A Study of a Complex Multi-Band Pass ΔΣ D/A Modulator for I,Q signal generation

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Outline

- Background & motivation
- Approach
- Complex bandpass ΔΣ modulator
- Complex multi-bandpass ΔΣ modulator
- Simulation result
- Conclusion

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- Conclusion & Future work

Background & Motivation

Communication devices
- cellular, wireless LAN, blue-tooth, low IF transmitter/receiver (use I,Q signal)

↓

I,Q signal generator is desired
- communication IC testing (receiver)

Important!

↓

High quality + low cost
I,Q Signal Generator

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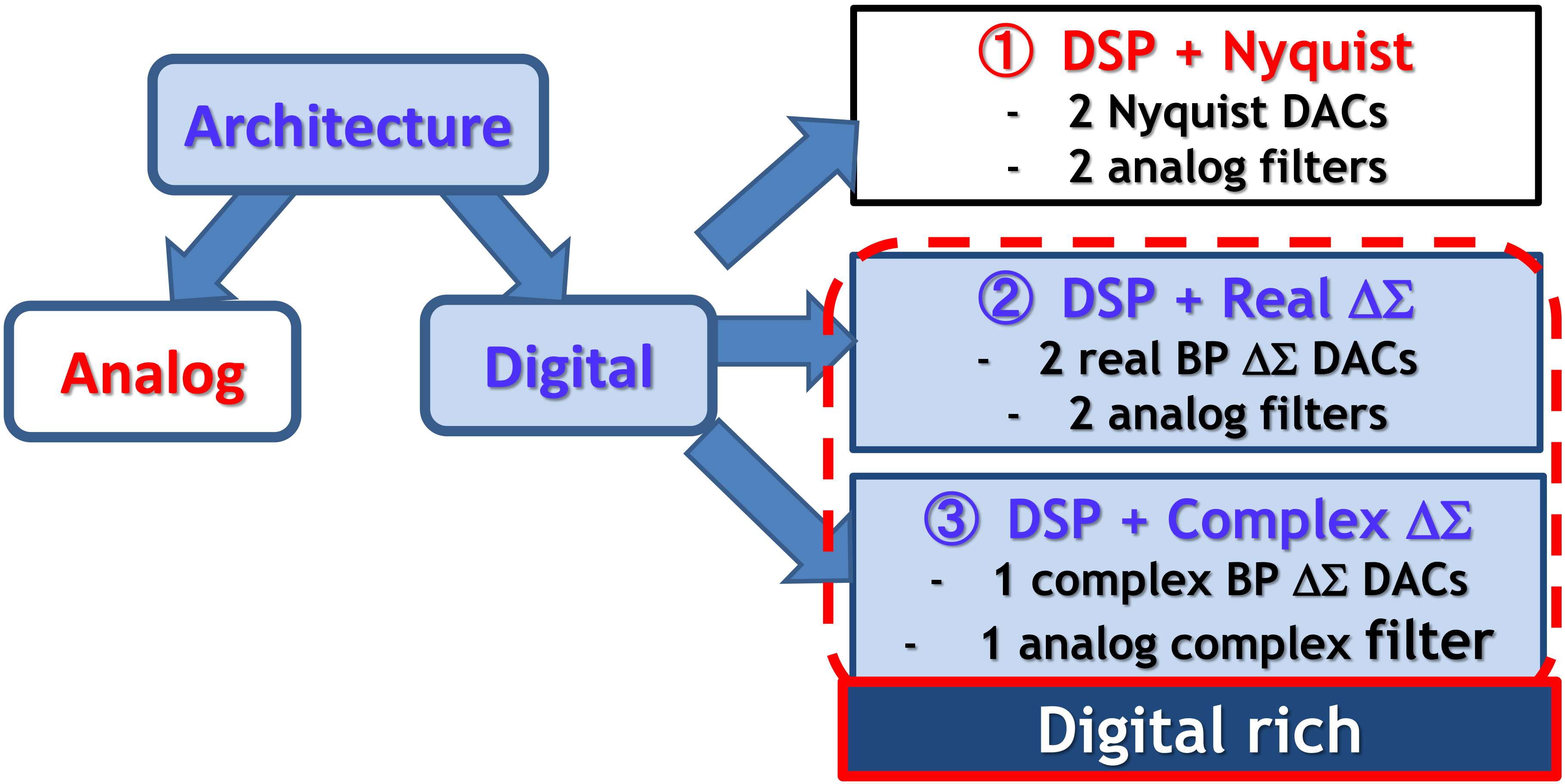
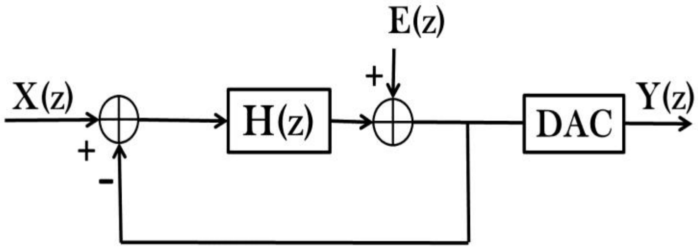
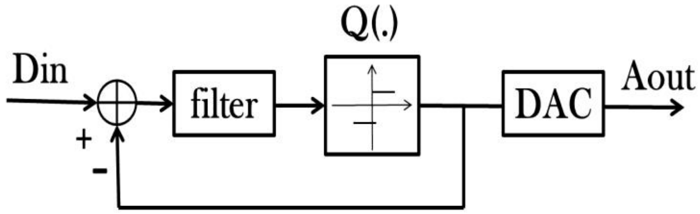
Approach:
I,Q Signal Generation Architecture



Why Delta-Sigma (ΔΣ) Modulator?

- Only simple analog circuit
- Easy to design in digital
  - High speed
  - Low power consumption
  - Low cost
- Easy to configure
  - programmable





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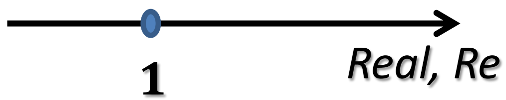
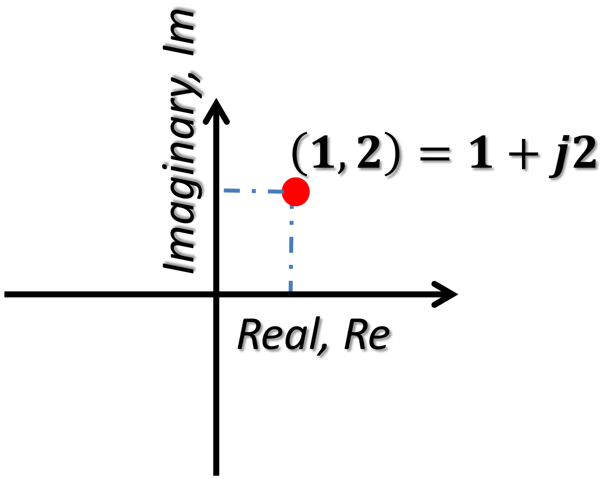
What is complex number?



Real number

- $I_{in}(n), Q_{in}(n) \rightarrow I_{out}(n), Q_{out}(n)$

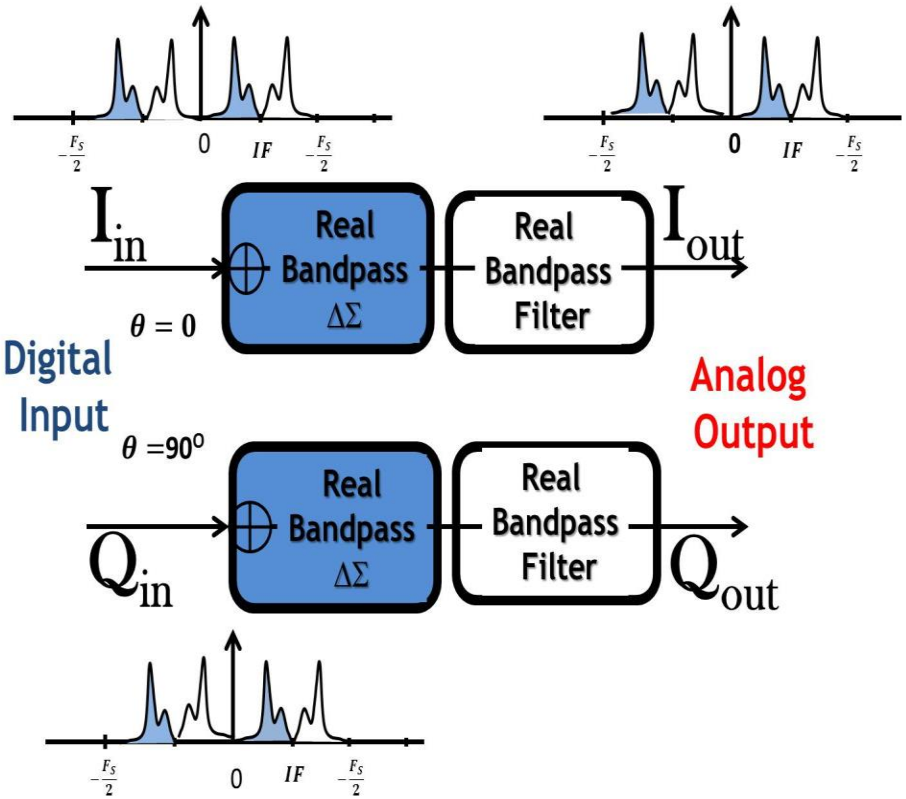


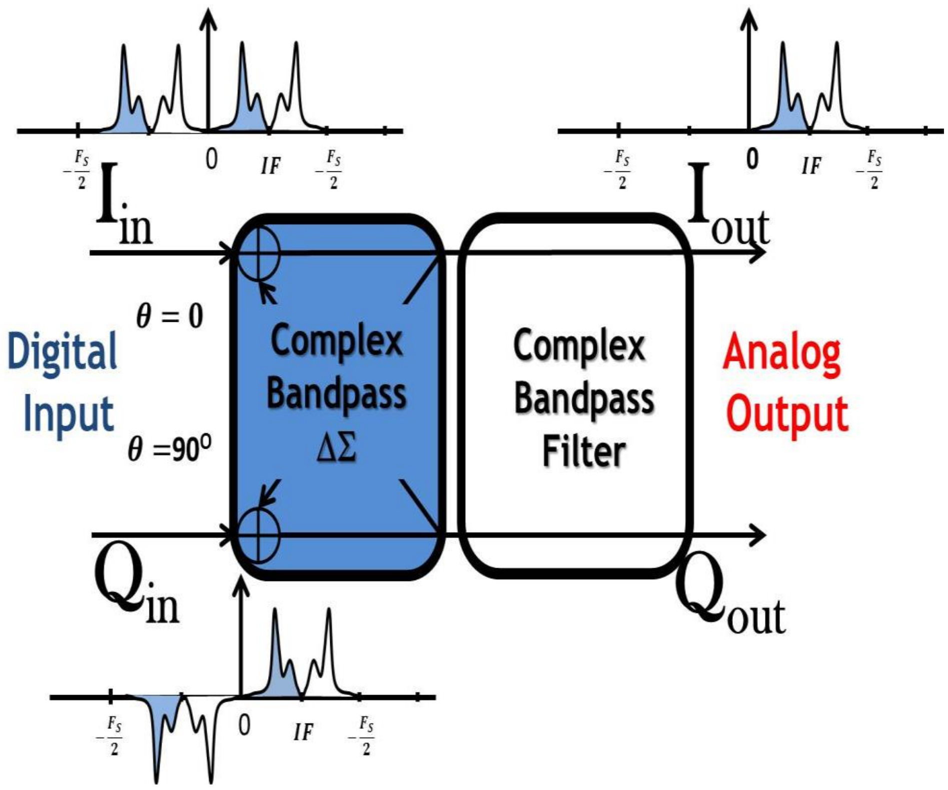
Complex number

- $I_{in}(n) + jQ_{in}(n) \rightarrow I_{out}(n) + jQ_{out}(n)$

I – In phase (real) , Q – In Quadrature (imaginary)

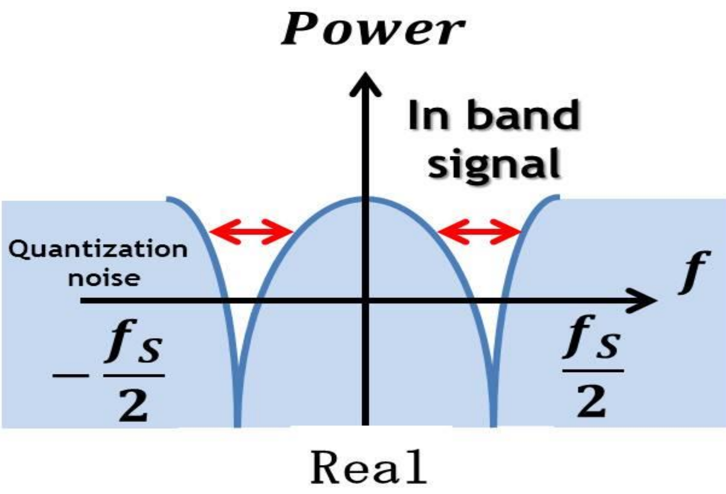
Filtering



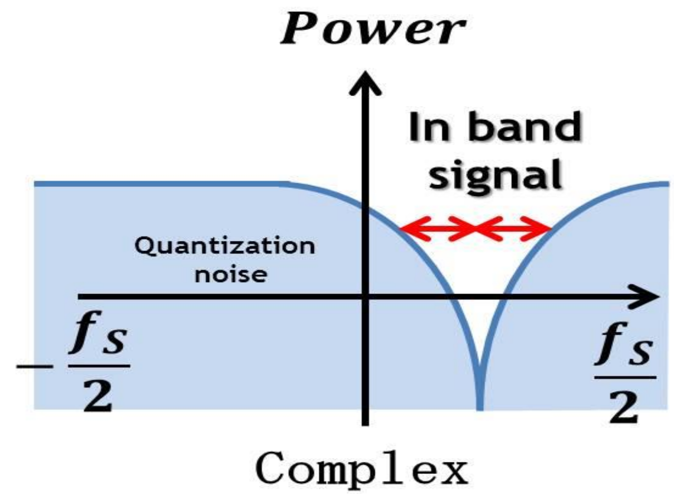


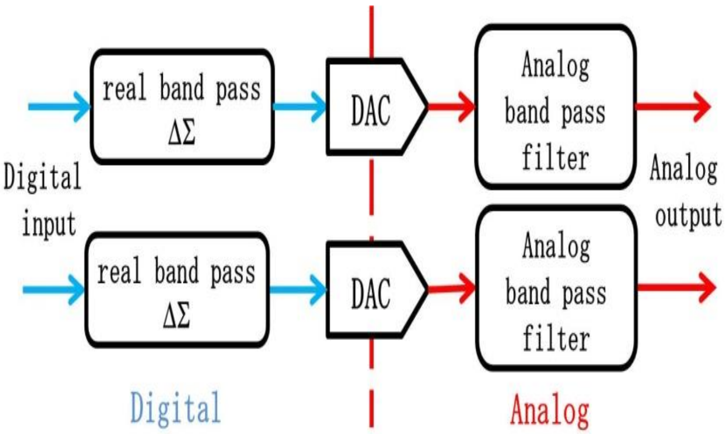
more filtering stage ←→ less filtering stage

Real & Complex



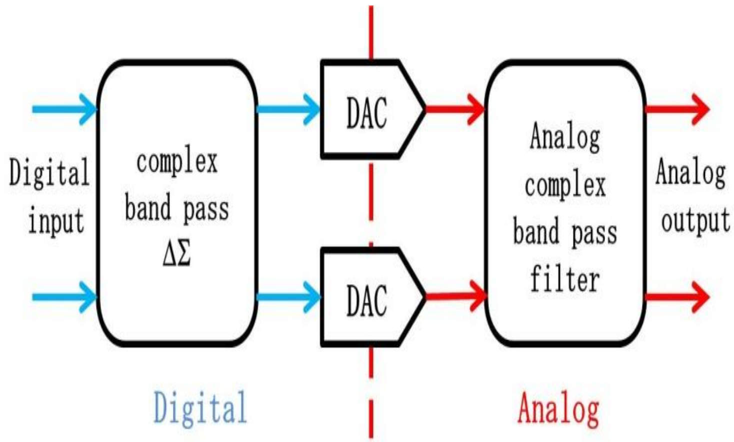
bandwidth



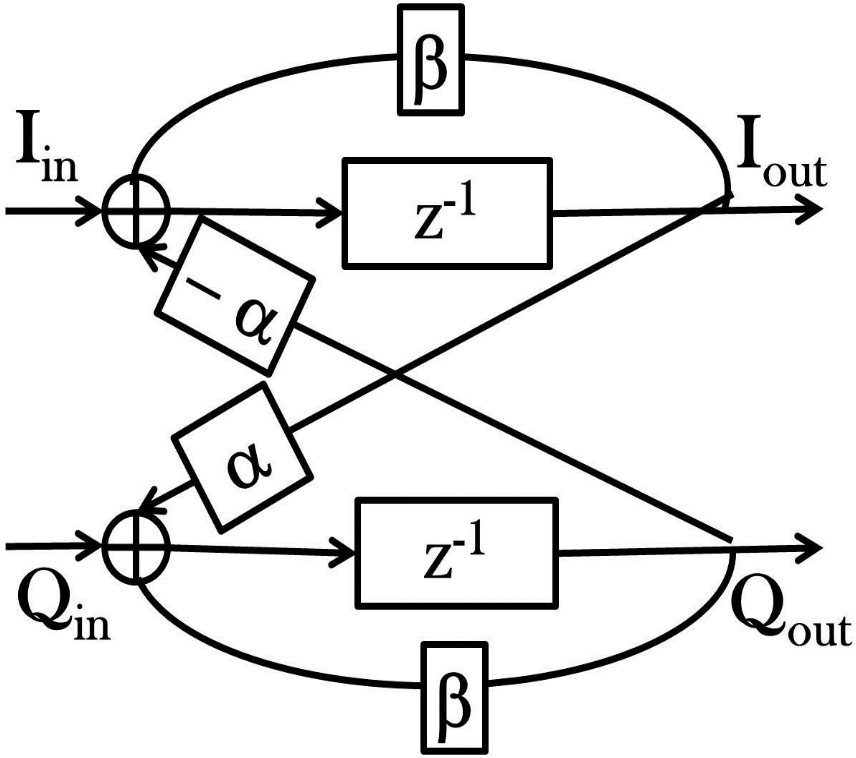


Power consumption

Cost



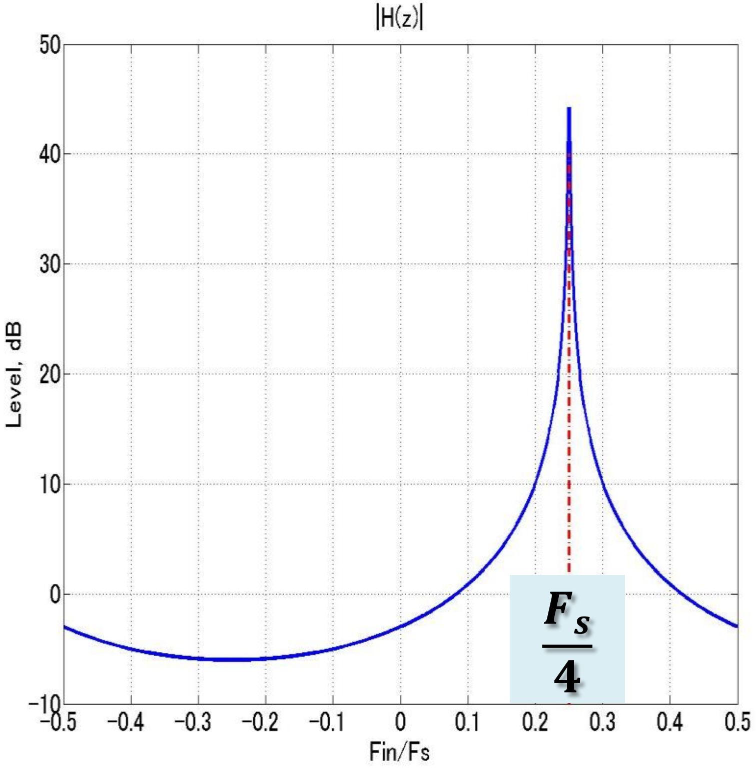
Complex Band pass Filter



$$H(z) = \frac{1}{z - (\beta + j\alpha)}$$

Transfer function

Frequency response



Frequency Response

Case: negative

$$\begin{cases} I_{in}(t) = cos(2\pi f_o t) \\ Q_{in}(t) = -sin(2\pi f_o t) \end{cases} \rightarrow e^{-j2\pi f_o t}$$

filter

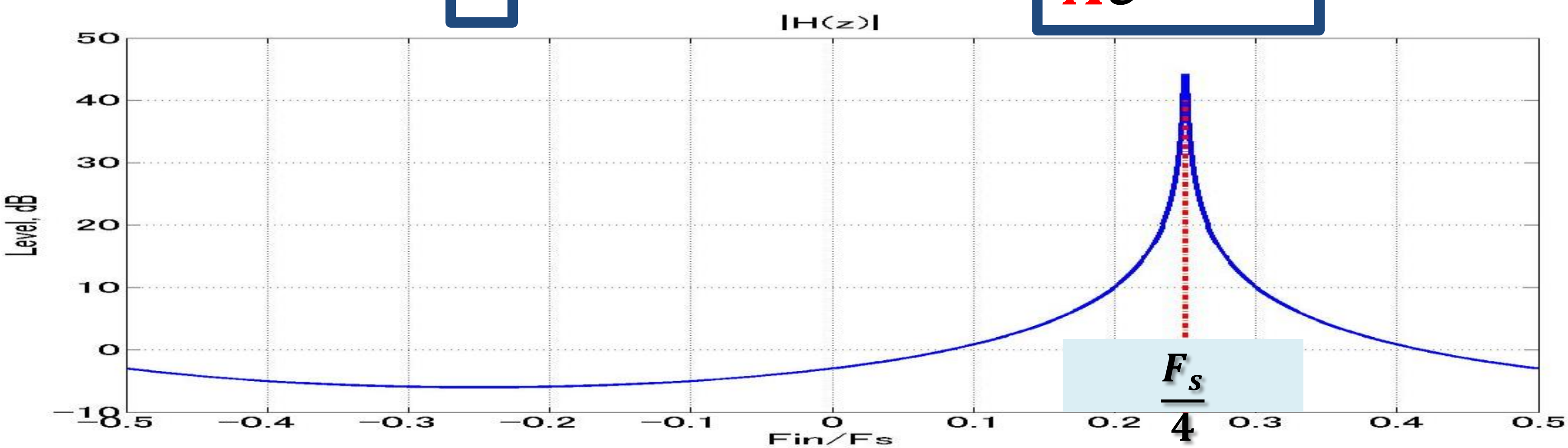
0

Case: positive

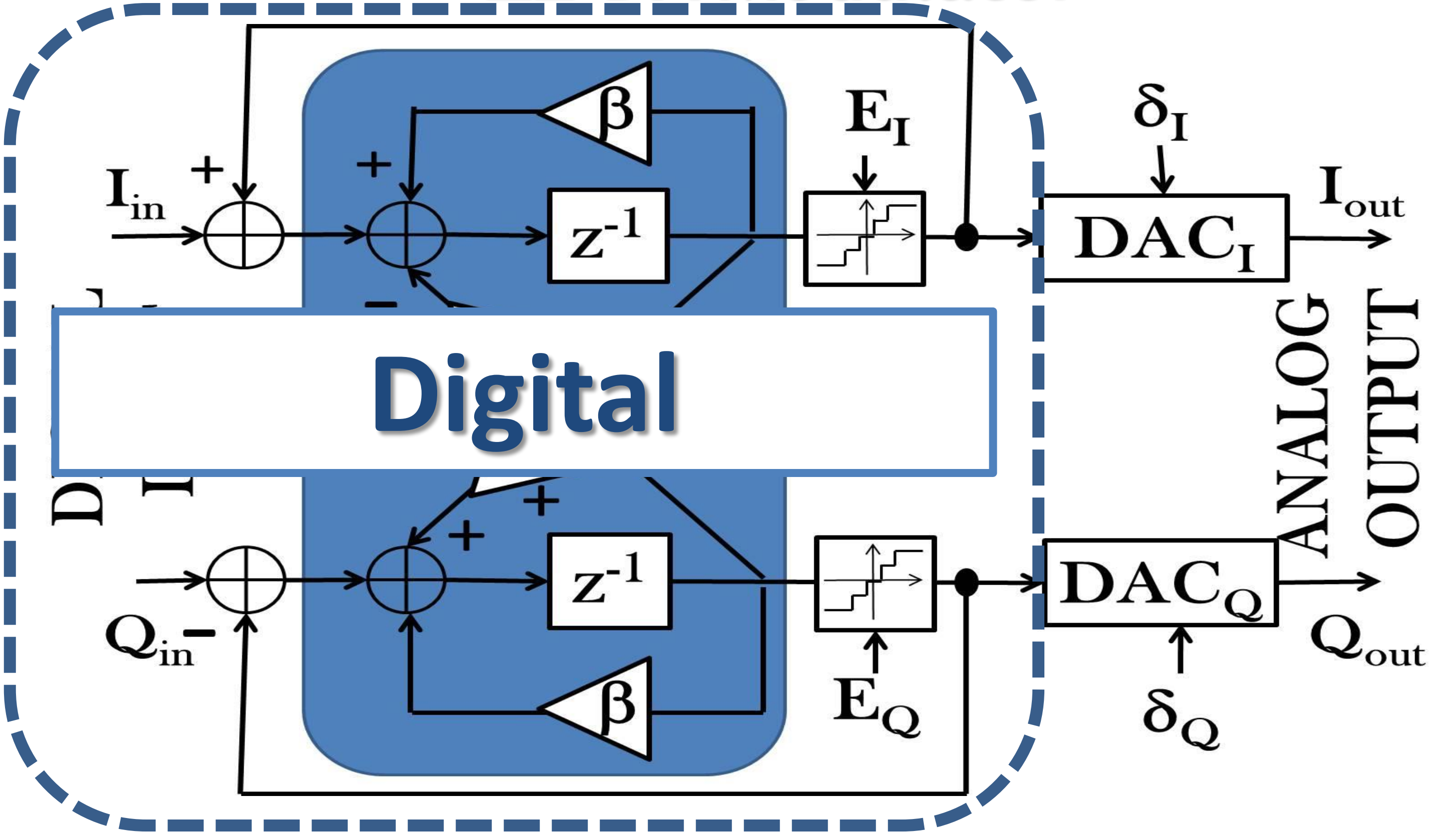
$$\begin{cases} I_{in}(t) = cos(2\pi f_o t) \\ Q_{in}(t) = sin(2\pi f_o t) \end{cases} \rightarrow e^{j2\pi f_o t}$$

filter

$$Ae^{j2\pi f_o t}$$



1st order Complex Band Pass ΔΣ DA Modulator

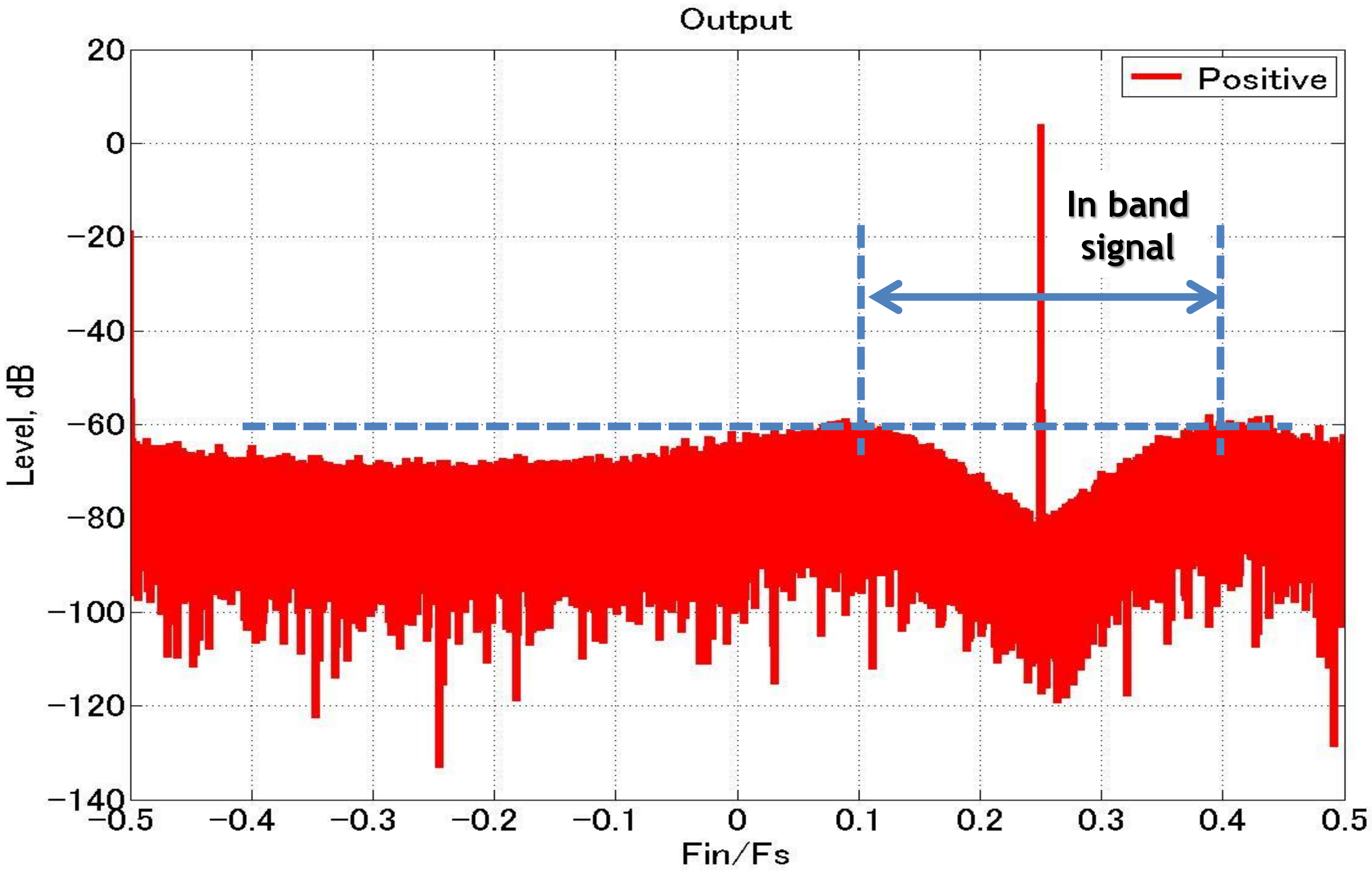


① Oversampling
② Noise-shaping

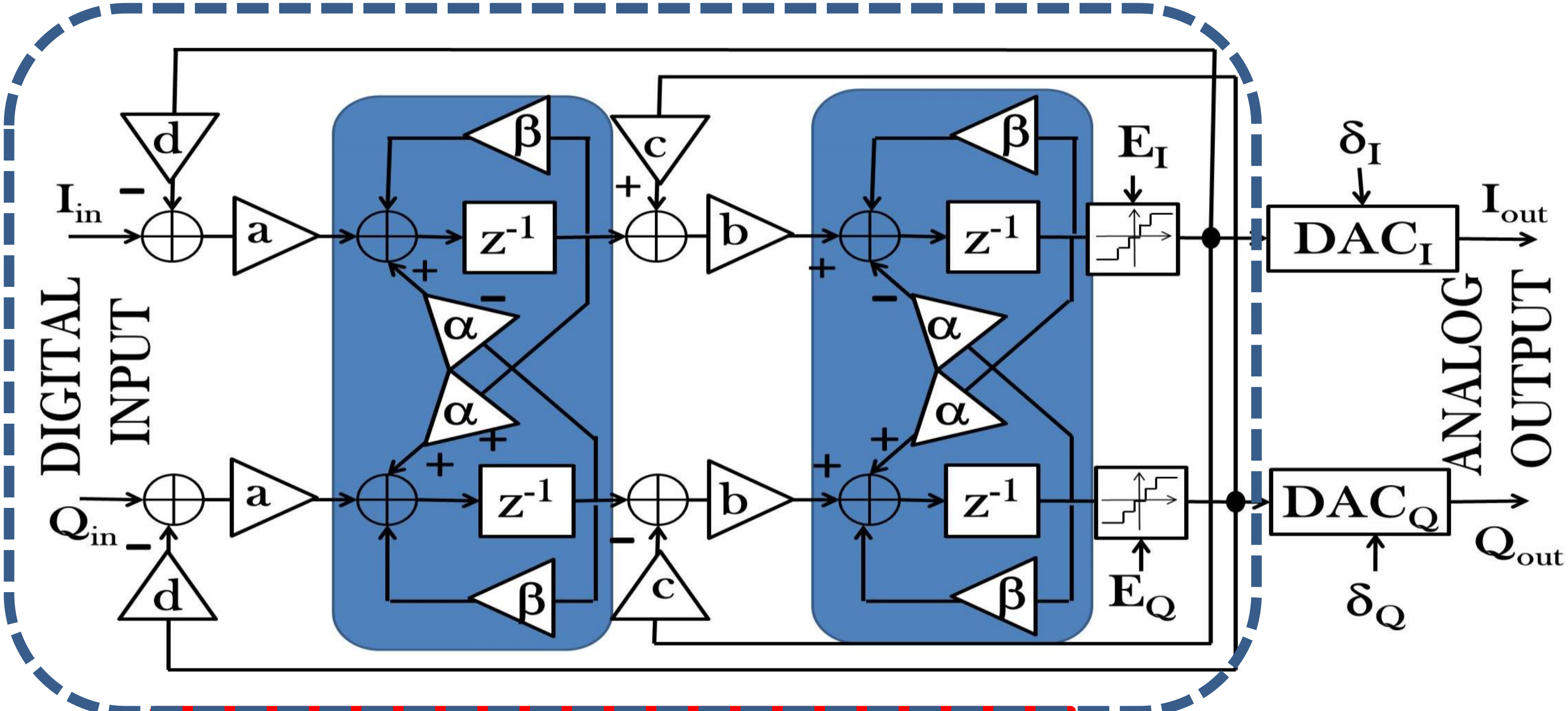
$$Y(z) = \frac{H(z)}{1+H(z)} X(z) + \frac{1}{1+H(z)} E(z)$$

$H(z) \to \infty, STF = 1$ $H(z) \to \infty, NTF = 0$

1st order Complex Bandpass ΔΣ Output Spectrum

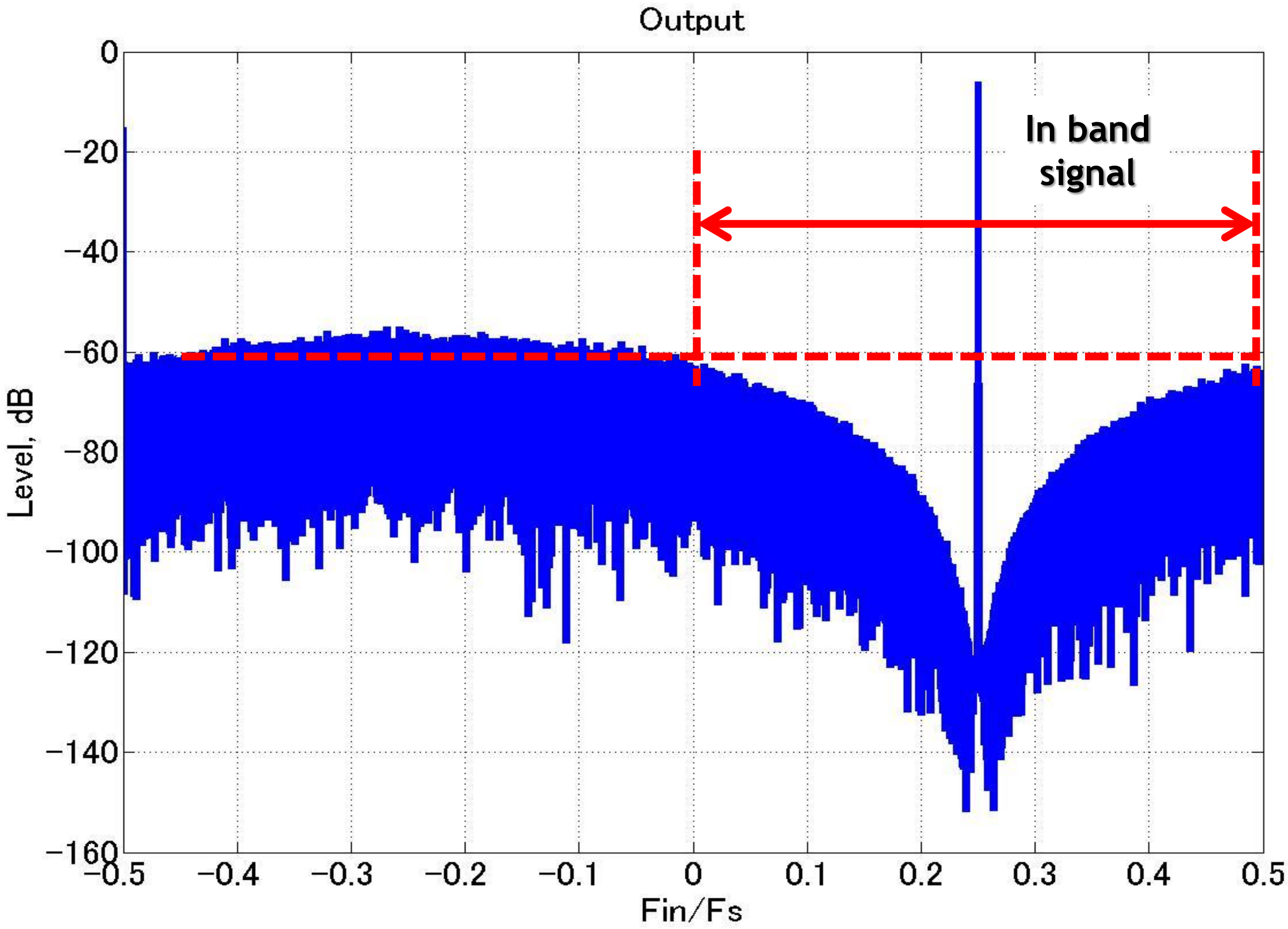


2nd order Complex Band Pass ΔΣ DA Modulator



No I,Q mismatch in modulation

2nd order Complex Bandpass ΔΣ Output Spectrum



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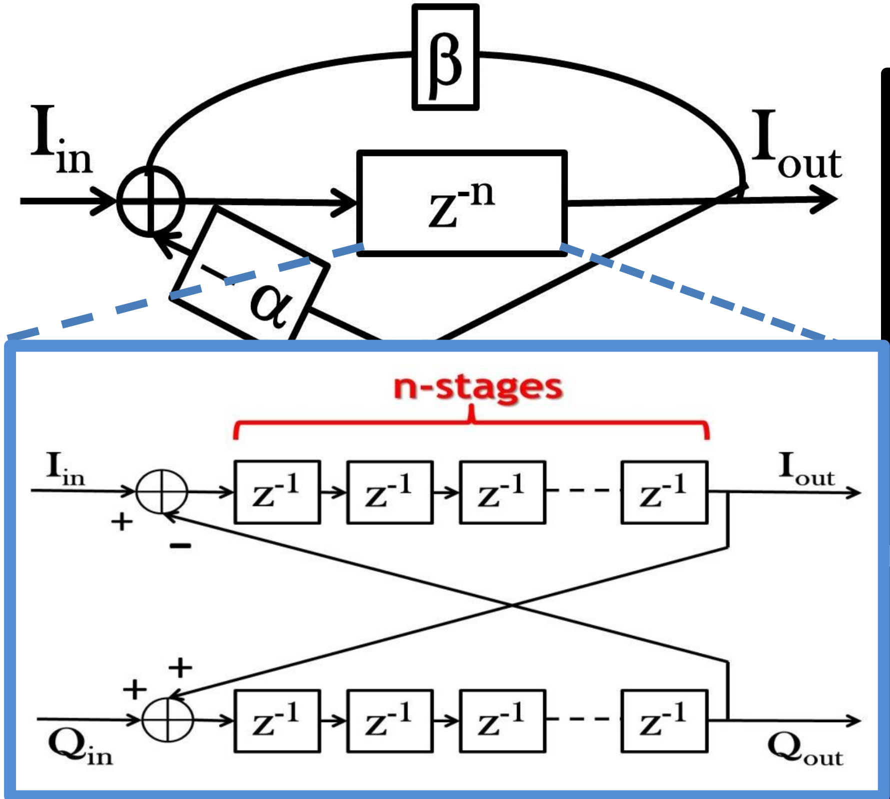
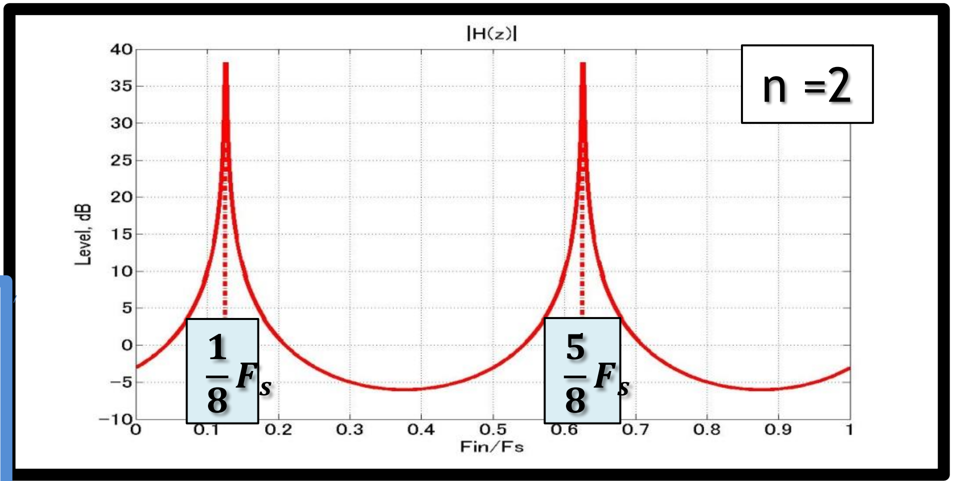
Complex Multi-Band pass Filter

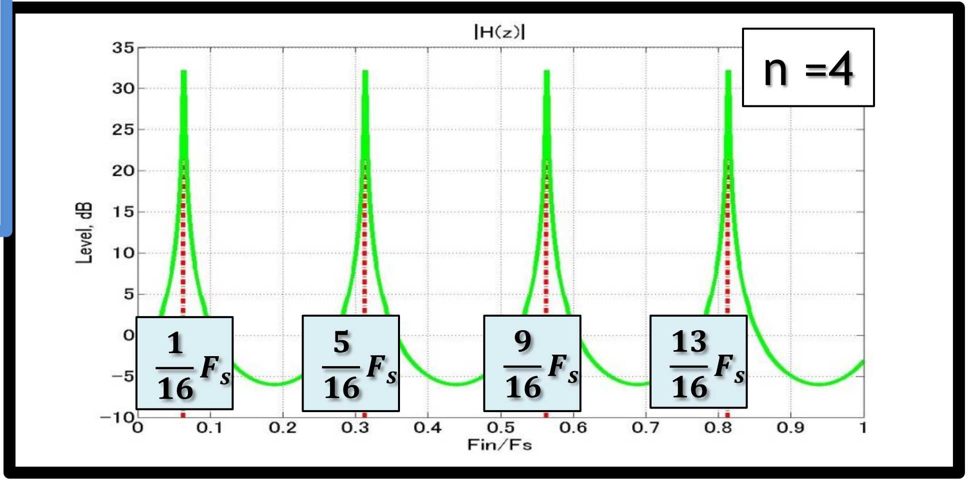


$$H(z) = \frac{1}{z^n - (\beta + j\alpha)}$$

Transfer function

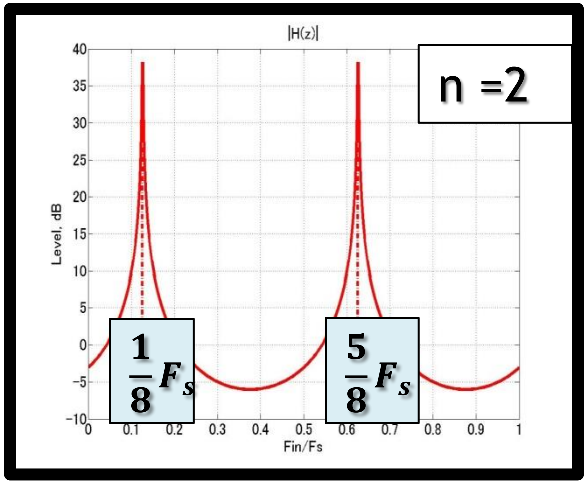
Frequency response

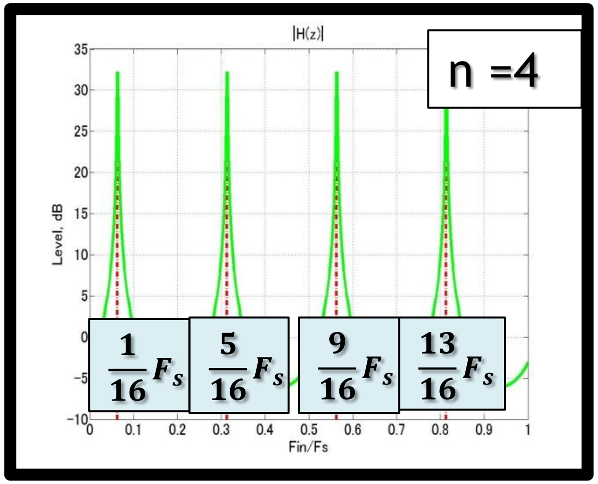




Frequency Response

Frequency response





Case: n=2

$$\begin{cases} I_{in}(t) = cos(2\pi f_o t) + cos(2\pi f_1 t) \\ Q_{in}(t) = sin(2\pi f_o t) + sin(2\pi f_1 t) \end{cases}$$

filter

$$A_0 e^{j2\pi f_o t} + A_1 e^{j2\pi f_1 t}$$

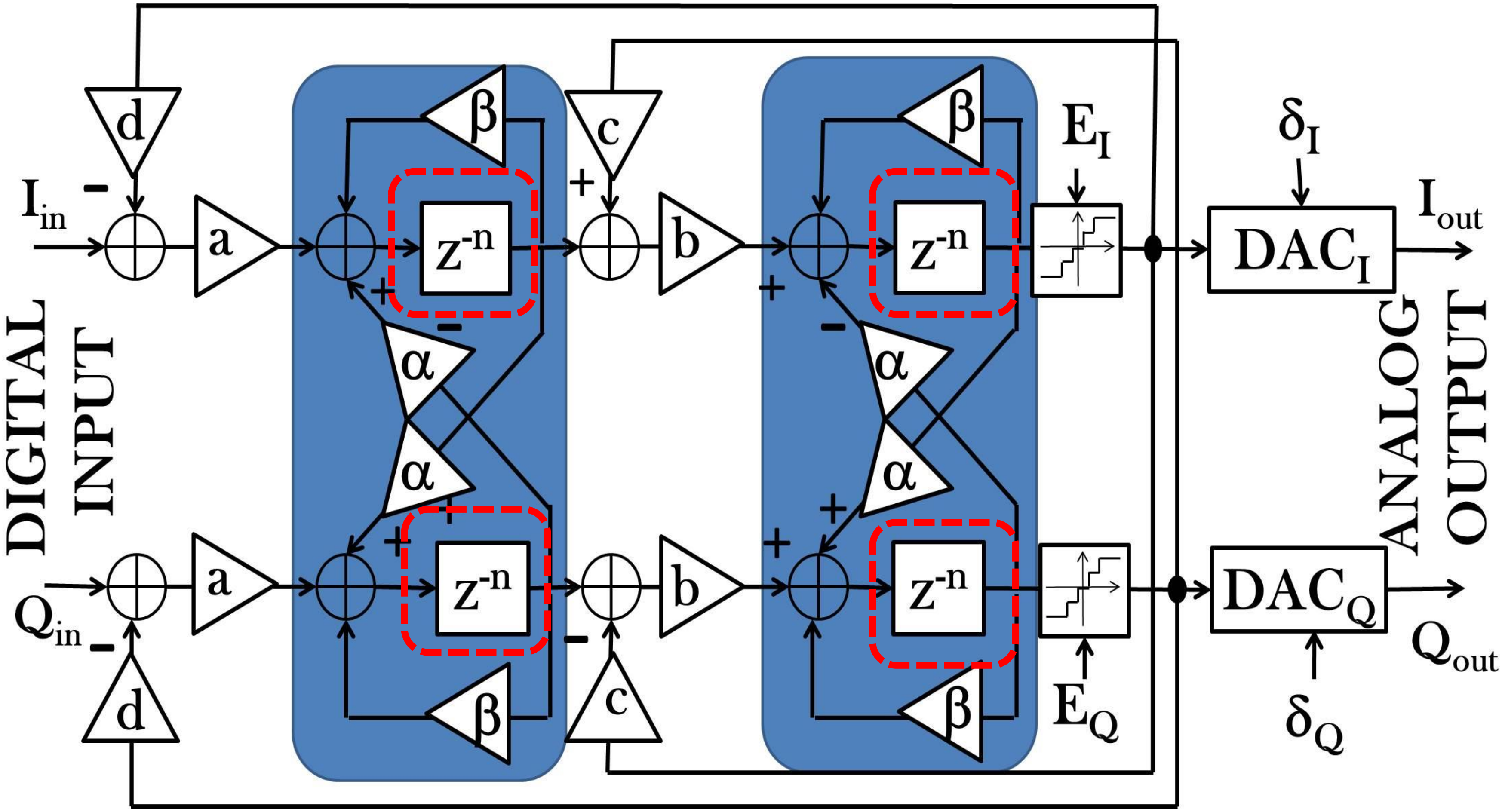
n-stages

$$\begin{cases} I_{in}(t) = cos(2\pi f_o t) + cos(2\pi f_1 t) + cos(2\pi f_2 t) + \dots cos(2\pi f_n t) \\ Q_{in}(t) = sin(2\pi f_o t) + sin(2\pi f_1 t) + sin(2\pi f_2 t) + \dots sin(2\pi f_n t) \end{cases}$$

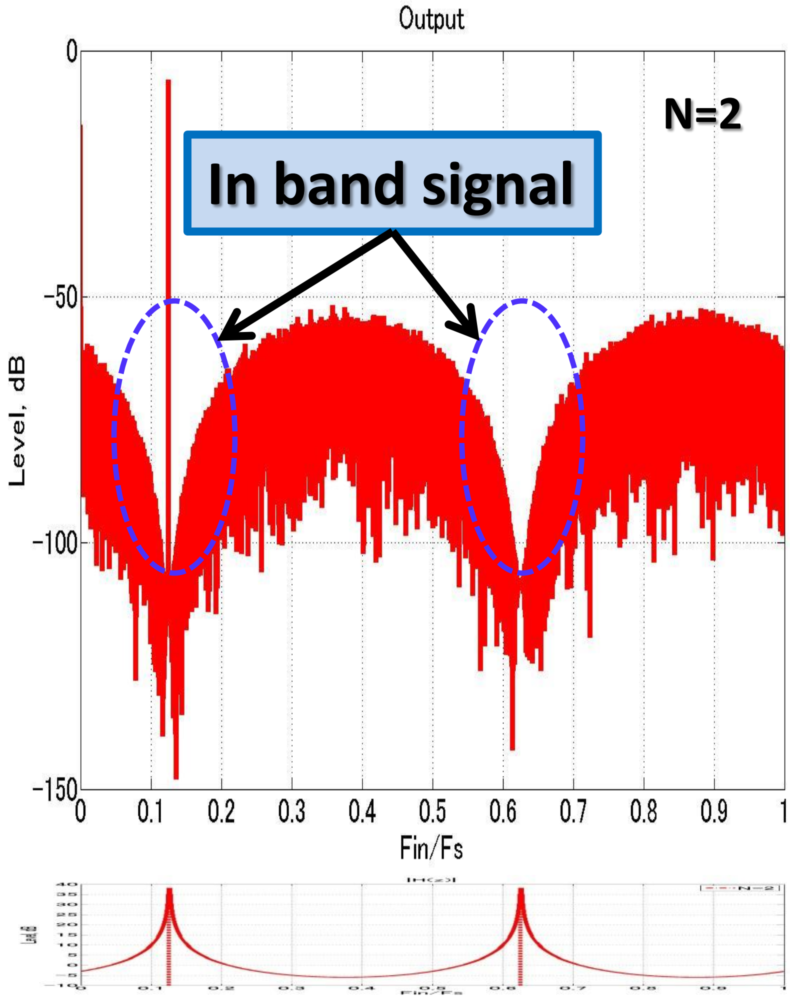
filter

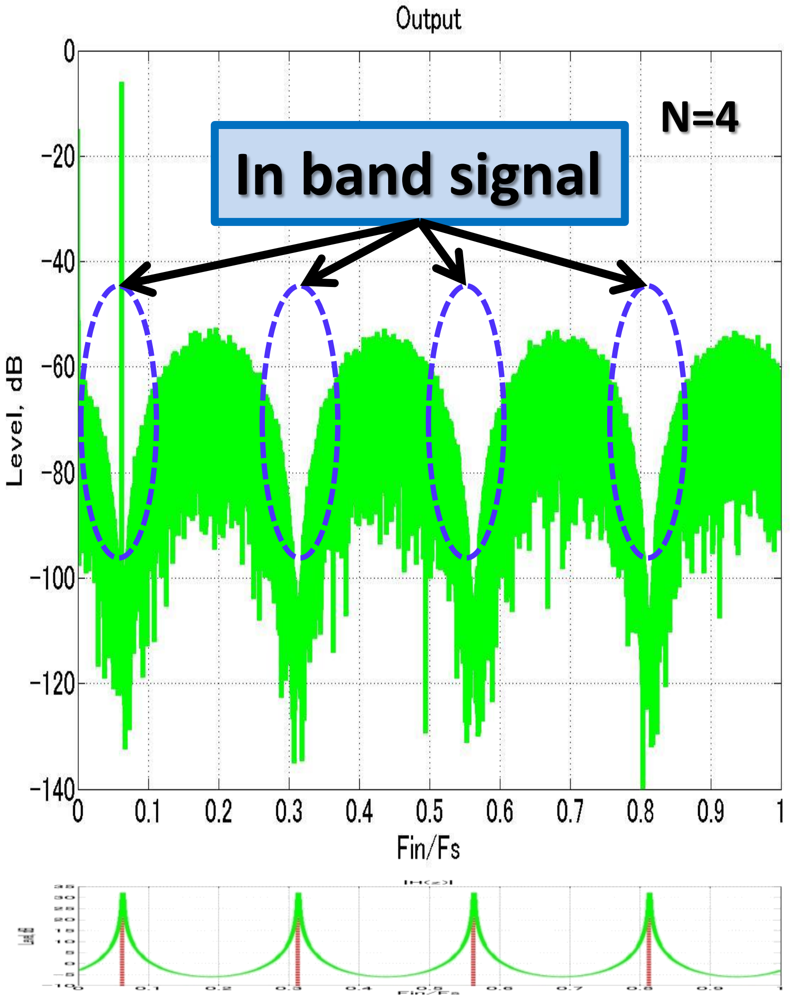
$$A_0 e^{j2\pi f_o t} + A_1 e^{j2\pi f_1 t} + A_2 e^{j2\pi f_2 t} + \dots + A_n e^{j2\pi f_n t}$$

2nd order Complex Multi-Band Pass ΔΣ DA Modulator



Complex Multi-Bandpass(1)





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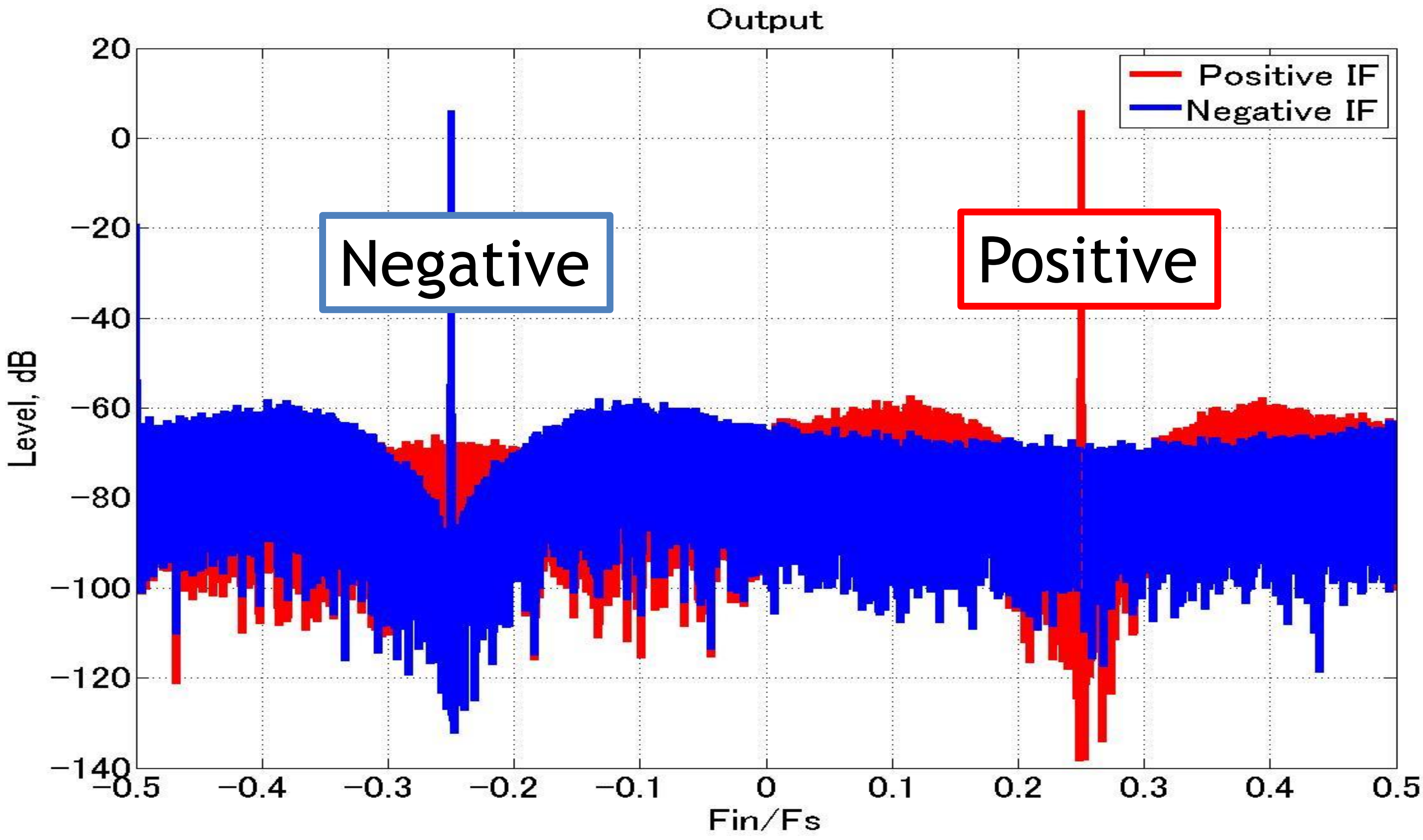
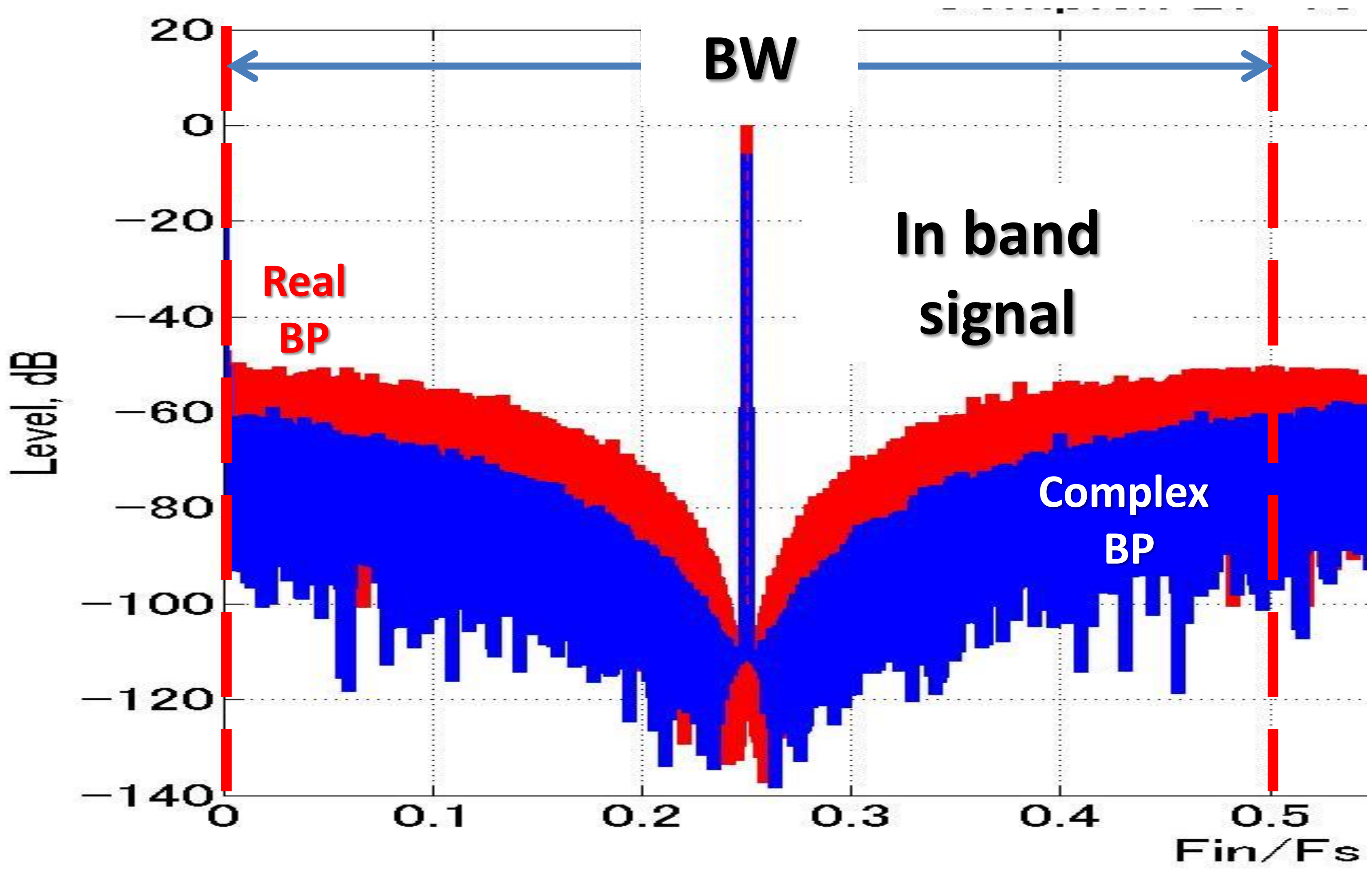
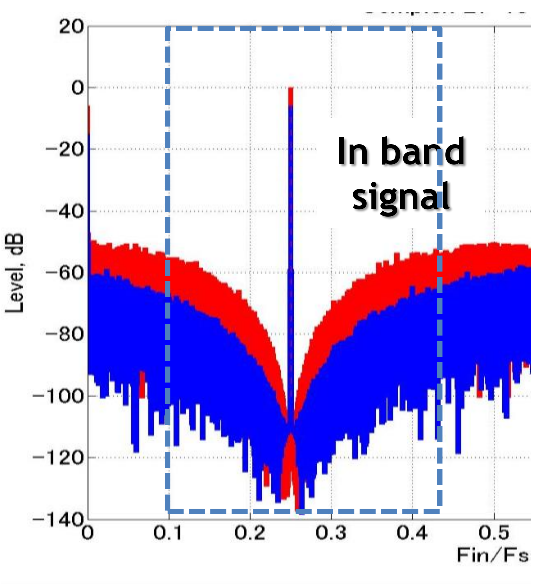
Positive & Negative

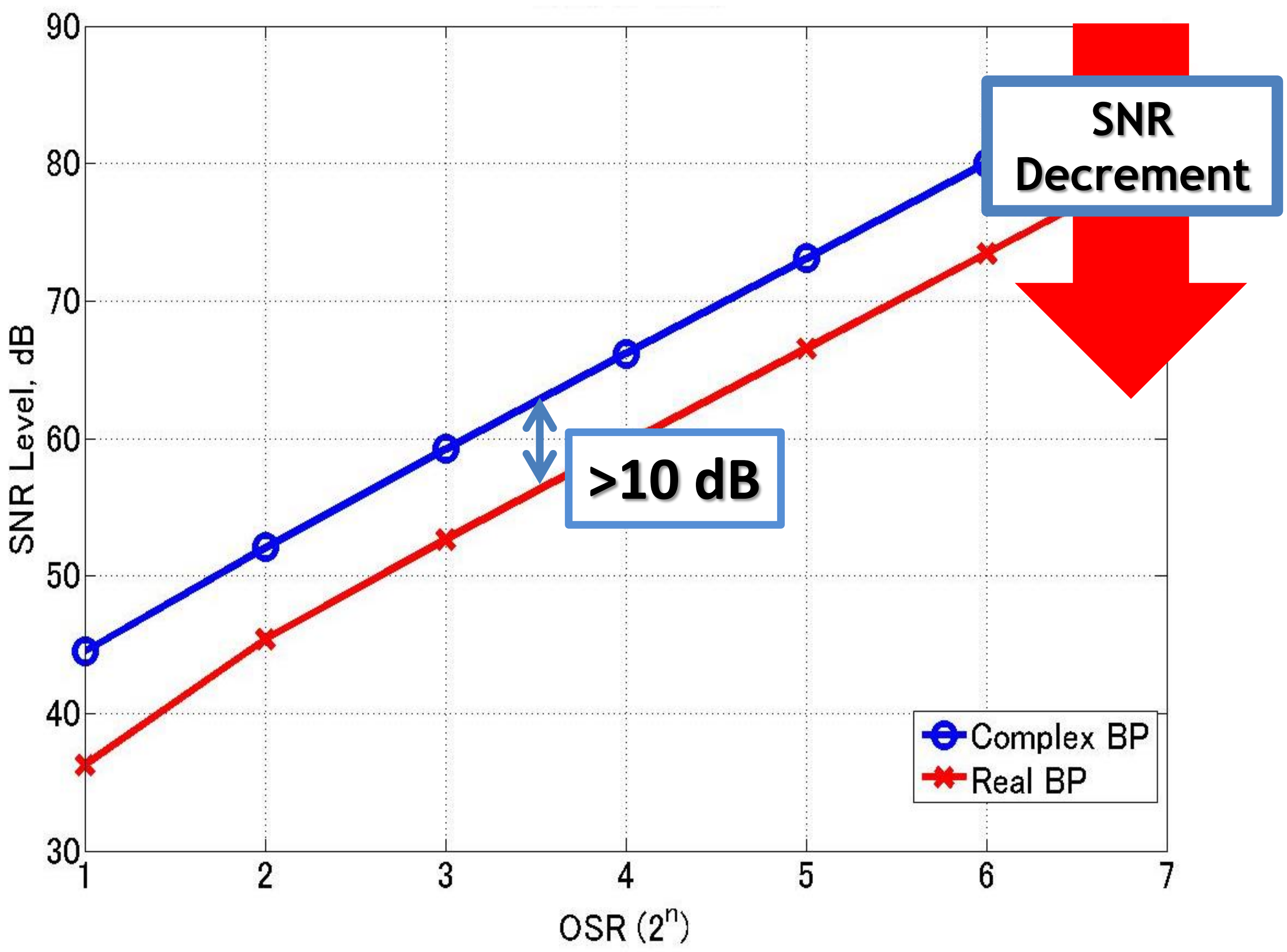


Real versus Complex

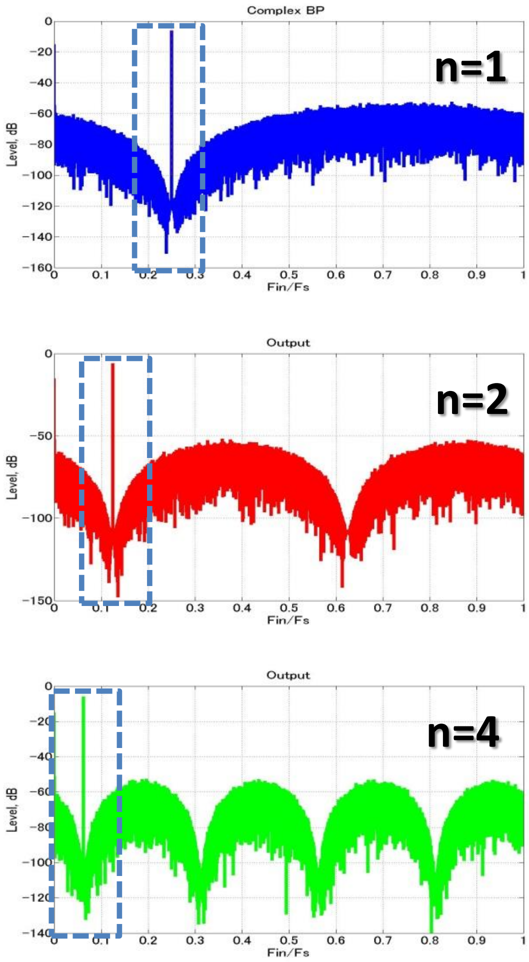


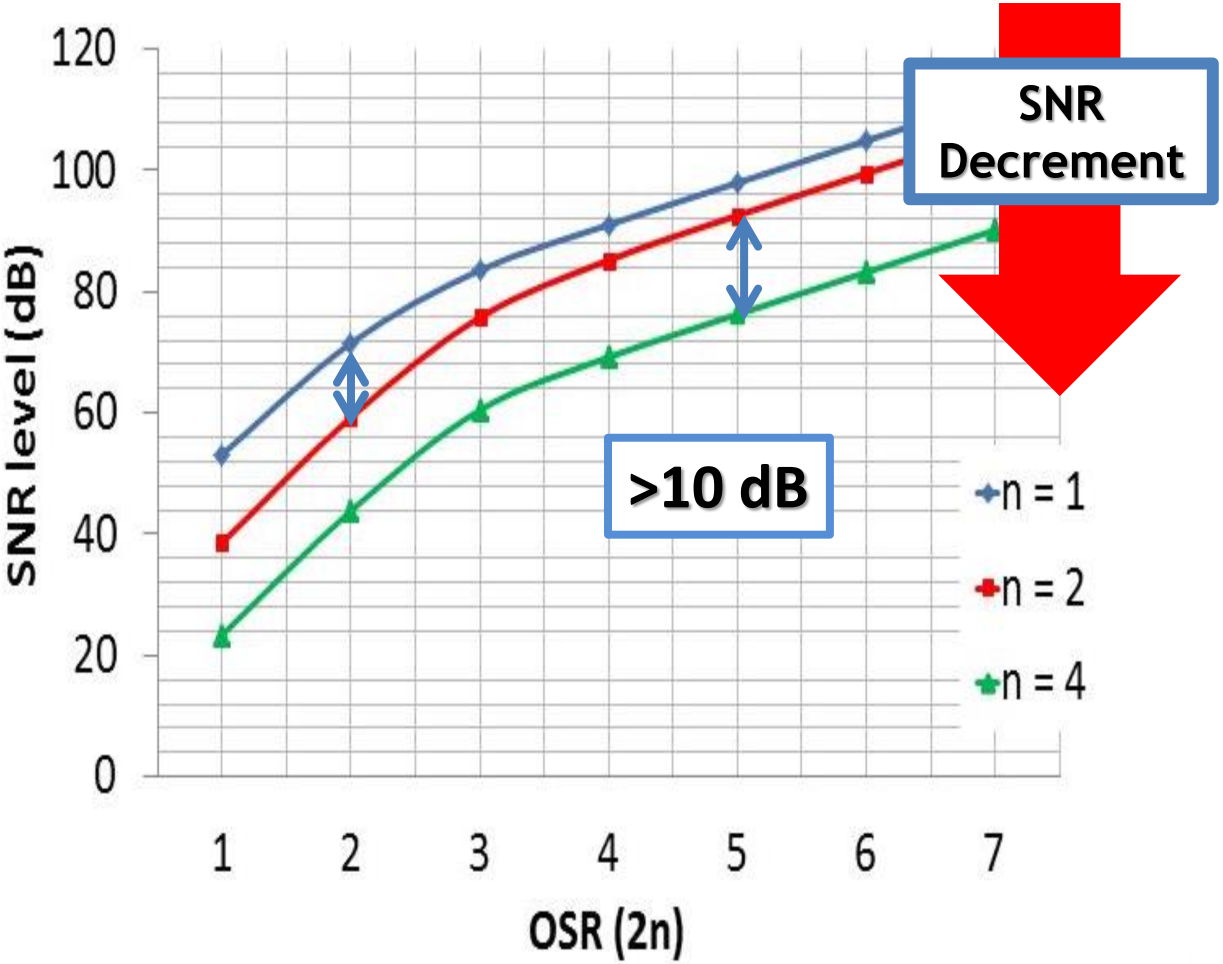
Real versus Complex(2)





Complex Multi-Bandpass (2)





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Conclusion

- Real & complex ΔΣ modulator
  - Digital rich
  - SNR → Complex BP ΔΣ > Real BP ΔΣ

Suitable for a high quality, low cost for I,Q signals generation

- Complex multi-bandpass ΔΣ modulator
  - lower SNR compare to single tone

Suitable for a high quality, low cost multi-tone I,Q signals generation

Thank you very much