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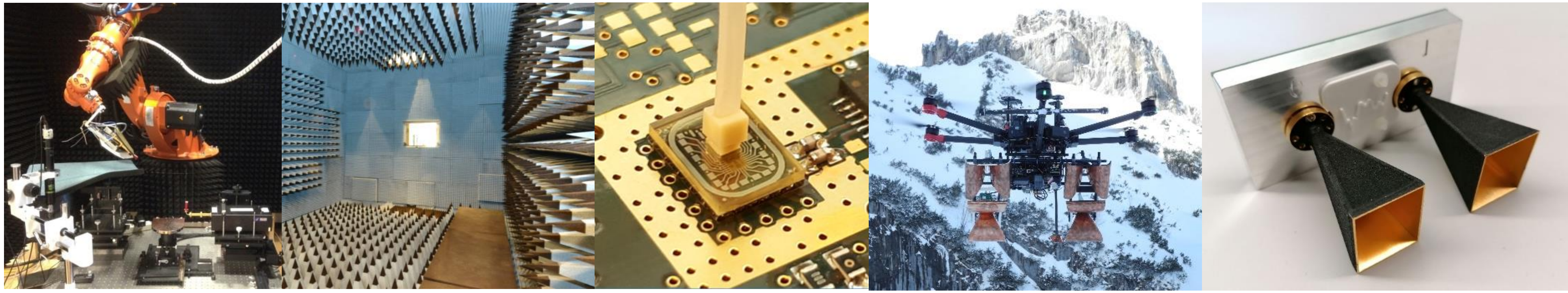
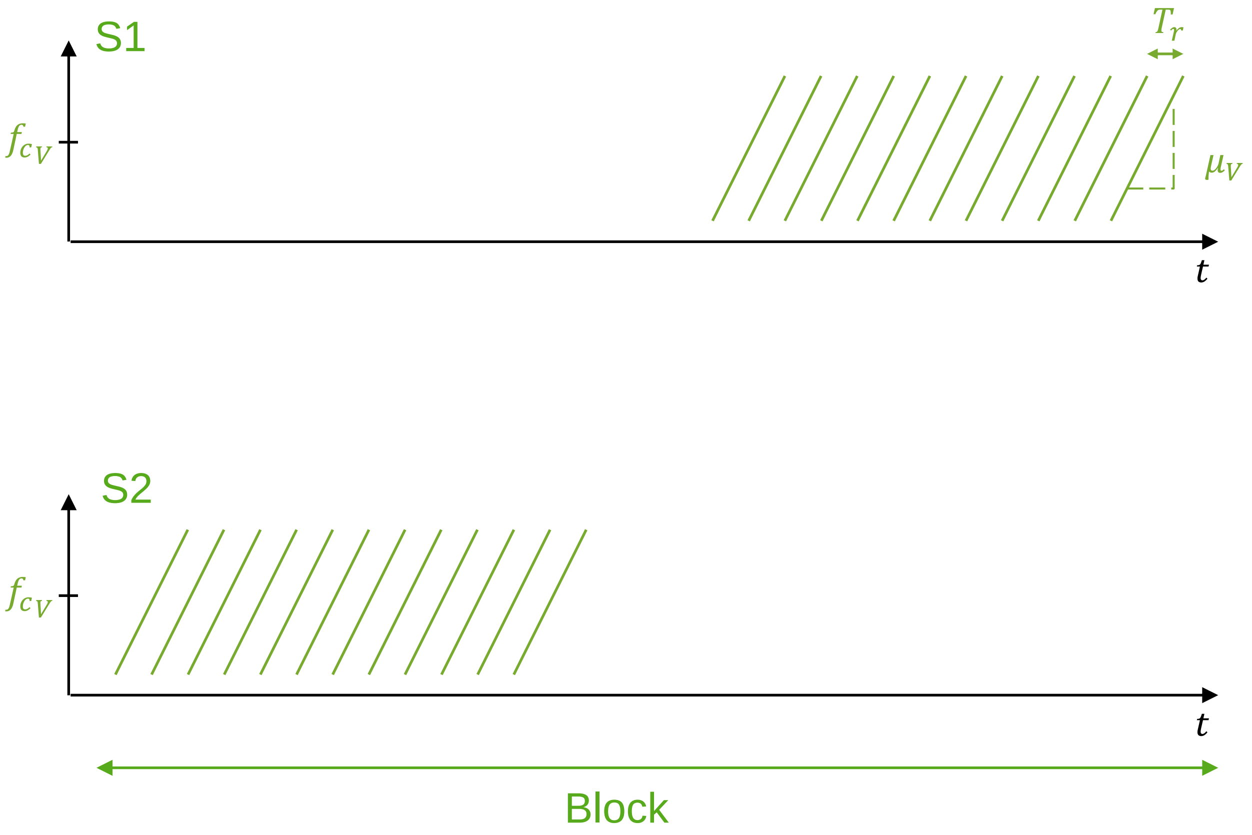


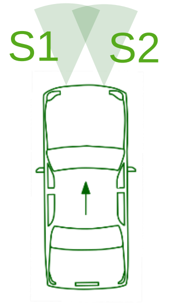
Interference mitigation using radar sensor networks

Lizette Lorraine Tovar Torres

Multiple Sensors for Interference Suppression I

- Two victim sensors with same parameters f_{c_V}, μ_V, T_r

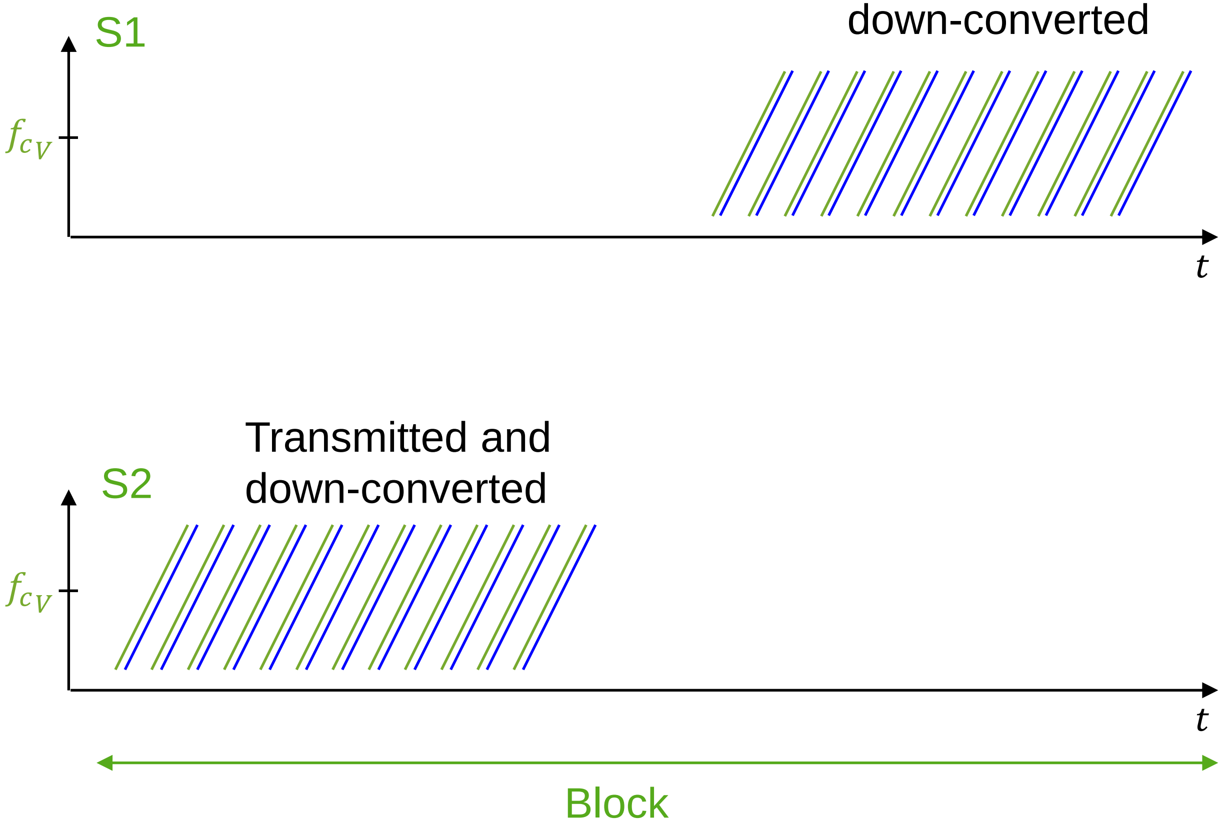


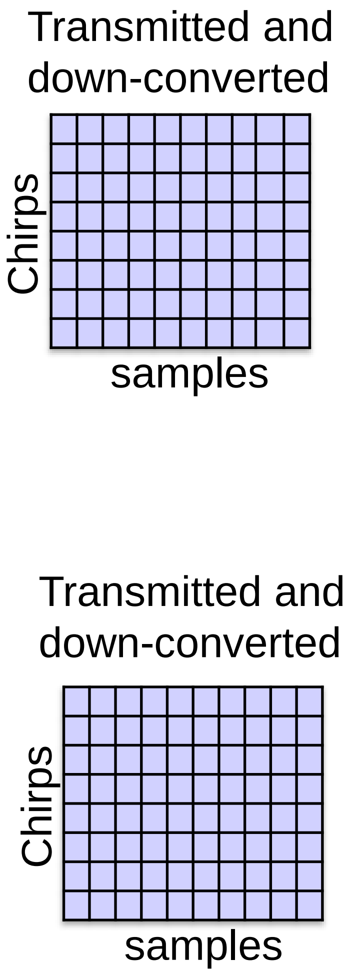


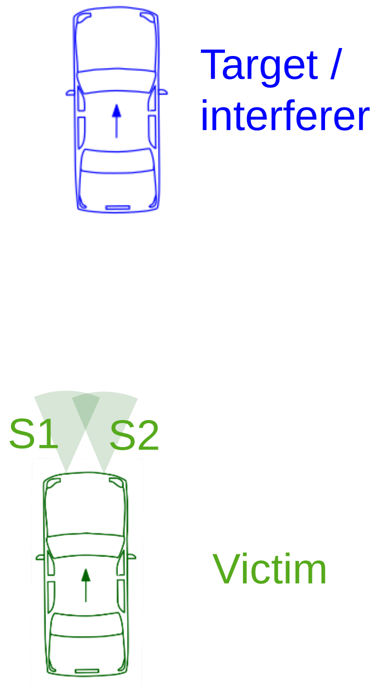
Victim

Multiple Sensors for Interference Suppression I

- Two victim sensors with same parameters f_{cV}, μ_V, T_r







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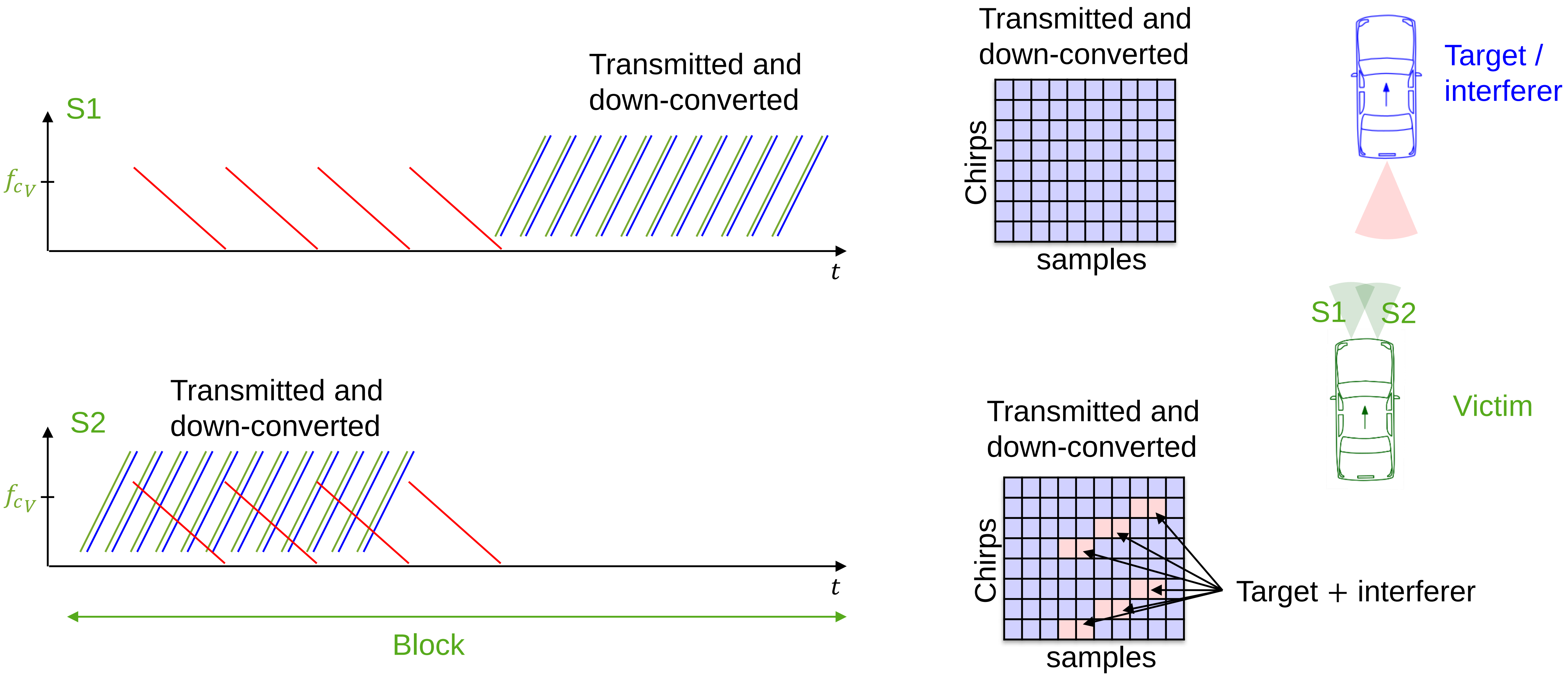
Multiple Sensors for Interference Suppression II

- Two victim sensors with same parameters $f_{c_V},\ \mu_V, T_r$



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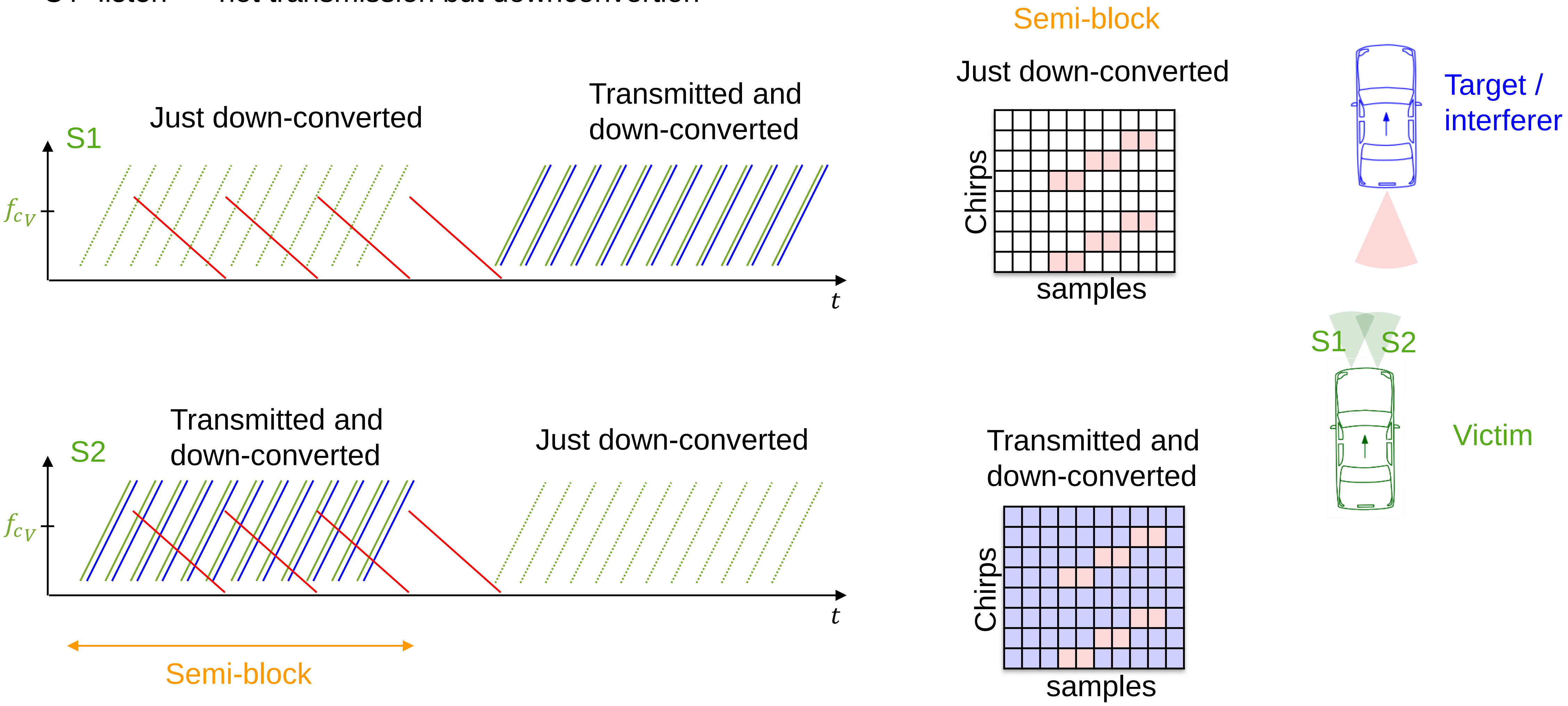
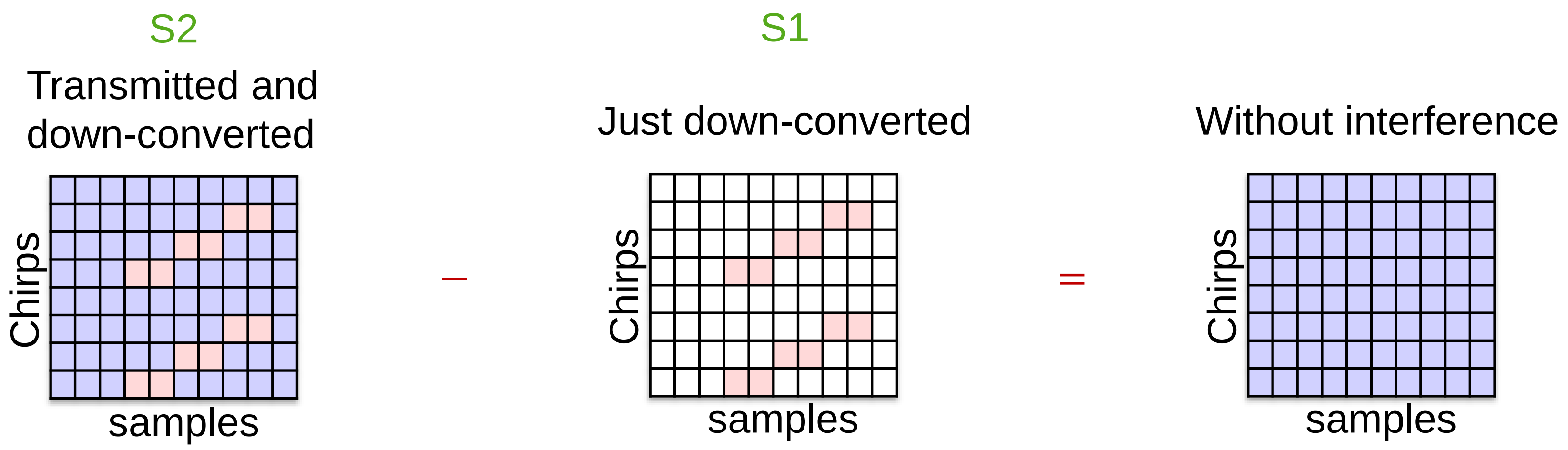
Multiple Sensors for Interference Suppression III

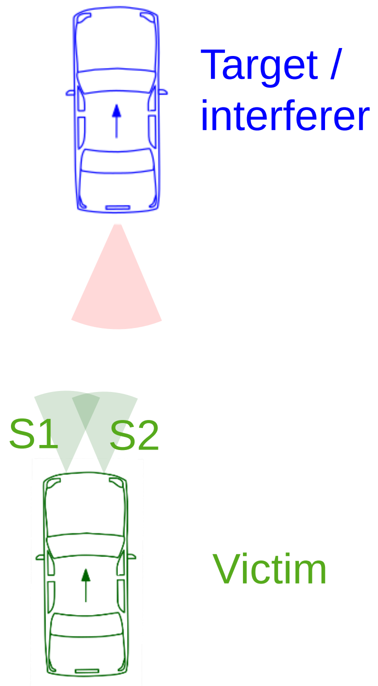
- S1 “listen” → not transmission but downconvertion



Multiple Sensors for Interference Suppression IV

- Perform subtraction (time or frequency?)





- Works if the interferers information is exactly the same in S1 and S2
  - Interferers range is not the same
  - S1 and S2 are not exactly the same
    - Oscillator
    - PLL

Challenges – Sensor Differences I

$$\Delta\mu = \mu_{\mathrm{I}} - \mu_{\mathrm{V}}$$

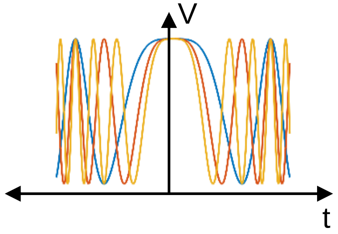
$$\Delta f_c = f_{c_{\mathrm{I}}} - f_{c_{\mathrm{V}}}$$

$$\varphi_{IF_1}(t) = 2\pi\left(\underbrace{\left(\frac{\Delta\mu}{2} - \mu_I\frac{V}{c}\right)}_{a}t^2 + \underbrace{\left(\Delta f_c - f_{c_I}\frac{V}{c} - \frac{\mu_I}{c}R\right)}_{b}t + \underbrace{\left(-\frac{f_{c_I}}{c}R\right)}_{c}\right)$$

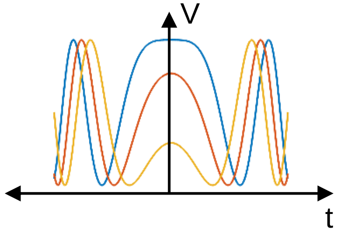
$$= 2\pi\left(a\left(t - \underbrace{\left(-\frac{b}{2a}\right)}_{e}\right)^2 + \underbrace{\left(c - \frac{b^2}{4a}\right)}_{g}\right)$$

$$= 2\pi(\ a(t-e)^2 + g\ )$$

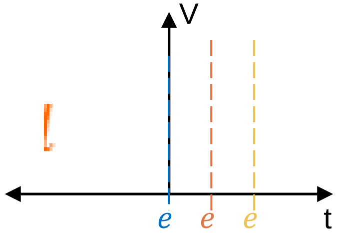
$$\cos(\ at^2) \rightarrow \Delta\mu$$

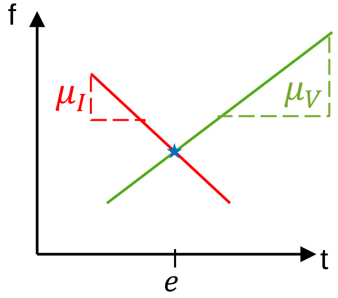


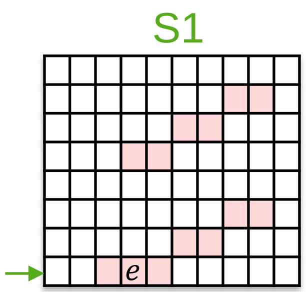
$$\cos(\ t^2 + g\ ) \rightarrow \Delta\mu, \Delta f_c, R$$



$$\cos(\ (t-e)^2) \rightarrow\ \Delta\mu, \Delta f_c, R$$

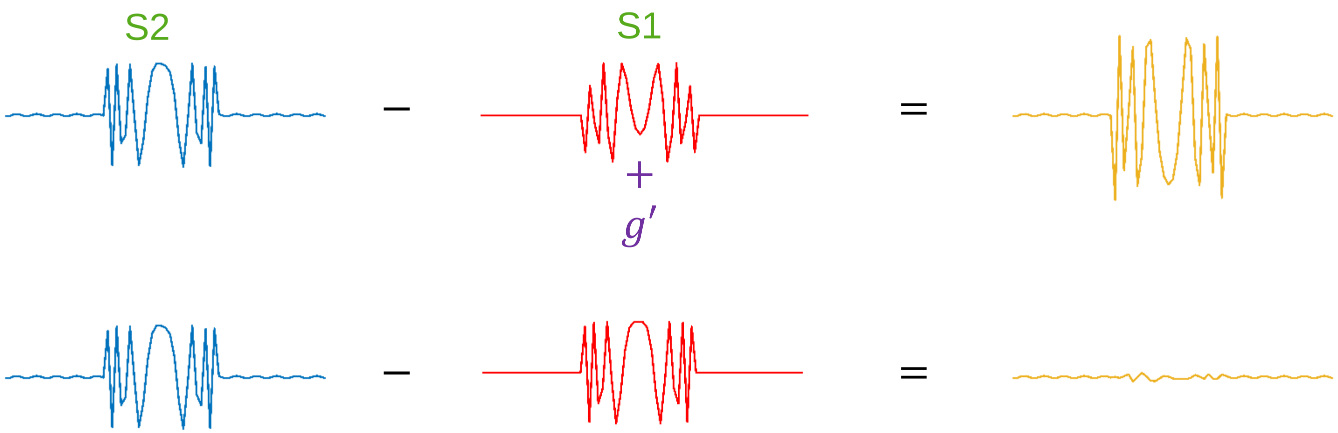




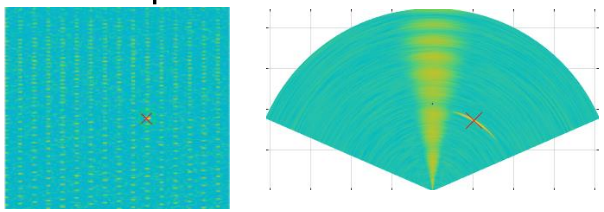


Challenges – Sensor Differences II

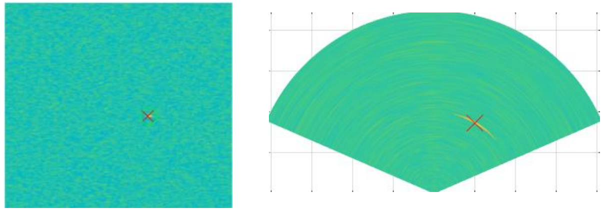
- Interferers are not placed at the same distance of S1 and S2
  - Interferers range → R $\varphi_{IF_1}(t) = 2\pi(\ a(t-e)^2 + g\ )$
  - very small path difference, the interferer center e is not moved $\varphi_{IF_1}(t) = 2\pi(\ a(t-e)^2 + g\ )$
  - Add g' to correct the phase difference introduced by R



- S2 not repaired



- S2 repaired



Works for multiple targets too ☺ ☺

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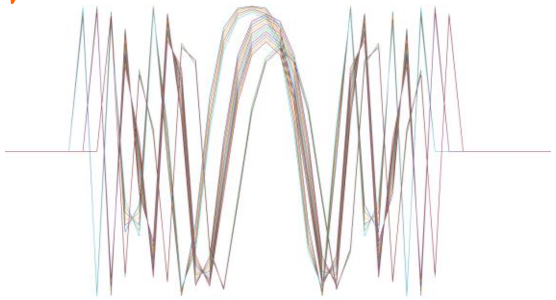
Challenges – Sensor Differences III

- Victim sensors S1 and S2 are not exactly the same
  - Parameter variation → f_{c_V}, μ_V $\quad \varphi_{IF_1}(t) = 2\pi(\ a(t-e)^2 + g\ )$
  - Frequency Stability $25\ \mathrm{ppm} \rightarrow 2\ \mathrm{MHz}$

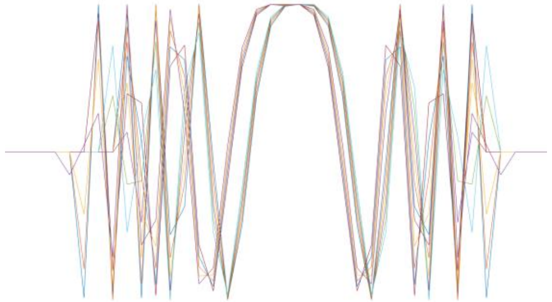
$f_{c_V} \rightarrow 77\ \mathrm{GHz} : 100\ \mathrm{KHz} : 77.002\mathrm{GHz}$



$\varphi_{IF_1}(t) = 2\pi(\ a(t-e)^2 + g\ )$

$e \rightarrow 1-3$ samples

$\mu_V \rightarrow B_V \rightarrow 1\ \mathrm{GHz} : 50\ \mathrm{MHz} : 1.5\ \mathrm{GHz}$



$\varphi_{IF_1}(t) = 2\pi(\ a(t-e)^2 + g\ )$

$a, e \rightarrow$ neglected

- Phase noise?
- PLL phase difference?

However, not all the samples of S1 are used!

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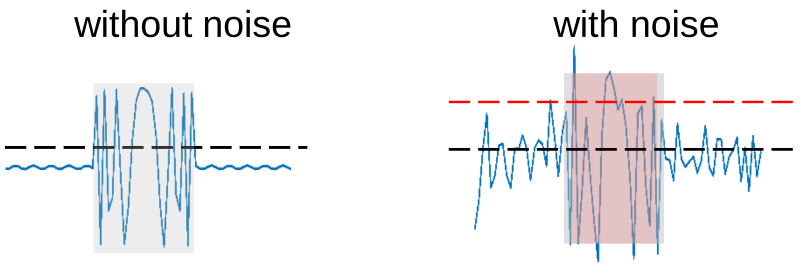
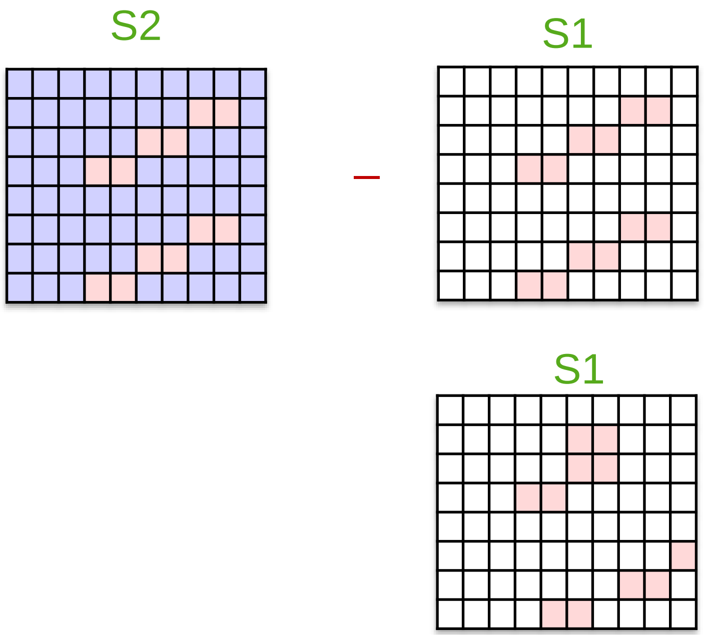
Challenges – Sample Association

- Reliable interference detection
  - Neglected affected samples
  - Weak interference not detected

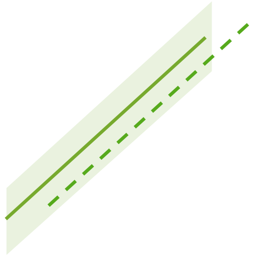


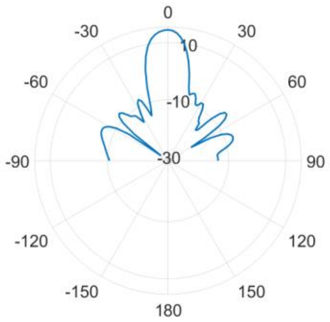
- Association of affected samples in S1 and S2
  - Missing or added affected samples
  - Shifted position of affected samples
  - Multiple interferers

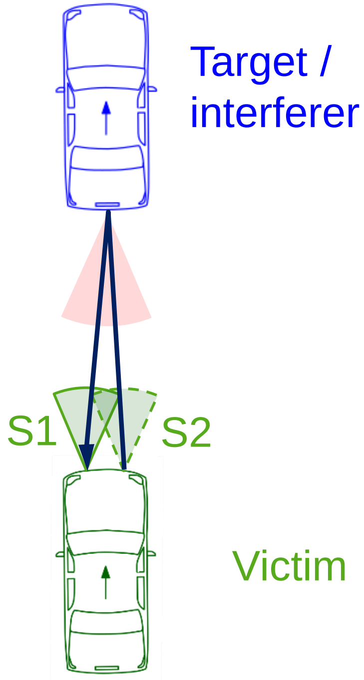


Challenges – Sensor Interaction

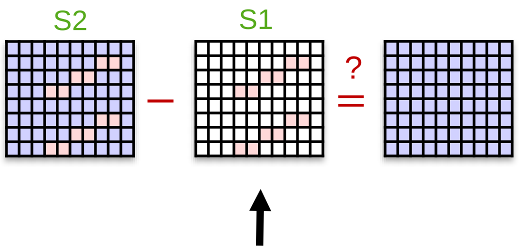
- Self interference between S1 and S2
  - Possible ghost target → known
  - $\mu_{V1} \neq \mu_{V2}$ → ?
  - Not strong influence because of FoV







- Bistatic measurement of S1: S2-target-S1
  - S1 contains also target information → problem?
    - Attenuated
    - Twice the range
  - Subtract just the affected cells

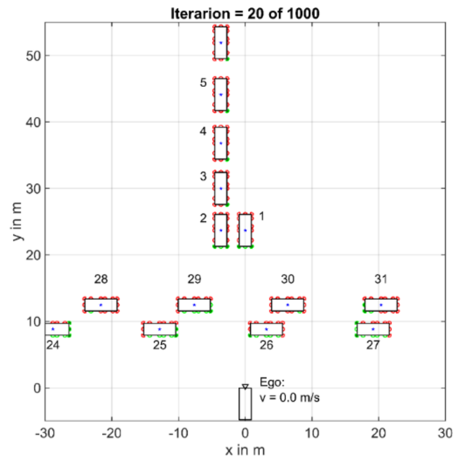


Does not contain ONLY the interferer information

Multiple Sensors for Interference Suppression - Calendar

Grantt Chart	Start	End	##	2021												2022									
			D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O
Two Sensors for Interference Suppression																									
* Simulation for two victim sensors																									
* Reliable Interference detection methods																									
* Interference phase correction due to path difference																									
* Incoherent sensor network under interference - Slope and fc variation - Phase noise - Phase difference in the PLL																									
* Mutual interference and ghost target analysis																									
* Influence of bistatic measurement of S1: S2-target-S1																									
* Measurements																									

Backup Slides

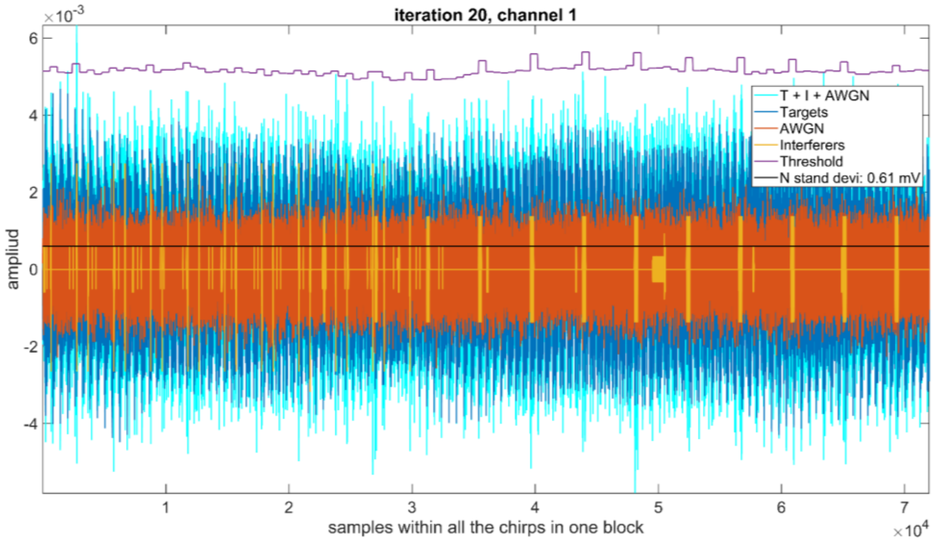


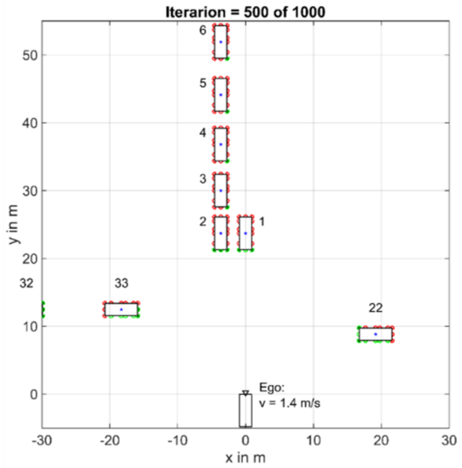
Interference information:

block 1: 5 of 30 sensors are actually interfering the MRR victim sensor

type	car_num	sen_pos	r	azi	Gr	azi_i	Gt	A_mV	num_int_spl	p_aff_spl	p_aff_splW
'MRR'	4	6	34.5	-4.6	20	-4.6	20	3.9	740	1	0.9
'SRR'	2	6	21.5	-7.4	19.9	-7.4	10	2	2938	4.1	4.8
'SRR'	6	6	49.6	-3.2	20	-3.2	10	0.9	383	0.5	0.5
'MRR'	24	1	27.6	-73.3	4.8	-3.3	20	0.9	910	1.3	1
'SRR'	27	8	19.4	59.9	10.5	-30.1	6.3	0.5	985	1.4	1.6

- % of interf samples per block without repetition: 8.18% of 72000 samples
- max interferernce power per block: -11.90dBm



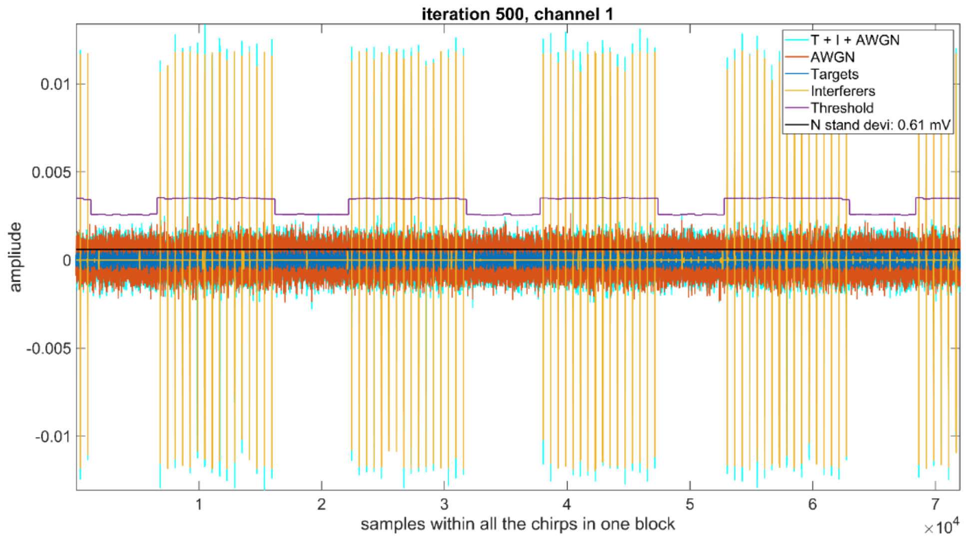


Interference information:

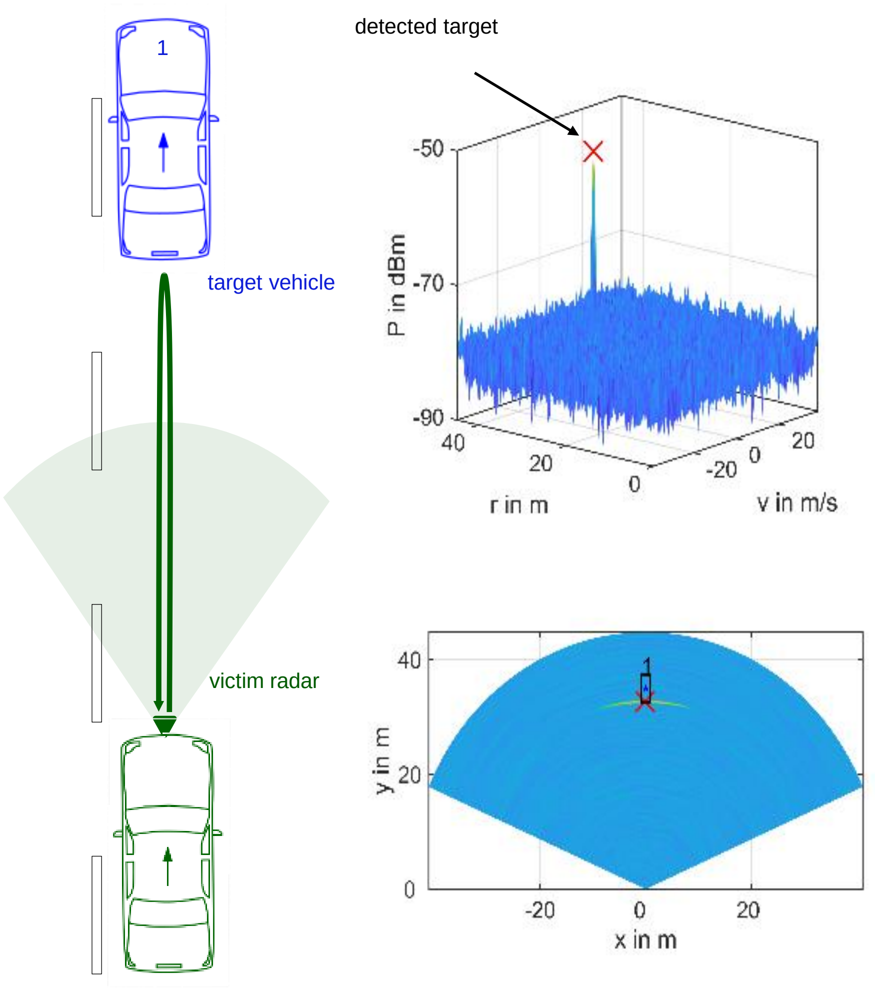
block 1: 6 of 34 sensors are actually interfering the MRR victim sensor

type	car_num	sen_pos	r	azi	Gr	azi_i	Gt	A_mV	num_int_spl	p_aff_spl	p_aff_splW
'LRR'	2	14	21.6	-9.7	19.8	-9.7	28.8	16.8	1679	2.3	4.7
'SRR'	6	13	49.6	-3.2	20	16.8	8.8	0.8	702	1	1
'LRR'	28	14	86.8	-81.7	3	8.3	21.3	0.3	465	0.6	0.7
'LRR'	31	14	45.6	-74.1	4.8	15.9	11.9	0.2	1102	1.5	2.6
'SRR'	24	8	49.7	78.7	2.2	-11.3	9.9	0.1	346	0.5	0
'SRR'	29	1	72.8	-80.9	3.3	-10.9	9.5	0.1	372	0.5	0.4

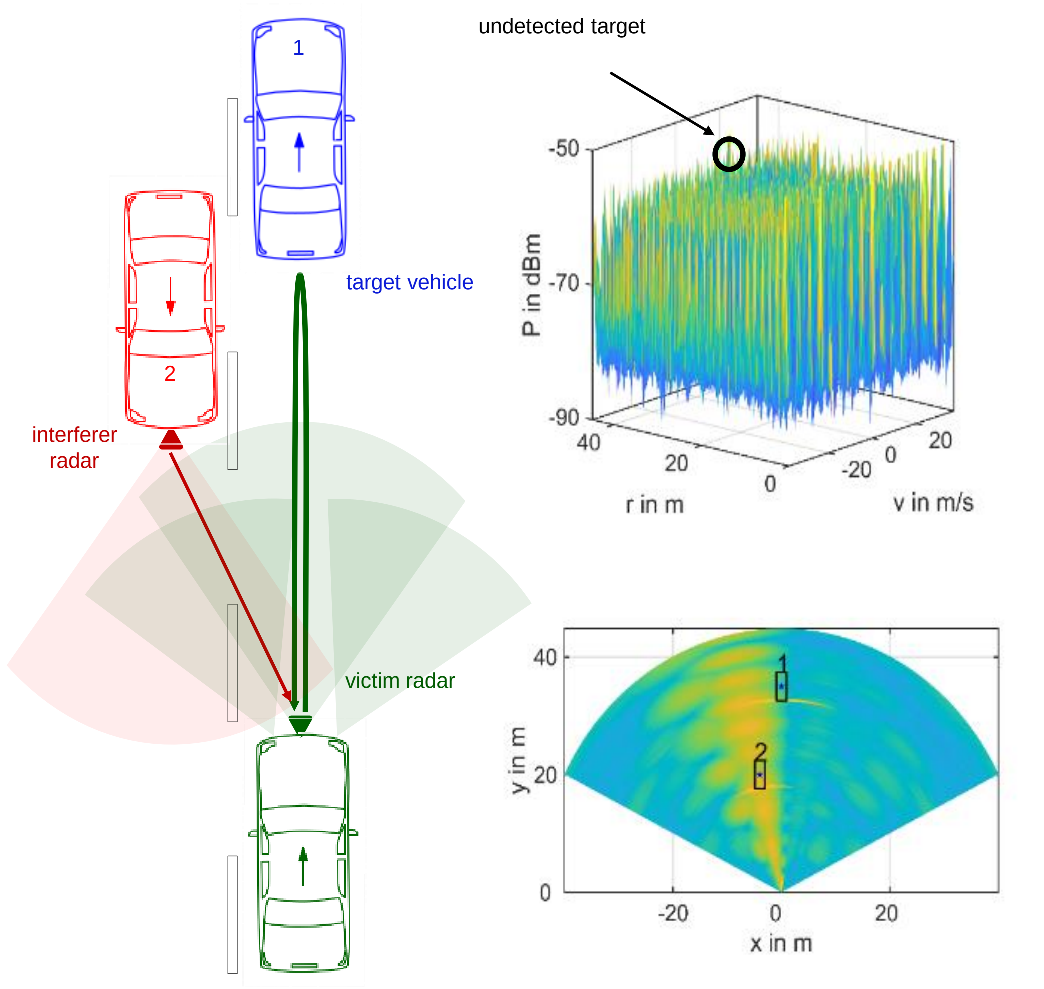
- % of interf samples per block without repetition: 5.96% of 72000 samples
- max interferernce power per block: -4.81dBm

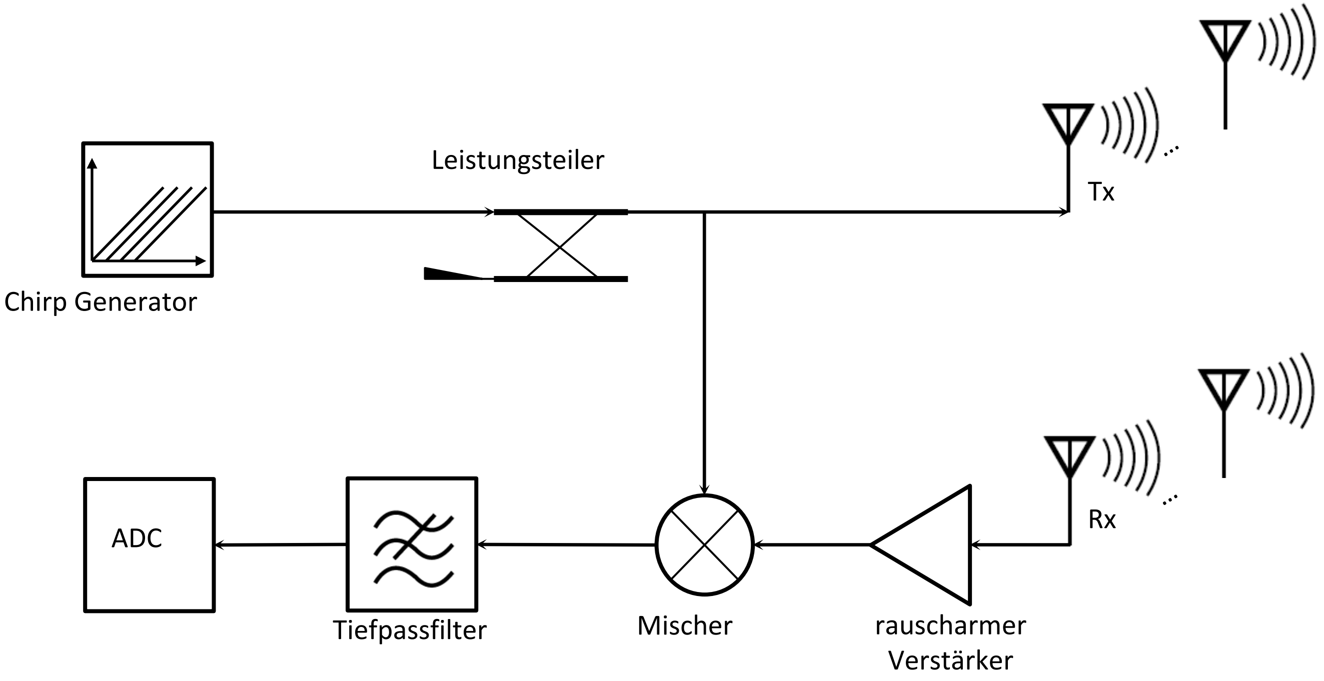


Without interference



With interference




Leistungsteiler
Tx
Chirp Generator
Rx
ADC
Tiefpassfilter
Mischer
rauscharmer
Verstärker