True Transient 3D EM/Circuit Co-Simulation Using CST STUDIO SUITE

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Today's engineers are increasingly confronted with simulation tasks that involve the simulation of two types of problems: 3D electromagnetic structures and electronic circuits. The combination of these problems is commonly referred to as EM / circuit co-simulation. Not only can a distinction be made between the methods used to perform a co-simulation, but also in the type of co-simulations available. The need for co-simulation can be seen in many application areas such as antenna design, filter tuning, UWB applications, PCB and signal integrity analysis, RFIDs, etc.

In real-world applications, even with modern computing power, it is simply not feasible to perform tuning tasks on 3D EM/circuit models without employing some sort of "divide and conquer" approach. Unnecessarily large and complex simulations are avoided using co-simulation techniques. Co-simulation also allows the 3D structure and/or the circuit models to be divided into several sections and solved separately, which can then be combined to produce the result of the complete system. This is a type of decomposition which can result in significant gains in terms of simulation speed and can therefore be used for the efficient synthesis and optimization of microwave devices and sub systems.

In order to describe the behavior of a 3D structure accurately, the full-wave result should be included in the design process. This is because the 3D EM simulation result accounts for all typical effects such as crosstalk or parasitics, with no approximations. A standard EM/circuit co-simulation then solves the full problem by incorporating the 3D structure's S-parameters into the circuit simulation.

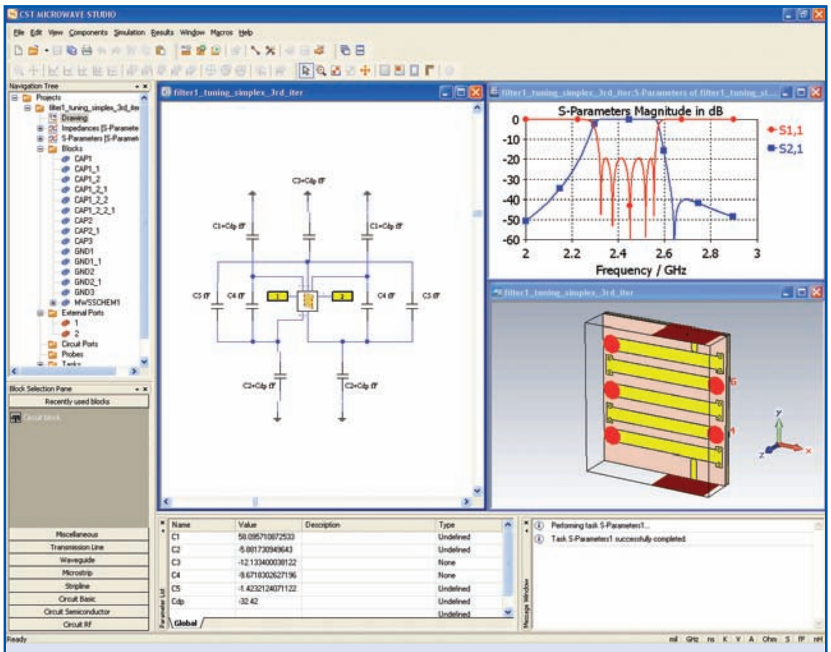

Figure 1: Tuning of a microstrip band-pass filter using standard EM/circuit co-simulation

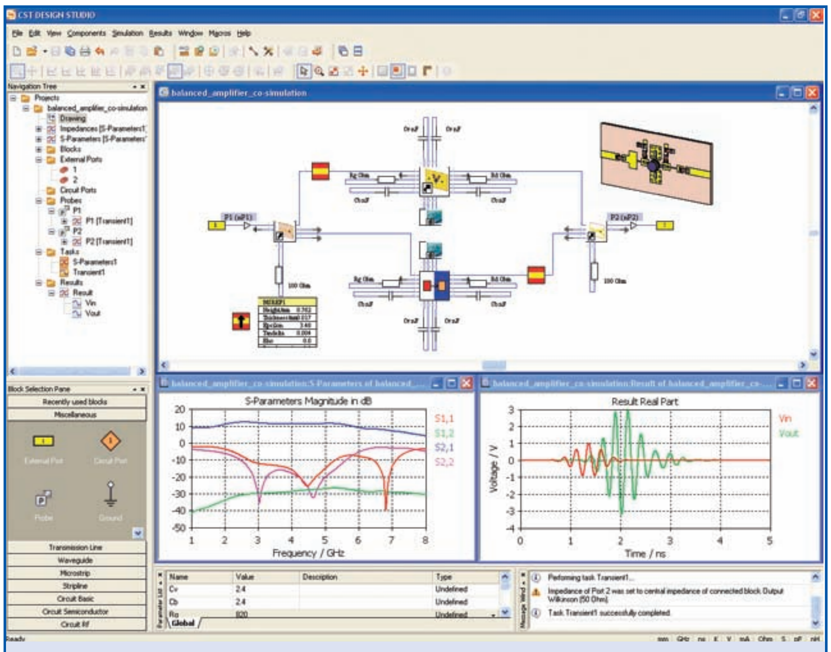

Figure 2: Standard co-simulation of a balanced amplifier (Transient + S-Parameter task)

In CST STUDIO SUITE™, CST MICROWAVE STUDIO® (CST MWS) is used for 3D EM simulations, whereas the synthesis and circuit parts are provided by CST DESIGN STUDIO (CST DS). Both tools are tightly integrated in CST DESIGN ENVIRONMENT™.

CST now offers in addition a new transient 3D EM/circuit co-simulation method based on a truly coupled approach which can speed up the simulation for many types of applications, compared to the standard method.

Standard EM/Circuit Co-Simulation

Most commercial packages utilize the standard co-simulation approach. This is based on obtaining the complete S-parameter matrices of the 3D EM structure, in CST's case by means of a CST MWS simulation, and other components (e.g. touchstone files of measurement results) and consequently performing a circuit analysis. Using CST DS, two options are available. The first possibility is to perform an S-parameter task where the circuit simulation is performed in the frequency domain. Alternatively, a transient analysis can be carried out using an automatically created equivalent spice circuit of the 3D EM structure, which includes linear and non-linear circuit elements or networks providing waveforms from time-domain probes. Arbitrary excitation signals may be applied. In both cases, the resulting 3D fields can be obtained.

Once the complete S-parameter matrix of the 3D structure has been obtained, the optimization only needs to be performed at the circuit level. This is much faster than performing a full-wave 3D EM optimization since unnecessary 3D simulations are avoided. A typical application of this is the design of an antenna array's feeding network or the tuning of a planar filter as shown in Figure 1 where the S-parameter task in CST DS was applied.

A more complex example consisting of several 3D EM structures is shown in Figure 2. This is an example of a balanced amplifier designed using the standard co-simulation approach in CST STUDIO SUITE. The circuit model consists of two Wilkinson dividers (input and output), two quarter-wavelength microstrip lines and a single amplifier to be connected in both branches (cloned in the bottom branch). The single amplifier model includes 3D layout, SMD components and packaged transistor model. All layout discontinuities and crosstalk between components are correctly taken into account. S-parameters and time-domain results

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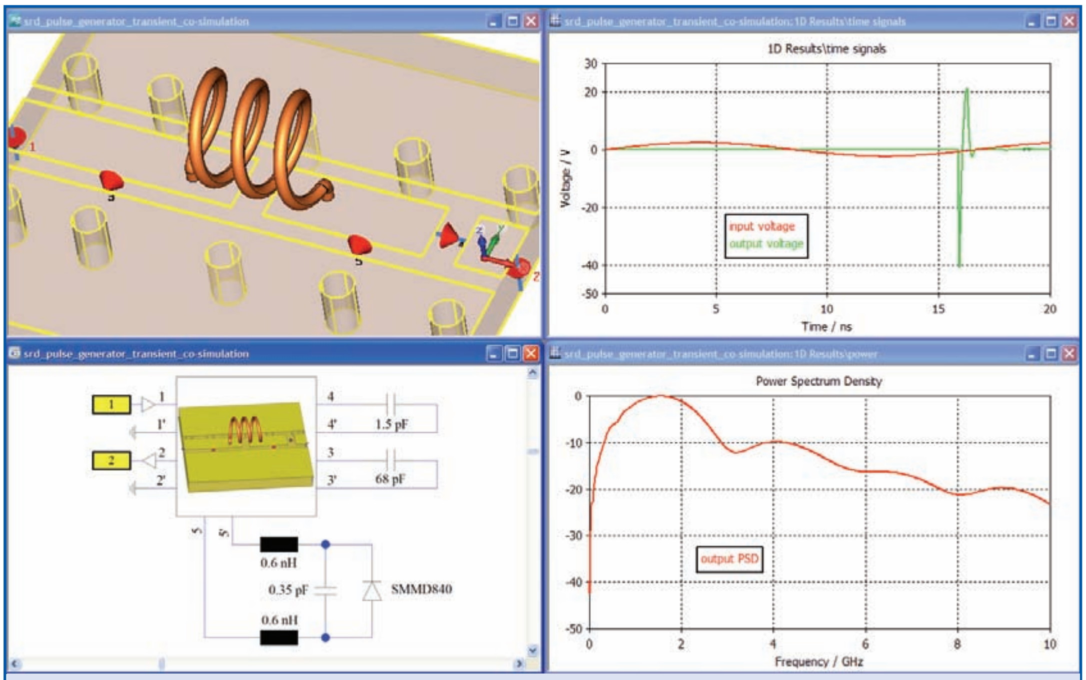

Figure 3: SRD pulse generator

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(UWB Gaussian pulse 2.7-5.3 GHz) are available using standard co-simulation as shown in Figure 2.

Transient EM/Circuit Co-Simulation

A more efficient method for applications whose 3D model has a significant number of ports is the transient co-simulation approach. Here, the user is able to excite only the ports of interest. In contrast to the standard co-simulation, a full S-matrix calculation is not necessary. Therefore the simulation may actually be faster for multi port devices. Furthermore, the simulation is fully consistent and bidirectional and can be classed therefore as a true co-simulation.

Typical applications which lend themselves to such an approach include UWB applications (sub-nanosecond pulses, strongly nonlinear components) and the signal integrity analysis of PCBs with a significant number of lumped elements or circuit networks connected to the 3D model.

An example of a step-recovery diode (SRD) pulse generator is shown in Figure 3. The pulse generator consists of a 3D EM structure, which is a coplanar waveguide layout including a helical coil, two lumped capacitors, and an SRD. A spice model of the SRD is used which also includes the parasitic elements of the SMD package. The pulse generator is excited with a harmonic signal passing through a low-pass filter reaching the SRD connected in parallel. The strong non-linearity of the SRD produces a very sharp peak, which is additionally filtered by a DC blocking capacitor at the output.

Also shown in Figure 3 are the waveforms of the input voltage and current as well as the output voltage. The ratio of the duration of the input signal to the monopulse output can be clearly seen. The width of the monopulse, 0.45 ns, has a spectrum in the range of several GHz. The sub-nanosecond pulse is produced by the SRD when the current changes direction from forward to reverse. The step-recovery effect occurs close to the maximum derivative of the current (at about 16 ns). In order to obtain correct results using any frequency domain approach, more than 300 harmonics would need to be taken into account.

This article has demonstrated the state-of-the-art EM/circuit co-simulation possibilities available to MW and RF engineers. The traditional standard EM/circuit co-simulation as well as the transient EM/circuit co-simulation methodologies have been discussed. CST STUDIO SUITE offers both these techniques, providing design engineers with the best approach for the task at hand.

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