IMS2023 Student Design Competition

SDC2 - 3D-Printed and Surface-Mounted Bandpass Filter in X-band

Detailed description and rules

Introduction

With the recent developments of 3D printing technologies, and the widespread use in school and research facilities, the question of whether practical filters can be 3D printed and used in conjunction with printed circuit boards. The goal of this competition is to both investigate what can be created using 3D printing and how can these printed parts be mounted on circuit boards. X-band was chosen as the frequency of interest since the wavelength is reasonably small and therefore it is expected that the parasitic effects of the mounting will not be detrimental to the filter performance.

Design specifications and rules

This competition would require students to 3D-print a passive, RF filter. The filter would have to be assembled onto a printed circuit board so that it can be connected to a network analyzer to demonstrate test results at the end of the competition through SMA M or F connection. The filter itself should operate over X-Band with a center frequency of 10 GHz and a 3-dB bandwidth of 1 GHz. The filter insertion loss will be measured at three points in the passband, 9.75 GHz, 10 GHz, and 10.25 GHz. The filter rejection will be measured at 2 GHz, 9 GHz, 11 GHz, and 18 GHz. Bonus points will be given if there are no spurs above -30 dB down to 2 GHz and up to 18 GHz. Furthermore, the size of the 3D printed part will be measured, with points given for achieving miniaturization beyond an air-filled empty cavity design.

The students are expected to create their own 3D structures and printed circuit boards using whatever methods they have available to them. As an example, the 3D printed structure could be realized using a fused deposition modeling (DFM) printer. It can then be coated using conductive paint and/or plated. Non-metallic structures can also be used. The printed circuit boards could be created using printed circuit board plotters or photolithography. The size of the circuit board should not exceed the size of the 3D-printed-part footprint by more than what is necessary to mount the SMA connectors. It is recommended to bring a second, unmounted version of the 3D-printed filter for the size measurement.

Evaluation process

The filter designs will be measured using a 2-port network analyzer. The S-parameters will be used to evaluate the electrical performance of the filter. Then the physical dimensions of the 3D printed part will be measured to evaluate the achieved miniaturization. These parameters will then be used to calculate the final score as listed in the next section.

Scoring

The passband insertion loss will be measured at 9.75 GHz, 10 GHz, and 10.25 GHz, scaled by 3, and rounded to the nearest 0.1 dB. These values will be kept negative. Stopband rejection will be measured at 2 GHz, 9 GHz, 11 GHz, and 18 GHz and rounded to the nearest 0.1 dB. The measured values at 2 GHz and 18 GHz will be taken as a positive number and divided by a factor of 50. The measured values at 9 GHz and 11 GHz will be taken as a positive number and divided by a factor of 10. The physical dimensions of the 3D printed part will be measured using a ruler. The volume of the 3D-printed part will be compared to the expected volume of a fourth-order, air-filled, cavity-based filter (2x2 configuration) This reference volume is 23 cm^3. The ratio of the reference filter volume over the measured volume will then be squared and multiplied by the sum of all of scaled measurements. Finally, 1 point bonus will be granted for filters which exhibit a spurious free range (defined as no transmission greater than -30 dB) down to 2 GHz and 1 point bonus for a spurious free range up to 18 GHz. Students can therefore receive 0 points, 1 point, or 2 points for the spurious range. The highest score will win the competition. Below is the

Overall: (3*(S_{21}@9.75GHz+S_{21}@10GHz+S_{21}@10.25GHz) - (S_{21}@2GHz+S_{21}@18GHz)/50 - (S_{21}@9GHz+S_{21}@11GHz)/10)*(23/measured_volume)^2 + ([0, 1, or 2] bonus depending on spurs).

An example of scoring for an example filter is below:

Example measured values:		Example scaled values:
2 GHz:	-58.3 dB	1.17 (1.17 = 58.3/50)
9 GHz:	-5.1 dB	0.51
9.75 GHz:	-0.2 dB	-0.6 (0.6 = 0.2*3)
10 GHz:	-0.2 dB	-0.6
10.25 GHz:	-0.2 dB	-0.6
11 GHz:	-4.3 dB	0.43
18 GHz:	-34.9 dB	0.70
Volume:	11.5 cm^3	4 (4 = $(23/11.5)^2$)
Spurs below:	No	1
Spurs above:	No	1

The total score for this filter is the sum of the example scaled values times the volume ratio squared plus the two bonus points: (1.17+0.51-0.6-0.6-0.6+0.43+0.70)*4+2 = 7.46.

Supporting MTT-S Technical Committee

TC-5 and TC-16

Contact information

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