Error filtering and the drive beam accelerating structure length

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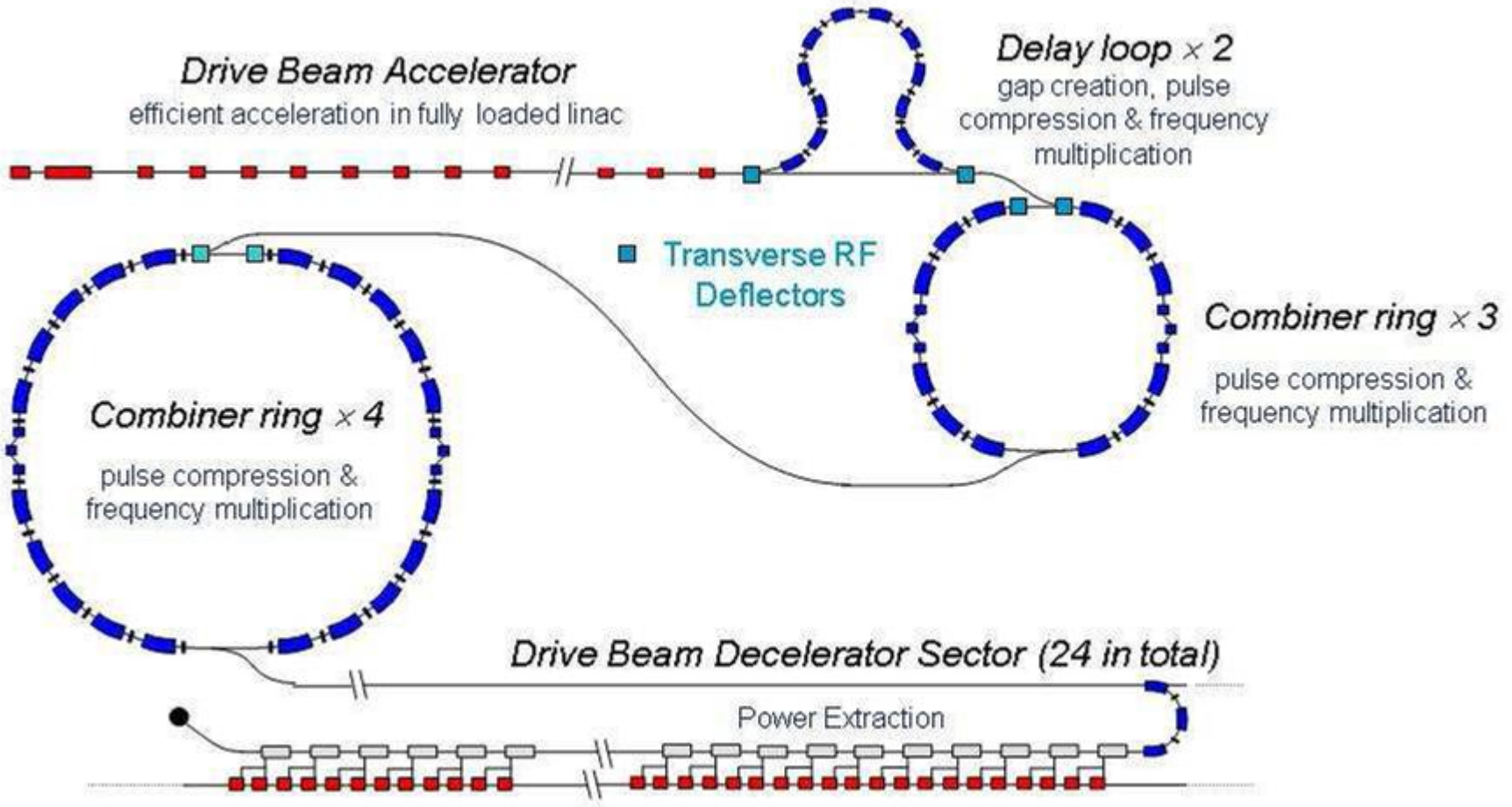
- Baseline structure length considerations
- Error filtering by realistic structure
- Dependency of error filtering on the structure length

Drive beam layout

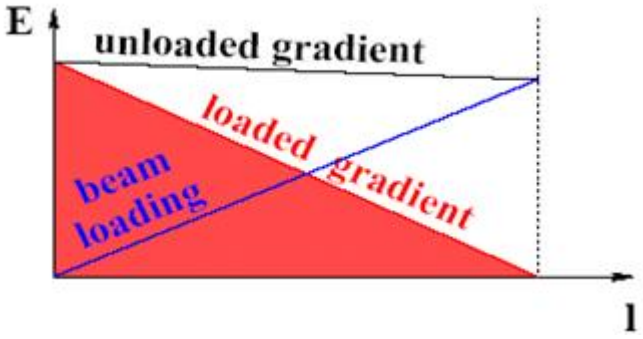


Beam loading and RF filling

Beam error function is folded with two functions of the accelerating structure:

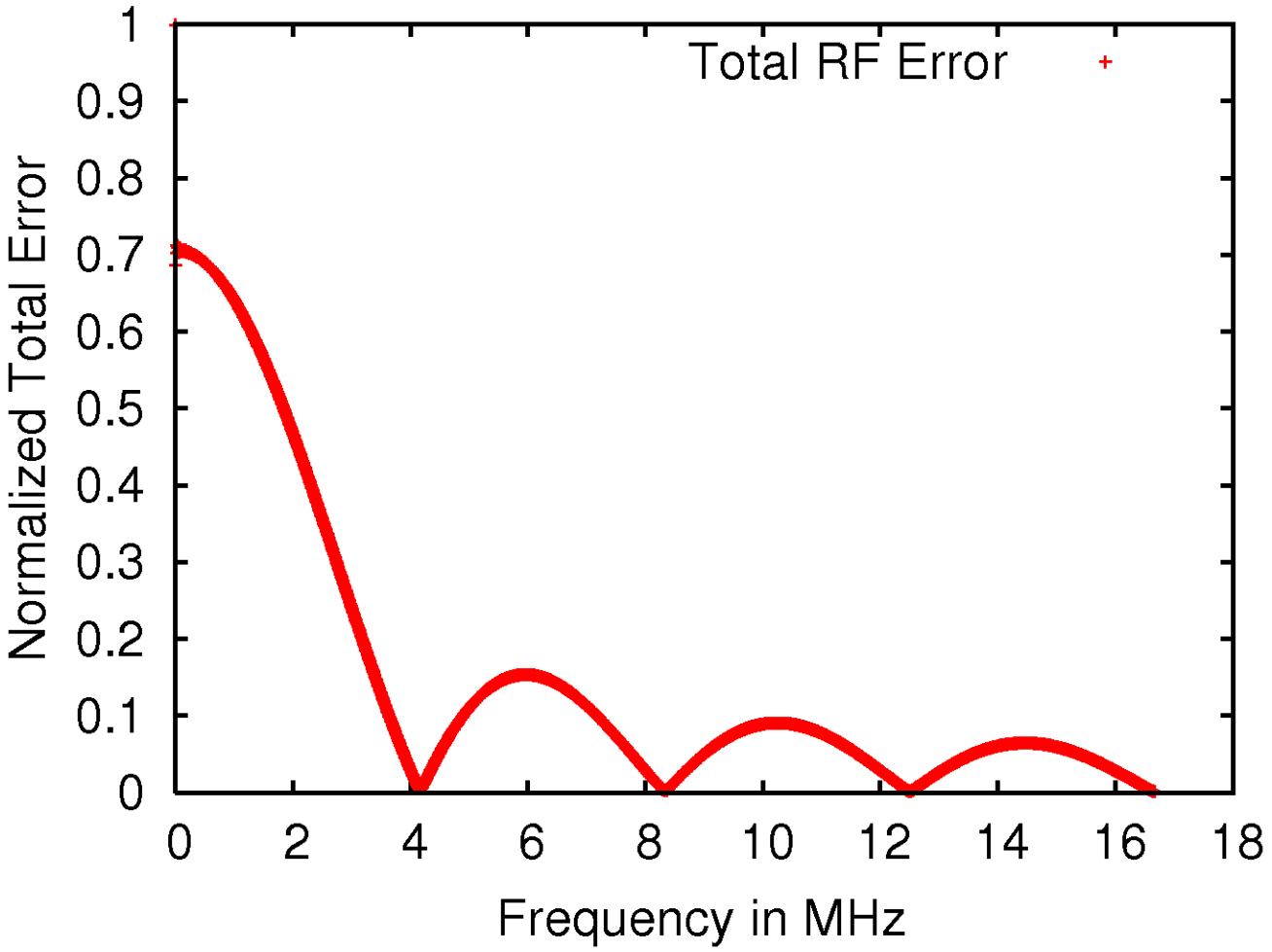
1. RF filling – response of the RF structure to the incoming RF wave pulse
   (ideally rectangular)

2. Beam loading – response of the RF structure on the beam bunches propagating through it
   (ideally triangular)

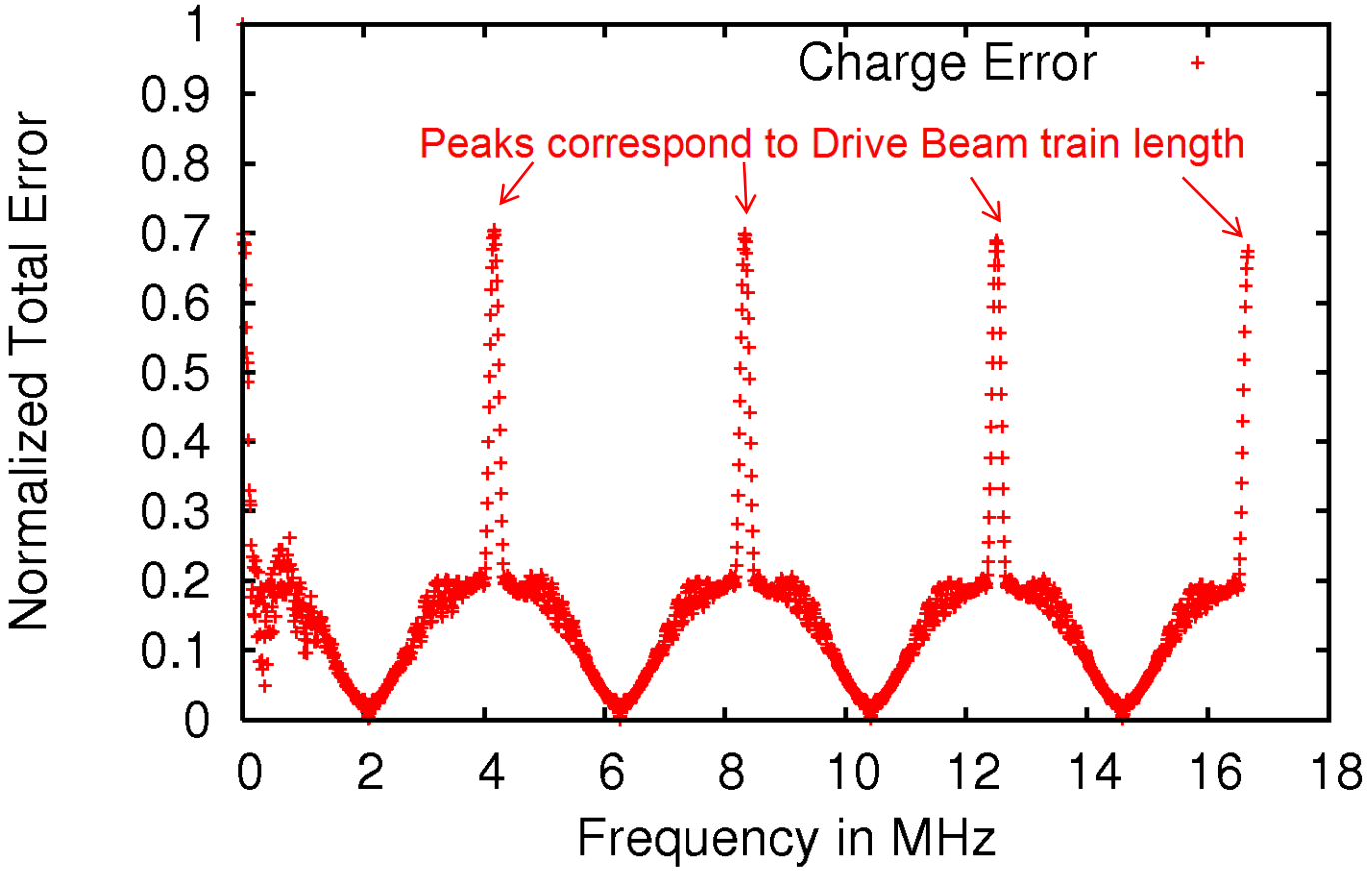


Phase error caused by errors in the RF filling

Errors with wavelength equal to the RF structure length are filtered out



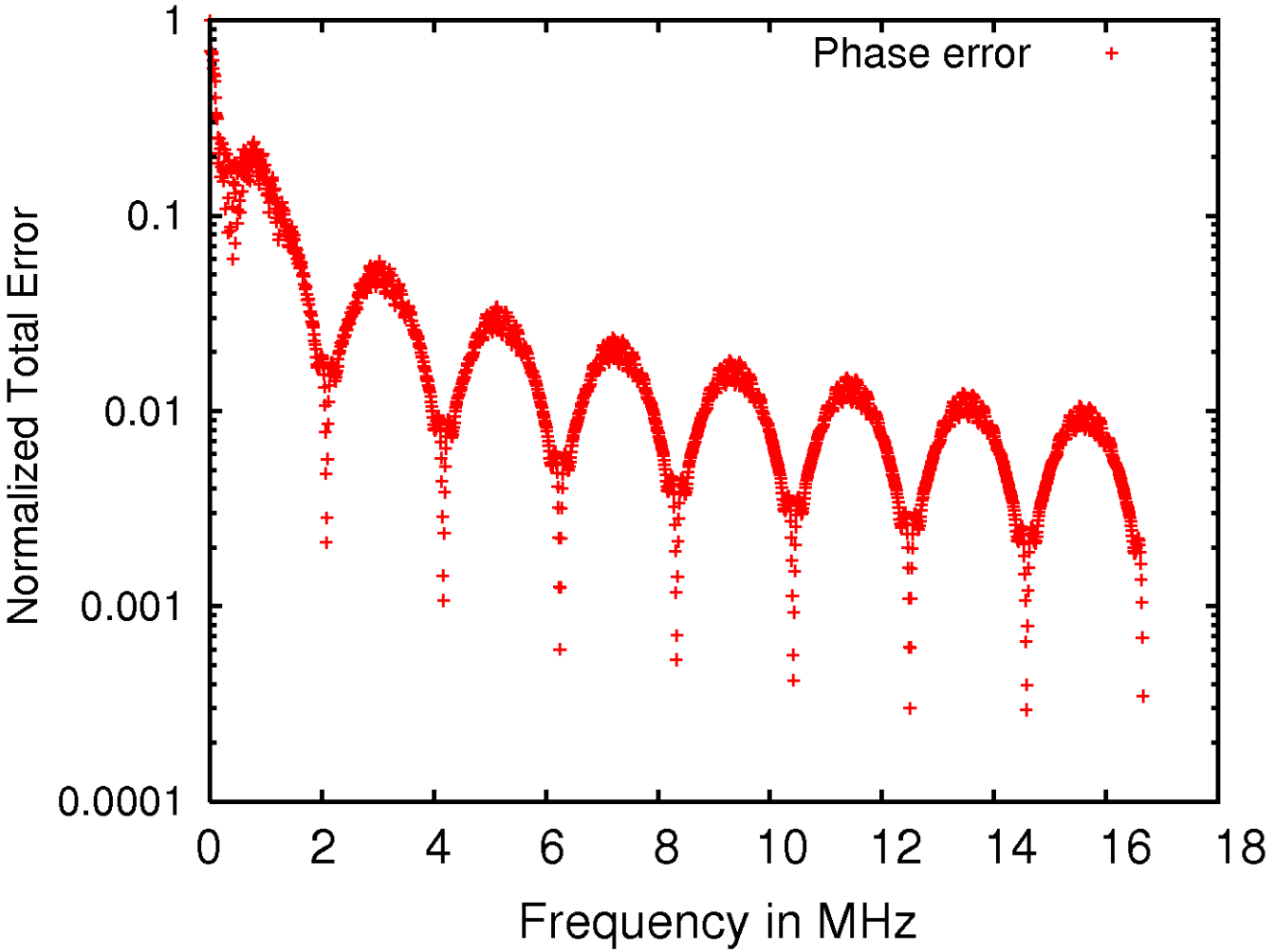
Errors of the drive beam filtered by the recombination scheme



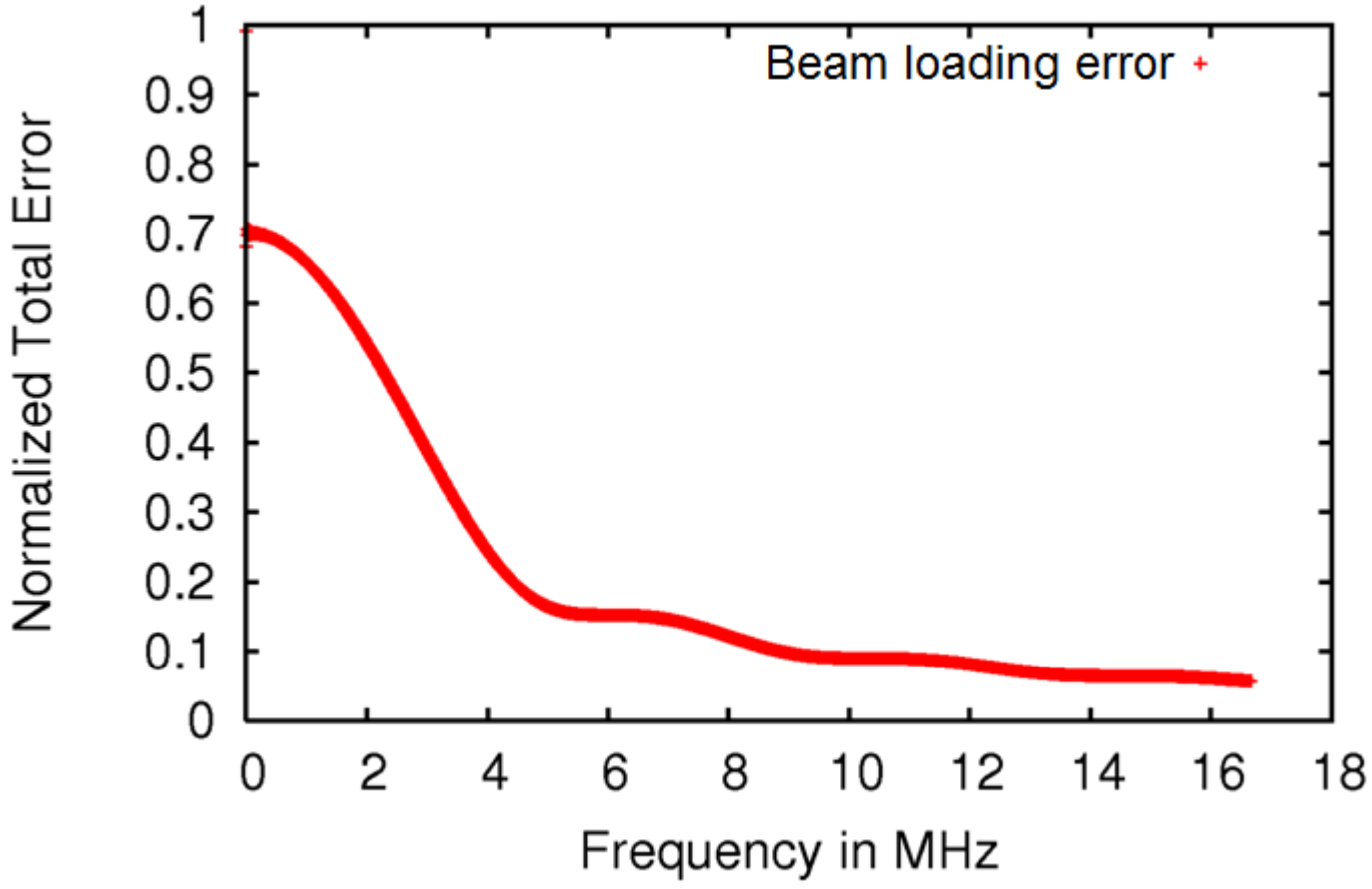
⇒ Baseline design: Set drive beam RF structure length equal to the train length (73m), so the peaks are filtered out

Total phase error caused by RF filling error

Multiplying the functions shows that the peaks can be filtered out

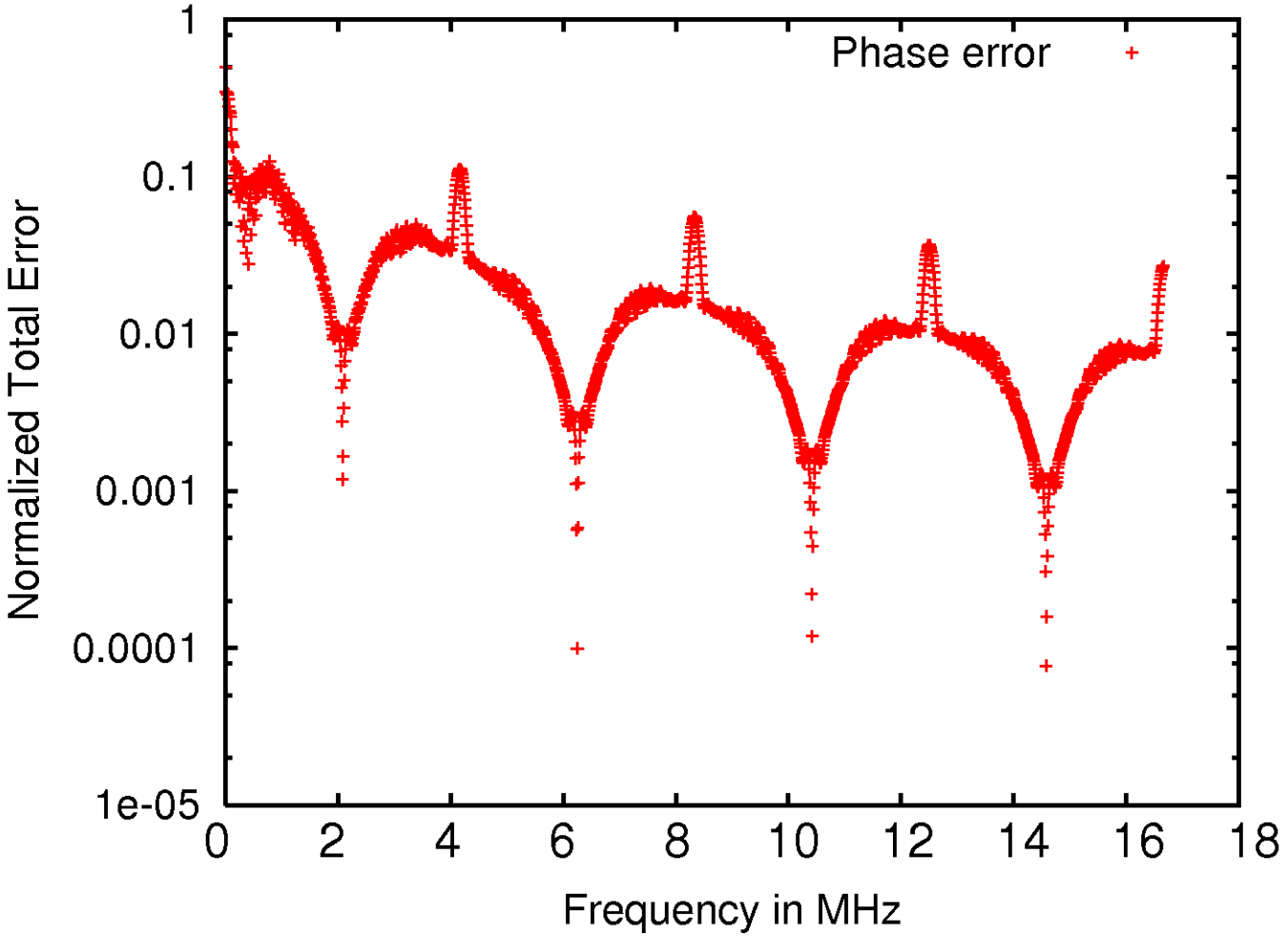


Beam loading error as a function of charge error frequency



Total phase error caused by beam loading error

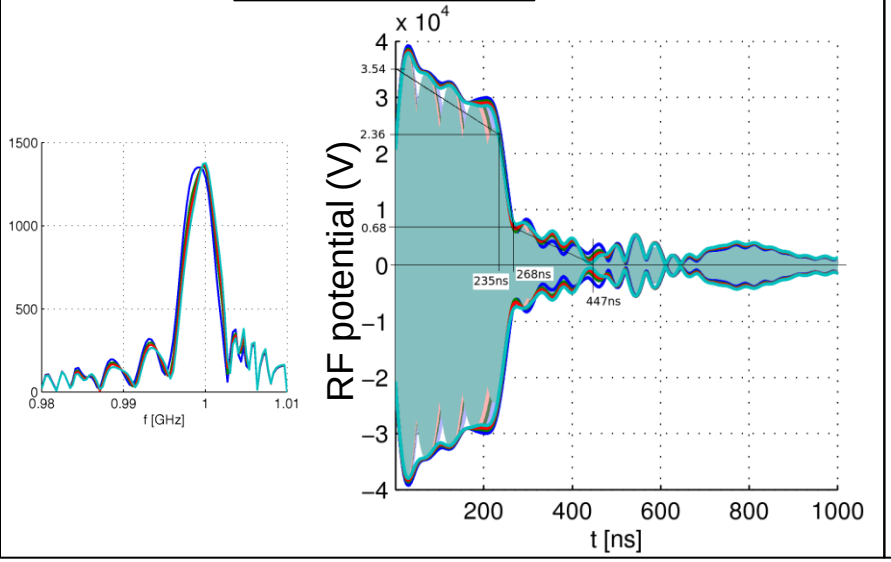
High frequencies are suppressed, peaks are not particularly filtered



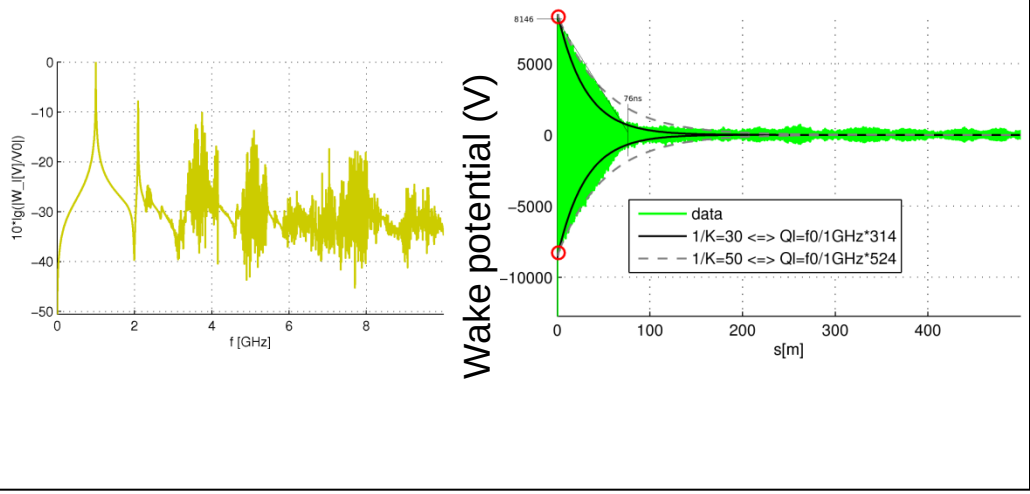
Realistic RF filling and beam loading functions

Simulation by R.Wegner

RF potential

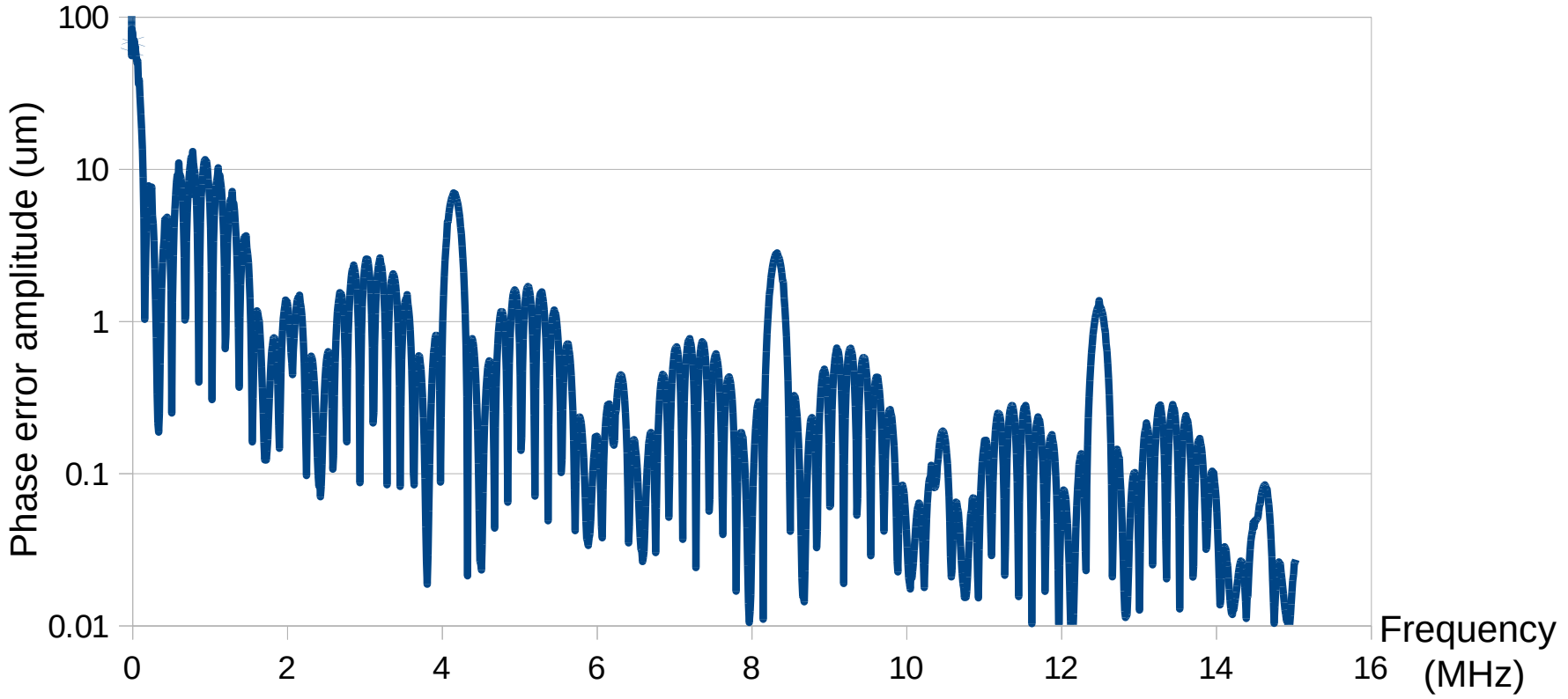


Wake potential



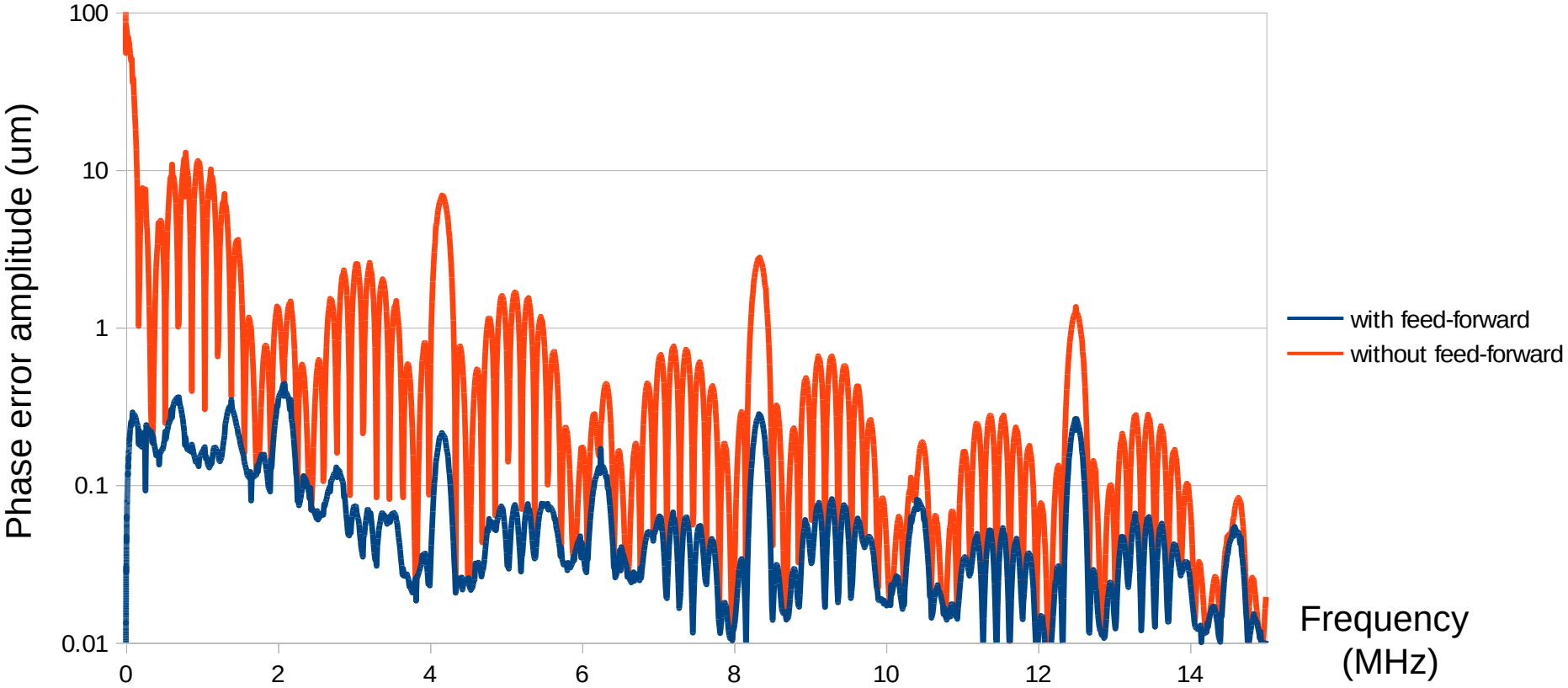
- Calculated in frequency domain, then fft to time domain
- Higher order resonances included in wake fields calculation
- 3 points per sinus wave, hence strong beating in RF potential

Result – realistic phase error caused by the RF amplitude jitter



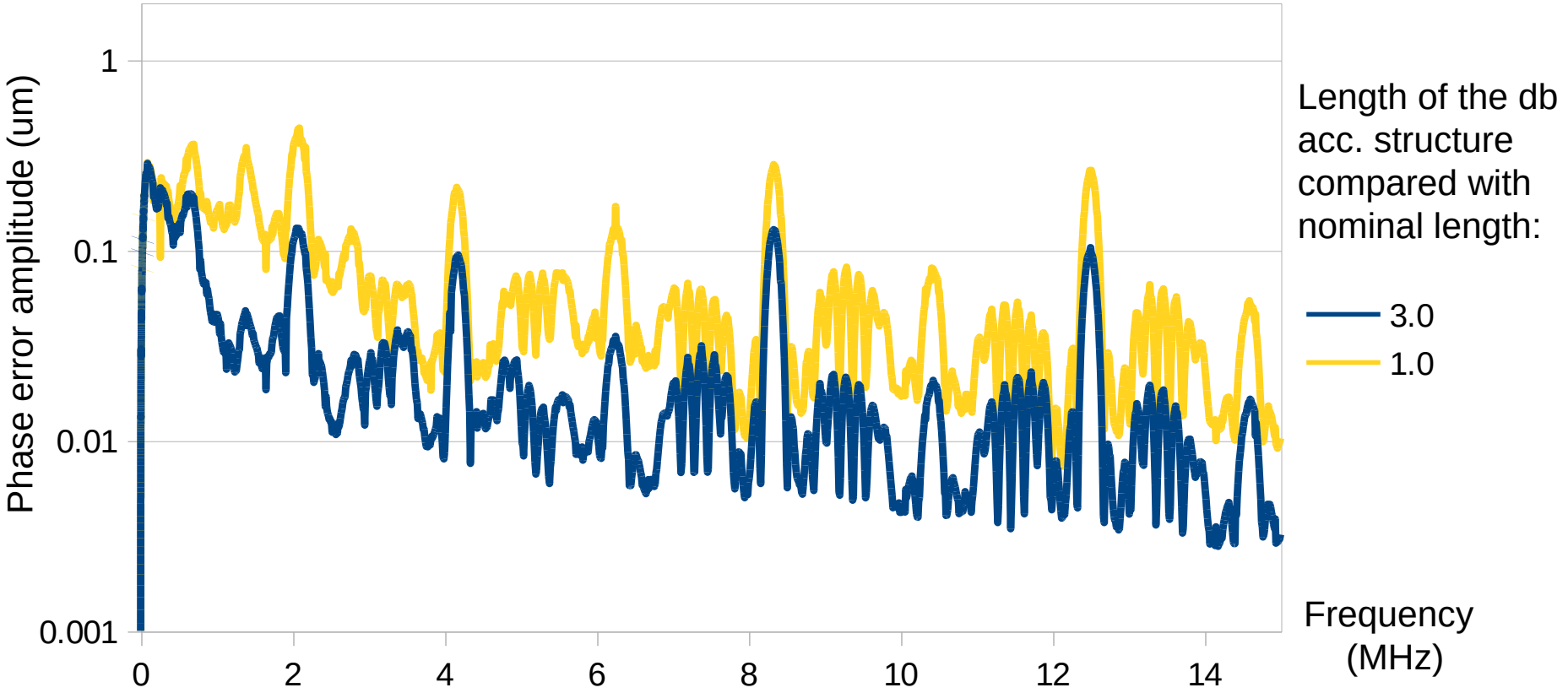
- Peaks from 73 m long trains in combination scheme are not filtered out
- Suppression of high frequencies

Phase error correction with help of the feedforward



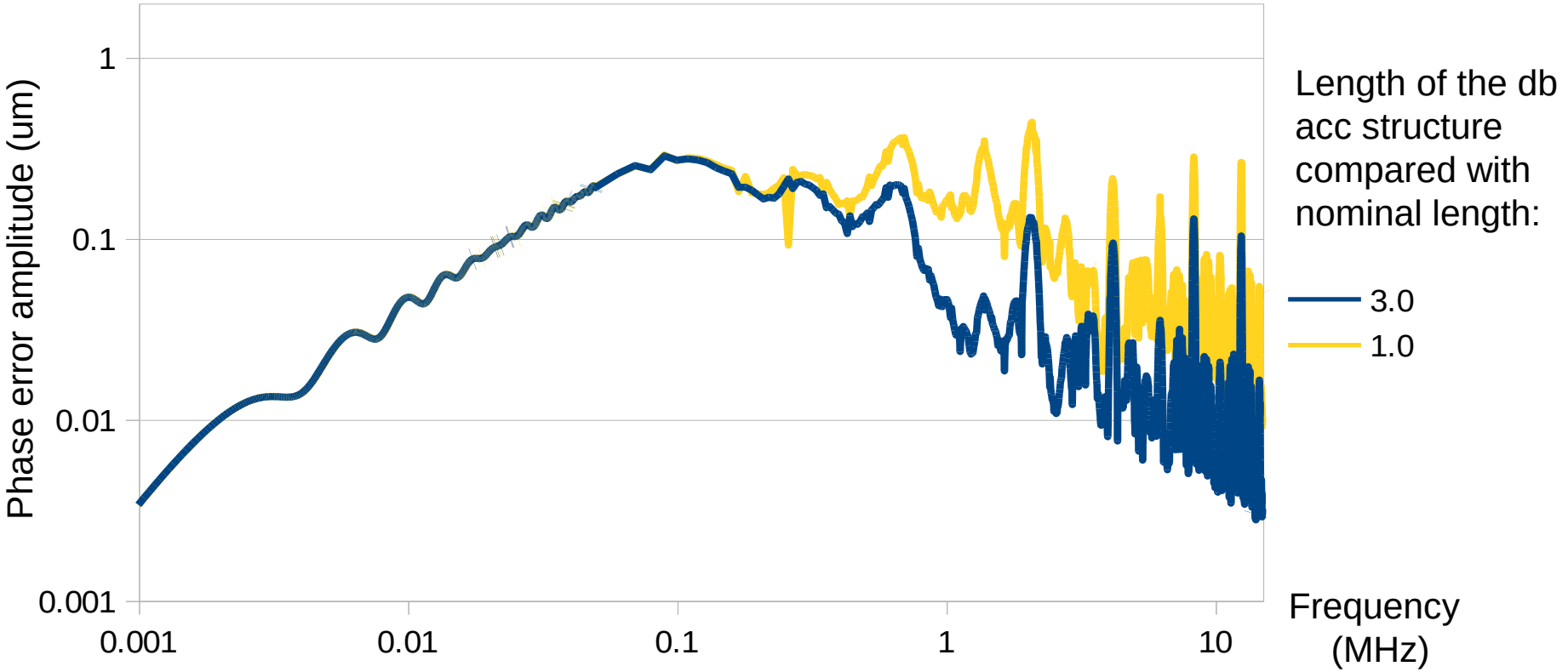
- Assume 30 nm averaging for feed-forward correction (~33MHz bandwidth)
- Feed-forward reduces low-frequency error particularly well

Modifying the length of the accelerating structure



- Longer accelerating structure means that the folding of the functions happens over a longer period of time => filtering works better
- Since the peaks are not filtered out by the structure anyway, it is a viable alternative

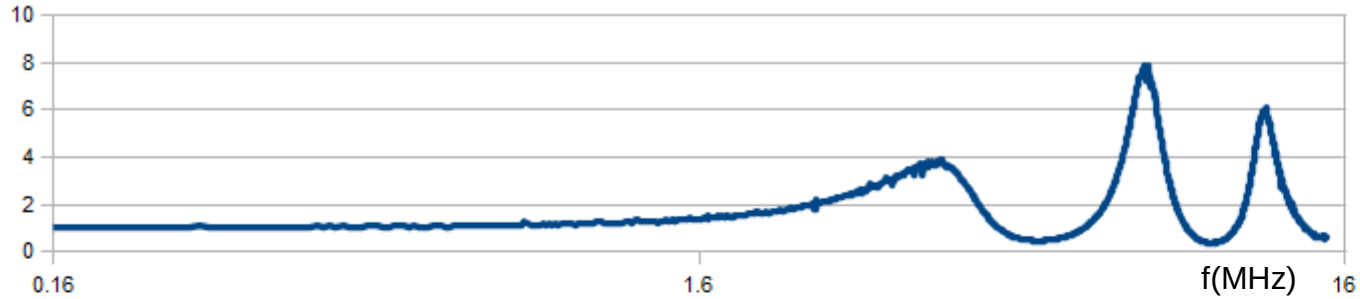
Modifying the length of the accelerating structure



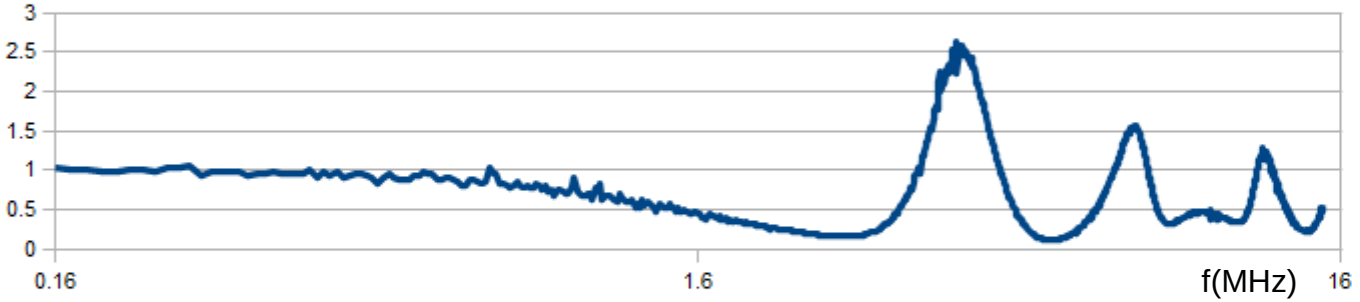
- The effect is stronger at higher error frequencies

Comparison of different structure lengths with baseline length

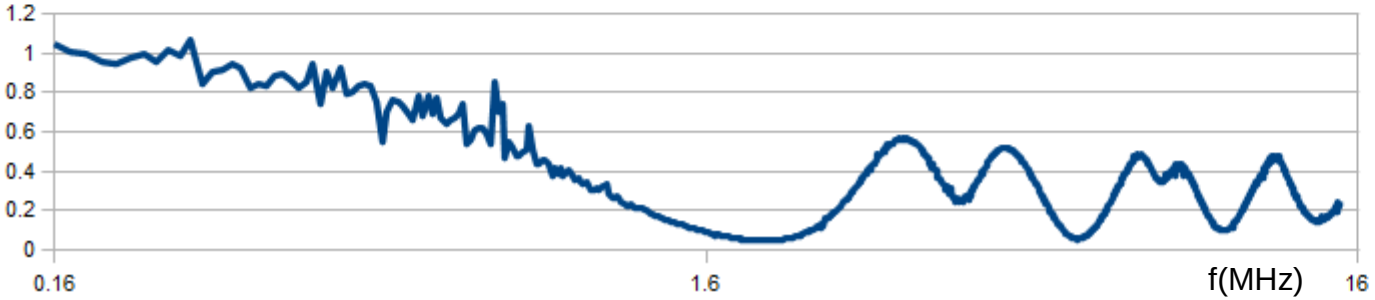
Error with
0.8 × 73 m structure length
÷
Error with nominal length



Error with
1.4 × 73 m structure length
÷
Error with nominal length

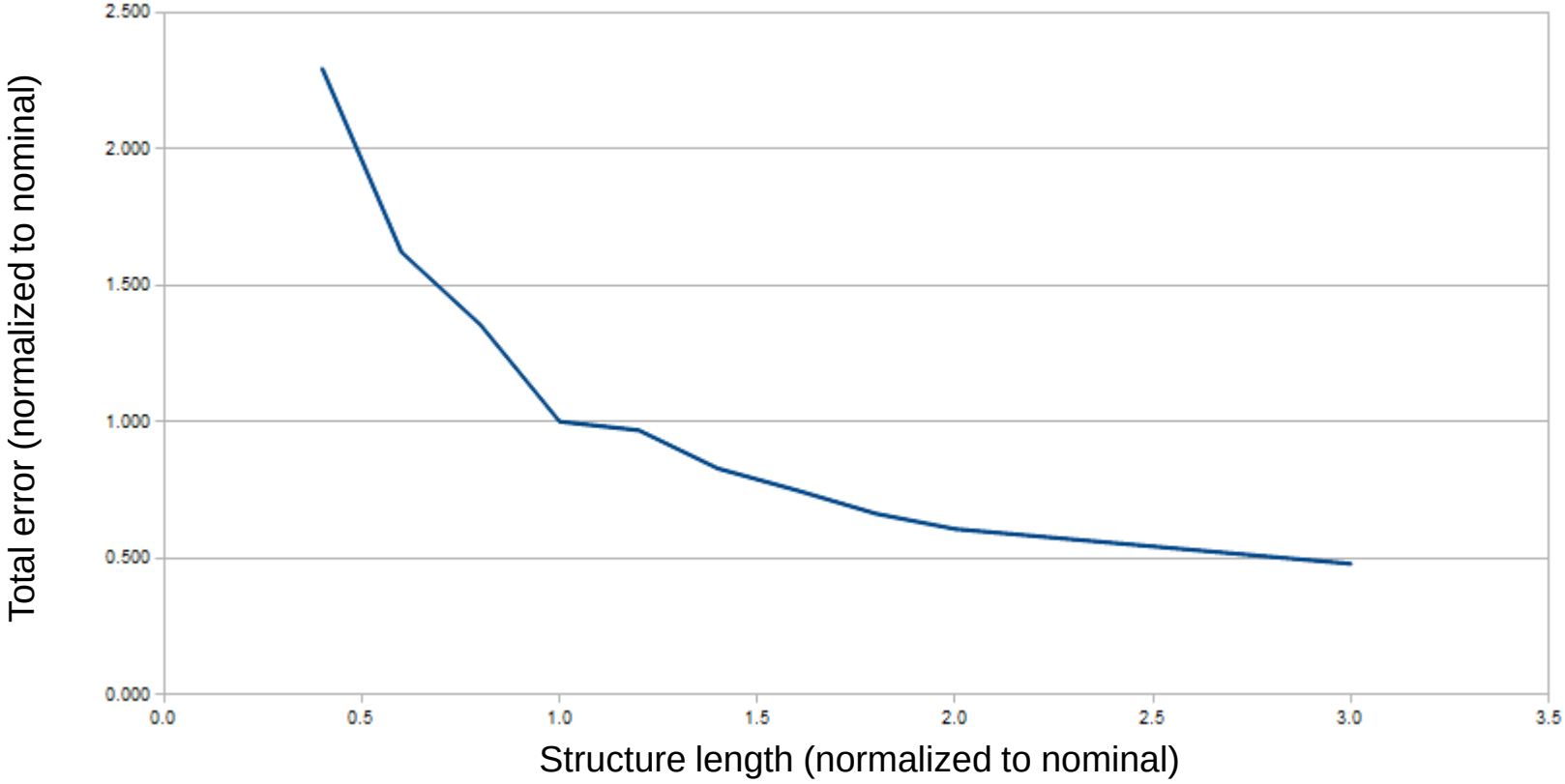


Error with
2.0 × 73 m structure length
÷
Error with nominal length



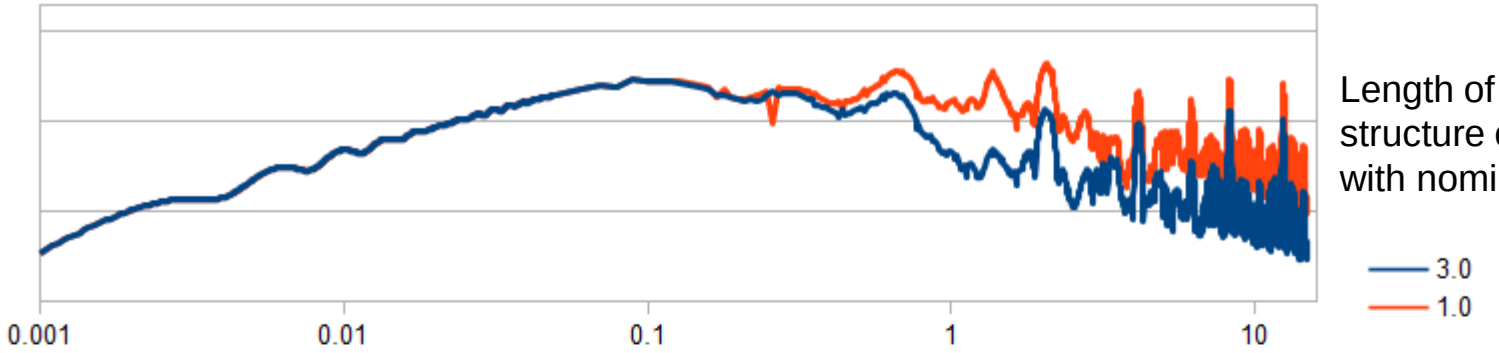
Total error as function of structure length

$$A = \sqrt{\int_{50Hz}^{15MHz} a^2(f)P(f)df}$$

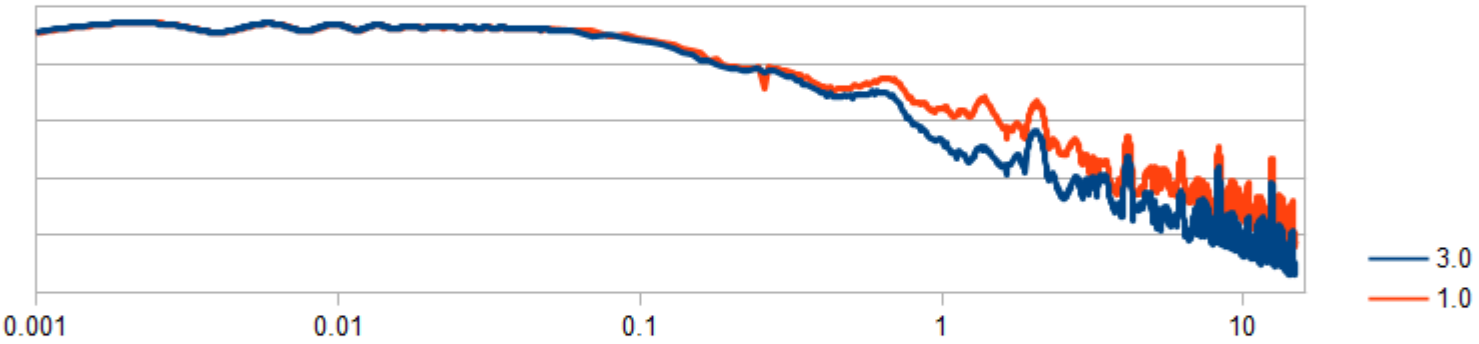


Different sorts of noise

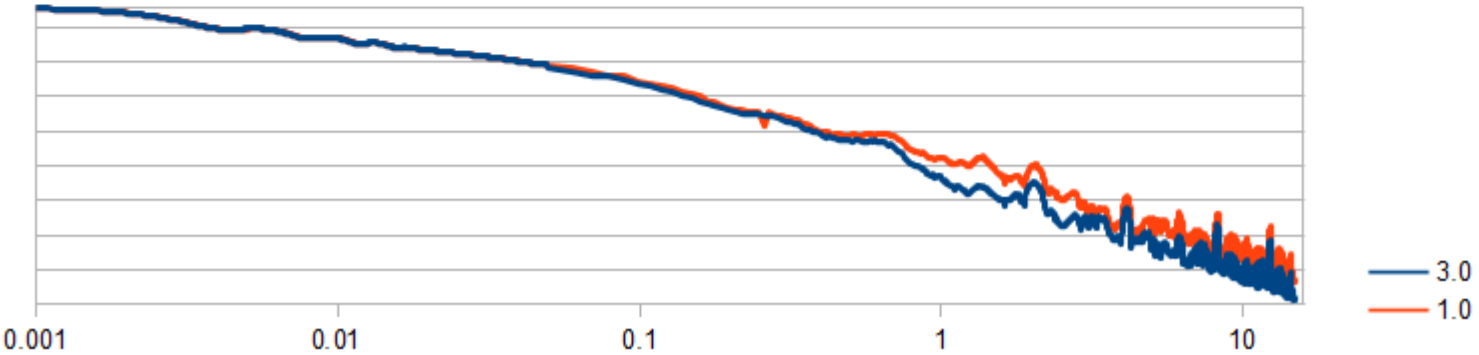
White noise (~const.)



Pink noise (~1/f)



Red noise ($1/f^2$)

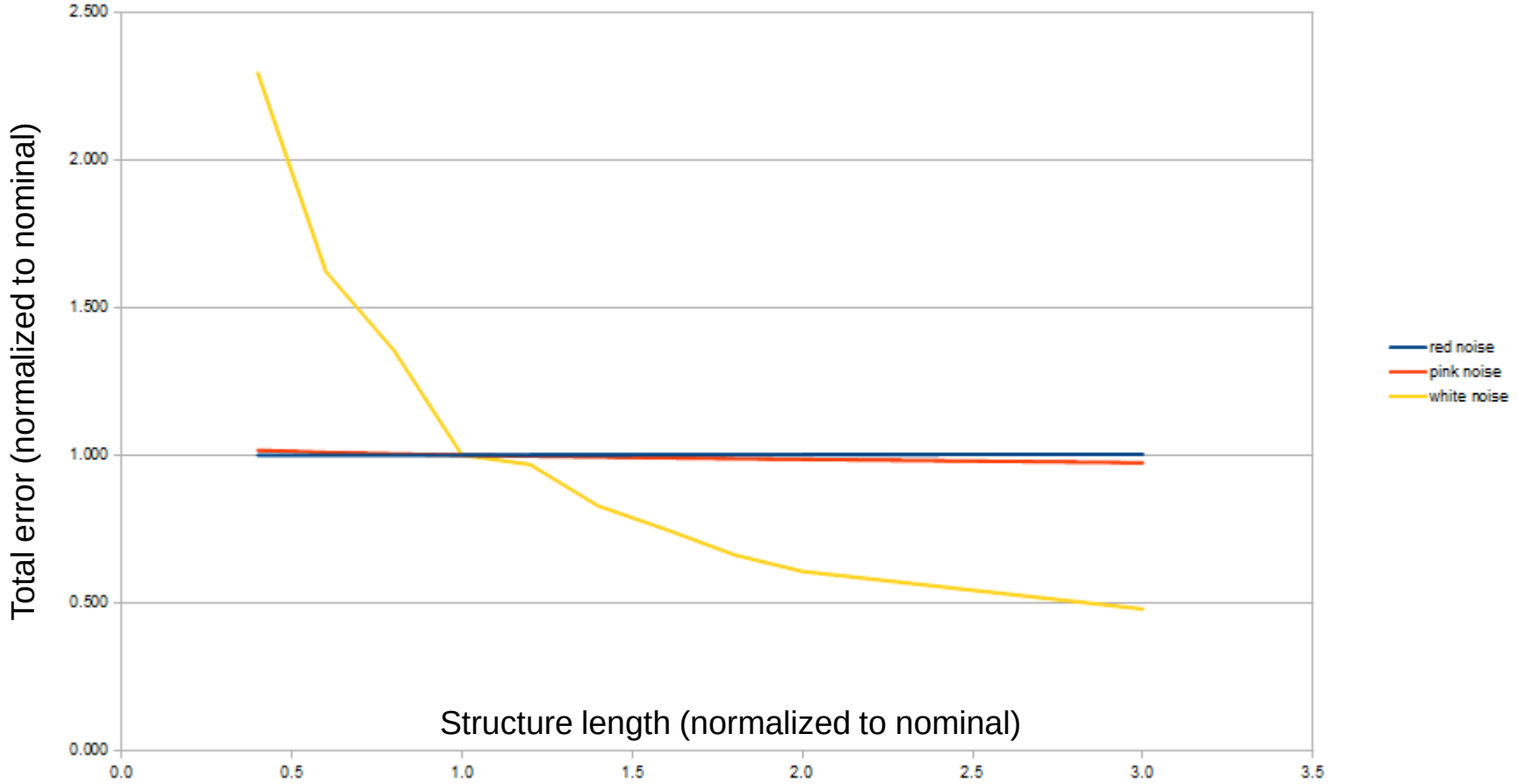


Length of the db acc structure compared with nominal length:

3.0
1.0

Total error for different sorts of noise as a function of structure length

$$A = \sqrt{\int_{50Hz}^{15MHz} a^2(f)P(f)df}$$



Conclusions

- Since the RF filling is not rectangular, precise filtering of the resonant frequency works only partially

- Longer structures filter error better, esp. high-frequency error
  - If the effect is significant depends on the error spectrum

- If longer structure is cheaper, no reason to keep the baseline design from the point of view of tolerances