

USRP N210 + UBX40 Filter Test

Characteristics of a 20Mhz Filter (after Mixer, before ADC)

*This is being done by Mr.Aragon.

Experiment Design

Fixed:

- Input Signal (sine wave)
- RF frequency (f_c) (but with different f_c for different iterations)

Independent Variable:

- DSP frequency (f_{DSP}), Local oscillator frequency (f_{LO}), such that:

$$f_c = f_{DSP} + f_{LO}$$

Dependent Variable:

- Power Level (dB)

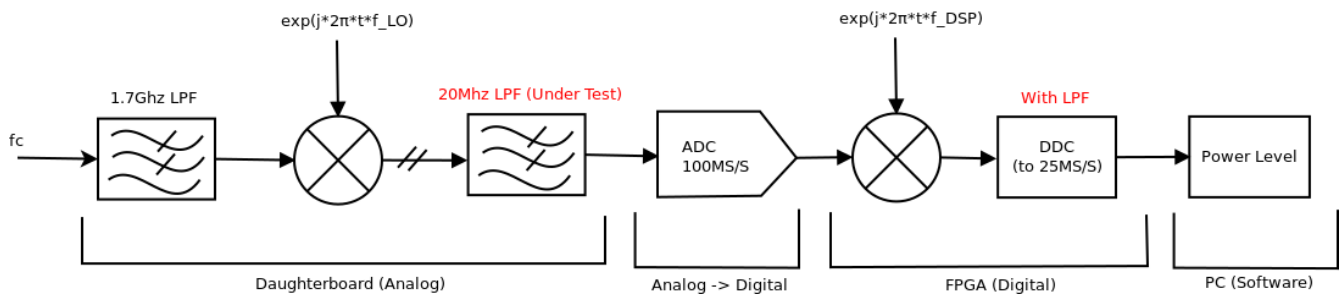


Figure 1. Block Diagram of the System (for 20Mhz LPF testing).

*Above diagram assumes 900Mhz RF frequency with 25MS/s effective sampling rate. UBX board may use different paths for different settings. For an example, that 1.7Ghz low-pass filter is only applicable when the RF frequency is equal to or lower than 1.5Ghz.

Full block diagram of the UBX board is available at :

https://www.ettus.com/content/files/UBX_Data_Sheet.pdf .

Results

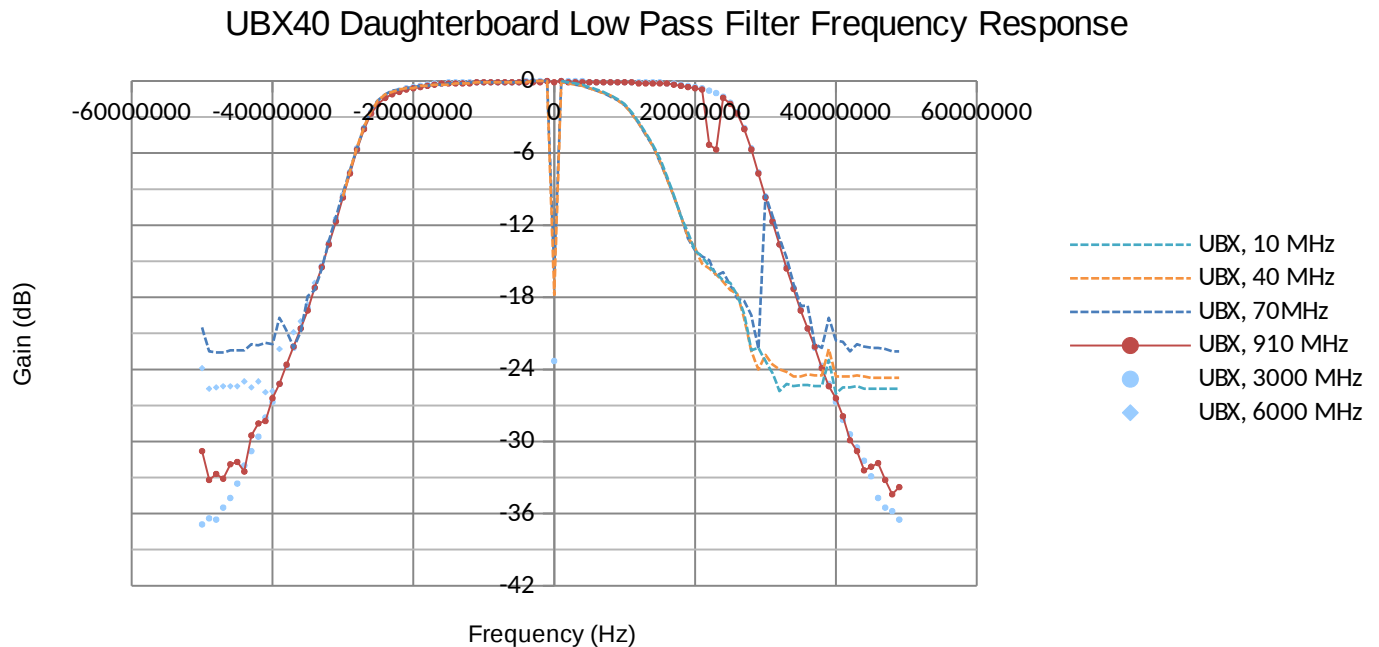


Figure 2. Frequency Response of the 20Mhz Filter

*Observed frequency response of the low pass filter for the 10~70Mhz and 910-6000Mhz RF frequency are significantly different. Mr.Aragon is investigating this issue.

Conclusion

- The frequency response of the low pass filter at 50Mhz is -30~ -36dB.
- There are unexpected variations in the results (dependence on the RF frequency). Mr.Aragon is investigating the reason.

Characteristics of the DDC Filter

Since the signal output from the ADC is not aliased significantly (at least for the 900Mhz range which was tested), frequency response of the DDC's low pass filter can be approximated by measuring the frequency response of the USRP N210 + UBX daughterboard system itself.

Experiment Design

Fixed:

- Input Signal (sine wave) : approx. 903Mhz with amplitude approx. 45dB higher than the noise floor of the receiver.

Independent Variable:

- Local oscillator frequency (f_{LO})

* $f_{DSP} = 0$, so $f_c = f_{LO}$ for this experiment.

Dependent Variable:

- Power Level, in relative to the noise floor; observed from the FFT data.

The location of the (real or aliased) inputted signal on the frequency domain is either f_c , $f_c+25\text{Mhz}$, or $f_c-25\text{Mhz}$. The relative power level of the signal is calculated by:

$$\frac{\text{Power level of the signal}}{\text{Noise floor}}$$

, where the power level of the signal or the noise floor are determined by:

$$\Re\left(\frac{F(k)}{\text{FFT points}}\right)^2 + \Im\left(\frac{F(k)}{\text{FFT points}}\right)^2$$

, where $F(k)$ is the FFT point (in complex) corresponding to the target frequency. The noise floor can be estimated by finding the minimum power level for all k .

The results are represented in logarithmic scale (dB) for convenience. Since it is already in power level, it can be done by calculating $10 \cdot \log_{10}(\text{relative power level})$.

Figure 3 shows the block diagram of the system.

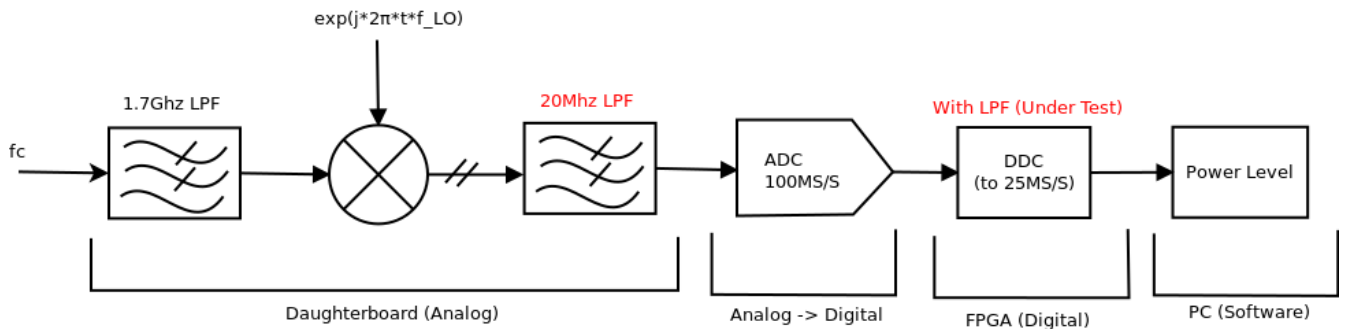


Figure 3. Block Diagram of the System (for the DDC's LPF).

*Again, above diagram assumes 900Mhz RF frequency with 25 MS/s effective sampling rate.

Results

Table 1. Frequency Offset vs Received Power Level

Frequency Offset (Mhz)	Power Level (dB)
-15.50	3.0
-15.25	6.5
-15.00	10.5
-14.50	19.2
-14.00	26.4
-13.50	30.2
-13.00	36.1
-12.00	41.2
0.00	43.5
12.00	42.0
13.00	37.3
13.50	29.4
14.00	26.7
14.50	19.7
15.00	11.0
15.25	7.4
15.50	4.0

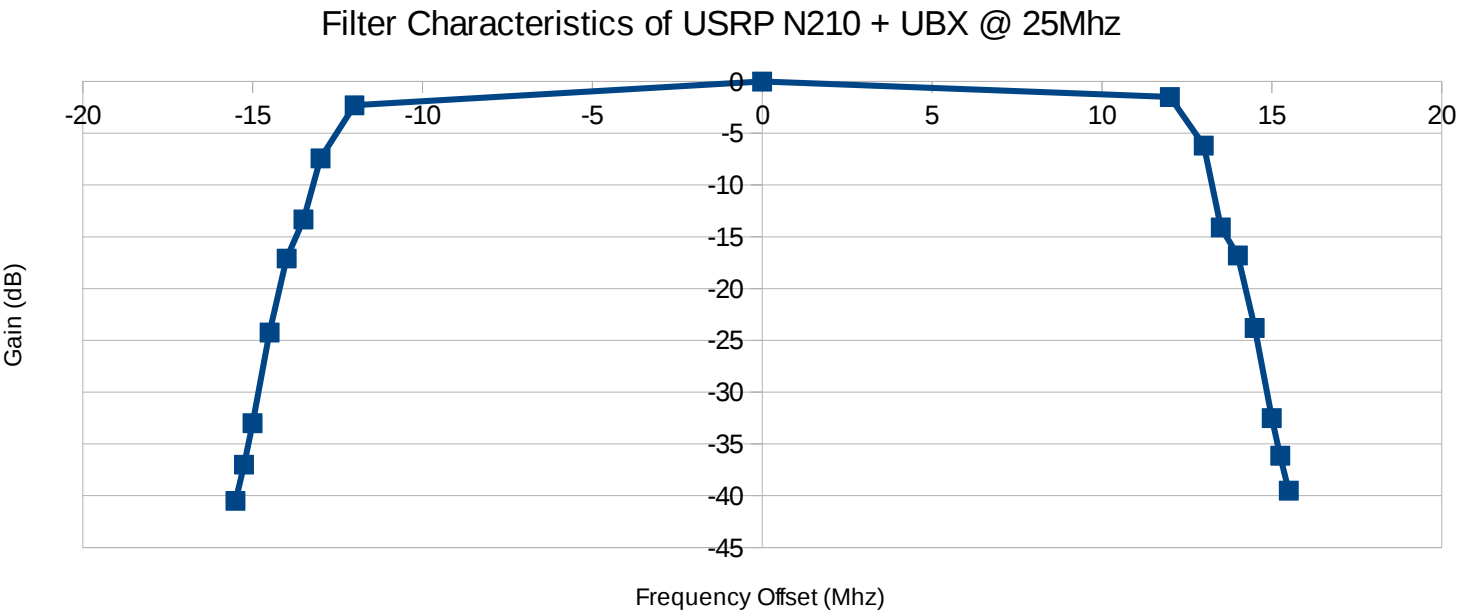


Figure. 4: Filter Characteristics of USRP N210 + UBX daughterboard (@ 25.0MS/s).

Conclusion

- Aliasing is unavoidable: for the 25MS/s effective sampling rate (=25Mhz bandwidth), the filter may let pass approx. 30Mhz of signal.

Solution for Aliasing #1 – Using Lower Effective Sampling Rate

One possible fix for the problem is using a relatively low effective sampling rate (=higher decimation rate on USRP). The DDC will automatically adjust the filter to match the decimation rate.

Experiment Design

Experiment on the above section (“Low-Pass Filtering by the DDC”) is repeated, but with the effective sampling rate of 12.5MS/s (instead of 25MS/s).

Results

Frequency Offset (Mhz)	Power Level (dB)
-7.75	3.0
-7.50	13.0
-7.00	29.9
-6.50	37.9
-6.00	42.3
0.00	44.3
6.00	41.7
6.50	37.0
7.00	27.5
7.50	13.3
7.75	3.0

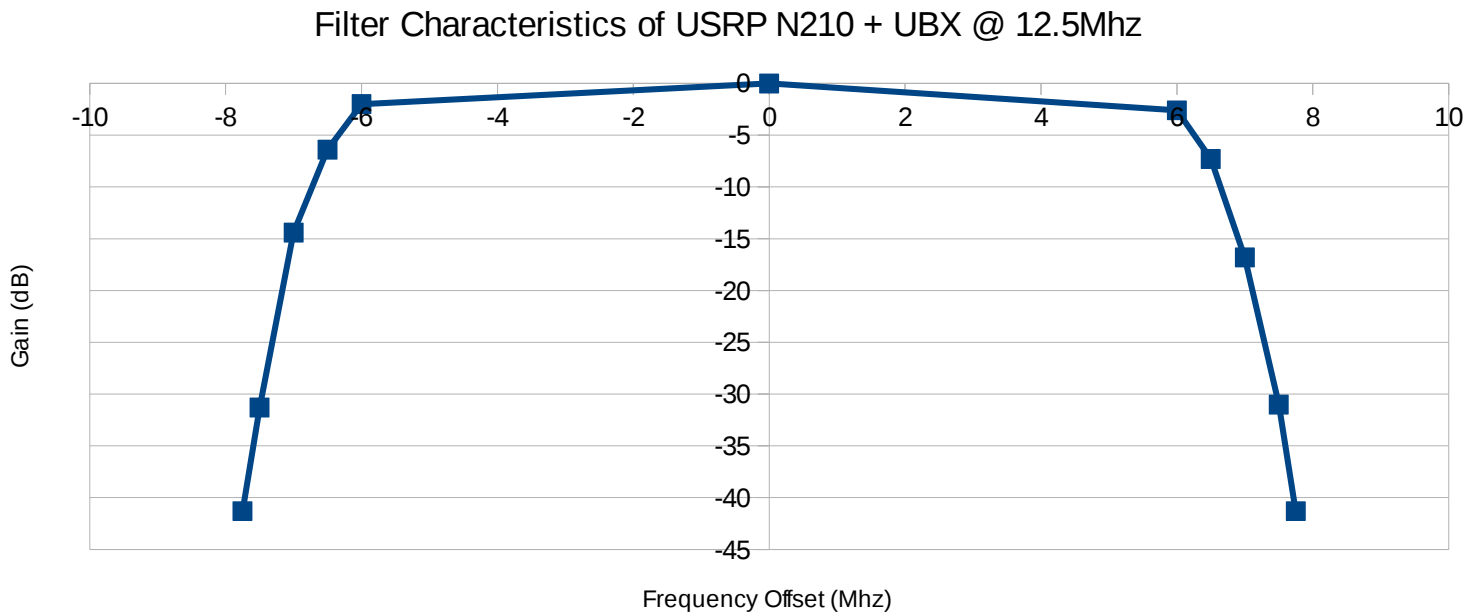


Figure. 5: Filter Characteristics of USRP N210 + UBX daughterboard (@ 12.5MS/s).

Conclusion

- The absolute amount (bandwidth) of aliased signal decreases as we increase the decimation rate.
- So, if the signal of interest has a relatively low bandwidth, we can simply use a low effective sampling rate (Scanner Configuration :: Instantaneous Bandwidth per snapshot).

*Different effective sampling rates (down to 250kS/s) are also tested, but not shown. In most cases, the above result holds.

*Note that USRP N200/N210s cannot use the half band filter with some effective sampling rates, especially when $(100\text{MS/s}) / (\text{Effective Sampling Rate})$ is not an even number (like 20MS/s). In such cases, the filter may perform worse. Try different effective sampling rate in such cases.

Solution for Aliasing #2 – Using Non-Zero DSP Frequency (IF Frequency)

As done in “Characteristics of a 20Mhz Filter (after Mixer, before ADC)” section, it is possible to “move” the analog low-pass filter by introducing a non-zero DSP frequency (IF frequency). This can be used to suppress signals in known frequencies.

Unfortunately, CityScape stations do not support this function yet (as of Nov 26, 2016).

Other Data Quality Concerns

There are other factors which may affect the IQ data quality. They are usually due to the nonlinearity of the components, variations in the components, or due to the signal leakages within the system.

Here is a list of possible quality issues (*not comprehensive):

- DC component (LO leakage)
- Spurious signals from other leakages or mismatches (ex : baseband anomalies of UBX boards)
- IQ amplitude / phase offsets
- Harmonics
- IIP2, IIP3
- ADC overload

DC components and IQ imbalances are automatically corrected by the UHD driver (assuming the station is correctly calibrated). ADC overload and intermodulation issues can be corrected or suppressed by adjusting the receiver amplifier gain.

Ettus Research provides RF performance measurement results for the UBX daughterboard at:
https://files.ettus.com/performance_data/ubx/UBX-without-UHD-corrections.pdf

Appendix – UHD_USRP_PROBE

linux; GNU C++ version 5.3.1 20151219; Boost_105800; UHD_003.009.002-0-unknown

-- Opening a USRP2/N-Series device...
-- Current recv frame size: 1472 bytes
-- Current send frame size: 1472 bytes

UHD Warning:

Unable to set the thread priority. Performance may be negatively affected.

Please see the general application notes in the manual for instructions.

EnvironmentError: OSError: error in pthread_setschedparam

Device: USRP2 / N-Series Device

Mboard: N210r4
hardware: 2577
mac-addr: a0:36:fa:38:38:2d
ip-addr: 192.168.10.2
subnet: 255.255.255.255
gateway: 255.255.255.255
gpsdo: none
serial: E2R28MEUP
FW Version: 12.4
FPGA Version: 11.1

Time sources: none, external, _external_, mimo
Clock sources: internal, external, mimo
Sensors: mimo_locked, ref_locked

RX DSP: 0
Freq range: -50.000 to 50.000 MHz

RX DSP: 1
Freq range: -50.000 to 50.000 MHz

RX Dboard: A
ID: UBX-40 v1 (0x0078)
Serial: 30CEDF1

RX Frontend: 0
Name: UBX RX

Antennas: TX/RX, RX2, CAL
Sensors: lo_locked
Freq range: 10.000 to 6000.000 MHz
Gain range PGA0: 0.0 to 31.5 step 0.5 dB
Bandwidth range: 40000000.0 to 40000000.0 step 0.0 Hz
Connection Type: IQ
Uses LO offset: No

RX Codec: A
Name: ads62p44
Gain range digital: 0.0 to 6.0 step 0.5 dB
Gain range fine: 0.0 to 0.5 step 0.1 dB

TX DSP: 0
Freq range: -50.000 to 50.000 MHz

TX Dboard: A
ID: UBX-40 v1 (0x0077)
Serial: 30CEDF1

TX Frontend: 0
Name: UBX TX
Antennas: TX/RX, CAL
Sensors: lo_locked
Freq range: 10.000 to 6000.000 MHz
Gain range PGA0: 0.0 to 31.5 step 0.5 dB
Bandwidth range: 40000000.0 to 40000000.0 step 0.0 Hz
Connection Type: QI
Uses LO offset: No

TX Codec: A
Name: ad9777
Gain Elements: None