ANALYSIS OF CASCADED FILTERS WITH DECIMATION

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Digital filters create essential part of most digital signal processing systems. In many applications, cascade of decimation filters appears. We present system for analysis of cascaded decimating filters in MATLAB.

1. Introduction

In many applications (such as digital radio receivers), cascade of decimation filters appears (see Figure 1 for an example). To reduce hardware requirements, filter with only few coefficients or a cascaded integrator-comb (CIC) filter is used on the top position, working on the highest sampling frequency ([1], [2]). Lower sampling frequency achieved by decimation allows utilising of more complex filters on lower positions of cascade, resulting in required total frequency characteristic.

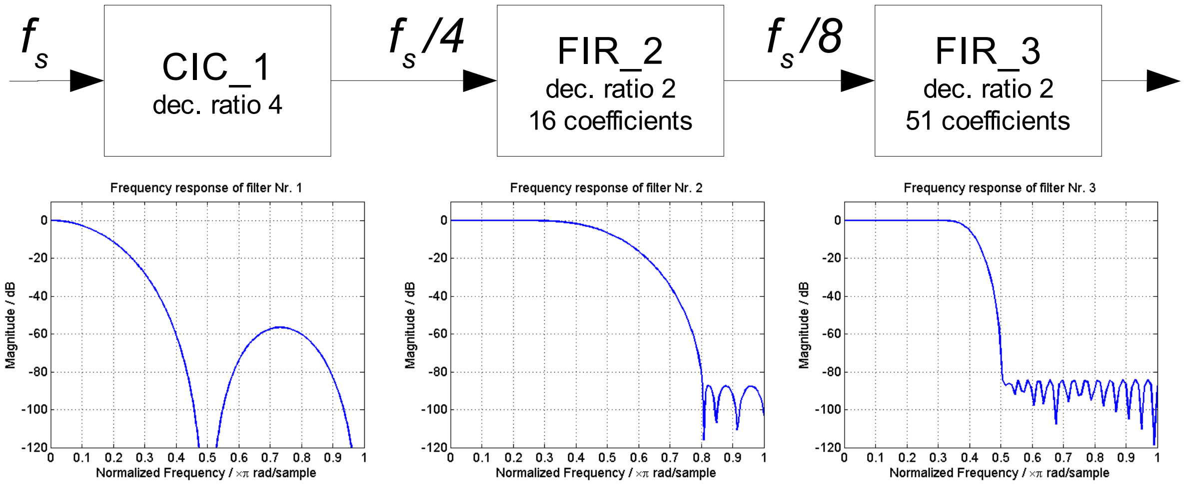

Figure 1: Example of cascaded decimating filters

2. Decimation, aliasing and frequency characteristics

During decimation, low-frequency part of spectrum is mixed with other parts of spectrum. If there is insufficient rejection of high-frequency signal components, useful signal in low-frequency range gets destroyed.

Another problem may occur in the passband range. Since the low-frequency signal has to pass through all filters, their passband ranges must have insignificant rejections, not to weaken the useful signal.

To analyse features of the cascade, first, frequency responses of several filters are computed and evaluated in dB. Then, particular frequency responses are mirrored and extended to desired range. While the first filter's characteristics stays intact, frequency response of the second filter is repeated according to the decimation ratio of the first one, thus being projected into the original frequency range. Similarly, frequency responses of next stages are repeated according to resulting decimation ratio of all preceding stages, as seen in Figure 2. Total frequency response is computed by simple addition of particular characteristics.

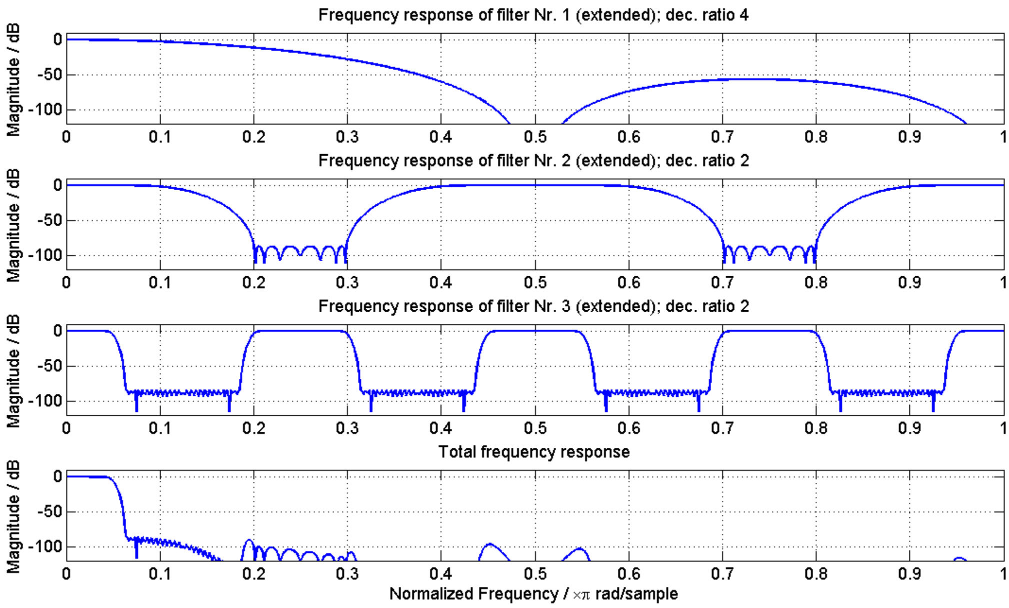

Figure 2: Extended frequency responses of filters from Figure 1

3. Analysis in MATLAB

Computing gets started by calling filter_casc function. Syntax is as follows:

```
freq_resp = filter_casc(filter_spec)
```

or

```
freq_resp = filter_casc(filter_spec, pts) ,
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where filter_spec is a cell containing specification of filters (see Figure 3), pts is desired size of elemental frequency response of the last filter (optionally) and freq_resp is output array containing frequency responses.

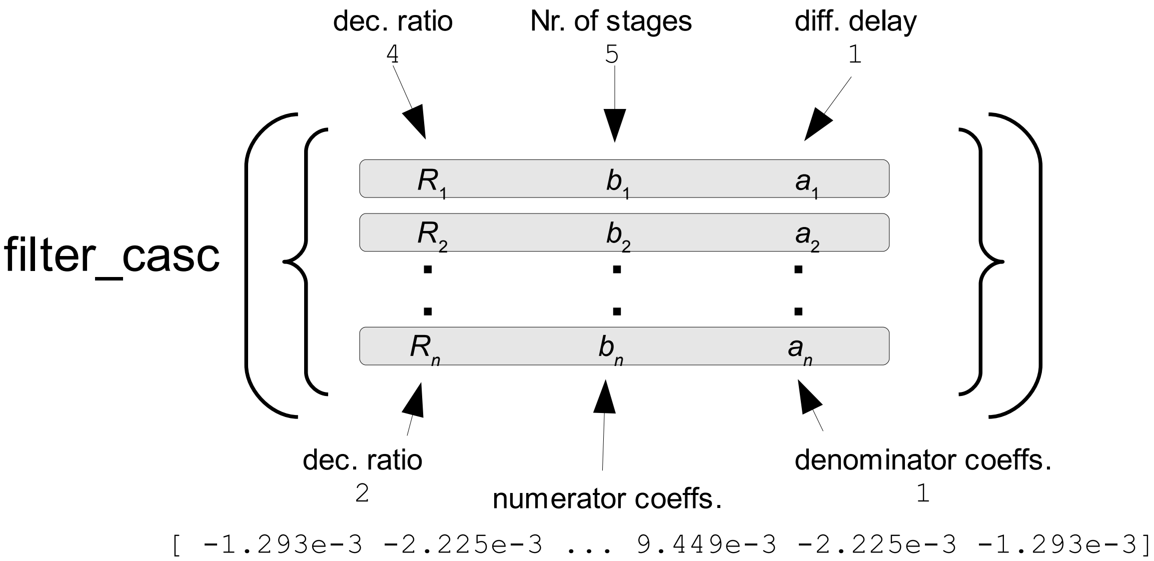

Figure 3: Structure of the input cell: every row specifies a CIC or FIR/IIR

In input cell, decimation ratio and filter coefficients (or parameters of the CIC filter) for every stage of cascade are entered, as shown in Figure 3. The total number of stages is arbitrary. Note that filter_spec automatically recognises CIC and FIR/IIR filter: if there are only single numbers on both positions b_n and a_n, the row is interpreted as specification of CIC filter (decimation ratio, number of stages and differential delay of CIC filter). Corresponding frequency response is computed by prepared function cic_fce. In case of vectors of numbers on positions b_n and/or a_n, the row is interpreted as a specification of FIR or IIR filter and frequency response is computed using MATLAB freqz function.

Rows of the output array comprise frequency responses of individual filters and total frequency response of filter cascade in dB (in the last row) – similarly as shown in Figure 2.

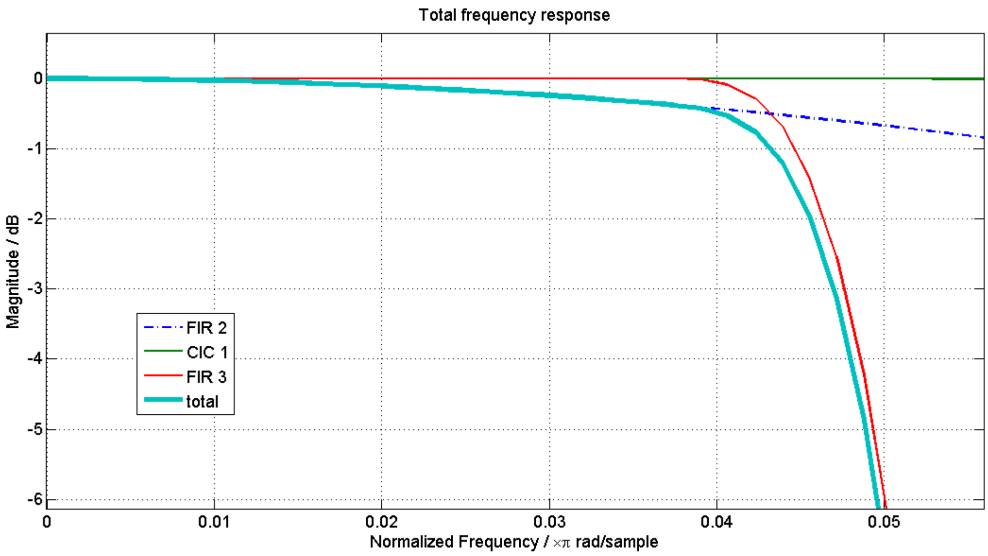

Figure 4: Particular and resulting (bold) frequency responses - detail of passband

One can easy observe rejection of frequency components that will be folded into the low-frequency part of spectrum during the decimation or details of passband range as it can be seen in Figure 4.

4. Conclusion

Presented function filter_casc allows easy analysis of cascaded filters with decimation. Together with the cic_fce function, it is also possible to analyze structures containing CIC filters.

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References

[1] Eugene B. Hogenauer, *An Economical Class of Digital Filters for Decimation and Interpolation*, IEEE,Transactions on Acoustics, Speech, and Signal Processing, Vol. ASSP-29, No. 2, 1981.

[2] *CIC Compiler v1.2, Product Specification*, Xilinx, 2008, [online], <http://www.xilinx.com/support/documentation/ip_documentation/cic_compiler_ds613.pdf>

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