

# New System Simulator Includes Spectral Domain Analysis

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With advances in RF and wireless technology, it is often the case that the corresponding advances in system complexity are greater than any added complexity of the individual components that make up the system at the circuit level. Thus, Applied Computational Sciences (ACS) developed the Visual System Architect (VSA) program to automate the design and analysis of these kinds of systems. To address the need for computer-aided engineering (CAE) at the circuit level, ACS has offered design automation in the form of circuit synthesis, simulation, and optimization for more than a decade with the LINC2 Pro EDA/CAE software. Now, with the Visual System Architect, RF and microwave circuit design can be appropriately driven by system design that connects product specifications to circuit level specifications.

The Visual System Architect from ACS offers a large variety of new design and analysis capability for designing at the system level. The program renders obsolete many of the traditional spreadsheet and system cascade calculators once used to analyze system performance. The Visual System Architect adds the flexibility and ease of use of schematic based system simulation as shown in Figure 1. Schematics or system level block diagrams are quickly and easily created from a comprehensive menu of system component behavioral models such as amplifiers, filters, mixers, splitters and attenuators etc.

The program is not limited to a single chain of cascaded components. The system schematic allows the user to construct systems of arbitrary topology. The system simulator can analyze schematics with multiple cascades driven by any number of signal power sources. For example, the Visual System Architect can analyze a transmitter and receiver chain

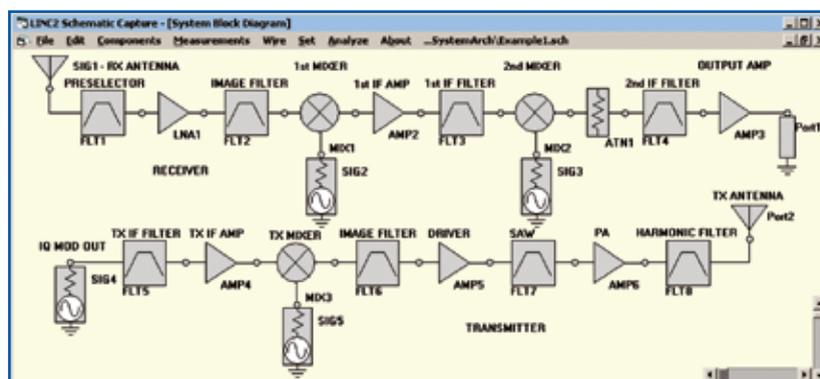


Figure 1: The ACS Visual System Architect's System Schematic

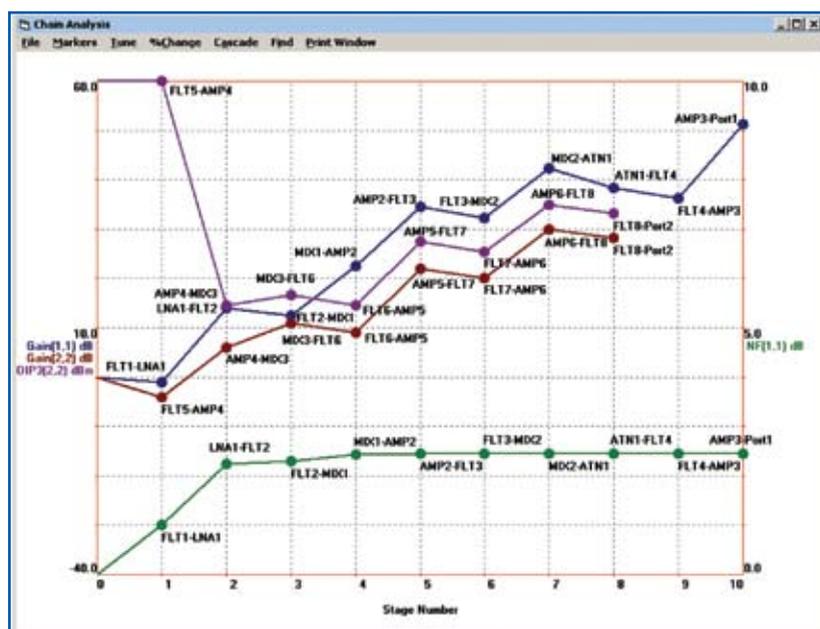


Figure 2: The Visual System Architect's Cascade Budget Analysis Plots



Figure 3: The Visual System Architect's Power Sweep Plots

simultaneously, each with different signal sources and separate local oscillators for the up-converter and down-converter stages respectively. Plots of

power budget, efficiency, gain, IP3 (intercept point) and NF (noise figure) are provided on a cumulative stage-by-stage basis as well as a tabular summary

of total system performance. Figure 2 shows a typical cascade system budget plot. Each data point represents a system performance parameter at a circuit node or interface point between stages.

However, the Visual System Architect goes beyond the traditional budget plots to offer a much wider array of performance measurement methods and analysis tools. For example, Figure 3 shows a power sweep that graphically displays the linear range as well as the P1dB point and compression curve characteristics for the entire system cascade. The Tune menu allows the user to vary any component parameter to immediately see its effect on system linearity or changes to the compression point. The bold curve in Figure 3 represents the initial power sweep while the light curve shows the changes after tuning. The Power Sweep Set menu allows the user to select the range over which input power will sweep.

The ability to display an input-output power sweep curve extends to any point in the system, not just to the output port. Thus, the user can probe any node internal to the system and view the linear range and compression curve characteristics of the system up to and including the selected component.

### Power Spectral Analysis

One of the most challenging tasks an RF designer is faced with is to ensure that spurious signals are not generated and propagated through the system to places where they may degrade circuit or system performance. Undesired spurious signal products (or spurs) can degrade the sensitivity of a receiver or put a stage into compression and prevent the modulation on a desired signal from passing through the system properly. Spurious signals can mix with other spurs or they can mix with desired sig-

nals to create even more undesired spurs that are harmful to system performance, often to the extent of causing the product to fail to meet a number of key specifications. Moreover, spurs may be created in a wireless product that propagate to the antenna port to produce unwanted conducted emissions that involve regulatory issues. Non-compliance with regulatory standards will prevent a product from reaching the market regardless of how well the product performs otherwise.

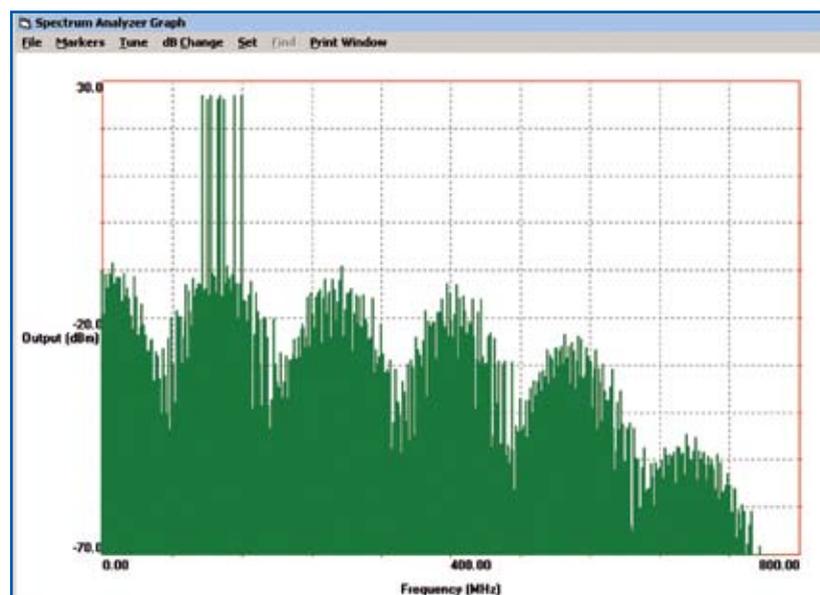
Spurs can be generated by the inter-modulation of more than one desired signal as a result of the non-linearity of a device or stage in the system. In this case new spurious signals are created that were not there before. However, not all undesired signals are the result of newly created spurs. A mechanism by which desired signals can show up as undesired signals in other parts of the system is through leakage paths. For example, the local oscillator signal can leak over to the mixer's RF port and travel through a receiver or transmitter path to the antenna port causing unwanted conducted emissions.

To address the serious issue of spurs, ACS developed the Visual System Architect software with two very powerful analysis tools. One for viewing the spectral content at any node in the system and the other to track the creation and propagation of all spurs throughout the system.

### More than a Spectrum Analyzer

The Spectrum Analyzer is a measurement tool that can be placed at any node in the system schematic to see the full power spectrum at that point. For example, simply connect a Spectrum Analyzer Measurement at the output port(s) of the system to view the output spectrum of the entire product or system.

At first glance the Visual System Architect's Spectrum Analyzer graph window looks a lot like the screen of a typi-



*Figure 4: Power Spectrum Output Plot from the ACS Visual System Architect*

cal spectrum analyzer bench instrument. The spectrum plot displays the entire power spectrum content at any point in the circuit. However, unlike any physical spectrum analyzer, the user can select any component parameter from the Tune menu and adjust its value to see its effect on the production of spectral content. For example, the user could interactively adjust the third order intercept point on a power amplifier to see the effect on the level of 3rd order inter-modulation products at the output. All the signal sources driving the system are listed in the Tune menu as well. This allows the user to adjust the input power to the system from any signal source while viewing the resulting change in the levels of all affected signals and spurs.

Another capability not found in a physical spectrum analyzer is the ability to select any signal or spur on the spectrum analyzer plot and view a detailed history of data showing how the signal was created. Every displayed signal can be traced back to its origins, stage-by-stage, component-by-component. Imagine the value of a spectrum analyzer that can tell you not only the frequency and amplitude of a signal but also where the signal originated, what path it followed to get to the point of observation and measurement and all the transformations it went through along the way!

Figure 4 shows the output spectrum for an amplifier driven by eight VHF signal sources ranging from 115 MHz to 160 MHz. Note that the eight input signals are not evenly spaced throughout the band and they are not all the same amplitude. The Visual System Architect accepts any input spectrum, placing no restrictions on the frequency, amplitude or phase of these signals. The signals input to the system can be represented on the system schematic by signal generators producing up to 3 simultaneous tones per generator.

Additionally, a signal generator can be file based so that an entire spectrum of any number of signals can be loaded into the system at once. The program does not restrict the number of signals in the input spectrum. However, the very first stage in the amplifier (producing the spectrum in Figure 4) with only 8 input tones generates 5064 new signals due to 5th order non-linear effects alone. Nearly 2000 more new signals were created in the lower order terms from these eight inputs as well. These 7000 signals would then become inputs to a following stage, with each successive stage increasing the number exponentially until exhausting computer memory.

It is obvious that some form of signal proliferation management must be applied to prevent overwhelming computer resources. This program

employs a number of signal management methods that actually enhance the presentation of the resulting spectral display for the user. Some of these methods include the following. One option is to combine signals at the same frequency according to their amplitude and phase. No data is lost by simply consolidating like signals at each node.

Because signals below a certain level are of no interest to the user anyway, they can be discarded if they fall below a level preset by the user. The non-linear amplifier model is an example of a model that allows the user to set the threshold level for signals at the local (stage) level. Settings made at the stage level would override any global settings.

Yet another method of signal management is to allow the user to set a spectral window through which signals are allowed to propagate if they fall within the specified frequency bounds. For example, if harmonics above the third are not of interest then the user can set the upper bounds of the analysis window to the frequency of the third harmonic, with the result that all signals greater than three times the fundamental will be discarded.

### Accurate Full-Spectrum Simulation and Analysis

The program allows any number of input tones (subject to system memory considerations) and does not restrict the number of signals generated in a system simulation. In fact, the program does what most other system simulators cannot - simulate and display every signal possible with 100% accuracy (relative to the model used and rendered to the precision of the computer's operating system). Every new signal created by non-linear components is included, up to the order of the component model used. Other simulators may use Fourier transforms, harmonic balance or other iterative algorithms to simulate the signals generated and their levels as they propagate through the system. By

their nature, these other simulators make approximations or are computationally inefficient because they follow an iterative routine to converge on an answer. The Visual System Architect is mathematically exact. It simulates every signal possible in the system without imposing assumptions (such as narrow bandwidth) and without requiring estimations of the number of sample points (does not use Fourier transforms). Instead, the program computes each signal directly from an exact mathematical formula without ever using an iterative loop with convergence testing.

To alleviate undue burden on computer system resources, the user is allowed to decide what signals, if any, should be dropped from the analysis. For example, it is rarely of any value to track a -180 dBm signal through the system. Hundreds or thousands of signals this small would only clutter the spectrum display without providing any significant information.

### The VSA Signal Tree- Unique System Signal and Spur Viewer

The Visual System Architect provides unique user access to a detailed analysis of every signal and spur in the entire system. The System Signal and Spur Viewer window automatically organizes all these signals and spurs into a tree structure that provides nearly instant access to detailed information on any signal anywhere in the system (as shown in Figure 5). At the highest level of the signal tree structure is a list of all the signals present at a given node (the output node, for example). Click on any one of these signals and the next level in the tree opens for that signal. A list of all the signals involved in the creation of the selected signal are displayed at this next lower level in the tree. Clicking the “+” symbol in front these “ancestor” signals displays the next level of signals - all the signals involved in creating the selected ancestor. This process continues down to the end (or lowest level) of the branch

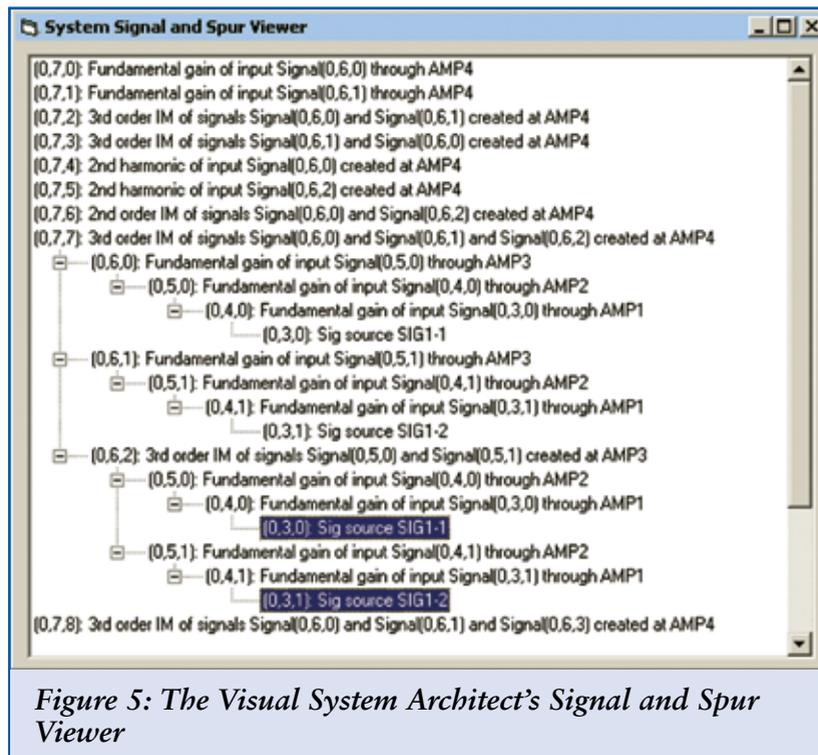


Figure 5: The Visual System Architect's Signal and Spur Viewer

where the origin of the signal is located.

### Each Signal Uniquely Identified

Each signal in the signal tree is uniquely identified with the following information about the signal:

A three dimension array vector of the form (Source, Node, Index) that uniquely identifies each signal according to the Source that was the ultimate origin of the signal, the Node at which the signal exists and the Index that identifies this signal among the array of signals that may be present at this node.

A description of the signal present at this node. The description states whether the signal is a fundamental, a harmonic (including the harmonic number) or an inter-modulation product (including the type of intermod involved).

The unique identification (vector) of the signal or signals that are the immediate ancestors of the signal (i.e. all of the signals that, when applied as inputs to the current system component, come together in the described manner to produce the signal). For example, the description “3rd order IM of Signal(0,6,0) and Signal(0,6,1) created at AMP4” indicates that signal (0,6,0) and signal (0,6,1) applied to the input of AMP4 produced the cur-

rent signal through third order inter-modulation in AMP4 (a non-linear amplifier).

The system component that produced the signal, as identified by the component's reference designator (e.g. AMP4).

Expansion of the signal tree (clicking through a branch in the tree) yields the path a particular component of the signal travels from its source to arrive at the point of observation. Additionally, any signal at any node along the path can be right clicked to reveal its frequency, amplitude and phase.

### Summary and Conclusions

The Visual System Architect from ACS includes the cumulative system budget analyses that are essential to successful system design, analysis, system performance verification and report generation. Full spectral analysis provides a spectrum analyzer view of all signals and spurs at any point in the system. With the System Signal and Spur Viewer the user can trace any signal or spur through the system back to its source.

System design and analysis productivity is enhanced by the flexibility and ease of use of schematic based system simulation. The ability to drag and drop circuit or system components onto the schematic page from an inclusive menu of component models allows the user to quickly construct

system diagrams of arbitrary topology. “What if” scenarios can quickly and easily be tested by simply dragging components into new lineup configurations.

### The LINC2 Software Suite

With the addition of the LINC2 Pro circuit design and simulation software suite (also from ACS), system level designs created with the Visual System Architect can proceed to the detailed circuit design level, all within a common integrate user interface.

LINC2 is a high performance RF and microwave design and simulation program from ACS. In addition to schematic based circuit simulation, optimization and statistical yield analysis, LINC2 Pro includes many value-added features for automating design tasks, including circuit synthesis.

LINC2 offers exact circuit synthesis, schematic capture, circuit simulation, circuit optimization and yield analysis in a single affordable design environment. Now, with the Visual System Architect, RF and microwave circuit design can be suitably driven by system design that connects product specifications to circuit level specifications. The Visual System Architect software provides tuning and optimization at the system level to help ensure that a product will comply with required specifications before valuable resources are committed to detailed circuit design and prototyping.

More information about the ACS Visual System Architect and LINC2 Pro can be found on the ACS web site at [www.appliedmicrowave.com](http://www.appliedmicrowave.com).