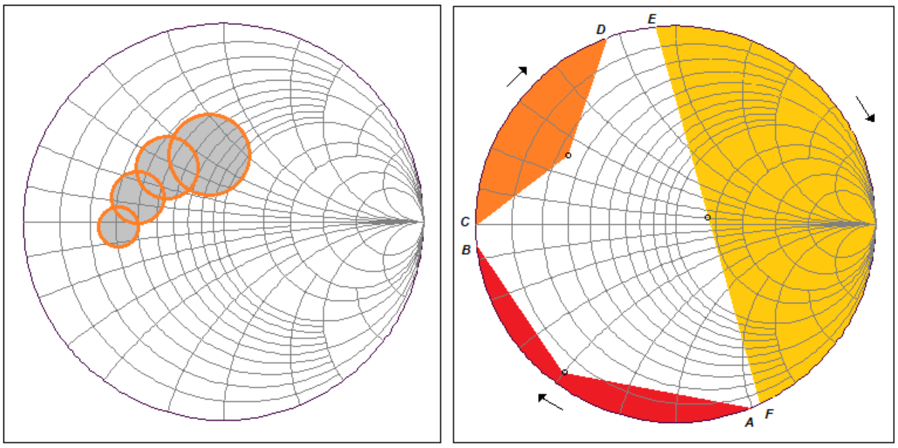
Setting Up Load-Pull or Source-Pull Matching Problems in the Ampsa ADW / MW

Pieter L.D. Abrie, Ampsa (Pty) Ltd.

When a matching problem is defined by load-pull or source-pull data (measured or derived from a large-signal model), the simplest way to set up the matching problem in the ADW / MW is to enter the data directly into the Impedance-Matching module (open a new .mmi file). Specific impedances or circular areas can be targeted at the fundamental frequencies (see Figure 1), while specific impedances or harmonic sectors can be targeted at the second and/or third harmonic frequencies.

The bandwidth of a harmonic control problem must be less than an octave. Overlapping harmonic bands are allowed in the Impedance-Matching module and in the post-processing circuit files exported by it - The second harmonic targets override the third (or vice versa) at overlap frequencies. When the circuit terminations are augmented to define a load-pull or source-pull problem in the Analysis Module of the ADW / MW, overlapping harmonic bands are not allowed (reduce the bandwidth, target only the second harmonic or use the post-processing format).

A harmonic sector is defined by the area bounded by two intersecting lines and the Smith chart edge (see Figure 1). The intersect point of the lines (local origin) must be inside the Smith chart ($|\Gamma| < 1.0$). Note that two complementary areas are associated with any two lines. The area to be targeted is set by the sequence in which the two edge intersects are specified. The sequence must be for clockwise rotation from the first point to the second. The intersects are specified in the ADW / MW by specifying the reactance or the reflection coefficient angle associated with each point.



Fundamental-frequency circular area targets   Examples of harmonic sectors.

Figure 1. In the Amplifier Design Wizard (ADW) or the Matching Wizard (MW), points or circular areas can be targeted for matching at the fundamental frequencies, while points, circular areas or harmonic sectors can be targeted at the harmonic frequencies.

The Convert Circles option provided on the Terminations page of the Impedance-Matching module can be used to target load-pull or source pull circles at the fundamental frequencies. This wizard calculates the equivalent passive problem [1] for the load-pull or source-pull circle specified (see Figure 2). The equivalent passive problem for a load-pull circle will change the source impedance and transducer power gain target for the matching problem at the frequency selected in the Terminations table before using the Convert Circles command. The load impedance and transducer power gain will change when a source-pull circle is targeted.

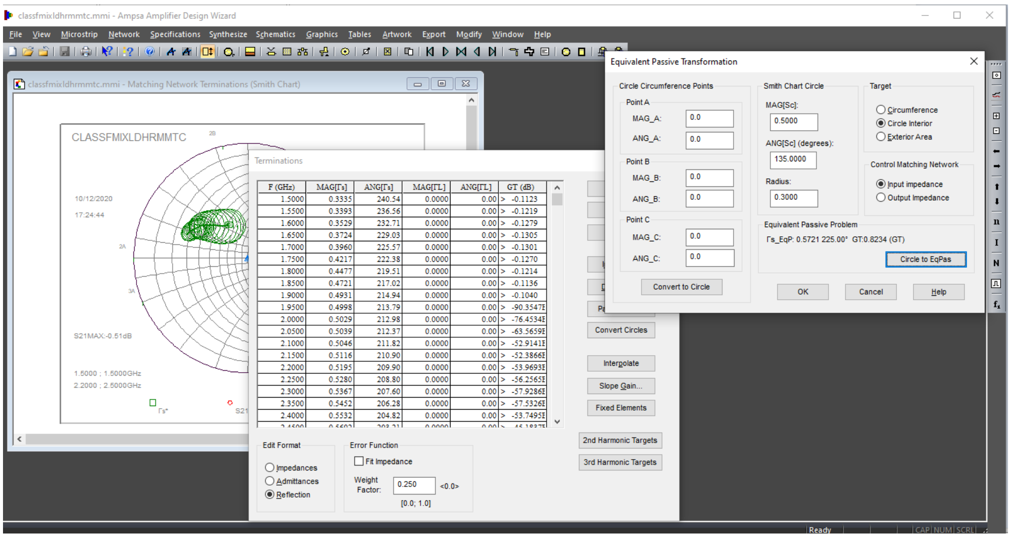


Figure 2. The fundamental-frequency specifications for a matching problem and the options provided when the equivalent passive problem for a Smith chart circle is calculated.

Harmonic sectors are defined in the ADW / MW by specifying the local origin and the two edge intersects at each harmonic frequency. An example of second-harmonic specifications is provided in Figure 3. The local origin of each sector is defined by its reflection coefficient. The edge intersects are defined by the reactance values, or the angles of the reflection coefficients associated with the intersects points. As stated above, the two intersects must be specified in the sequence associated with clockwise rotation from the first intersect to the second. For load-pull problems, the load termination of the matching network must also be specified at each harmonic frequency, while the source terminations must be specified for source-pull problems.

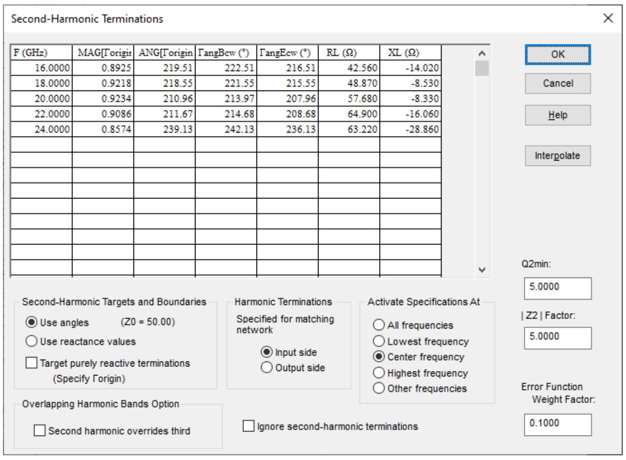


Figure 3. The second harmonic sectors and load termination specified for a matching problem.

Allowance for some fixed components between the matching network and the reference plane for the load-pull or source-pull data is made in the impedance-matching module. The fixed components allowed on the input or output side of a matching network in the ADW / MW are shown in Figure 4. The fixed components include series lines (pads) and stubs for biasing purposes.

Note that C_i and L_i in Figure 4 can be used to model the output capacitance and inductance of a transistor, that is, if greater complexity is not required for accurate modeling. This allows moving the reference plane for the matching network to the intrinsic output reference plane of the transistor. Similarly, C_o and L_o could be used to move the reference plane to the intrinsic input reference plane of the transistor.

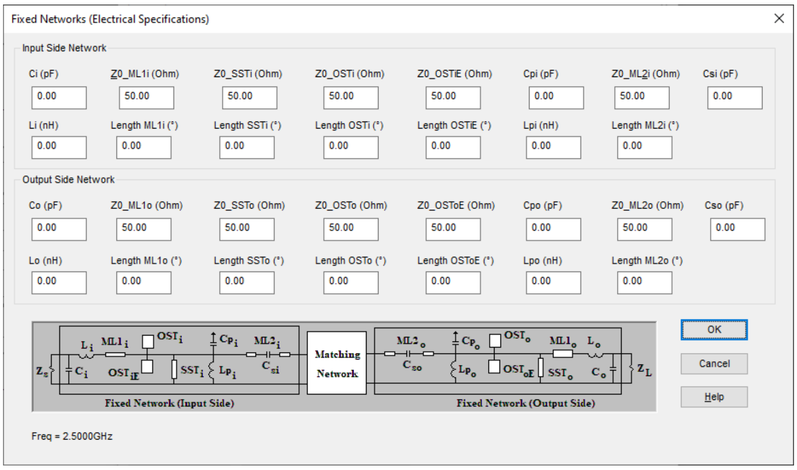


Figure 4. The fixed components allowed on the input or output side of a matching network in the ADW / MW.

When more flexibility is required (complex transistor models, symmetrical transistor combination networks, etc), the fixed components required can be specified in the Analysis Module. In the example shown in Figure 5, a symmetrical power combining network for a MMIC amplifier was first reduced to its single-ended equivalent. (The T-junctions at the symmetry points were modified to create the equivalent.) The IIM wizard was then used to define the new matching problem to be solved. The insertion point for the matching network to be designed is shown by the arrow.

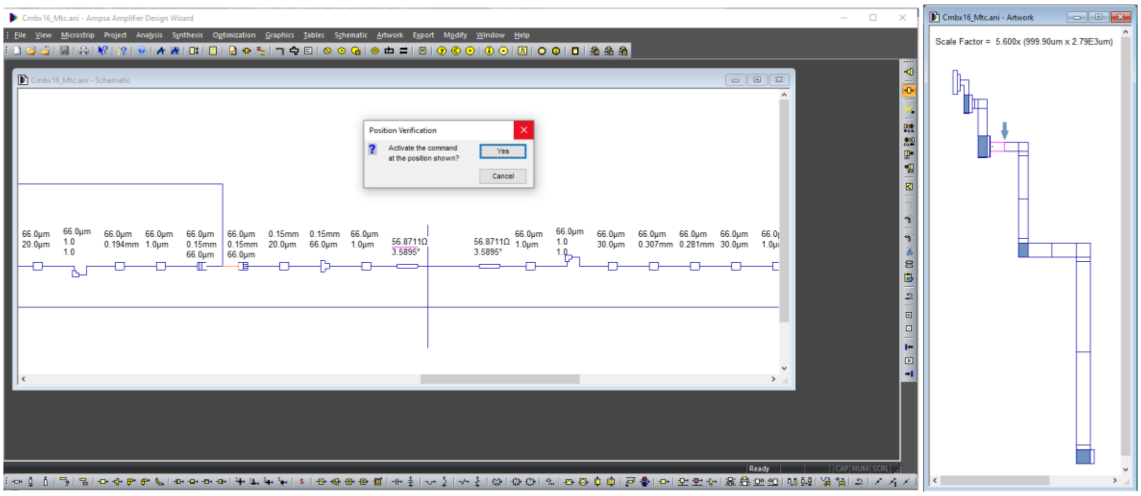


Figure 5. An example of setting up a matching problem in the ADW / MW analysis module by using the IIM Wizard. The matching network is required at the marked position in the artwork shown on the right. Single-ended equivalents are used for the combining sections in the matching network.

The procedure for setting up the load-pull circuit file for the example in Figure 5 is summarized below:

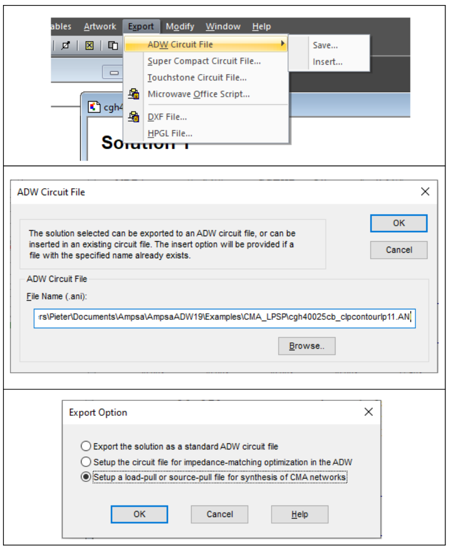
1. Open a new impedance-matching data file (.mmi file). Use the load-pull or source-pull data to define the fundamental-frequency and harmonic control problems. The fundamental-frequency targets can be points or circular areas. Use sectors for the harmonic targets.
2. Synthesize solutions to the defined matching problem, select a solution, and then use the Export | ADW/MW Circuit File | Save menu command to export this solution to an ADW circuit file (see Figure 6). Modify the default name for the new circuit file (if necessary) and then select the format of the new file. The load-pull / source pull option should be used here. The frequency block and the terminations block created for this example are also shown in Figure 6. Note the 1:1 correspondence between the fundamental frequencies and the associated harmonic frequencies (required). Assuming that the matching problem is a load-pull problem, the format used for a fundamental-frequency circle or point is:

   F_{GHz} MAG[Γ_s] ANG[Γ_s] (G_T) or F_{GHz} R_s X_s (G_T),

   where Γ_s is the conjugate of the reflection coefficient of the load-pull target (point match), or the reflection coefficient of the equivalent passive source termination (circle match). G_T is 1.0 for a point match, or the transducer power gain associated with the equivalent passive problem when the target is a circular area. G_T must be specified as a number (maximum: 1.0). The format used to specify a harmonic sector is:

   F_{GHz} MAG[Γ_{so}] ANG[Γ_{so}] ($AngA$, $AngB$) or F_{GHz} R_{so} X_{so} ($AngA$, $AngB$),

   where Γ_{so} or $R_{so}+jX_{so}$ defines the conjugate of the sector origin. The Smith chart edge intersects of the two boundary lines are specified by $AngA$ and $AngB$. The angles must be specified in degrees and in the sequence associated with clockwise rotation from point A to point B. When $AngA = AngB$, the harmonic terminations at that frequency will ignored when the error function is calculated.
3. Open the new circuit file and edit the schematic as required. Delete the exported matching network.
4. Select the insertion point for the matching network to be designed and use the IIM wizard to setup the specifications for this network. Solve the defined problem with a CMA network or synthesize solutions to it by using the Impedance-Matching module. Note the IIM wizard option to use CMA networks in Figure 7. Use the Modify Problem command to open the Impedance-Matching Options dialog.
5. Export the best solution obtained to the circuit file (Export | ADW/MW Circuit File | Insert menu command) and use the optimization features to optimize the network.

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FREQUENCIES
FL=2.4000GHz  FI=50.0000E-3GHz  FH=2.6000GHz
FL=4.8000GHz  FI=100.0000E-3GHz  FH=5.2000GHz
FL=7.2000GHz  FI=150.0000E-3GHz  FH=7.8000GHz
ENDF
*
TERMINATIONS
*
ΓS
2.4000  0.65 174.15  (0.9945)
2.4500  0.65 173.90  (0.9945)
2.5000  0.65 173.64  (0.9945)
2.5500  0.66 173.38  (0.9945)
2.6000  0.66 173.10  (0.9945)
4.8000  0.6149 93.59  (320.67°, 210.90°)
4.9000  0.6174 91.03  (326.84°, 211.92°)
5.0000  0.5992 88.40  (332.60°, 213.76°)
5.1000  0.5800 81.70  (338.67°, 216.09°)
5.2000  0.5801 78.68  (346.15°, 216.55°)
7.2000  0.5269 25.53  (348.89°, 319.82°)
7.3500  0.6699 43.59  (326.26°, 305.07°)
7.5000  0.7806 55.75  (310.64°, 295.20°)
7.6500  0.8760 66.85  (300.21°, 288.73°)
7.8000  0.9241 71.72  (293.45°, 284.66°)
*
RL=  50.00Ω
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Figure 6. (a) The different formats allowed when a matching network is exported in the ADW / MW. (b) The frequency block and terminations block created for this example.

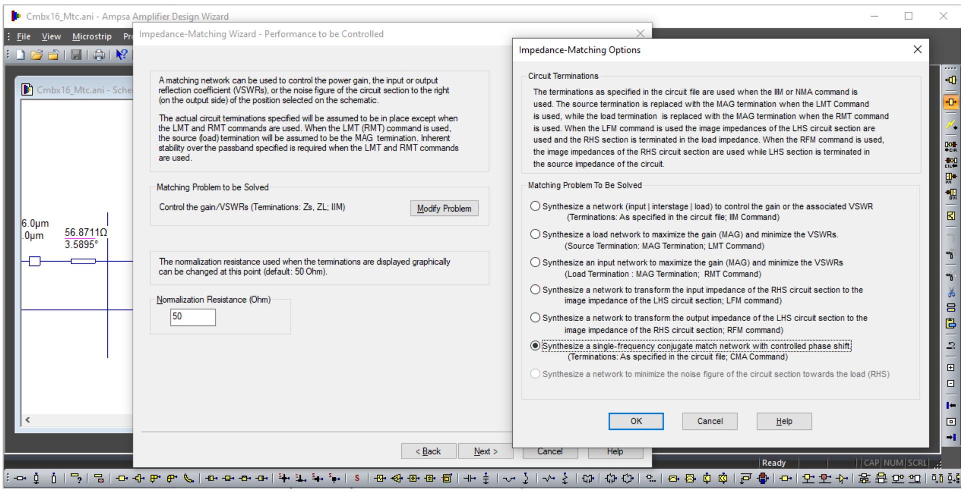

Figure 7. The CMA option provided in the IIM wizard. Use the Modify Problem command to open the Options dialog.

When a standard ADW / MW circuit file is created (see the Export Options in Figure 6), the terminations set for the new circuit file are the fundamental-frequency source and load terminations of the matching network. No harmonic control information will be exported to the circuit file.

When a matching network is exported for post-processing and/or optimization (second Export option in Figure 6), the fundamental-frequency and harmonic-frequency targets are exported to the circuit file by using specialized commands (HBAI, HBBI, IMSF, IMHA, IMHB, …), while the source and load terminations are set to be purely resistive. Post-processing may include adding stubs and capacitors to the network to allow for *dc* biasing, as well as replacing basic components with more advanced components. (An inductor with pads can be replaced with a spiral inductor, a capacitor with pads can be replaced with a MIM capacitor, etc.). The modified network is usually optimized to restore or improve the fundamental-frequency, as well as the harmonic-frequency performance. The error function used for optimizing the network is similar to that used in the Impedance-Matching module.

The Analysis Module commands used to edit the error function for the optimization and the impedance-matching optimization command are shown in Figure 8. The Impedance-Matching Smith Chart command can be used to display the input or output impedance of the matching network in the style used in the Impedance-Matching module. When the modified matching network is analyzed (Analysis command in Figure 8), the *MRD* and the harmonic errors are also calculated.

Note that the terminations specified for an ADW / MW circuit file can be viewed or edited by using the Project | Terminations menu command (see Figure 9). The option to calculate the equivalent passive problem associated with a Smith chart circle (load-pull or source-pull circle) is also provided in the dialog box opened. The Show LP/SP Information option can be used to view or edit the transducer power gain (fundamental frequencies) and the edge intersect angles (harmonic frequencies) specified for a load-pull or source-pull matching problem. The Initialize command should be used to convert the specifications for standard source or load terminations to load-pull or source-pull format.

The specifications can also be viewed or edited in a Text view in the Analysis Module.

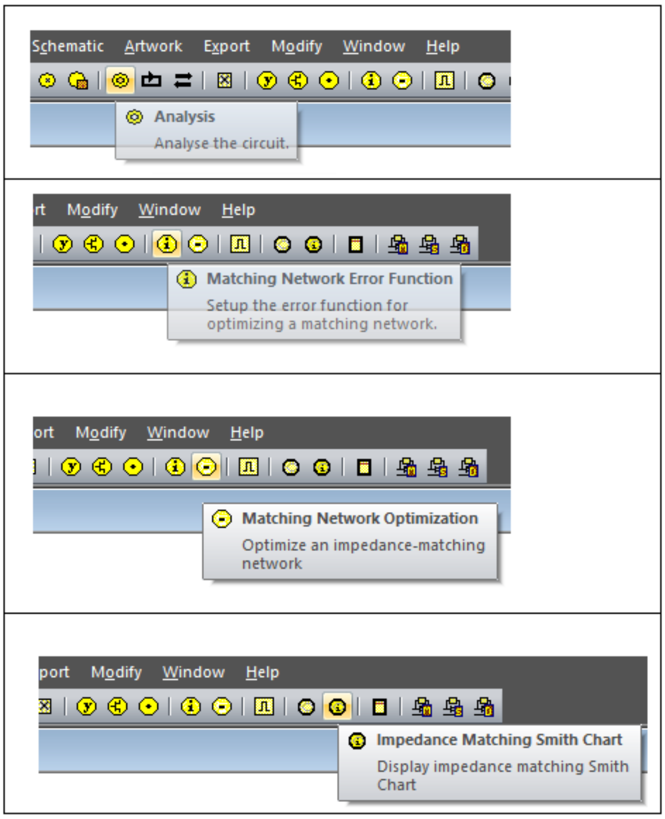

Figure 8. Analysis module commands frequently used during post-processing of a synthesized matching network.

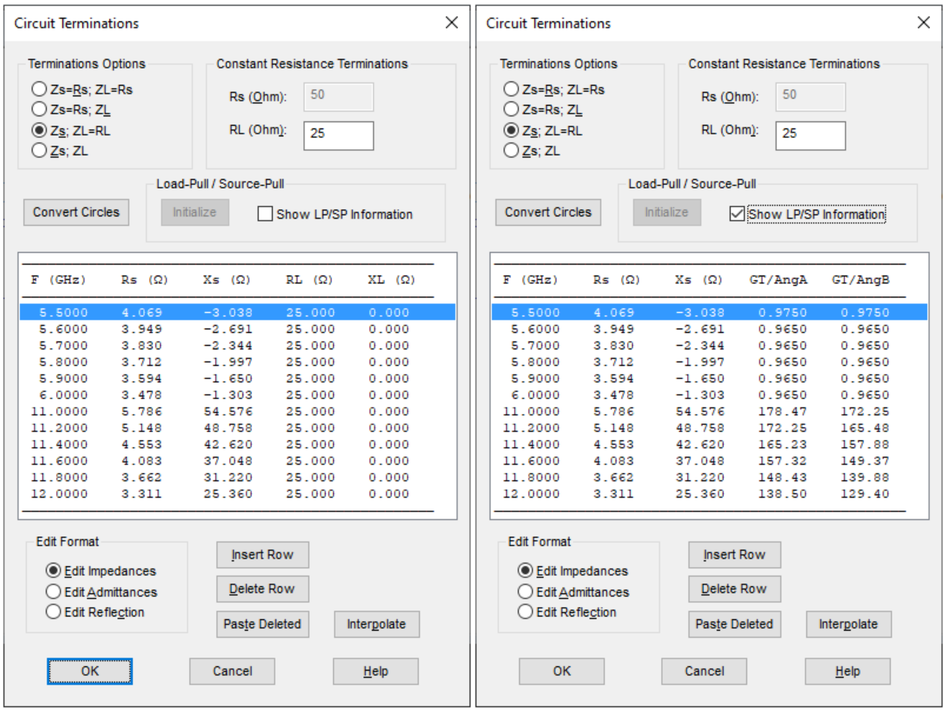

Figure 9. The terminations of an ADW / MW circuit can be viewed or edited by using the Project | Terminations menu command. Note the Convert Circles option.

The procedure for setting up load-pull or source-pull specifications by augmenting the specifications for the circuit terminations is outlined below:

1. Specify the fundamental-frequencies, the associated harmonic frequencies and the passband of interest (Use the Project | Frequencies menu command). The second-harmonic and/or third-harmonic terminations can be controlled. The only frequencies allowed are the fundamentals and the corresponding second and/or third harmonics. Because a matching network can only present one termination at a given frequency, the bandwidth must be less than an octave. When a frequency is both a second harmonic and a third harmonic, targets should be set for the fundamentals and the second harmonics only.

2. Specify the circuit terminations to be the conjugates of the load-pull or source-pull targets at the fundamental frequencies and the conjugates of the harmonic sector origins at the harmonic frequencies (Use the Project | Terminations menu command – The dialog box shown in Figure 9 will then be opened). If a circle instead of a point will be targeted at a fundamental frequency, use the source or load impedance associated with the equivalent passive problem instead of the load-pull or source-pull impedance. Use the Convert Circles command to calculate the equivalent passive problems.

3. With the circuit terminations at the fundamental and harmonic frequencies specified, use the Initialize command shown in Figure 9 to convert the specifications for the source terminations or the load terminations to ADW load-pull or source-pull format. Edit the transducer power gain values (fundamental frequencies) and the Smith chart intersect angles (harmonic frequencies) as required. The sequence of the intersect angles must be for clockwise rotation from the first angle (*AngA*) to the next (*AngB*).

4. Use the OK command to update the circuit terminations.

5. Select the schematic element to the left of the insertion point for the matching network to be designed and then use the IIM command on the Synthesis toolbar to set up the matching problem. When the CMA option shown in Figure 7 is selected, phase-controlled networks (T-networks, PI-networks or Stepped-Line networks) can be synthesized to solve the matching problem. If this option is not selected, the Impedance-Matching module will be launched by the IIM wizard to solve the problem. Lumped, distributed (commensurate or non-commensurate) or mixed lumped/distributed networks can be synthesized by the Impedance-Matching module.

References

[1] Pieter L.D. Abrie, Design of RF and Microwave Amplifiers and Oscillators, Boston: Artech House, Inc. 1999.