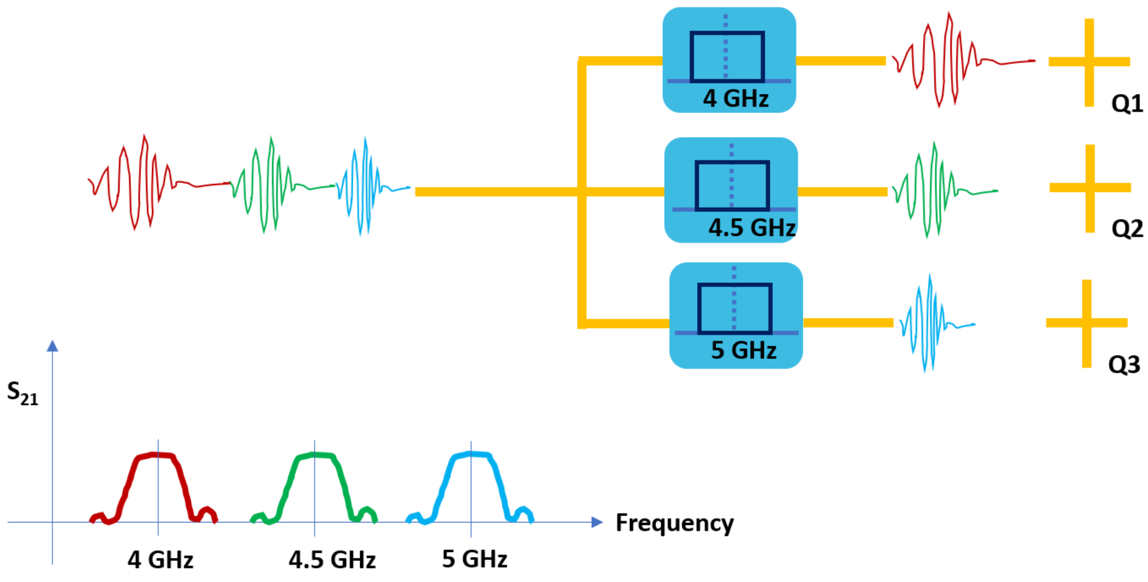
Master's thesis projects co-supervised by the Microwave Electronics and Quantum Technology groups at MC2

PROJECT 2: Frequency multiplexing for multi-qubit control

Background: Scaling up the number of qubits in a quantum processor requires reliable fabrication of qubits with predictable frequencies that are closely spaced within a frequency span, e.g. 4 – 8 GHz, but the ones that can share a single source will have to fit within a mor narrow frequency range, 0.75-2 GHz. For quantum-state control, each qubit needs several microwave cables, which should be connected to the lowest-temperature stage of a cryogenic refrigerator containing the chip. These include XY or drive lines to change the state of the qubit, Z lines to control the frequency of the qubits and resonator-feedline readout lines.

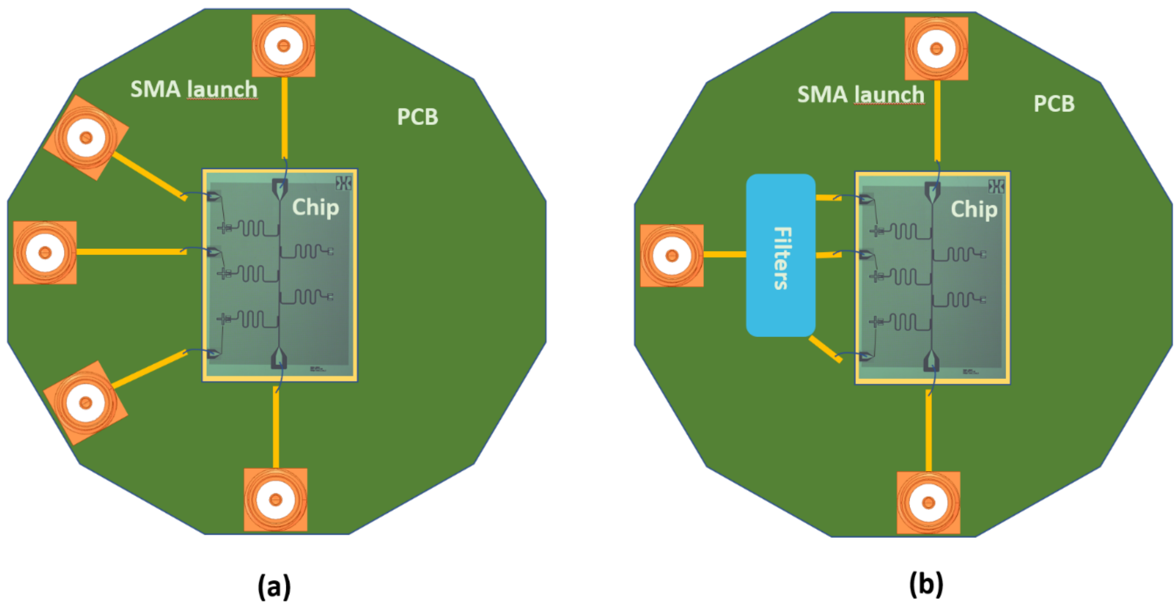
Once the number of qubits exceeds about 20, we start facing a hard problem of increasing the number of microwave cables. Considering that each cable has many filters, connectors and feedthroughs along its path, the hardware bottleneck is reached very fast. Adding more hardware to the fridge also requires a higher cooling power.

Project Goals: In this project, the goal is to use a frequency-multiplexing scheme in order to reduce the number of control (XY-line) cables by at least a factor of two or three. *Qubit readout is already frequency-multiplexed up to around 10 qubits in state-of-the-art implementations. By contrast, frequency multiplexing of XY control has not been demonstrated before.* This involves designing several microwave diplexers (2 or 3) on a PCB that fan out the incoming pulse from one line into the corresponding qubit, based on the central carrier frequency of the incoming pulse (4 - 5 GHz) and its bandwidth (100 – 200 MHz). This design helps us reduce the number of XY-pulse cables from 20 to below 10. The filters can be designed either using surface-mount components on a printed circuit board (PCB) or by designing distributed waveguide components on the PCB.



A bank of band-pass filters separates and forwards each pulse to its corresponding qubit. The number of XY or drive cables is reduced by a factor of 3 in this simplified example.

The design and simulation of the filters is performed in ADS or Microwave Office with inputs from HFSS simulations of the qubit processor chip and package. Room temperature and cryogenic test of the filter module is performed in close collaboration with experimental colleagues.



Design (a) shows a simple example where each qubit has its own XY-line, therefore three SMAs on the left side of the PCB and three cables are required. In design (b), a triplexer filter reduces the number of SMA/cables to three. The incoming pulse is directed to its corresponding qubit depending on the frequency.

Supervisors: These projects are co-supervised by principal investigators in the Microwave Electronics and Quantum Technology Laboratories a. These projects will contribute to the goal of the Wallenberg Center for Quantum Technologies (WACQT), which is to scale up the size of our quantum processor to 100 qubits. For more information about the activities of both groups consult with the websites, publications or directly contact Professors **Per Delsing, Herbert Zirath, Christian Fager, Jonas Bylander, and Simone Gasparinetti.**

https://www.chalmers.se/en/centres/wacqt/Pages/default.aspx
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For more detailed questions about each project please feel free to contact us or directly ask **Daryoush Shiri** (researcher at QTL) via [shiri@chalmers.se].