We2G-3

An Active Self-Interference Cancellation Coupler with 60 dB Isolation Applied in a 24 GHz SFCW Radar

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Outline

- Self-interference in SFCW radars
- Design considerations
- Calibration and characterization
- Measurement results
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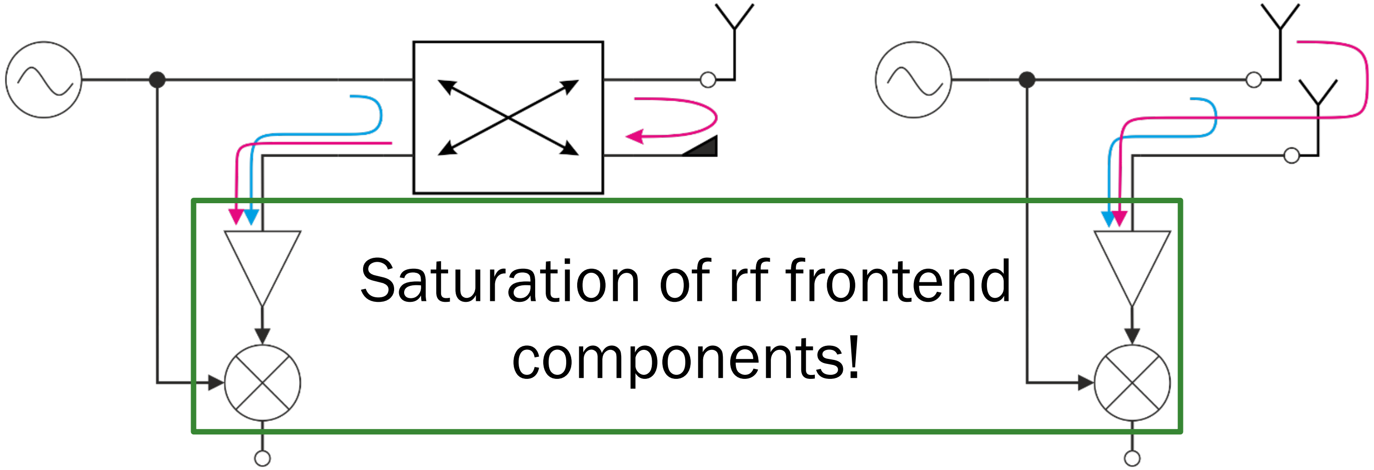
Sources of Self-Interference

- Antennas:
  - Input mismatch (monostatic)
  - Coupling (bistatic)
- PCB:
  - Non-perfect isolation
  - Coupling between microstrip lines



Receiver Desensitization

- Theory:
  - Polynomial approximation

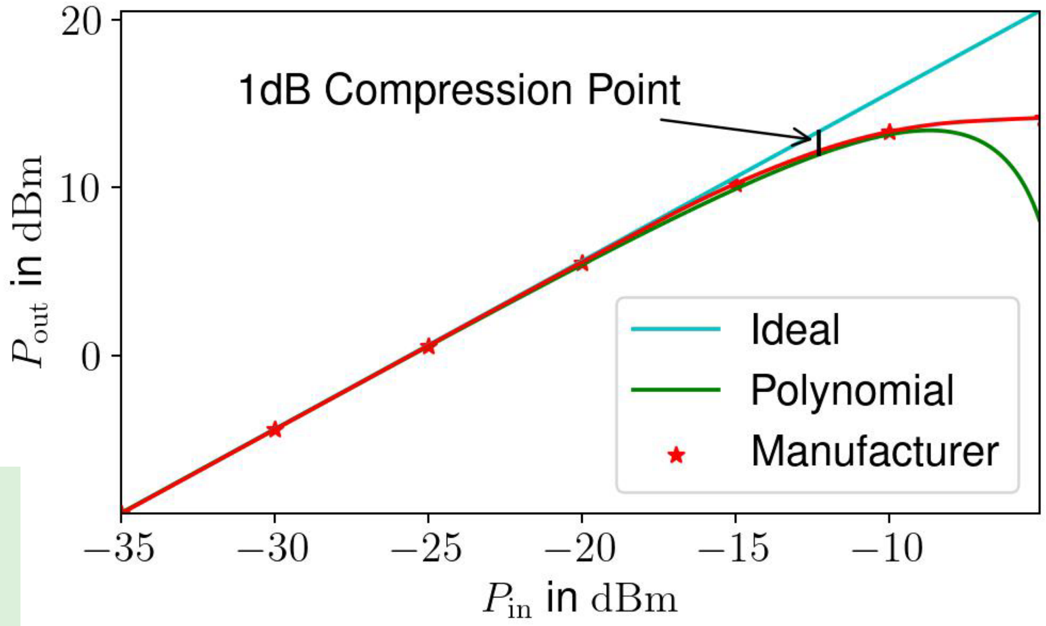
$$v_{\text{out}}(v_{\text{in}}) = a_1 v_{\text{in}} + a_3 v_{\text{in}}^3$$

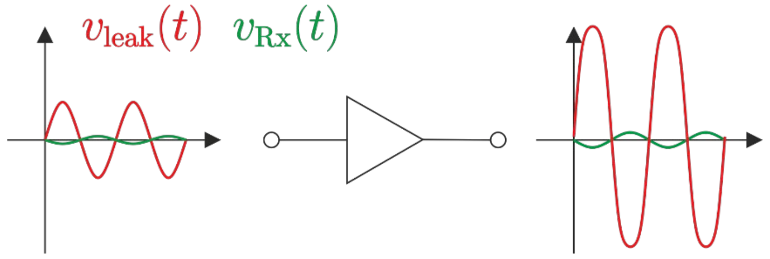
  - Gain compression

$$v_{\text{leak,out}} \approx a_1 \cdot v_{\text{leak,in}} \left[1 + \frac{3a_3}{4a_1} v_{\text{leak,in}}^2\right]$$

  - Desensitization

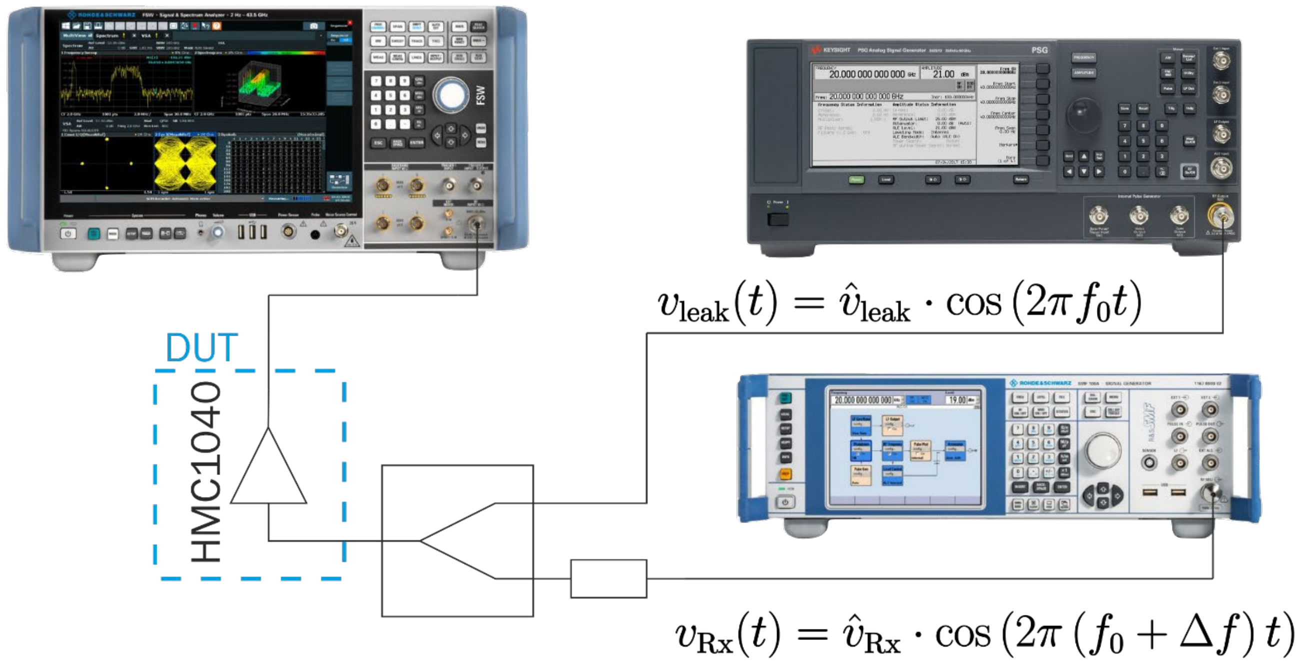
$$v_{\text{Rx,out}} \approx a_1 \cdot v_{\text{Rx,in}} \left[1 + \frac{3a_3}{2a_1} v_{\text{leak,in}}^2\right]$$

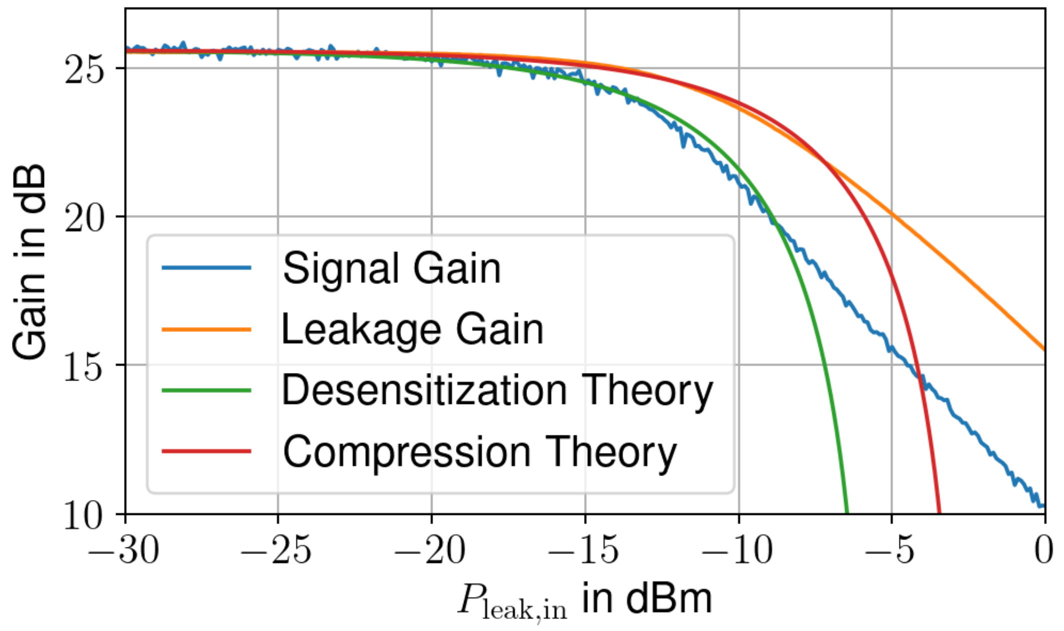




LNA Desensitization

$P_{\mathrm{Rx}} = -50\ \mathrm{dBm}$ $f_0 = 24\ \mathrm{GHz}$ $\Delta f = 1\ \mathrm{MHz}$

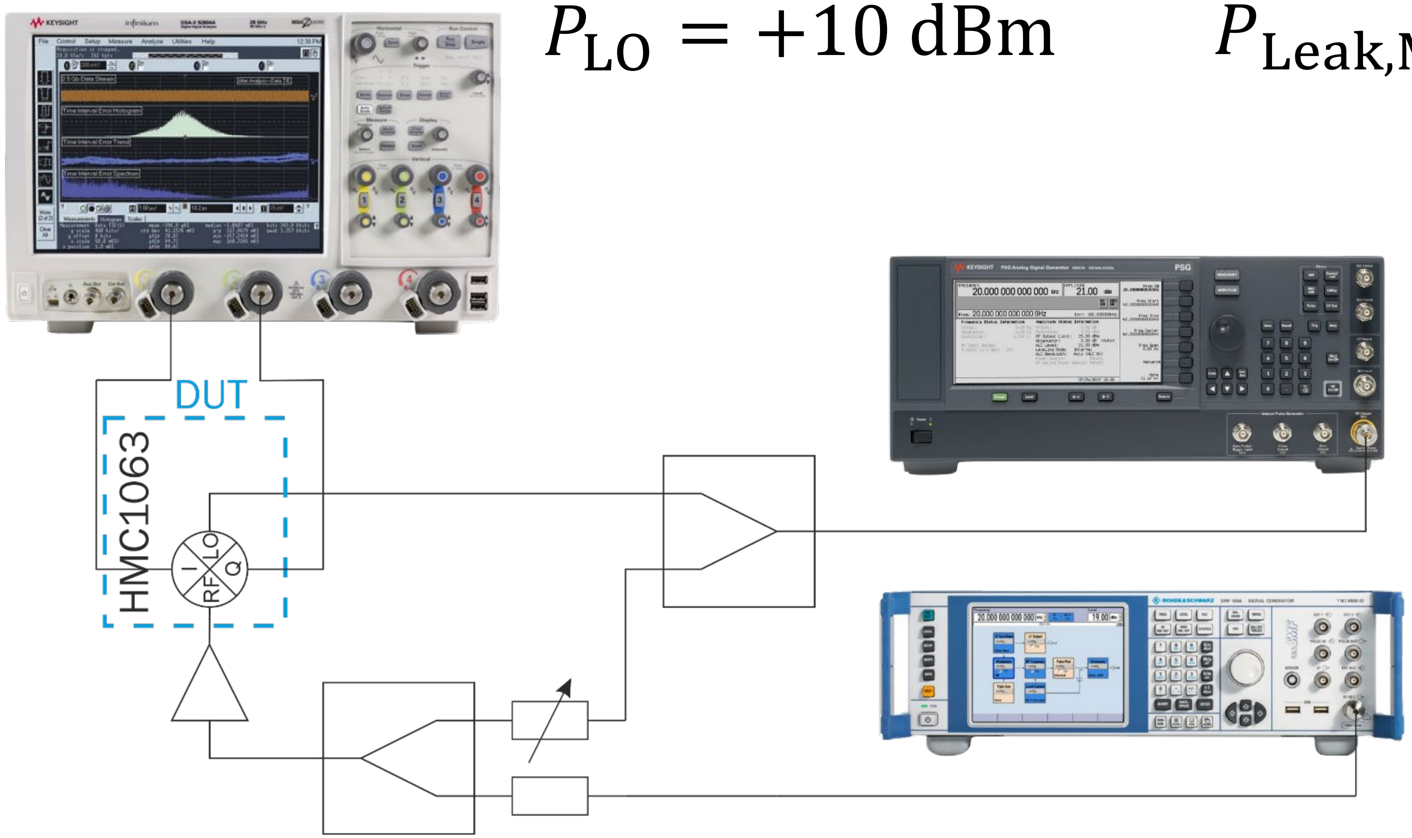


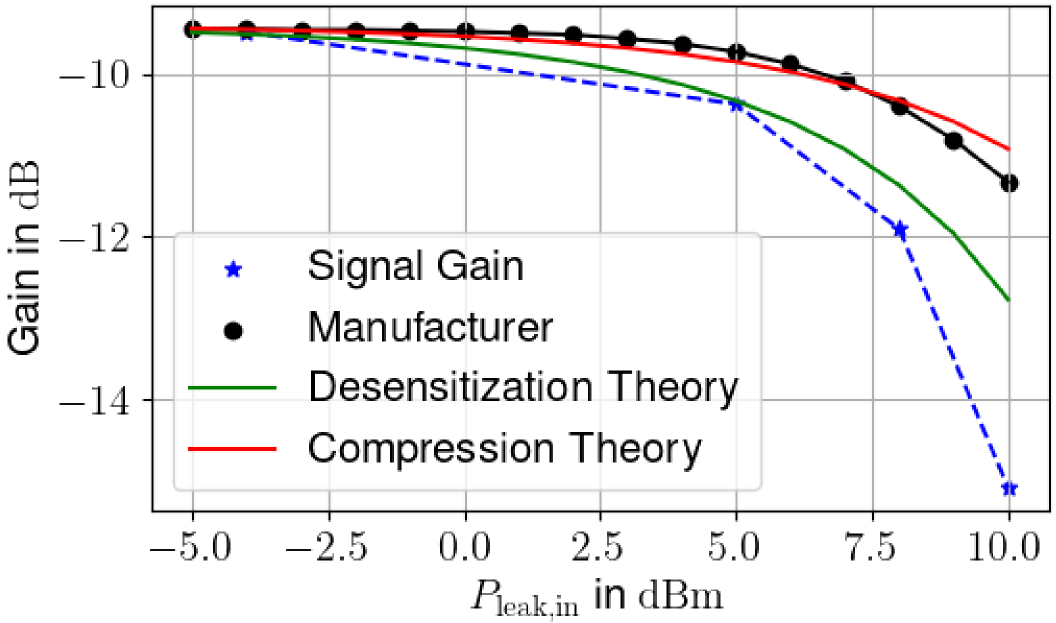


Mixer Desensitization

$P_{\mathrm{Rx}} = -50\ \mathrm{dBm}$ $f_0 = 24\ \mathrm{GHz}$ $\Delta f = 1\ \mathrm{MHz}$

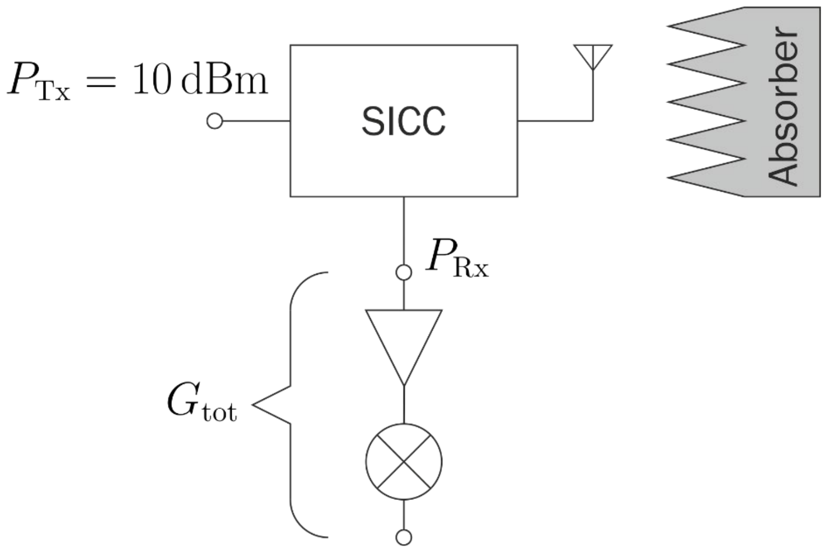
$P_{\mathrm{LO}} = +10\ \mathrm{dBm}$ $P_{\mathrm{Leak,Mix}} = \{-4, 5, 8, 10\}\ \mathrm{dBm}$

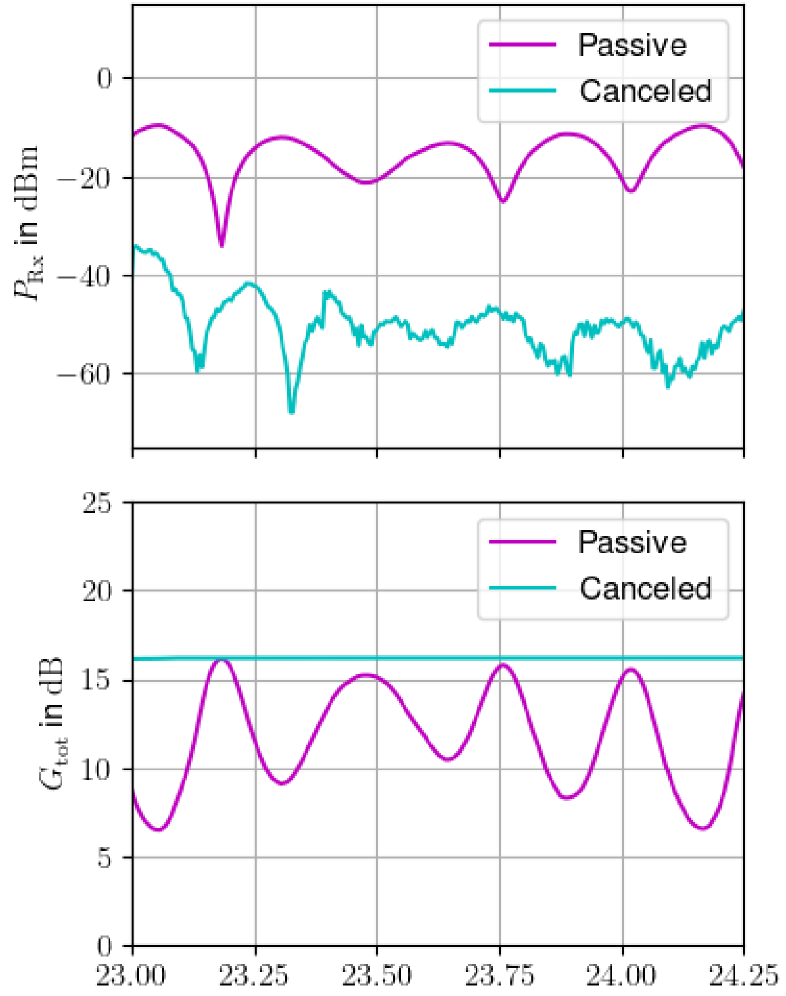




Receiver Desensitization

- Consequences for our monostatic radar
  - Measure leakage power
  - Simulate desensitized gain





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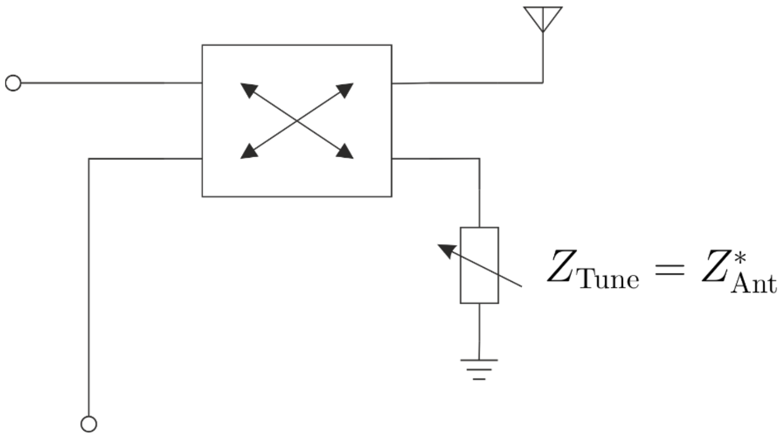
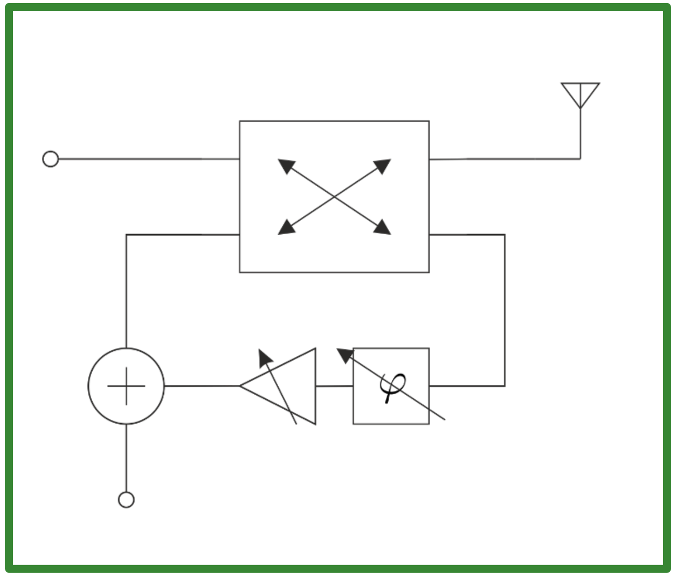
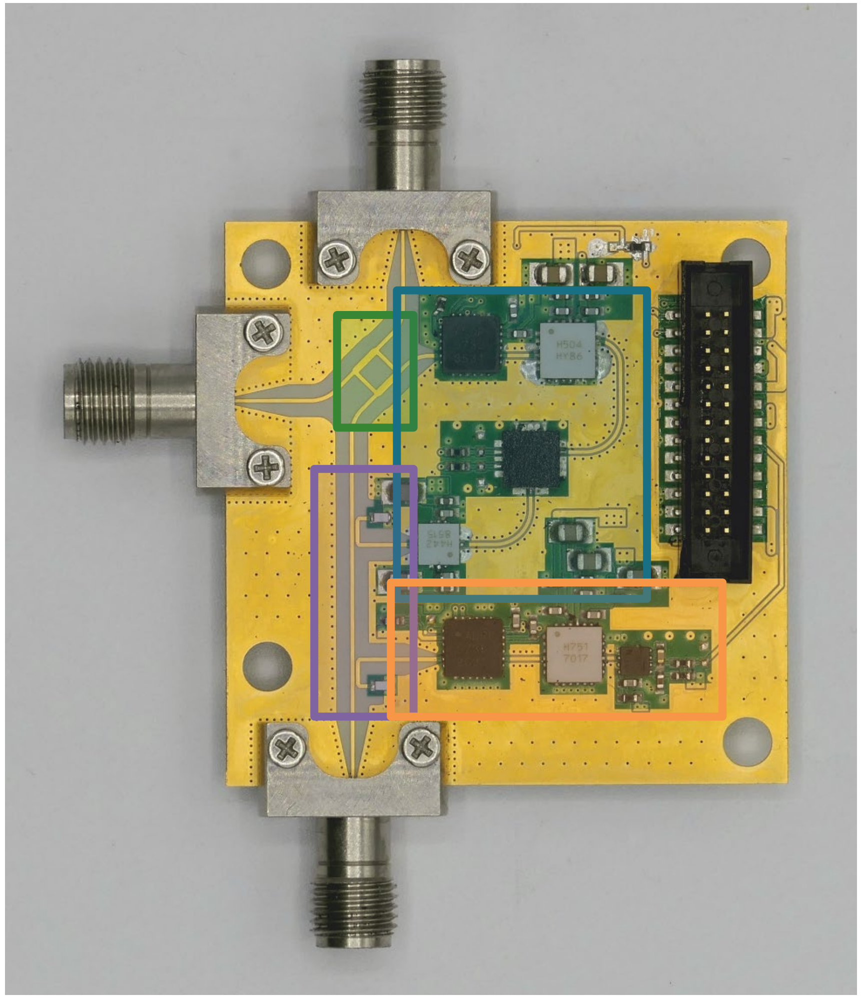
Possible Techniques

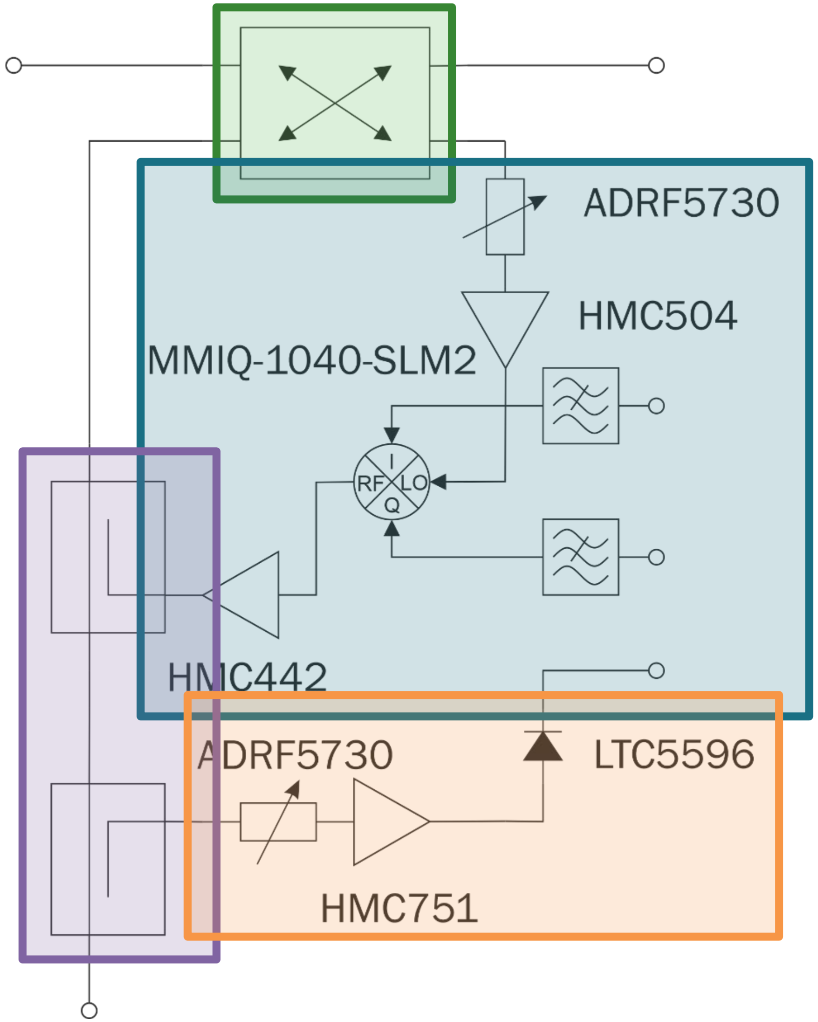




	Insertion Loss	Noise Figure	Power Consumption	Component Availability	Setting Range	Linearity	Design Effort
Impedance tuner	+	+	+	-	-	-	-
Vector modulator	-	-	-	+	+	+	+

Realized Design





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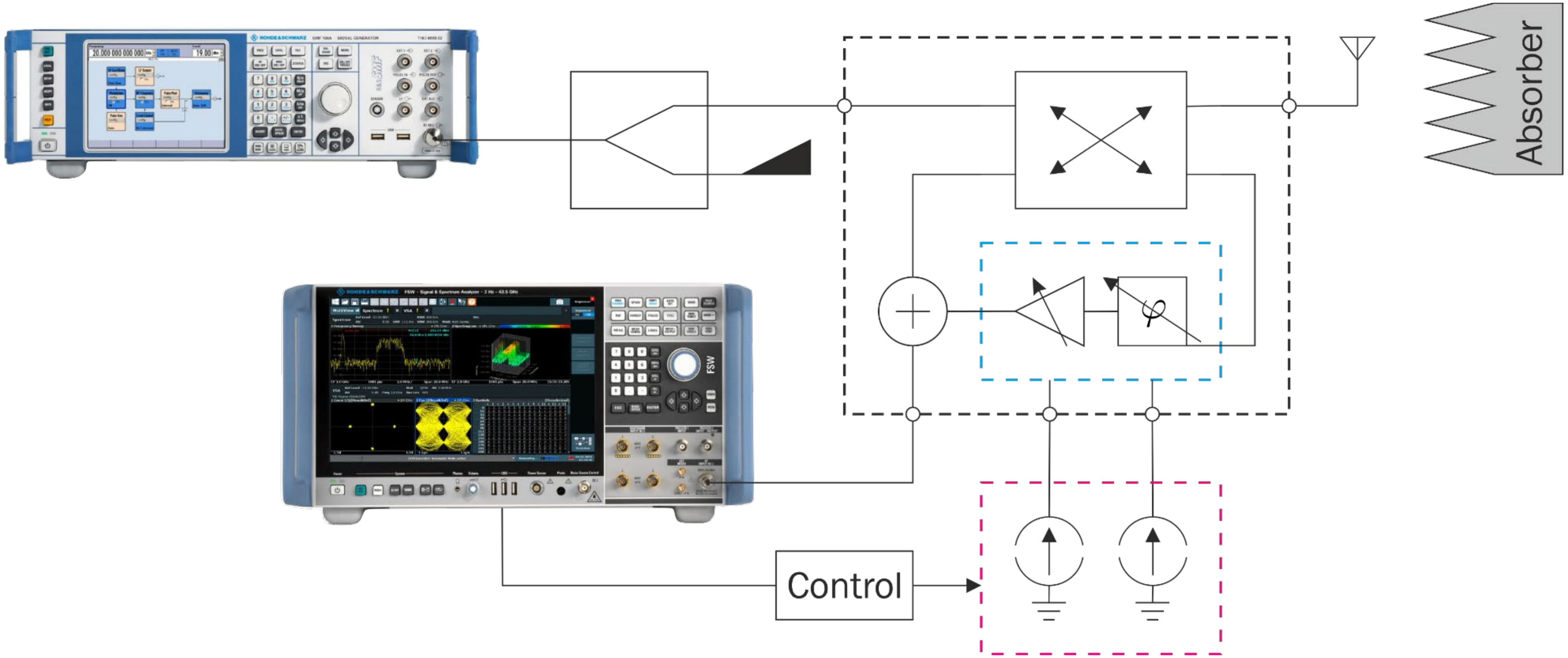
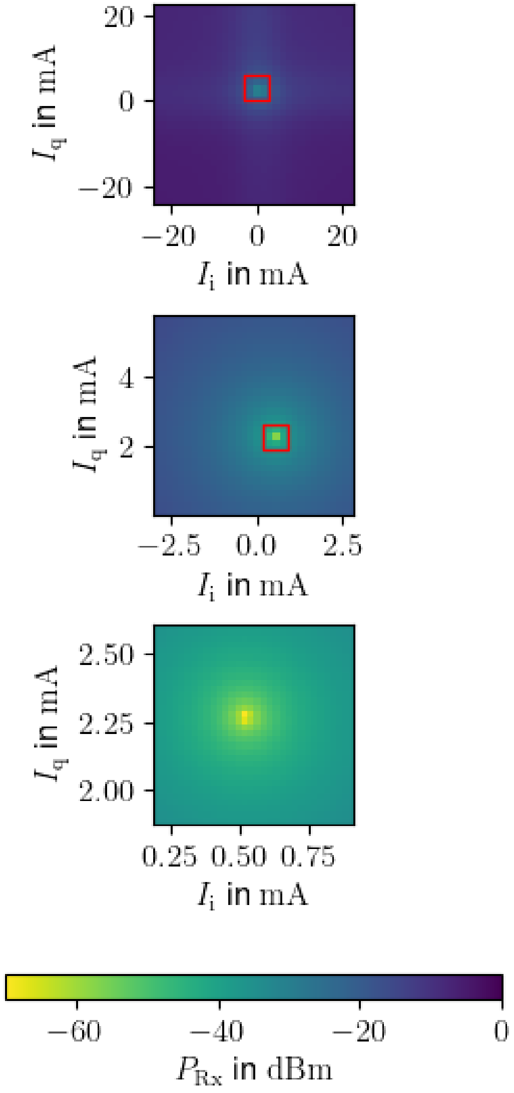
Pre-calibration

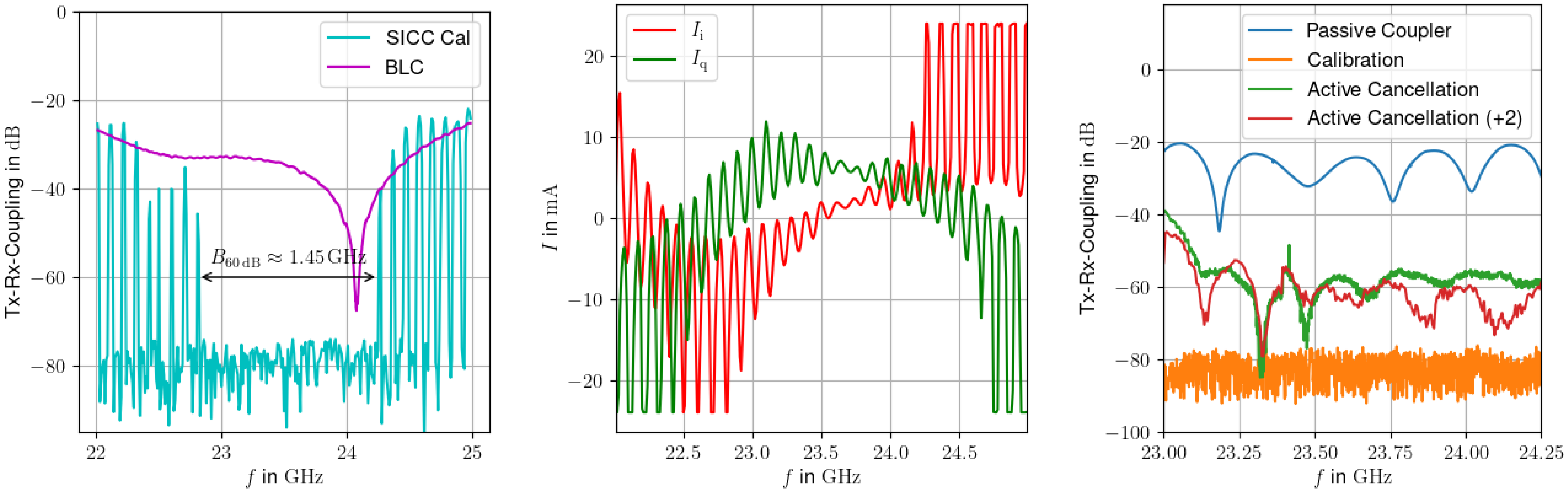
- $P_{\mathrm{Tx}} = 10\ \mathrm{dBm}$
- Iterative grid search for each frequency





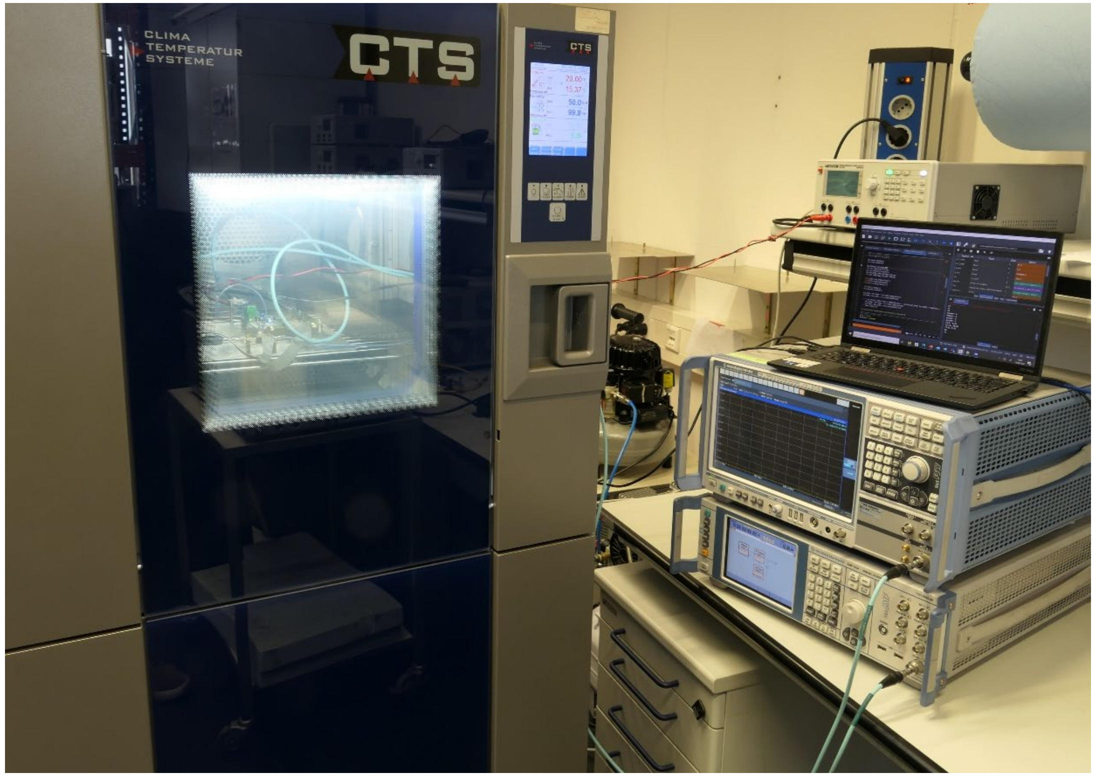
Isolation Measurements

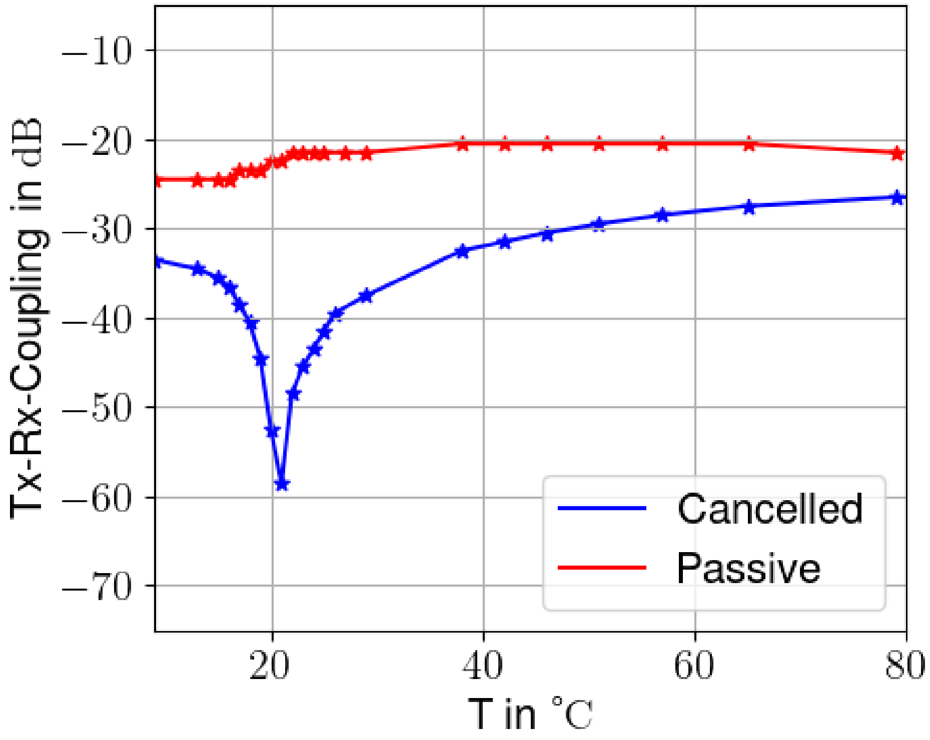
- Optimized IQ currents for $f = 22 \ldots 25\ GHz$
- Verification with time offset (2 days)



Isolation over Temperature

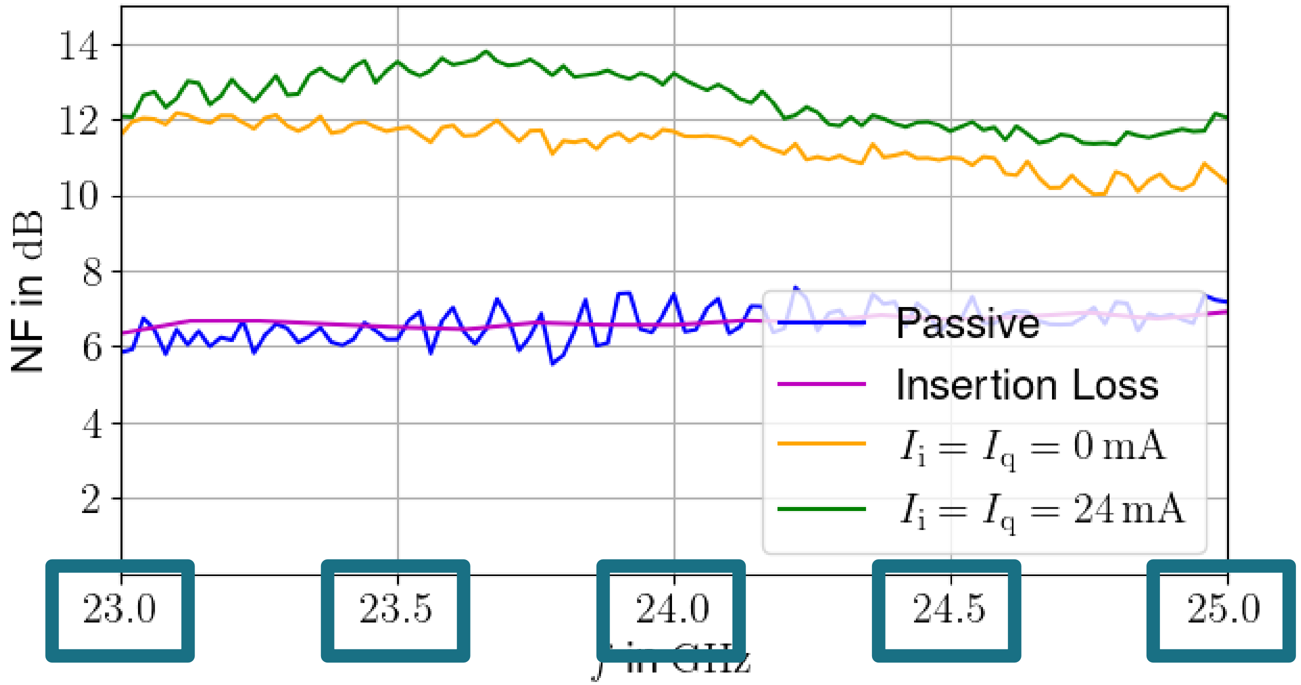
- Calibrated at 20 °C (68 °F)
- Constant rel. humidity ≈ 50 %
- $f = 24\ \mathrm{GHz}$

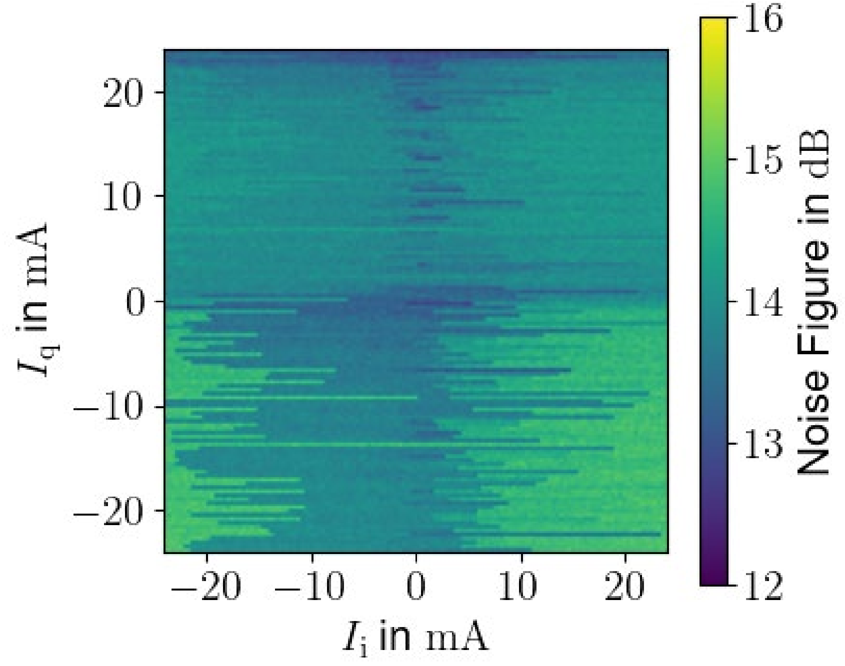




Noise Figure

- Measured with Y-factor method (R&S FSW43)
- Passive NF in accordance with insertion loss





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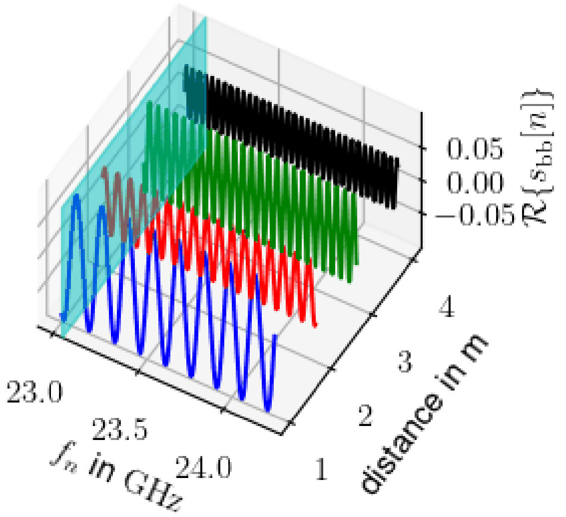
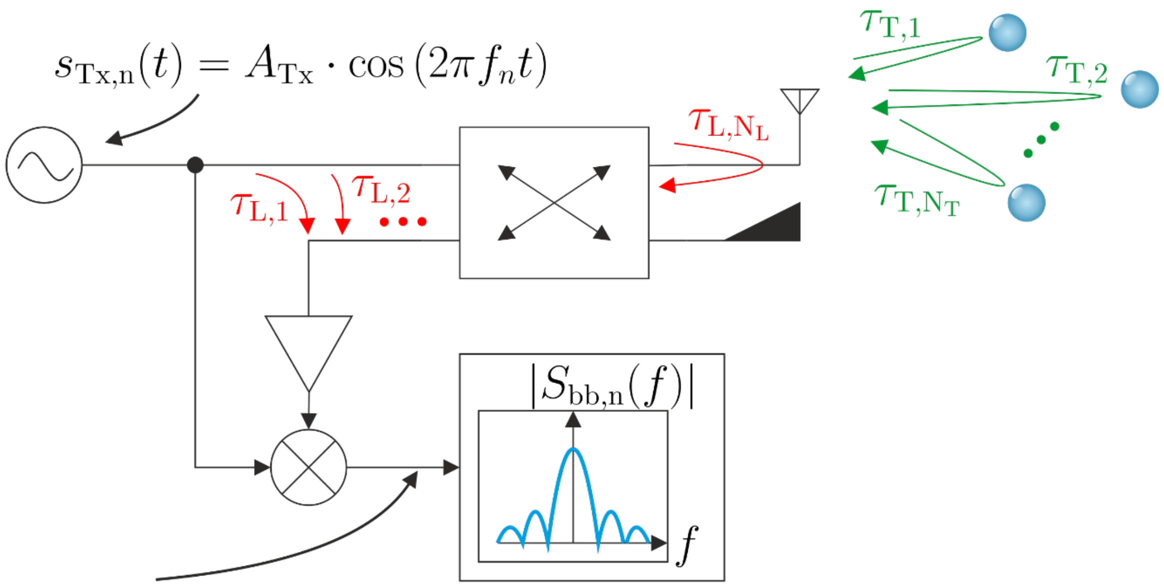
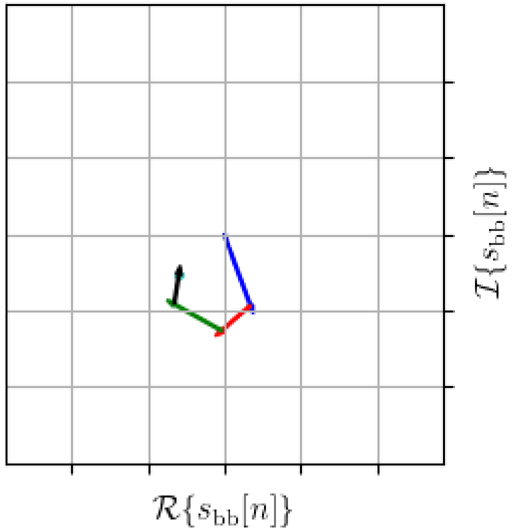
SFCW Recap

- Sampling the scene with stepped CW signals
- Information carried by complex phasor at DC



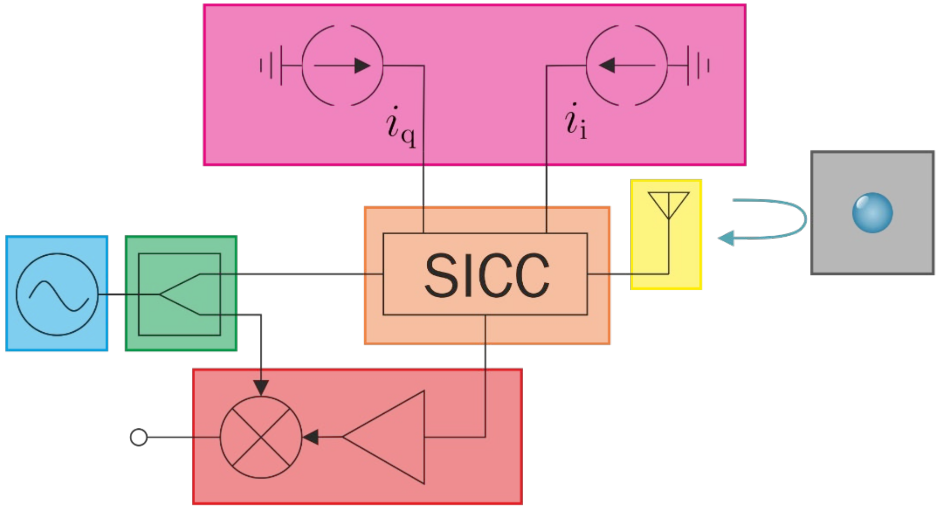


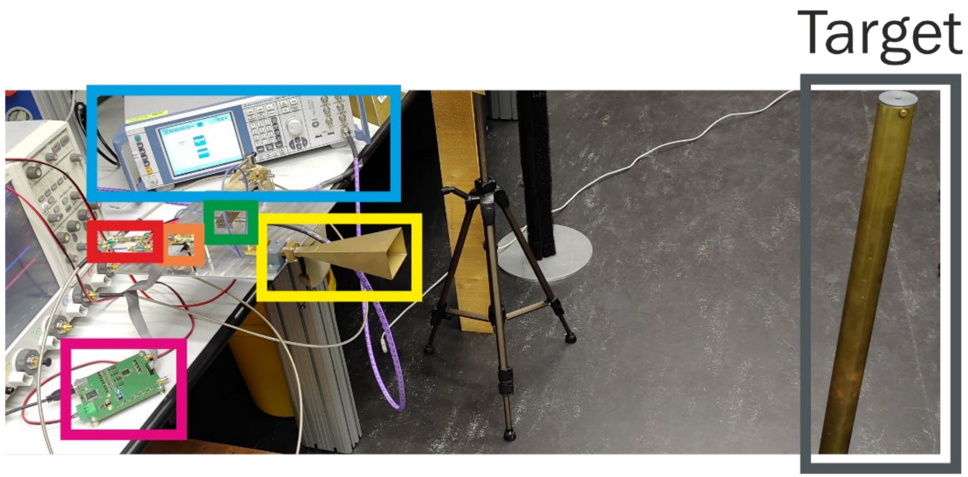


$$s_{bb}[n] = \sum_{i=1}^{N_L} A_{L,i} \cdot e^{-j2\pi f_n \tau_{L,i}} + \sum_{j=1}^{N_T} A_{T,i} \cdot e^{-j2\pi f_n \tau_{T,i}}$$

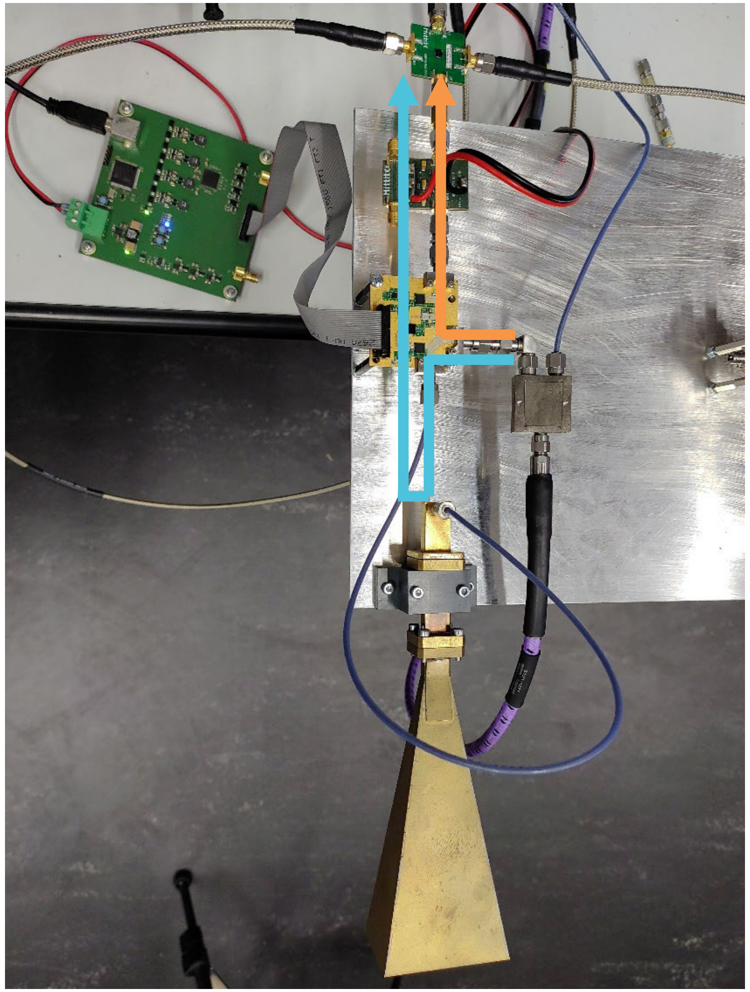
SFCW Measurement Results

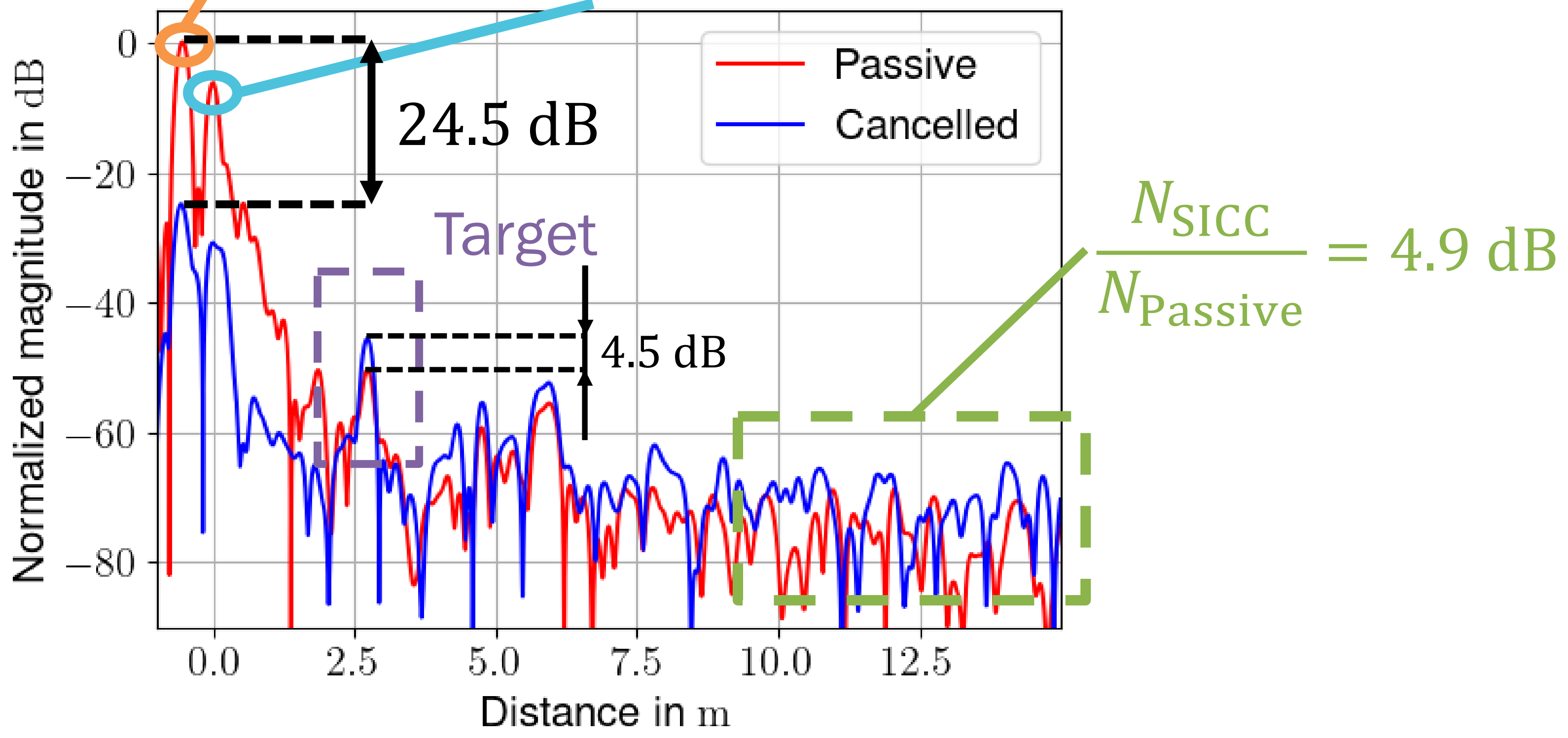
- Setup:
  - $f_n = 23 \dots 24.25\ \text{GHz}$
  - $\Delta f = 5\ \text{MHz} \rightarrow R_{\text{max}} \approx 30\ \text{m}$
  - $T_{\text{meas},n} = 10\ \text{ms}$
  - $P_{\text{Tx}} = 10\ \text{dBm}$
  - Target: metal rod
    - $d_1 = 2.56\ \text{m}$
    - $d_2 = 0.40\ \text{m}$



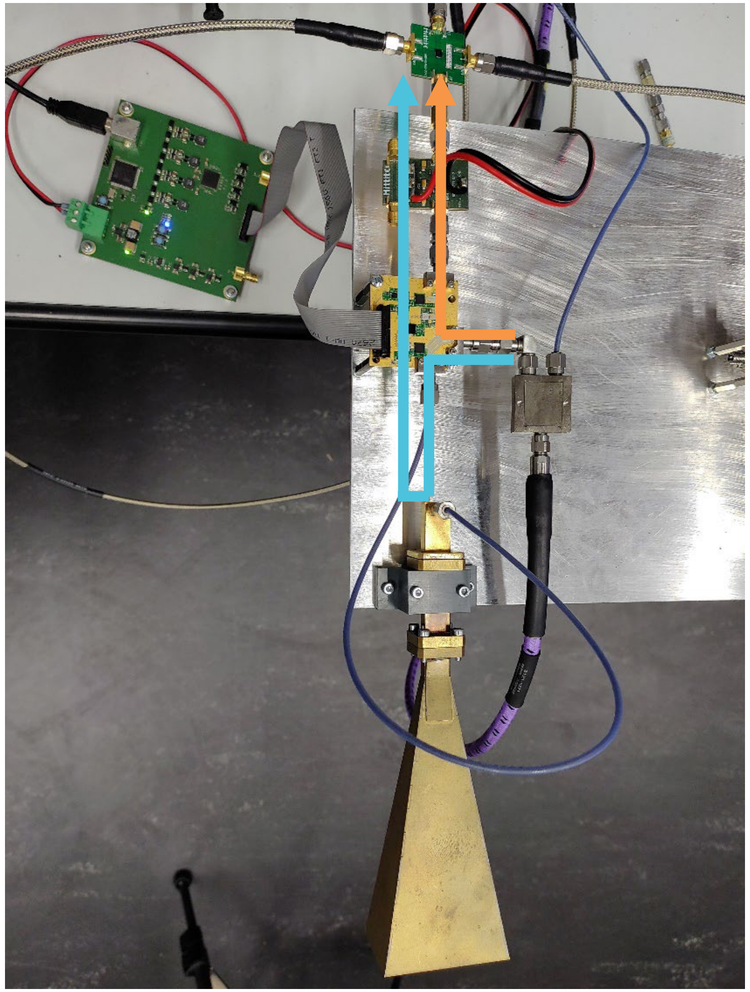


SFCW Measurement Results

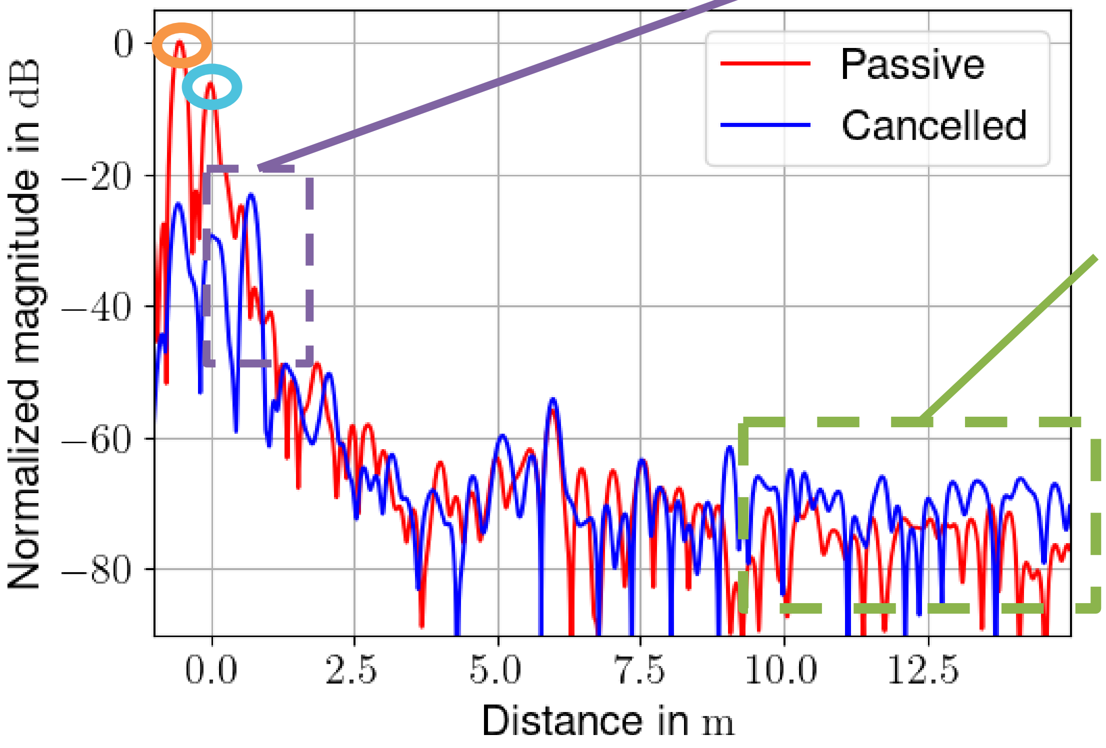




SFCW Measurement Results



Target (covered by leakage for passive coupler)



$$\frac{N_{\mathrm{SICC}}}{N_{\mathrm{Passive}}} = 5.2\ \mathrm{dB}$$

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- What should we take from the presentation
  - Self-interference may affect receiver gain
  - System concepts of SICC
  - Environmental influence on calibration
  - Degradation of rx noise figure
  - Usability depends on radar scenario ($\mathrm{NF} \leftrightarrow G_{\mathrm{Rx}}$)

Summary

- What needs to be evaluated?
  - Adaptive cancellation control between radar measurements
  - Quantitative measure of SICC usability
  - Extend for usage in FMCW radars
  - Account for degradation of receiver linearity due to self-interference