Design optimization of LiteBIRD LFT detectors

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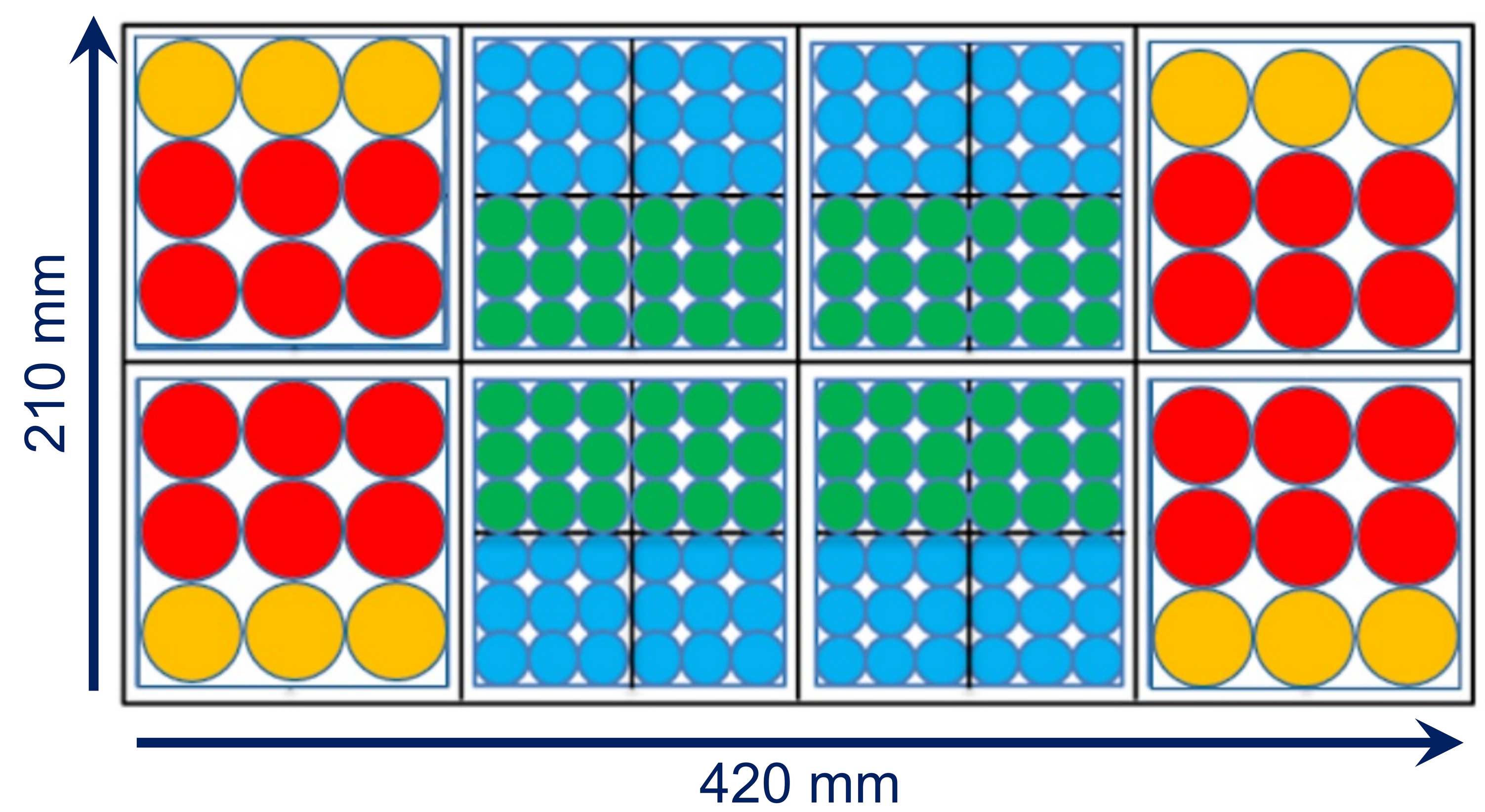
Abstract: The upcoming CMB satellite mission LiteBIRD will cover a broad frequency range from ~40 to ~400 GHz. Roughly 4000 superconductive TES detectors will be divided into 15 frequency channels split between 3 telescopes. QUP is in charge of developing and assembling the focal plane of the Low Frequency Telescope (LFT). LFT will employ tri-chroic pixels consisting of lenslet-coupled broadband sinuous antennas and on-chip band-defining filters fabricated with niobium on silicon wafers. Here we show an update of the design procedure for LiteBIRD LFT pixels, highlighting optimization procedure and trade-off studies to achieve the mission goal of measuring the CMB polarized signal with unprecedented sensitivity.

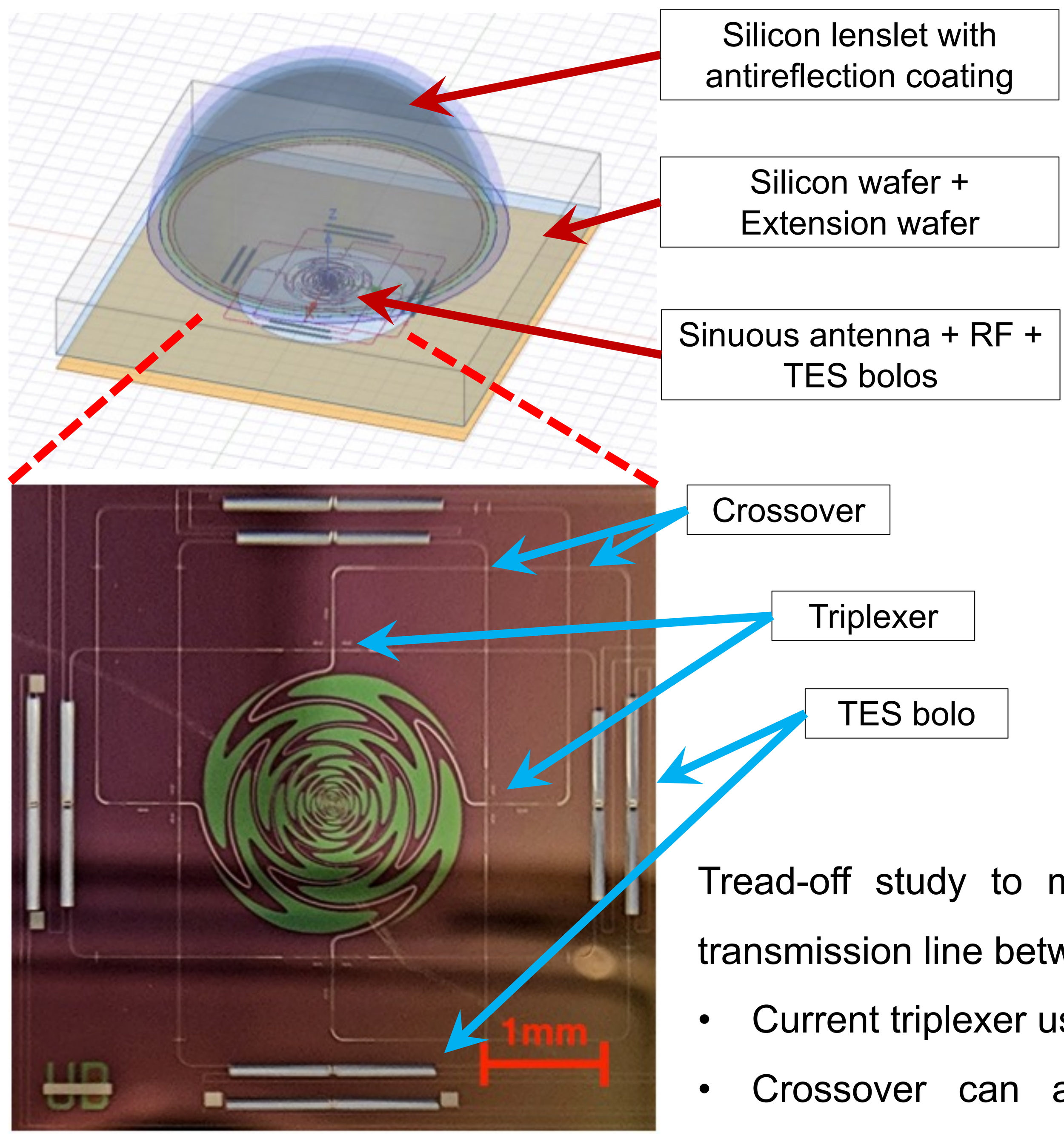
LFT focal plane



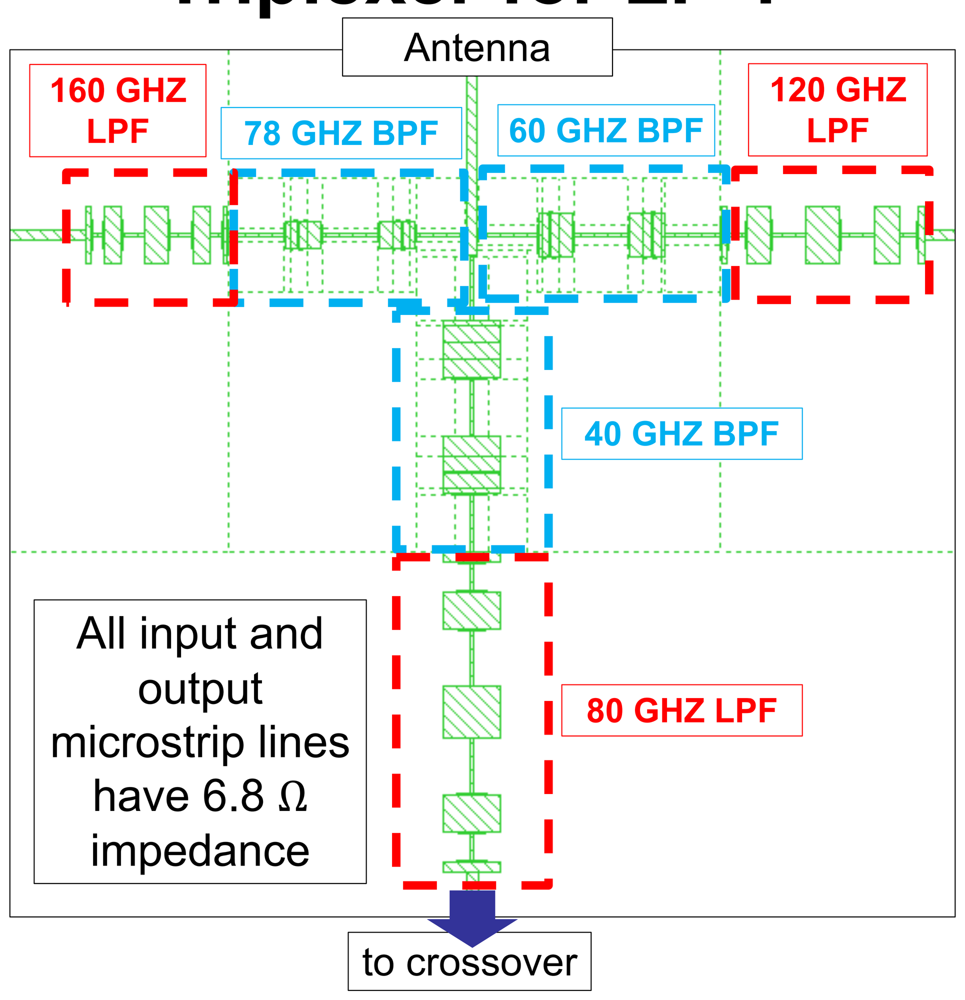
Pixel	Frequency [GHz]	Diameter [mm]	Pixels per wafer	Wafers	Bolos per channel
LF-1	40 – 60 – 78	32	6	4	48
LF-2	50 – 68 – 89	32	3	4	24
LF-3	68 – 89 – 119	16	18	4	144
LF-4	78 – 100 – 140	16	18	4	144

LFT will cover the frequency range 34 – 161 GHz. In order to maximize the throughput with the limited volume available in space we will use POLARBEAR 2 heritage technology: broadband dual-polarization sinuous antenna, coupled to silicon lenslet. Each antenna feeds 6 TES bolometers (1 per frequency and polarization). This architecture requires a number of RF components that need to be optimized for each frequency band: sinuous antennas, on-chip filters (triplexer), crossovers, impedance transformers, etc.

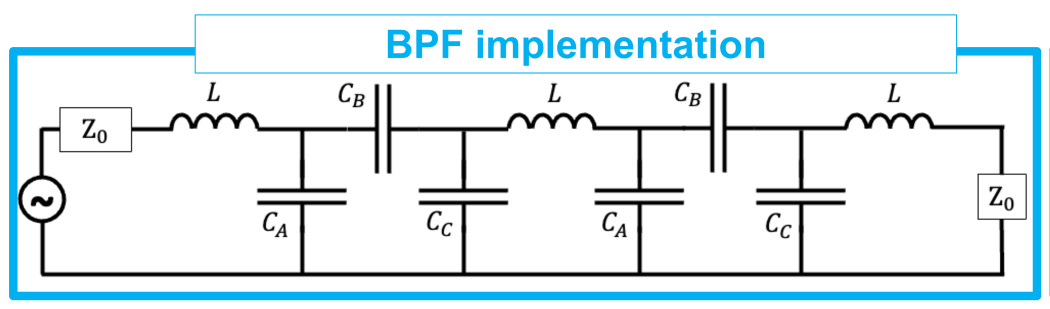
Pixel structure



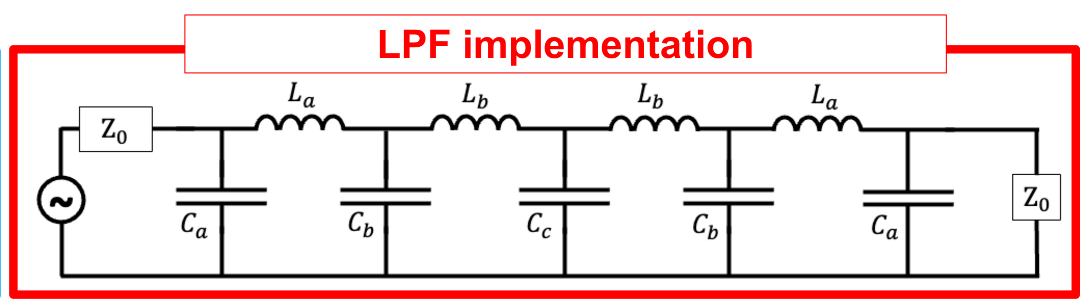
Triplexer for LF-1



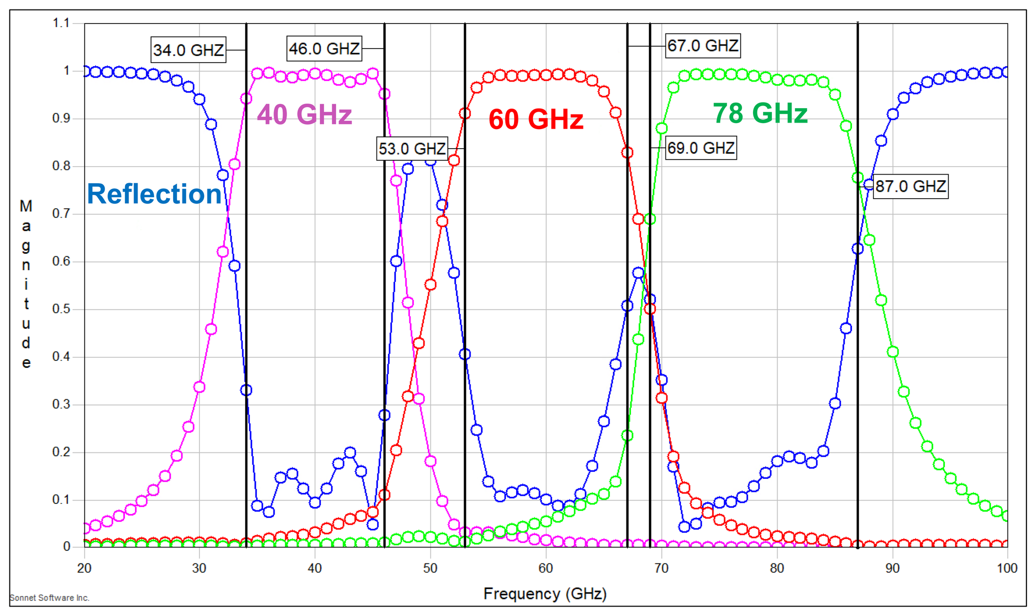
BPF implementation



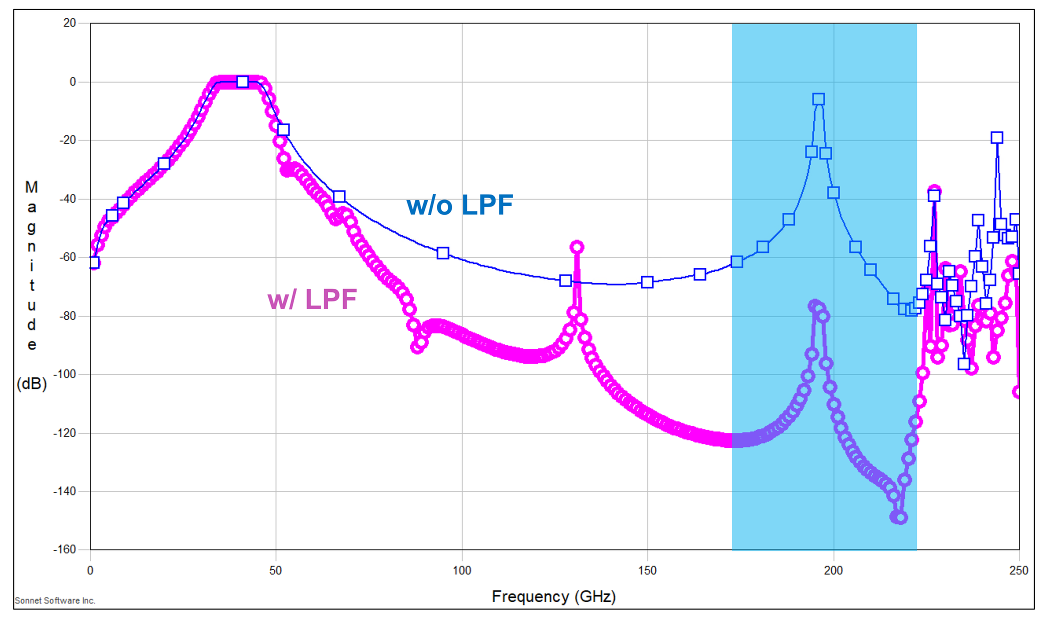
LPF implementation



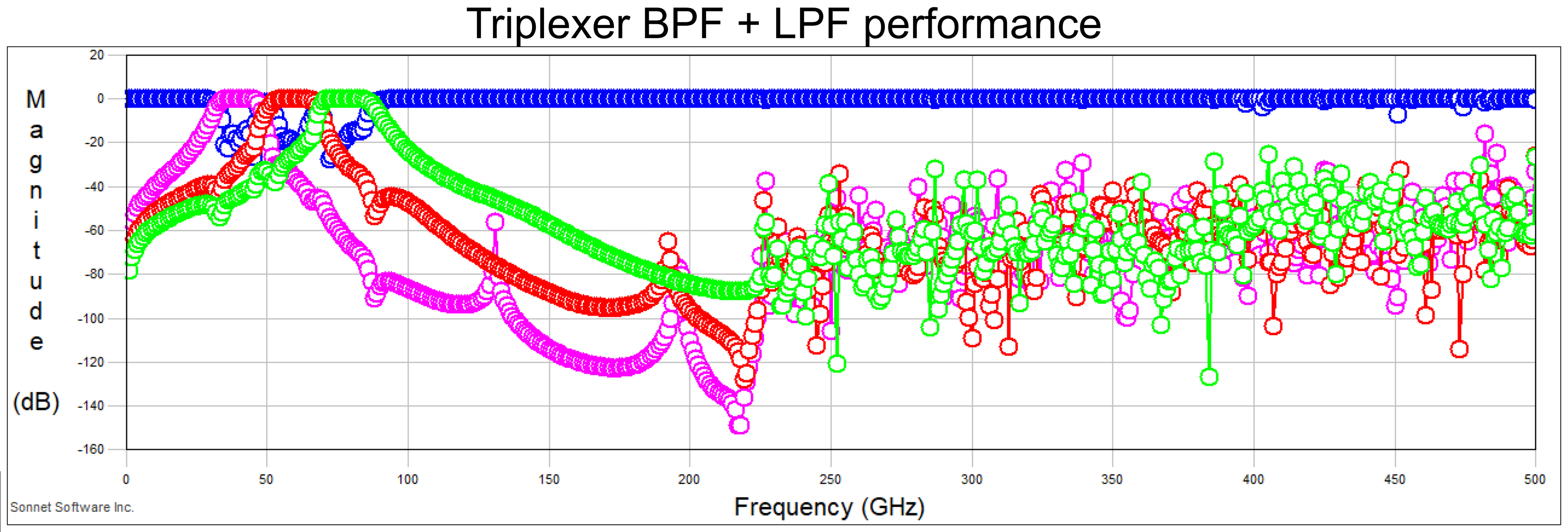
Triplexer performance



40 Ghz out-of-band without LPF



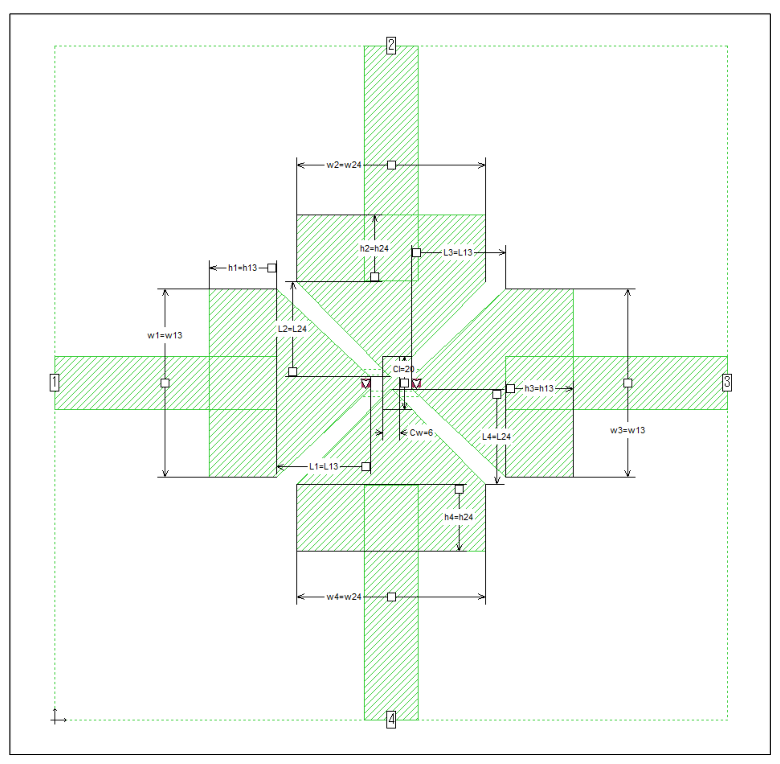
Triplexer BPF + LPF performance



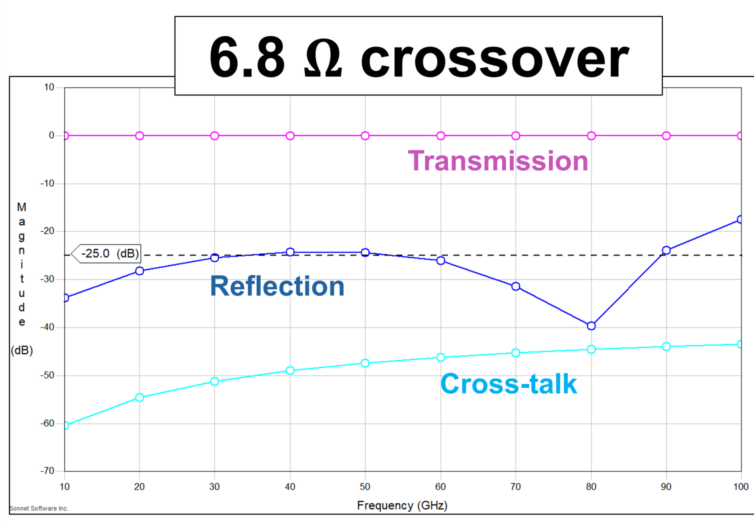
Tread-off study to minimize complexity of the components on the transmission line between triplexer and bolo:

- Current triplexer uses low 6.8 Ω impedance microstrip-line
- Crossover can achieve better performance with higher input impedance, but this solution requires impedance transformer

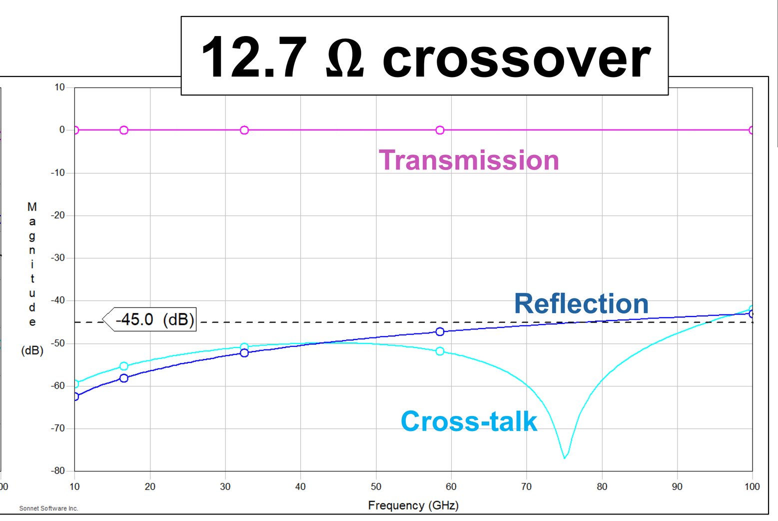
Crossover



6.8 Ω crossover

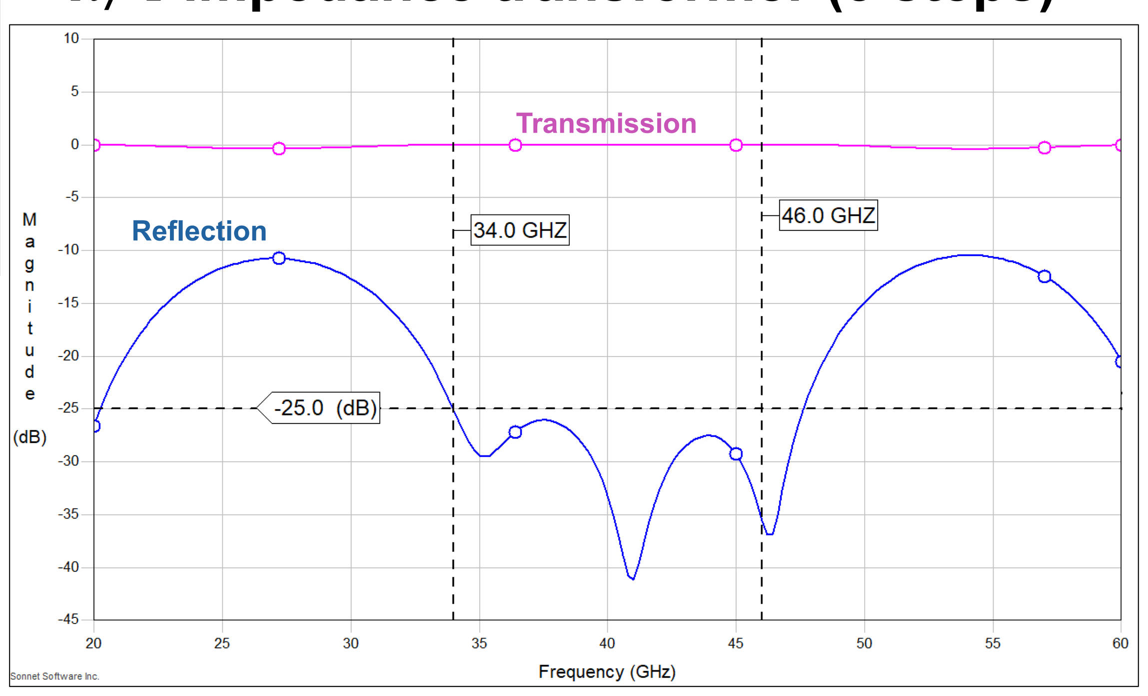


12.7 Ω crossover



High impedance crossover can achieve better performance but requires a "long" (~1 mm) impedance transformer that results in performances similar to the lower impedance crossover.

$\lambda/4$ impedance transformer (3 steps)



Ongoing and future work:

- Optimization of sinuous antenna for 32 mm and 16 mm pixels (some preliminary results already available ask me if you are interested),
- Optimization of RF components for all other LFT frequency bands,
- Various R&D to optimize the design-fabrication process.

[1] LiteBIRD Collaboration, "Probing Cosmic Inflation with the LiteBIRD Cosmic Microwave Background Polarization Survey"

[2] Westbrook, B. et al., "Development of the Low Frequency Telescope Focal Plane Detector Modules for LiteBIRD"