# Radio Frequency Self-Interference Cancellation Filter Chip

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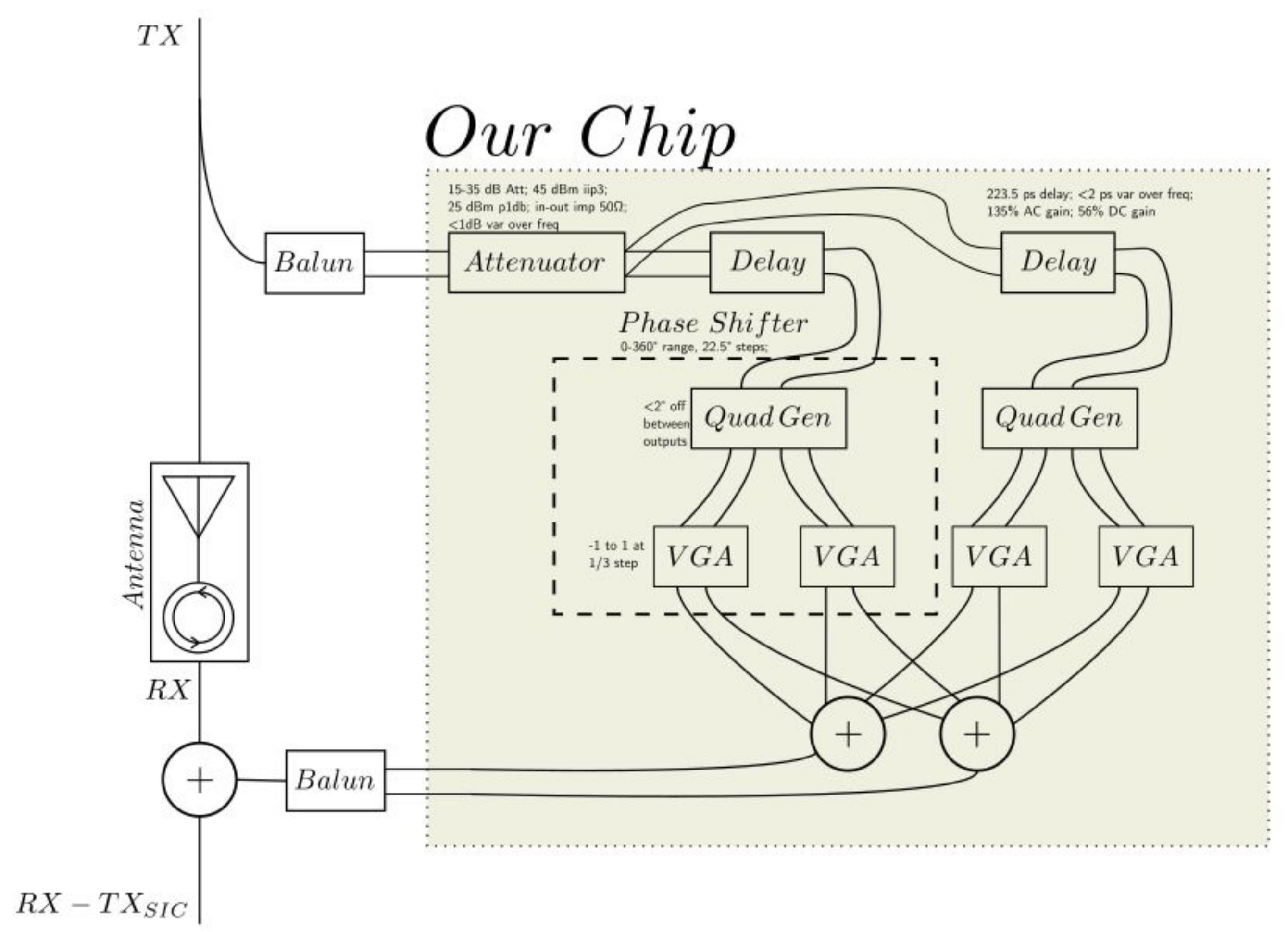
## Motivation

- Current wireless standards either communicate with different carrier frequencies or by sending at different times
- Sending and receiving on the same carrier frequency and at the same time causes a large amount of self interference from the strong transmit signal and the weak receive signal.
- Objective: design a FIR filter to cancel the interference on the receive line generated by the transmit signal

## Block Diagram

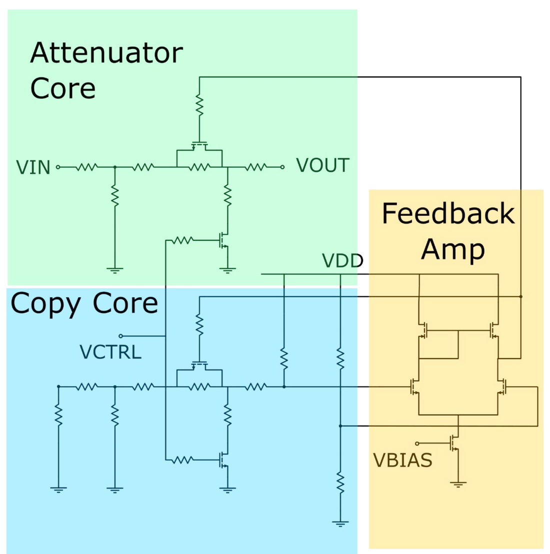


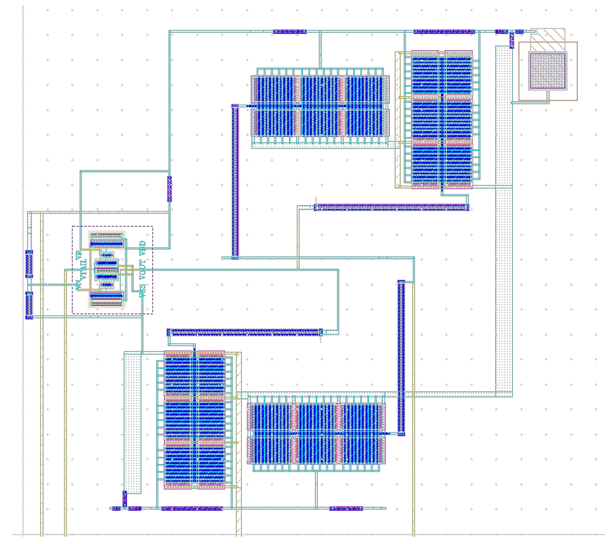

- FIR filter requires variable gain, time delay, and phase
- Two taps improves the cancellation bandwidth with different time and phase combinations
- Summing done in the current domain (shorting multiple paths together)

## Requirements

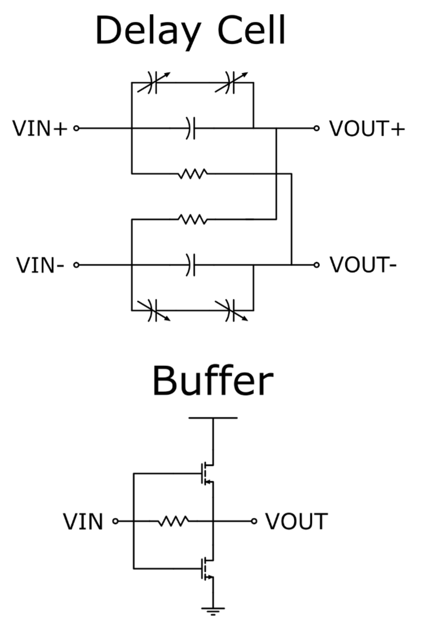
| Criteria | Goal |
|---|---|
| Center Frequency | 900 MHz |
| Bandwidth | 40 MHz |
| Cancellation | 20 dB |
| Linearity | 15 dBm P1dB, 25 dBm IIP3 |
| Noise Power | -87 dBm |

## Circuit Block Design and Layout

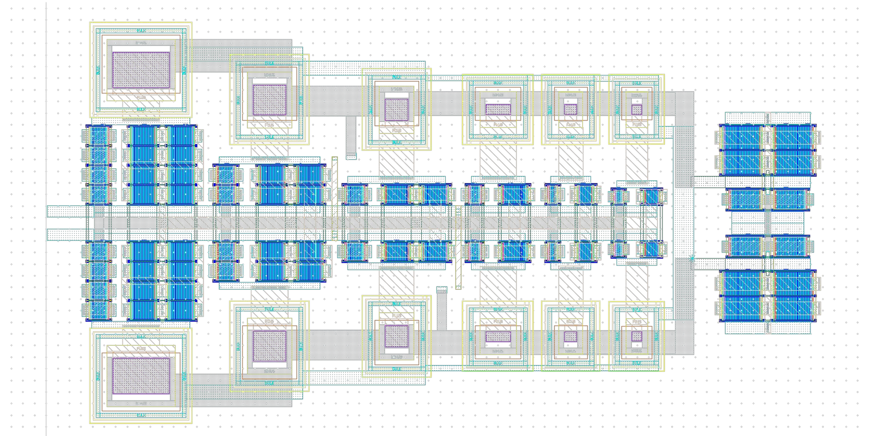


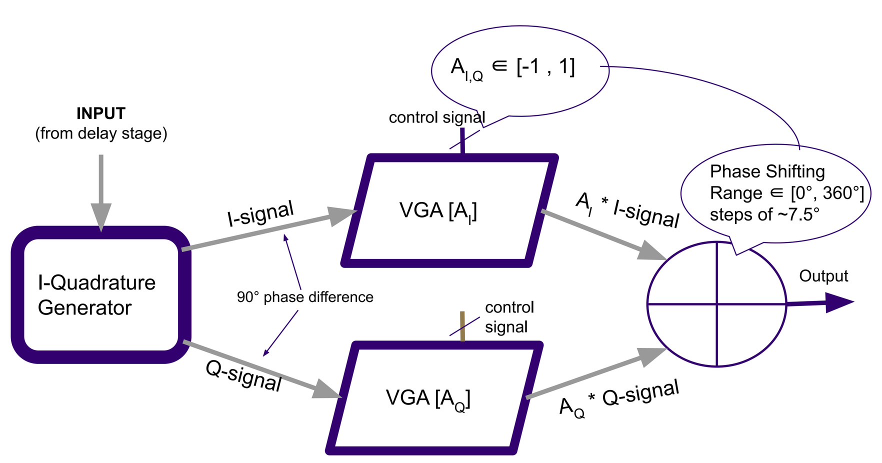



- First stage purely passive attenuator for most linearity
- Second stage variable attenuation with copy core feedback for more linearity control



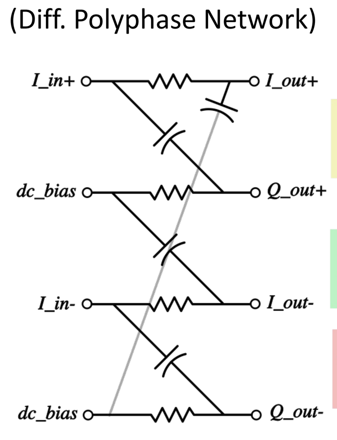

- Variable capacitance for variable delay
- Implemented with binary weighted caps
- Multiple cells strung together with buffers for larger time delay



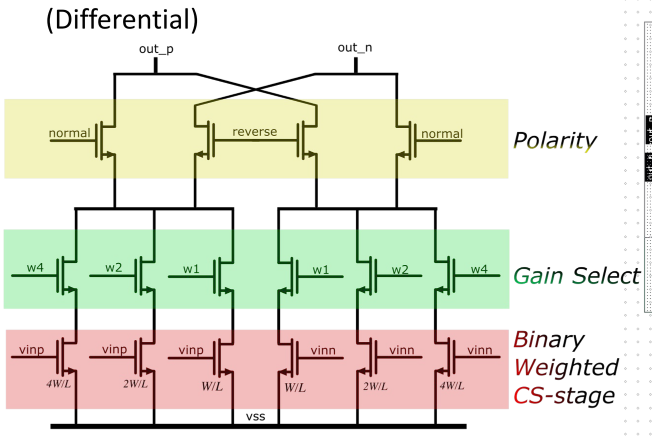



- Following delay stage: IQ-Vector modulation based phase shifter
- IQ voltage signal fed into binary weighted transconductance stage of variable gain amplifier (VGA)
- Phase shifting control through VGA tuning & current domain summing

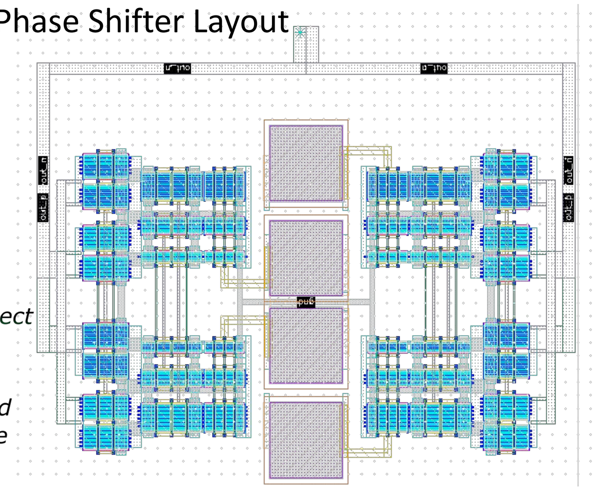
Quadrature Generator (Diff. Polyphase Network)



Variable Gain Amplifier (Differential)




Phase Shifter Layout

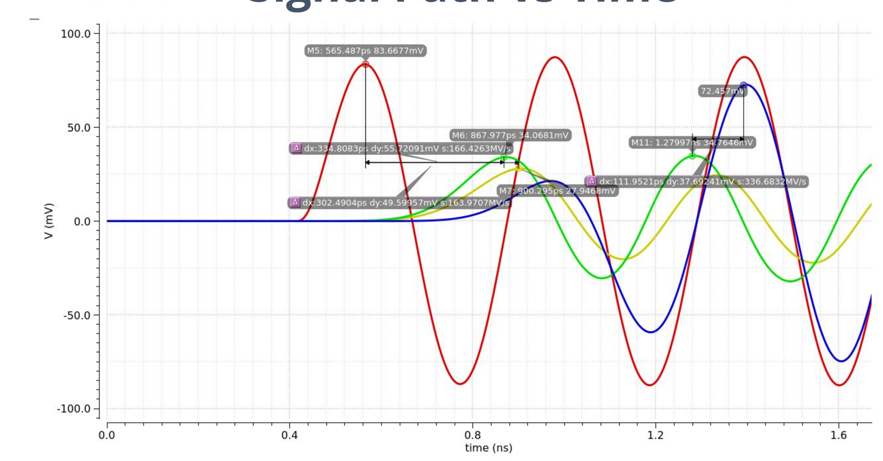


## Simulation and Results

### Tracing the signal path

- Attenuation comes first ■
- Delay from first tap ■
- Delay from second tap ■
- Combined signal with phase delay ■

### Signal Path vs Time

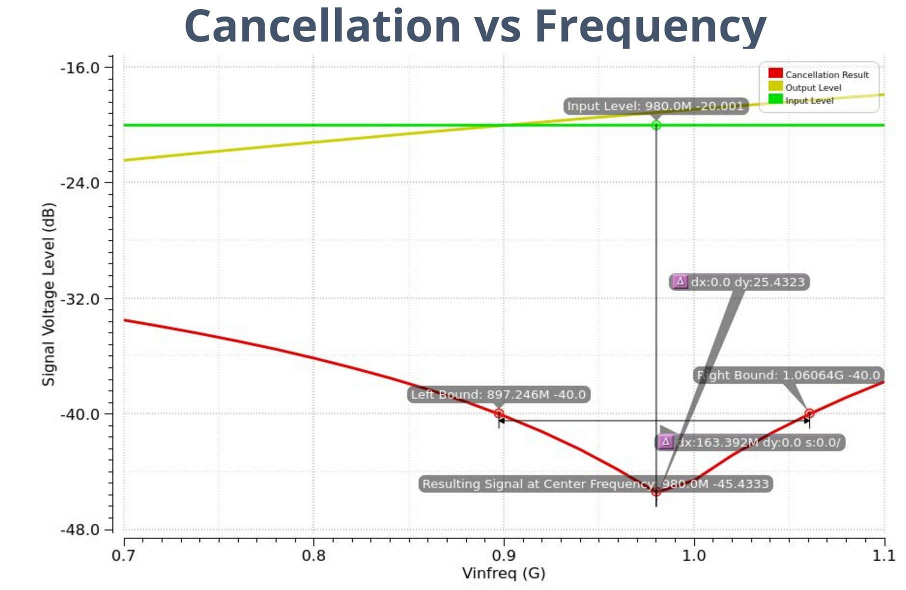


### Cancellation Results

- Cancelled Signal Voltage ■
- Input Signal Voltage ■
- Output Signal Voltage ■

Output and input signal matched at target frequency, yet signal cancellation is not maximized there!

### Cancellation vs Frequency




| Criteria | Results |
|---|---|
| Center Frequency | 980 MHz |
| Bandwidth | 160 MHz |
| Cancellation | 20-25 dB |
| Linearity | 18 dBm P1dB, 28 dBm IIP3 |
| Noise Power | -94 dBm |

## Conclusion

- First stage cancellation must be highly linear and low in noise
- There is often direct trade offs between linearity and noise
- Tunability often adds more components -> less linearity and less noise
- Creating deeper first stage cancellation could enable full duplex wireless

## Future Work

- More linear -> transmit line can produce a stronger outward signal
- Less noise -> longer transmission range
- Higher bit resolution tuning / more filter taps -> larger bandwidth

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