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Two-Tone Signal Generation for Communication Application ADC Testing

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Outline

- Research Background
- Conventional Method
- Proposed Method
- Experimental Results
- Conclusion

Outline

- Research Background

Research Background

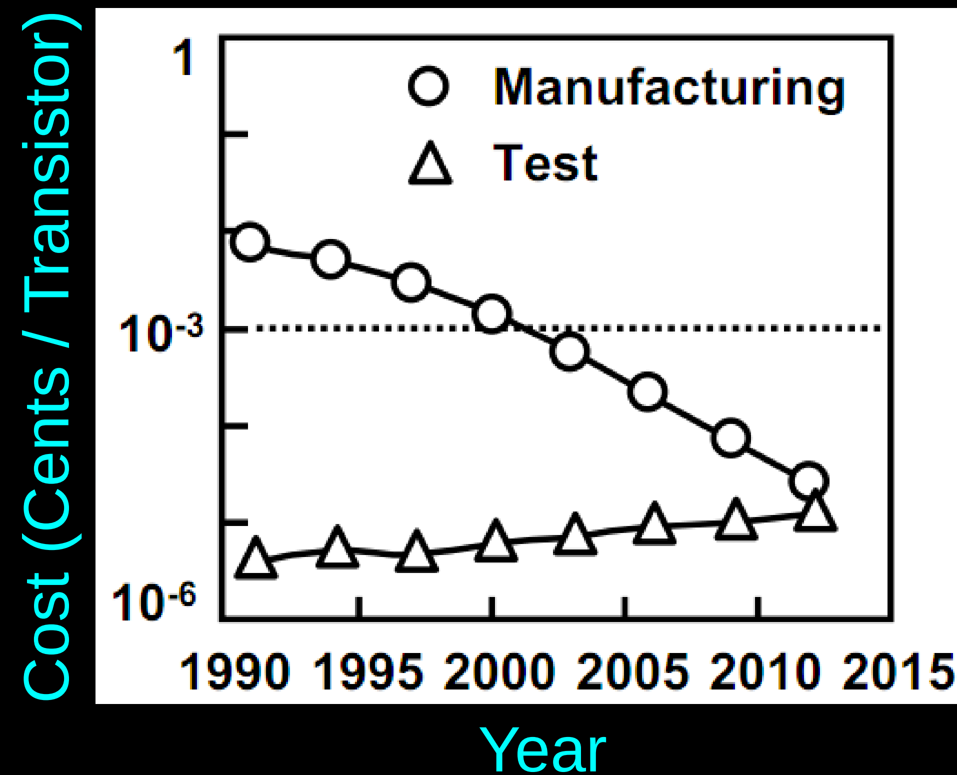
Mixed signal SoC, communication devices

Analog digital converter (ADC) is key component

Manufacturing cost → Lower

Test cost → Higher

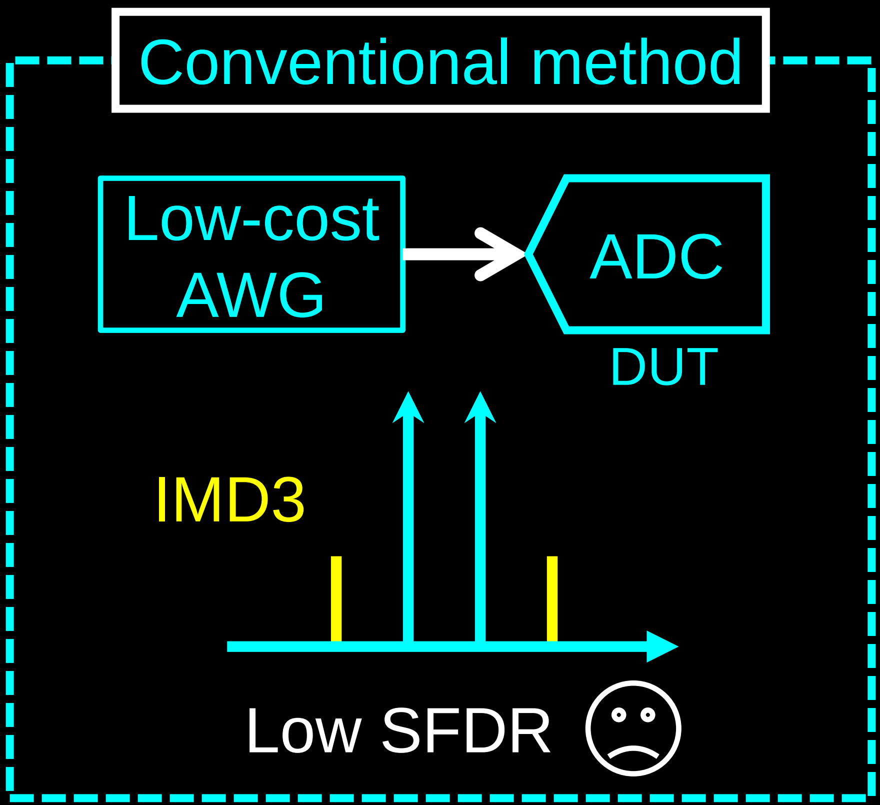
Need for low cost test

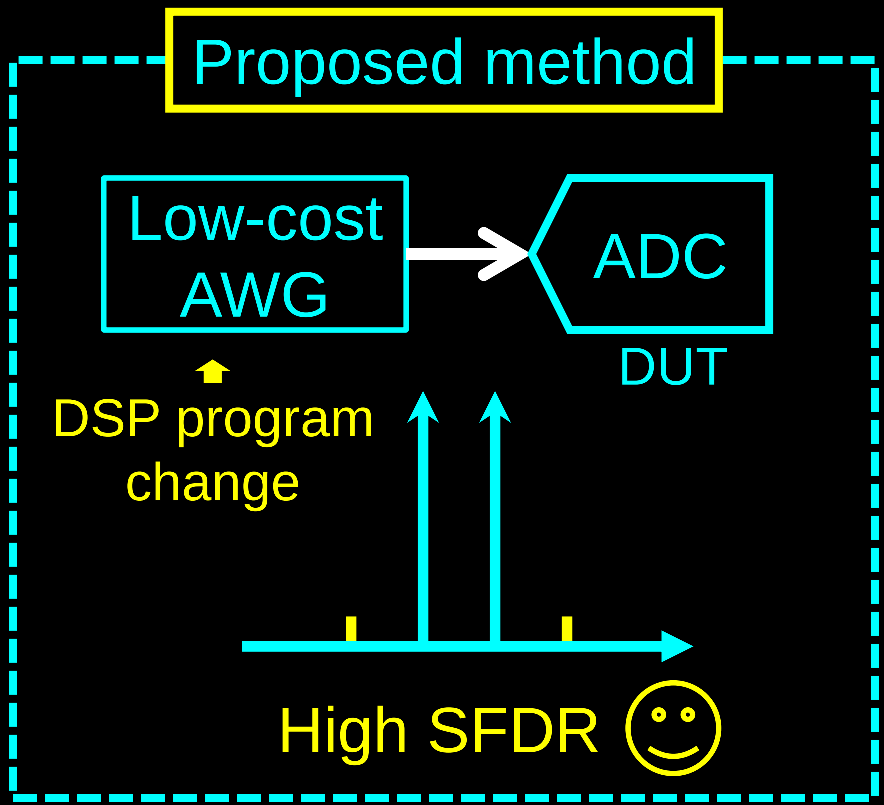


Cost of test trend
(ITRS 2001)

Research Goal

Low distortion two-tone signal generation
for communication application ADC testing
with low-cost AWG





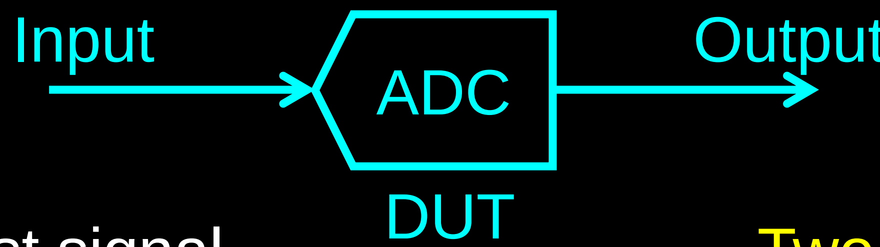
AWG : Arbitrary Waveform Generator

SFDR : Spurious-Free Dynamic Range

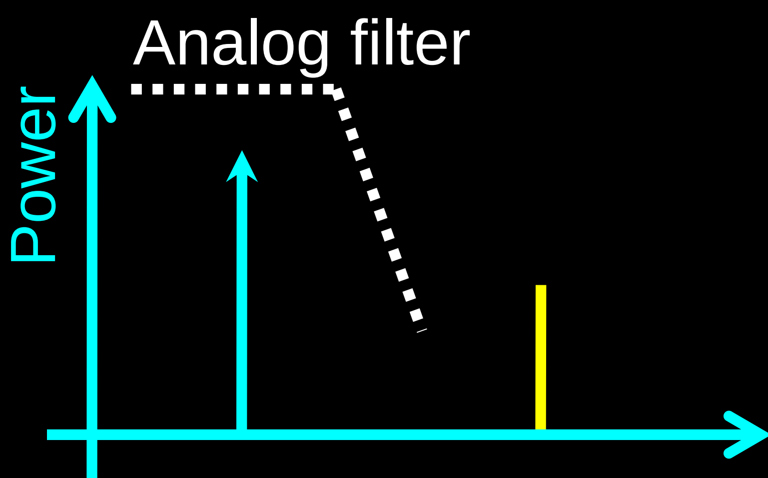
Need for Two-tone Test Signal

Communication application ADC

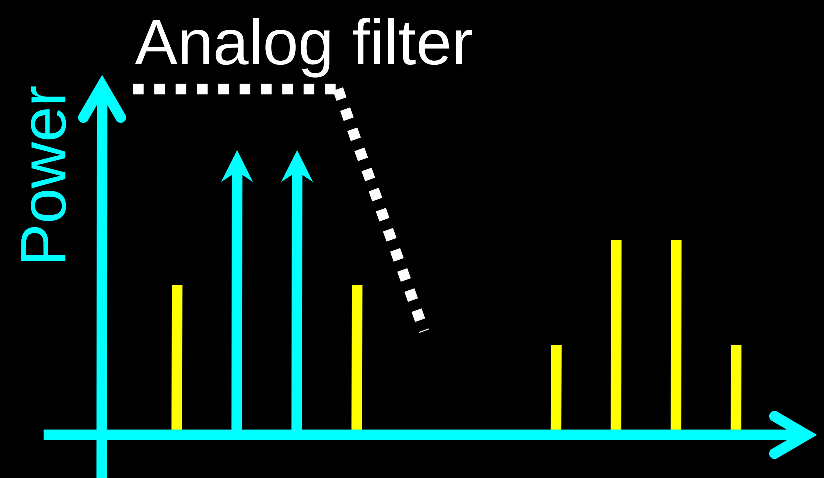
Receive narrow band & high frequency signal



Single-tone test signal



Two-tone test signal

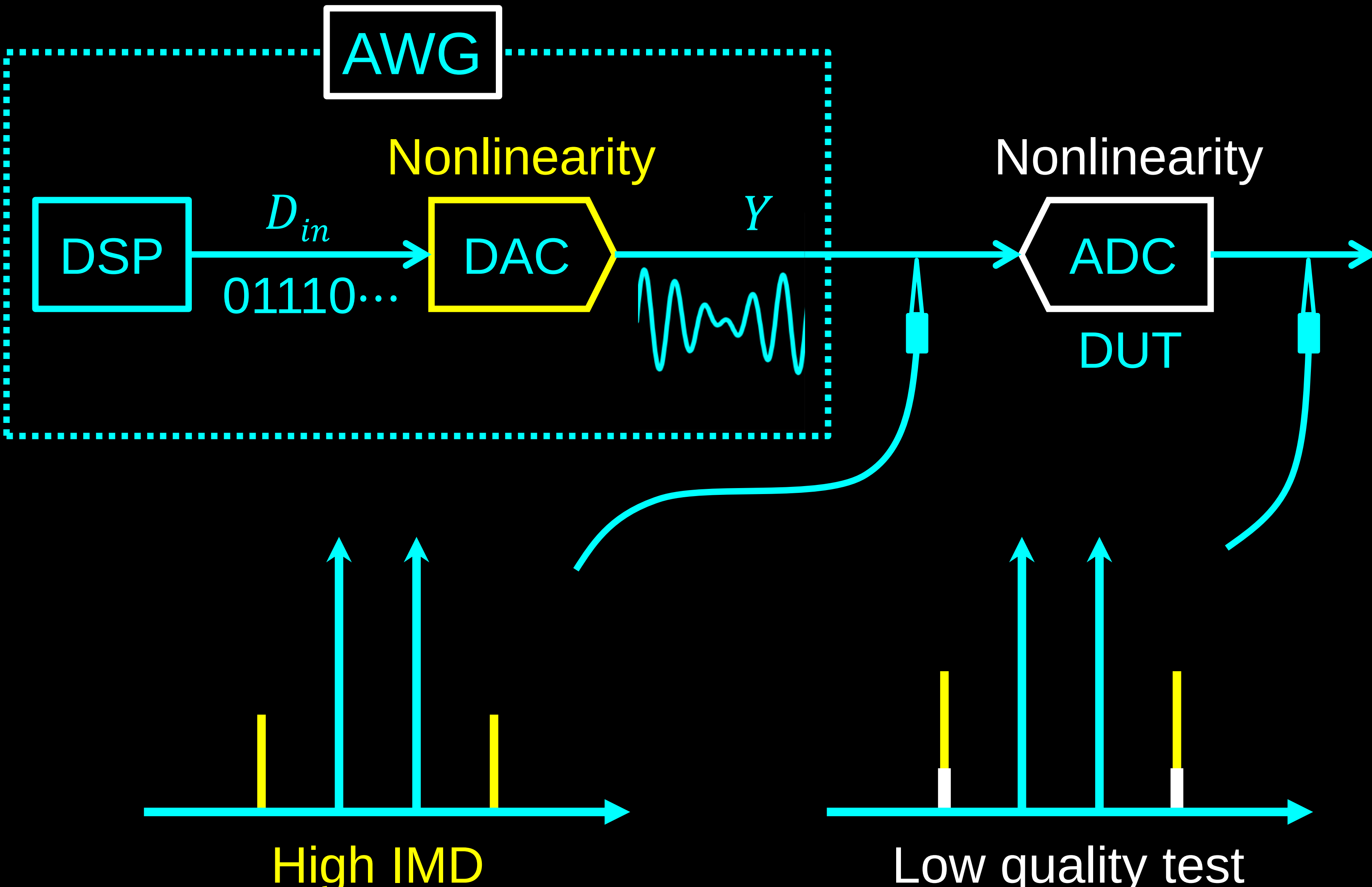


Output spectrum

Cannot test nonlinearity of ADC

Can test nonlinearity of ADC

Two-Tone Signal Generation with AWG

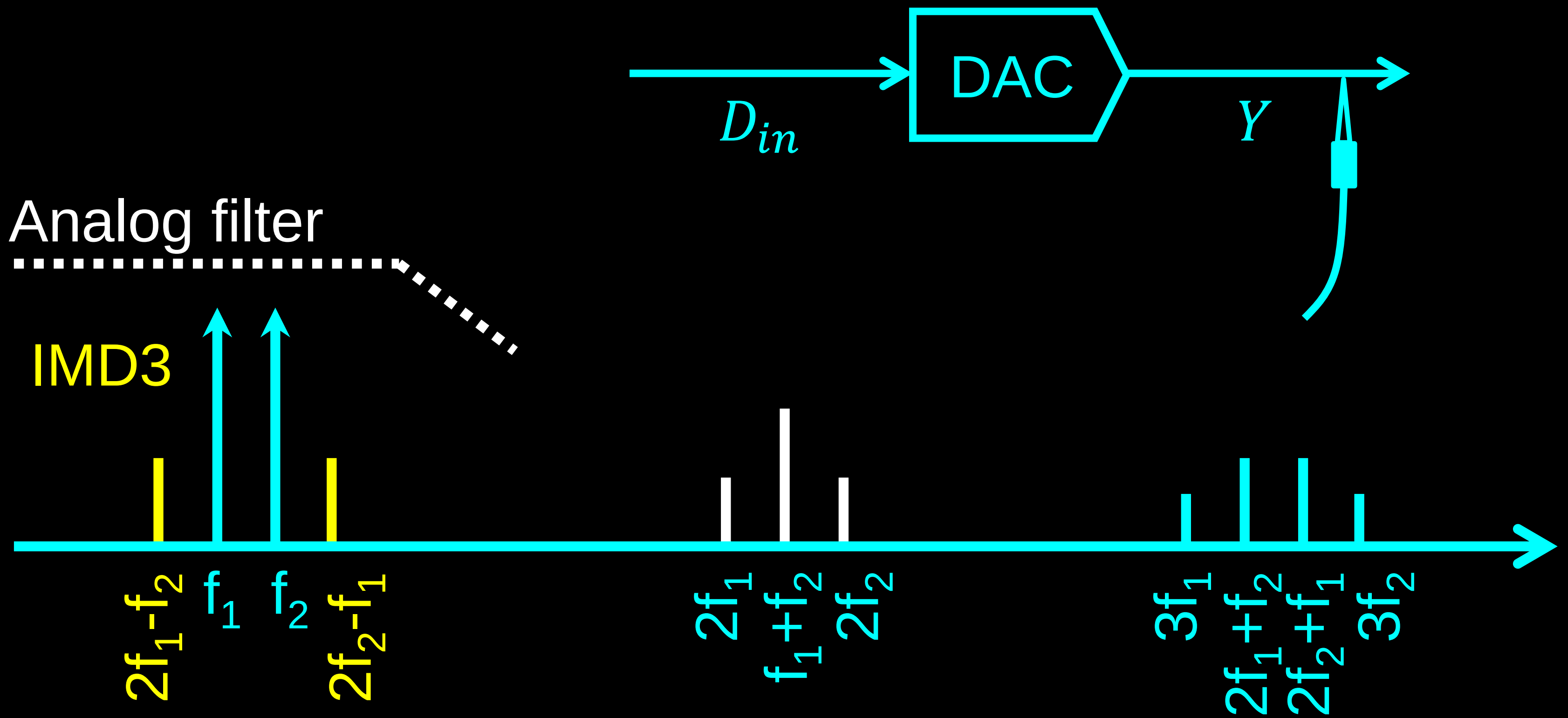


DAC : Digital Analog Converter IMD : Inter Modulation Distortion

Distortion by Nonlinearity DAC

Ideal DAC $Y = a_1 D_{in}$

Actual DAC $Y = a_0 + a_1 D_{in} + a_2 D_{in}^2 + a_3 D_{in}^3 + \cdots$

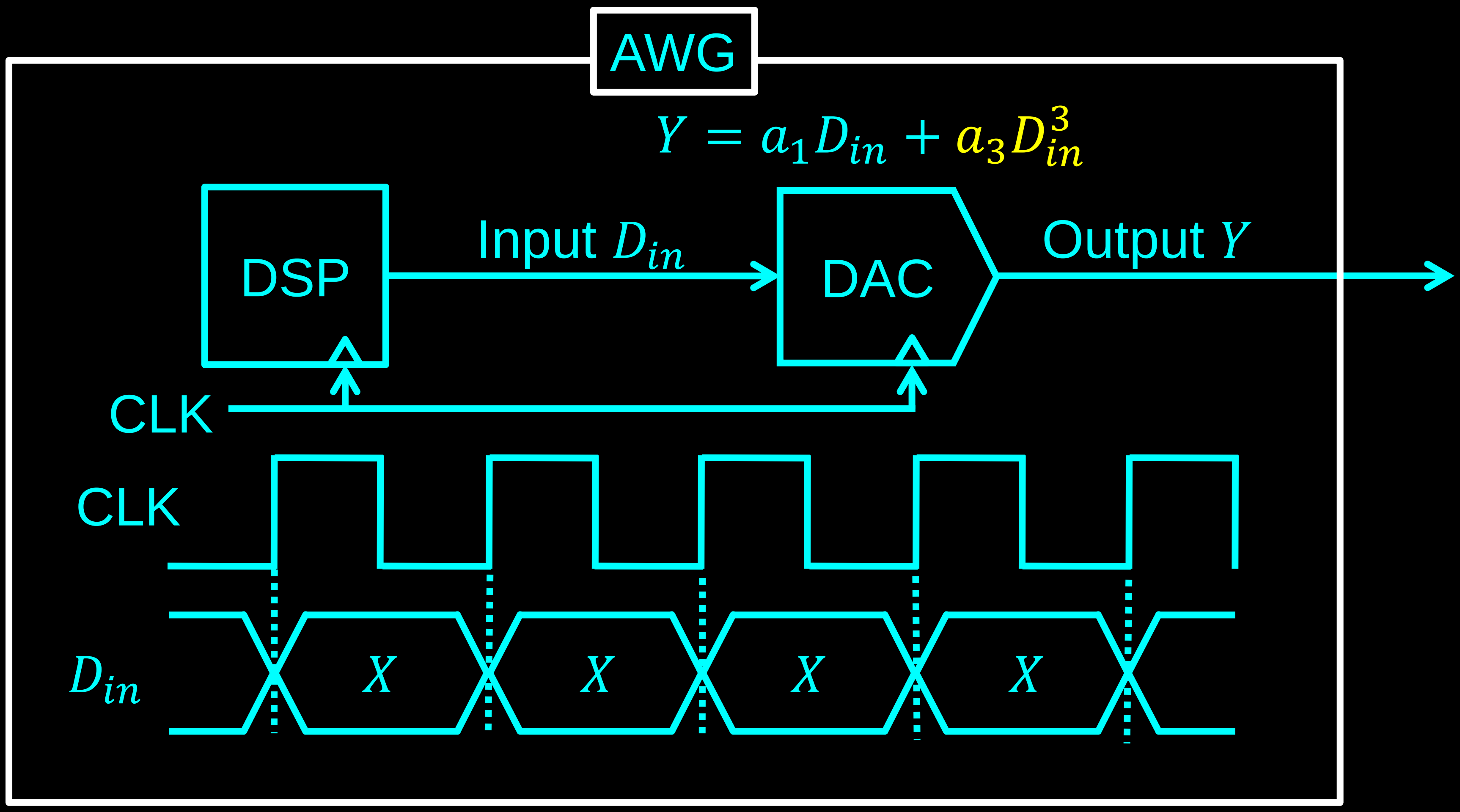


Cannot remove IMD3 with analog filter

Outline

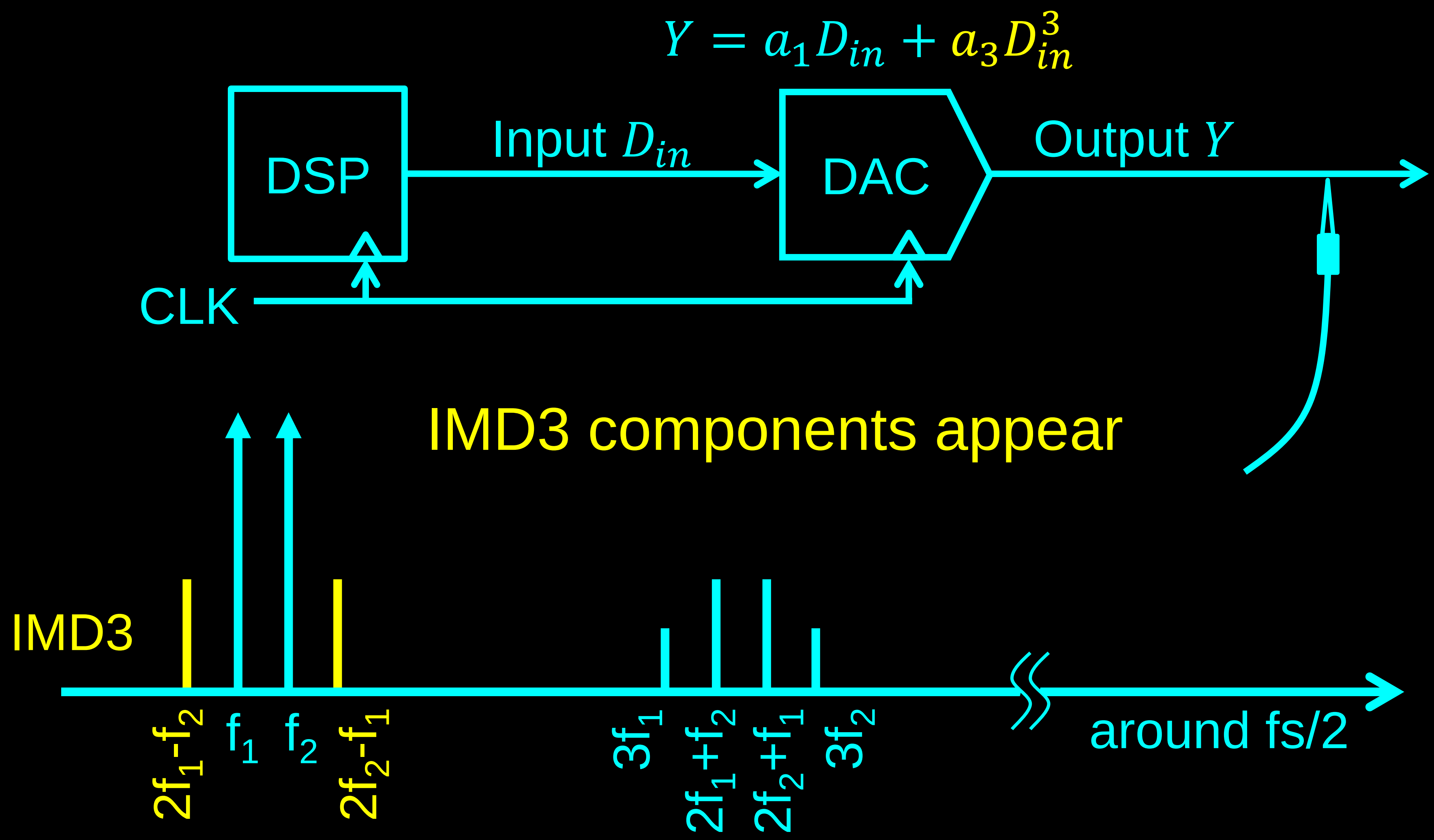
- Conventional Method

Conventional Method



$$X = A \cdot \sin(2\pi f_1 n T_s) + B \cdot \sin(2\pi f_2 n T_s)$$

Conventional Method



Outline

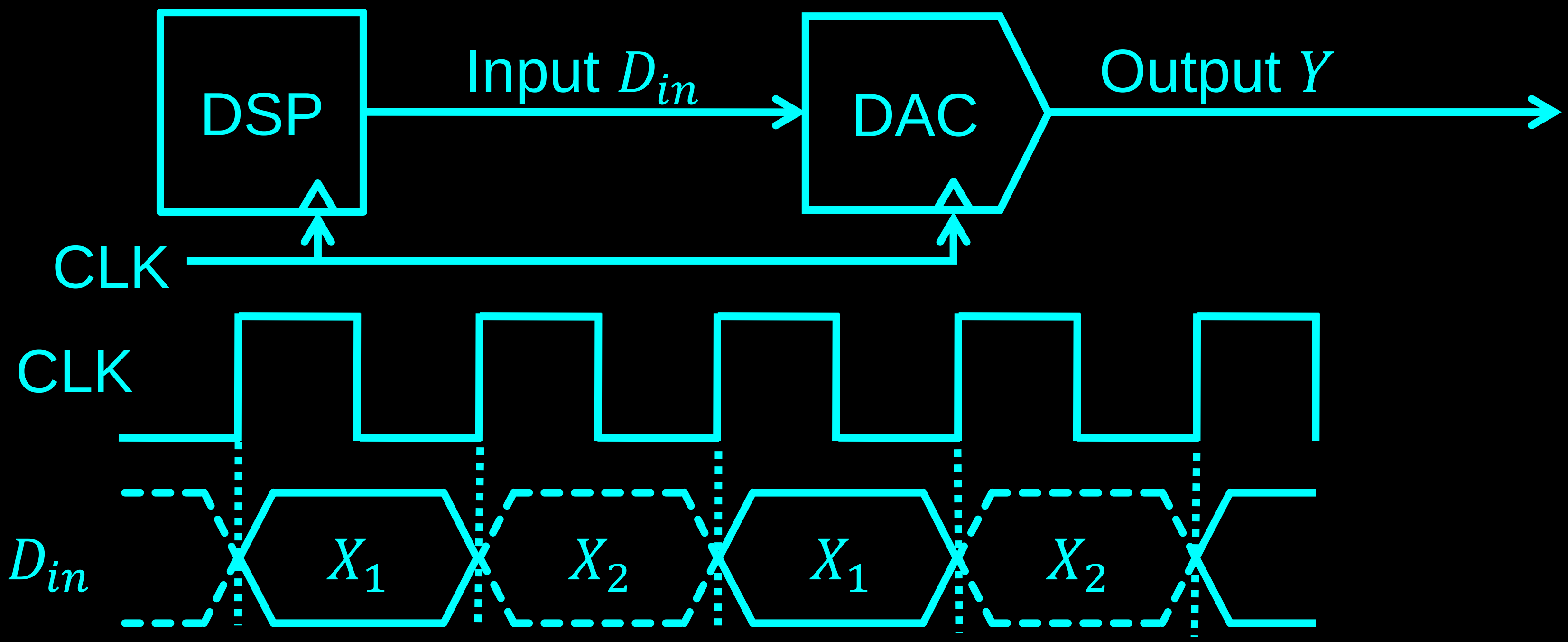
- Proposed Method

Proposed Method

- Phase Switching
- Frequency Switching
- Combination of Phase & Frequency Switching

Phase Switching

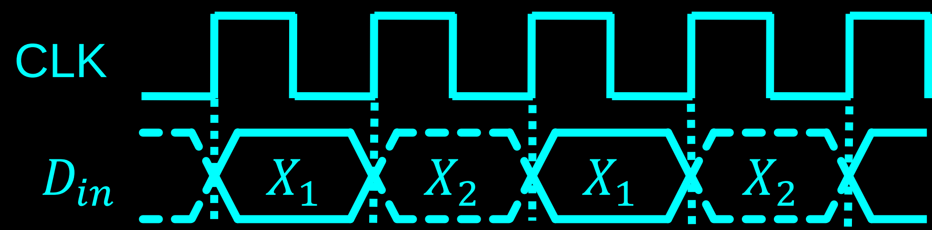
$$Y = a_1 D_{in} + a_3 D_{in}^3$$



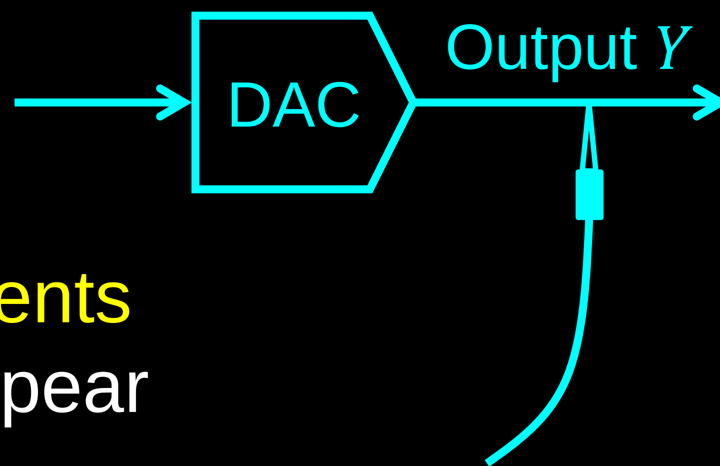
$$X_1 = A \cdot \sin\left(2\pi f_1 n T_s + \frac{\pi}{6}\right) + B \cdot \sin\left(2\pi f_2 n T_s - \frac{\pi}{6}\right)$$

$$X_2 = A \cdot \sin\left(2\pi f_1 n T_s - \frac{\pi}{6}\right) + B \cdot \sin\left(2\pi f_2 n T_s + \frac{\pi}{6}\right)$$

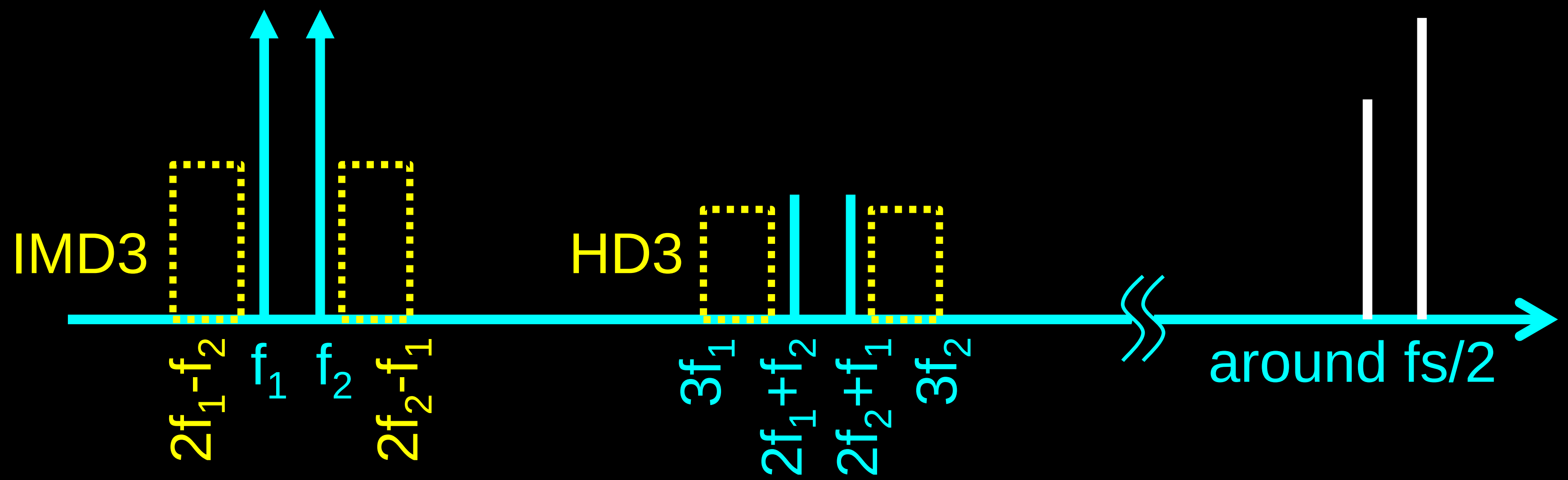
Phase Switching Effects



$$Y = a_1 D_{in} + a_3 D_{in}^3$$

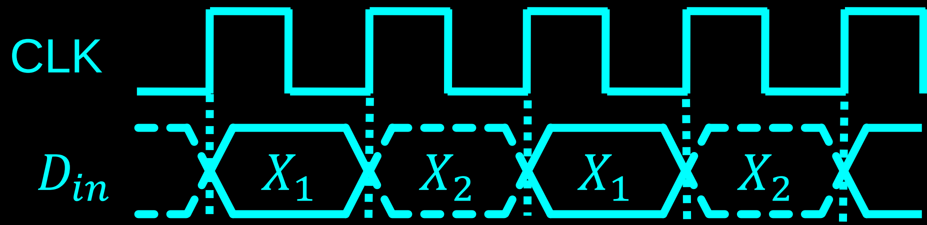


- Cancel IMD3 components
- Switching spurious appear

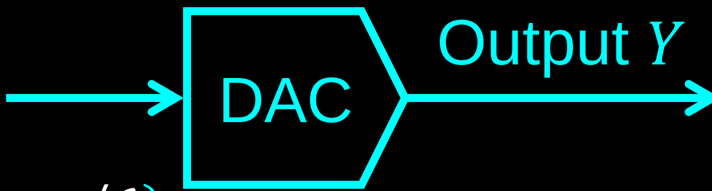


HD : Harmonic Distortion

Principle of Phase Switching

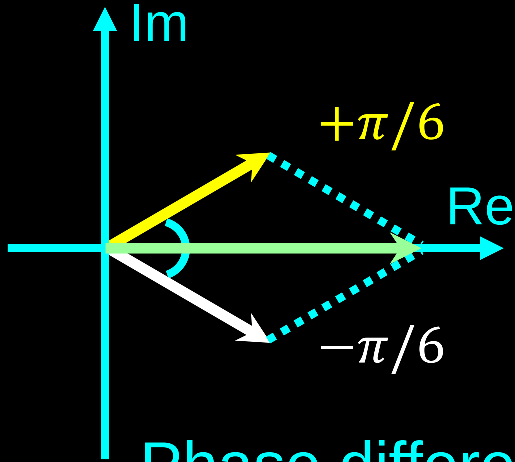


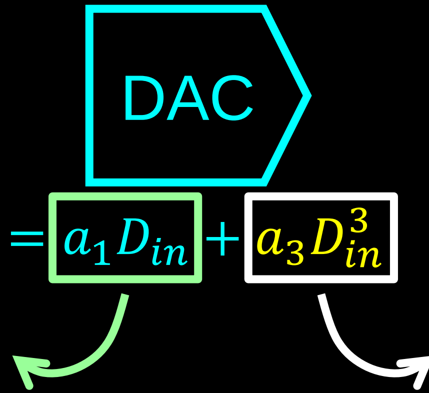
$$Y = a_1 D_{in} + a_3 D_{in}^3$$



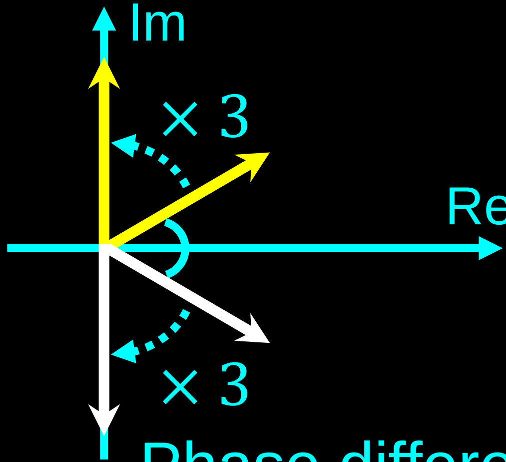
$$X_1 = A \cdot \sin(2\pi f_1 n T_s + \boldsymbol{\pi/6}) + B \cdot \sin(2\pi f_2 n T_s - \boldsymbol{\pi/6})$$

$$X_2 = A \cdot \sin(2\pi f_1 n T_s - \boldsymbol{\pi/6}) + B \cdot \sin(2\pi f_2 n T_s + \boldsymbol{\pi/6})$$





$$Y = \boxed{a_1 D_{in}} + \boxed{a_3 D_{in}^3}$$



Phase difference

$\pi/3$

Phase difference

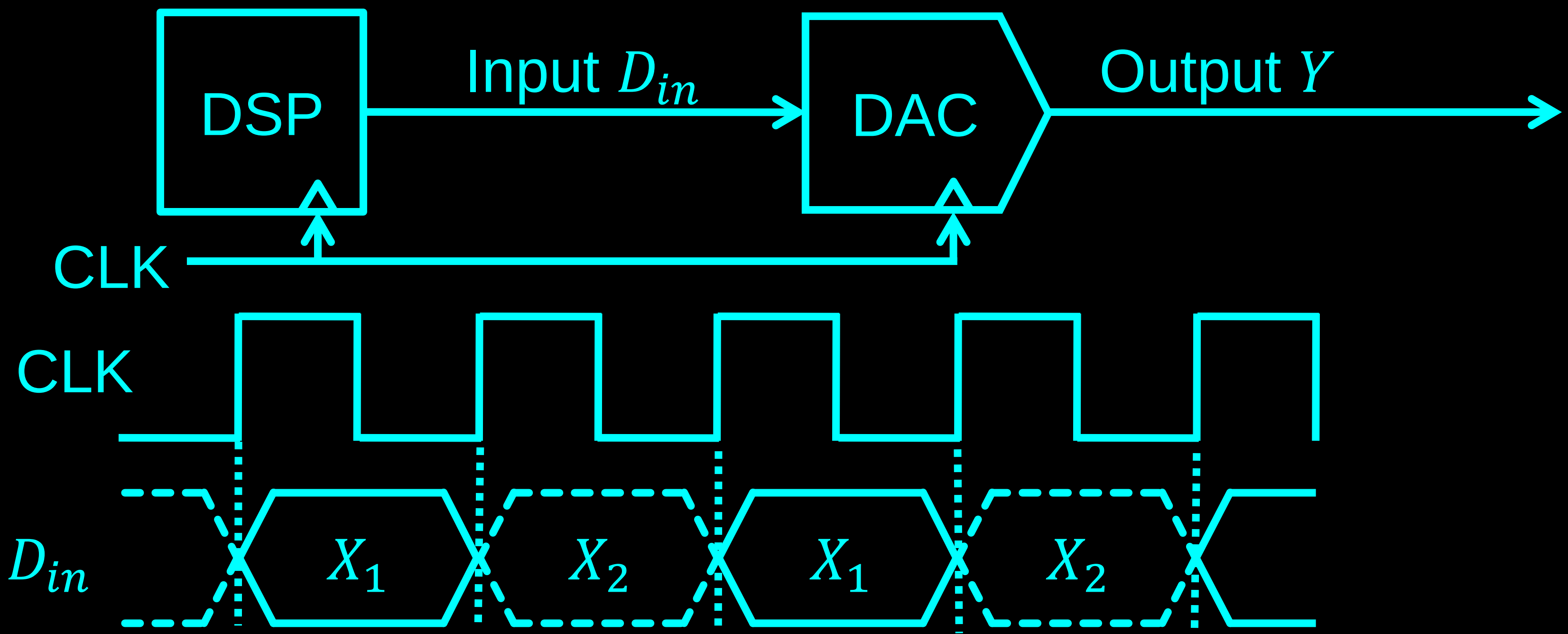
$3 \times \pi/3 = \pi$

Fundamental component

Distortion component

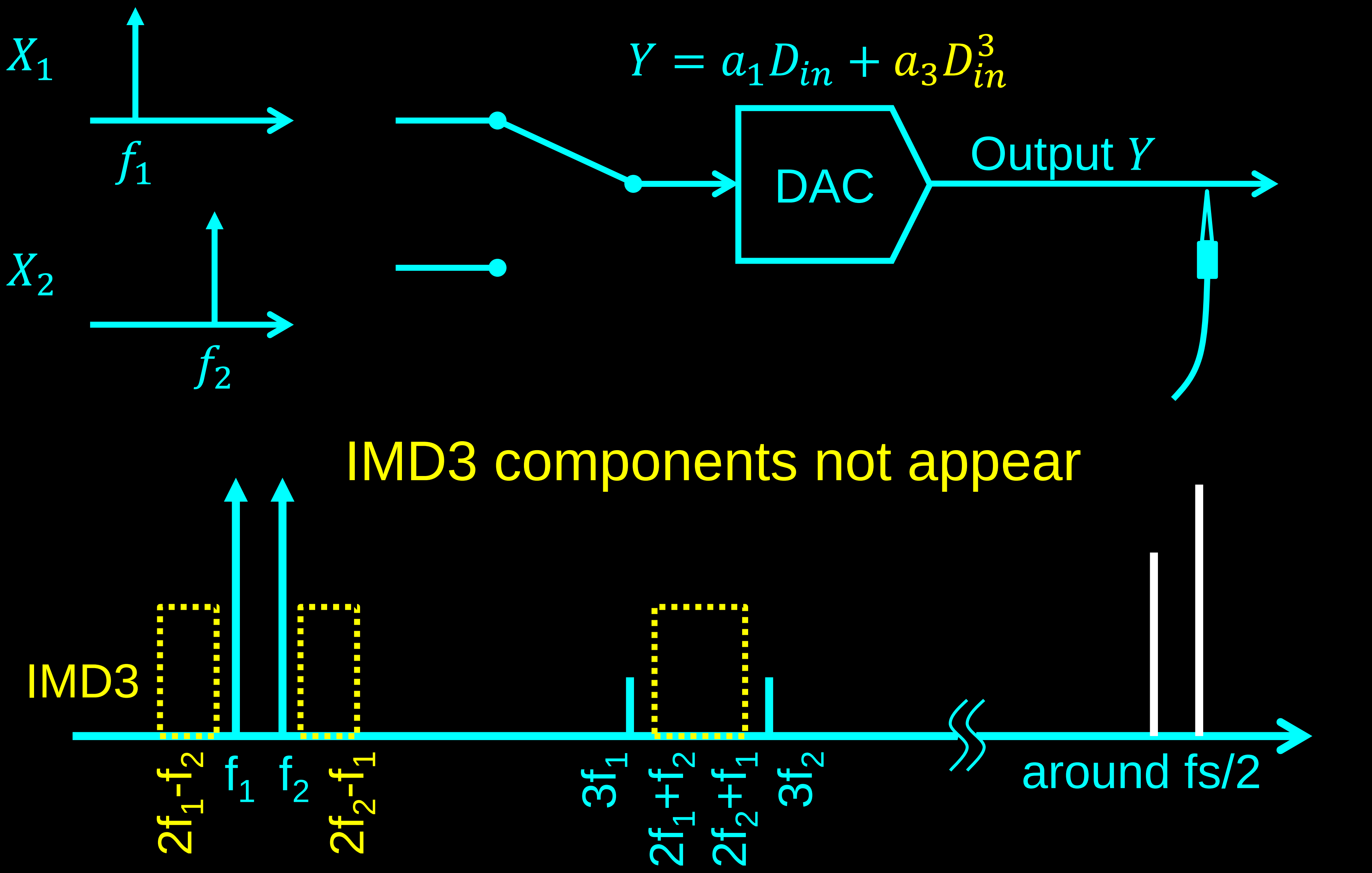
Frequency Switching

$$Y = a_1 D_{in} + a_3 D_{in}^3$$



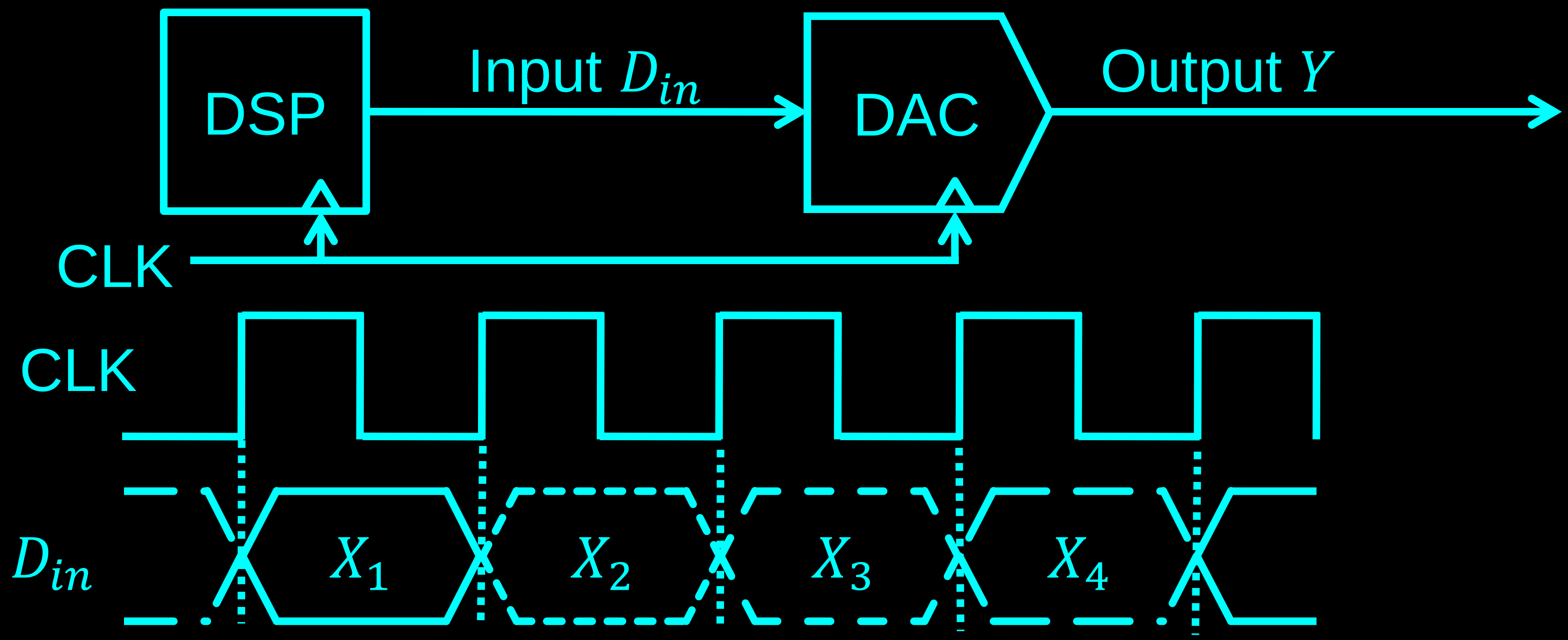
$$X_1 = A \cdot \sin(2\pi f_1 n T_s) \qquad X_2 = B \cdot \sin(2\pi f_2 n T_s)$$

Frequency Switching Effects



Combination of Phase & Frequency Switching

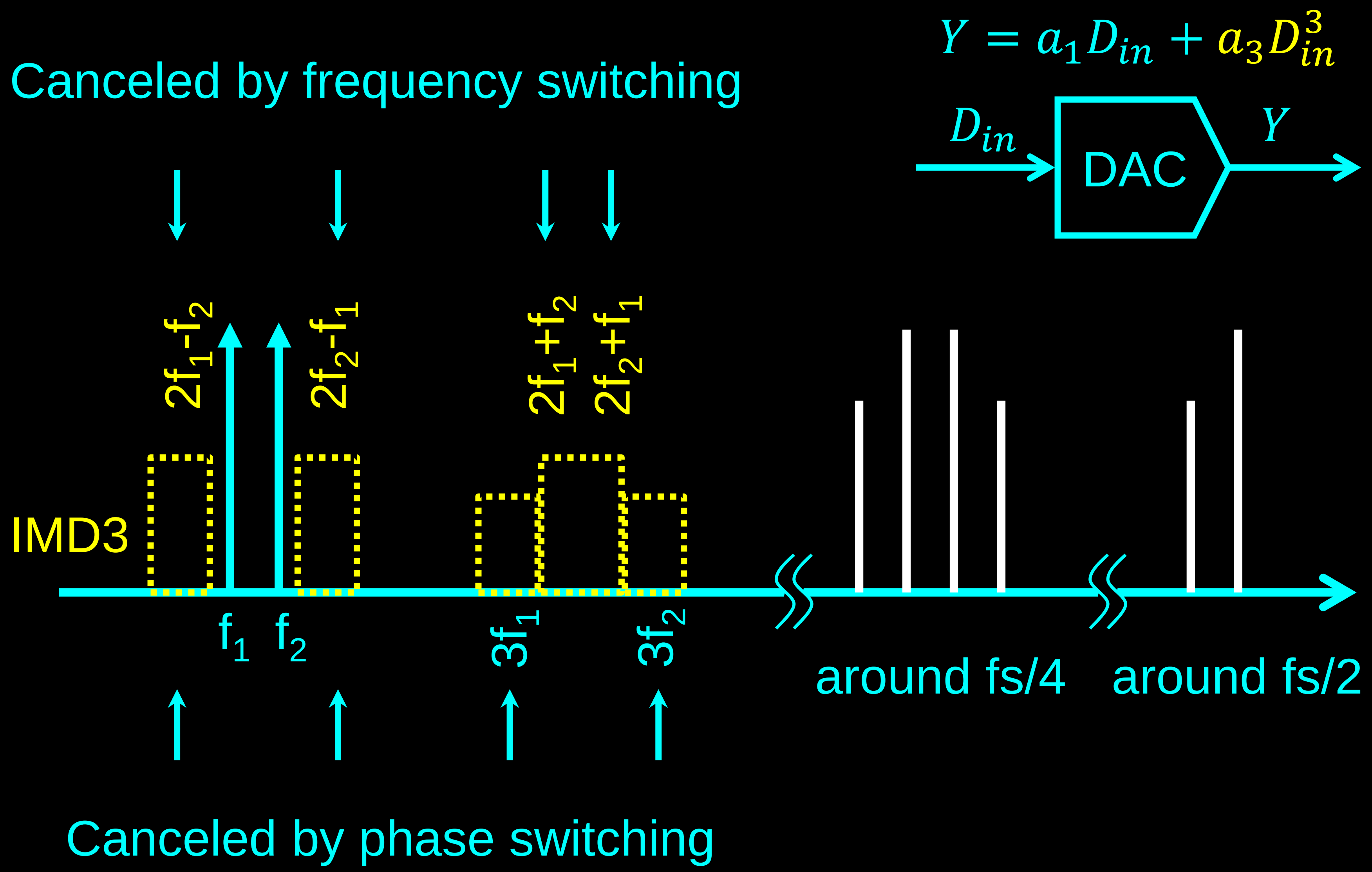
$$Y = a_1 D_{in} + a_3 D_{in}^3$$



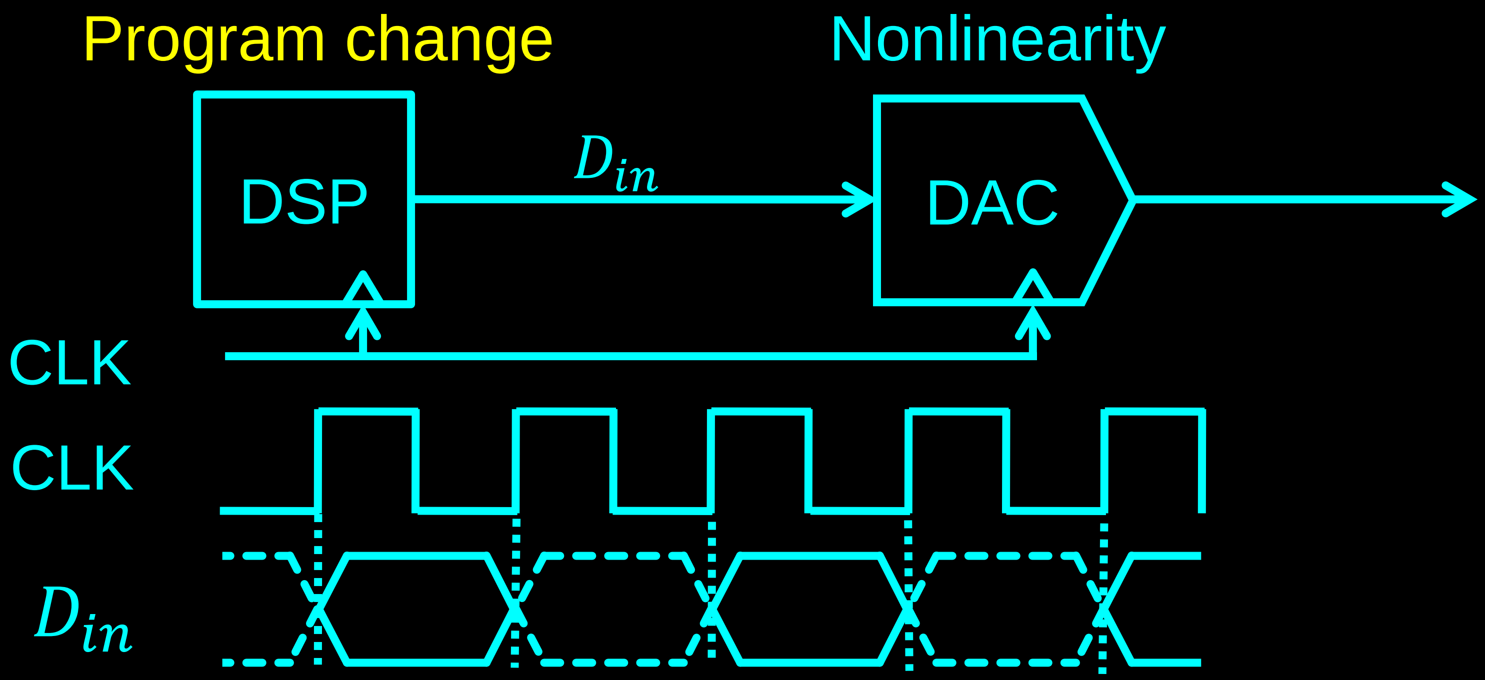
$$X_1 = A \cdot \sin\left(2\pi f_1 n T_s + \frac{\pi}{6}\right) \qquad X_2 = B \cdot \sin\left(2\pi f_2 n T_s - \frac{\pi}{6}\right)$$

$$X_3 = A \cdot \sin\left(2\pi f_1 n T_s - \frac{\pi}{6}\right) \qquad X_4 = B \cdot \sin\left(2\pi f_2 n T_s + \frac{\pi}{6}\right)$$

Phase & Frequency Switching Effects



Merit of Proposed Methods

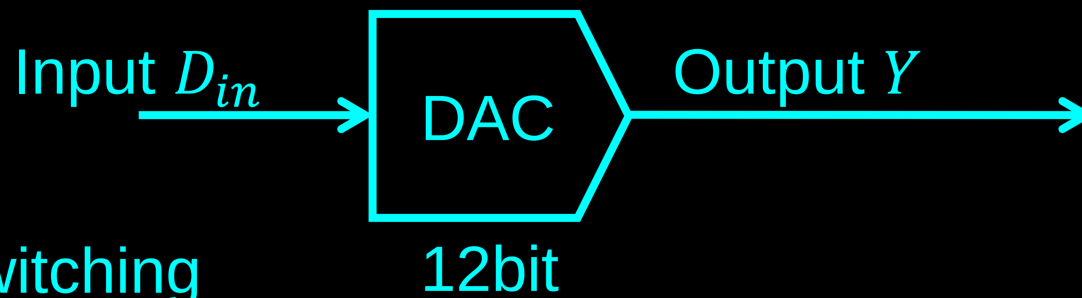


- No need for the DAC nonlinearity identification
  - ➢ No need for calibration
- Only DSP program change
  - ➢ No hardware change

Simulation Condition

- Conventional
- Proposed
  - Phase switching
  - Frequency switching
  - Phase & Frequency switching

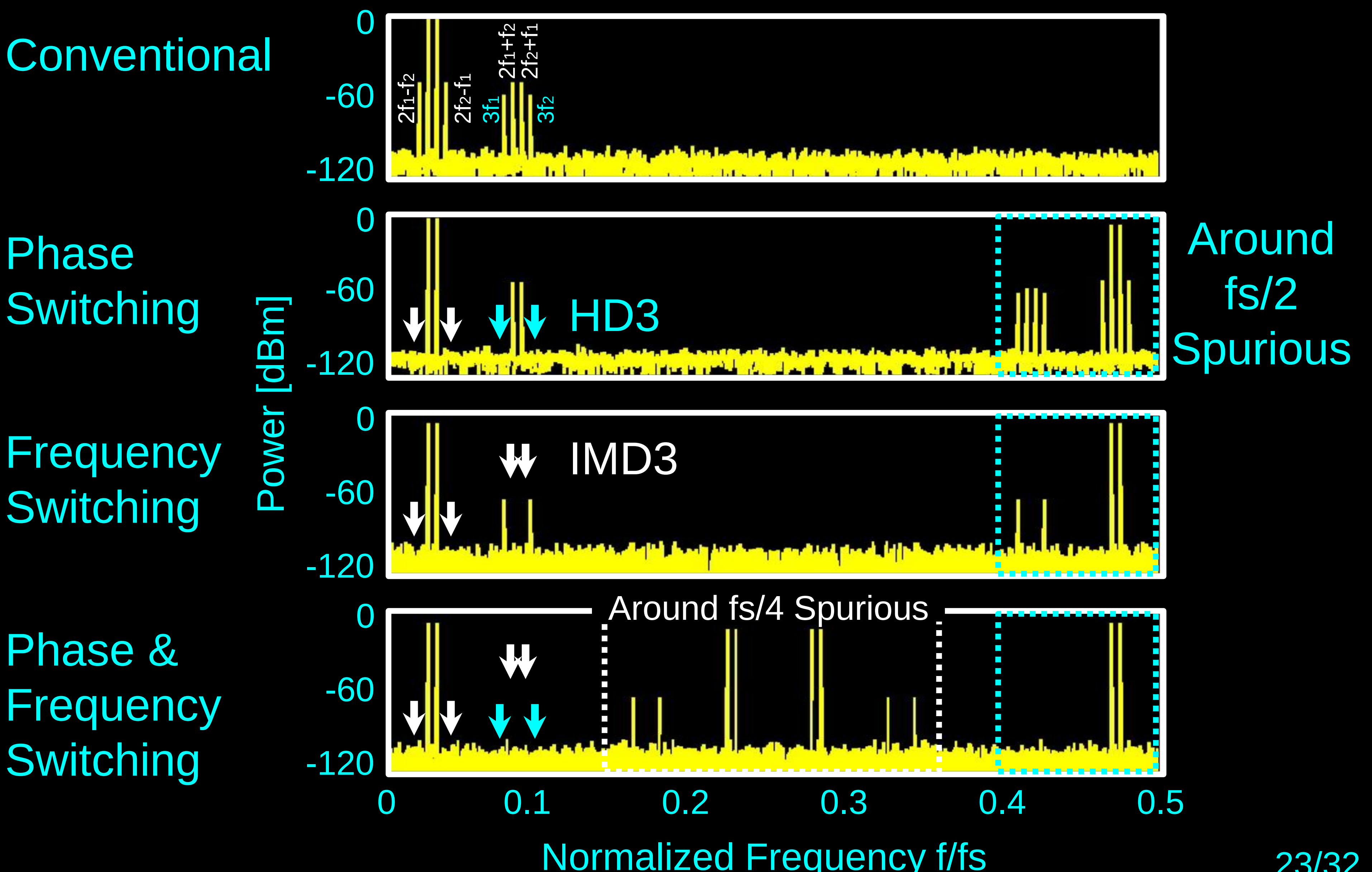
$$Y = D_{in} - 0.005D_{in}^3$$



Input frequency f_1	99
Input frequency f_2	122
Amplitude	1
Sampling frequency	4000

Simulation by Matlab

Phase, Frequency, Phase Freq. Switching



Outline

- Experimental Results

Experimental Condition

AWG

Agilent 33220A

Frequency range	1uHz to 6MHz
Amplitude resolution	14bit
Max sampling rate	50MSa/s

Signal →

Spectrum analyzer

ADVANTEST R3267

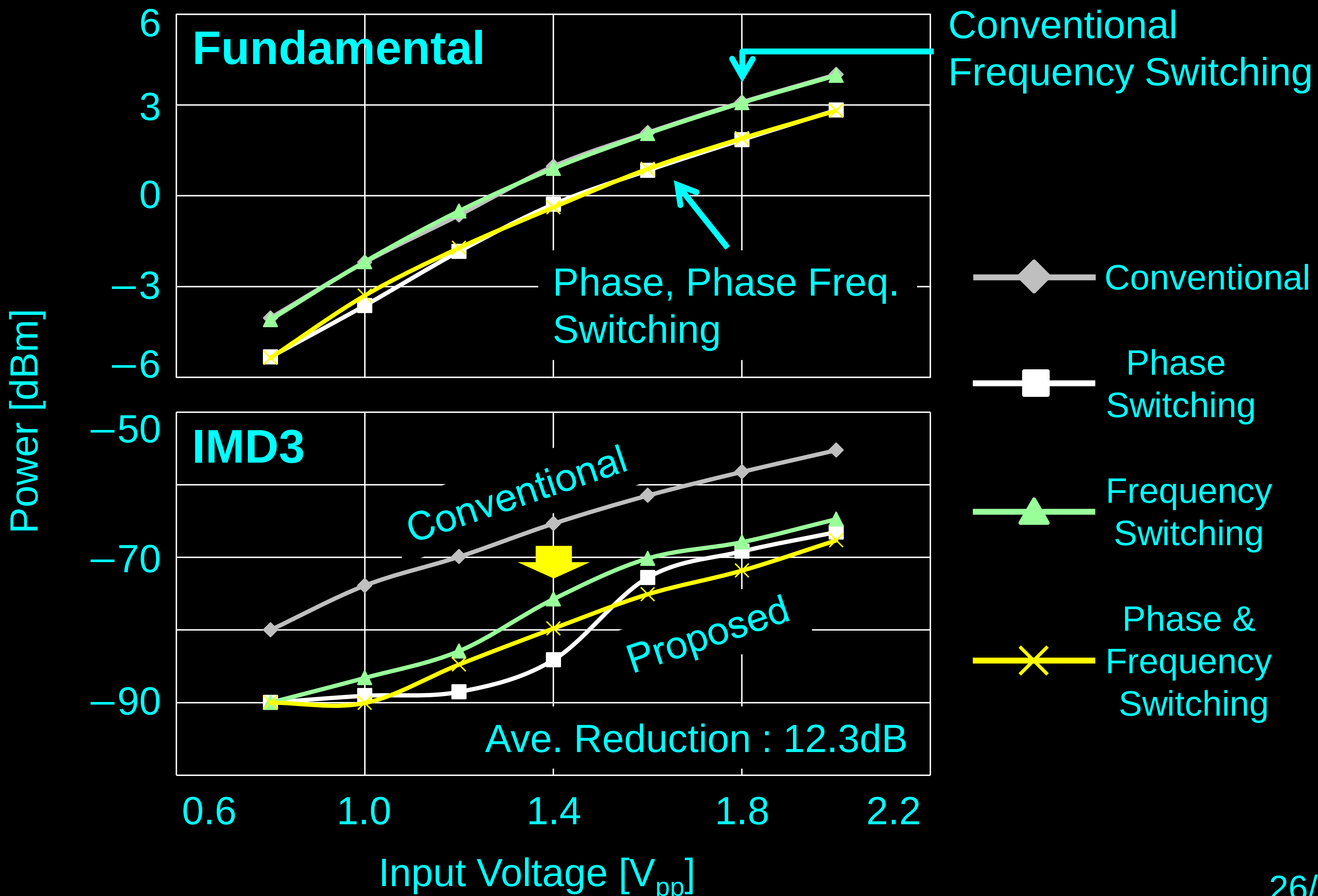
Frequency range	100Hz to 8GHz
RBW	10Hz to 30MHz

※ RBW : Resolution Band Width

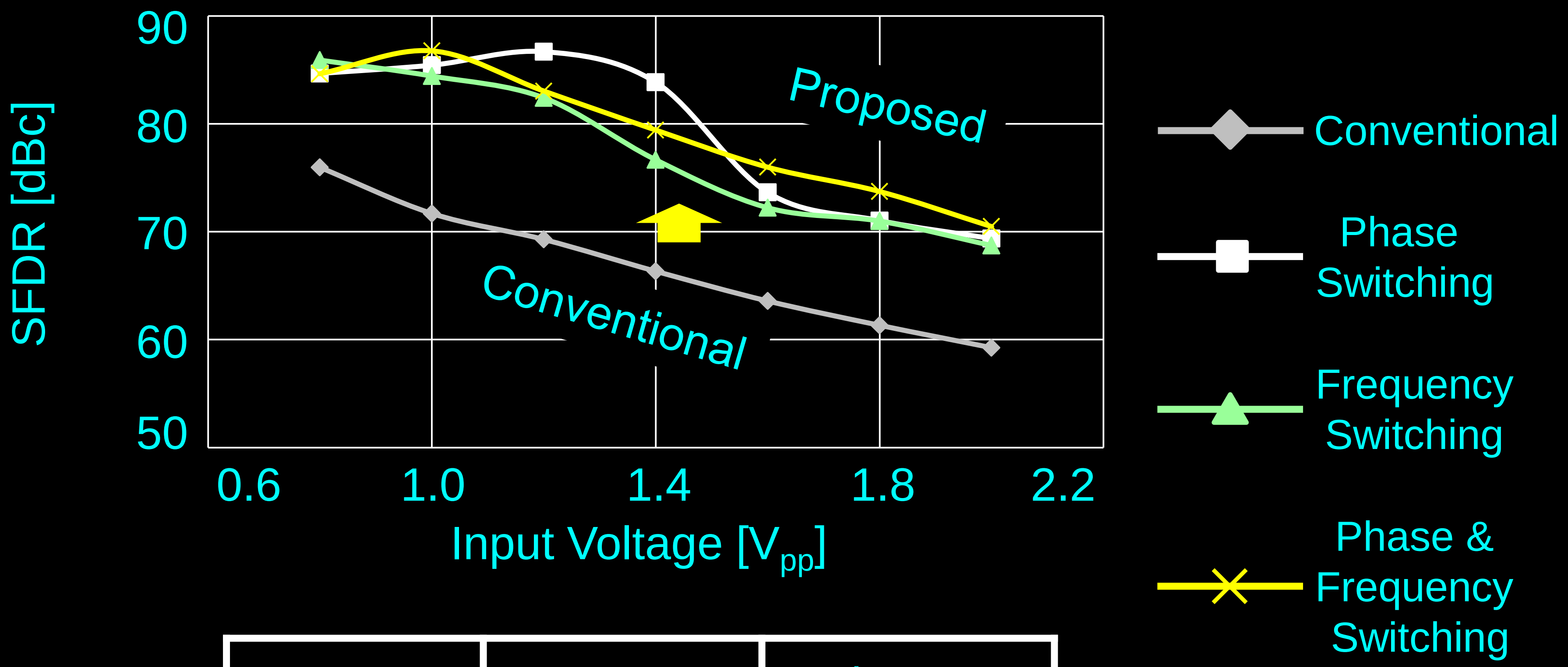
Test Signal

Two-tone signal	200kHz , 220kHz
Sampling rate	10MSa/s
Input voltage	0.8 to 2.0V_{pp} (0.2V step)

Experimental Results

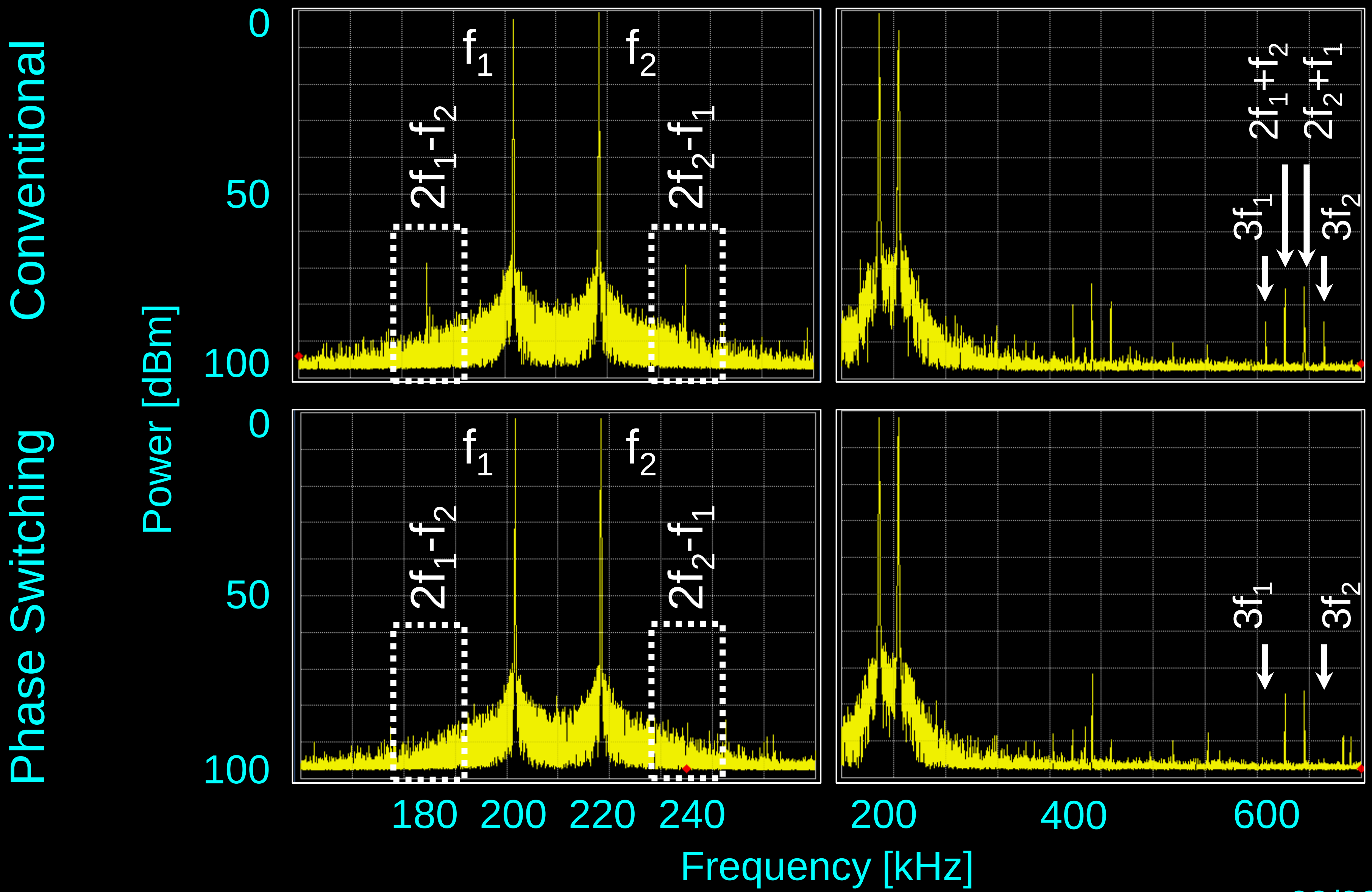


SFDR Improvement

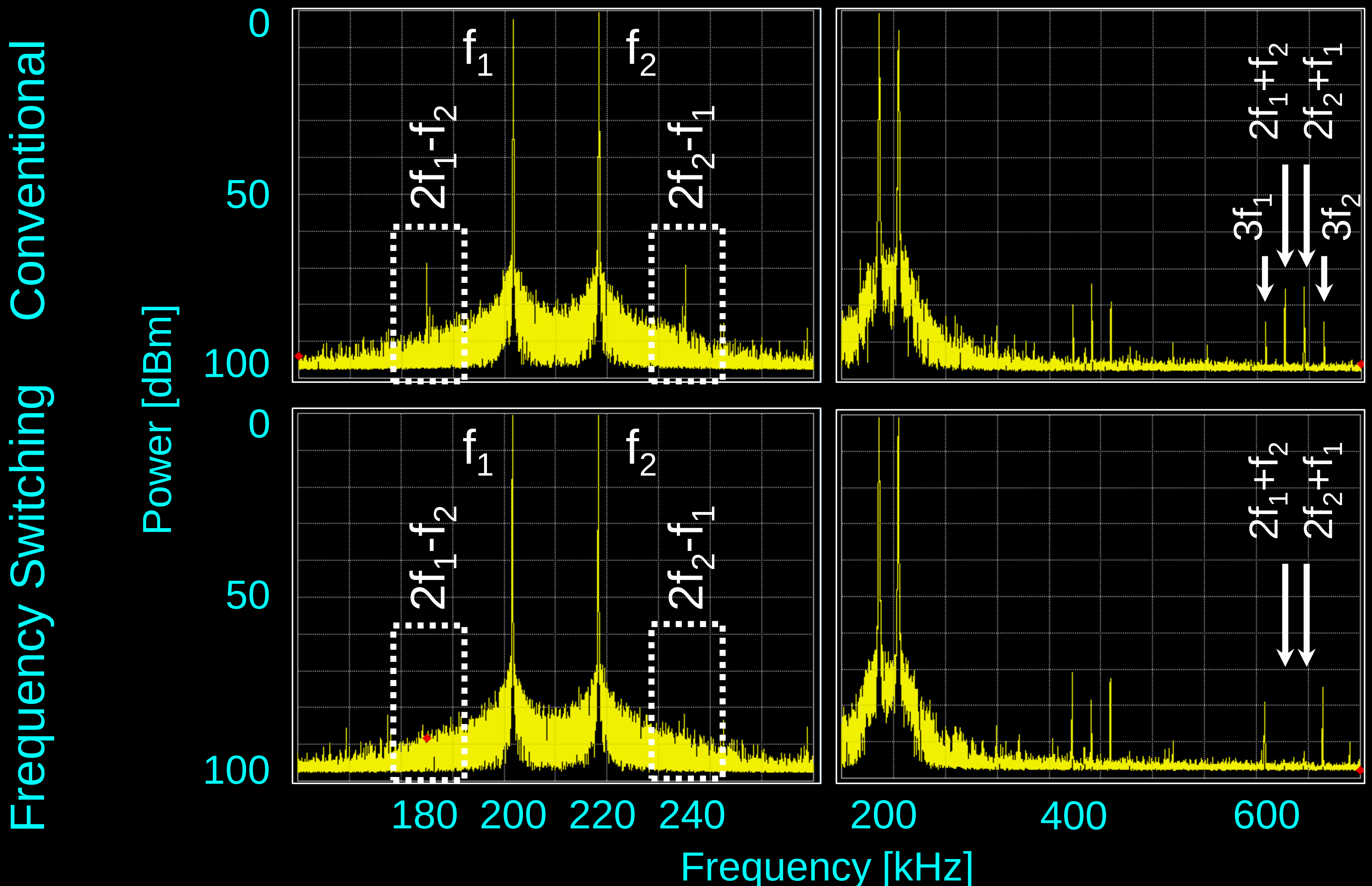


Phase Switching	Frequency Switching	Phase & Frequency Switching
+12.5 dB	+10.6 dB	+12.4 dB

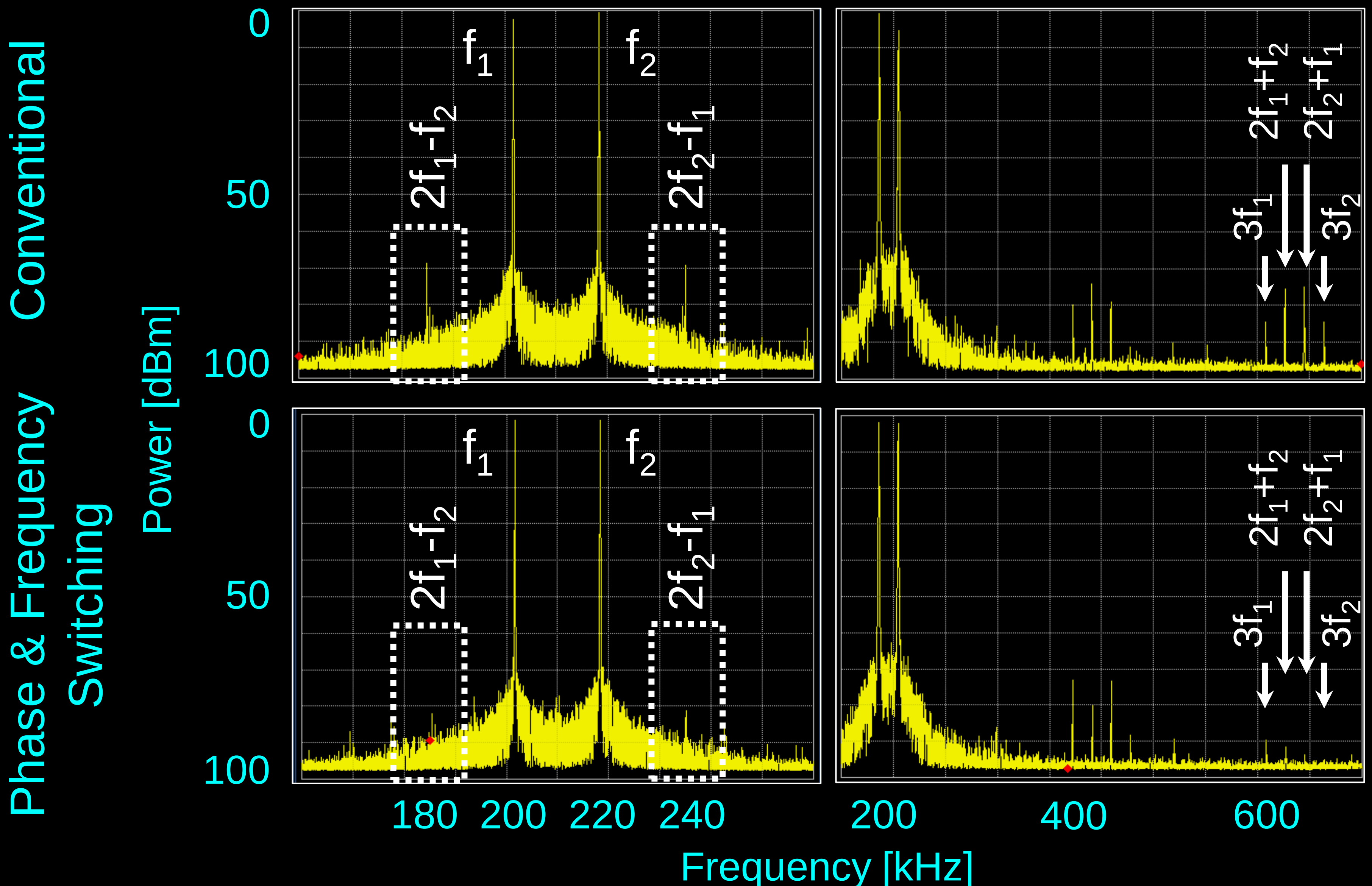
Phase Switching



Frequency Switching



Phase & Frequency Switching



Outline

- Conclusion

Conclusion

- For low distortion two-tone signal generation with low-cost AWG
  - Proposed 3 methods
    - No need for the DAC nonlinearity identification
    - Only DSP program change
    - No hardware change, no calibration

- Effectiveness of our proposed methods
    - Verified by simulation, and experimental results
      - IMD3 reduction and SFDR improvement

Question

Q：今後の課題、どのようなアプリケーション

Q：3トーン、4トーンに応用すると分解能はどうなるか

C：IMD3の取り方はいいがSFDRの取り方が良くない。
スカートを持つような図にするべき

Presented by Keisuke Kato