

# Splitting S-Parameter into Two Equal Half using Optimization Techniques

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As described in literature, splitting of S-parameter into two equal half can be achieved by first converting S-parameters into T-matrix and then using simple mathematical operation S-parameters can be split into two equal half. The methodology can however be applied to special cases of 2 port S-parameters under certain limitations. There is no robust methodology available today which allow splitting of an arbitrary set of S-parameter into two equal half easily.

The article presents a generic optimization based simulation methodology to split an arbitrary set of S-parameters into two equal half using Agilent's Advanced Design System (ADS). The methodology could be applied up to six ports. Simulation setup is the key to achieve this functionality. The techniques can be further extended to higher number of ports but will require additional efforts. It is assumed that the S-parameters are generated using symmetrical structures which are assumed to be connected back to back with an arbitrary termination.

Rather than exhaustive set of test fixtures, calibrations and measurements, the technique presented in this paper heavily rely on computing power which is commonly available today on desktop computer. The methodology does not make any assumptions regarding fixture models and topology. As the extraction mechanism is purely mathematical in nature, it does not rely on the physical constraints & topology of the physical structure which can sometime results in unphysical behavior.

A low pass filter circuit as shown in figure 1.0 along with termination impedance is used here to demonstrate technique, however the methodology can be applied to arbitrary simulated or measured S-parameters.



Figure 1: A low pass filter equivalent circuit

The simulated S-parameters response is shown in figure 2:

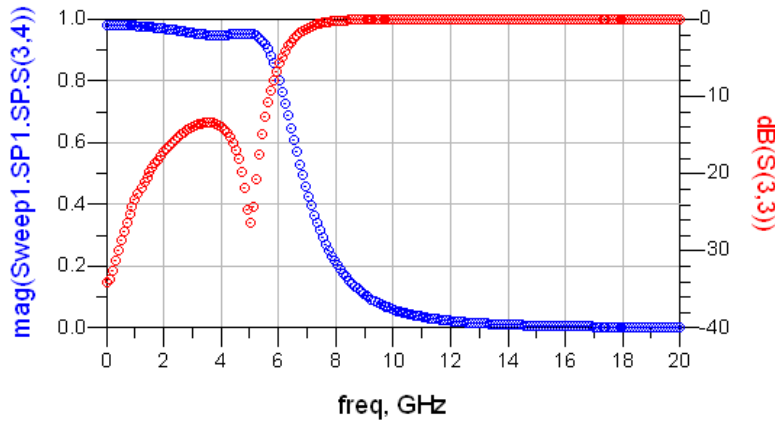


Figure 2: The simulated insertion loss mag plot and return loss plot in dB

The goal is to split S-parameters into two equal half from DC to 20 GHz.

The splitting of this structure into two half requires following steps:

1. Create a cascaded (two block) S-parameter representation of the circuit using Equation based linear component from ADS. As we want to split these S-parameter into two equal half, these blocks must be connected back to back as shown in figure 3.0

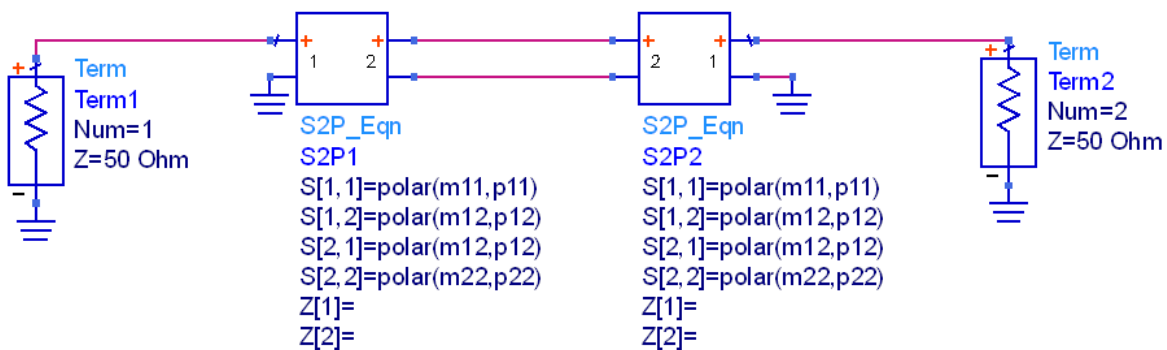


Figure 3: Two equations based linear component connected back to back

The equation based linear components in ADS enables us to define, the S-parameter behavior using a complex equation instead of using a Touchstone file. Here for simplicity we assumed that the device is reciprocal in nature ( $S_{21}=S_{12}$ ) but the methodology will work fine even if the device is non-reciprocal. The parameters  $m_{11}$ ,  $p_{11}$ ,  $m_{12}$ ,  $p_{12}$ ,  $m_{22}$ ,  $p_{22}$  are defined as optimization variables with magnitude range optimization variation from 0 to 1 and phase variation from -180 to 180 deg

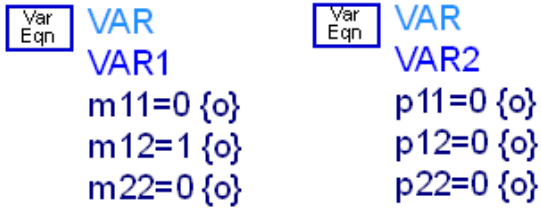


Figure 4: Optimization variable setup

2. Setting up frequency step optimization :

Regular optimization setup could be not be used here to optimize this circuit as the variable value need to change as a function of frequency while the cascaded equation bases S-parameter component uses a single value for variables m11, p11, m12, p12, m22, p22 at a given instance of time and the value cannot be easily defined as a function of frequency from DC to 20 GHz. We need to find an alternative way to efficiently run this optimization to get a good fit with original S-parameter over required frequency range.

Low pass filter and the cascaded S-parameters are placed on the same schematic page within ADS (shown in figure 5) and optimization goals are defined to get a good match between S-parameter insertion and return loss of two networks.

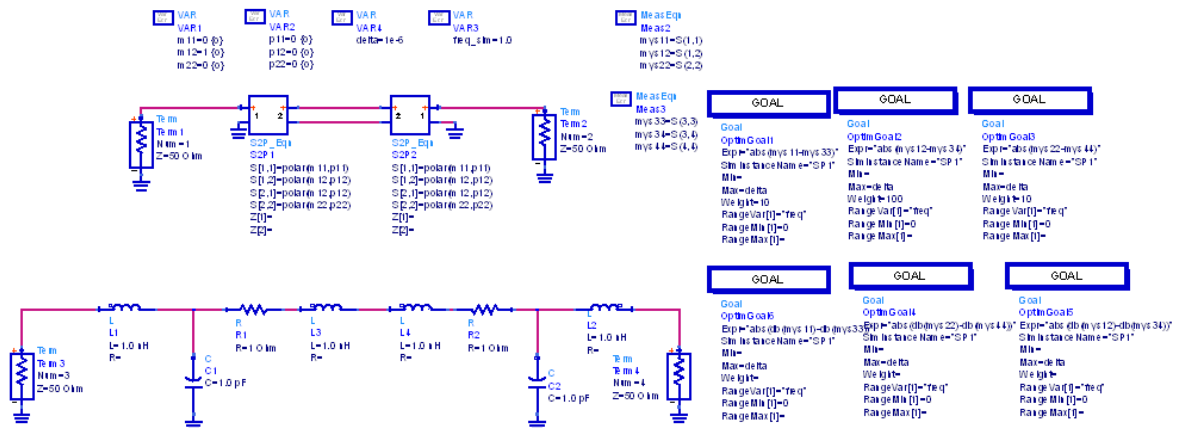


Figure 5: The original schematic and cascaded networks with associated optimization goals

Two level nested parameter sweep is used to overcome limitations associated with parameter value being single valued at a given frequency (shown in figure 6). In fact it is the most critical part of simulation setup which enables S-parameters splitting into two equal half. As a result of this optimization setup, the S-parameters magnitude and phase are generated and optimized at every

frequency point using step by step approach. Running optimization with every frequency step makes optimization process more efficient and provides robust convergence even for very large frequency bandwidths.

PARAMETER SWEEP	S-PARAMETERS	OPTIM
ParamSweep Sweep1 SweepVar="freq_sim" SimInstanceName[1]="SP1" SimInstanceName[2]="Optim1" SimInstanceName[3]= SimInstanceName[4]= SimInstanceName[5]= SimInstanceName[6]= Start=0 Stop=20 Step=	S_Param SP1 Freq=freq_sim GHz	Optim Optim1 Optim Type=Gradient MaxIters=500 DesiredError=0.0 StatusLevel=4 FinalAnalysis="None" EnableCockpit=yes

Figure 6: The optimization setup

ADS2009 Update 1 uses optimization cockpit (figure 7) was used to Split S-parameter into two half. The simulation was on Z800 machine.

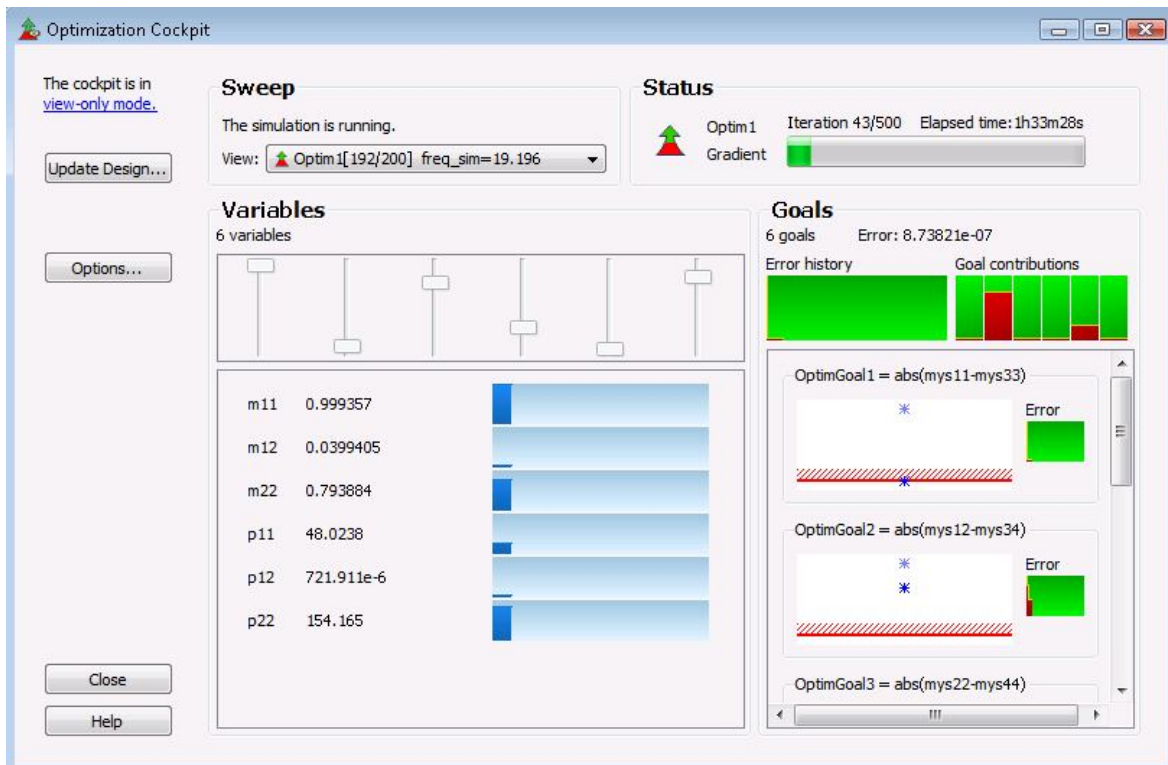


Figure 7: Optimization cockpit within ADS 2009 Update 1

Optimization cockpit has advantage over traditional approach that optimization can be paused at any time, optimization algorithm could be changes, and the variables could be updated for their values and range during optimization process without exiting.

Figure 8 compares the response of the optimized split cascaded network with original S-parameter. Both network responses show an excellent agreement. Phase response also is well matched (not shown here).

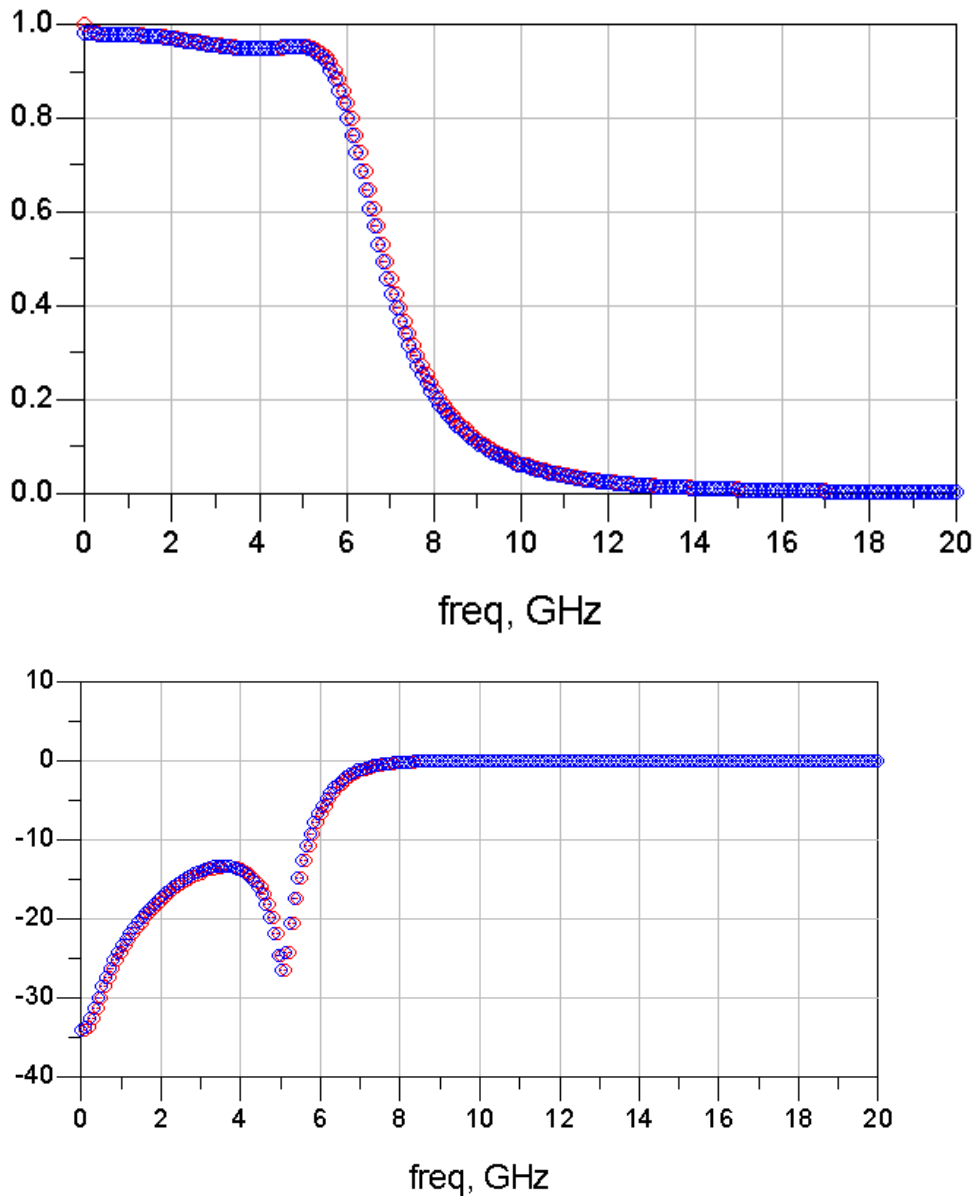


Figure 8: Comparison of S-parameter response from split S-parameter (blue) with original S-parameter (red).

The split parameters S-parameter magnitude and phase value are extracted from the data display by listing OPTIM.m11, OPTIM.p11, OPTIM.m12, OPTIM.p12, OPTIM.m22, and OPTIM.p22.

ADS archive project Split\_SP.zip is attached. The design "divide\_s\_parameters.dsn" provides the simulation setup and the corresponding DDS page compares the S-parameter of the lumped equivalent with the split S-parameter performance during optimization process.

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