SDC7 - Reflectionless High-pass Filter Design for Load-Pull Measurement Setups

Detailed description and rules

Introduction

Filters are frequently used and are essential products in communication systems. They are passive components that process a signal to select (such as a bandpass filter) or eliminate a specific frequency (such as a notch filter). Traditional filter topologies demonstrate large reflections out of the pass band due to their structures. This may cause stability problems in wideband systems.

Re-designing filters with reduced reflections (or matched) in the stopband is possible, and it supports the systems' reliability since it helps to eliminate unexpected resonances and oscillations [1,2].

Large signal measurement setups are quite complicated systems often requiring many different components used to control power and impedances. They are mostly used for source-pull and load-pull measurements. Although it is expected that a DUT should remain stable enough to perform source-pull and load-pull measurements, band-limited components, such as circulators and diplexers, can cause unwanted resonances on load-pull setups, leading to oscillations during the measurements.

The stability of RF transistors and circuits is a vast topic but, we know that some basic methods can prevent oscillations. Providing a wideband 50 Ω termination at the input of the network is quite handy to improve the stability [3]. Figure 1 depicts an active load-pull setup's input stage. In this configuration, the bias-tee and coupler often provide wide operation bandwidth with small insertion loss. However, the circulator below 10 GHz typically has less than 20% bandwidth. This means that it will have a large reflection outside of the operation band which might cause undesired resonances.

In this design competition, the students will design a reflectionless filter to use in a load-pull setup to improve the stability of the DUT.

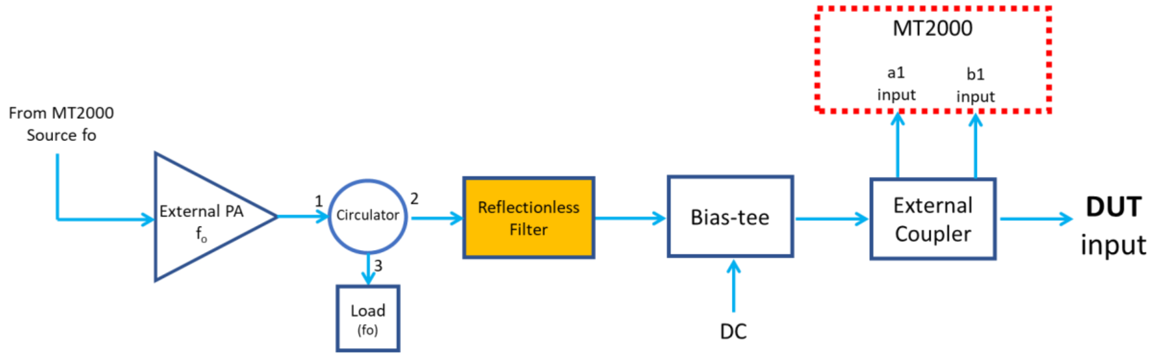

Figure 1. Input stage configuration of an active load-pull setup.

Resources:

[1] Matthew A. Morgan, Reflectionless Filters, Artech House Publishers, 2017

[2] Mini-Circuits, "Reflectionless filters improve linearity and dynamic range," Microw. J., vol. 58, no. 8, pp. 42–50, Aug. 2015.

[3] O. Ceylan, L. Marco-Platon, S. Pires, "Refine Biasing Networks for High PA Low- Frequency Stability", 2018, Microwaves & RF, 57(4), 52–56.

Design specifications and rules

In this competition, the students will design a reflectionless bandpass filter. Here are the design specs and rules:

- Passband: > 2.3 GHz, max 1.5 dB insertion loss (up to min 4 GHz) (There is no limit for max frequency) (Check the "Scoring" for details)
- Stopband: < 1.7 GHz, min 10 dB insertion loss (There is no limit for min frequency) (Check the "Scoring" for details)
- S11 and S22 should be lower than -13 dB in the passband and stopband.
- Any substrate materials and passive components (ceramic, multi-layer, etc.) are allowed to design the circuits.
- The connectors should be Female type and suitable for 3.5 mm Male cable connections (such as 2.92 mm, 3.5 mm, or SMA)
- The total area of the designs should not exceed 500 cm^2 (25 cm x 20 cm).
- No active components, such as transistors or ICs are allowed. There should not be any biasing requirement or battery (or supercapacitor) connected.

Students can contact the organizing committee for their questions and technical guidance anytime. We are more than happy to answer their questions and share our design and fabrication experience.

The Design Competition is open to teams of undergraduate and/or graduate students that are registered at a university or other educational institution. Students must show a valid student ID during the competition.

Students may enter as individuals or as a team. There may be no more than three students on a team. Each student may be a member of only one team. Each team may submit up to two entries but can only receive an award for one entry. There is no age restriction.

The students are advised to use e-mail addresses issued by their respective institutions for all communication regarding the competitions instead of personal e-mails (e.g., Gmail, Hotmail).

Evaluation process

A wideband VNA will be used to measure the S-parameters of the designed filters. The VNA will be calibrated at 0 dBm power using a Maury Characterized Calibration Kit, using SOL-R (unknown thru) and Insight Software. All measurements are referenced to 50 Ω impedance.

Before measurements, the organization committee will visually inspect the submitted circuit to ensure that there are no active components or biasing present. Sealed casings are not allowed. If the circuit is placed in a package or enclosure, it should be suitable for visual inspection (removable cover, transparent box, etc.).

The students will connect their circuit(s) to the VNA RF cables for the measurements. The implemented circuits should be structurally reliable enough to handle mechanical forces such as torquing and cable tension. The competition committee does not accept any responsibility in case of physical damages during the competition. The designs meeting the technical design rules will be evaluated during the competition.

No tuning is allowed during the S-parameter measurement while the circuit is connected to the VNA.

The connectors of the measurement ports will be 3.5mm Male type phase-stable coaxial cables. Therefore, the designs should have suitable Female connectors at their input and output ports. Max of 10 minutes will be given to each circuit to complete cable connections and prepare the circuit for the measurement. If there is enough time after measuring all of the participants' circuits, it may be possible to re-measure some circuits if time permits.

Remote participation is allowed. But the circuits should arrive at the Maury Microwave US location at least 5 days before the competition. The organizers will do their best to protect the circuits and measure safely. Organizers do not accept any responsibility in the case of an damage or loss during the shipment.

Scoring

The winner will be determined by the circuit that achieves the widest bandwidth in compliance with the design rules. The below scoring will be used to evaluate the designs based on their 2-port S-parameter measurement results:

- Passband (>4 GHz) Score = ([Max Frequency (S11 < -13 dB & S21 > -1.5 dB)] – 4) x 2 {max score is 10}
- Stopband (<1.7 GHz) Score = (1.7 – [Min Frequency (S11 < -13 dB & S21 < -10 dB)]) x 10
- Insertion Loss Score = 1.5 - |Max insertion loss in dB| x 10
- Total Score = Passband Score + Stopband Score + Insertion Band Score

The jury might disqualify the designs not revealing a proper reflectionless filter characteristic to eliminate traditional reflective high-pass designs.

Figure 2 depicts the limitations based on simulation data. If there is a tie, the design having the min insertion loss will be the winner.

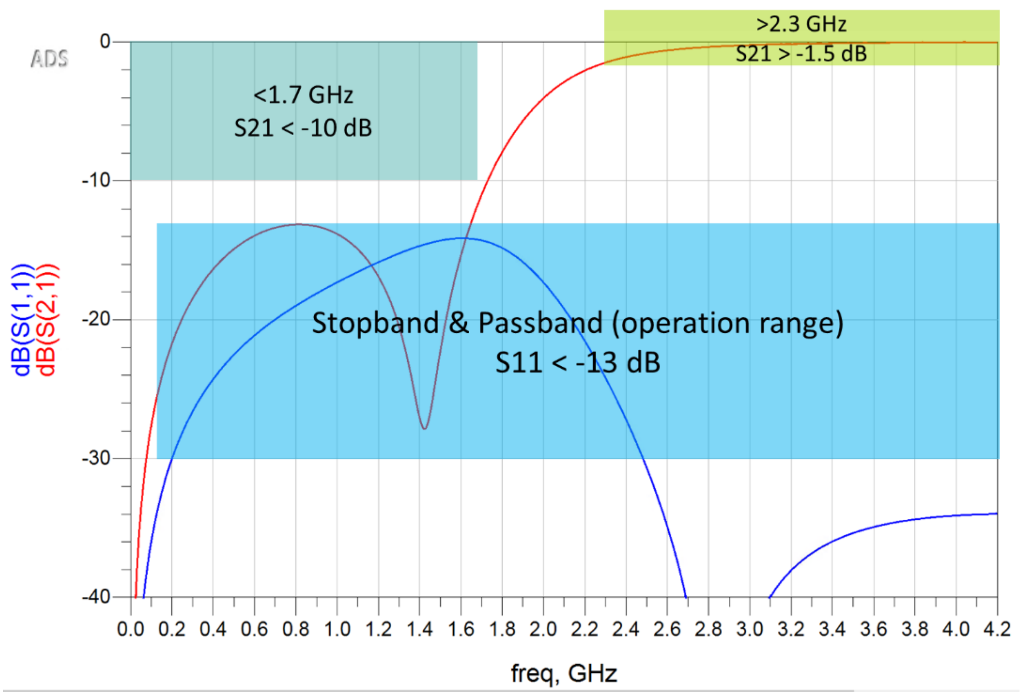

Figure 2. Design rules of S21 and S11 in the stopband and passband

Example Evaluation:

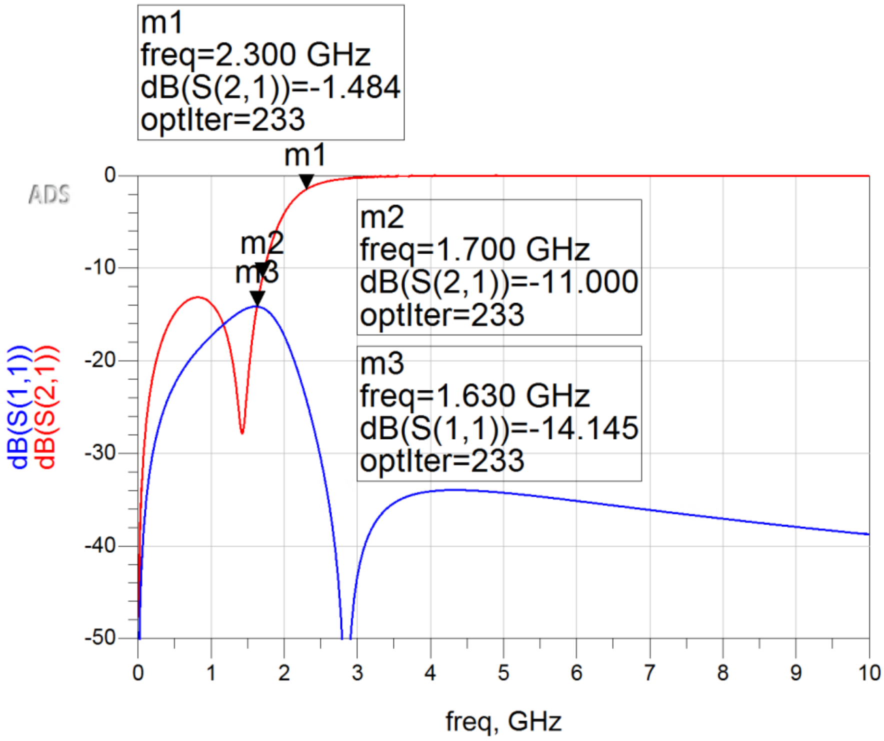

Figure 2. Evaluation example (simulated data).

The design meets:

1) S21 > -1.5 dB in the required (operation) band 2.3-4 GHz [Pass]
2) S11 < -13 dB in the required (operation) band 2.3-4 GHz [Pass]
3) Frequency limitations:
    a. Passband max frequency is **10 GHz** since S11<-13 dB and S21>-1.5dB above 4 GHz
    b. Stopband min frequency is 0 Hz since S11<-13dB and S21<-10dB below 1.7 GHz
    c. Max insertion loss is **-1.48 dB** in the passband.

Passband (>4 GHz) Score = (**10** – 4) x 2 = 12, final score is 10 due to max score limit.

Stopband (<1.8 GHz) Score = (1.7 – **0**) x 10 = 17

Insertion Loss Score = 1.5 - |**-1.48**| x 10 = 0.2

Total Score = Passband Score + Stopband Score + Insertion Band Score = 10 + 17 + 0.2 = 27.2

Supporting MTT-S Technical Committee

TC-5 Filters Committee

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