Amplifier Design Wizard Customization

If a license has been obtained for it, the discontinuity effects and the capacitor and spiral inductor models used in Multimatch can be customized by the user (Multimatch LIW850). Note that only the dielectric constant, the substrate and cover heights, and the metal thickness are used to decide if the user-defined models must be associated with a substrate used in the circuit. Some variations (factor 2) in the metal thickness and the cover height are allowed in deciding whether a substrate has been customized or not. If the substrate losses differ significantly from those associated with the substrate for which the discontinuity models were created, inaccurate results may be obtained.

You can check whether a substrate is considered to be user-defined by using the Project | Substrates Command. A "**User-Defined**" string is displayed below the specifications of such a substrate.

The specifications for the **user-defined discontinuities** and models are stored in a file of type ".inf" which is typically stored in the same directory as the Multimatch executable (default: "c:\Program Files\Ampsa\Amplifier Design Wizard"). The name of the **customization file** to be used (default: "ADW_CustomSubstrates.inf") can be modified by using the Project | Substrates Command. Note that different customization files are typically used for different foundry processes.

The customization file may be edited with an ASCII text editor (make a backup copy before you try this!). The data format is described below. Note that options are specified with "0" (No) or "1" (Yes). Options are indicated below with a "|". The "#" used should be replaced with an appropriate number.

To allow **verification** of the data read, a file with the same name but file type ".txt" is written to the Working Directory when the Project | Substrates Dialog is closed with the OK Command. When a new customization file has been created, you should compare the contents of the ".inf" file and the ".txt" file, and any differences should be resolved.

File Heading

A warning is displayed in the first line of the file. The **file version** for the specifications must be specified in the second line. The only option currently is Version 1. The number of substrates for which models will be specified must be specified in the third line. The models for up to 20 substrates can currently be customized. The fourth line in the file is blank. The specifications for **different substrates** are also separated with a single blank line.

Note that the **sequence** of any of the specifications made is fixed. This also applies to the coefficients specified for the fitting functions.

Format

```
WARNING: DO NOT DELETE ANY RECORDS (EMPTY RECORDS INCLUDED) FROM THIS FILE!
File Version = 1
Number of substrates = 1
```

Substrate Heading

The parameters of the substrate of interest must be specified next. Up to 20 substrates are allowed. The Substrate number can be between 1 and 20 and must be specified in ascending order (1 through 20). The substrate types allowed are currently stripline (Type=0) and microstrip (Type=1). The dimensions must be specified in the units listed below.

Format

```
SUBSTRATE: Substrate number = #: Type=0|1 er=# h=#mm T=#um HU=#mm
```

Via Specifications

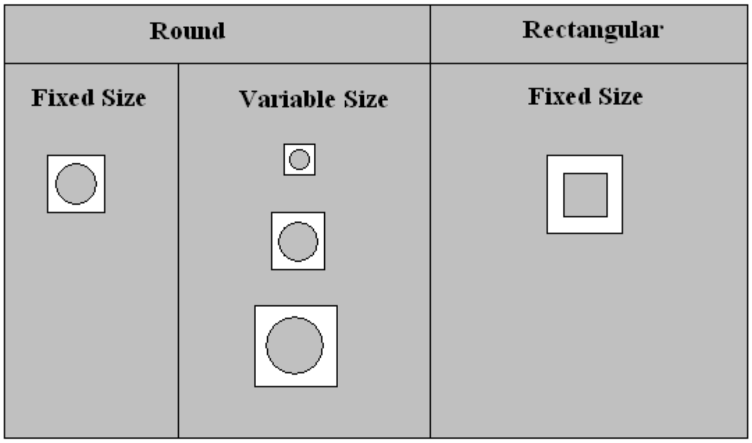

Figure 1 Rectangular or round vias are allowed when a substrate is customized. If rectangular vias are used, the size is fixed. When round vias are used, the size can be fixed or it can be stepped.

Round (1) or rectangular (0) **vias** are allowed. When round vias are used, the via size can vary (the sizes allowed are taken from the substrate specifications made in the circuit file). To fix the via size set “Fixed Size” to 1. The via size is set by the “ViaWidth” and “Vialength” parameters. The via pad is set by the “PadWidth” and “PadLength” parameters. The units as listed below must be used. When rectangular or square vias are used, the size must be fixed.

The **model** used for **fixed size** vias consists of an ideal inductor to ground connected to a series transmission line. The via inductance and equations for the viapad Z0 and the effective electrical length of the pad (at 100GHz) must be specified. The Z0 is assumed to be a weak function (second order polynomial function) of the frequency (in GHz):

$$Z_0\ (\mathrm{Ohm}) = A_0 + A_1 \times f_{\mathrm{GHz}} + A_2 \times f_{\mathrm{GHz}}{}^2$$

while the electrical length is a function of the frequency, as well as the pad width in micron:

$$PadAng\ (\mathrm{degree@100GHz}) = (A_{0\_\mathrm{weight}} + A_{1\_\mathrm{weight}} \times f_{\mathrm{GHz}}) \times \mathrm{POW}(\ W_{\mathrm{pad}\_um},\ B_{0\_\mathrm{power}} + B_{1\_\mathrm{power}} \times f_{\mathrm{GHz}})$$

When **variable size vias** are used, the standard Multimatch via model is used. Specify the Z0 and viapad length coefficients to be zero in this case.

Format

VIAS: Round=0|1 Fixed size=0|1 ViaWidth=#mm ViaLength=#mm PadWidth=#mm PadLength=#
Via Inductance=#pH
Viapad Z0(fGHz; Ohm): $A2$=# A_1=# A_0=#
Viapad Length (fGHz, Wpadum; deg@100GHz): A_{1_weight}=# A_{0_weight}=# B_1_power=# B_0_power=#

Curved Lines

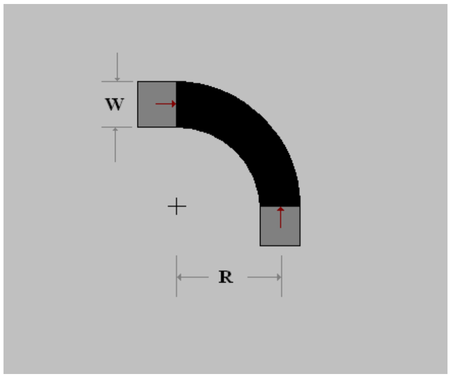

Figure 2 A curve is modeled in Multimatch as a straight line section with the same width. The length is calculated by assuming an effective path for the current around the curve. This path is defined by an offset from the center of the curve.

Curved lines are modeled in Multimatch as straight lines with the same width and different lengths. The effective length of the curve is determined by the length of the effective path (circular). At low frequencies the **effective path** is close to the center of the curve, while it moves closer to the inner edge of the curve at higher frequencies. The relative offset of the effective path from the center of the line must be specified as a fraction of the line width (typical values: 0.2 or 0.5).

Format

CURVES: Path offset from line center = # x LineWidth

Rectangular Bends (Symmetrical)

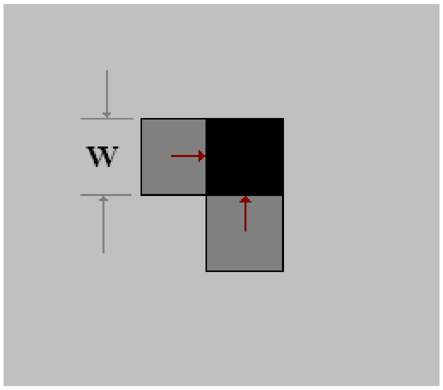

Figure 3 The effective length of a symmetrical rectangular bend can be customized. The bend is assumed to behave like a line with the same width as the lines connected to it.

Rectangular bends (symmetrical) are modeled in Multimatch as straight lines with the same width as the lines connected to it. A small capacitor at the center of the bend usually improves the fit of the model, but its effect is ignored in the current version of Multimatch. The effective length (often negative) of the bend is a function of the width of the connecting lines. The effective length is assumed to be a polynomial function of the line width (in micron). Up to third order polynomials can be used in the current release of the software:

$\textit{Bend Length}\ (\text{um}) = A_0 + A_1 \times W_{um} + A_2 \times W_{um}^2 + A_3 \times W_{um}^3$

Format

RECTANGULAR BENDS: Effective length (Wum; um): A_3=# A_2=# A_1=# A_0=#

Open Ends

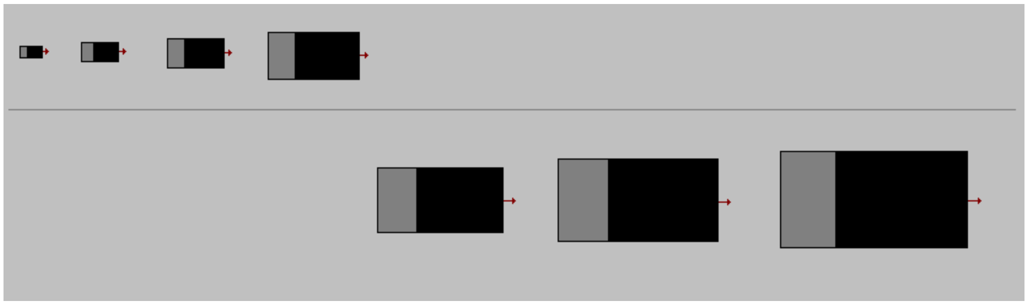

Figure 4 The effective length associated with an open-ended line can be customized by the user. Two equations may be provided - one for narrower lines and one for wide lines.

An open end is modeled in Multimatch as an extension of the physical length of the open-ended stub. A polynomial fit is assumed. To allow for a smooth fit, one polynomial can be used to fit lines of narrow width and another for the wider lines. The point used to decide on the polynomial to be used must also be specified (breakpoint). Up to fourth order polynomials are allowed:

$$\textit{Open End Length}\ (\mathrm{um}) = A_0 + A_1 \times W_{um} + A_2 \times W_{um}^2 + A_3 \times W_{um}^3 + A_4 \times W_{um}^4$$

Format

OPEN ENDS: Breakpoint Width = # um
Narrow Lines Open End Extension (um): A5= # A_4= # A_3= # A_2= # A_1= # A_0= #
Wide Lines Open End Extension (um): A5= # A_4= # A_3= # A_2= # A_1= # A_0= #

Steps

Steps are modeled in Multimatch by assuming the wider line of the step to be slightly longer than its physical length. Different values (up to 10) for the narrow side width should be selected, and the width of the wider line should then be varied. A polynomial fit is assumed for each case and up to a third order polynomial may be used:

$$\textit{Step Wide Line Extension}\ (\mathrm{deg@100GHz}) = A_0 + A_1 \times W_{\mathrm{wide}\_um} + A_2 \times W_{\mathrm{wide}\_um}^2 + A_3 \times W_{\mathrm{wide}\_um}^3$$

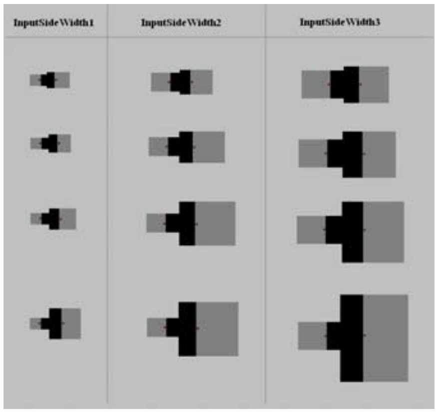

Figure 5 The extension of the length of the line on the wide side of a step can be customized. The customization is done for different widths of the line on the narrow side.

Format

STEPS: Number of narrow side line widths used = 6
Narrow Side Width1 = # um; Line Extension(degree@100GHz): A_3=# A_2=# A_1=# A_0=#
Narrow Side Width2 = #um; Line Extension(degree@100GHz): B_3=# B_2=# B_1=# B_0=#
Narrow Side Width3 = #um; Line Extension(degree@100GHz): C_3=# C_2=# C_1=# C_0=#
Narrow Side Width4 = #um; Line Extension(degree@100GHz): D_3=# D_2=# D_1=# D_0=#
Narrow Side Width5 = #um; Line Extension(degree@100GHz): E_3=# E_2=# E_1=# E_0=#

Symmetrical T-junctions

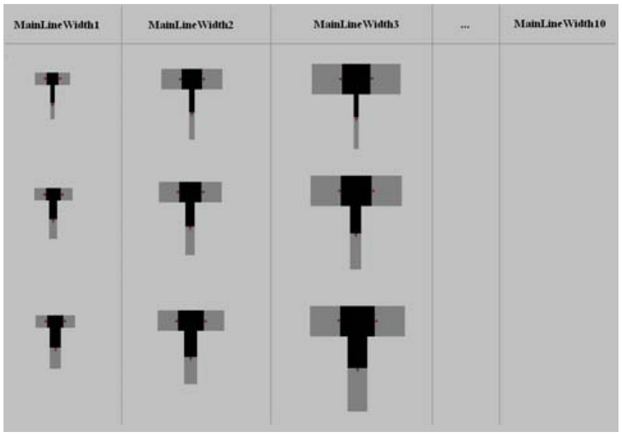

Figure 6 The offsets in the main-line and the stub reference planes of a symmetrical T-junction can be customized. The customization is done for different widths of the main-line sections (that is, the main-line width is fixed and the stub width is stepped).

Symmetrical T-junctions are modeled in Multimatch as ideal junctions with **offsets in the reference planes** for the two main line sections and the stub (positive offsets imply that the associated line will be electrically longer than expected from its physical length). The offsets are measured from the center of the junction. Note that the stub width is usually limited in Multimatch to ensure that the **loading and transformer effects** expected at the junction are small.

When EM (or other) simulations are done to characterize the T-junctions, different widths should be selected for the main line (up to 10 different values may be selected), and the stub width should then be varied. A polynomial fit is assumed for each case and the order of the polynomial may be up to third order:

$$\textit{Increase in Main Line Section Length}\text{ (um)} = A_0 + A_1 \times W_{\text{stub}\_um} + A_2 \times W_{\text{stub}\_um}^2 + A_3 \times W_{\text{stub}\_um}^3$$

$$\textit{Increase in Stub Length}\text{ (um)} = B_0 + B_1 \times W_{\text{stub}\_um} + B_2 \times W_{\text{stub}\_um}^2 + B_3 \times W_{\text{stub}\_um}^3$$

Format

SYMTEEs: Number of main line widths used = 3
Main Line Width1 = #um; Main line section offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width1 = #um; Stub offset from center (um): B_3=# B_2=# B_1=# B_0=#
Main Line Width2 = #um; Main line section offset from center (um): C_3=# C_2=# C_1=# C_0=#
Main Line Width2 = #um; Stub offset offset from center (um): D_3=# D_2=# D_1=# D_0=#
Main Line Width3 = #um; Main line section offset from center (um): E_3=# E_2=# E_1=# E_0=#
Main Line Width3 = #um; Stub offset from center (um): F_3=# F_2=# F_1=# F_0=#

Symmetrical Crosses

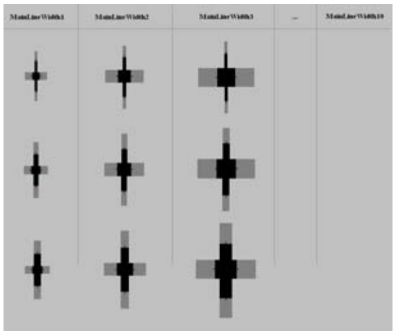

Figure 7 The offsets in the reference planes for the main line and the stubs of a symmetrical cross can be customized. The customization is done for different widths of the main-line sections (that is, the main-line width is fixed and the stub width is stepped).

Symmetrical cross-junctions are modeled in Multimatch as ideal junctions with reference plane offsets for the two main line sections and the two stubs. The offsets are measured from the center of the junction. Note that the width of the stubs are usually limited in Multimatch to ensure that the **loading and transformer effects** expected at the junction are small.

When EM (or other) simulations are done to characterize the cross junctions, different widths should be selected for the main line (up to 10 different values may be selected), and the (double) stub width should then be varied. A polynomial fit for the offset is assumed and up to a third order polynomial may be used:

$$\textit{Increase in Main Line Section Length}\ (\mathrm{um}) = A_0 + A_1 \times W_{\mathrm{stub}\_um} + A_2 \times W_{\mathrm{stub}\_um}^2 + A_3 \times W_{\mathrm{stub}\_um}^3$$

$$\textit{Increase in Stub Length}\ (\mathrm{um}) = B_0 + B_1 \times W_{\mathrm{stub}\_um} + B_2 \times W_{\mathrm{stub}\_um}^2 + B_3 \times W_{\mathrm{stub}\_um}^3$$

Format

SYMCROSSES: Number of main line widths used = 3
Main Line Width1 = #um; Main line section offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width1 = #um; Stub offset from center (um): B_3=# B_2=# B_1=# B_0=#
Main Line Width2 = #um; Main line section offset from center (um): C_3=# C_2=# C_1=# C_0=#
Main Line Width2 = #um; Stub offset from center (um): D_3=# D_2=# D_1=# D_0=#
Main Line Width3 = #um; Main line section offset from center (um): E_3=# E_2=# E_1=# E_0=#
Main Line Width3 = #um; Stub offset from center (um): F_3=# F_2=# F_1=# F_0=#

Parallel-plate Capacitors

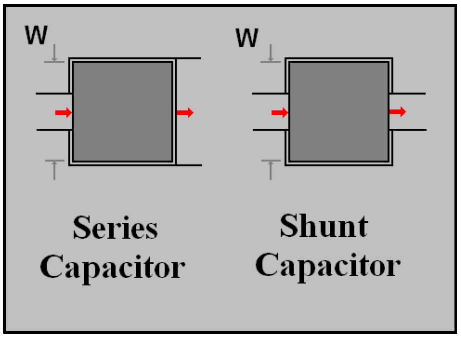

Figure 8 The series and shunt parallel-plate capacitor models can be customized. Note that the connection to the bottom plate of the series capacitor is assumed to have the same width as the bottom plate. Consistent rules should be created for deciding the air-bridge width.

The capacitance density of any parallel-plate capacitors to be used (if any) must be specified. The specification is required in picoFarad per millimeter squared. The offset of the bottom plate of each capacitor relative to the top plate must also be specified (in um) in the same line (typically, 2um). The difference in the widths of the two plates is double the offset specified.

Format

PARALLEL PLATE CAPACITORS: Capacitance density = #pF/mm^2 Bottom plate extension on each side = #um

Series parallel-plate capacitor

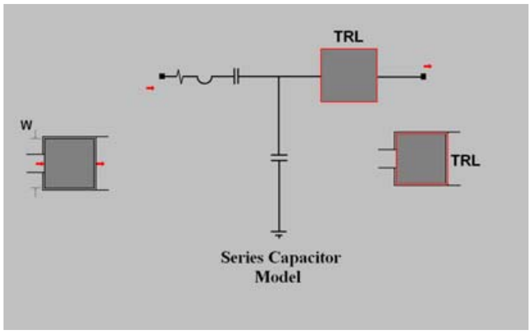

Figure 9 The model used for a series parallel-plate capacitor. Note that the line width in the model is taken to be that of the top plate, while the length is the top plate length extended on one side with the bottom plate offset.

Series parallel-plate capacitors (SPLC) are modeled in Multimatch as an ideal series capacitor with series resistance and inductance, a (small) capacitor to ground and a series line. The reference planes are assumed to be at the edge of the top plate on one side (airbridge side) and the edge of the bottom plate on the other side. Only **square capacitors** are modeled in this release, but the results are usually still good when the capacitor is rectangular in shape. If models were not fitted for series parallel-plate capacitors, set the “SPLC Used” parameter equal to 0.

The transmission line (TRL) is assumed to be on the side of the bottom plate connection (wide side). The line width is taken to be that of the top plate, and the length is the distance from the edge of the top plate of the capacitor, on the air-bridge side, to the edge of the bottom plate on the other side.

The series capacitance is determined by the capacitance density specified and the area of the capacitor (Width×Length). It is assumed that there is no fringing effect.

The resistance is a function of the capacitor size (width in micron; square capacitor assumed). A fourth order polynomial fit

$$R \text{ (Ohm)} = A_0 + A_1 \times W_{um} + A_2 \times W_{um}^2 + A_3 \times W_{um}^3 + A_4 \times W_{um}^4$$

or an exponential fit

$$R \text{ (Ohm)} = Power\_Constant \times \text{pow}(W_{um}, Power\_Exponent)$$

can be provided for it. This option is set with the “Use Polygon” switch. Specify zero values for the coefficients of the option not used.

The series inductance and shunt capacitance also depends on the capacitor size. Up to fourth order polynomials can be specified for the inductance in picoHenry:

$$L \text{ (pH)} = B_0 + B_1 \times W_{um} + B_2 \times W_{um}^2 + B_3 \times W_{um}^3 + B_4 \times W_{um}^4$$

and the shunt capacitance in femtoFarad:

$$C_{\text{shunt}} \text{ (fF)} = C_0 + C_1 \times W_{um} + C_2 \times W_{um}^2 + C_3 \times W_{um}^3 + C_4 \times W_{um}^4$$

A minimum value for the inductance must also be specified (pH). This value is used to clip the value calculated if necessary.

Format

SPLC (SERIES PLATE CAPACITORS; square): Used = 0

or

SPLC (SERIES PLATE CAPACITORS; square): Used = 1
SPLC Resistance (Ohm): Use Polygon = 0|1 Power_Constant=# Power_Exponent=#
Resistance (Ohm): A_4=# A_3=# A_2=# A_1=# A_0=#
Inductance (pH): B_4=# B_3=# B_2=# B_1=# B_0=# Lmin=#pH
Shunt Capacitance (fF): C_4=# C_3=# C_2=# C_1=# C_0=#

Shunt parallel-plate capacitor (Overlay capacitor)

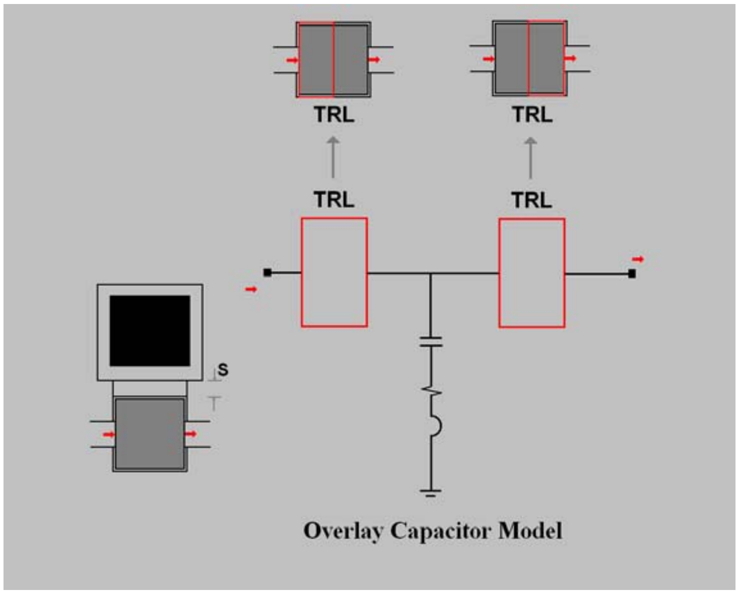

Figure 10 The model used for a shunt parallel-plate capacitor (overlay capacitor). Note that the length of each line in the model is taken to be half of the top plate length, but that the line width is taken to be the bottom plate width.

The ground connection required by a shunt parallel-plate capacitor (overlay capacitor; GPLC) can be provided with one or two **vias**. When a single via is used, the via can be centered or it can be connected to a bottom plate edge. In the offset case, the via can be moved away from the capacitor by the separation distance specified. When the via is centered, the top plate can be opened above the via too (reliability issues). If this is done, the cut-out in the top plate should be larger than the via to ground. The extra offset to be used, can also be specified. The offset is also used to ensure that the cut-out in the top plate is not too large (minimum top plate conductor width).

When a rectangular via is used, it makes sense to rotate the via when the capacitor is long enough. When the capacitor length exceeds the “Rotate Threshold” specified, the via will be rotated (the model must be fitted accordingly). The separation from the bottom plate edge can be different for the two cases.

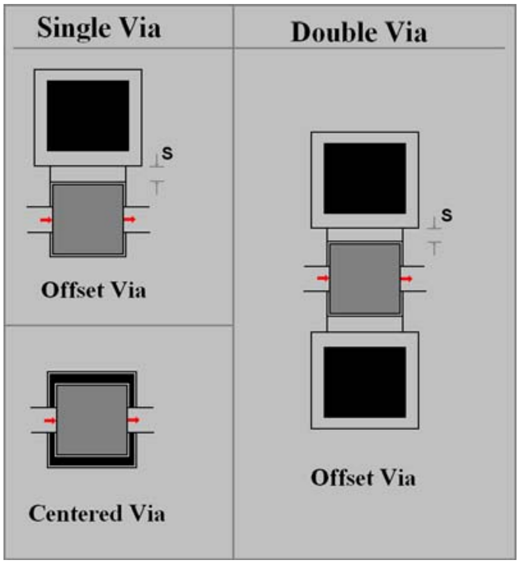

Figure 11 The different overlay capacitor via connections allowed. A centered via or an offset via can be used. Note that the separation between the bottom plate of the capacitor and the via pad can be controlled.

Overlay capacitors are modeled as a series combination of a capacitor, a resistor and an inductor connected to ground, sandwiched between two series connected transmission lines (refer to Figure 10). The width of the transmission line (TRL) on each side is set by the bottom plate and its length is taken to be half of that of the top plate. Only **square capacitors** are modeled in this release, but the results are usually still good when the capacitor is rectangular in shape. If models were not fitted for shunt parallel-plate capacitors (overlay capacitors), set the "GPLC Used" parameter equal to 0.

The equation for the capacitance (square capacitor) is assumed to be of the form

$$C\ (\mathrm{fF}) = \mathit{Power\_Constant} \times \mathrm{POW}(\ W_{um}, \mathit{Power\ Exponent})$$

The constant is usually close to the Capacitance density/1000, while the exponent is usually close to 2.

The **resistance** is a function of the capacitor size (width in micron; square capacitor assumed). Similar to the series plate capacitors, a fourth order polynomial fit,

R (Ohm) = $A_0 + A_1 \times W_{um} + A_2 \times W_{um}^2 + A_3 \times W_{um}^3 + A_4 \times W_{um}^4$,

or an exponential fit

R (Ohm) = $Power\_Constant \times \mathrm{POW}(W_{um}, Power\_Exponent)$

can be provided for the resistance. This option is set with the “Use Polygon” switch. Specify zero values for the coefficients of the option not used.

The **inductance** is calculated from the resonance frequency specified for the capacitor. A fourth order polynomial must be specified for the resonance frequency:

F_{res} (GHz) = $A_0 + A_1 \times W_{um} + A_2 \times W_{um}^2 + A_3 \times W_{um}^3 + A_4 \times W_{um}^4$

Format

GPLC (OVERLAY CAPACITORS; square): Used = 0

or

GPLC (OVERLAY CAPACITORS; square): Used = 1
GPLC Vias: Single via = 1|0 Centered via = 0|0 Top plate via = 0|1 Top plate via offset = #um
Via offset: Via separation in_line = #um Via separation rotated = #um Rotate Threshold = #um
Capacitance (fF): Power_Constant=# Power_Exponent=#
Resistance (Ohm): UsePolynomial= 0|1 Power_Constant=# Power_Exponent=#
Resistance (Ohm): A_4=# A_3=# A_2=# A_1=# A_0=#
Resonance Frequency (GHz): A_4=# A_3=# A_2=# A_1=# A_0=#

Square Spiral Inductors

Square spiral inductors with 5 through 24 **segments** can be used in Multimatch. Inductors with an even number of segments can be used to provide a 90 degree change in direction between the input and output nodes of the inductor. If models were not fitted for spiral inductors, set the specification for the number of spiral inductor data sets to 0.

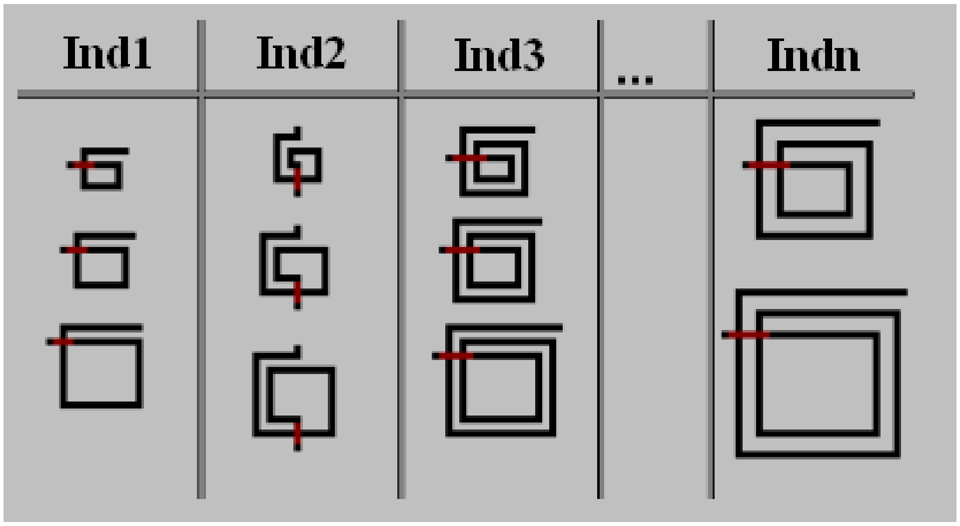

Figure 13 Different spiral inductor templates can be customized by the user. The number of segments and the line width and spacing are kept constant in each case, while the inductor size (width) is varied.

The **model** used for the (square) spiral inductor is shown in Figure 14. Equations should be provided for the model components with the inductor size (width; W_{um}) as variable, and with the number of segments (n) and the line width (*LiWi*) and spacing (*LiSpa*) fixed in each set. Different line widths and line spacings can be used in the different sets. The number of segments can also be different in different sets. Note that full length (5, 6, 9, 10, 13, 14, 17, 18, 21, 22 segments) or centered (7, 8, 11, 12, 15, 16, 19, 20, 23, 24 segments) connections are used. Up to 20 inductor templates can be provided.

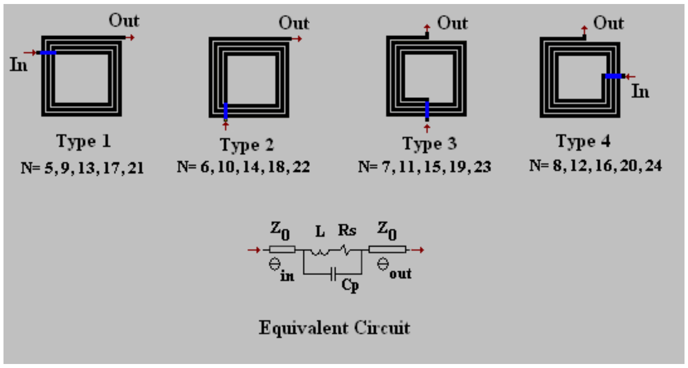

Figure 14 The connections made to Multimatch spiral inductors depend on the number of segments used. The different options are shown above. The model used for these inductors is also shown. Note that the width of the lines used in the model is usually much wider than the line width used in the spiral.

A second order polynomial can be used to specify the inductance in each case (in nH) as a function of the inductor width (W_{um}) specified in micron. The form of this equation is:

$$L\ (\text{nH}) = L_0 + L_1 \times W_{um} + L_2 \times W_{um}^{\;2}$$

The series resistance per unit length is modeled as:

$$R_s\ (\text{Ohm/mm}) = R_0 + R_1 \times \text{SQRT}(\,f\,)$$

where f is the frequency of interest and the resistance is calculated per unit line length in Ohm per millimeter. The inductor line length is calculated as follows:

5, 9, 13, 17 and 21 segments

$$Length = \{\, -((n\text{-}2)/2+1) \times (n\text{-}2)/2 + ((n\text{-}1)/4+2) \} \times (LiWi+LiSpa) + n \times (W - 2 \times LiWi) + (n\text{-}1) \times LiWi/\text{SQRT}(2)$$

6, 10, 14, 18 and 22 segments

$$Length = \{\, -((n\text{-}3)/2+1) \times (n\text{-}3)/2 + (2 - (n\text{-}2)/4) \} \times (LiWi+LiSpa) + n \times (W - 2 \times LiWi) + (n\text{-}1) \times LiWi/\text{SQRT}(2)$$

7, 11, 15, 19 and 23 segments

$$Length = (0.5 + n - n \times n/4) \times (LiWi+LiSpa) + (n\text{-}1) \times (W - 2 \times LiWi) + (n+1) \times LiWi/\text{SQRT}(2) - LiWi + LiSpa$$

8, 12, 16, 20 and 24 segments

$Length = (0.75 + n - n \times n/4) \times (LiWi + LiSpa) + (n\text{-}1) \times (W - 2 \times LiWi) + (n+1) \times LiWi/\mathrm{SQRT}(2) - LiWi + LiSpa$

The parasitic capacitance (fF) of the inductor is assumed to be of the form

C_p (fF) = $C_0 + C_1 \times W_{um}$.

The two lines used in the model can have different lengths. The characteristic impedance of the two lines is assumed to be the same, while the two line lengths (in degrees at 100GHz) are modeled as:

$Ang\_In = A_0 + A_1 \times W_{um}$

and

$Ang\_Out = B_0 + B_1 \times W_{um}$

Note that the **air-bridge** side of the inductor is assumed to be on the input side during the modeling. The inductor can, however, be flipped around in the artwork view. The air-bridge can be an underpass or an overpass (the Multimatch artwork assumes an overpass).

Format

SPIRAL INDUCTORS (SQUARE): Number of inductor data sets to be specified = 0

or

SPIRAL INDUCTORS (SQUARE): Number of inductor data sets to be specified = 3
SPIRAL INDUCTOR1: NumSegm=# Line width=#um Line spacing=#um
SPIRAL INDUCTOR1 INDUCTANCE (nH): L_A_2=# L_A_1=# L_A_0=#
SPIRAL INDUCTOR1 RESISTANCE (Ohm per mm of line length): Rser_A_1=# Rser_A_0=#
SPIRAL INDUCTOR1 CAPACITANCE (fF): Cpar_A_1=# Cpar_A_0=#
SPIRAL INDUCTOR1 LINES: Z0=# OHM; ANGLES (degrees@100GHz) AngIn_A_1=# AngIn_A_0=#; AngOut_A_1=# AngOut_A_0=#
SPIRAL INDUCTOR2: NumSegm=# Line width=#um Line spacing=#um
SPIRAL INDUCTOR2 INDUCTANCE (nH): L_A_2=# L_A_1=# L_A_0=#
SPIRAL INDUCTOR2 RESISTANCE (Ohm per mm of line length): Rser_A_1=# Rser_A_0=#
SPIRAL INDUCTOR2 CAPACITANCE (fF): Cpar_A_1=# Cpar_A_0=#
SPIRAL INDUCTOR2 LINES: Z0=# OHM; ANGLES (degrees@100GHz) AngIn_A_1=# AngIn_A_0=#; AngOut_A_1=# AngOut_A_0=#

SPIRAL INDUCTOR3: NumSegm=# Line width=#um Line spacing=#um
SPIRAL INDUCTOR3 INDUCTANCE (nH): L_A_2=# L_A_1=# L_A_0=#
SPIRAL INDUCTOR3 RESISTANCE (Ohm per mm of line length): Rser_A_1=# Rser_A_0=#
SPIRAL INDUCTOR3 CAPACITANCE (fF): Cpar_A_1=# Cpar_A_0=#
SPIRAL INDUCTOR3 LINES: Z0=# OHM; ANGLES (degrees@100GHz) AngIn_A_1=# AngIn_A_0=#; AngOut_A_1=# AngOut_A_0=#

As an illustration of the advantage of customizing the Multimatch models used, the performance of the matching network shown in Figures 15 is compared in Figures 16 and 17.

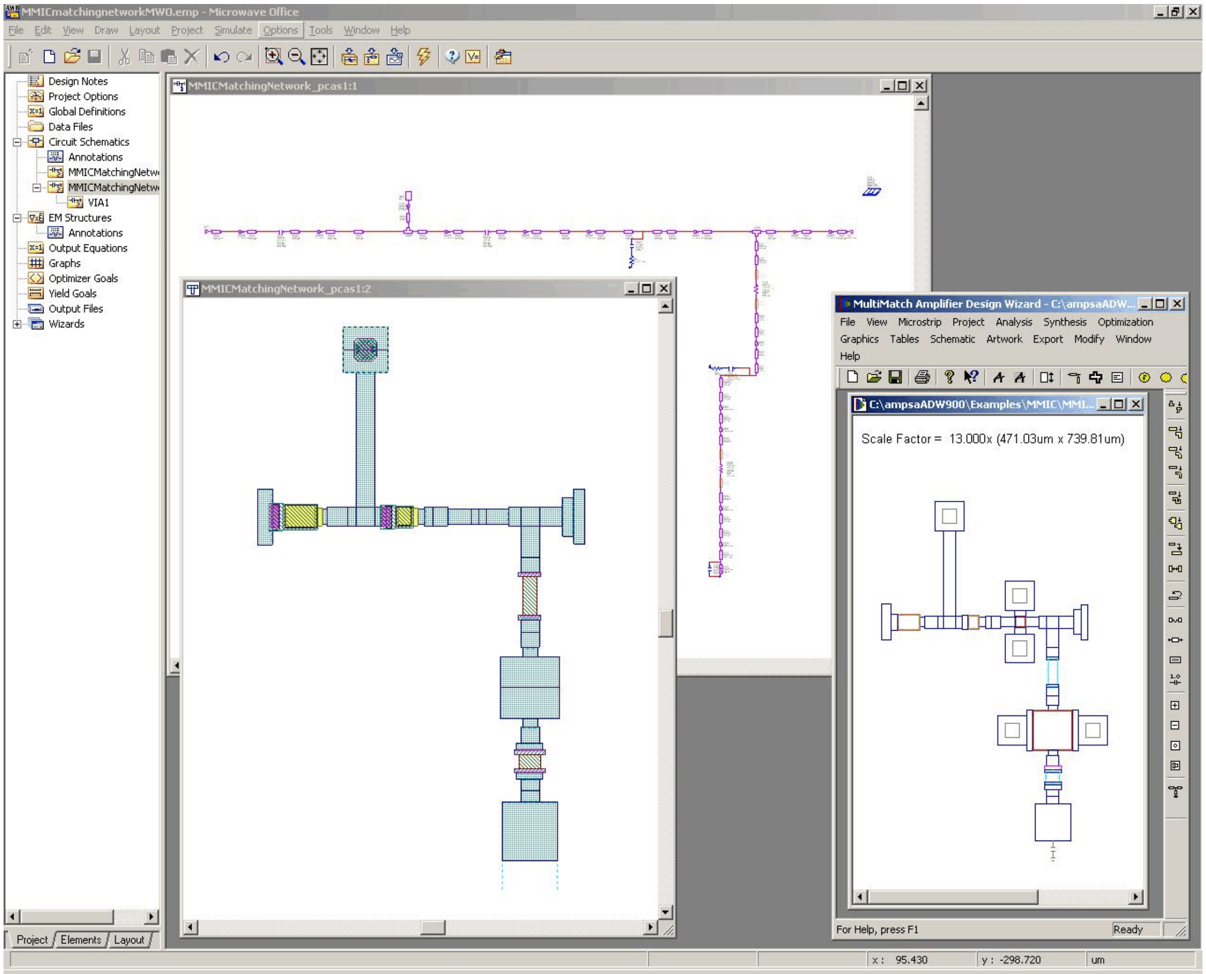

Figure 15 A Multimatch matching network exported to Microwave Office^{TM} after running the script created by Multimatch and making corrections to the thin-film resistors pads.

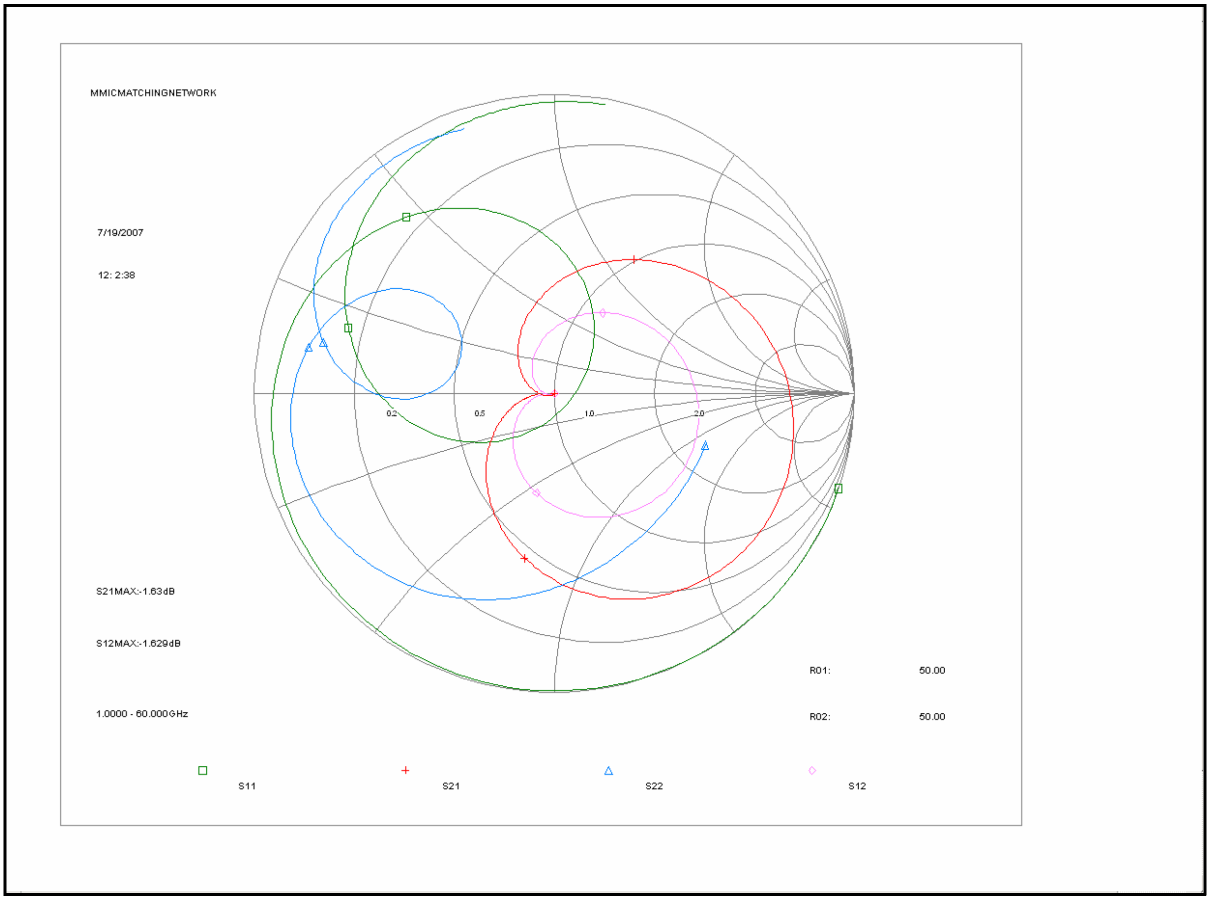

Figure 16 The *S*-parameters of the matching network of Figure 15 as simulated with Multimatch.

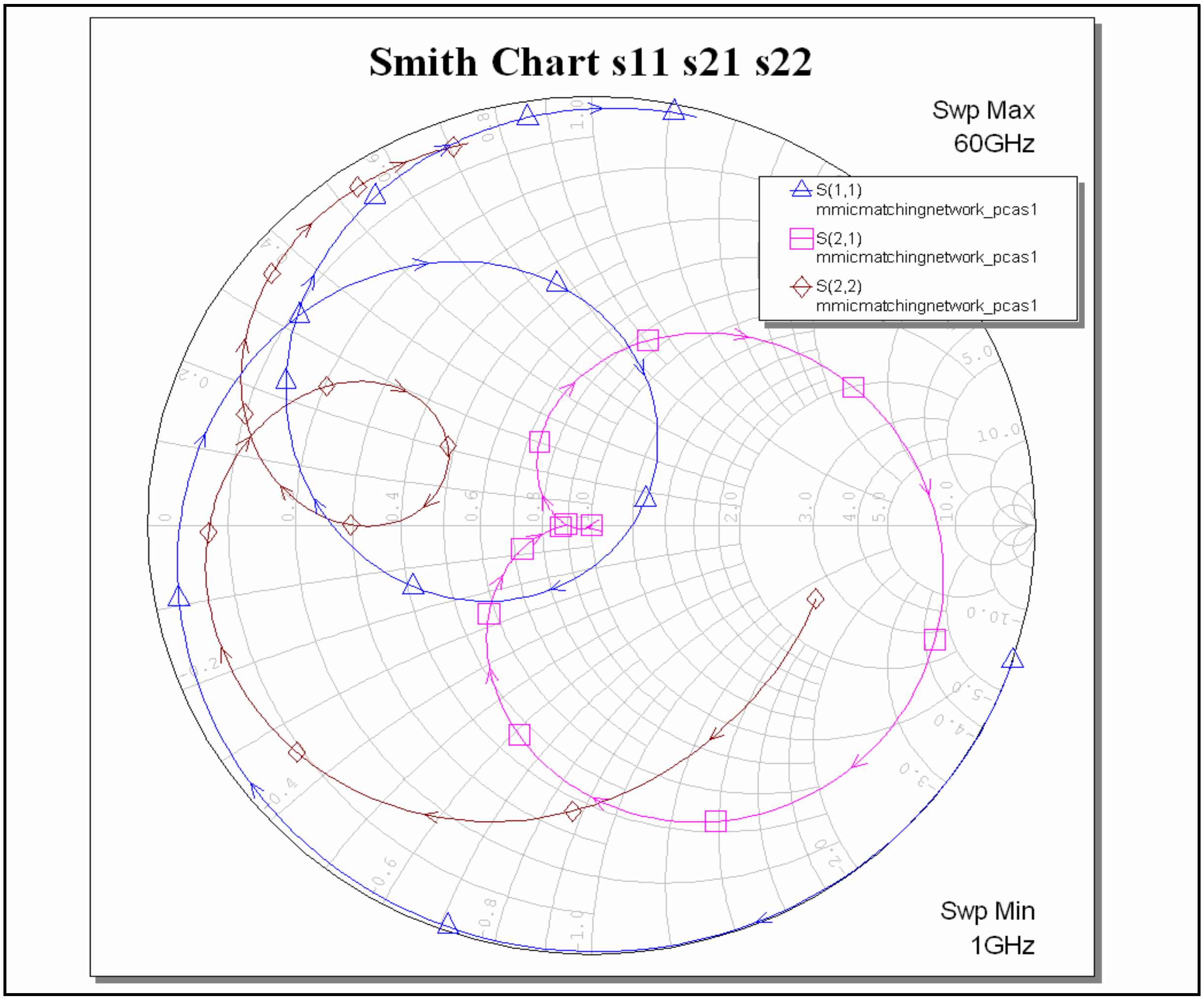

Figure 17 The *S*-parameters of the matching network of Figure 15 as simulated with Microwave Office$^{\mathrm{TM.}}$. The circuit was simulated by using X-models.

The *S*-parameters of a 9-segment square spiral as simulated with Multimatch and Microwave Office$^{\mathrm{TM}}$ are compared in Figure 18 and 19. The agreement is good, but not perfect. Note that the Multimatch model is based on EM simulations of the complete spiral, while the Microwave Office$^{\mathrm{TM}}$ model is based on coupled-line calculations.

Also note that the formula provided by Tang and Chow [1] for the low frequency inductance has been implemented in Multimatch (The effect of the ground plane has been included. A minor correction is required in the inductance formula published). The average accuracy claimed is better than 2%.

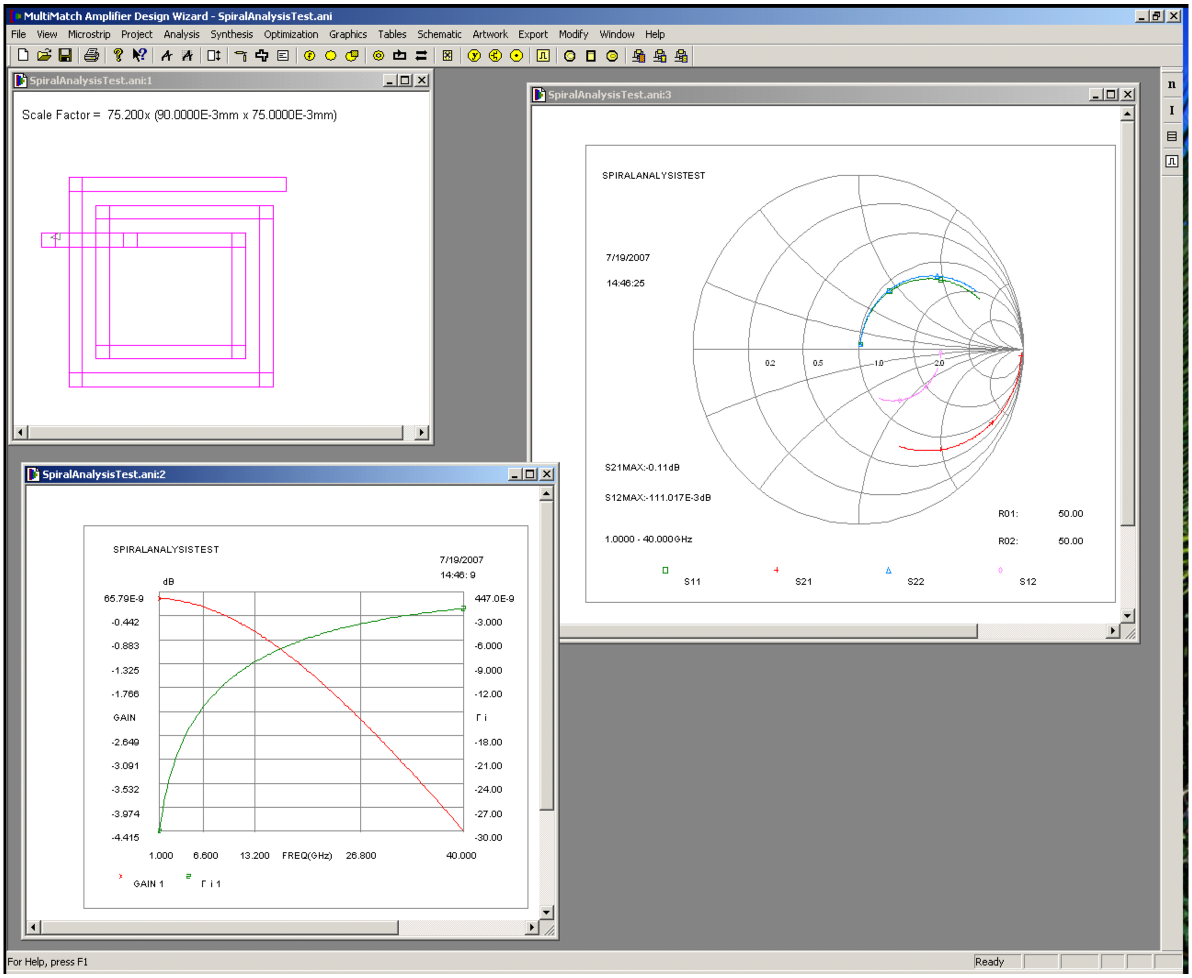

Figure 18 The *S*-parameters of a 9-segment square spiral as simulated in MultiMatch (LIW850).

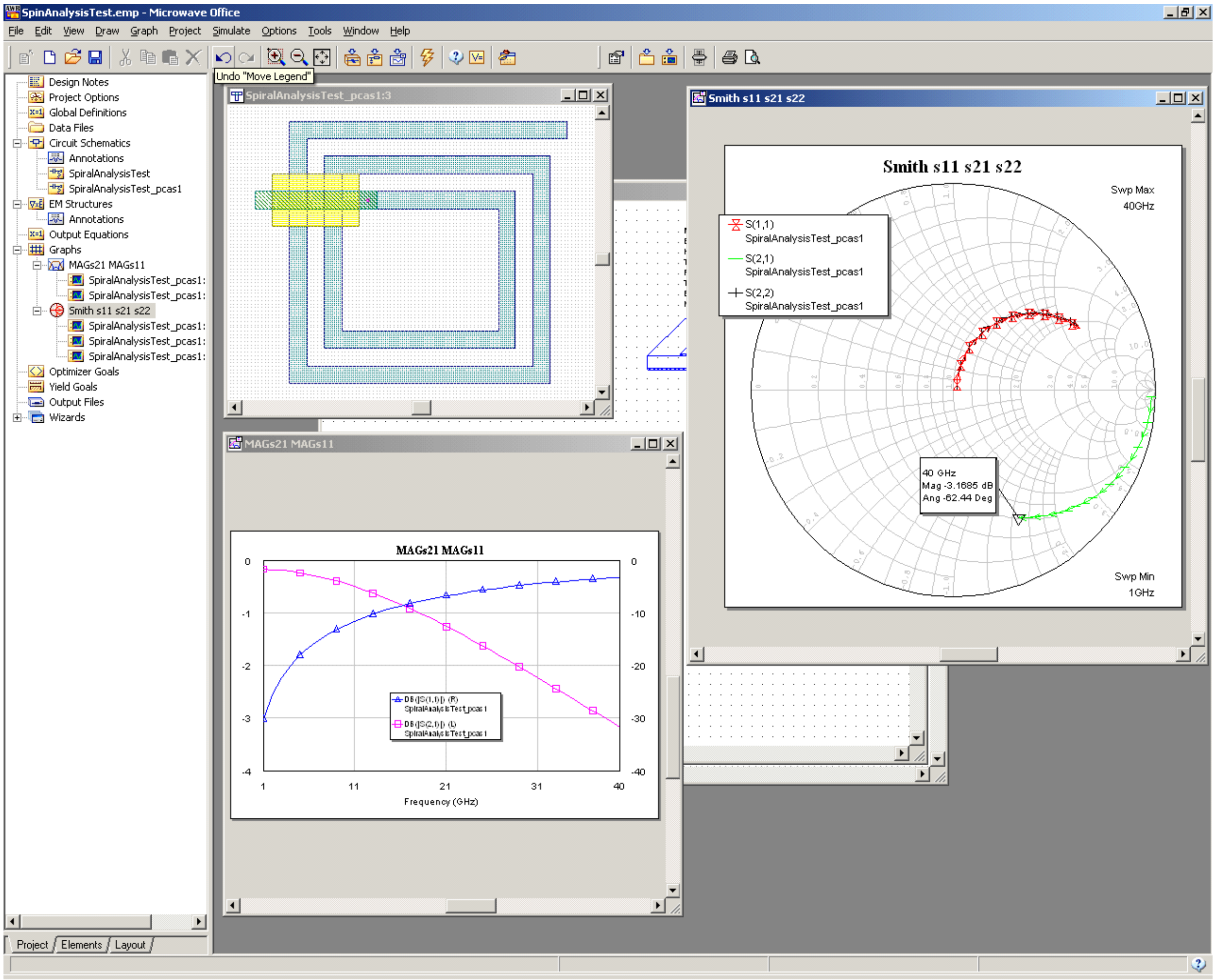

Figure 19 The *S*-parameters of a 9-segment square spiral as simulated in Microwave Office^{TM}.

References.

Wan. C. Tang and Y. Leonard Chow, “Simple CAD Formula for Inductance Calculation of Square Spiral Inductors with Grounded Substrate by Duality and Synthetic Asymptote”, Microwave and Optical Technology Letters, Vol. 34, No. 2, July 20, 2002.

Complete Substrate Specification Example

WARNING: DO NOT DELETE ANY RECORDS (EMPTY RECORDS INCLUDED) FROM THIS FILE!
File Version = 1
Number of substrates = 1

SUBSTRATE: Number=1 Type=1 er=12.90 h=0.10000mm T=2.00um HU=20.00000mm
VIAS: Round=0 Fixed size=1 ViaWidth=#mm ViaLength=#mm PadWidth=#mm PadLength=#mm
Via Inductance=#pH
Viapad Z0(Ohm): A_2=# A_1=# A_0=#
Viapad Length (degree@100GHz): A_1_weight=# A_0_weight=# B_1_power=# B_0_power=#
CURVES: Path offset from line center = # x LineWidth
RECTANGULAR BENDS: Effective length (um): A_3=# A_2=# A_1=# A_0=#
OPEN ENDS: Breakpoint Width = #um
Narrow Lines Open End Extension (um): A5=# A_4=# A_3=# A_2=# A_1=# A_0=#
Wide Lines Open End Extension (um): A5=# A_4=# A_3=# A_2=# A_1=# A_0=#
STEPS: Number of narrow side line widths used = 5
Narrow Side Width1 = #um; Line Extension(degrees@100GHz): A_3=# A_2=# A_1=# A_0=#
Narrow Side Width2 = #um; Line Extension(degrees@100GHz): A_3=# A_2=# A_1=# A_0=#
Narrow Side Width3 = #um; Line Extension(degrees@100GHz): A_3=# A_2=# A_1=# A_0=#
Narrow Side Width4 = #um; Line Extension(degrees@100GHz): A_3=# A_2=# A_1=# A_0=#
Narrow Side Width5 = #um; Line Extension(degrees@100GHz): A_3=# A_2=# A_1=# A_0=#
SYMTEEs: Number of main line widths used = 3
Main Line Width1 = #um; Main line section offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width1 = #um; Stub offset from center (um): B_3=# B_2=# B_1=# B_0=#
Main Line Width2 = #um; Main line section offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width2 = #um; Stub offset from center (um): B_3=# B_2=# B_1=# B_0=#
Main Line Width3 = #um; Main line section offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width3 = #um; Stub offset from center (um): B_3=# B_2=# B_1=# B_0=#
SYMCROSSES: Number of main line widths used = 3
Main Line Width1 = #um; Main Line Section Offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width1 = #um; Stub Offset from center (um): B_3=# B_2=# B_1=# B_0=#
Main Line Width2 = #um; Main Line Section Offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width2 = #um; Stub Offset from center (um): B_3=# B_2=# B_1=# B_0=#
Main Line Width3 = #um; Main Line Section Offset from center (um): A_3=# A_2=# A_1=# A_0=#
Main Line Width3 = #um; Stub Offset from center (um): B_3=# B_2=# B_1=# B_0=#
PARALLEL PLATE CAPACITORS: Capacitance density = #pF/mm^2 Bottom plate extension on each side = #um
SPLC (SERIES PLATE CAPACITORS; square): Used = 1
SPLC Resistance (Ohm): Use Polygon = 1 Power_Constant=0.0 Power_Exponent=0.0
SPLC Resistance (Ohm): A_4=# A_3=# A_2=# A_1=# A_0=#
SPLC Inductance (pH): A_4=# A_3=# A_2=# A_1=# A_0=# Lmin=#
SPLC Shunt Capacitance (fF): A_4=# A_3=# A_2=# A_1=# A_0=#
GPLC (OVERLAY CAPACITORS; square): Used = 1
GPLC Vias: Single via = 1 Centered via = 0 Top plate via = 0 Top plate via offset = 0um
GPLC Via offset: Via separation in_line = #um Via separation rotated = #um Rotate Threshold = #um
GPLC Capacitance (fF): Power_Constant=# Power_Exponent=#
GPLC Resistance (Ohm): UsePolynomial=0 Power_Constant=# Power_Exponent=#
GPLC Resistance (Ohm): A_4=0.0 A_3=0.0 A_2=0.0 A_1=0.0 A_0=0.0
GPLC Resonance Frequency (GHz): A_4=# A_3=# A_2=# A_1=# A_0=#
SPIRAL INDUCTORS (SQUARE): Number of inductor data sets to be specified = 3
SPIRAL INDUCTOR1: NumSegm=9 Line width=10um Line spacing=5um
SPIRAL INDUCTOR1 INDUCTANCE (nH): L_A_2=# L_A_1=# L_A_0=#

SPIRAL INDUCTOR1 RESISTANCE (Ohm per mm of line length): Rser_A_1=# Rser_A_0=#
SPIRAL INDUCTOR1 CAPACITANCE (fF): Cpar_A_1=# Cpar_A_0=#
SPIRAL INDUCTOR1 LINES: Z0=# OHM; ANGLES (degrees@100GHz) AngIn_A_1=# AngIn_A_0=#; AngOut_A_1=# AngOut_A_0=#
SPIRAL INDUCTOR2: NumSegm=13 Line width=10um Line spacing=5um
SPIRAL INDUCTOR2 INDUCTANCE (nH): L_A_2=# L_A_1=# L_A_0=#
SPIRAL INDUCTOR2 RESISTANCE (Ohm per mm of line length): Rser_A_1=# Rser_A_0=#
SPIRAL INDUCTOR2 CAPACITANCE (fF): Cpar_A_1=# Cpar_A_0=#
SPIRAL INDUCTOR2 LINES: Z0=#OHM; ANGLES (degrees@100GHz) AngIn_A_1=# AngIn_A_0=#; AngOut_A_1=# AngOut_A_0=#
SPIRAL INDUCTOR3: NumSegm=17 Line width=10um Line spacing=5um
SPIRAL INDUCTOR3 INDUCTANCE (nH): L_A_2=# L_A_1=# L_A_0=#
SPIRAL INDUCTOR3 RESISTANCE (Ohm per mm of line length): Rser_A_1=# Rser_A_0=#
SPIRAL INDUCTOR3 CAPACITANCE (fF): Cpar_A_1=# Cpar_A_0=#
SPIRAL INDUCTOR3 LINES: Z0=#OHM; ANGLES (degrees@100GHz) AngIn_A_1=# AngIn_A_0=#; AngOut_A_1=# AngOut_A_0=#