AN125
Measuring AM to PM Conversion

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Abstract:
This paper outlines how to measure AM to PM conversion of a circuit with the AEA Technology two port network analyzers.

Introduction:

AM to PM conversion creates nonlinearity in a system or subcircuit that plays a major role in phase noise performance. When the input signal level changes, a well behaved amplifier maintains the same delay time to for a signal to travel through the circuit. Engineers minimize AM to PM conversion to minimize the phase noise added to a signal. Below is the formula for AM to PM conversion:

AM to PM (degrees/dB) = d(phase)/d(amplitude)

As the attenuator setting decreases (input increases), the output level increases. When an amplifier has AM to PM conversion, the phase delay (gain phase) shifts by some degrees in response to the signal level change.

Circuit AM to PM conversion may be measured using any 2 port network analyzer. When measuring active circuits, protect the front end of the analyzer with an attenuator between the circuit output and the analyzer S21 input. The AEA technology network analyzers were designed for isolation measurements (i.e. gain < 0 dB), so the attenuator should be slightly greater than the expected circuit gain. Quality connections to the analyzer, attenuator, and circuit are required to get accurate readings. Use coaxial connectors for all signal path connections. Connectors at the circuit end of the cables allow a convenient way to perform cable nulling.

Test setup:

Amplifier circuits require one or two attenuators, where the total attenuation offsets the expected amplifier gain to 0 dB (or a few dB of loss). The attenuator will need to be split to provide a variable input level to the amplifier. If you use an output attenuator, consider it as part of the test fixture when cable nulling. If you use an input attenuator, include it when performing the cable null (apply Open-Short-Load to fixture side of the attenuator. Passive circuits require no attenuators.
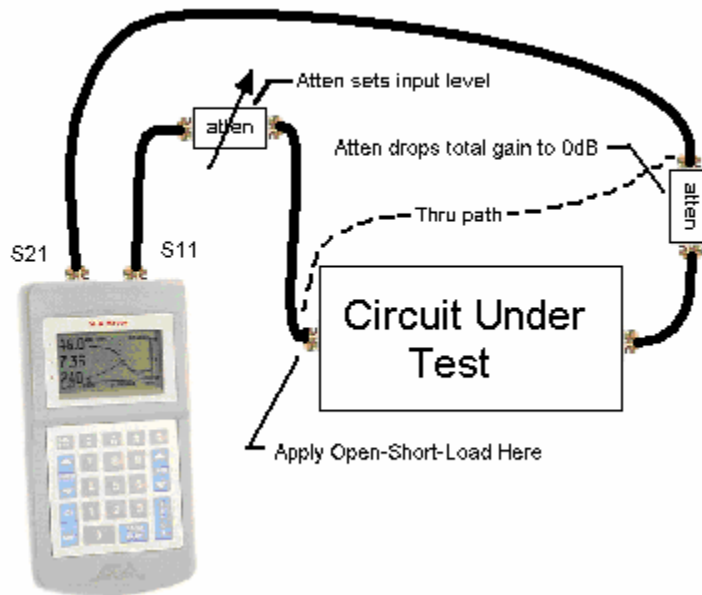
Test fixture quality is a key factor in measuring the circuit under test. Use good PCB mount coaxial connectors for the input and output ports. A ground plane usually improves performance by reducing stray inductance in the power distribution. Beware that many RF circuits, especially active ones, operate differently if the I/O ports use coaxial pigtails instead of good connectors. Using coaxial connectors for the I/O ports allows you to replace the test fixture with a barrel connector when cable nulling the "thru" path. Any power supply or control inputs should be well bypassed with capacitors to the fixture ground plane. Once you have created your fixture, measurements can begin.

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Steps to Measure AM to PM conversion:

1. Set the network analyzer center frequency and sweep range to cover the frequencies of interest. If you have a multiple band situation, you should prestore multiple sweeps to cover the various bands.
2. Set at least one of the plots to an S21 reading (linear gain, log gain, or gain phase). You may look view two plots at once on the analyzer. If you want to measure and save the S11 data also, then the second plot _must_ be one of the S11 plots. The S11 plots are only valid for the attenuator setting that the cable null was done for. You will have to mathematically or graphically remove the effect of the attenuator at other settings. You may view more than two plots simultaneously by operating the network analyzer via the PC Vision software. PC Vision Hint: read one plot, take the effort to save all the plot settings the way you like it (axes formats, colors, labels, etc) then select Chart Window|Save Settings. Future readings will be presented in a similar manner.
3. Cable null the network analyzer, including cables, input attenuator, and adaptors. Consider the output attenuator as part of the test fixture, so it does not appear in the thru path nulling. Set the input attenuator to minimum (maximum input level).
4. Connect the cables to the test fixture input and outputs.
5. Apply power, if required, to the test fixture.
6. Set the attenuator to provide an input level that is near the maximum expected input level. Save this S21 data, it is the reference output level.
7. Take a second reading with the input attenuator set higher, (drop input level. Save the results.
8. Take readings, save plots as desired. See how circuit alterations affect the circuit characteristics. The AM to PM conversion equals the change in phase divided by the change in signal level (degrees/dB). This operation may be performed in Excel by exporting the data to an excel file and creating an AM to PM conversion macro for the data.
9. Use saved data to document your design.

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Use Excel to Process the Data:

1. Read the data from the unit into PC Vision (get new data or read memory). Save the data: File|Export Data|Excel (or as Text if you prefer).
2. Use Excel to open the file with the saved data (*yourfile*.xls). It is possible to also use archived files (*yourfile*.aea) or text files (*yourfile*.txt). Create a new sheet. Select the new sheet; be sure to erase all columns of data on the new sheet.
3. Optionally add labels to top row.

<p align="center">Excel AM to PM conversion Example</p>

	A	B	C	D	E	F
1	Freq	Phase 1	Gain 1	Phase 2	Gain 2	AM to PM
2	1.000	178.374	-9.938	174.815	-0.171	-0.364
3	1.000	178.079	-9.950	174.617	-0.176	-0.354
4	1.000	177.763	-9.960	174.414	-0.182	-0.342
5	1.000	177.448	-9.967	174.205	-0.187	-0.332
6	1.001	177.162	-9.974	173.989	-0.193	-0.324
7	…	…	…	…	…	…

4. Paste the frequency data into column A. Paste four more columns of data into columns B to E, two from high input level, and two from the low level.
5. Enter formula into column F: =(B2-D2)/(C2-E2).
6. Highlight cells F2 to F82 (or F102 … depending on points of data). Select Edit|Fill|Down to paste formula into all the frequency points.
7. Perform any other analysis that you need. The AM to PM conversion data is in column F

Conclusion:

AEA Technology two port network analyzers may be used to measure your circuit's AM to PM conversion, and will provide useful displays to guide you in the design of the circuit.

References:

AN101   When to Use Cable Null, AEA Technology
AN120   Measuring Amplifier Gain, AEA Technology
AN121   Measuring Group Delay
AN122   Measuring Gain Compression, AEA Technology
AN124   Measuring Differential Circuits, AEA Technology