IEEE802.3aq Channel model ad-hoc

Task2: TP3 - ISI Generator Block for Stressed Sensitivity Test

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Contributions and Support from:

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1. ISI Generator Block for Stressed Sensitivity Test

Goals

- different impulse response shapes will exercise actual equalizers in different ways, more than one “synthetic” stressor will likely be needed,
- we can group the modelled channel responses into groups such as precursor-heavy, quasi-symmetrical, and postcursor-heavy (can be a mirror image of precursor-heavy),
- analysis of three possible implementations (BT LPF, two peak impulse response, and three peak impulse response) as proposed in [aronson_2_0704],
- define reference fibre pulse response to be used for analysis based on available channel models (see Note),
- define optimum pulse shape to be used for two or three peak impulse response,
- find a minimum range of values for A1, A2 and Δt and A0, A1, A2, $\Delta t1$ and $\Delta t2$, respectively, that will satisfy the majority of impulse response as defined by the channel model.

Note: We have to start with a limited number of selected fibres in order to understand the feasibility of implementation and how many sets of variables have to be defined. We can decide if we want to cover all channels or limited number of significant cases, based on the complexity and importance.

2. ISI Generator Block for Stressed Sensitivity Test

Evaluation methodology

- evaluate the possibility of using a BT LPF for ISI generator block.
- select a limited number of fibres with performance at the limit allowed in the current link budget. I will use representative fibres from the 65 fibres (Cambridge model, 300m) having PIE-L values between 4 and 5 dB).
- the use of 300m models instead of 220m will give the margin for other impairments not accounted for (connectors, transmitter and receiver nonlinearities).
- use pulse shapes that can be generated in the lab with minimal new equipment.
- optimize A1, A2, and Δt (A0, A1, A2, $\Delta t1$ and $\Delta t2$) for minimum square error (MSE), with reasonable resolution (2 or 3 digits).
- the optimization will be based on minimizing the peak error (errpk) and the relative error signal area (PSR)

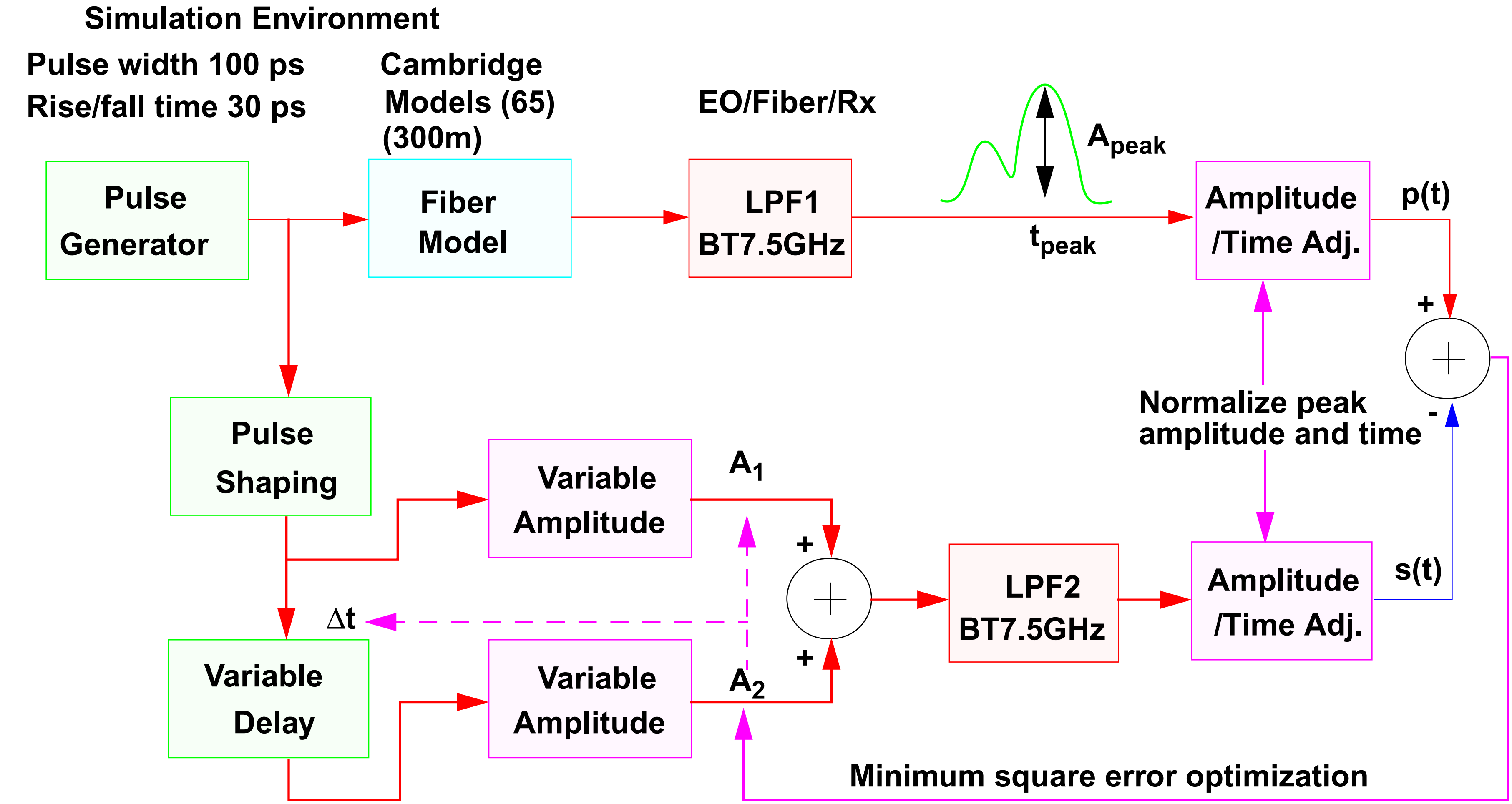
$$errpk = \frac{|p(t) - s(t)|_{pk}}{|p(t)|_{pk}}$$

, where p(t) is the fibre pulse response and s(t) is the stressor

$$PSR = 10x\log\left(\frac{\int_t |p(t)|^2 dt}{\int_t |p(t) - s(t)|^2 dt}\right)$$

- the initial resolution step for Δt is 5ps.
- for a given set of amplitudes and delay times, we can calculate the effective errpk and PSR.

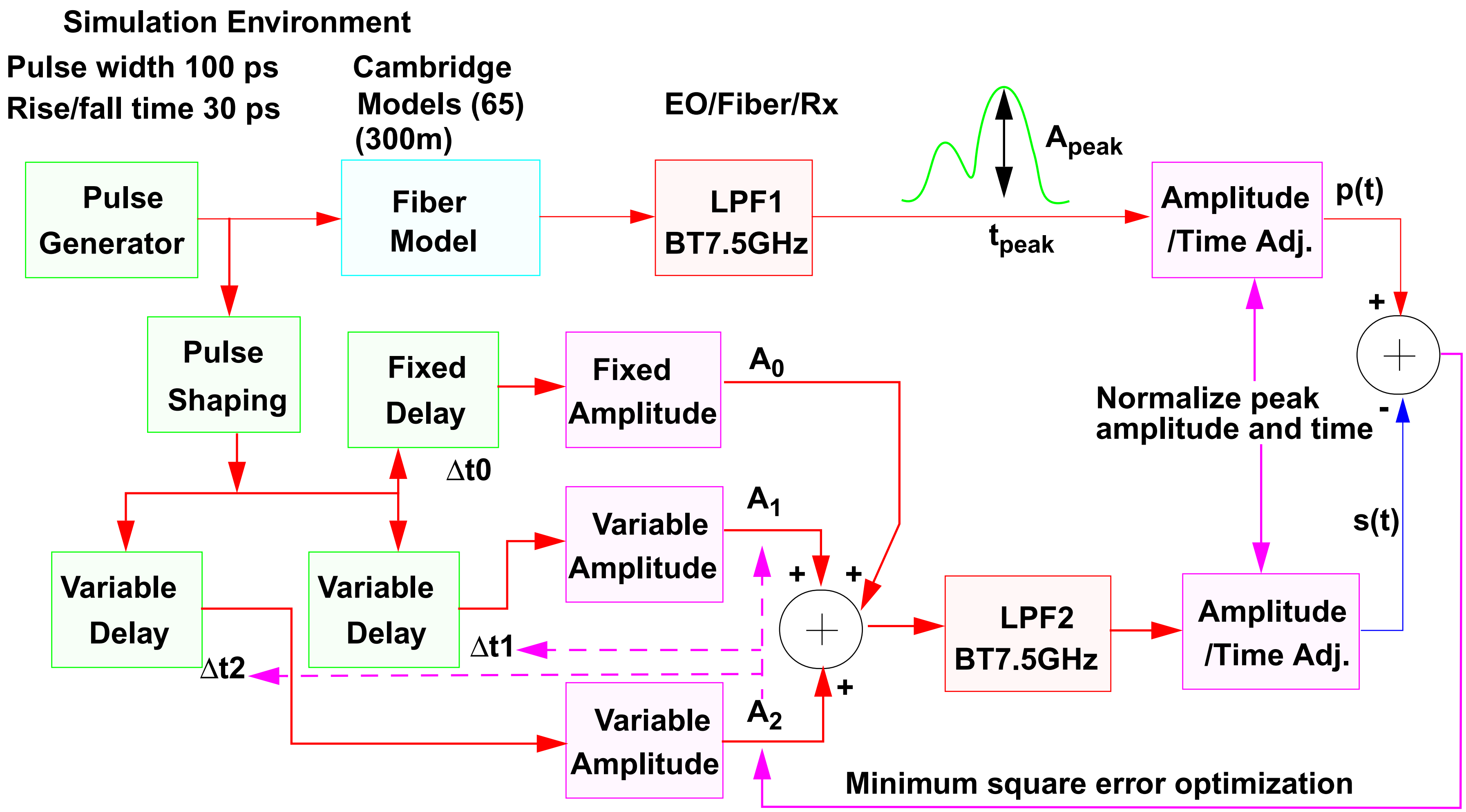
3. Two peak impulse response ISI generator block



The simulation environment for fiber path consists of the fiber model (Cambridge model), a BT LPF 7.5 GHz and a normalization block to adjust for peak amplitude value and time.

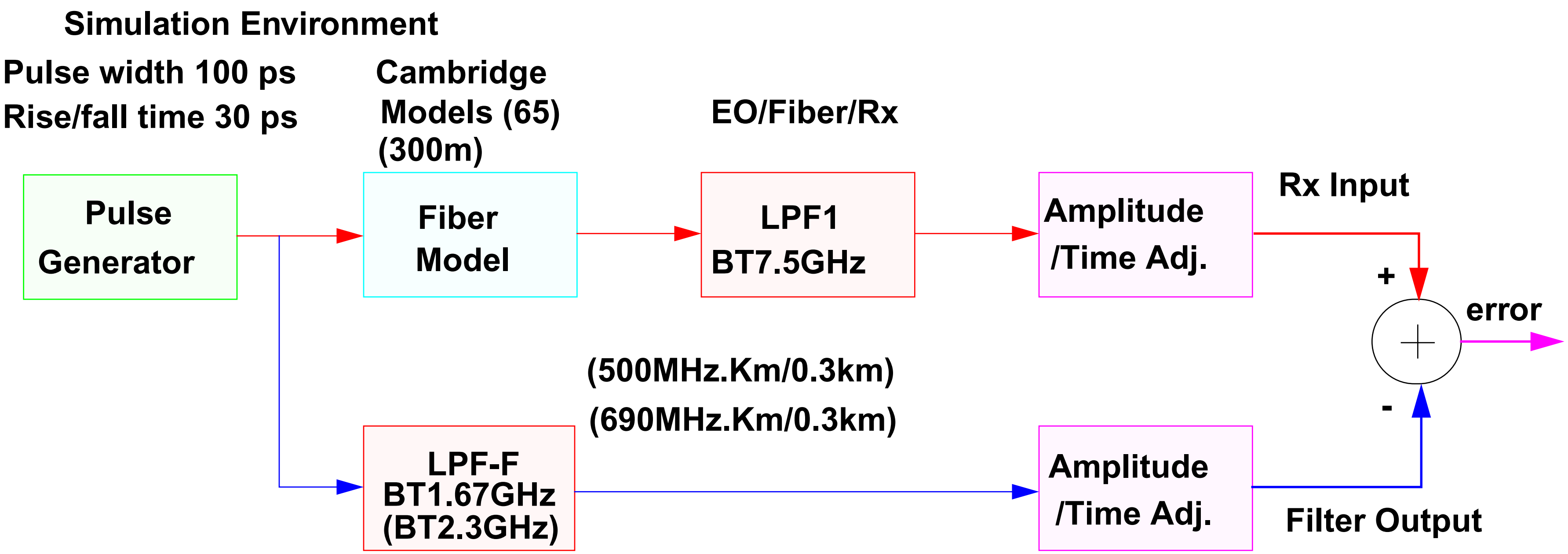
The ISI generator block path consists of a pulse shaping block, a variable delay block, two variable amplitude blocks, an adder and the same BT LPF and normalization block.

4. Three peak impulse response ISI generator block



There are three delay blocks in the simulation environment. We can adjust Δt1 and Δt2 relative to Δt0 such that the two peaks can be symmetrical relative to the main pulse A_0, or on the same side (pre-cursor or post-cursor).

5. BT Low Pass Filter Option



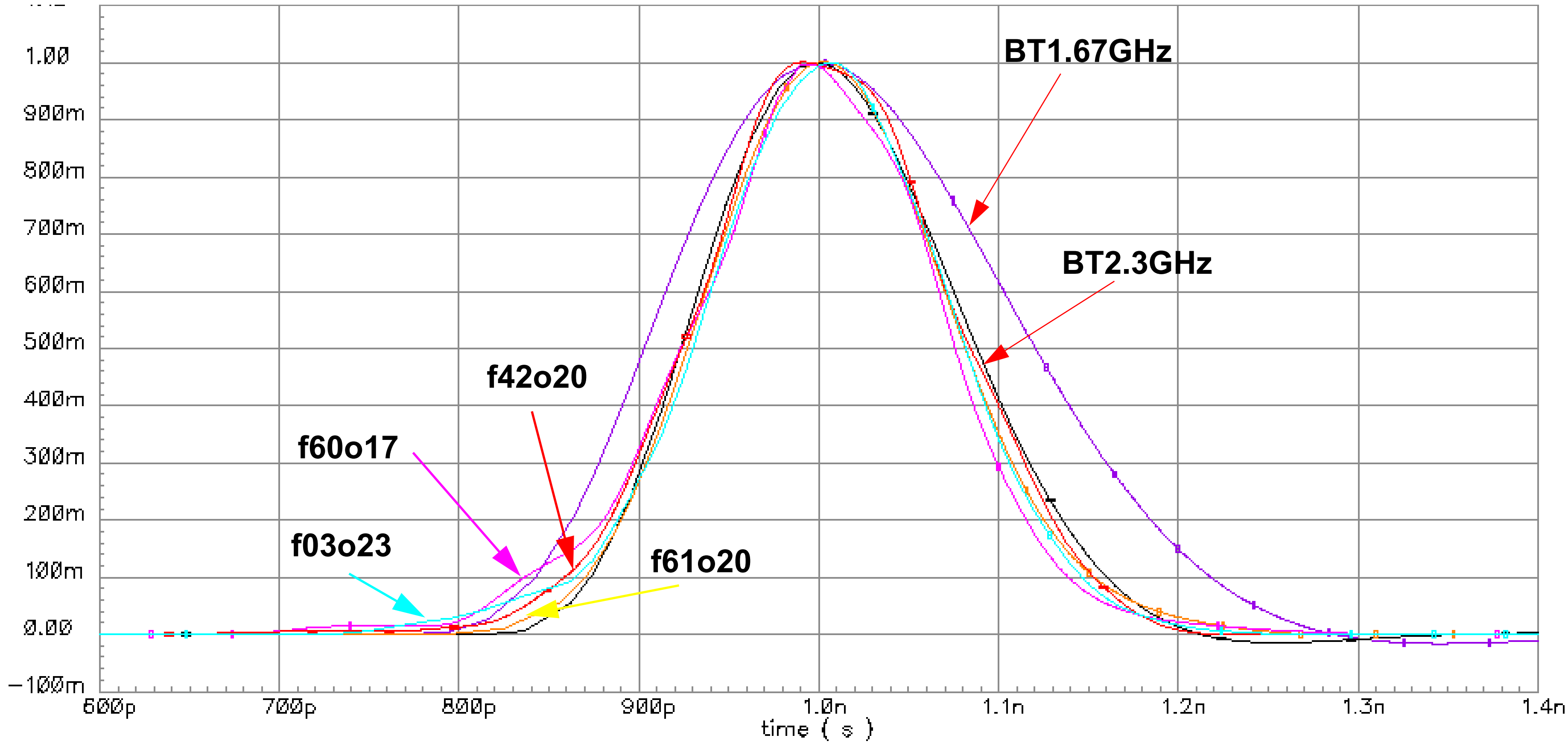
Two simulations using selected models based on PIE-L value 4 to 5 dB and quasi-symmetrical impulse response, and two low pass filters (BT1.67GHz and BT2.3GHz).

Note: The second Low-Pass Filter (BT7.5GHz LPF) is not needed, the fiber emulator filter (LPF-F) has a much lower bandwidth.

The amplitudes and timing are adjusted for minimum error value and minimum error signal area.

The error signal is evaluated relative to the signal peak amplitude (%) and signal area relative to the error signal area (SNR*).

6. ISI Generator Block using BT Filters and quasi-symmetrical pulse response



- For quasi-symmetrical pulse response fibres, the filter approximation BT1.67GHz is to pessimistic.
- The error for filter approximation using BT2.3GHz

Fiber model	f03o23	f42o20	f60o17	f61o20
Peak Error	8.6%	7%	12%	6%
PSR	19.7dB	23.2dB	16.1dB	23.2dB

7. ISI Generator Block using Three Peak Impulse Response Approximation

- The simulation environment is shown in slide 5.
- The pulse shaping circuit is a Low Pass Filter BT 9 GHz, forcing the rise and fall times (20% to 80%) to be ~30 ps.
- Two Low Pass Filters (LPF1 and LPF2) BT 7.5 GHz are used to model the receiver (ROSA). The pulse responses and the respective synthesised pulse responses are evaluated at the receiver output.
- The optimization algorithm is based on minimum square error, or maximum PSR as defined on slide 3.
- If more than one set of values is found, the set of values with minimum peak error (errpk, as defined in slide 3) will be used.
- The set of values given in Table 1, are normalized forcing A_0 to 1, and A_1 and A_2 lower than 1 (no amplification).
- The set of values given in Table 2, are normalized forcing A_0 to 1 and Δt_0 to 0, as proposed in [aronson_2_0704].
- The fiber model f43o23 has the PIE-L higher than 5 dB.
- The pulse response of the selected fibres and the respective synthesised pulse responses (red curves), are shown in the last three slides.

8. Optimization Results (1)

Table 1: Parameter Values for A_0=1

Fiber	A_0	A_1	A_2	Δt_0 [ps]	Δt_1 [ps]	Δt_2 [ps]	PSR [dB]	Errpk [%]
f18o23	1.000	0.825	0.736	70	0	170	20.6	16
f54o17	1.000	0.936	0.349	0	80	125	16.9	17
f51o17	1.000	0.333	0.489	220	0	125	19.4	12
f48o17	1.000	0.344	0.478	280	0	155	15.4	12.6
f50o17	1.000	0.189	0.708	230	0	135	29.2	6
f47o17	1.000	0.187	0.375	225	0	130	26.7	6.5
f42o23	1.000	0.807	0.922	125	0	80	24.7	6
f64o23	1.000	0.818	0.931	120	0	70	21.3	10.5
f03o23	1.000	0.431	0.517	60	125	0	22.5	7
f42o20	1.000	0.941	0.570	60	0	115	21.2	9.8
f60o17	1.000	0.867	0.323	0	65	115	18.7	14
f61o20	1.000	0.916	0.676	55	0	115	24.2	6
f43o20	1.000	0.647	0.324	0	85	195	23.9	7
f18o17	1.000	0.510	0.325	0	110	240	17.6	11
f43o23*	1.000	0.800	0.500	215	120	0	18.9	12

9. Optimization Results (2)

Table 2: Parameter Values for A_0=1 and Δt_0=0

Fiber	A_0	A_1	A_2	Δt_0 [ps]	Δt_1 [ps]	Δt_2 [ps]	PSR [dB]	Errpk [%]
f18o23	1.000	1.212	0.892	0	70	170	20.6	16
f54o17	1.000	0.936	0.349	0	80	125	16.9	17
f51o17	1.000	3.003	1.468	0	220	125	19.4	12
f48o17	1.000	2.907	1.390	0	280	155	15.4	12.6
f50o17	1.000	5.291	3.746	0	230	135	29.2	6
f47o17	1.000	5.348	2.005	0	225	130	26.7	6.5
f42o23	1.000	1.239	1.143	0	125	80	24.7	6
f64o23	1.000	1.222	1.138	0	120	70	21.3	10.5
f03o23	1.000	0.834	1.934	0	125	60	22.5	7
f42o20	1.000	1.063	0.606	0	60	115	21.2	9.8
f60o17	1.000	0.867	0.323	0	65	115	18.7	14
f61o20	1.000	1.092	0.738	0	55	115	24.2	6
f43o20	1.000	0.647	0.324	0	85	195	23.9	7
f18o17	1.000	0.510	0.325	0	110	240	17.6	11
f43o23*	1.000	1.600	2.000	0	120	215	18.9	12

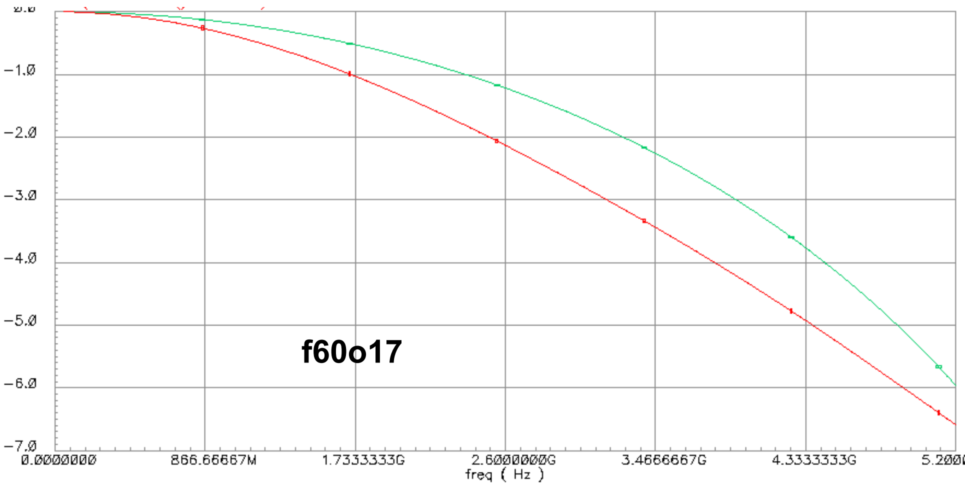
10. Optimization Results (3)

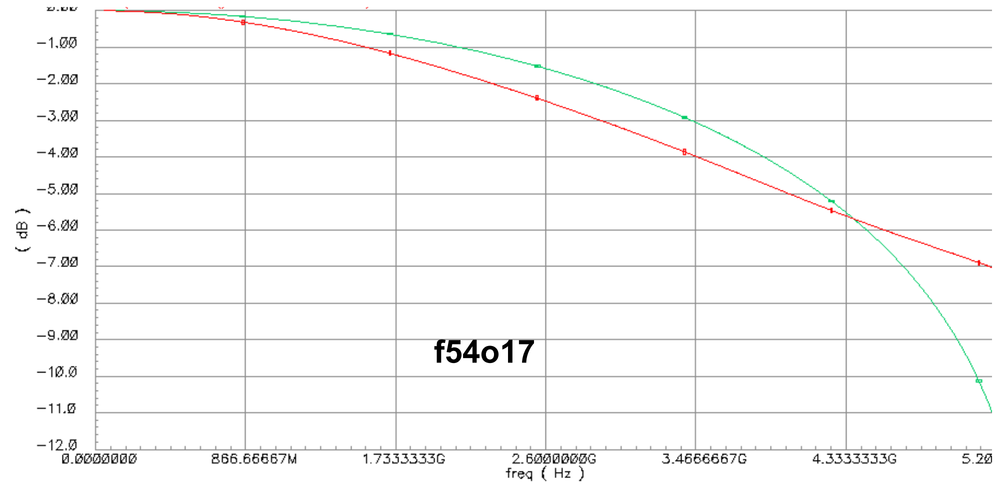
Table 3: P_LE and P_DFE for fibers and stressors with low PSR

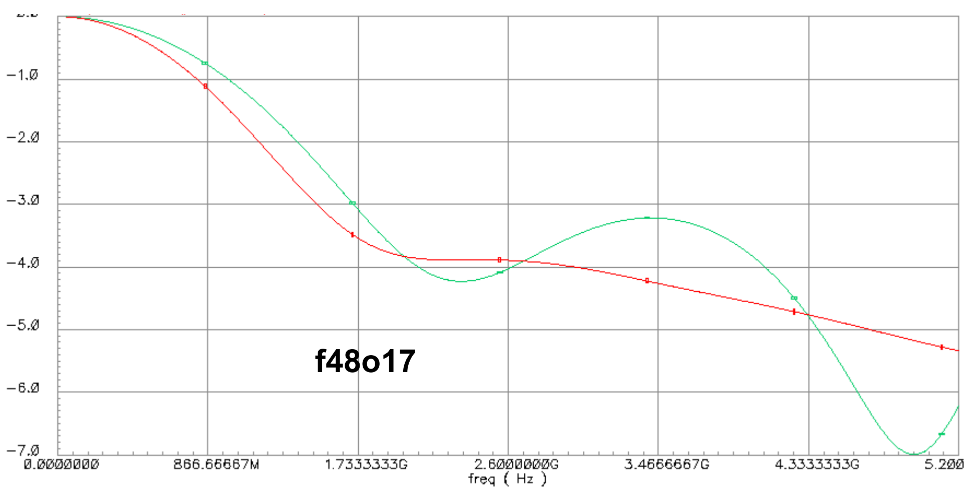
Fiber	PSR [dB]	Errpk [%]	P_LE [dB] Fiber	P_LE [dB] Stressor	P_DFE [dB] Fiber	P_DFE [dB] Stressor
f60o17	18.7	14	3.9	2.1	2.5	1.8
f54o17	16.9	17	4.96	7.1	2.8	2.6
f48o17	15.4	12.6	4.7	5.1	3.4	3.3
f43o23*	18.9	12	6.6	5.5	3.8	3.4

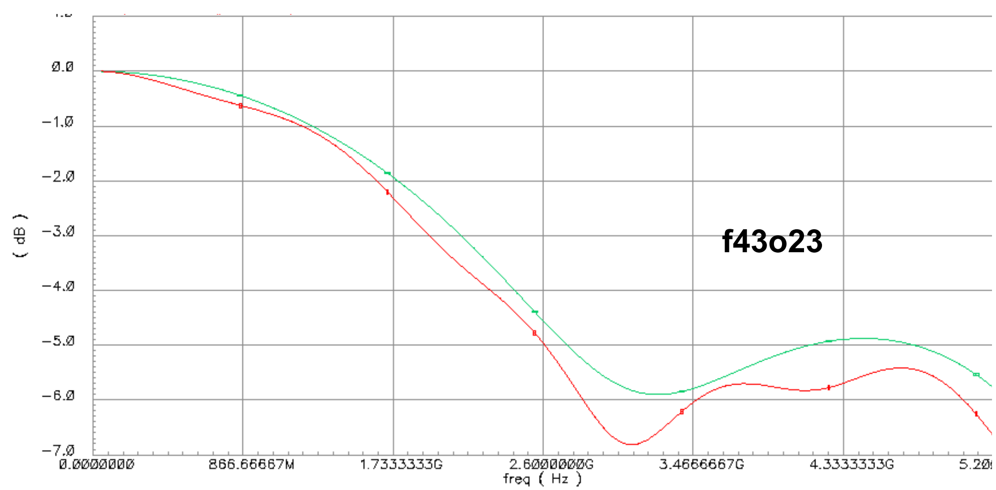
- The four fibers chosen have the lowest PSR values (all lower than 20 dB)
- P_LE is the ideal linear equalizer optical penalty based on the fiber and stressor pulse responses
- P_DFE is the ideal DFE equalizer optical penalty based on the fiber and stressor pulse responses
- The frequency response for fibers and stressors are shown on the next slide
- The last fiber f43o23 has P_LE higher than 4.5 dB (current budget limit).

11. Fiber (red) and Stressor (green) Frequency Response (0 to 5.2 GHz)









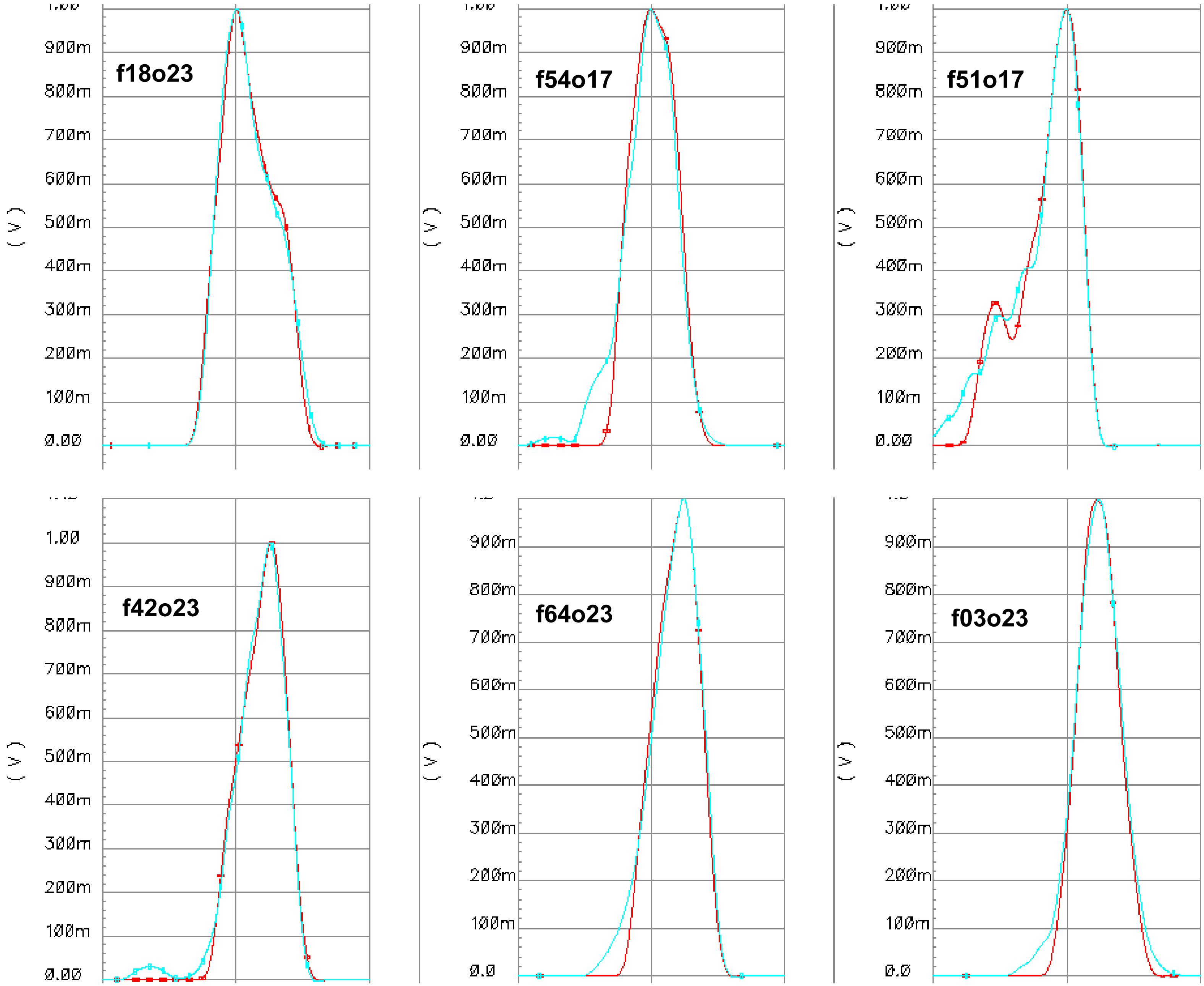
12. Summary

- The low pass filter option BT 2.3GHz, can be used as a first approximation ISI generator block for quasi-symmetrical pulse response fibres having the PIE-L 4 to 5 dB.
- The low pass filter option BT1.67GHz is too pessimistic for the same group of pulse response fibres.
- Three peak impulse response ISI generator block can be used for stressed sensitivity test, assuming that the amplitudes and delays can be made programmable.
- Another alternative is to select only a limited number of pulse responses (possible 3, quasi-symmetrical, post-cursor and pre-cursor type pulse response) and have the ISI block generator with fixed delays and amplitudes.

Fiber	type	A0	A1	A2	Δt_0 [ps]	Δt_1 [ps]	Δt_2 [ps]
f18o17	post-cursor	1	0.51	0.325	0	110	240
f48o17	pre-cursor	1	2.907	1.39	0	280	155
f42o20	symmetrical	1	1.063	0.606	0	60	115

- For quasi-symmetrical pulse responses, the three peak ISI generator block and the low pass filter BT 2.3 GHz, give similar results (PSR and errpk).
- For pulse responses having pre-cursor or post-cursor characteristics, the approximation using three peak ISI generator block is reasonable (few PSR values of 16 to 20 dB, all others better than 20 dB).
- For the same pulse response characteristics, the low pass filter approximation fails (PSR values of 5 to 8 dB).
- The two peak impulse ISI generator block investigation is in progress. The results will be presented as soon as they will be available.

13. Fiber Pulse Responses and Synthesized Stressors (1)



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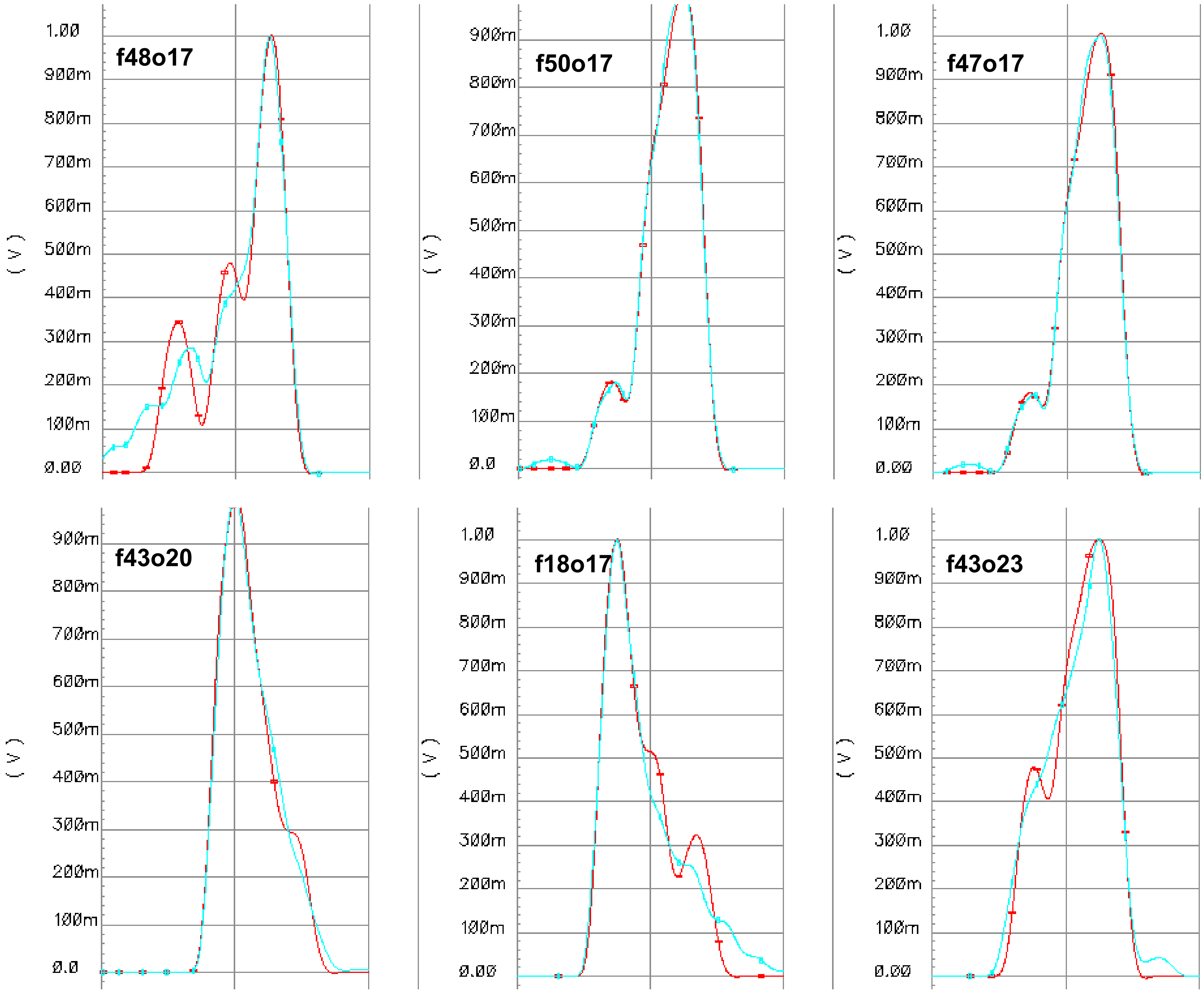
14. Fiber Pulse Responses and Synthesized Stressors (2)



15. Fiber Pulse Responses and Synthesized Stressors (3)