhanced coarse model.

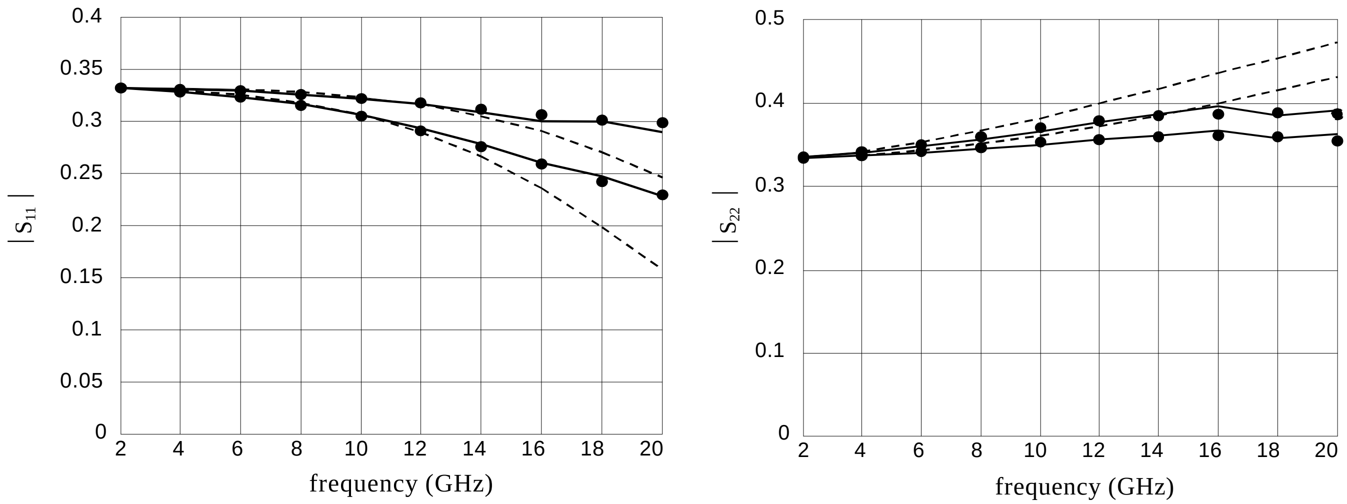


(a)



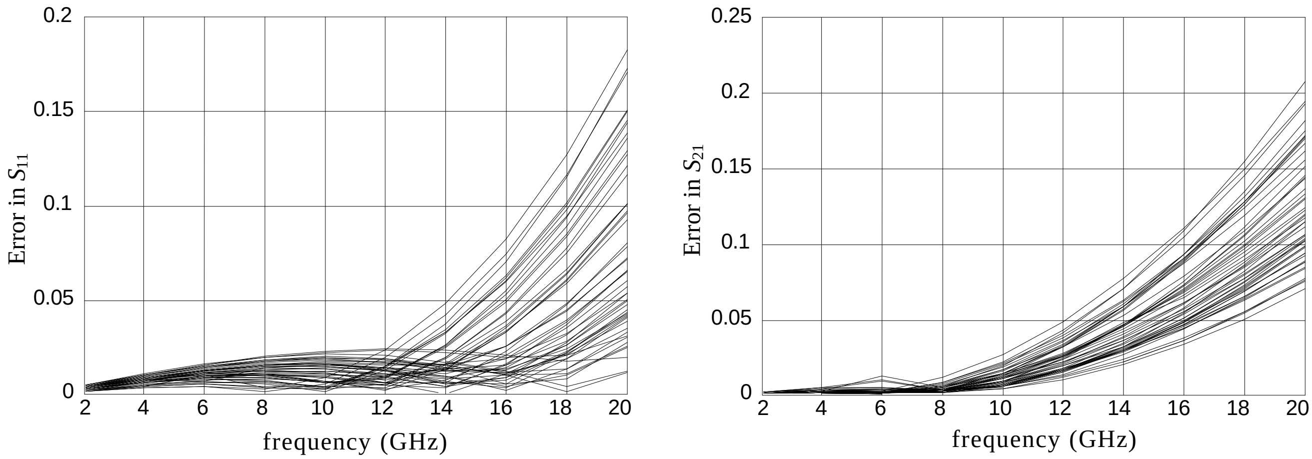
(b)

Fig. 17. Microstrip shaped T-junction: (a) the physical structure (fine model); (b) the coarse model.



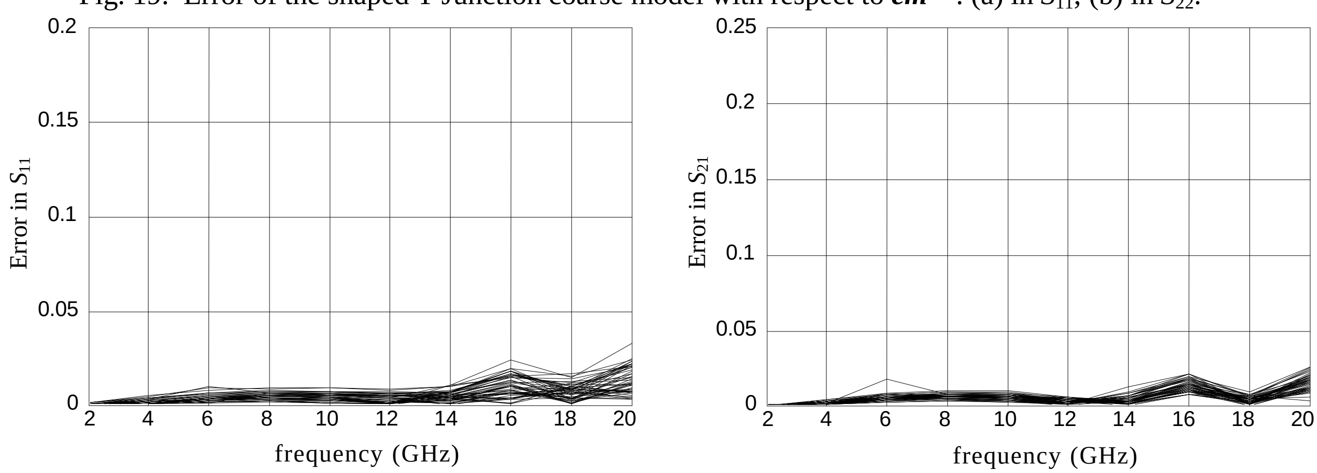
(a) (b)

Fig. 18. Responses of the shaped T-Junction at two test points in the region of interest by Sonnet's ***em*** (?), by the coarse model (---) and by the enhanced coarse model (?): (a) $|S_{11}|$; (b) $|S_{22}|$.



(a) (b)

Fig. 19. Error of the shaped T-Junction coarse model with respect to ***em***™: (a) in S_{11}; (b) in S_{22}.



(a) (b)

Fig. 20. Error of the shaped T-Junction enhanced coarse model with respect to ***em***™: (a) in S_{11}; (b) in S_{22}.

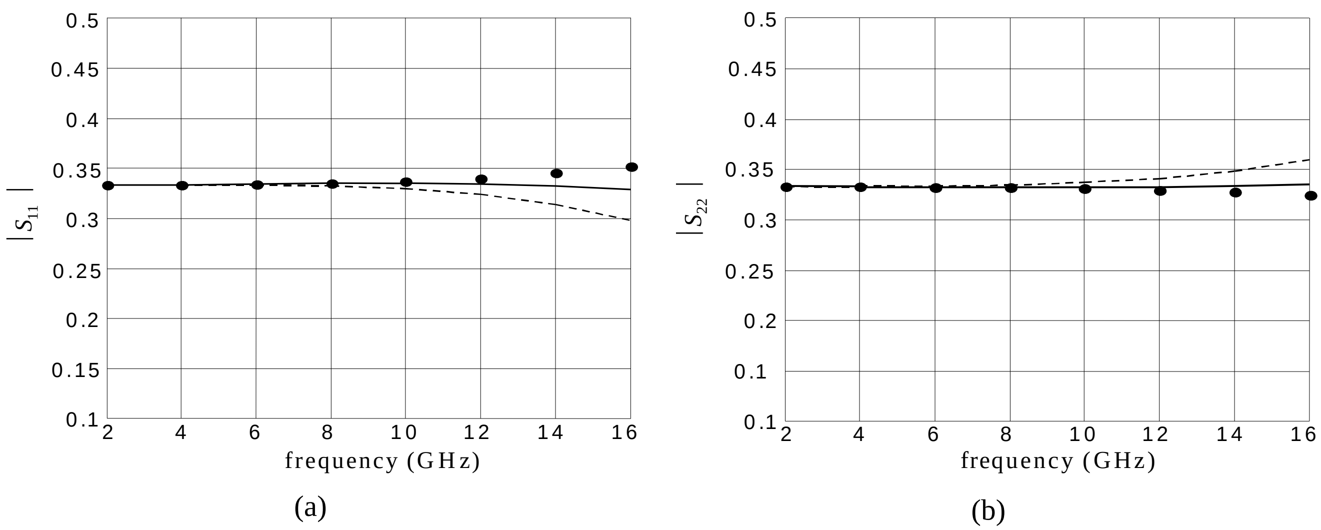


Fig. 21. Responses of the optimum shaped T-Junction by Sonnet's ***em*** (?), by the coarse model (---) and by the enhanced coarse model (?): (a) $|S_{11}|$; (b) $|S_{22}|$.