Frequency Interleaved DAC System Design: Fundamental Problems and Compensation Methods

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Outline

- Research Background and Objective
- Principle and Structure of FI-DAC Architecture
- Fundamental Problems of FI-DAC Architecture in Principle and Their Compensation
  - Zero Order Hold
  - Phase Problems
- Conclusion

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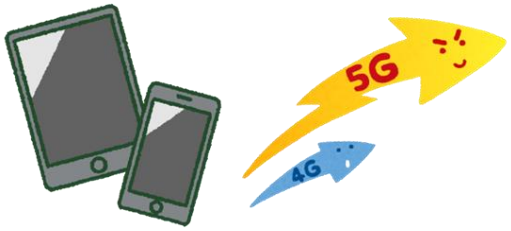
several GHz

Research Background and Objective

Communication is more wideband



Necessarily

Measurement of wideband devices for next-generation communication systems

Objective

Realization of DAC

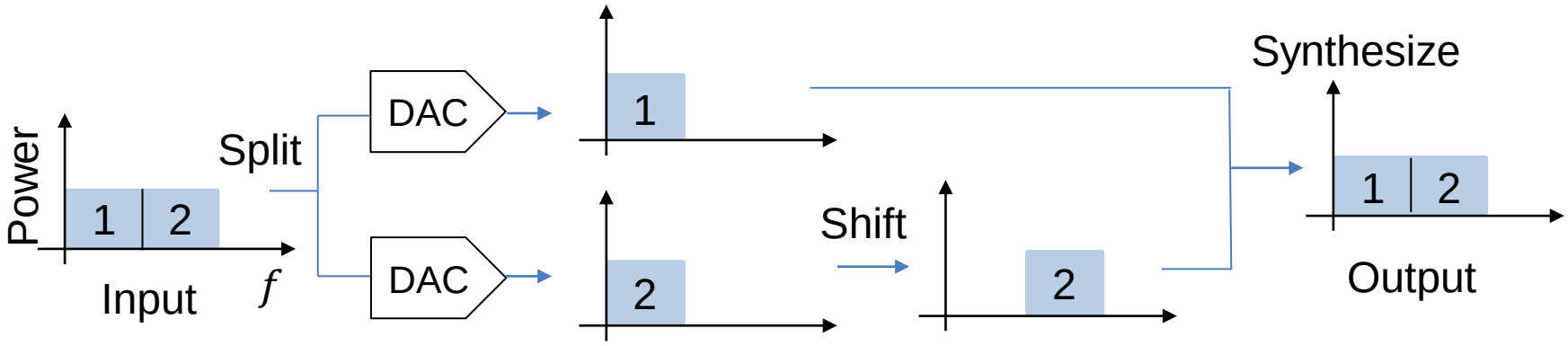
for ultra wideband signal generator

6G：Over 1 GHz　BW

Our Approach

Frequency Interleaved DAC (FI-DAC)

- Split input band
- Use multiple DACs (sub-DAC)
- Shift bands in frequency domain and synthesize



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FI-DAC Architecture

4 channel FI-DAC Architecture

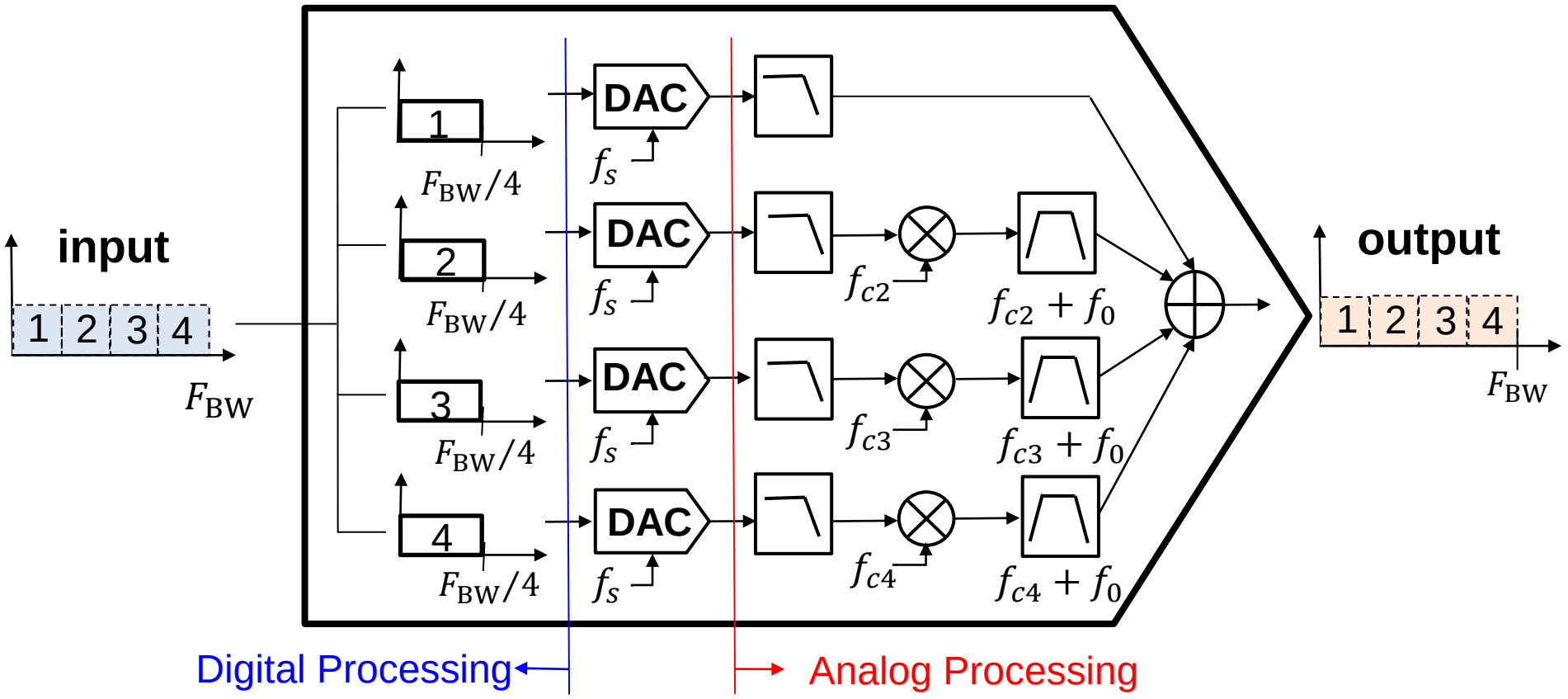
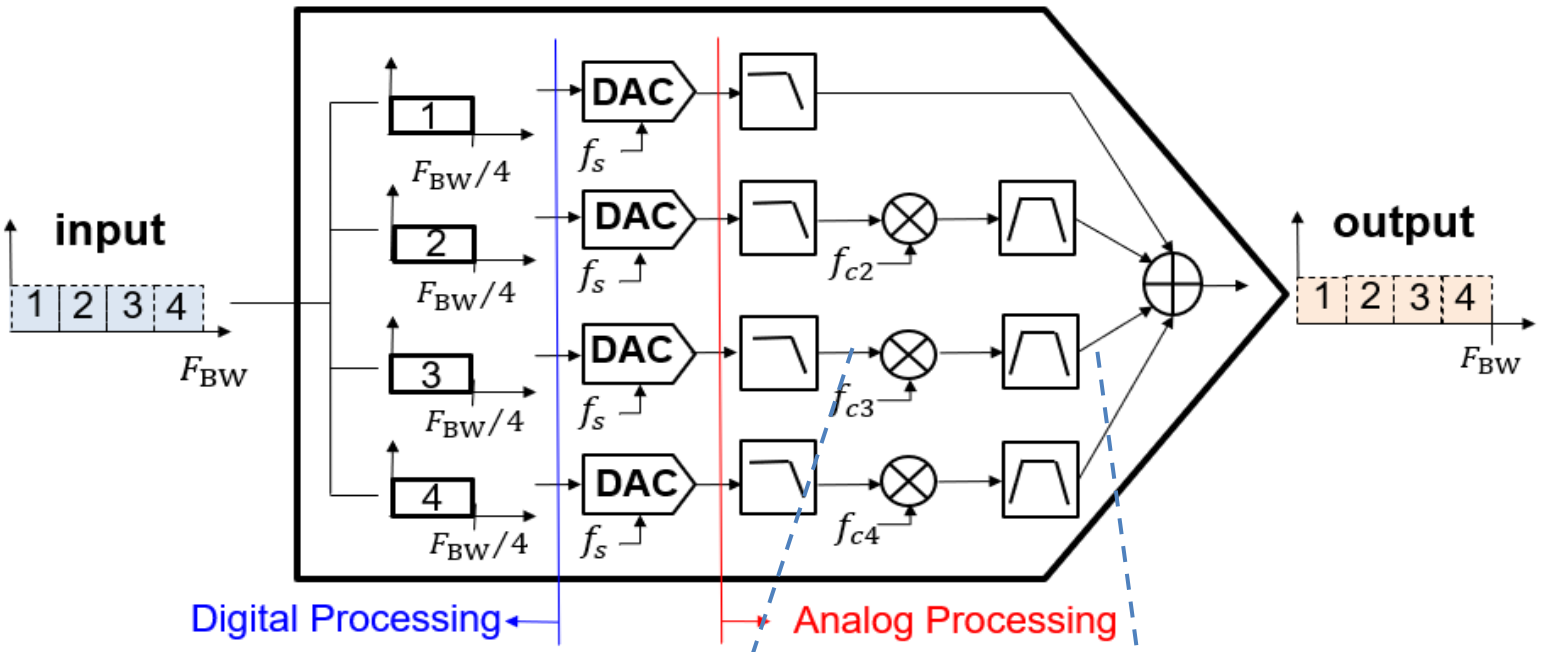


Image Component Issue



Suppressed by analog filters

f_s: sampling frequency
f_{ck}: carrier frequency

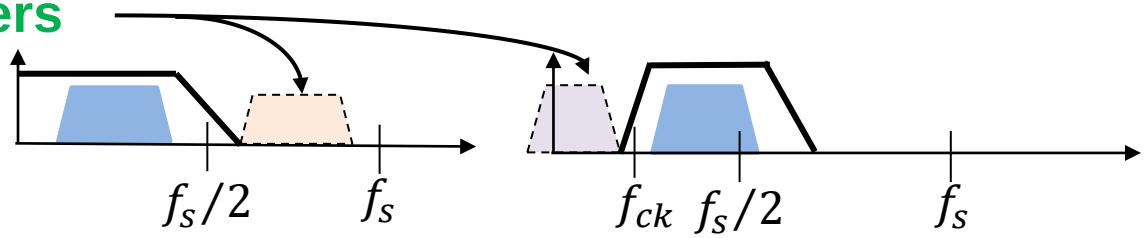
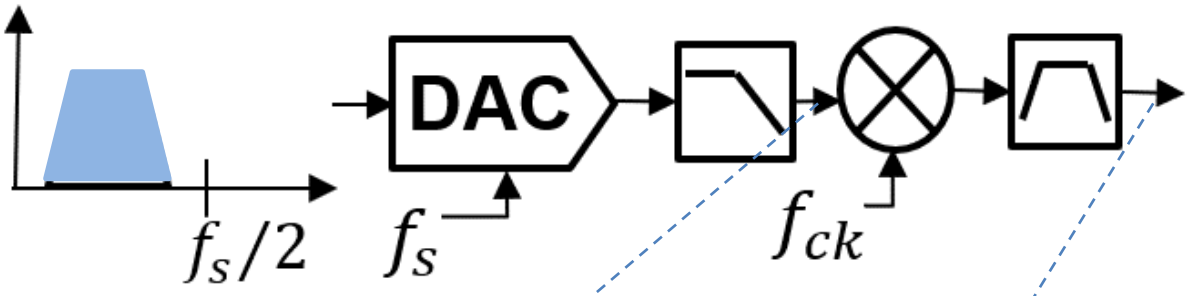


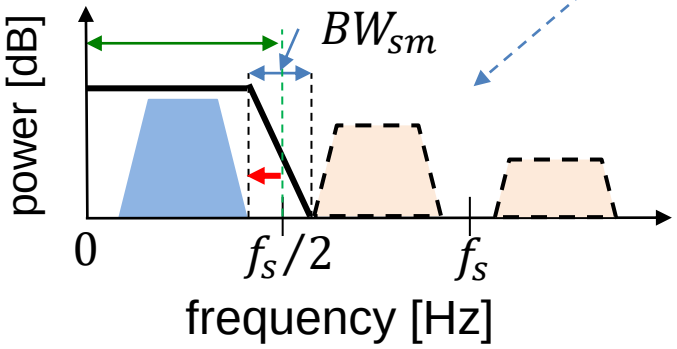
Image component by DAC

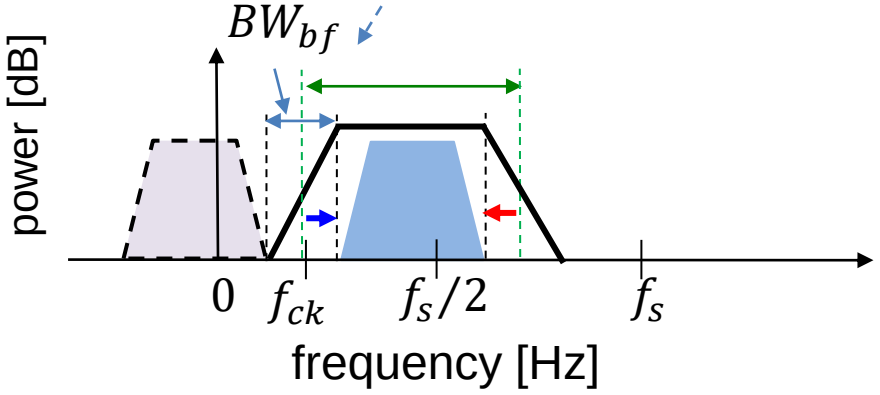
Image component by modulation

Restriction of Sub-DAC Bandwidth



Signal bandwidth input to sub-DAC





BW_{sm}: Smoothing filter transition bandwidth

BW_{bf}: Analog bandpass filter transition bandwidth

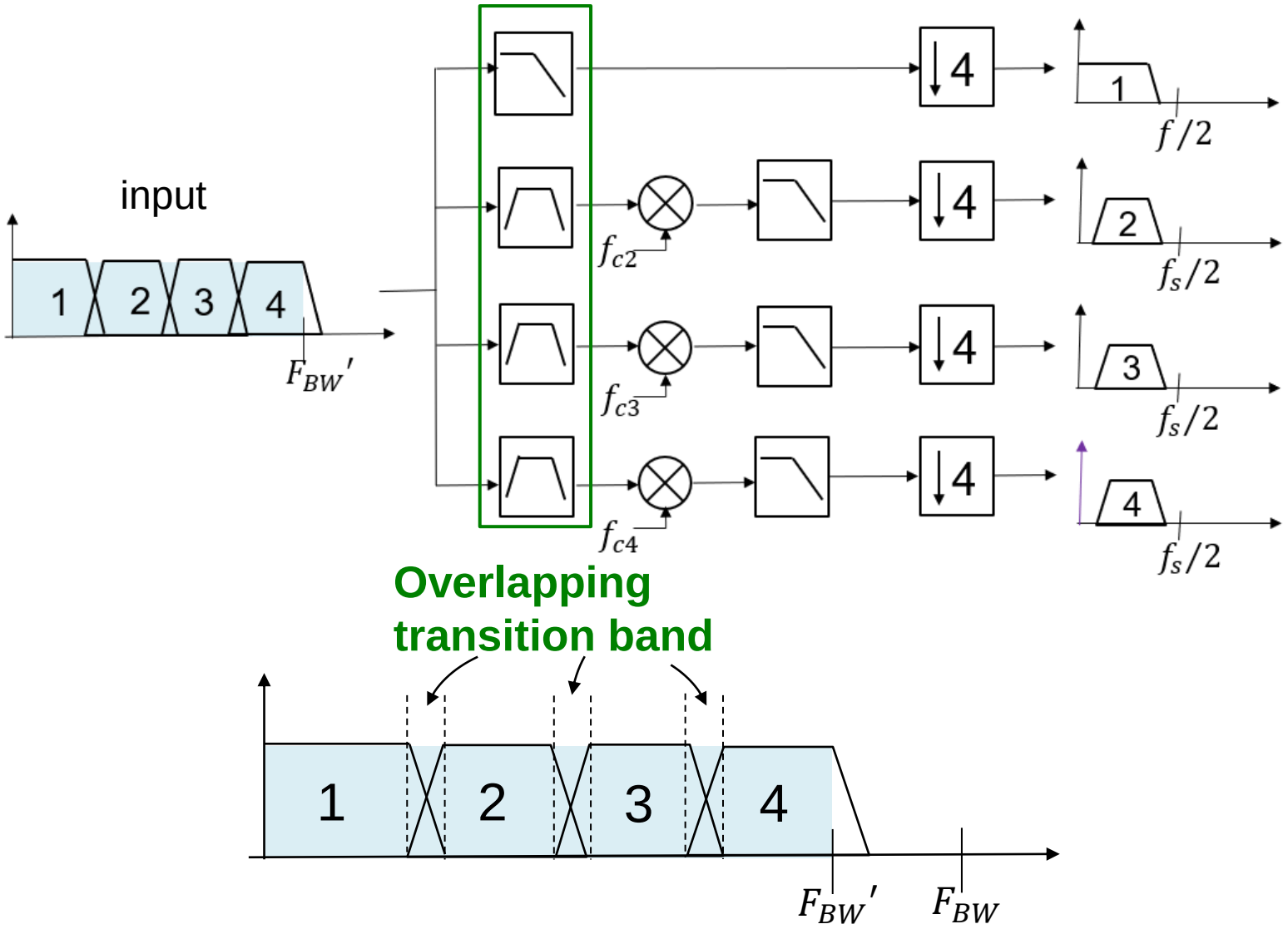
Image component by DAC

Image component by Modulation

Band Splitting Processing

Digital processing

Subband filters



Overlapping transition band

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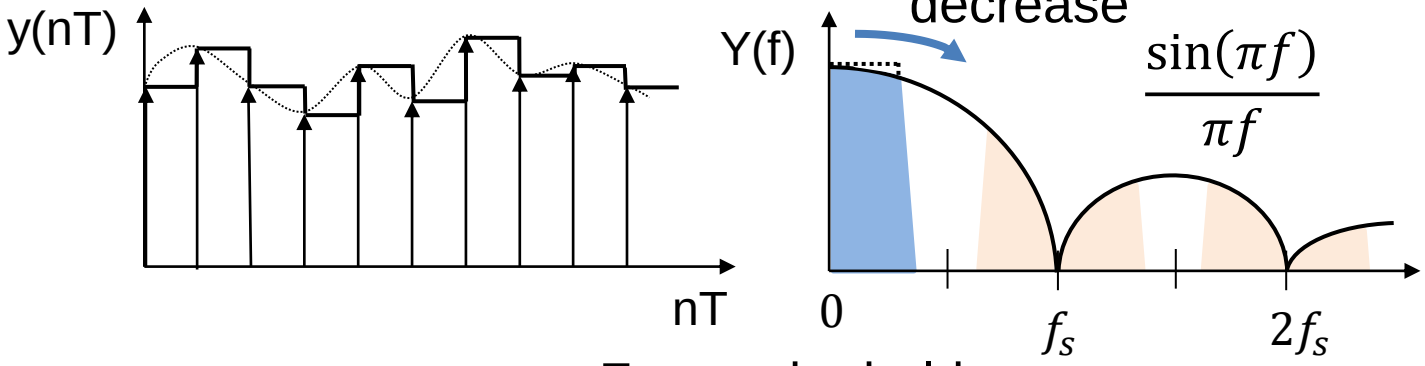
Zero Order Hold and Compensation

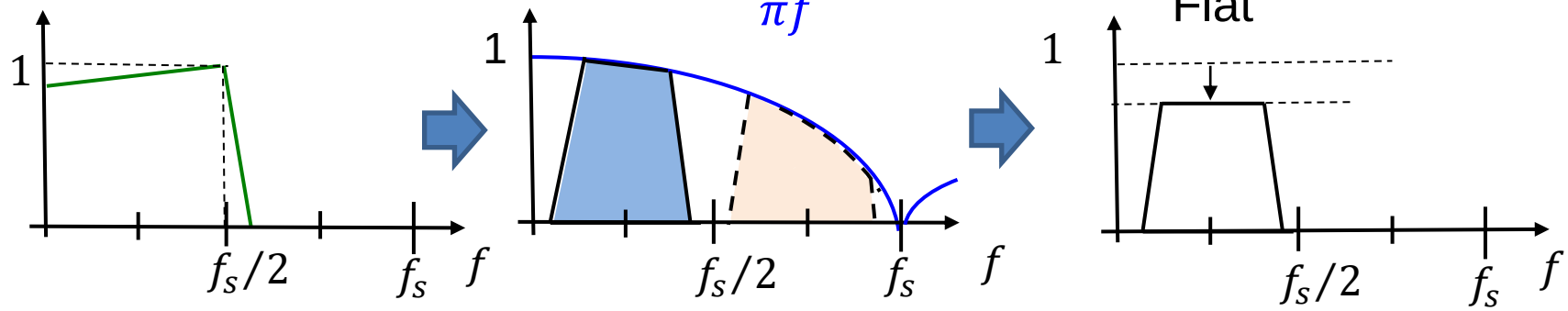


Zero order hold

compensation

Inverse sinc: $\frac{\pi f}{\sin(\pi f)}$

sinc: $\frac{\sin(\pi f)}{\pi f}$



Inverse sinc filter

Zero order hold

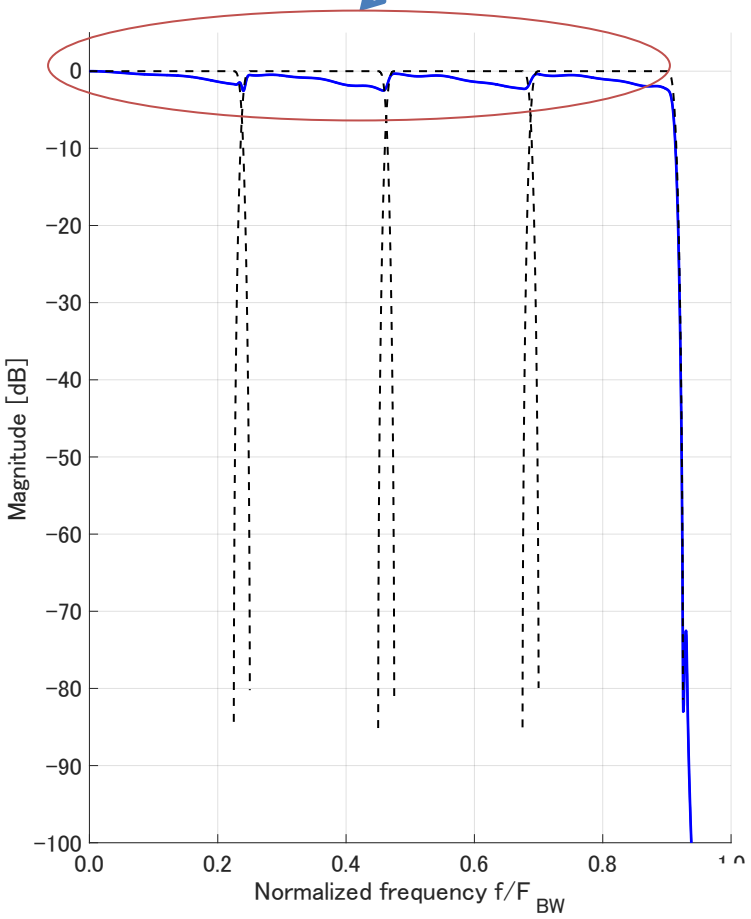
Sub-DAC output

Zero Order Hold Simulation

FI-DAC output

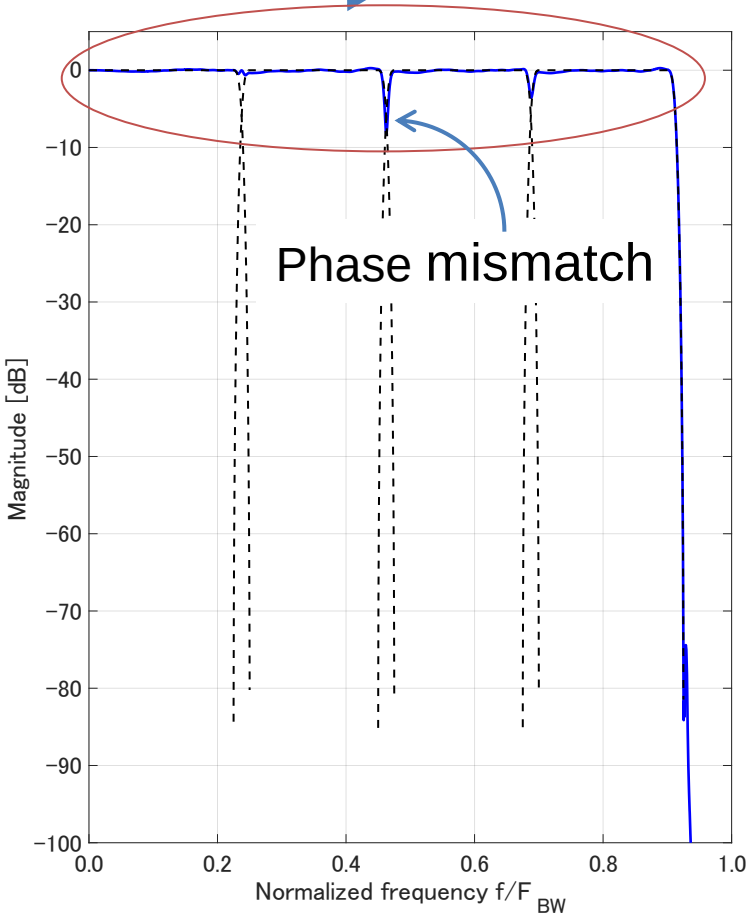
W/O compensation

Gradually decrease



W/ compensation

flat



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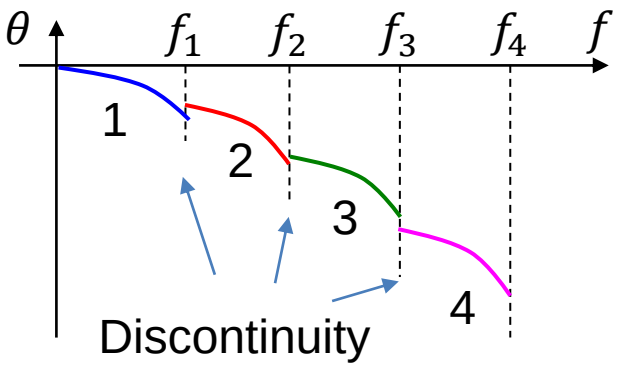
Requirements for Phase Characteristics

Problems

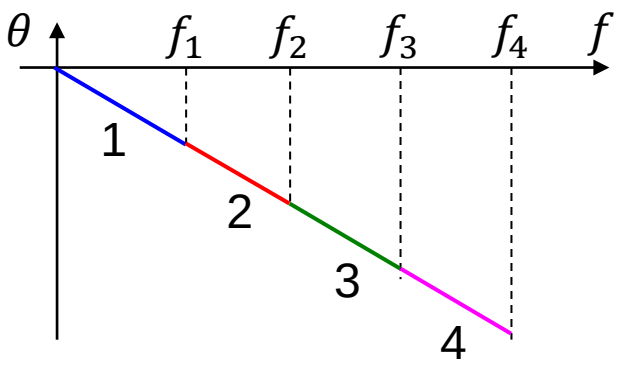
- Phase-nonlinearity characteristics of analog filters
- Differences in group delay among channels
- Phase discontinuity among adjacent channels

Phase characteristics

W/O compensation



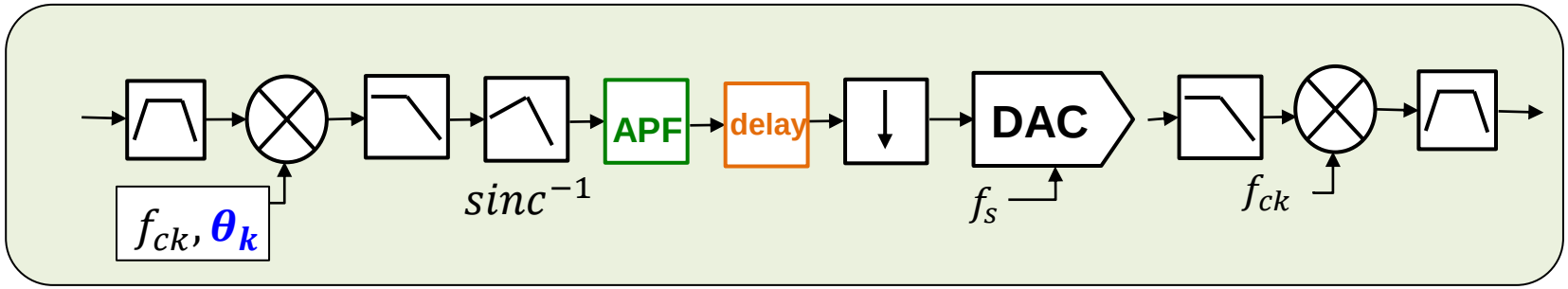
W/ compensation



Phase Compensation

Problems	Compensation Methods
Phase-Nonlinearity characteristics of analog filters	Applying all-pass filters
Differences in group delay among channels	Changing sampling timing
Phase discontinuity among adjacent channels	Adjusting initial phases of carrier signals in digital signal processing

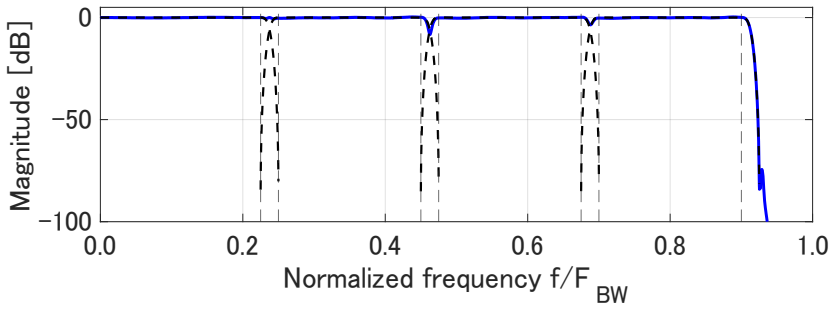
k-th channel

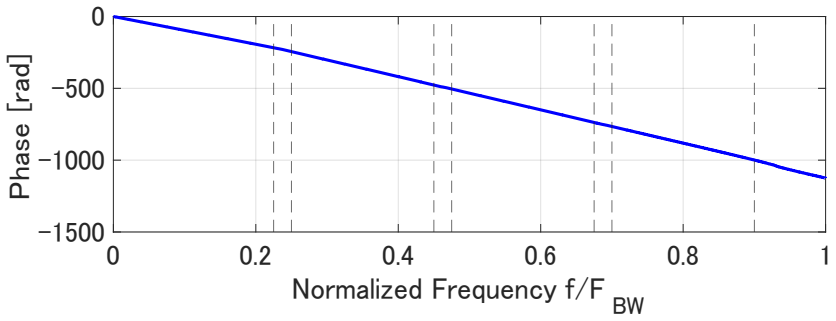


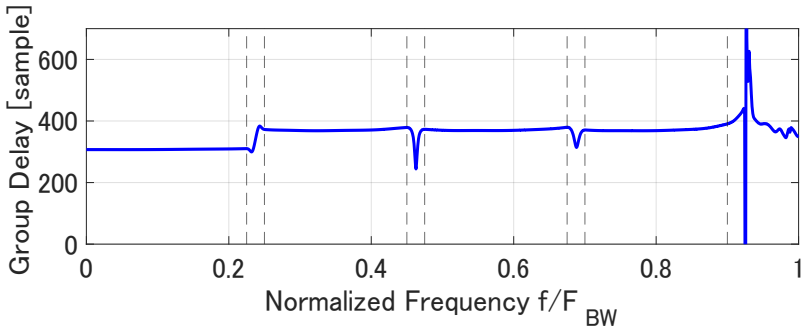
Phase Compensation Simulation

FI-DAC output

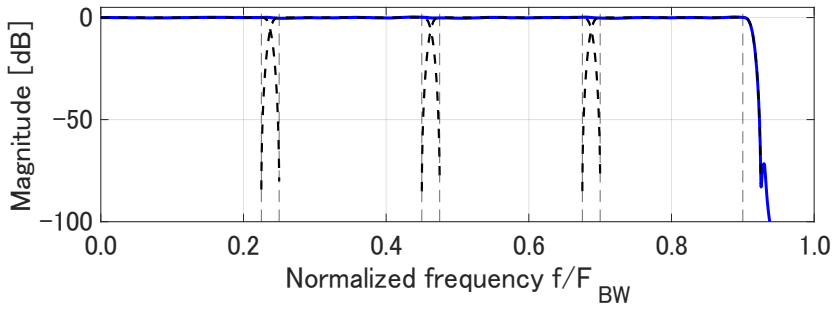
W/O compensation

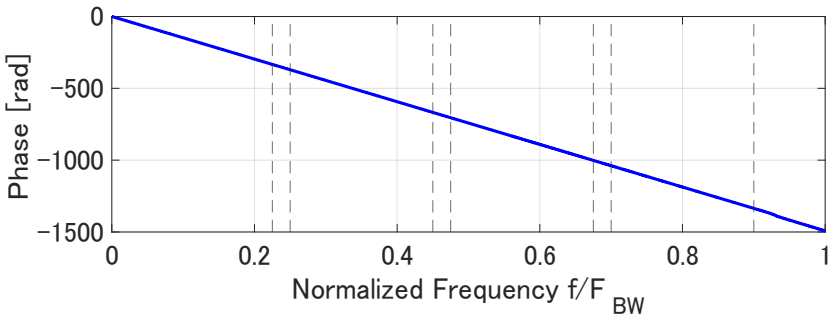


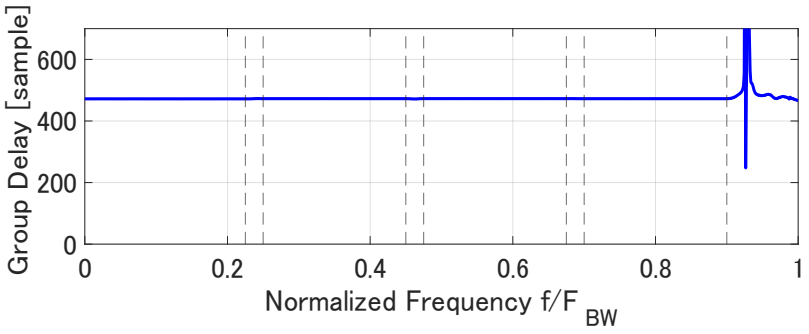




W/ compensation



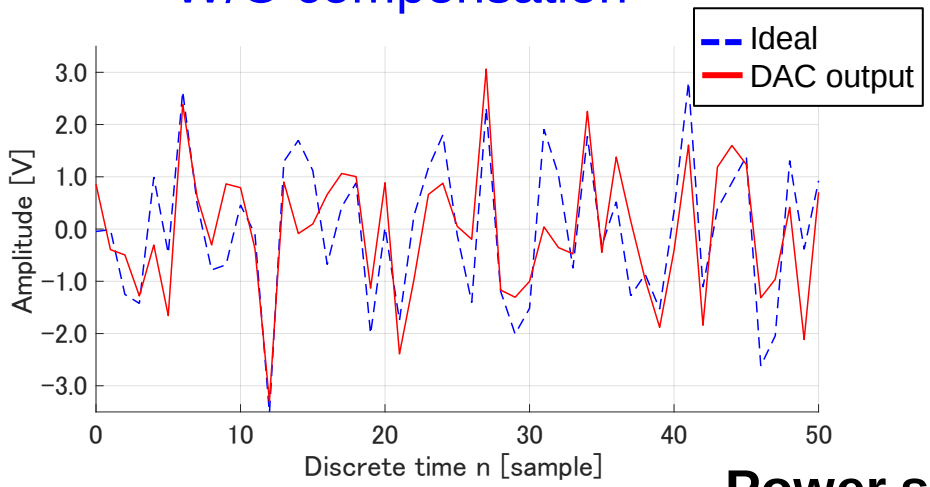




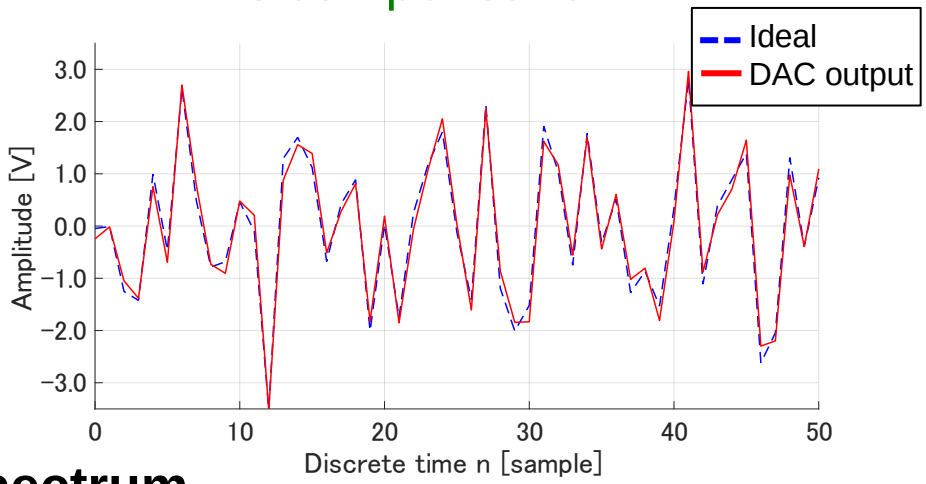
4-tones Wave Simulation

FI-DAC output
Time waveform

W/O compensation

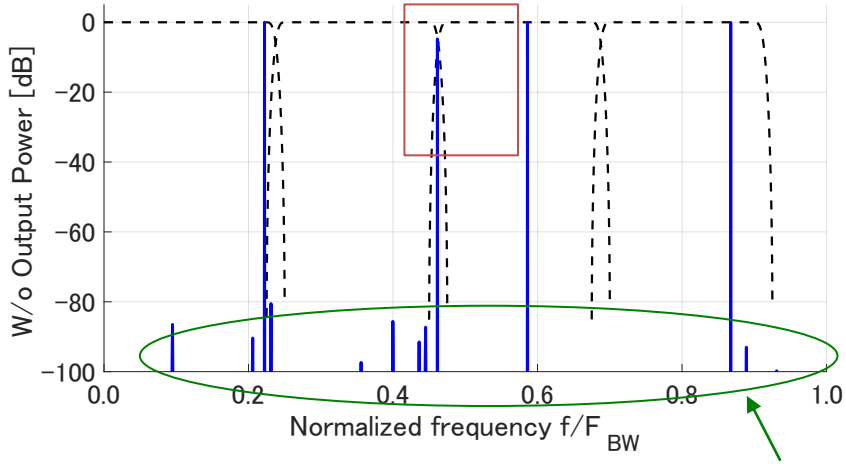


W/ compensation



Power spectrum

Phase mismatch



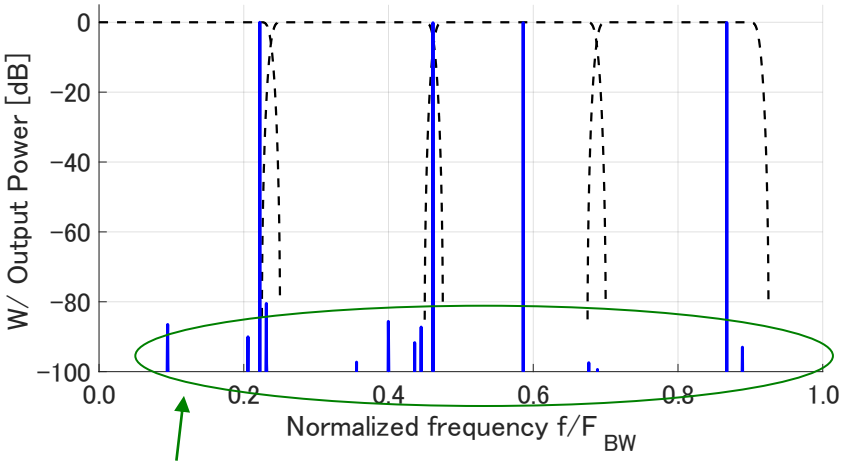


Image component by modulation

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Conclusion

- Investigation of basic configuration of frequency interleaved DAC architecture
- Signal attenuation by DAC zero order hold

  →Applying inverse sinc filter
- Phase-nonlinearity

  →Applying all-pass filters
- Differences in group delay

  →Changing sampling timing
- Phase discontinuity among subband channels

  →Adjusting initial phases of carrier signals

Future Work

- Compensation of
  - Small delay (< sampling period)
  - Frequency response mismatch among channels

Thank you for listening