

# Frequency Response of Post-down-converter Digital Filters in the MI BPM EchoTek Board Setup

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This note describes the required GrayChip setup file frequency parameters and the frequency response to be expected from the EchoTek/GrayChip post-down-converter digital filters used in the Main Injector BPM. The four channels in each GrayChip are configured as:

- 53 MHz narrowband (for closed orbit)
- 2.5 MHz narrowband (for closed orbit)
- 53 MHz wideband (for turn-by-turn)
- 2.5 MHz wideband (for turn-by-turn)

## ***Configuration File Frequency Parameters***

The Echotek configuration file requires specification of two frequency values for each GrayChip channel, the digitizer frequency and the down-convert frequency. Given a digitizer clock frequency 10/7 times the nominal 53 MHz signal, the proper relationships between digitizer and down-converter frequency values are:

$$f_{\text{downconvert}_{2.5}} = f_{\text{digitizer}}/30$$

and

$$f_{\text{downconvert}_{53}} = 3/10 f_{\text{digitizer}}.$$

Absolute value of  $f_{\text{digitizer}}$  specified in setup file is not critical because the real frequency tracks the beam signal. The value used in the file is  $10/7 * 53.10468$  [MI frequency at 120GeV] = 75.863829. This then requires the down-convert frequency value for the 53 MHz channel to be set to 22.759149 and that for the 2.5 MHz channel to be set to 2.528794.

## ***Narrowband Filter Parameters***

The narrowband channels are configured with a decimation of 1536 in the CIC and 2 in each of the CFIR and PFIR sections. With a digitizer frequency ~75.86 MHz (it tracks at 10/7 time MRF), this gives a sampling interval of ~20.2 microseconds in the CFIR, ~40.5  $\mu$ s in the PFIR and ~81.0  $\mu$ s out of the PFIR.

The narrowband channel CFIR and PFIR filters each have eleven non-zero coefficients, shown in Table 1. These are the same for the 53 and the 2.5 MHz channels. The eleven tap “window” in the PFIR corresponds to a signal integration window of 445  $\mu$ s (11 x 40.5  $\mu$ s), that is about 40 MI turns.

## ***Wideband Filter Parameters***

Both wideband channels have a CIC decimation of 8 and CFIR and PFIR decimations of 2 each. With a 75.86 MHz digitizer frequency, the sampling interval is ~106 nanoseconds in the CFIR, ~211 ns in the PFIR and ~422 ns out of the PFIR.

The 53 MHz wideband channel CFIR has just two non-zero coefficients and the PFIR has four as shown in Table 2. The four tap “window” in the PFIR corresponds to a signal integration window of 844 ns (4 x 211 ns), about ½ of one Booster batch. This window is a compromise that includes signal from much of one batch while providing good isolation from adjacent bunches.

The 2.5 MHz wideband channel CFIR also has two non-zero coefficients, but the PFIR has eight as shown in Table 3. The eight tap “window” in the PFIR corresponds to a signal integration window of 1687 ns (8 x 211 ns). This window is sufficient to include signal from all four sequential 2.5 MHz bunches, typical of the beam for which this channel is used.

TOTAL_CFIR_COEFF= 11	TOTAL_PFIR_COEFF= 32
470	6000
1230	6000
2590	6000
4390	6000
6040	6000
8180	6000
6040	6000
4390	6000
2590	6000
1230	6000
470	6000

TABLE 1. Narrowband CFIR and PFIR Coefficients

TOTAL_CFIR_COEFF= 11	TOTAL_PFIR_COEFF= 32
32000	16000
32000	16000
	16000
	16000

TABLE 2. 53 MHz Wideband CFIR and PFIR Coefficients

TOTAL_CFIR_COEFF= 11	TOTAL_PFIR_COEFF= 32
32000	8000
32000	8000
	8000
	8000
	8000
	8000
	8000
	8000

TABLE 3. 2.5 MHz Wideband CFIR and PFIR Coefficients

## ***Frequency Response***

The output frequency response of the 2.5 MHz and 53 MHz narrowband channels is the same. The sampling rates, CIC decimation, and CFIR and PFIR coefficients are identical, only the down-convert frequencies differ. The 2.5 MHz and 53 MHz wideband channels differ from each other only in the number of non-zero PFIR coefficients; the bandwidth of the 53 MHz wideband channel is about twice that of the 2.5 MHz wideband channel. The frequency and step responses for the narrowband channels are shown in Figures 1-3. Those for the 53 MHz wideband channel are shown in Figures 4-6 and for the 2.5 MHz wideband channel in Figures 7-9. The 3db bandwidth of the narrowband channels is 1 KHz, the 53 MHz wideband channel about 500 KHz and the 2.5 MHz wideband channel about 250 KHz.

## ***Conclusion***

Frequency responses of the EchoTek digital filters for the Main Injector BPM configuration are shown. The narrowband (closed orbit) channels roll off to -3 dB at about 1 KHz. The response is not particularly flat up to 1 KHz and the attenuation of betatron frequency signals is not be as large as might be desired. There is flexibility in the setup to allow the possibility of fine-tuning the narrowband filter parameters with these objectives in mind. The 3 db bandwidth of the 53 MHz wideband (turn-by-turn) channel is about 500 KHz; that of the 2.5 MHz wideband channel is about 250 KHz. Operation at these bandwidths implies few non-zero filter taps, limiting the flexibility for special tailoring of the frequency response.

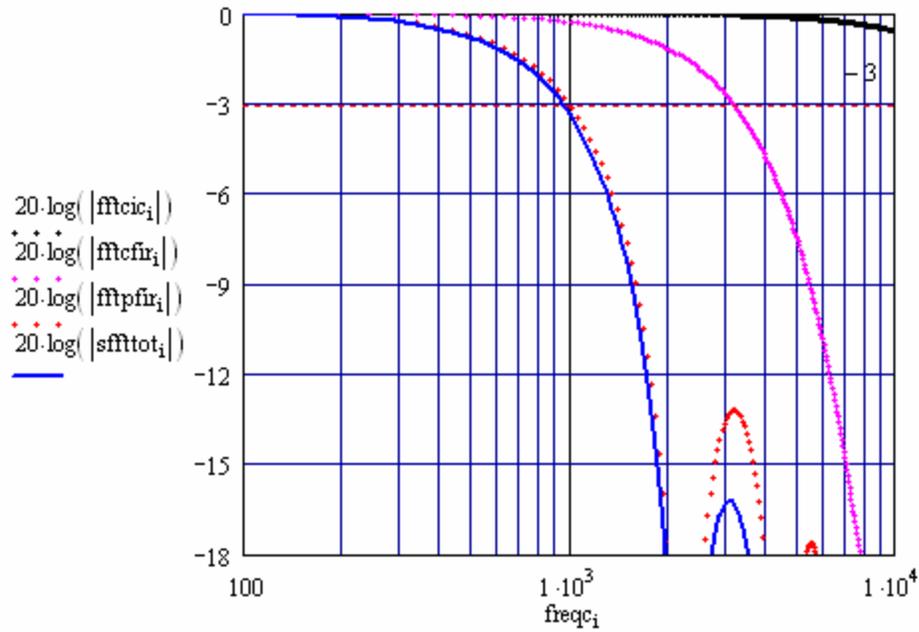


FIGURE 1. Narrowband Channels Filter Frequency Response (zoom)  
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)  
 Vertical scale dB, horizontal scale Hertz

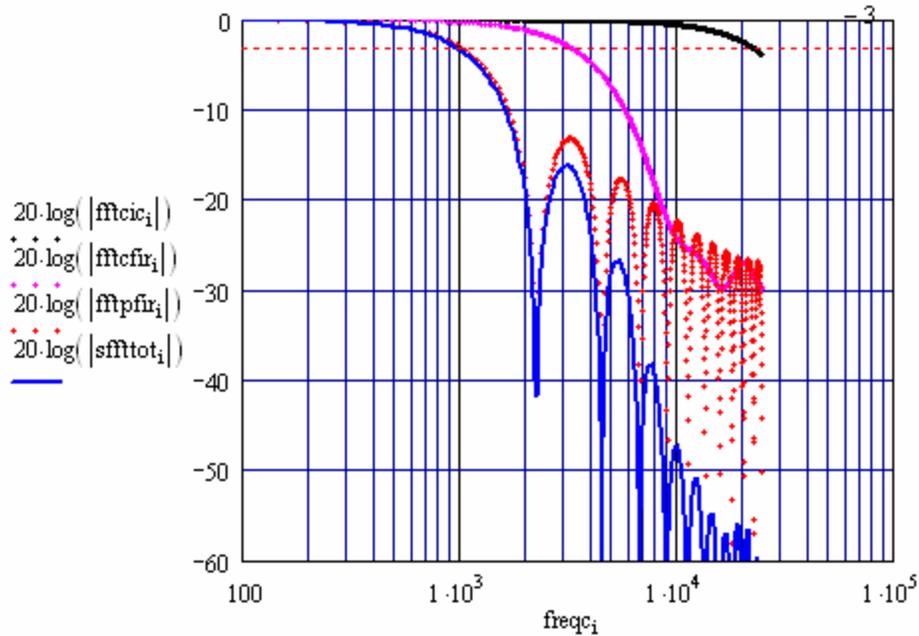


FIGURE 2. Narrowband Channels Filter Frequency Response (wide scale)  
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)  
 Vertical scale dB, horizontal scale Hertz

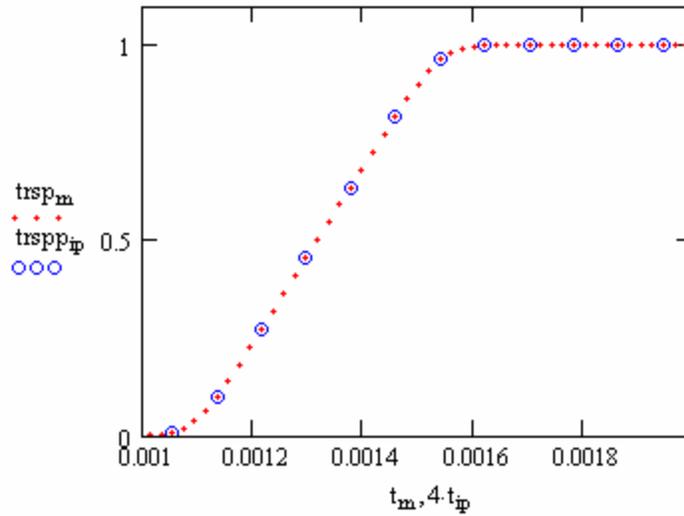


FIGURE 3. Narrowband Channels Combined Filter Step Response  
 CFIR data points (red dots) and PFIR output points (blue circles)  
 Vertical scale arbitrary, horizontal scale seconds

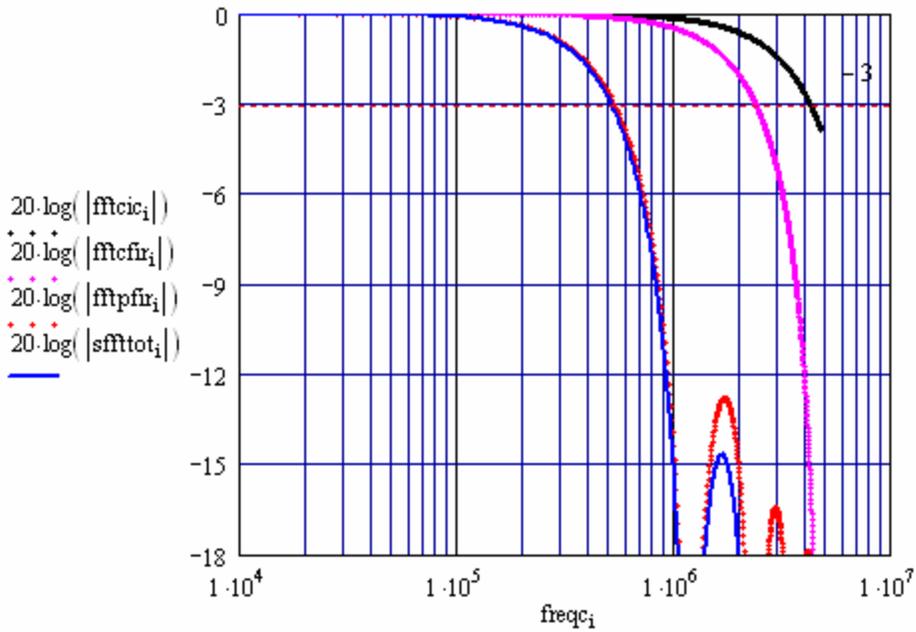


FIGURE 4. 53 MHz Wideband Channel Filter Frequency Response (zoom)  
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)  
 Vertical scale dB, horizontal scale Hertz

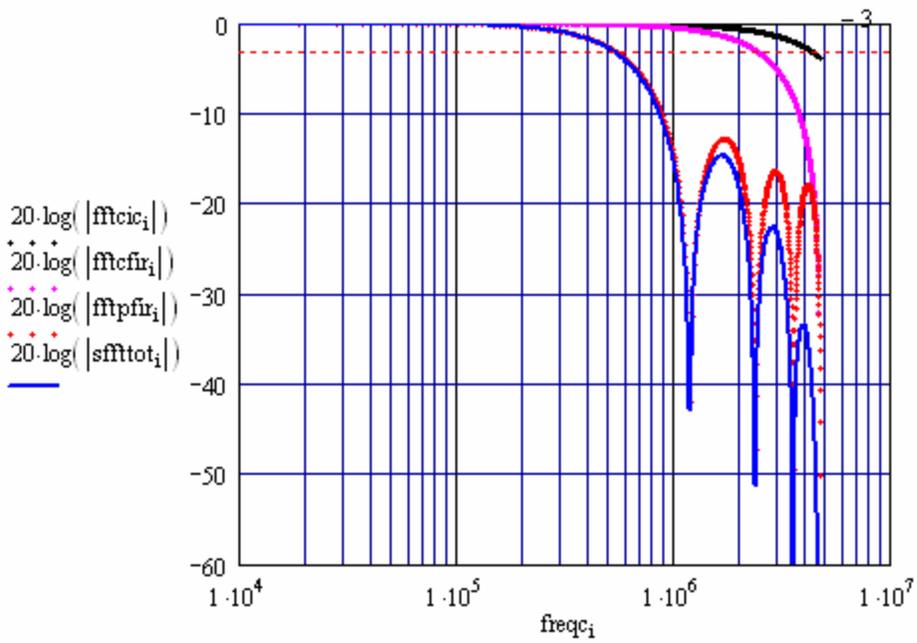


FIGURE 5. 53 MHz Wideband Channel Filter Frequency Response (wide scale)  
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)  
 Vertical scale dB, horizontal scale Hertz

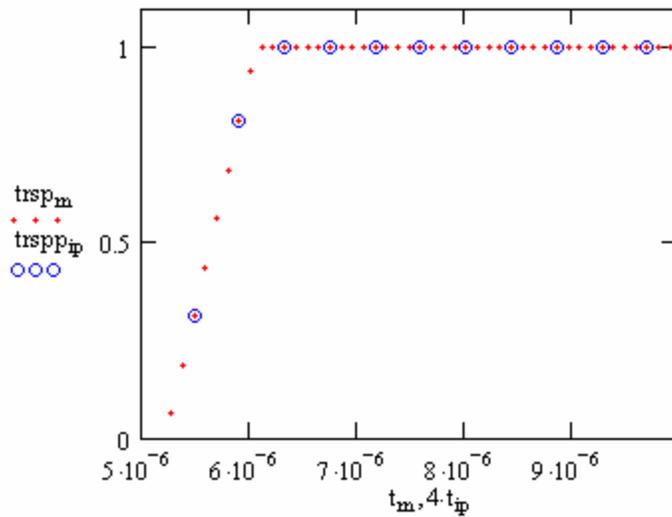


FIGURE 6. 53 MHz Wideband Channel Combined Filter Step Response  
 CFIR data points (red dots) and PFIR output points (blue circles)  
 Vertical scale arbitrary, horizontal scale seconds

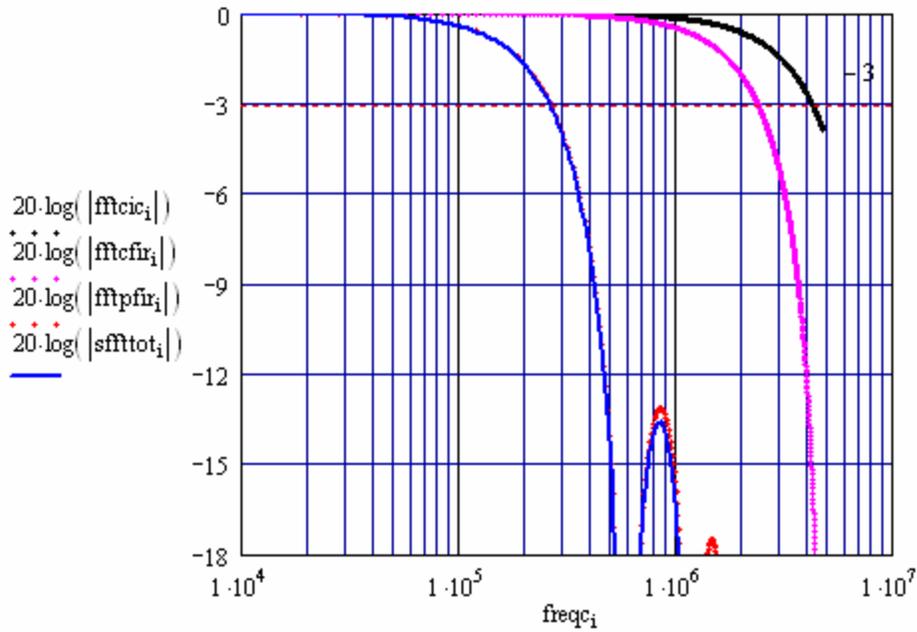


FIGURE 7. 2.5 MHz Wideband Channel Filter Frequency Response (zoom)  
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)  
 Vertical scale dB, horizontal scale Hertz

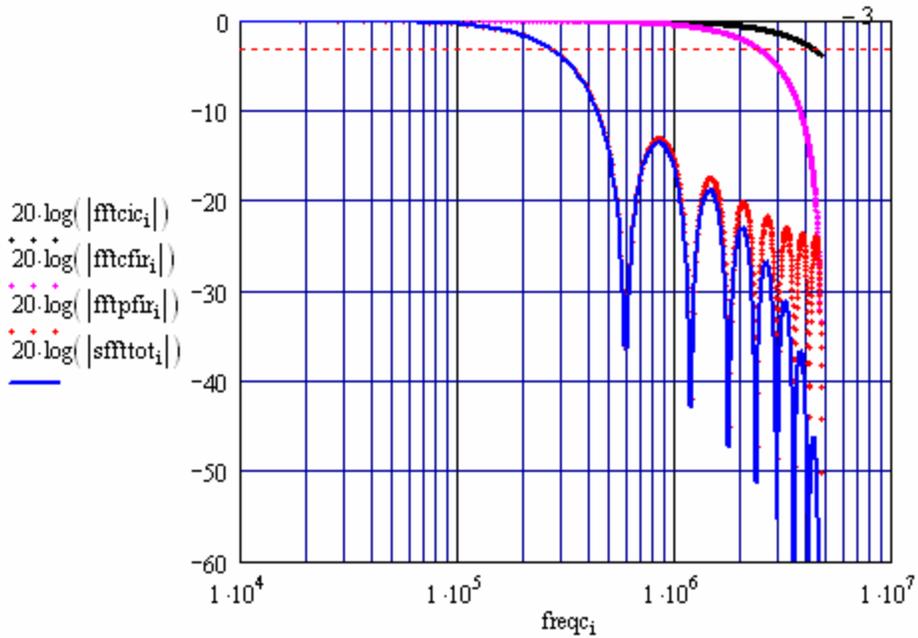


FIGURE 8. 2.5 MHz Wideband Channel Filter Frequency Response (wide scale)  
 CIC (black), CFIR (magenta), PFIR (red), Combined (blue)  
 Vertical scale dB, horizontal scale Hertz

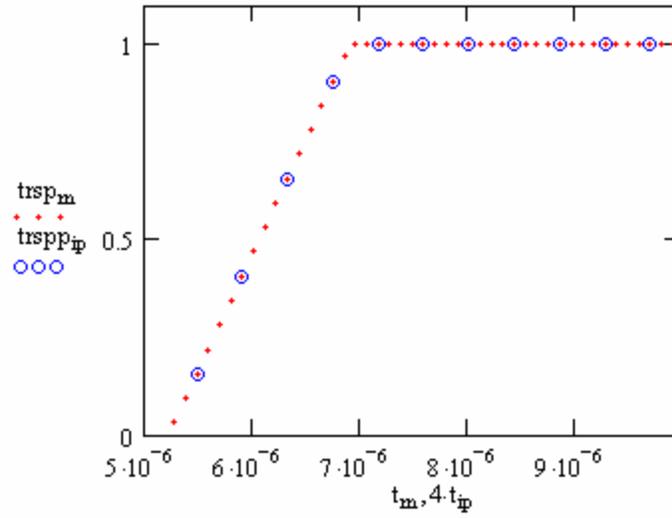


FIGURE 9. 2.5 MHz Wideband Channel Combined Filter Step Response  
 CFIR data points (red dots) and PFIR output points (blue circles)  
 Vertical scale arbitrary, horizontal scale seconds