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S47-2 Signal Processing
10:45-11:00
Oct.28, 2016(Fri)

High-Frequency Low-Distortion One-Tone and Two-Tone Signal Generation Using Arbitrary Waveform Generator

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Research Objective

Objective

Low-Distortion sine wave generation
for ADC test

Our Approach

DSP algorithm using
Arbitrary Waveform Generator

OUTLINE

- Research background
- Phase switching algorithm
- Proposed solutions and simulations
  - High-frequency signal
  - 3^{rd} and 5^{th} harmonics cancellation
  - Two-tone signals
- Conclusion

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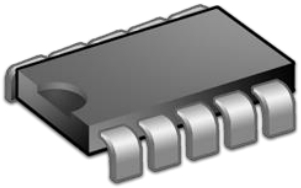
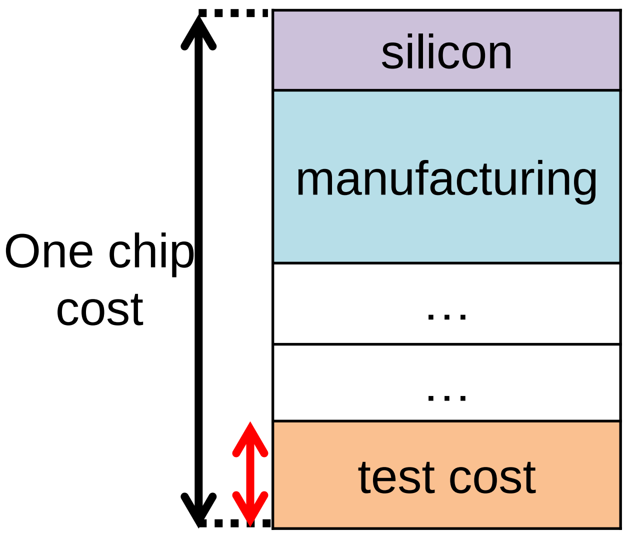
Research Background

Silicon cost per transistor ➡ **decreasing**





Test cost ➡ **increasing**

Low cost test

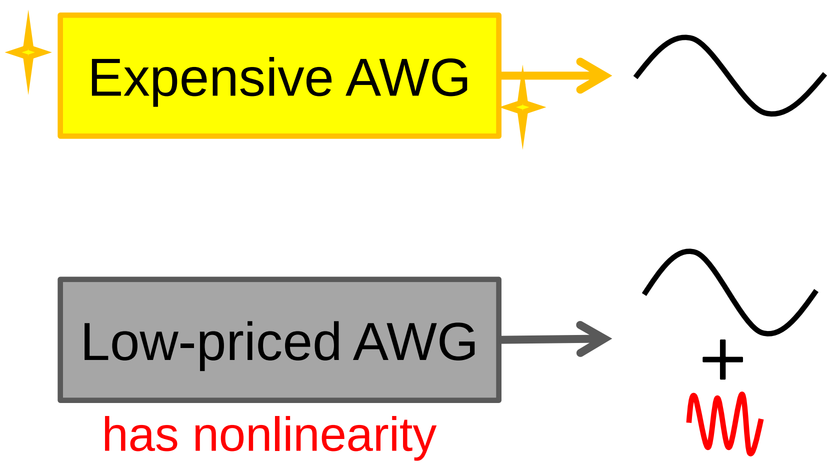
➡ **Low cost LSI production**

ADC Test Cost Using AWG

ADC test system :

AWG : Arbitrary Waveform Generator

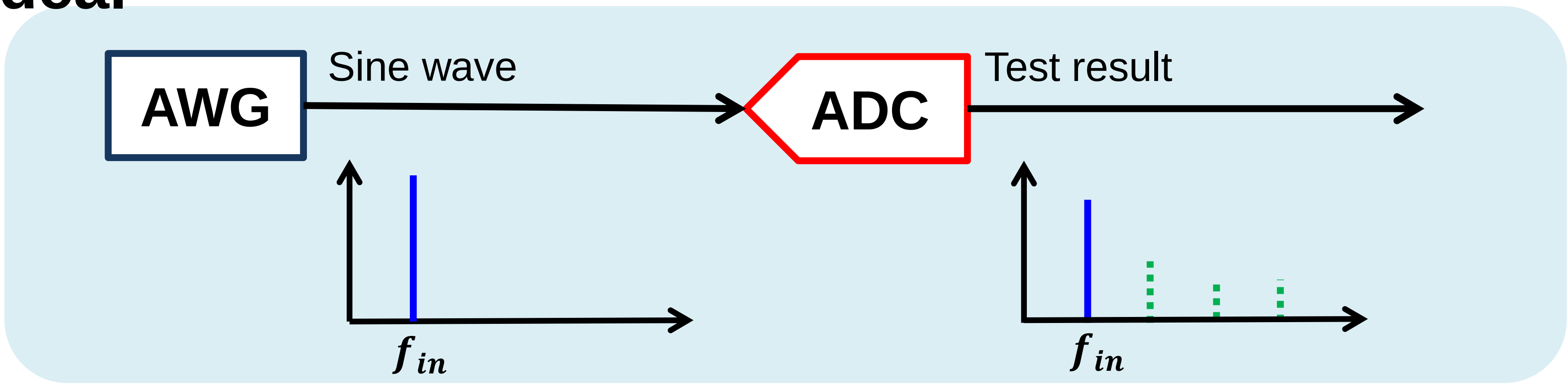
Expensive



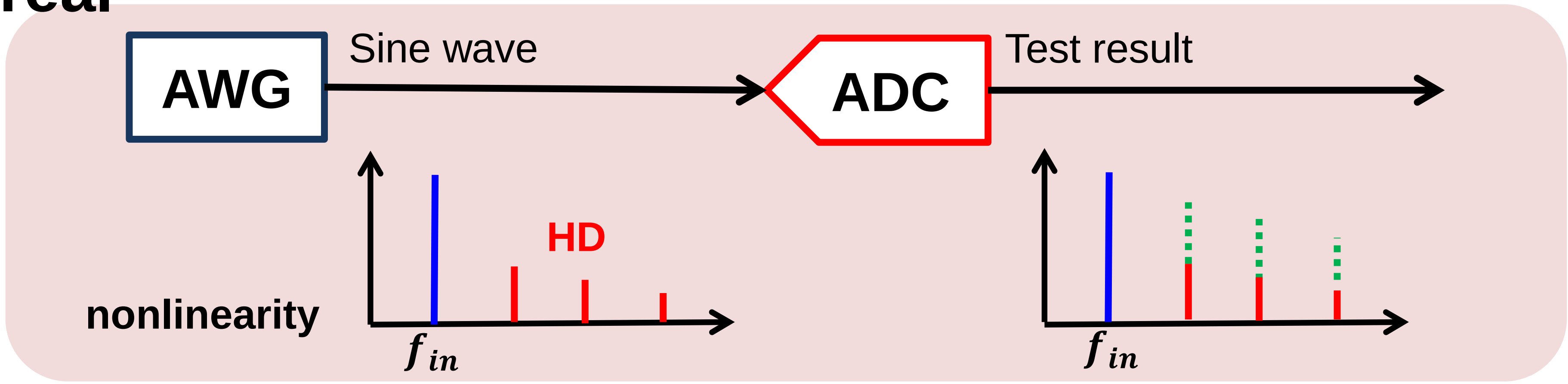
	Cost	Quality
Expensive AWG	×	○
Low-priced AWG	○	×
Low-priced AWG + Proposed method	○	○

Ideal and Real

ideal

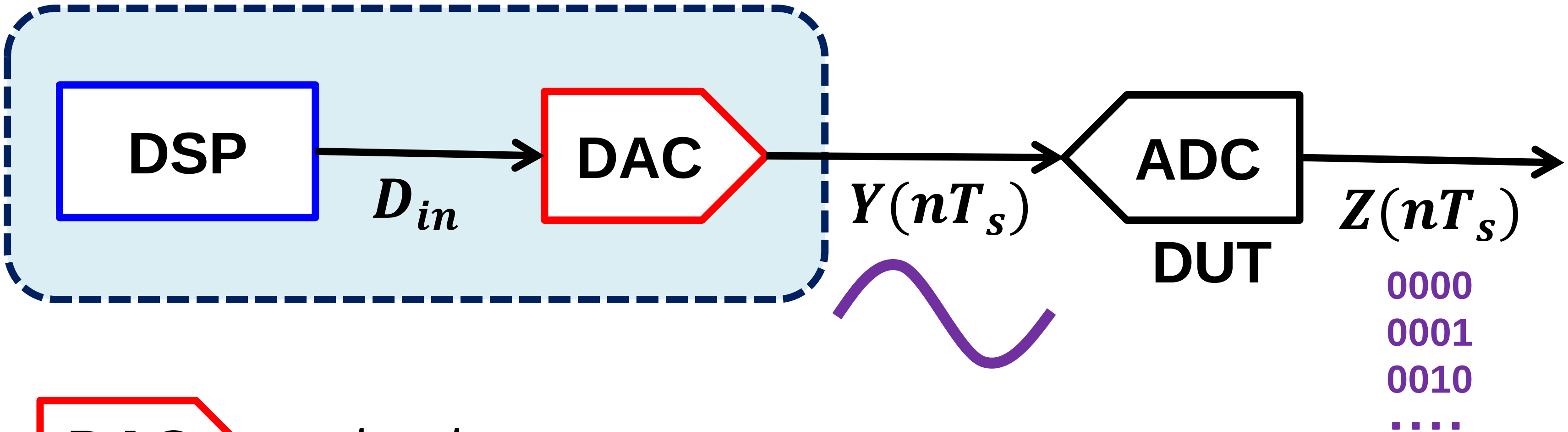


real



Arbitrary Waveform Generator

AWG (Arbitrary Waveform Generator)



- DAC output

$$Y(nT_s) = a_1 D_{in} + a_2 {D_{in}}^2 + a_3 {D_{in}}^3 + \cdots$$

DAC nonlinearity → harmonic distortion

Low-distortion signal generation
Only DSP program change

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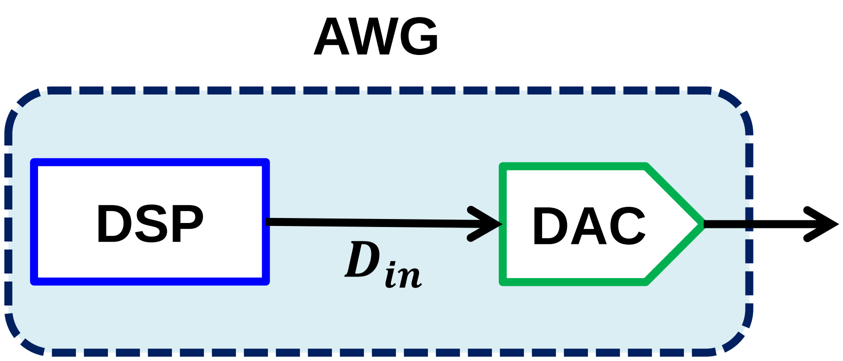
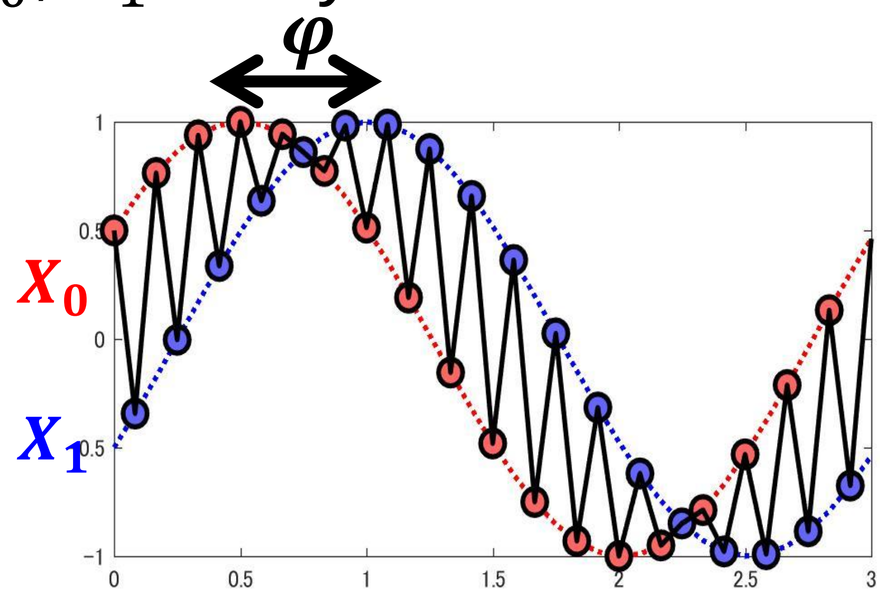
Our Preceding Study

Phase Switching Signal Method

Interleave sampling X_0, X_1 every one clock



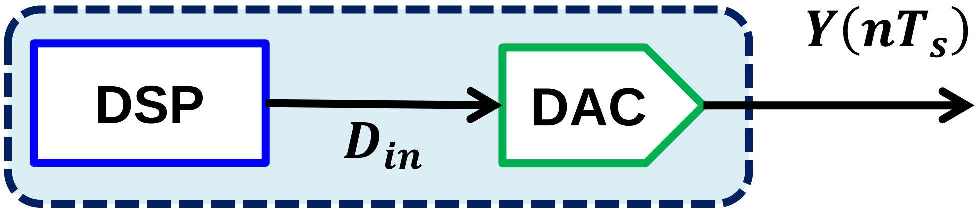


$$D_{in} = \begin{cases} X_0 = A\sin(2\pi f_{in} n T_s + \pi/6) & n\text{: even} \\ X_1 = A\sin(2\pi f_{in} n T_s - \pi/6) & n\text{: odd} \end{cases}$$

$$\varphi = \varphi_0 - \varphi_1 = \frac{\pi}{3}$$

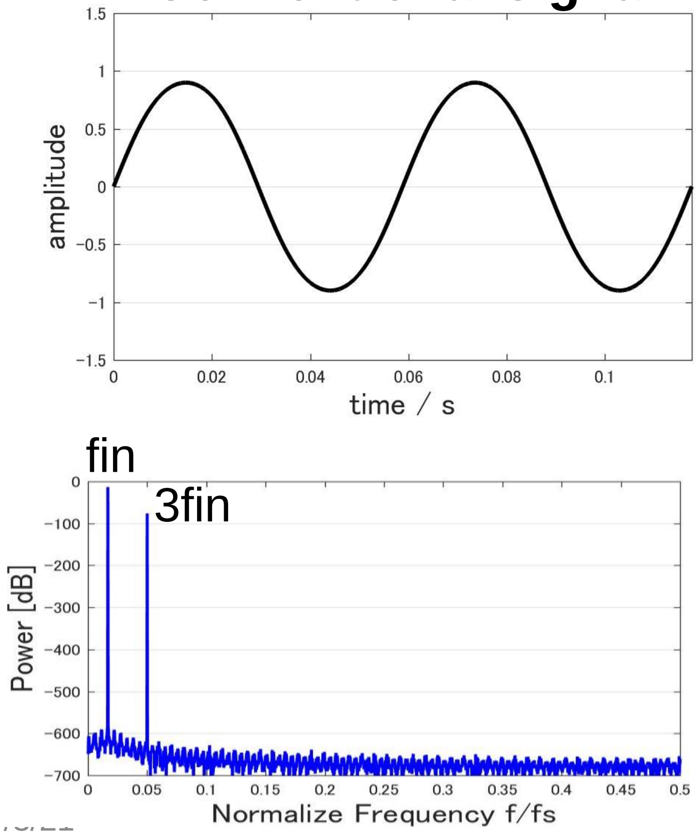
3rd order harmonics is cancelled

Low-frequency Signal Generation with Phase Switching

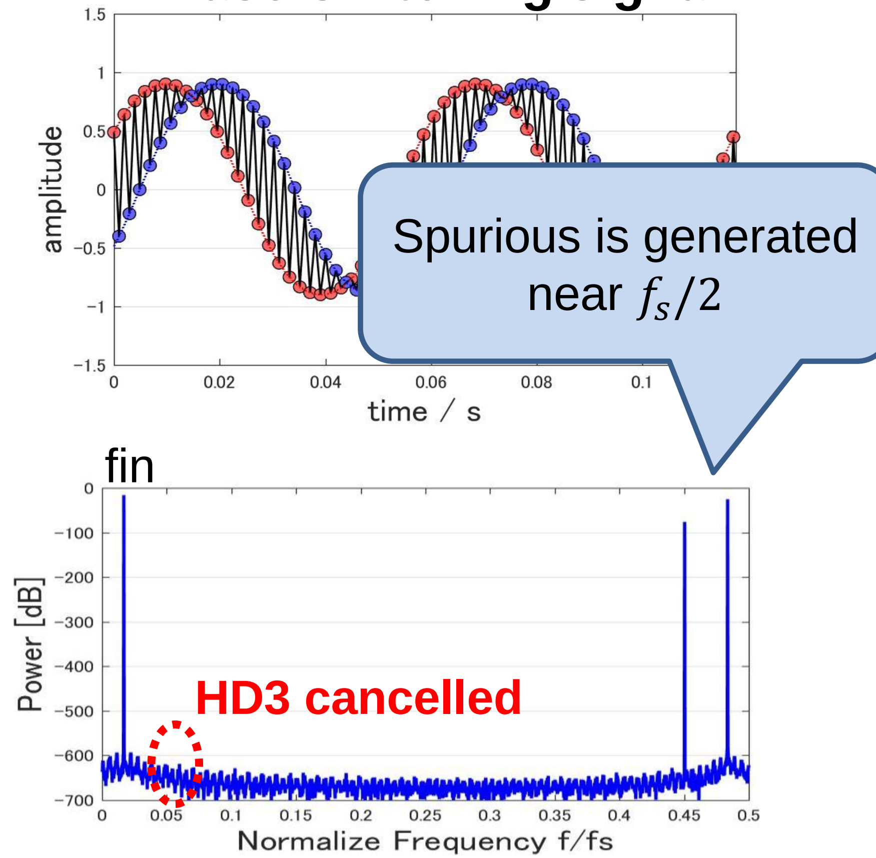


$$Y(nT_s) = a_1 D_{in} + a_3 {D_{in}}^3$$

Conventional signal



Phase-switching signal



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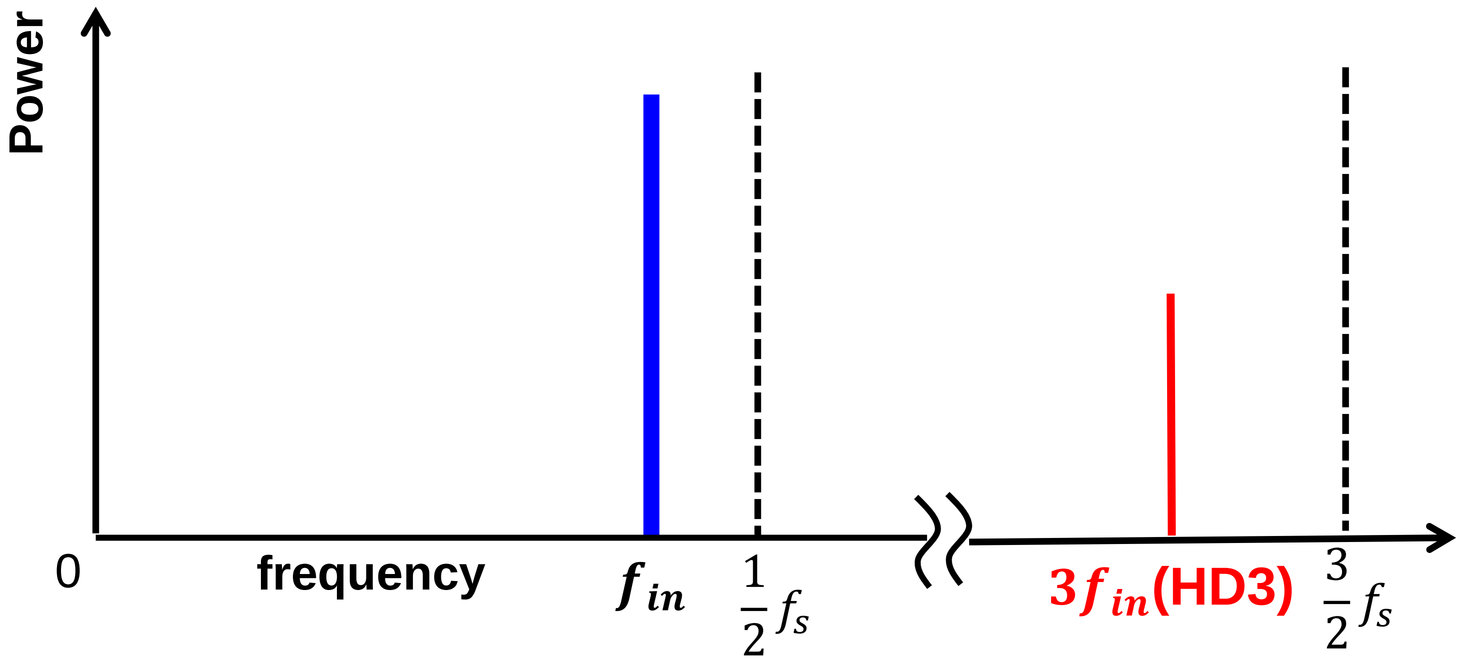
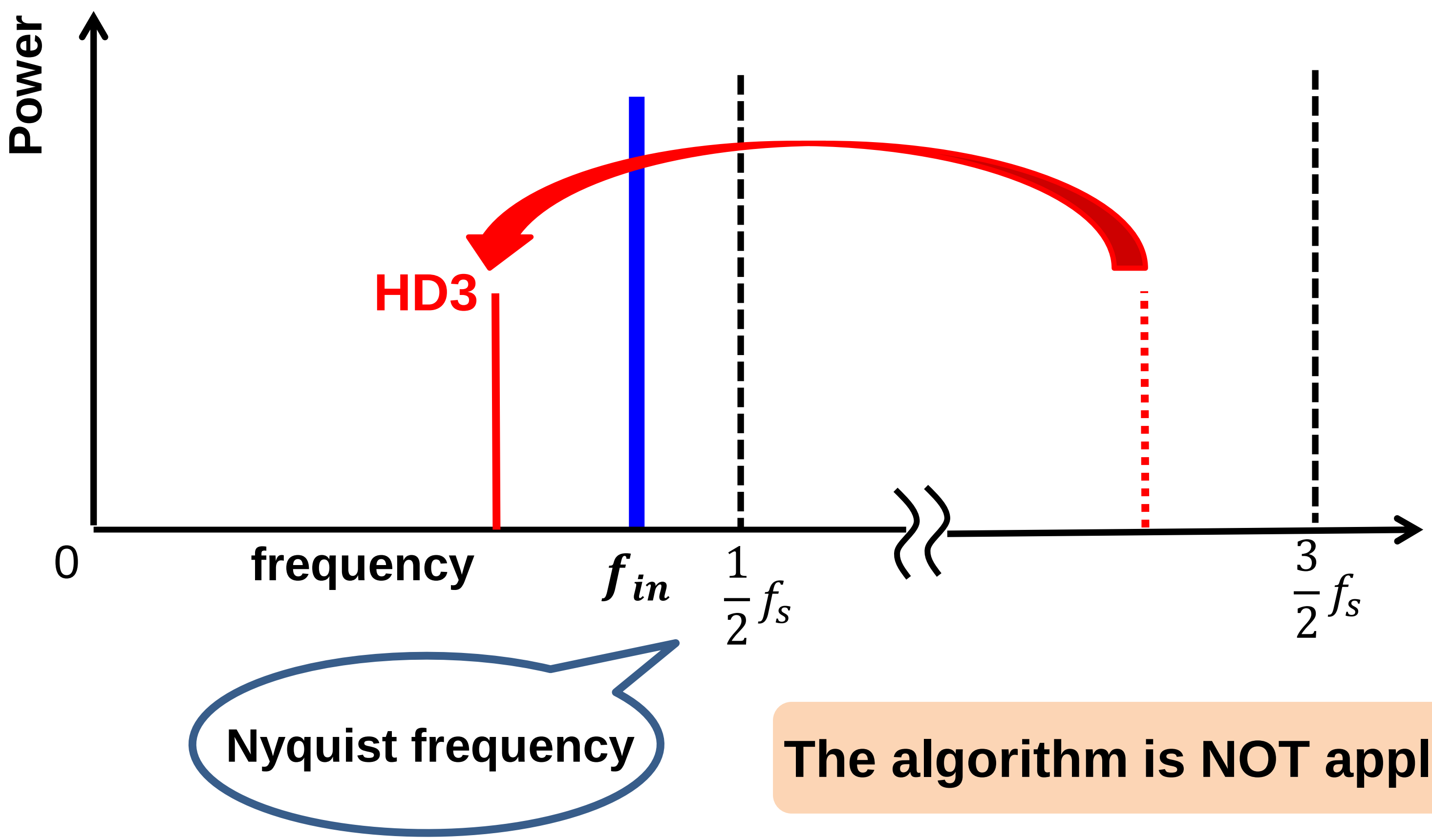
High-frequency Input Case

High-frequency signal = near the Nyquist frequency



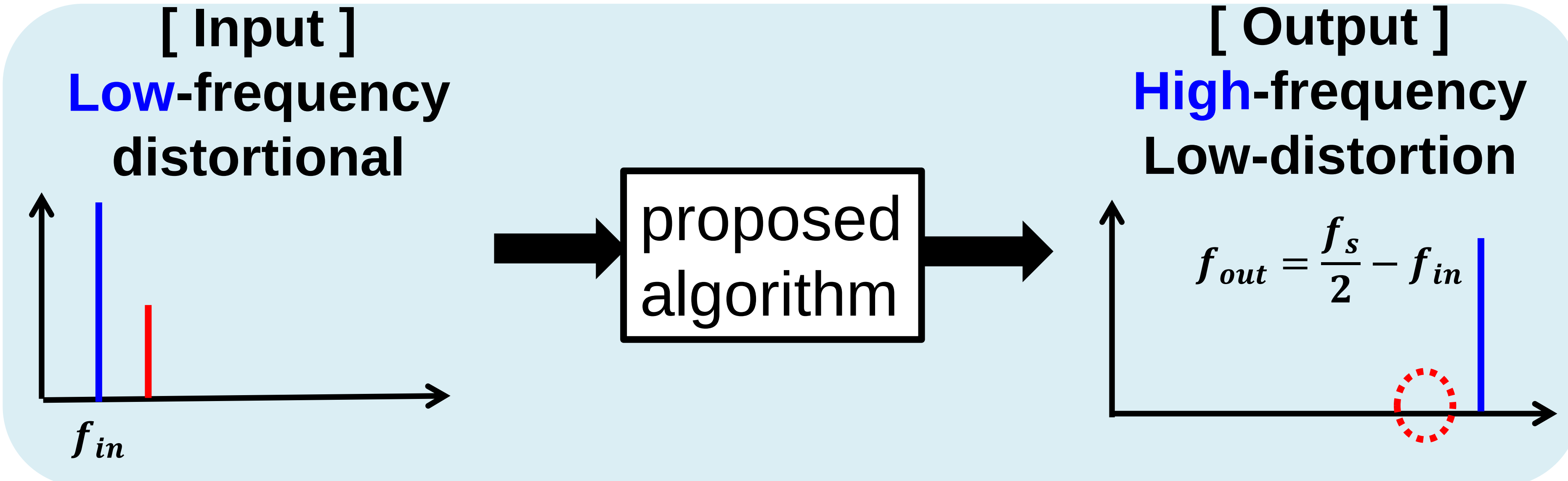
High-frequency Input Case

High-frequency signal = near the Nyquist frequency

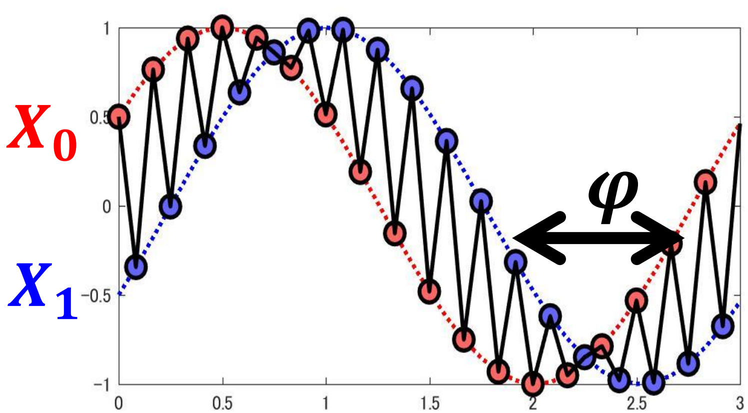


The algorithm is NOT applicable

Algorithm for High-Frequency Signal



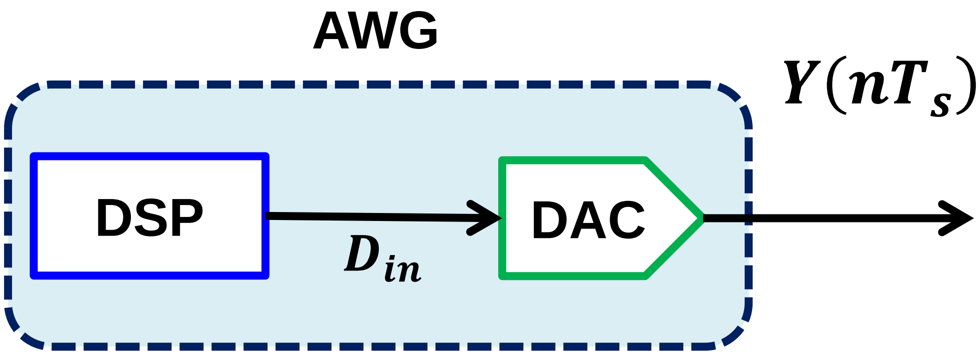
$$D_{in} = \begin{cases} X_0 = A\sin(2\pi f_{in} n T_s + \varphi_0) & n\text{: even} \\ X_1 = A\sin(2\pi f_{in} n T_s - \varphi_1) & n\text{: odd} \end{cases}$$



Nth order image is cancelled

$$\varphi = \varphi_0 - \varphi_1 = \frac{2\pi}{N}$$

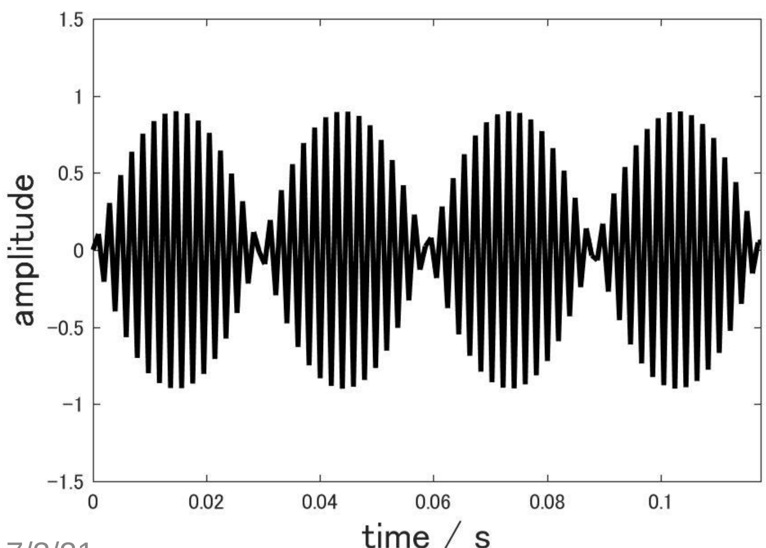
Conventional High-Frequency Signal

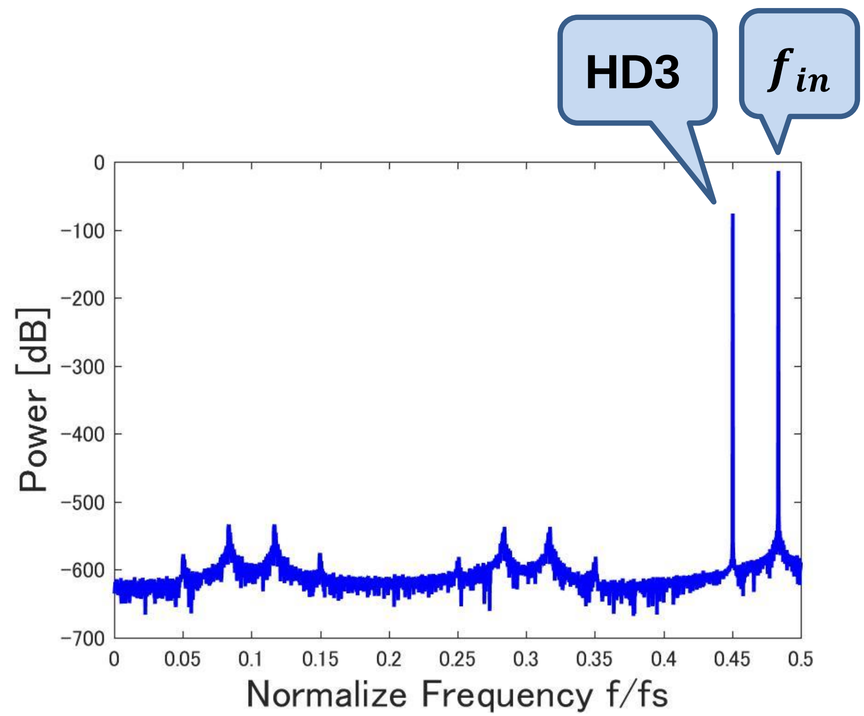


$$Y(nT_s) = a_1 D_{in} + a_3 {D_{in}}^3$$

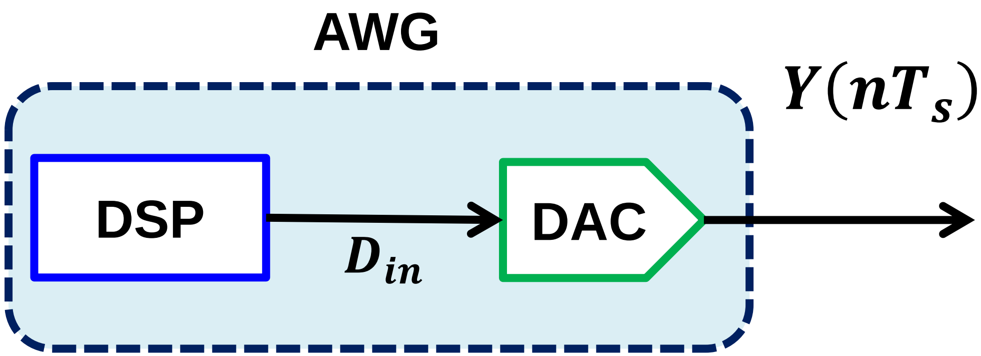
f_{in}/f_s	495/1024
a_1, a_3	1, -0.1

$$D_{in} = A\sin(2\pi f_{in} n T_s)$$





Proposed Signal

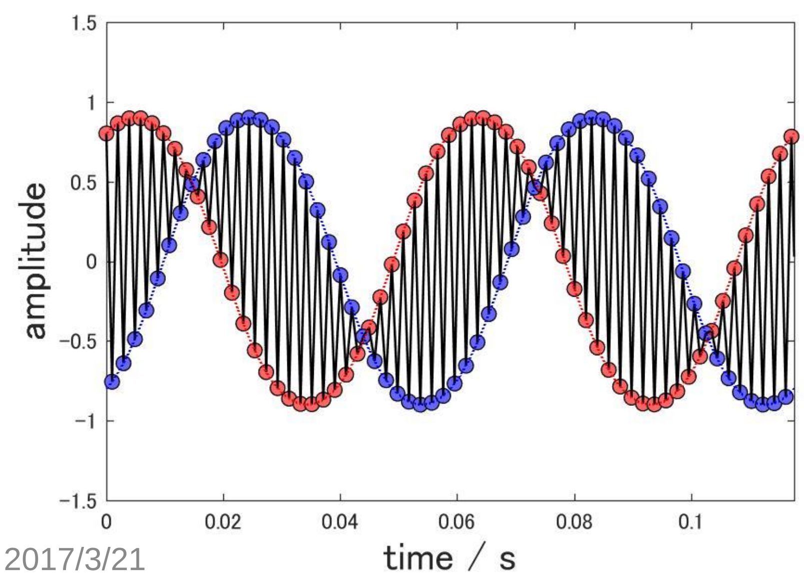


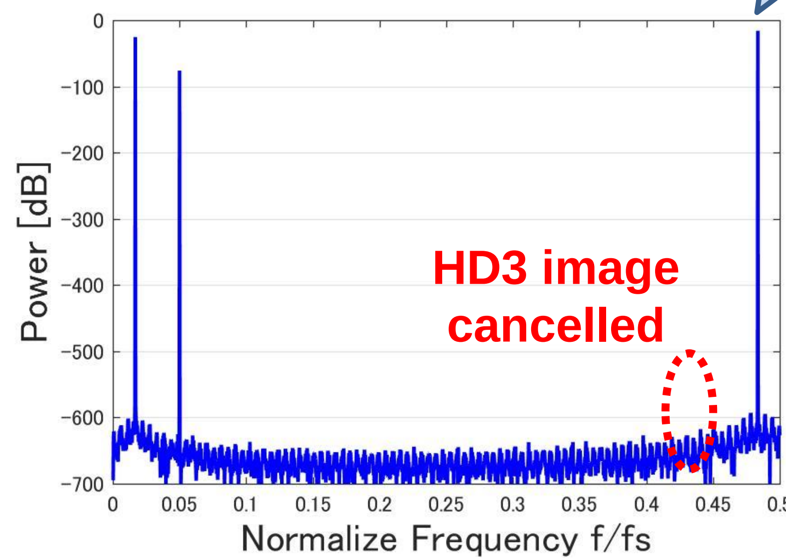
$$Y(nT_s) = a_1 D_{in} + a_3 {D_{in}}^3$$

f_{in}/f_s	17/1024
a_1, a_3	1, -0.1

$$D_{in} = \begin{cases} X_0 = A\sin(2\pi f_{in} nT_s + \pi/3) & n\text{: even} \\ X_1 = A\sin(2\pi f_{in} nT_s - \pi/3) & n\text{: odd} \end{cases}$$

Signal f_{out}





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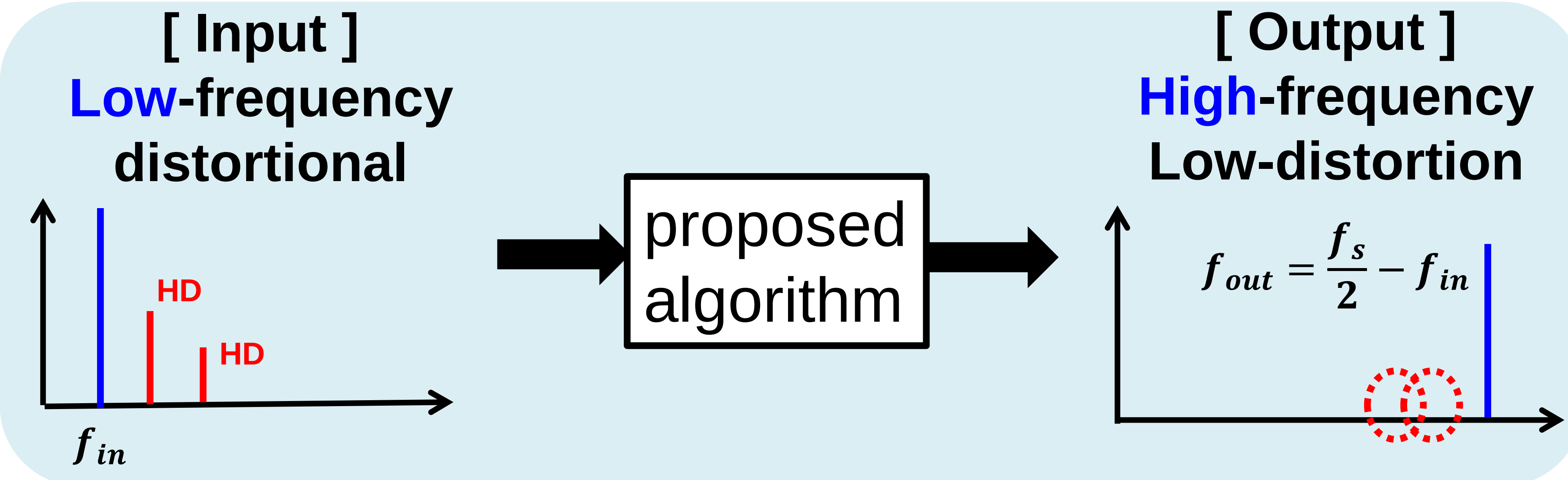
3rd and 5th Harmonics Cancellation At Once



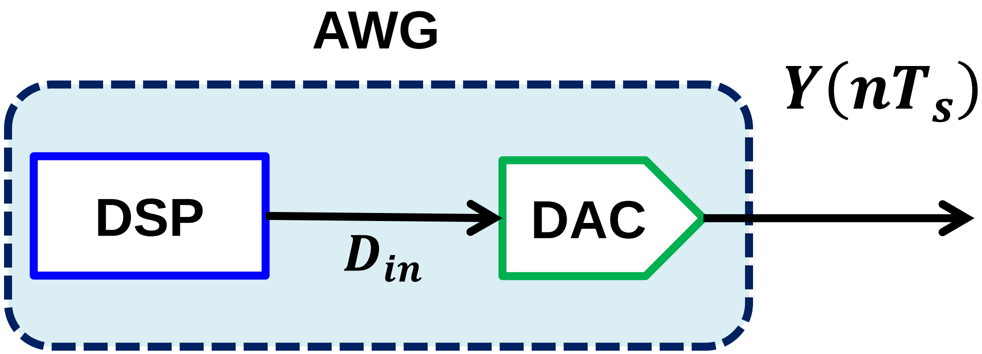
4 phase interleave

$$D_{in} = \begin{cases} X_0 = A\sin(2\pi f_{in} n T_s - \varphi_a - \varphi_b) & n = 4k \\ X_1 = A\sin(2\pi f_{in} n T_s - \varphi_a + \varphi_b) & n = 4k+1 \\ X_2 = A\sin(2\pi f_{in} n T_s + \varphi_a - \varphi_b) & n = 4k+2 \\ X_3 = A\sin(2\pi f_{in} n T_s + \varphi_a + \varphi_b) & n = 4k+3 \end{cases}$$

$$\varphi_a = \frac{\pi}{2N_x} \quad \varphi_b = \frac{\pi}{N_y}$$

*N*th order image is cancelled

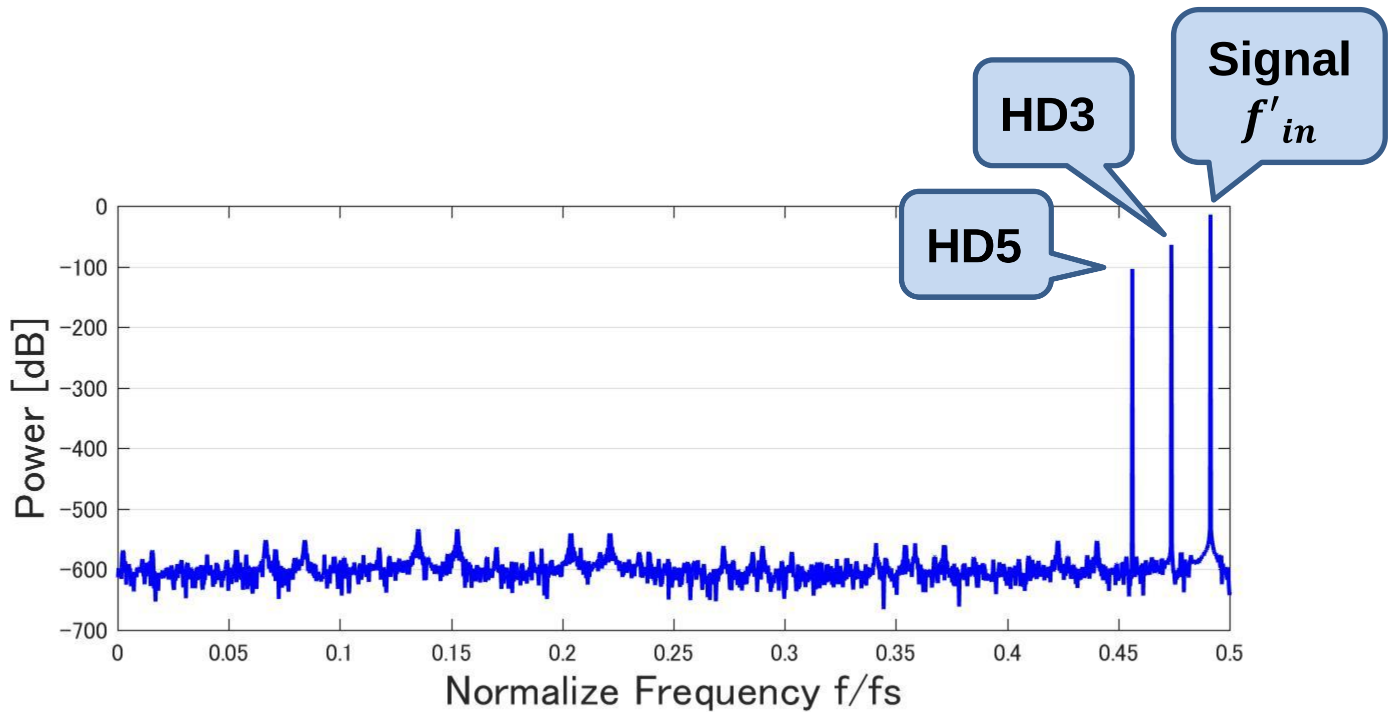
Signal with 3rd and 5th Harmonics



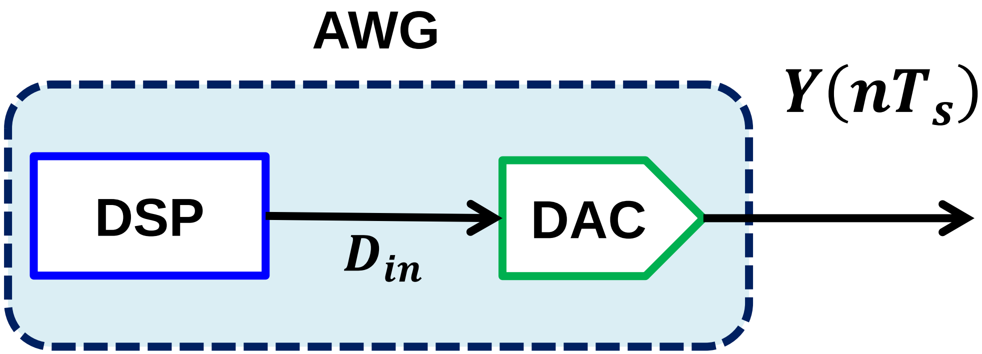
$$Y(nT_s) = a_1 D_{in} + a_3 {D_{in}}^3 + a_5 {D_{in}}^5$$

f_{in}/f_s	503/1024
a_1, a_3, a_5	1, -0.1, -0.08

$$D_{in} = A \sin(2\pi f'_{in} nT_s)$$



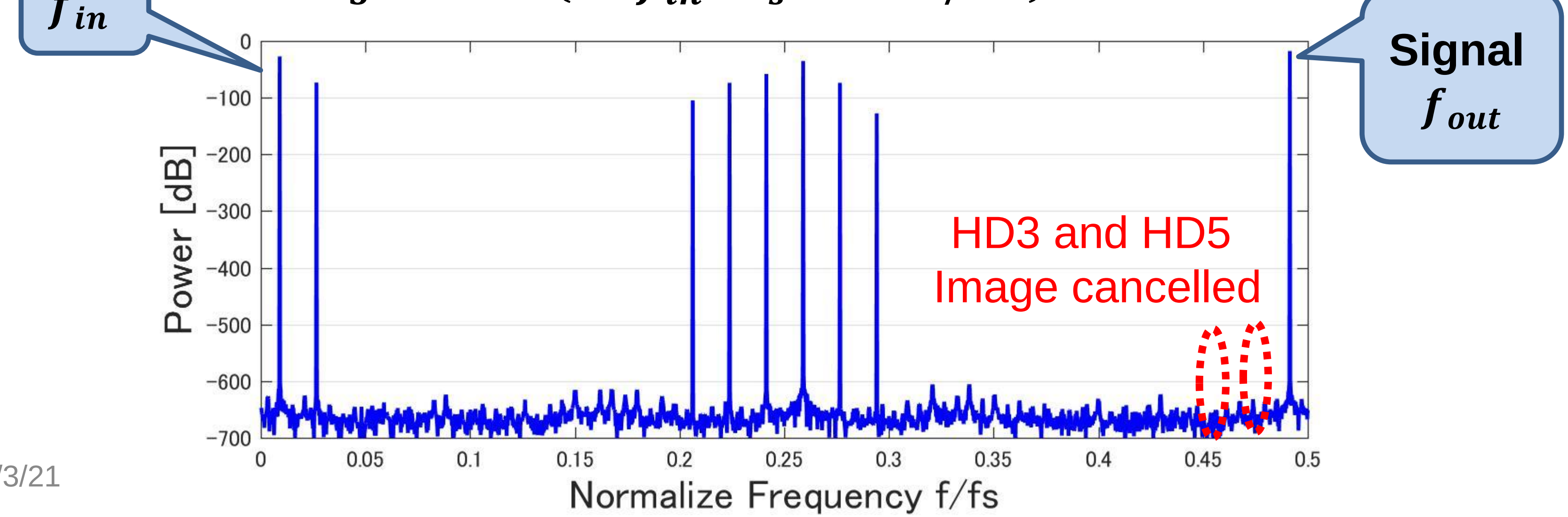
3rd and 5th Harmonics Cancellation



$$Y(nT_s) = a_1 D_{in} + a_3 {D_{in}}^3 + a_5 {D_{in}}^5$$

f_{in}/f_s	9/1024
a_1, a_3, a_5	1, -0.1, -0.08

$$D_{in} = \begin{cases} X_0 = A\sin(2\pi f_{in} nT_s - 11\pi/30) & n = 4k \\ X_1 = A\sin(2\pi f_{in} nT_s - \pi/30) & n = 4k+1 \\ X_2 = A\sin(2\pi f_{in} nT_s + \pi/30) & n = 4k+2 \\ X_3 = A\sin(2\pi f_{in} nT_s + 11\pi/30) & n = 4k+3 \end{cases}$$



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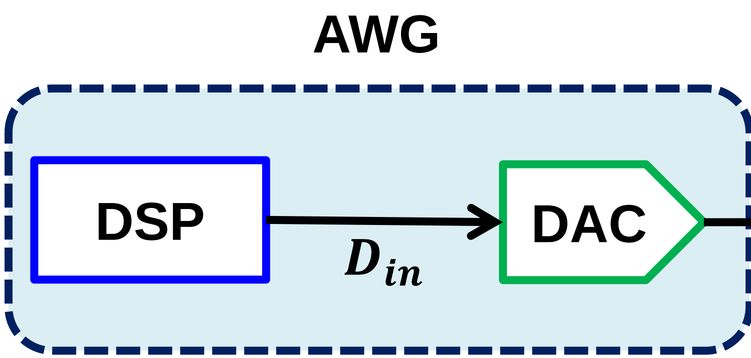
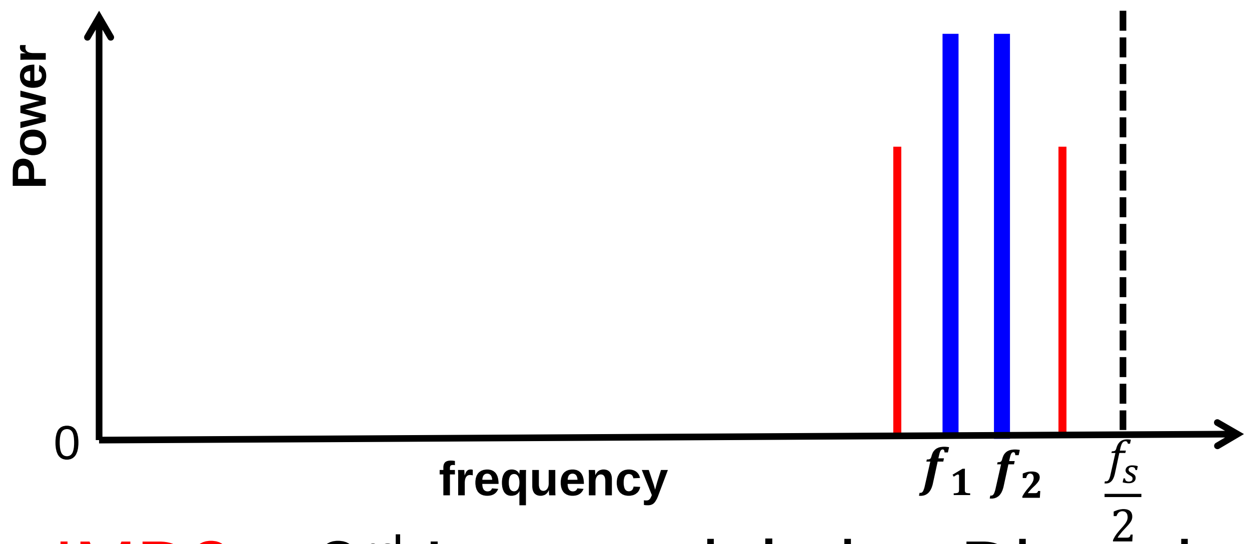
Two-Tone Signal Case



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

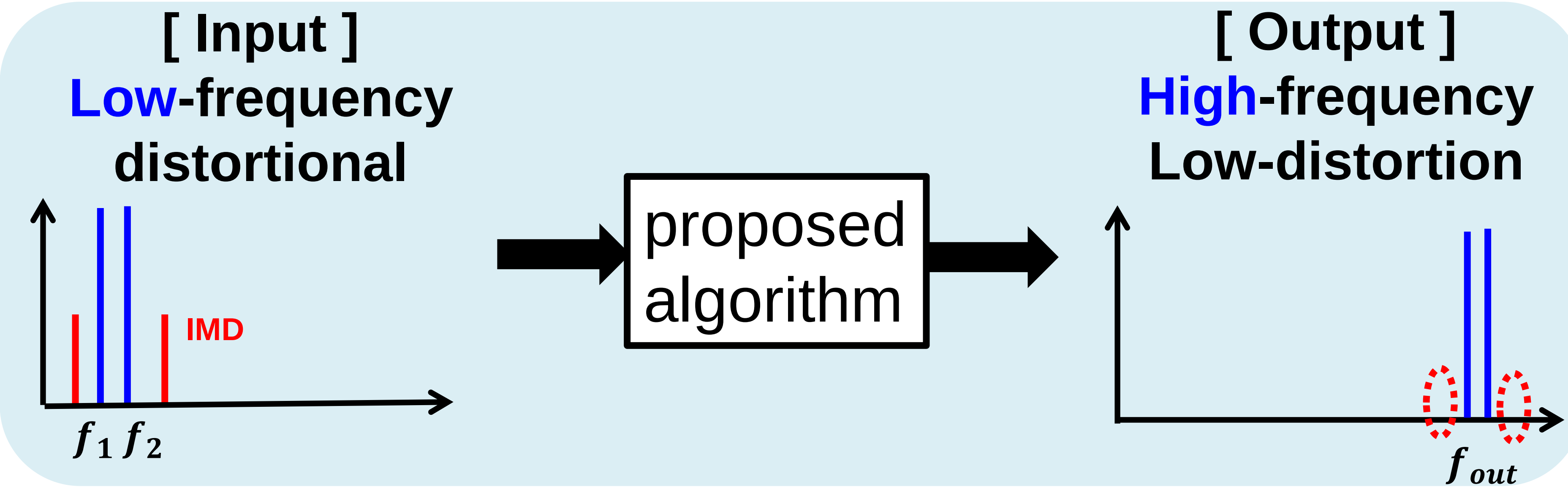
$$D_{in} = A\sin(2\pi f_1 nT_s) + B\sin(2\pi f_2 nT_s)$$



IMD3 = 3rd Intermodulation Distortion

The algorithm is NOT applicable

Algorithm For Two-Tone Signals

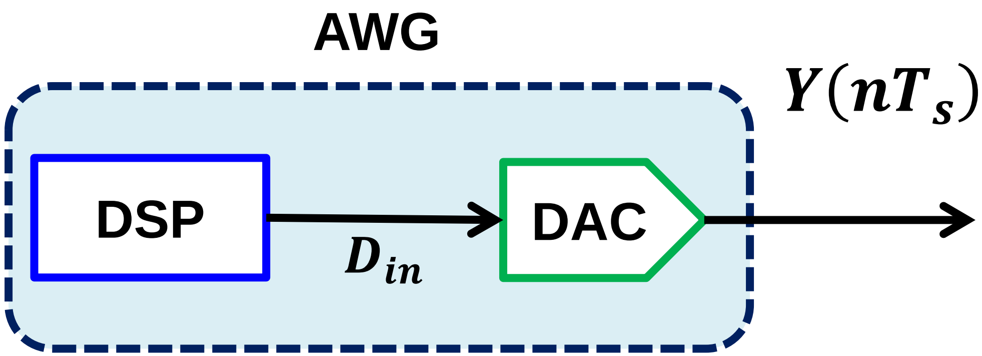


$$D_{in} = \begin{cases} X_0 = A\sin(2\pi f_1 n T_s + \varphi_0) + B\sin(2\pi f_2 n T_s - \varphi_0) & n\text{: even} \\ X_1 = A\sin(2\pi f_1 n T_s - \varphi_0) + B\sin(2\pi f_2 n T_s + \varphi_0) & n\text{: odd} \end{cases}$$

$$\varphi_0 = \frac{\pi}{N}$$

*N*th order IMD is cancelled

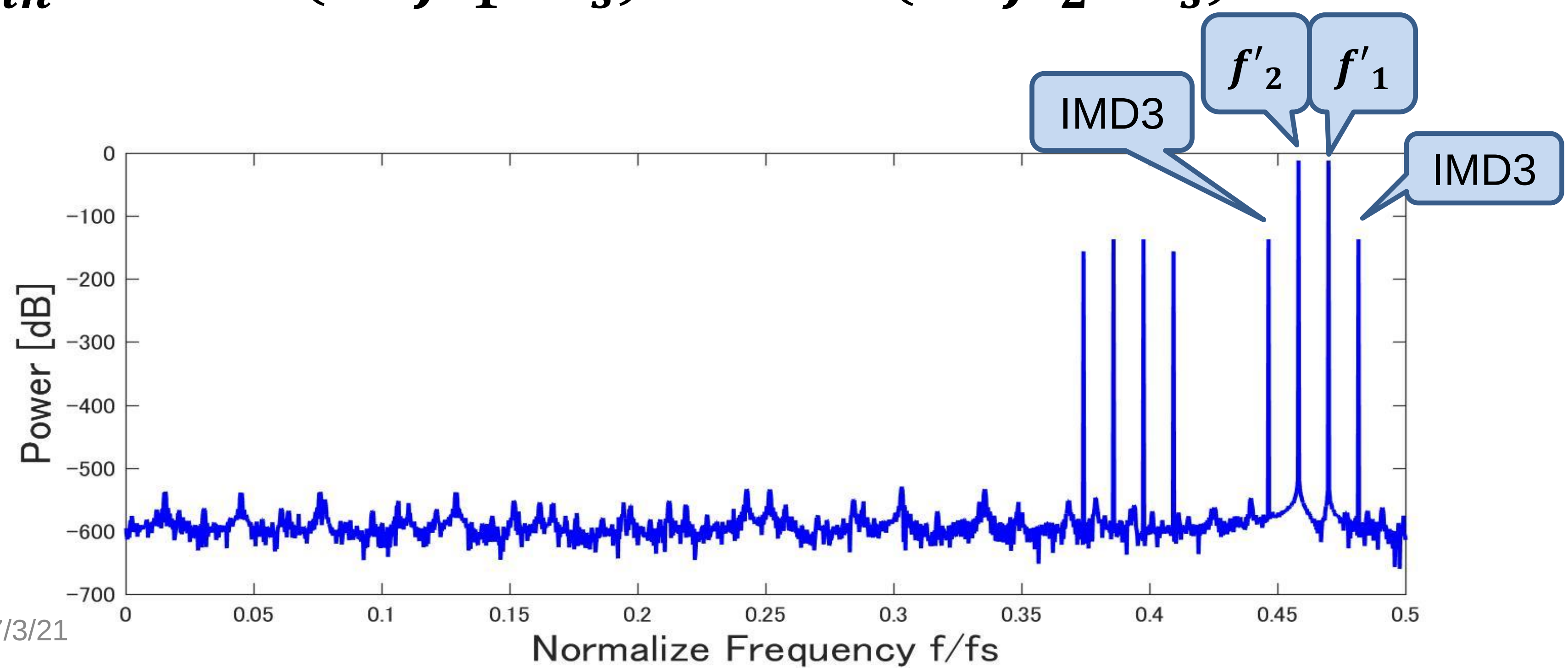
Two-Tone Signal and IMD3



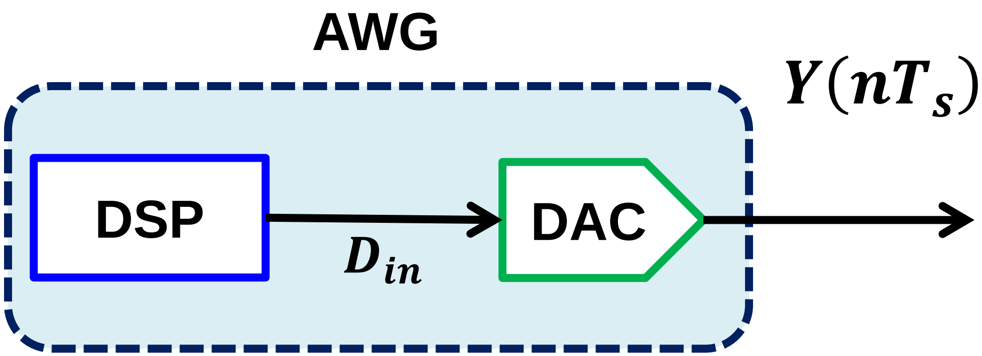
$$Y(nT_s) = a_1 D_{in} + a_3 {D_{in}}^3$$

$f_1, f_2/f_s$	481, 469/1024
a_1, a_3	1, -0.1

$$D_{in} = A\sin(2\pi f'_1 nT_s) + B\sin(2\pi f'_2 nT_s)$$



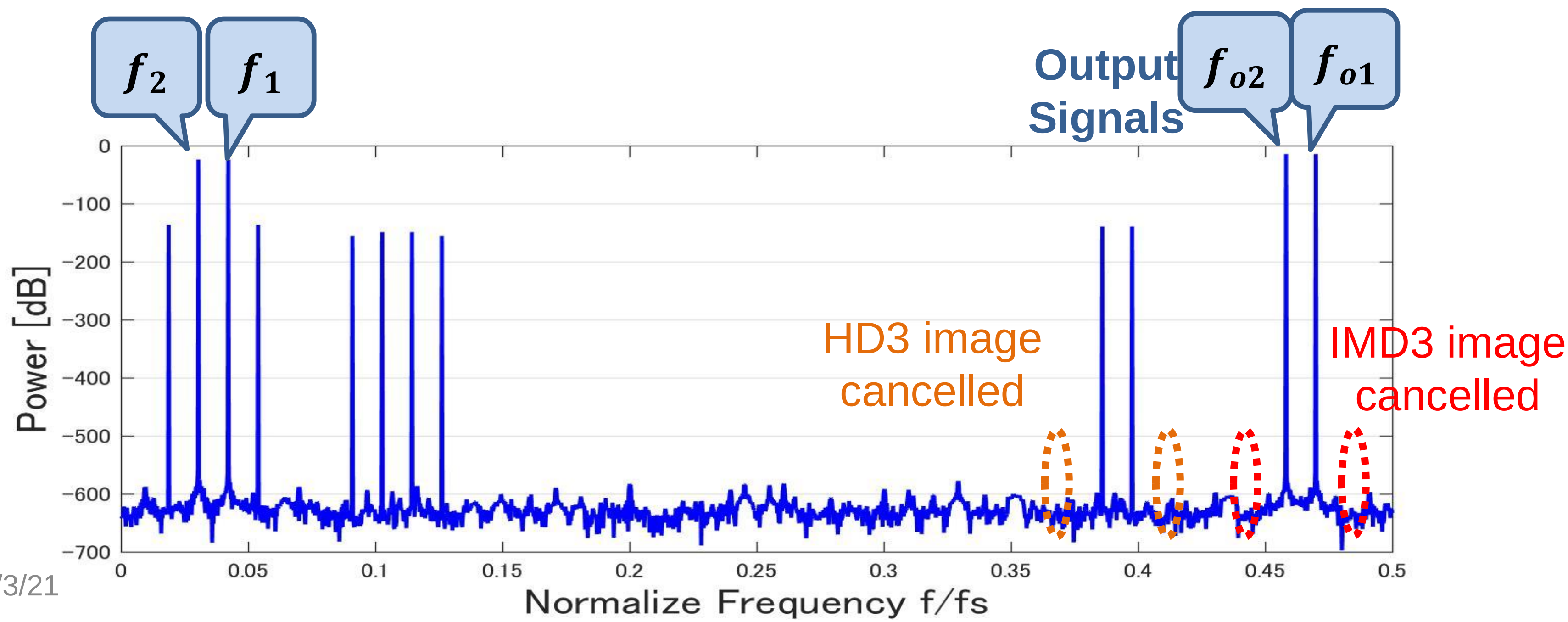
IMD3 Cancellation



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

$f_1, f_2/f_s$	31, 43/1024
a_1, a_3	1, -0.1

$$D_{in} = \begin{cases} X_0 = A\sin(2\pi f_1 nT_s + \pi/3) + B\sin(2\pi f_2 nT_s - \pi/3) & n\text{: even} \\ X_1 = A\sin(2\pi f_1 nT_s - \pi/3) + B\sin(2\pi f_2 nT_s + \pi/3) & n\text{: odd} \end{cases}$$



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Conclusion

- We have proposed high-frequency low-distortion signal generation algorithms with AWG.
- Single-tone and two-tone signal generation
- Need only for a simple analog HPF.
- No need for AWG nonlinearity identification.

Accurate measurement has been very important from thousands years ago

度量衡 統一 by 始皇帝