RFI Note #007

Design and Implementation of the Debuncher Bands 3 and 4 System Filters

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Abstract: The Debuncher stochastic cooling system has appreciable gain outside of its individual bands. This gain interferes with the ability of the system to cool antiprotons in the time from shot to shot. Bandpass filters were designed for bands 3 and 4 to reject the out-of-band signal. The parameters for these filters are presented and measurements shown.

I. Introduction

The Debuncher at FNAL has several frequency bands in its 4-8 GHz stochastic cooling system.[1] Unfortunately, the electronics, amplifiers, and surround equipment adds an out-of-band signal which decreases the cooling rate and/or ability of the stochastic cooling system to cool antiprotons. It was desired, therefore, to place bandpass filters on each band as necessary. Measurements on bands 1 and 2 showed that these systems did not require filters, however, bands 3 and 4 required filters. The topology of the filters will be described, parameters essential to the filter will be stated, and finally, measurements will be shown.

II. Design Criteria

The spectrum of the momentum system and betatron system for band 4 was measured and it was determined that a bandpass filter having a start frequency at 6.4 GHz, ending at 8.6 GHz. For band 3, it was determined that a bandpass filter having a start frequency of 5.4 GHz, ending at 7.5 GHz. Previous experience with broadband steep skirt filters[2] has shown that using a resonant coupled line structure provides excellent magnitude and phase response. The coupled

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[1]D. McGinnis, "4-8 GHz Debuncher Upgrade Array Impedance Response," Pbar Note #580, March 22 1998, http://cosmo.fnal.gov/documents/pbarnotes/pdf_files/PB580.PDF

[2]C. Deibele, "Design of Microwave Bandpass Filters for the Debuncher Stochastic Cooling System, Pbar Note #650, January 24, 2001, http://cosmo.fnal.gov/documents/pbarnotes/pdf_files/PB650.PDF

lines in this paper, however, are narrow band and the trace spacing was kept as wide as possible. Additionally, the number of resonant coupled lines was limited to four. The requirements for these filters required narrow trace spacing and five resonant coupled lines. A picture of the interior for the system filter number three is shown in Fig. 1.

The designs were optimized using Agilent Technologies[3] Series IV package. Once the

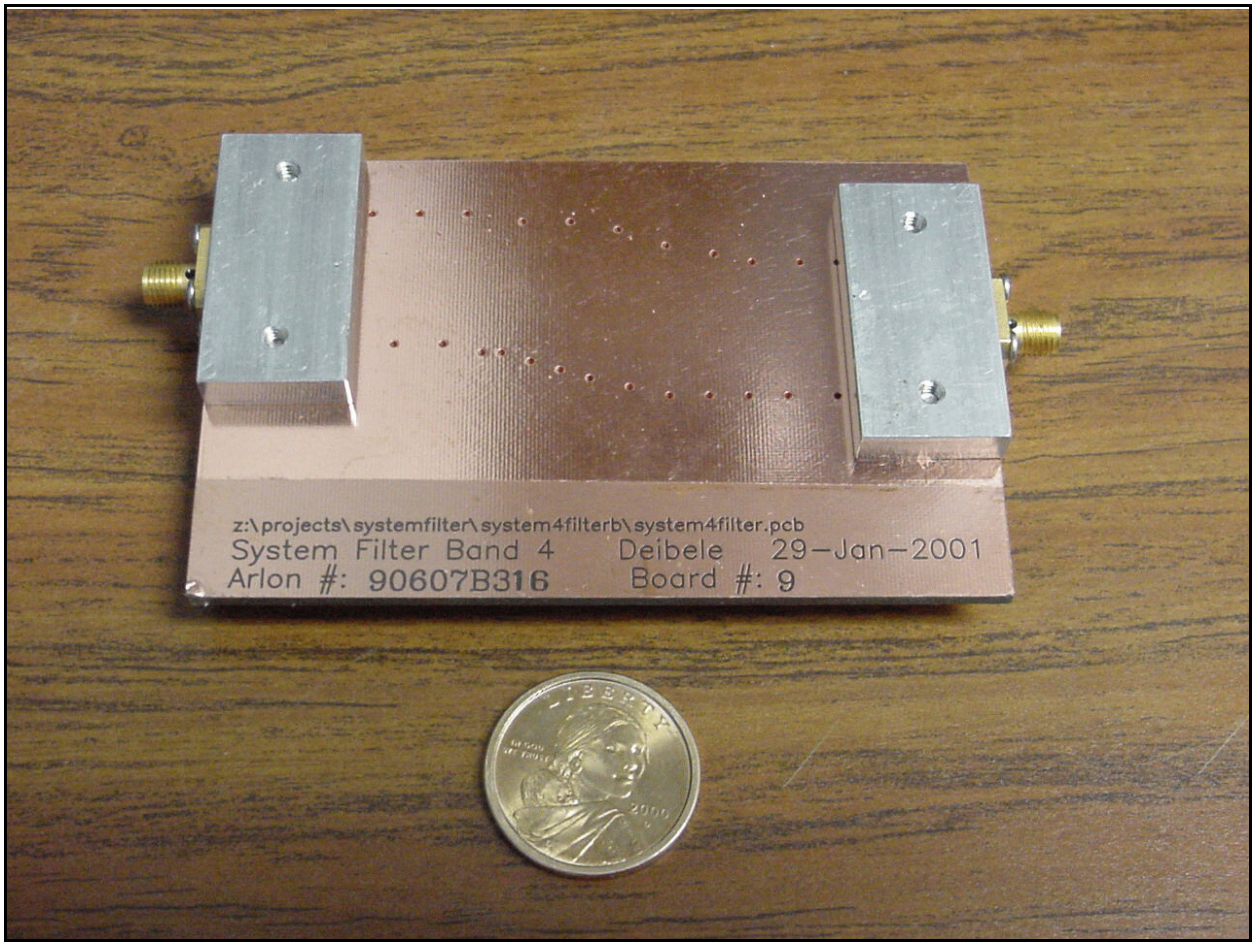

Figure 1. A sample of the assembled Band 4 filter. The board is three layers, namely two grounds sandwiched between two dielectric layers, with a trace layer in the middle. The boards are manufactured by Arlon, and are ½ oz copper, LX-04503355. The connectors are Macom 2052-1618-02. The aluminum parts that connect to the connector were manufactured by FNAL, and have a drawing numbers: 8035-MB-375836 and 8035-MB-375835.

[3]http://www.agilent.com

design was optimized and parameters were robust, the design was electromagnetically simulated using Ansoft's Ensemble[4] program. The final geometrical results from the electromagnetic optimization/simulation are presented in Table 1. A picture of the interior, or trace layer, is shown in Fig. 2.

Table 1.

	W_1	S_1	L_1	W_2	S_2	L_2	W_3	S_3	L_3	W_4	S_4	L_4	W_5	S_5	L_5
Band 3	33.7	6.0	247	53.9	6.0	306	56.7	6.0	277	52.8	6.0	280	33.7	6.0	302
Band 4	33.7	6.0	257	47.5	6.0	240	53.7	6.0	250	44.8	6.0	251	33.7	6.0	243

The trace width, coupled line separation, and length of each coupled line section for the filters. All lengths are in mils.

The measurement results are shown in Figs. 3-6. The results are within expected tolerances of the initial design presented by Series IV.

III. Conclusion

The production of the systems 3 and 4 filters went smoothly. It took circa one month from design to completion of the final boards. The measurement of the boards showed high reproducibility.

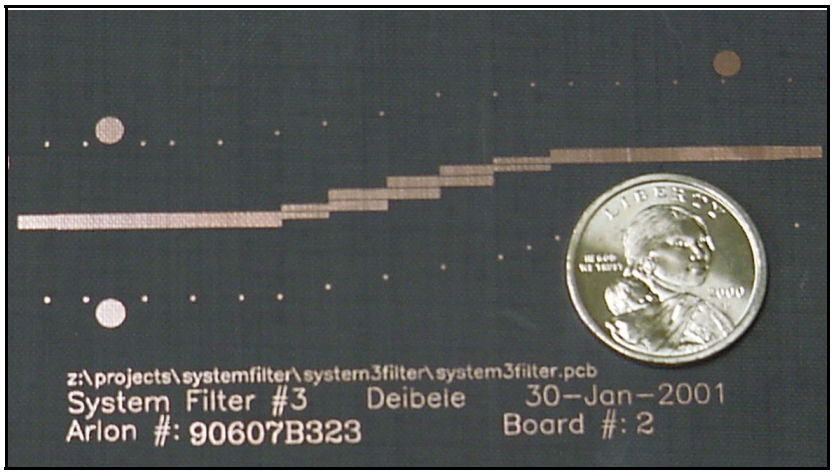

Figure 2. A picture of the inside of the system filter for band 3. Five coupled resonant lines are put together for the bandpass characteristic. The serial number of the board stock from Arlon is etched onto each layer and onto each board. The top and bottom boards are matched together. Additionally, notice that at the left and right edges, the trace becomes ten mils smaller (from 76 mils to 66 mils) to accommodate and broadband match the SMA connector.

[4]http://www.ansoft.com

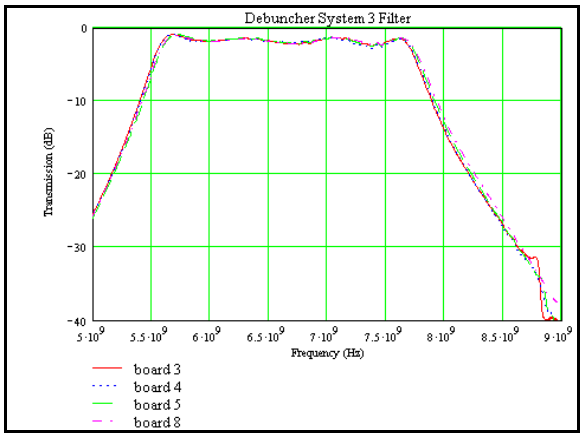

Figure 3. The transmission of the System 3 filter.

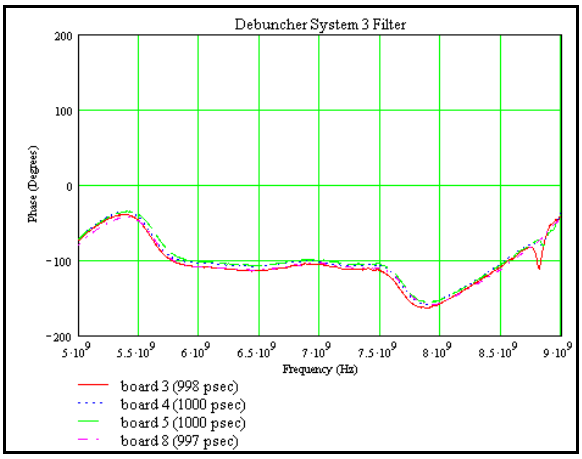

Figure 4. The phase of the system 3 filter. All filters experienced around 1 nsec of delay.

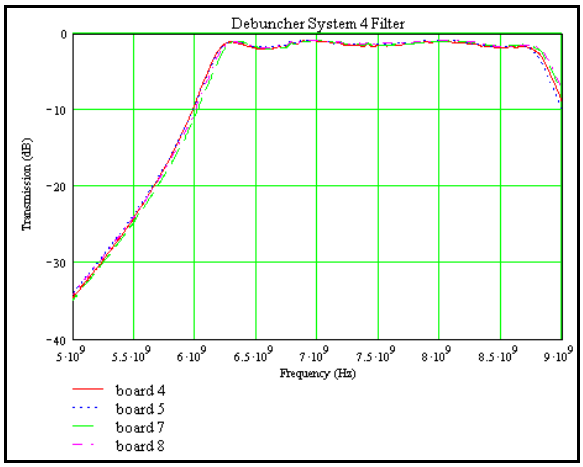

Figure 5. The transmission of the System 4 filter.

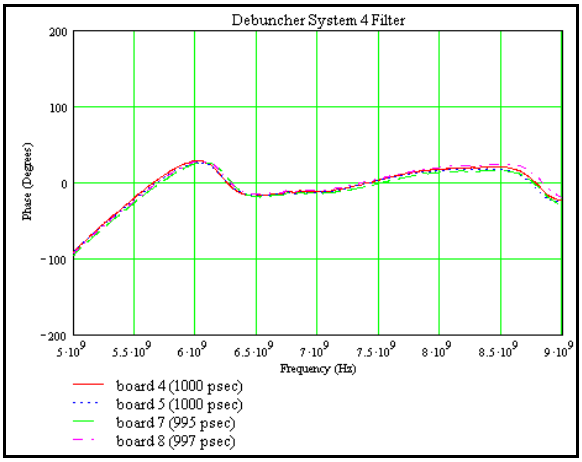

Figure 6. The phase of the System 4 filter with ~1 nsec of delay removed.