Low Cost Radar-Acquisation with USRP-N200 in Atmospheric Research

Nico Pfeffer

IAP/HS-Wismar

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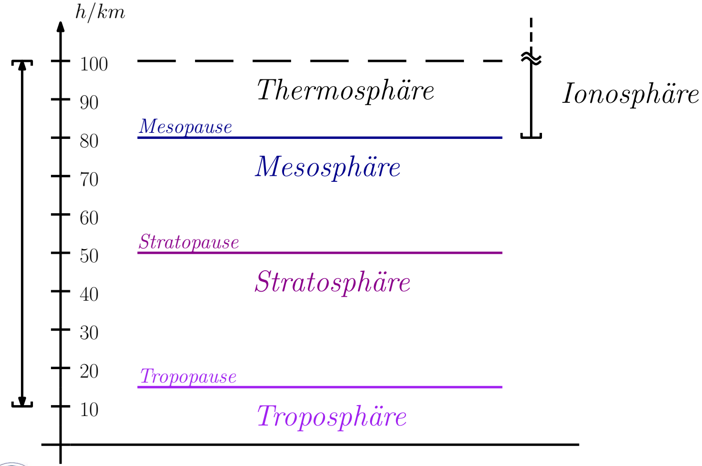
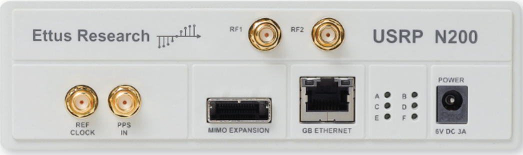

h/km
100
90
80
70
60
50
40
30
20
10
Thermosphäre
Ionosphäre
Mesopause
Mesosphäre
Stratopause
Stratosphäre
Tropopause
Troposphäre



- $f_{\mathrm{S,FPGA}} = 100\mathrm{MHz}$ Sample-Rate
- $f_{\mathrm{S,DAC}} = 400\mathrm{MHz}$ Sample-Rate
- $f_{\mathrm{TX}} \in \{0, 250\}\mathrm{MHz}$ (FPGA+DAC CORDIC)
- $f_{\mathrm{RX}} \leq 50\mathrm{MHz}\ (32.55\mathrm{MHz})$ no Aliasing
- $f_{\mathrm{RX}} \geq 50\mathrm{MHz}\ (53.50\mathrm{MHz})$ Aliasing

LEIBNIZ-INSTITUT FÜR ATMOSPHÄREN PHYSIK IAP

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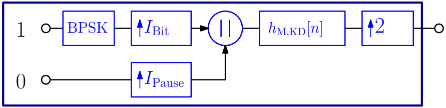
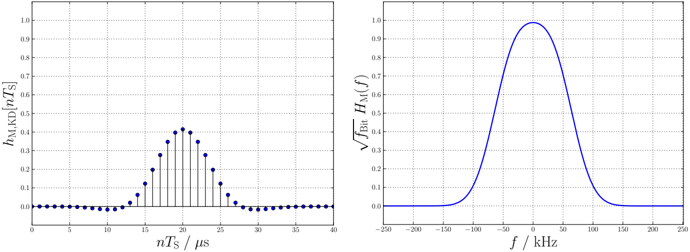
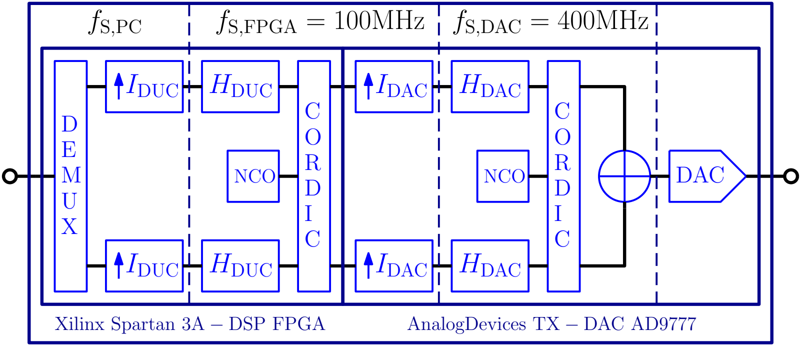


PC TX – Signal Synthesis

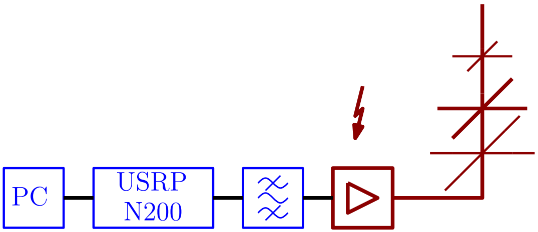


Transmitting with USRP-N200



USRP – N200 TX – Chain

Transmitting with USRP-N200



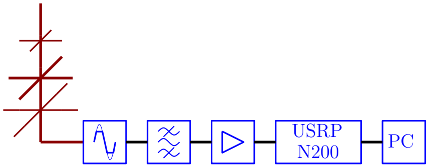
- Bandpass filters out DAC Spuries & Intermodulations
- Linear (Tube/Solid-State)-Amplifier up to 10kW

Nico Pfeffer pfeffer@iap-kborn.de IAP/HS-Wismar

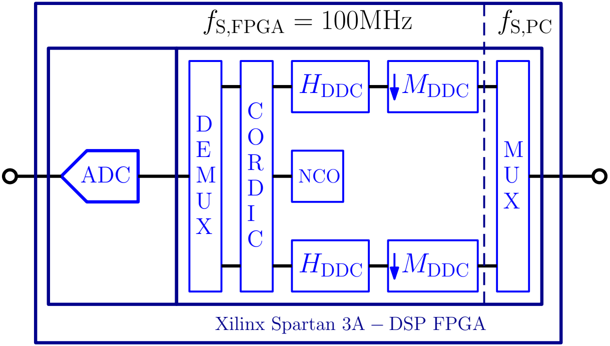
Signal Scatterer

- Clouds
- Airplanes
- Ground- / Sea-Clutter
- Inhomogenious Refractive-Index $n(\mathbf{r}, t)$
- Inhomogenious Electron-Densities $\rho(\mathbf{r}, t)$
- Plasma-Trail from Meteors

Receiving with USRP-N200



- Limiter cares about too much Input-Power
- Bandpass for unwanted Frequency components
- Pre-Amplifiers puts Signal-Amplitude up to Dynamic-Range of ADC



USRP – N200 RX – Chain

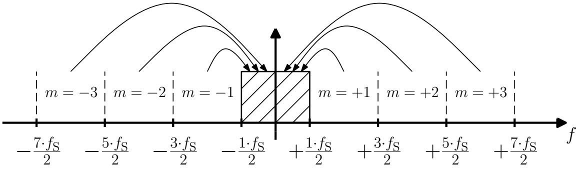
Receiving with USRP-N200

- the received analog signal with $f_{\mathrm{RX}}(\mathbf{r}, t) = f_{\mathrm{CF}} + f_{\mathrm{D}}(\mathbf{r}, t)$ is:

$$
\begin{aligned}
u_{\mathrm{E}}(t) &= \hat{u}_{\mathrm{E}}(t)\ \Re\{e^{\,2\pi j \cdot f_{\mathrm{RX}}(\mathbf{r},t)\cdot t}\ e^{\,j\cdot\varphi_{\mathrm{RX}}(t)}\} + w_{\mathrm{E}}(t) \\
&= \hat{u}_{\mathrm{E}}(t)\ \Re\{e^{\,2\pi j \cdot f_{\mathrm{CF}}\cdot t}\ e^{\,2\pi j \cdot f_{\mathrm{D}}(\mathbf{r},t)\cdot t}\ e^{\,j\cdot\varphi_{\mathrm{RX}}(t)}\} + w_{\mathrm{E}}(t)
\end{aligned}
$$

- when the signal is sampled by the ADC with $f_{\mathrm{S,FPGA}} = f_{\mathrm{S}}$ the following situation can happen:

$$
f_{\mathrm{CF}} = const = \begin{cases} f_{\mathrm{DDC}} & \text{, no aliasing} \\ f_{\mathrm{DDC}} + m\, f_{\mathrm{S}} & \text{, aliasing for } m \in \mathbb{Z}\backslash\{0\} \end{cases}
$$



- and the Center-Frequency for Down-Conversion is:

$$\frac{(2m-1)f_S}{2} < f_{CF} < \frac{(2m+1)f_S}{2}$$

$$f_{DDC} = f_{CF} - \underbrace{\left\lfloor \frac{2f_{CF} - f_S}{2f_S} \right\rceil}_{=m} f_S$$

- the sampled signal is:

$$u_{\mathrm{E}}[n] = \hat{u}_{\mathrm{E}}[n]\ \Re\{e^{2\pi j \cdot f_{\mathrm{DDC}} T_{\mathrm{S}} \cdot n}\ e^{2\pi j \cdot f_{\mathrm{D}}[\mathbf{r}, nT_{\mathrm{S}}]\, T_{\mathrm{S}} \cdot n}\ e^{j \cdot \varphi_{\mathrm{RX}}[n]}\} + w_{\mathrm{E}}[n]$$

- after passing the Cordic, the signal is:

$$\underline{u}_{\mathrm{BP}}[n] = u_{\mathrm{E}}[n]\ \hat{u}_{\mathrm{DDC}}\ e^{2\pi j \cdot f_{\mathrm{DDC}} T_{\mathrm{S}} \cdot n}\ e^{j \cdot \varphi_{\mathrm{DDC}}} + \underline{w}_{\mathrm{BP}}[n]$$

- which includes the *baseband* and $2 f_{\mathrm{DDC}}$ component
- $2 f_{\mathrm{DDC}}$ vanishes by passing the Decimation-Filter

- the Baseband-Signal can be described by:

$$\underline{u}_{\mathrm{BB}}[n] = \hat{\underline{u}}_{\mathrm{BB}}[n]\ e^{\,2\pi j\cdot f_{\mathrm{D}}[\mathbf{r},n]\,T_{\mathrm{S}}\cdot n} + \underline{w}_{\mathrm{BB}}[n] \quad \circ\!\!-\!\!\bullet \quad \underline{U}_{\mathrm{BB}}(f - f_{\mathrm{D}}[\mathbf{r},n])$$
$$= I_{\mathrm{BB}}[n] + j\cdot Q_{\mathrm{BB}}[n]$$

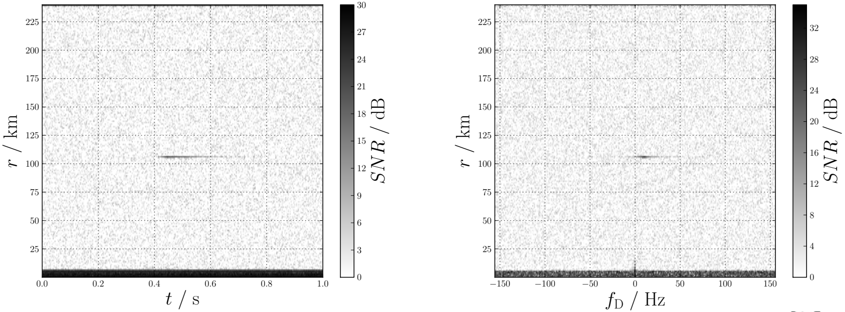
- with the Soft-Condition:

$$|f_{\mathrm{D}}[\mathbf{r},n]| < \frac{f_{\mathrm{S,PC}}}{2}$$

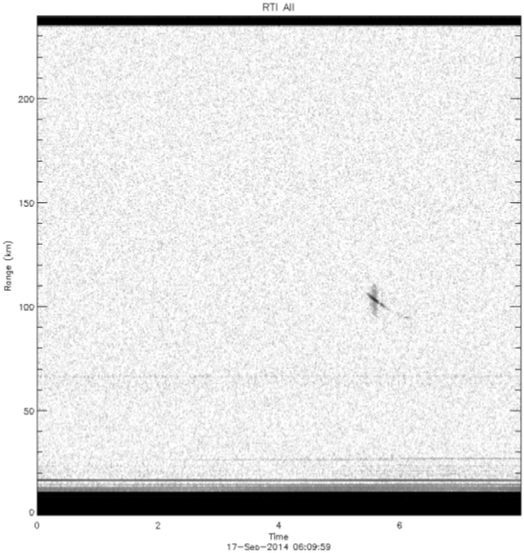
- and with the Hard-Condition:

$$|f_{\mathrm{D}}[\mathbf{r},n]| < f_{\mathrm{cutoff,matched}}$$

Results


r / km
t / s
SNR / dB
0.0
0.2
0.4
0.6
0.8
1.0
25
50
75
100
125
150
175
200
225
0
3
6
9
12
15
18
21
24
27
30
r / km
f_D / Hz
SNR / dB
−150
−100
−50
0
50
100
150
0
4
8
12
16
20
24
28
32

Results



Future

- Interferometry (Range $\rightarrow$ Altitude $\rightarrow$ $\mathbf{v}(\mathbf{r}, t)$)
- Fluctuation Estimation (realtime Coherent- and Incoherent-Integration)
- Deconvolution of overlapped echos
- Spread Spectrum (M-Sequence PRBS - CW)
- Digital Beamforming
- High resolution MST-radar

Future

THANK YOU