SKACH

The variable MID-band 6 filter: a key component for the MID-band 6/multi-band receiver (Work Package 2360)

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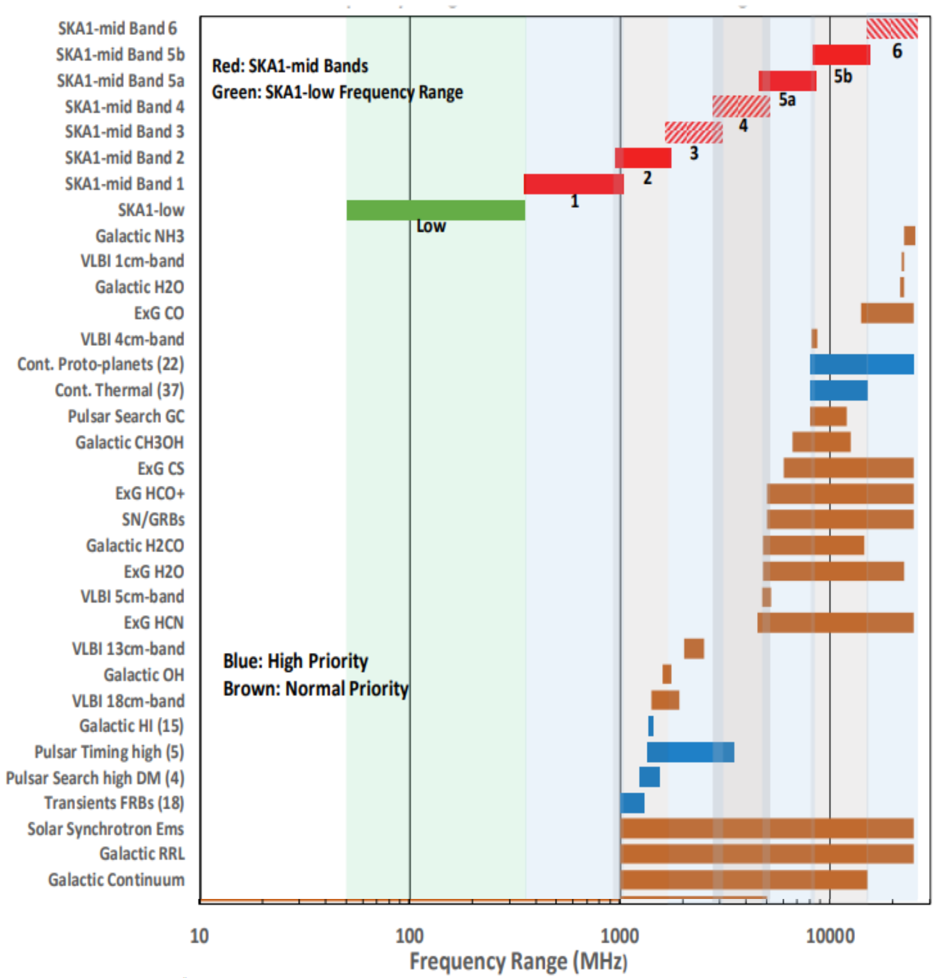
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences Western Switzerland

HEIG VD
SCHOOL OF ENGINEERING AND MANAGEMENT

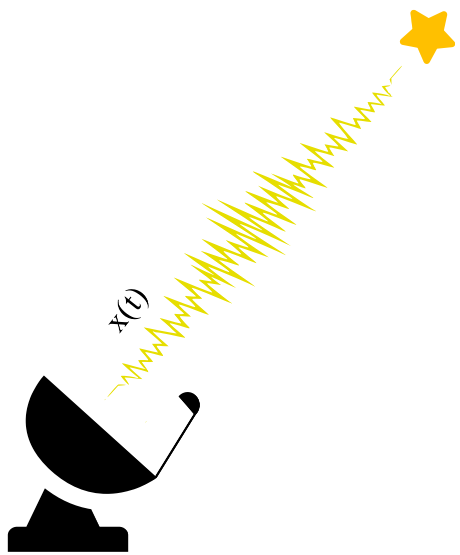
Mohammad Reza KHALVATI
12 Jan 2023

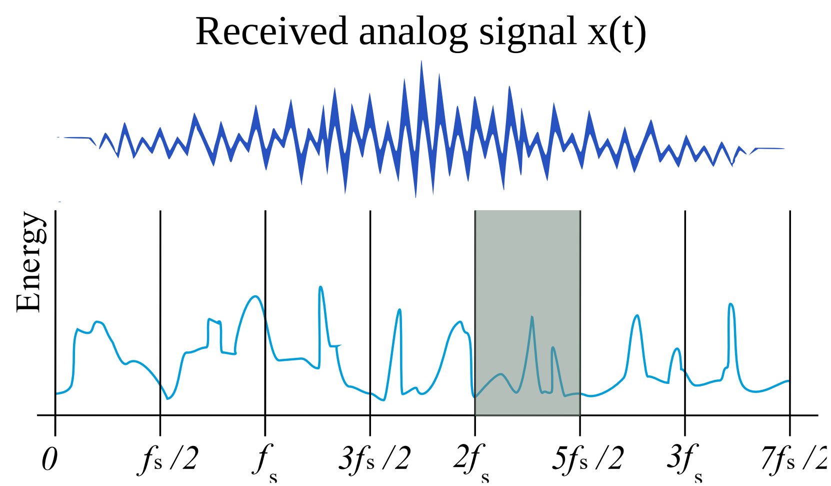
Toward Mid6

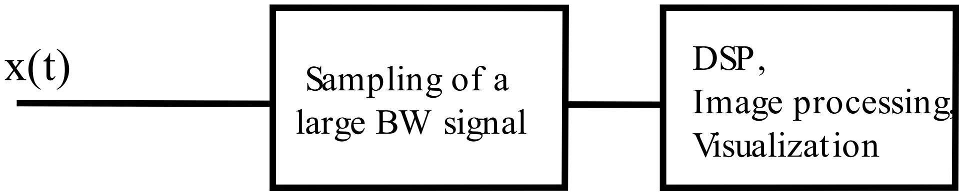


SKA1-mid Band 6
SKA1-mid Band 5b
SKA1-mid Band 5a
SKA1-mid Band 4
SKA1-mid Band 3
SKA1-mid Band 2
SKA1-mid Band 1
SKA1-low
Galactic NH3
VLBI 1cm-band
Galactic H2O
ExG CO
VLBI 4cm-band
Cont. Proto-planets (22)
Cont. Thermal (37)
Pulsar Search GC
Galactic CH3OH
ExG CS
ExG HCO+
SN/GRBs
Galactic H2CO
ExG H2O
VLBI 5cm-band
ExG HCN
VLBI 13cm-band
Galactic OH
VLBI 18cm-band
Galactic HI (15)
Pulsar Timing high (5)
Pulsar Search high DM (4)
Transients FRBs (18)
Solar Synchrotron Ems
Galactic RRL
Galactic Continuum
Red: SKA1-mid Bands
Green: SKA1-low Frequency Range
Blue: High Priority
Brown: Normal Priority
6
5b
5a
4
3
2
1
Low
10
100
1000
10000
Frequency Range (MHz)

Sampling

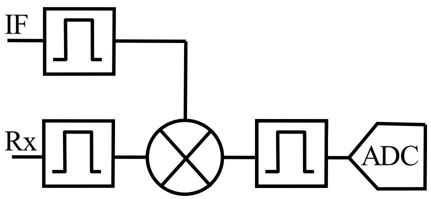

x(t)


Received analog signal x(t)
Energy
0
fs /2
f s
3fs /2
2f s
5fs /2
3f s
7fs /2


x(t)
Sampling of a large BW signal
DSP,
Image processing,
Visualization

Architecture

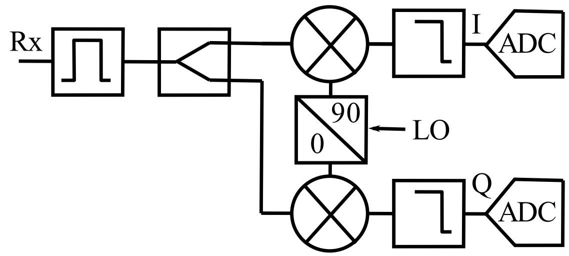
Heterodyne



Pros:
- ✔ Proven trusted
- ✔ High performance
- ✔ Optimum spurious noise
- ✔ High dynamic range
- ✔ EMI immunity

Cons&Challenges :
- ✘ SWaP
- ✘ Many filters

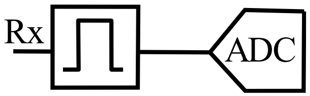
Down-Conversion/Zero IF



Pros:
- ✔ Maximum ADC bandwidth
- ✔ Simplest wideband option

Cons&Challenges:
- ✘ Image rejection (I/Q balance)
- ✘ In-band IF harmonics
- ✘ EMI immunity (IP2)
- ✘ DC and 1/f noise
- ✘ SWaP

Direct Sampling



Pros:
- ✔ Simple architecture
- ✔ No mixer

Cons&Challenges :
- ✘ ADC input bandwidth must be high
- ✘ Gain not distributed across frequency
- ✘ ADC DC power maybe high

Sampling Rate & Aliasing

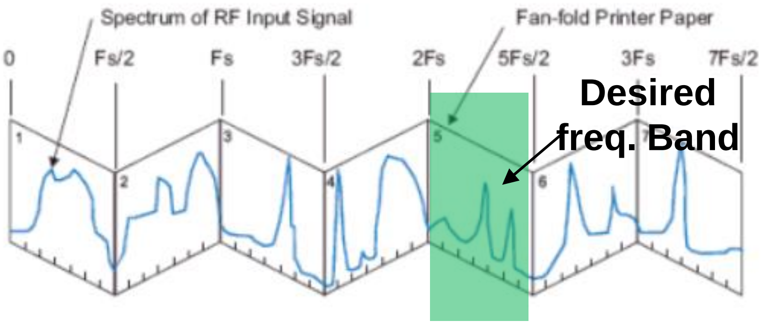
EV10AS940, one of the fastest possible ADC @ 10bit.

Main Features:

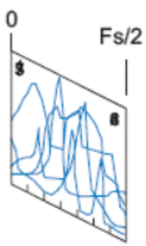
Max Sampling frequency (Fs): 12.8 GSPS.

BW(-3dB)	**35GHz**
Power	**2.5W @12.8 GHz**
SFDR	**55dB up to 35GHz**

But further below Nyquist, Aliasing occurs



Sampling outcome superimpose of aliases



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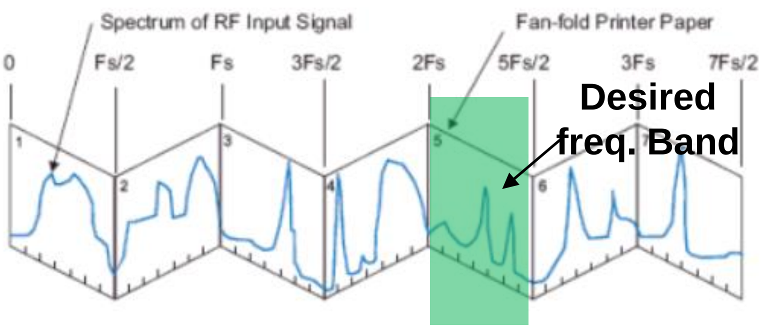
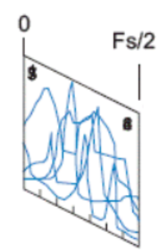
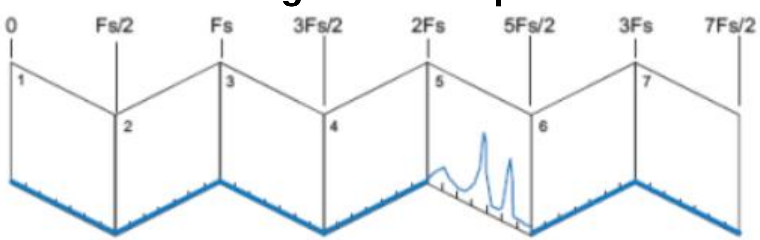
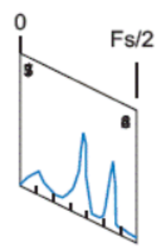


Sampling outcome superimpose of aliases



Anti-aliasing filter is required!





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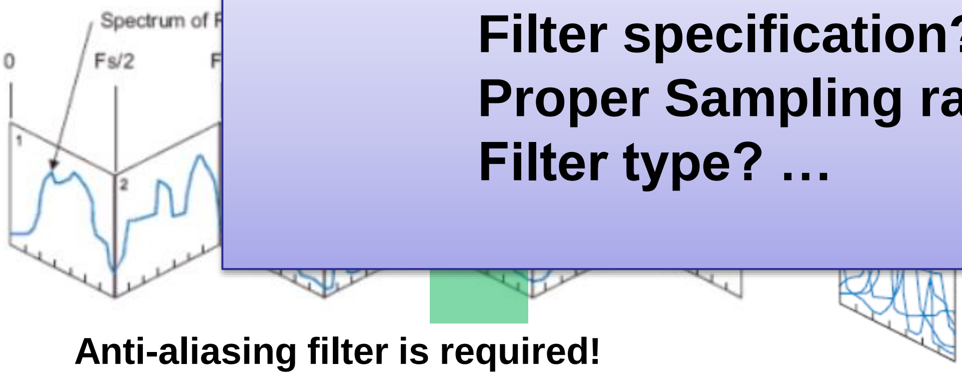
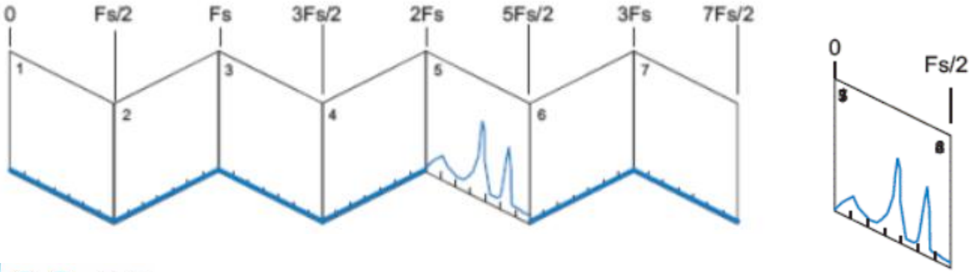
But furth



What are

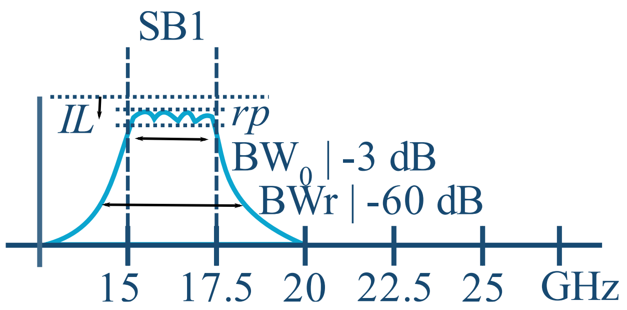
- **Filter specification?**
- **Proper Sampling rate?**
- **Filter type? …**

Anti-aliasing filter is required!

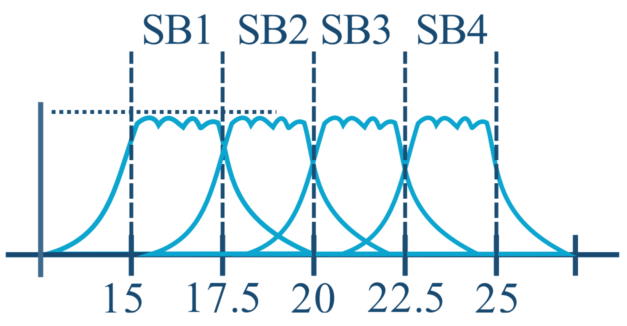


Frequency Plan

Bandpass Filter, total band to cover 15…25 GHz



Divided into Sub-Bands (SB)



4 Sub-bands

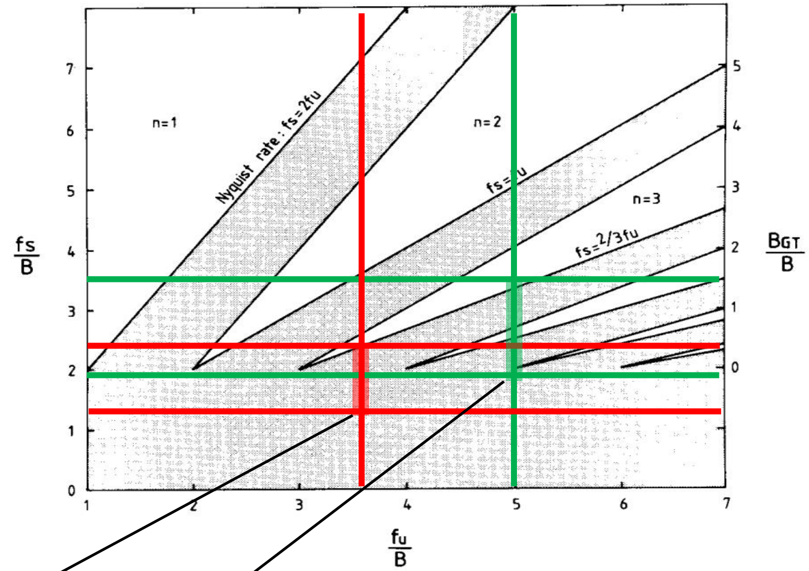
Filter Design

Cheby is selected.

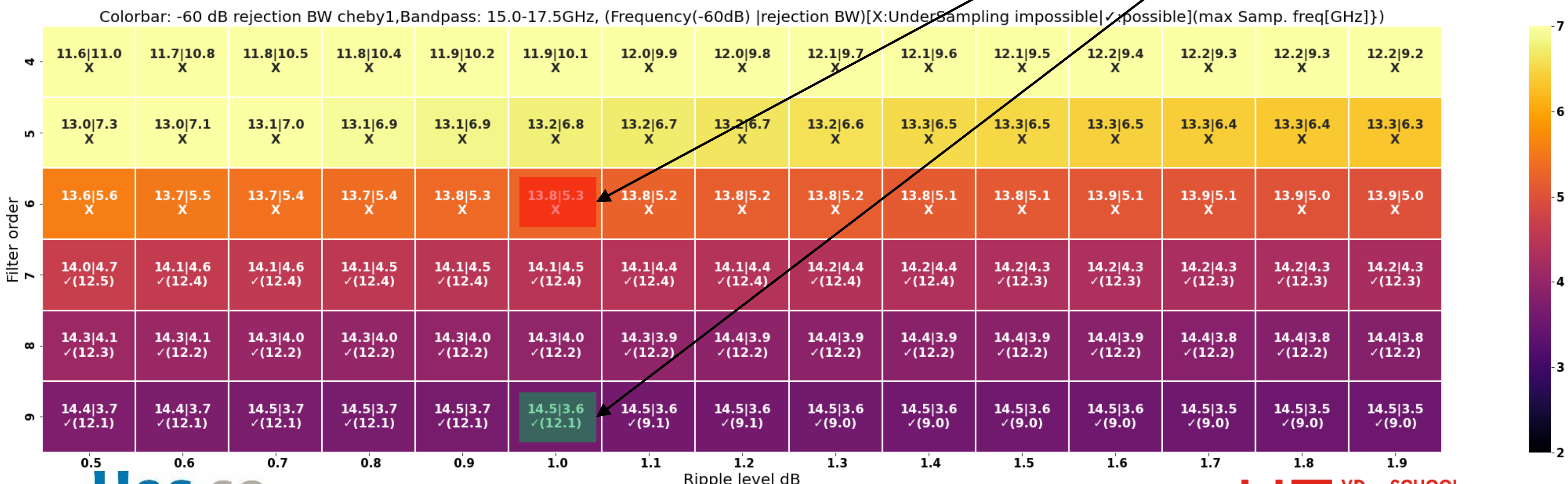
Goals & Constraints:

- **Determine**
  - **order N (odd orders are prefered)**
  - **Insertion loss IL**
  - **Quality factor Q**
  - **...**

$$\frac{2f_u}{n} \leq f_s \leq \frac{2f_l}{n-1}$$



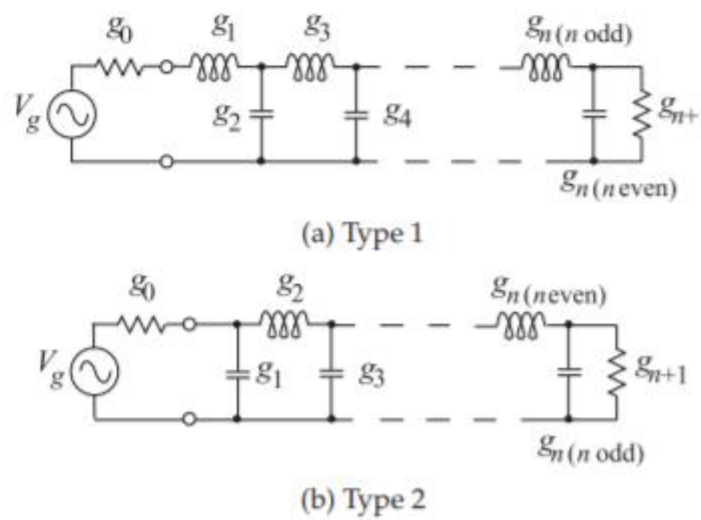
Python modules are developed



Insertion Loss

Q_0 is calculated using Dishal's method

$$IL(f_c) = \frac{4.343 f_c}{\Delta f Q_u} \sum_{i=1}^{N} g_i \text{ dB}$$



Calc IL dB @ f_0=16.25, BW=2.5 GHz and rp of Chebyshev circuit = 1 dB

Filter order \ Unloaded Q	10.0	114.7	219.5	324.2	428.9	533.7	638.4	743.2	847.9	952.6	1057.4	1162.1	1266.8	1371.6	1476.3	1581.1	1685.8	1790.5	1895.3	2000.0
9	29.6	2.6	1.3	0.9	0.7	0.6	0.5	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
8	32.4	2.8	1.5	1.0	0.8	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
7	42.1	3.7	1.9	1.3	1.0	0.8	0.7	0.6	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
6	45.0	3.9	2.1	1.4	1.0	0.8	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2
5	54.7	4.8	2.5	1.7	1.3	1.0	0.9	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3
4	57.7	5.0	2.6	1.8	1.3	1.1	0.9	0.8	0.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3

Calc IL dB @ f_0=16.25, BW=2.5 GHz and rp of Chebyshev circuit = 1.5 dB

Filter order \ Unloaded Q	10.0	114.7	219.5	324.2	428.9	533.7	638.4	743.2	847.9	952.6	1057.4	1162.1	1266.8	1371.6	1476.3	1581.1	1685.8	1790.5	1895.3	2000.0
9	33.1	2.9	1.5	1.0	0.8	0.6	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2
8	34.9	3.0	1.6	1.1	0.8	0.7	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
7	46.4	4.0	2.1	1.4	1.1	0.9	0.7	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2
6	48.3	4.2	2.2	1.5	1.1	0.9	0.8	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2
5	59.8	5.2	2.7	1.8	1.4	1.1	0.9	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3
4	61.7	5.4	2.8	1.9	1.4	1.2	1.0	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3

Q_0>400 → CavitySurfaces+losses of moving elements

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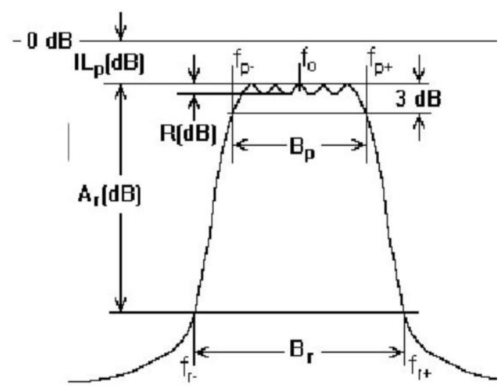
Specification of All SBs

R = 1 dB A_r = 60 dB

	1st band-pass f_{p-}: 15 GHz f_{p+}: 17.5 GHz					2nd band-pass f_{p-}: 17.5 GHz f_{p+}: 20.0 GHz					3rd band-pass f_{p-}: 20.0 GHz f_{p+}: 22.5 GHz					4th band-pass f_{p-}: 22.5 GHz f_{p+}: 25.0 GHz			
N-Order	F_{r-}	F_{r+}	B_r	Min FS		F_{r-}	F_{r+}	B_r	Min FS		F_{r-}	F_{r+}	B_r	Min FS		F_{r-}	F_{r+}	B_r	Min FS
4	11.936	21.992	10.056	-	4	14.344	24.4	10.056	-	4	16.773	26.829	10.056	-	4	19.216	29.272	10.056	-
5	13.161	19.945	6.7833	-	5	15.622	22.405	6.7832	-	5	18.091	24.875	6.7836	-	5	20.566	27.351	6.7845	-
6	13.775	19.056	5.2815	-	6	16.253	21.534	5.2816	-	6	18.736	24.018	5.2817	-	6	21.223	26.506	5.2827	-
7	14.124	18.586	4.4624	12.391	7	16.609	21.071	4.4623	-	7	19.098	23.562	4.4641	11.781	7	21.59	26.052	4.4627	-
8	14.341	18.305	3.9642	12.203	8	16.831	20.795	3.9639	10.397	8	19.324	23.289	3.9653	11.645	8	21.817	25.784	3.9673	10.314
9	14.485	18.122	3.6369	12.081	9	16.977	20.614	3.6363	10.307	9	19.472	23.111	3.6389	9.2445	9	21.967	25.608	3.641	8.5359

R = 1.5 dB A_r = 60 dB

	1st band-pass f_{p-}: 15 GHz f_{p+}: 17.5 GHz					2nd band-pass f_{p-}: 17.5 GHz f_{p+}: 20.0 GHz					3rd band-pass f_{p-}: 20.0 GHz f_{p+}: 22.5 GHz					4th band-pass f_{p-}: 22.5 GHz f_{p+}: 25.0 GHz			
N-Order	F_{r-}	F_{r+}	B_r	Min FS		F_{r-}	F_{r+}	B_r	Min FS		F_{r-}	F_{r+}	B_r	Min FS		F_{r-}	F_{r+}	B_r	Min FS
4	12.132	21.638	9.5058	-	4	14.55	24.055	9.5054	-	4	16.986	26.492	9.5061	-	4	19.436	28.942	9.5062	-
5	13.276	19.773	6.4967	-	5	15.74	22.237	6.4968	-	5	18.212	24.709	6.4968	-	5	20.69	27.187	6.4978	-
6	13.849	18.955	5.1056	-	6	16.329	21.435	5.1054	-	6	18.813	23.92	5.1066	-	6	21.3	26.407	5.1067	-
7	14.176	18.518	4.3422	12.345	7	16.663	21.006	4.3429	-	7	19.153	23.495	4.3421	11.748	7	21.644	25.989	4.3451	-
8	14.379	18.256	3.8765	12.17	8	16.87	20.747	3.8769	10.373	8	19.362	23.241	3.8788	11.621	8	21.859	25.736	3.8771	10.294
9	14.516	18.083	3.5671	9.0417	9	17.008	20.579	3.5711	10.289	9	19.502	23.075	3.573	9.2299	9	21.999	25.572	3.5728	8.524



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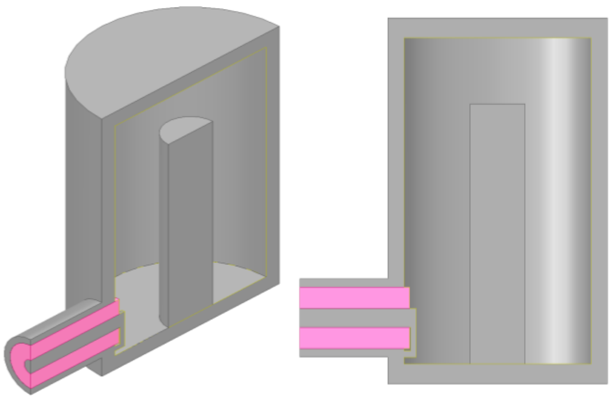
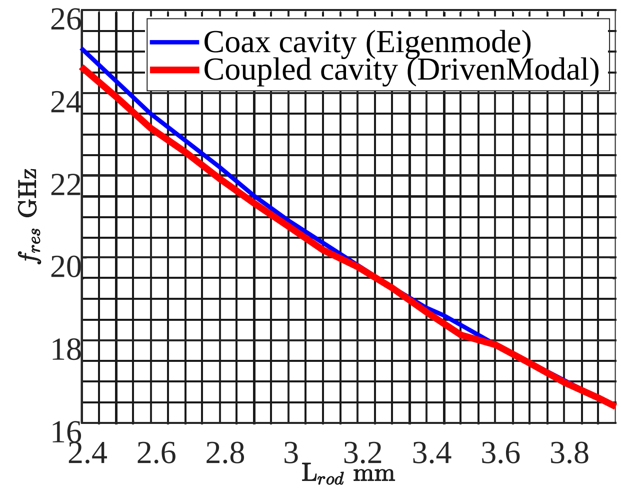
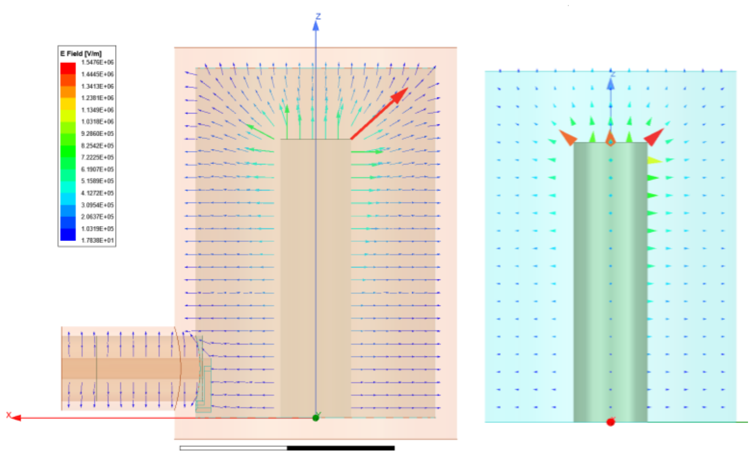
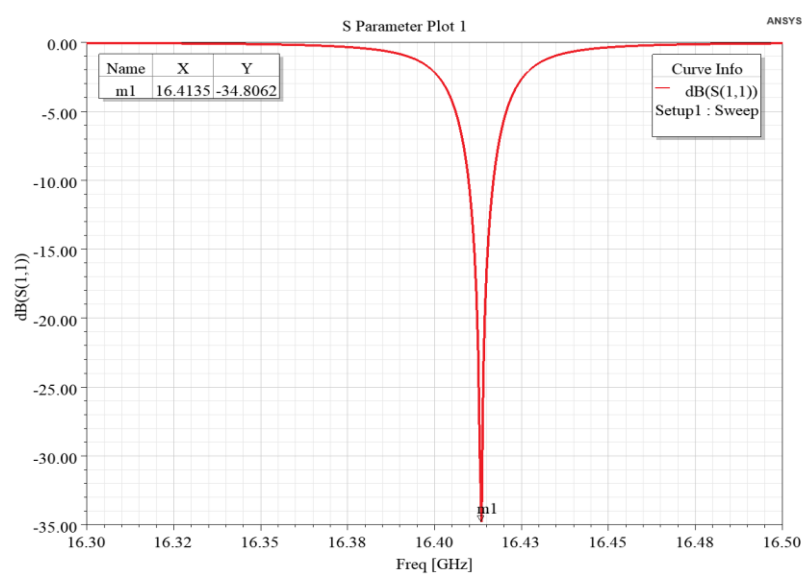
HEIG-VD School of Engineering and Management

Cavity cell design









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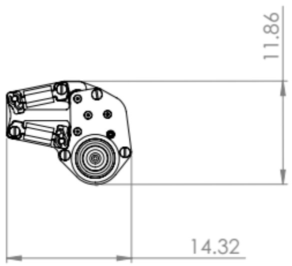
VARIABLE Passband filtering for undersampling ADCs

- Band to be covered 15-25GHz
- Or better 15-30GHz=1 octave (1:2 ratio) =WIDE band!
- Most «tunable filters» +-5% with standard methods: adjustable to some fixed specification
- ➔ we need to get back to basics and «make it move»
- ➔ we need an actuator
- ➔ fortunately we have one from a biomedical project



- Miniature step motor, Distance resolution ~0.1um/step! will be sufficient
- Lots of other technological challenges (sliding contacts at 20GHz???)

Summary

- Filter requirements, type and topology are determined.
- Filter architecture is chosen
- Using a wide band & Fast ADC
- Tunable design(possibility to switch between SBs).

Contacts

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Cavity Coupling Studies

Goal: How to couple cells effectively (to achieve a sufficient coupling level)