２０１６年5月２６日@千葉大学

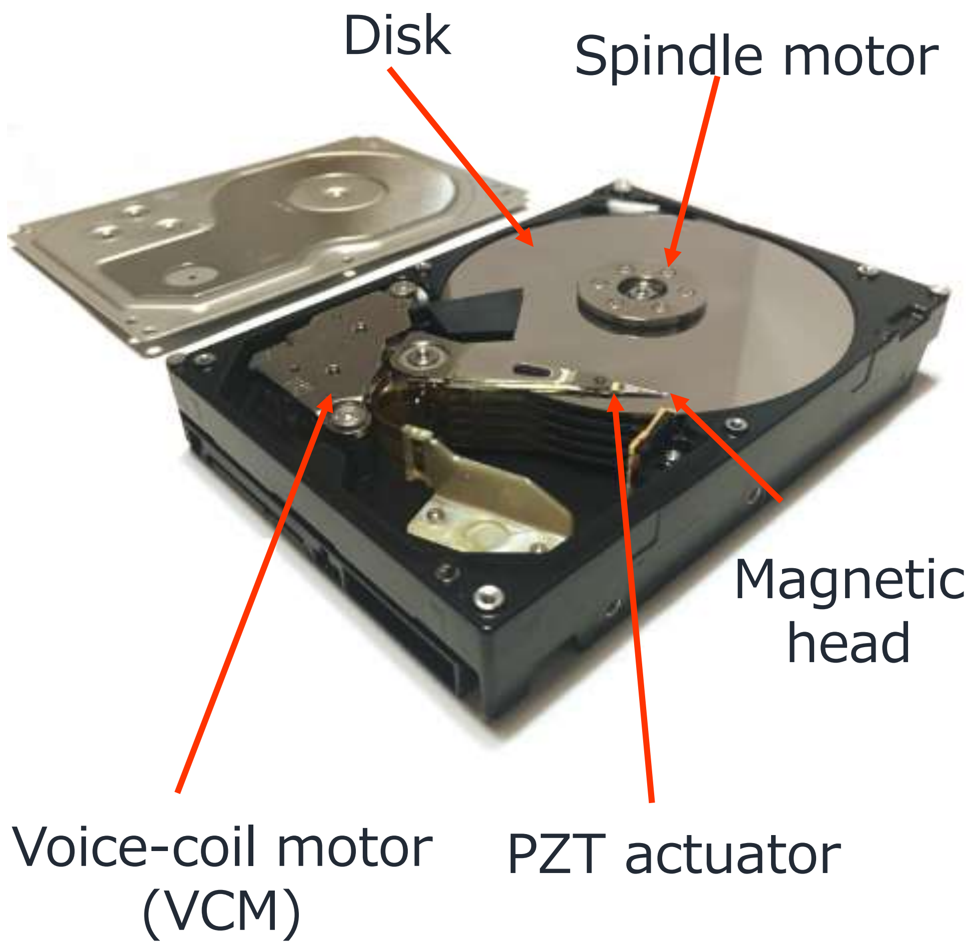
第7回 電気学会 モーションコントロールの高機能化に関する協同研究委員会

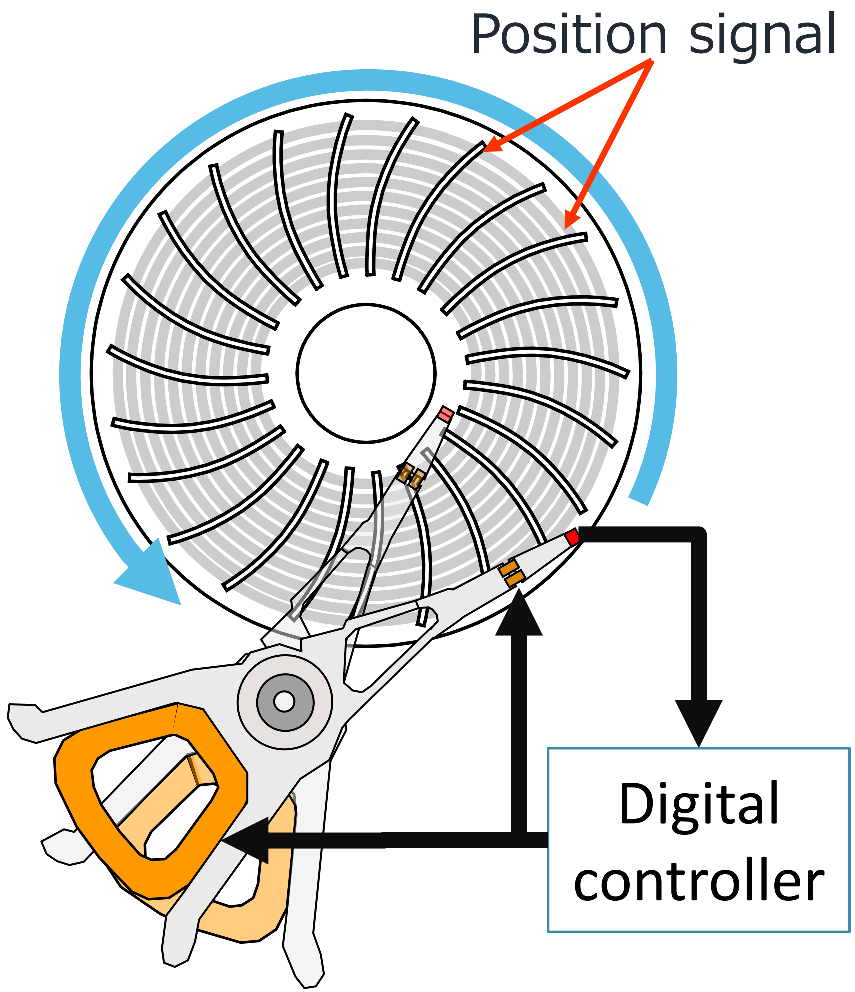
ハードディスクドライブの磁気ヘッド位置決め制御

千葉工業大学　機械工学科　熱海武憲

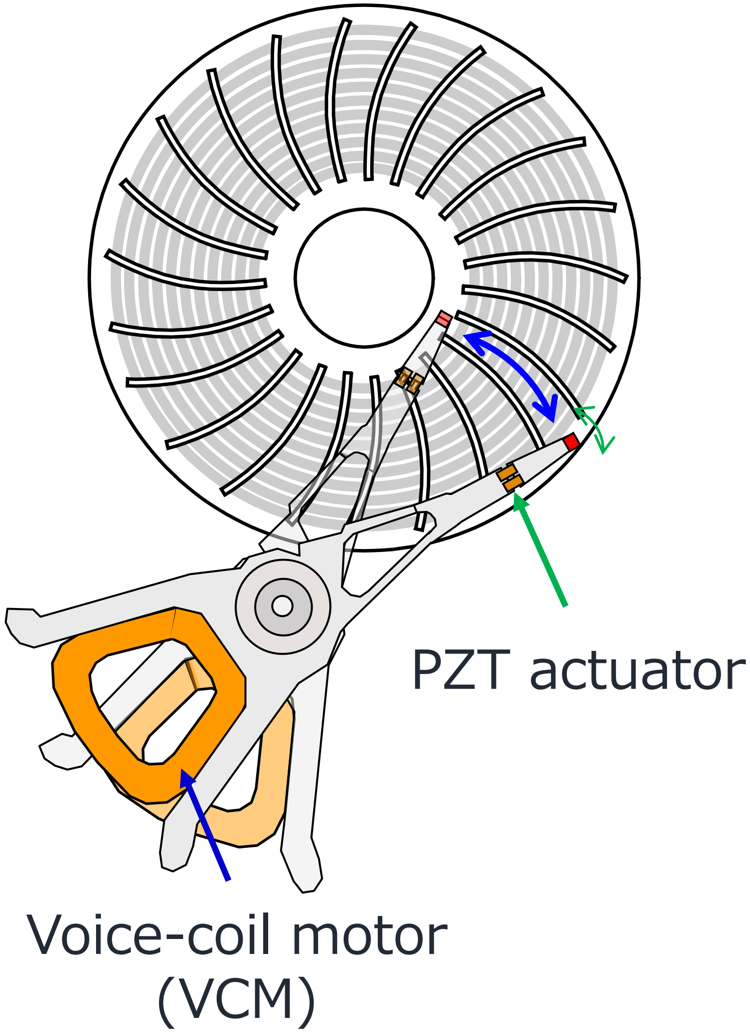
磁気ヘッドの位置を
より精密に制御する

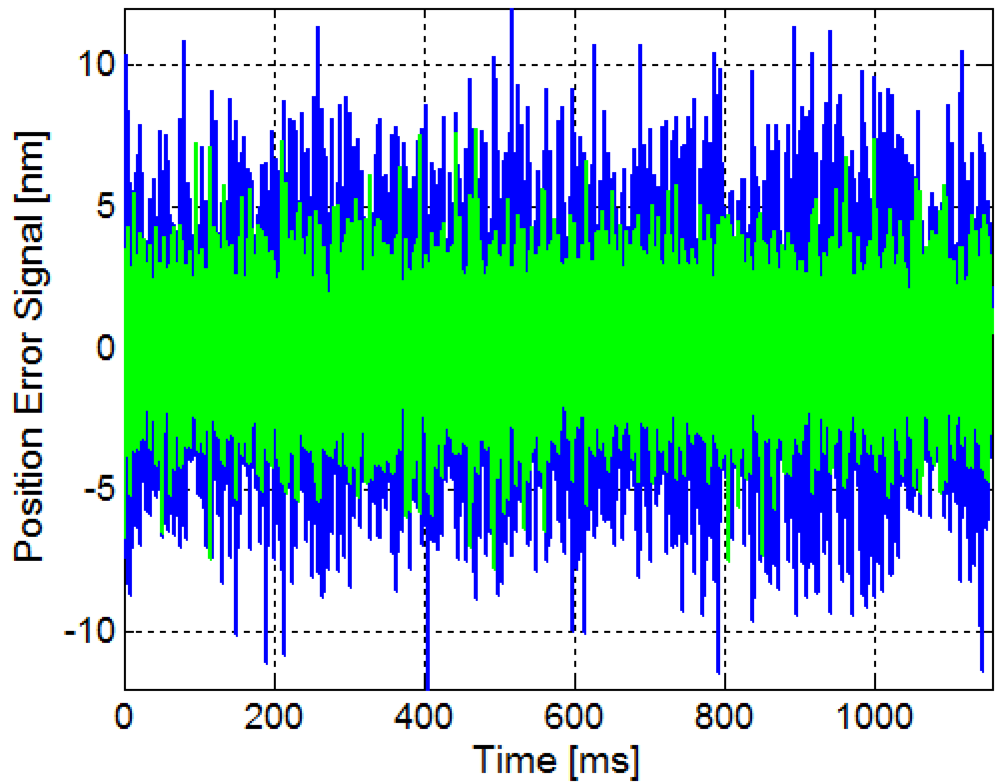
ＨＤＤの磁気ヘッド位置決め制御系





磁気ヘッドの位置決め誤差





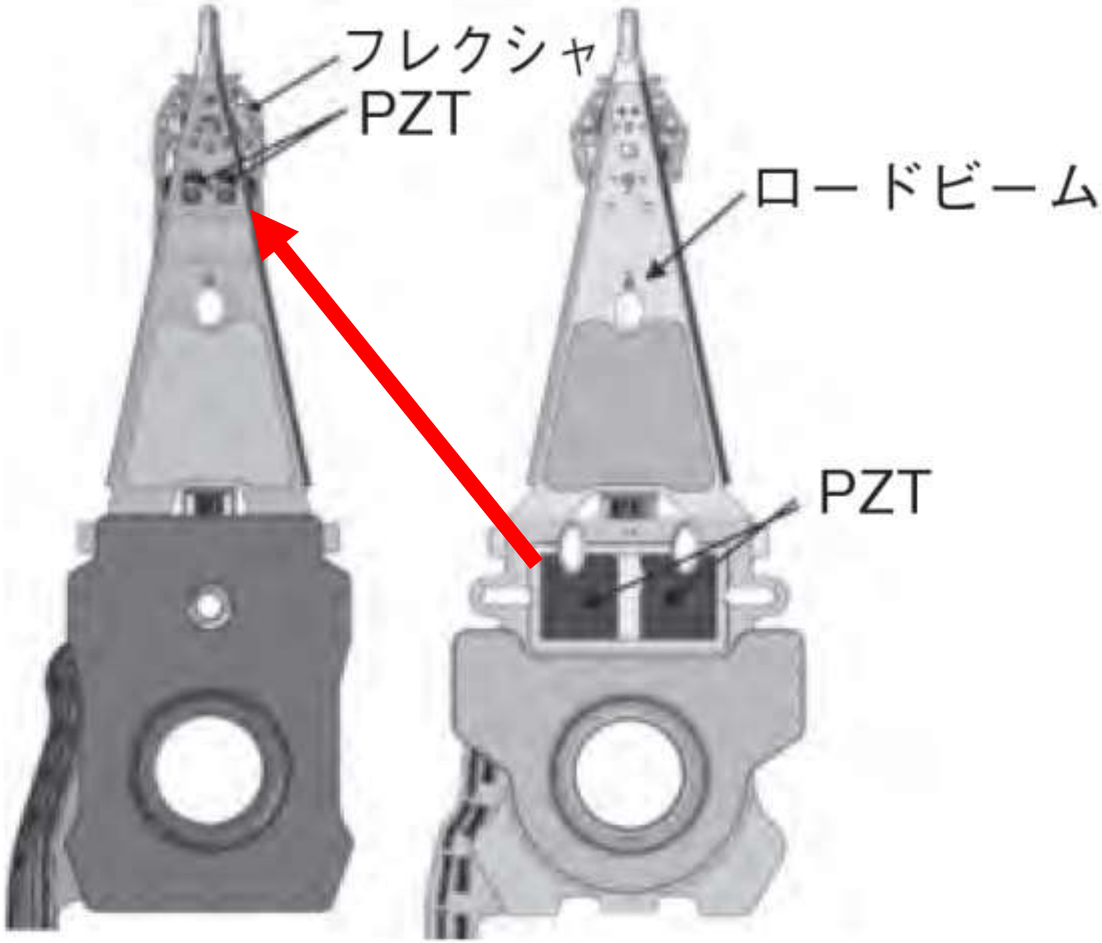


図３　マイクロアクチュエータ（左）と
ミリアクチュエータ（右）

日本機械学会誌　2016. 4　Vol. 119 No.1169　より引用

HGST Micro-actuator

Second-generation Dual-Stage Actuator for Better Head-positioning Accuracy

To increase hard disk drive (HDD) data density, the size of bits – the 1s and 0s that represent the information stored on the disk – decreases and the spacing between their concentric tracks shrinks. As these dimensions shrink, it becomes more difficult to position the read-write head's transducer element over the center of the data track.

Figure 1. HMA structure and actuation

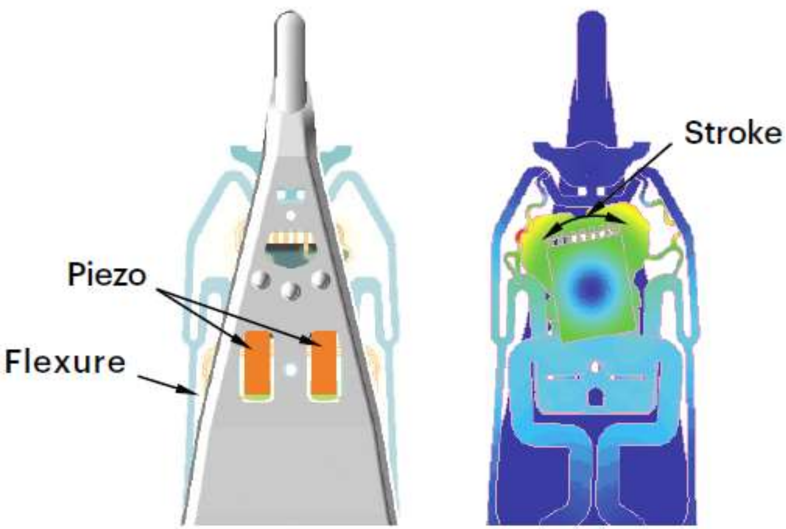
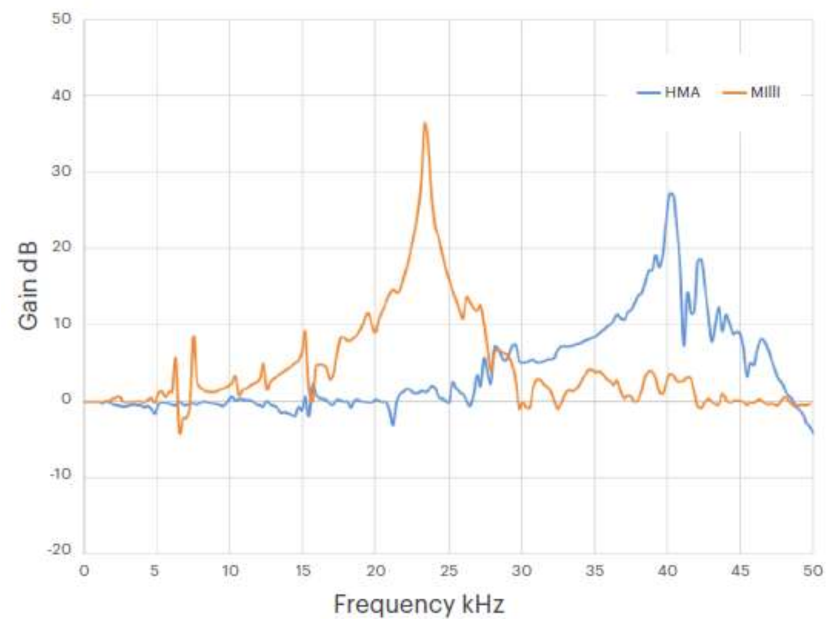


Figure 2. DSA plant transfer function comparison



https://www.hgst.com/sites/default/files/resources/HGST-Micro-Actuator-TB.pdf　より引用

HGST Micro-actuator

Figures 4 and 5 show the position-error signal (pes) comparison between the conventional Milli-actuator (blue) and HMA (green) DSA systems under an external vibration condition. The green line shows how significantly the HMA DSA system can reduce the head-positioning error caused by external vibration compared to Milli-actuator DSA system.

Figure 4. Position-error signal of HMA DSA compared to Milli DSA

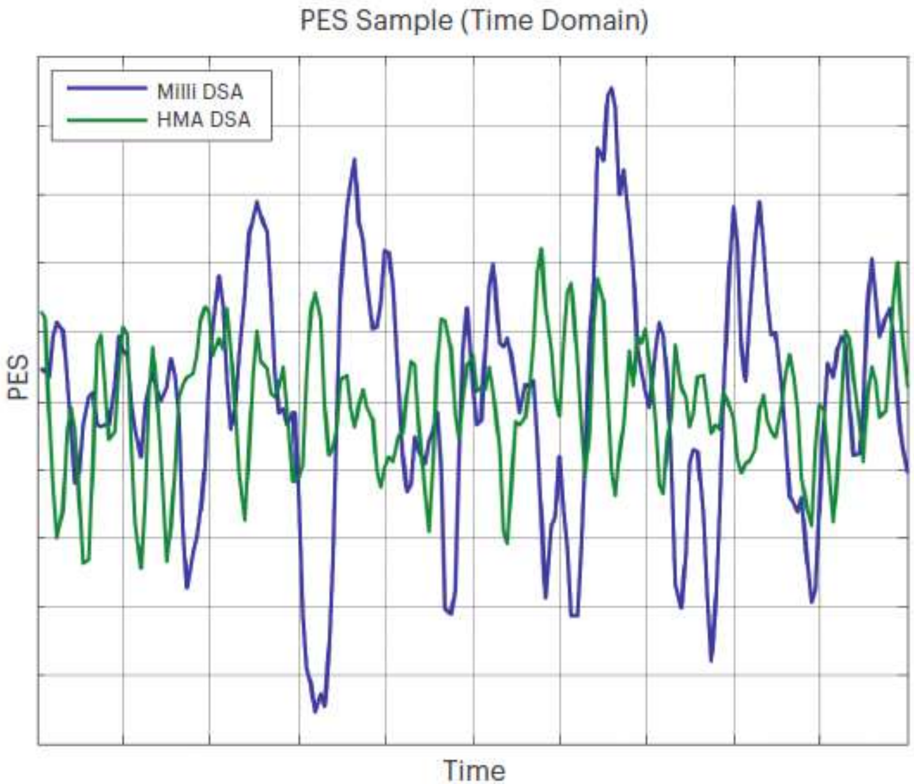
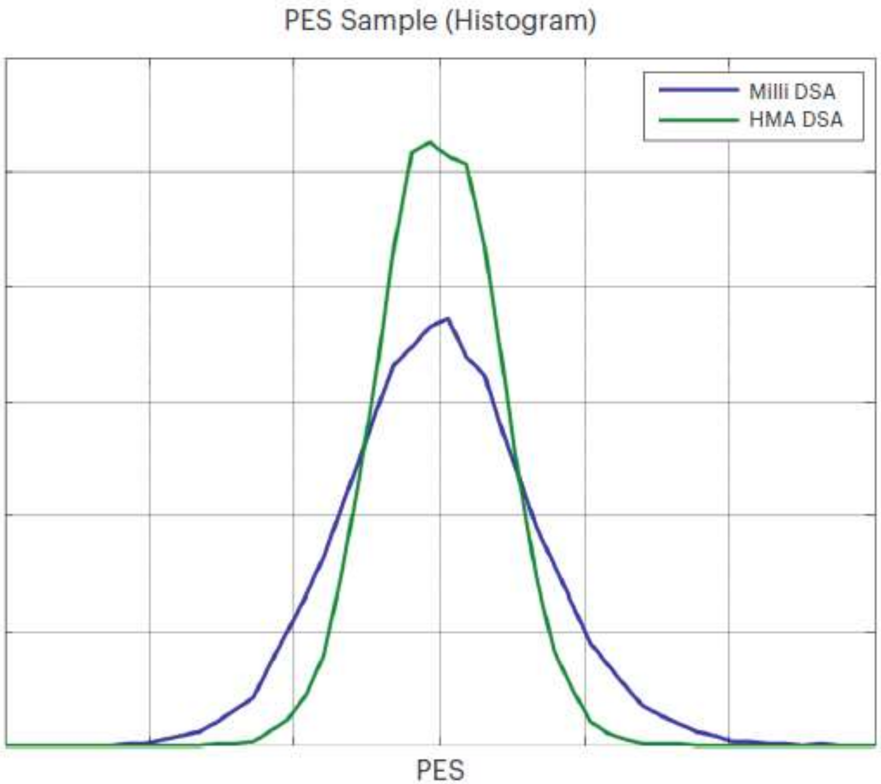


Figure 5. Position-error signal distribution of HMA DSA compared to Milli DSA



https://www.hgst.com/sites/default/files/resources/HGST-Micro-Actuator-TB.pdf　より引用

amazon.co.jp プライム | パソコン・周辺機器 | Office

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カテゴリー | マイストア | ギフト券 | タイムセール | Amazonで売る | ヘルプ | In English | 熱海武憲さん アカウントサービス

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パソコン・周辺機器 › PCパーツ › 内蔵ハードディスク

画像にマウスを合わせると拡大されます

HGST(エイチ・ジー・エス・ティー) Ultrastar He10 3.5inch 10TB 256MBキャッシュ 7200rpm SATA 6Gb/s HUH721010ALE600

HGST Japan

カスタマーレビューを書きませんか？

価格： ￥ 83,628

残り**4点** ご注文はお早めに 在庫状況について

住所からお届け予定日を確認 既定の住所を使用 詳細

お届け予定日：5/27~31 通常配送を利用した場合のお届け予定日です。

この商品は、ソフマップ が販売、発送します。 返品については出品者のリンクからご確認ください。

新品の出品：5 ￥ 82,998より

- メーカー型番:HUH721010ALE600
- インターフェース:6Gb/s SATA
- 容量:10TB
- 回転数(RPM):7200
- キャッシュ:256MB

› もっと見る

さらに先の技術

Takenori Atsumi,
``Emerging Technology for Head-Positioning System in HDDs'',
IEEJ Journal of Industry Applications, Vol. 5, No. 2, pp. 117-122, (2016-3)

Case 1: Film-coil actuator

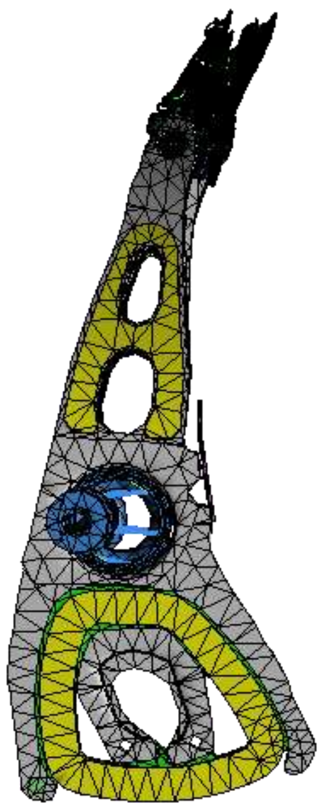
Case 2: Thermal actuator

Case 1: Film-coil actuator

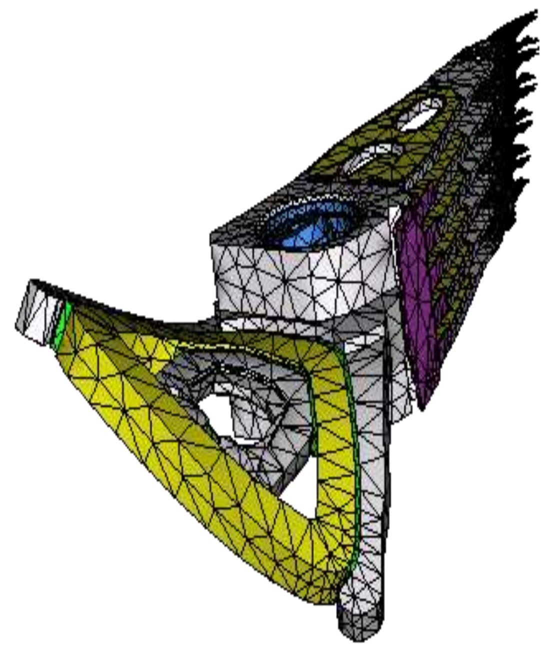
Case 2: Thermal actuator

Easy Excited Resonant Mode in HDDs

By VCM actuator
(Butterfly mode: 5.2 kHz)

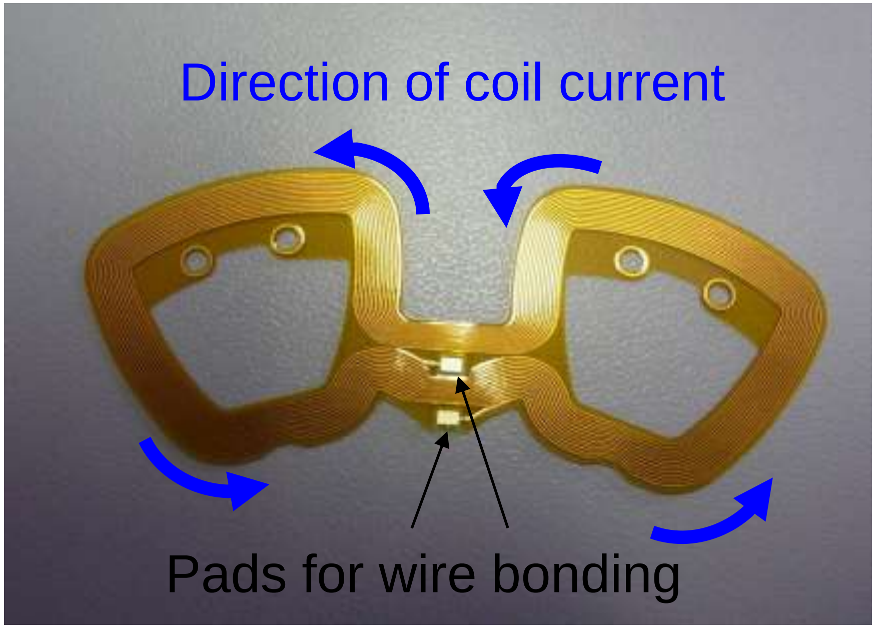


By external vibration
(Torsion mode: 3.5 kHz)

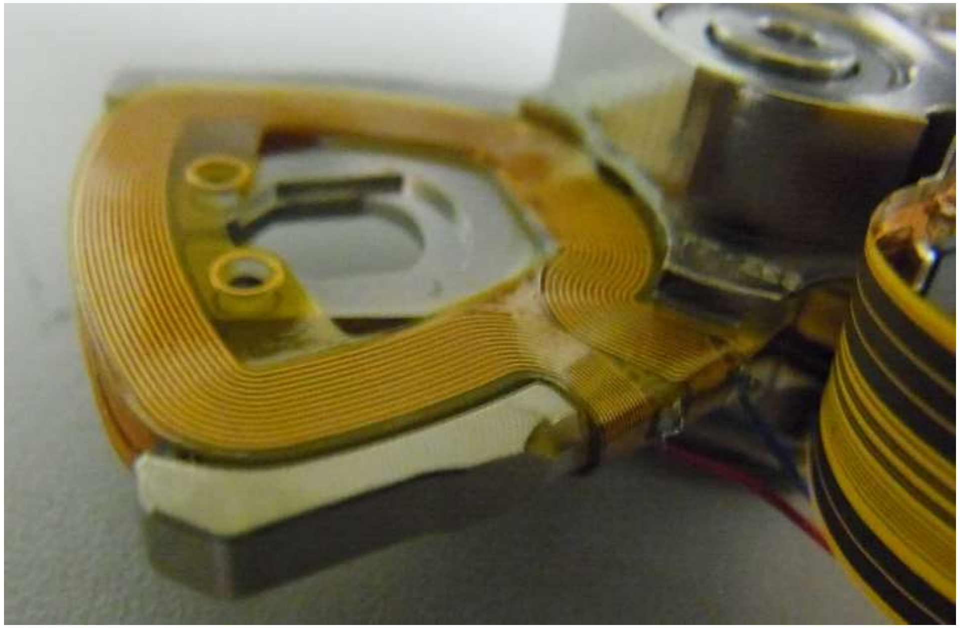


Film Actuator

Thin film coil
(Film actuator)

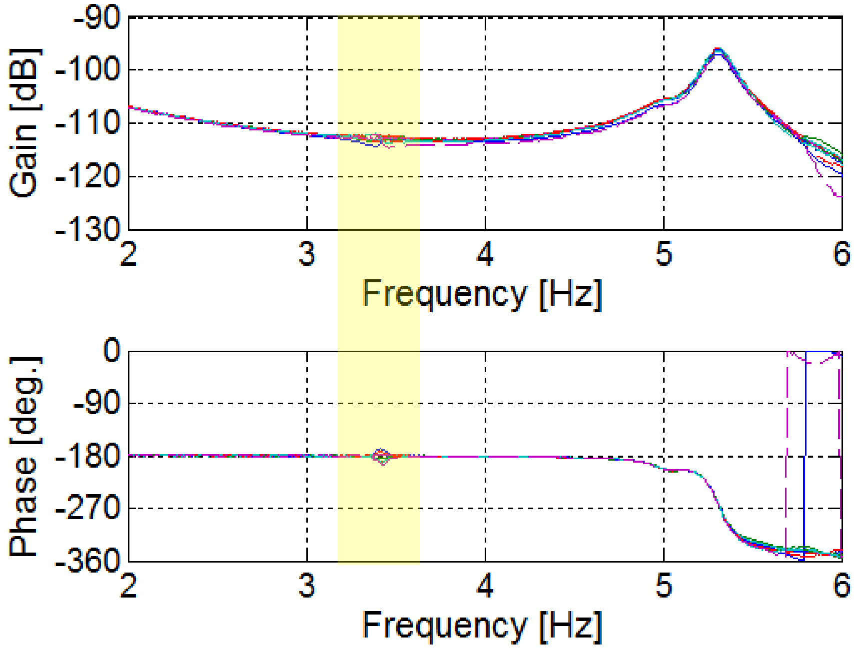


VCM with film actuator

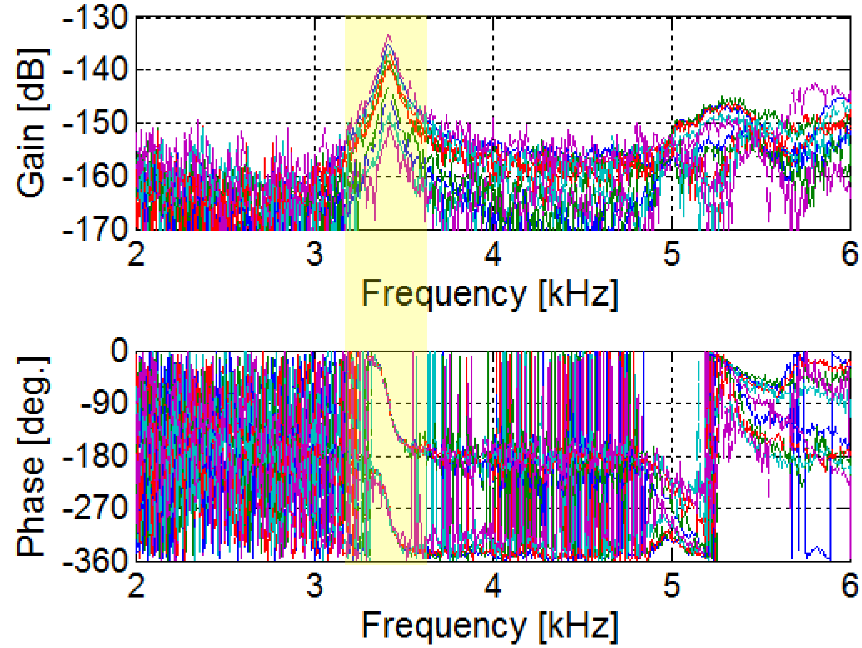


Frequency Response of Actuator

VCM actuator

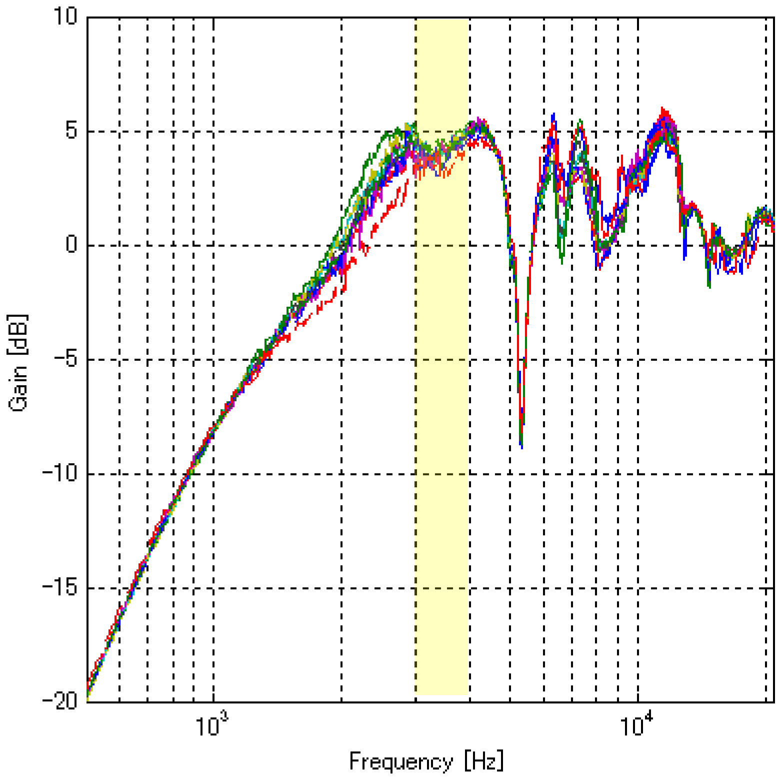


Film actuator

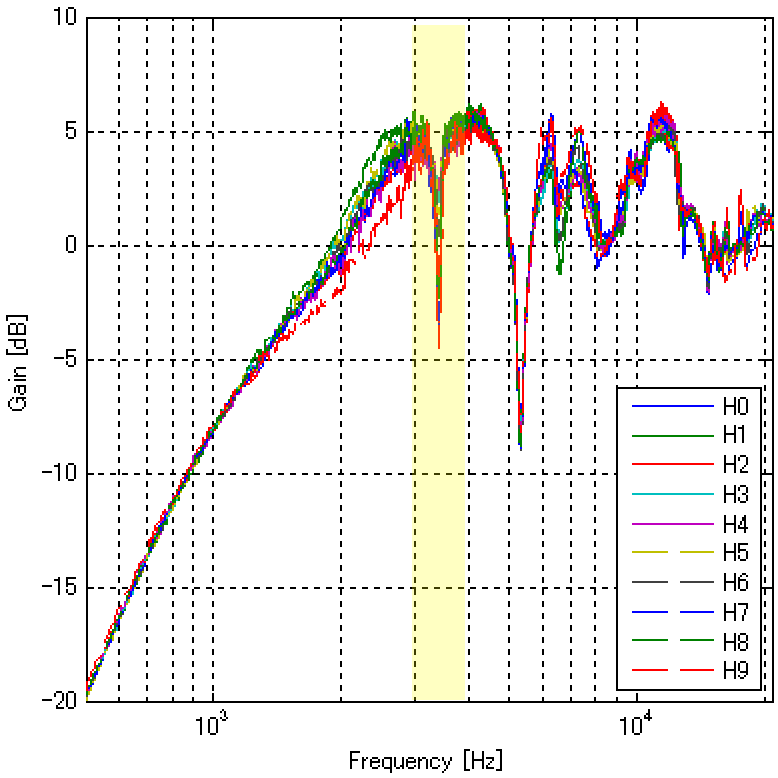


Comparison of Sensitivity Function

w/o Film actuator
(VCM+PZT)

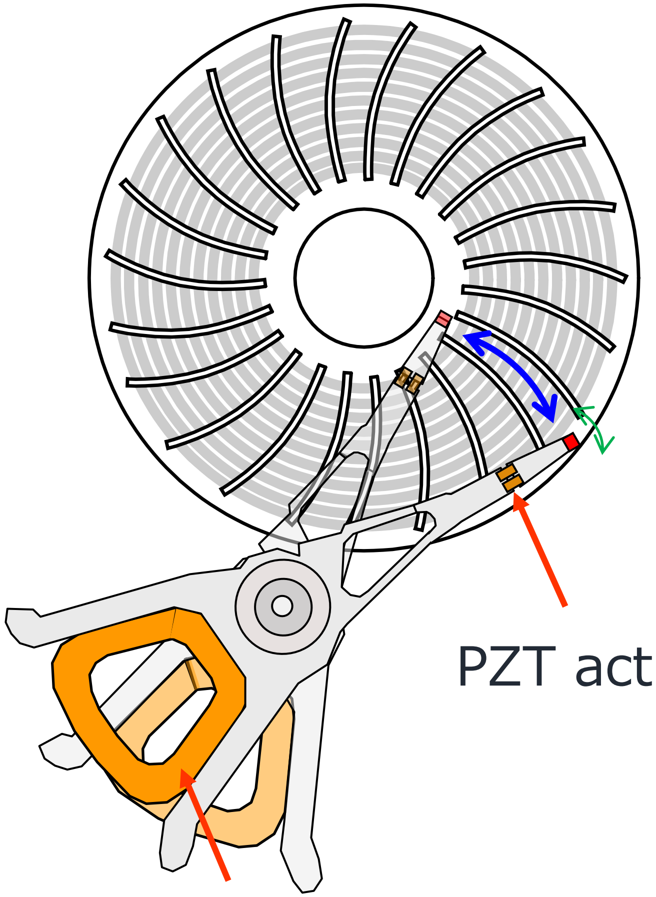


w/ Film actuator
(VCM +PZT+ Film)

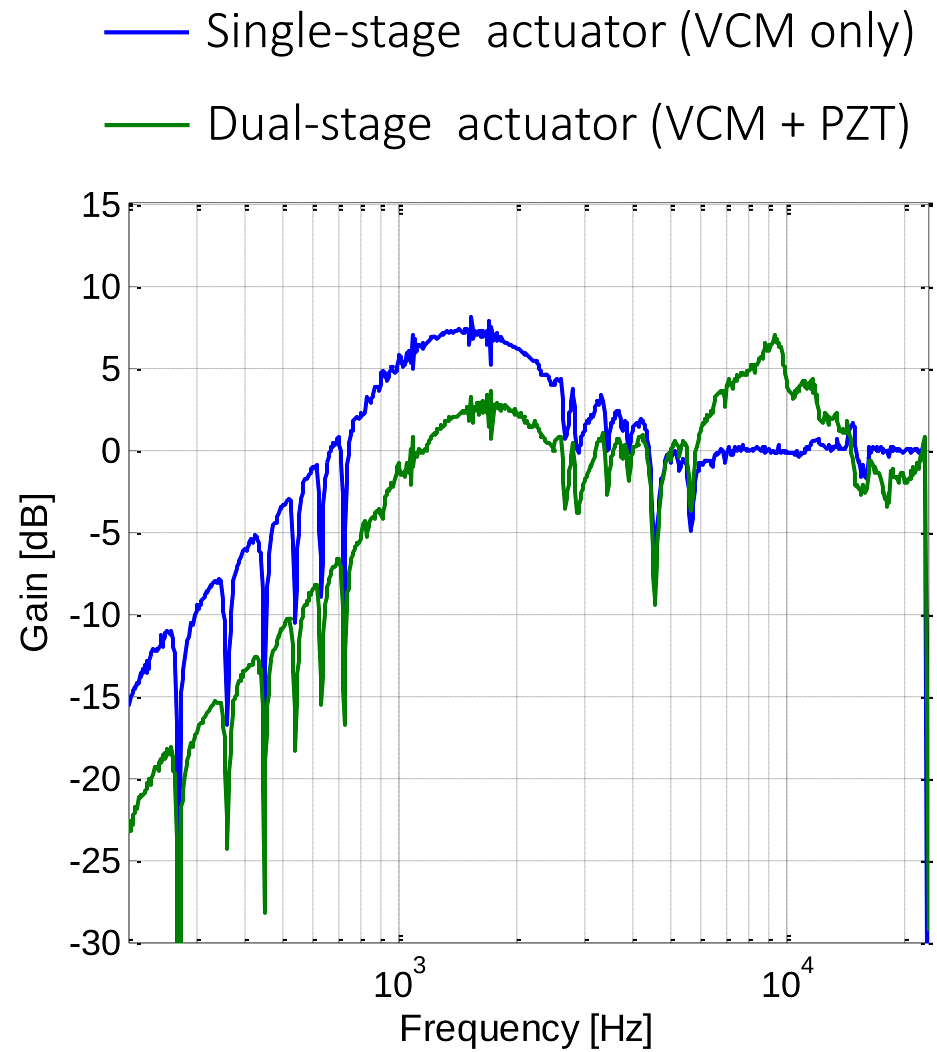


Case 1: Film-coil actuator

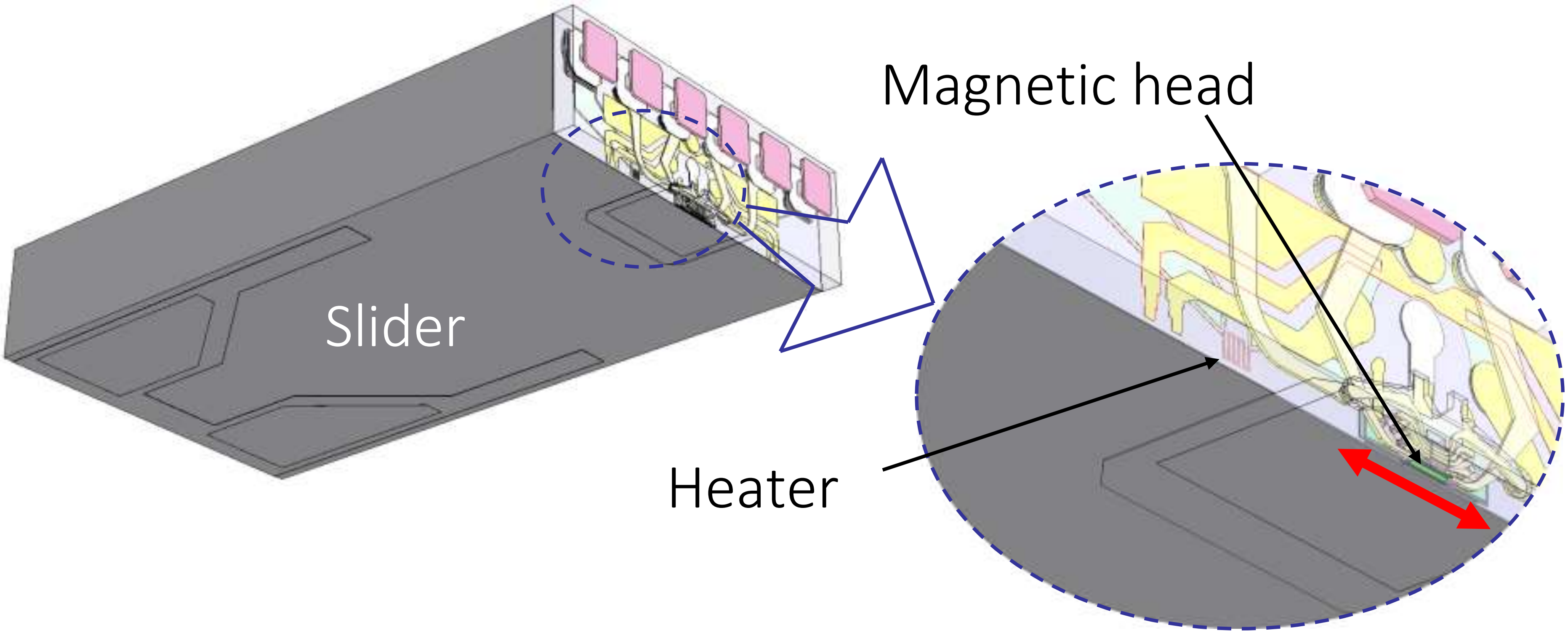
Case 2: Thermal actuator

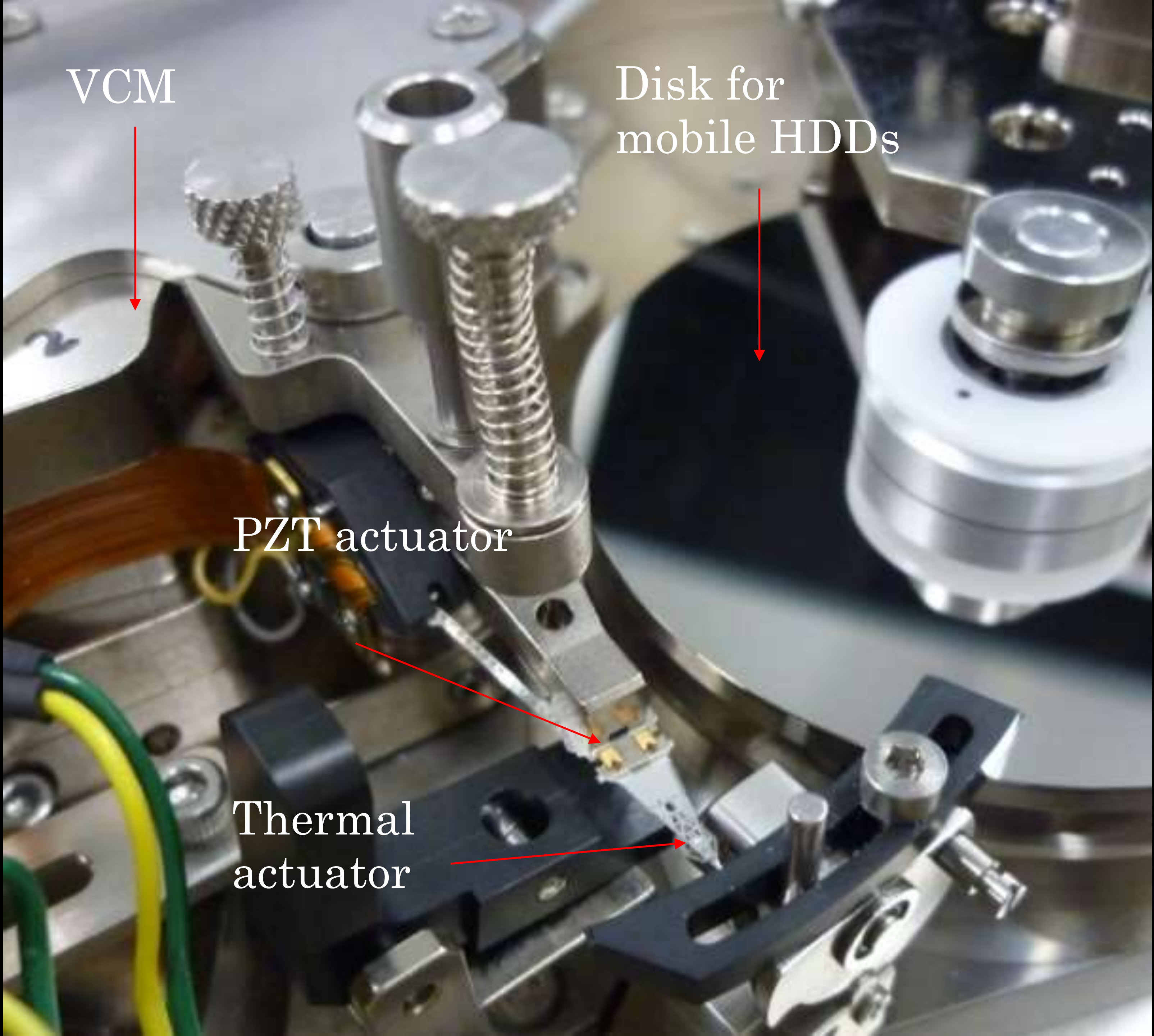


Sensitivity function

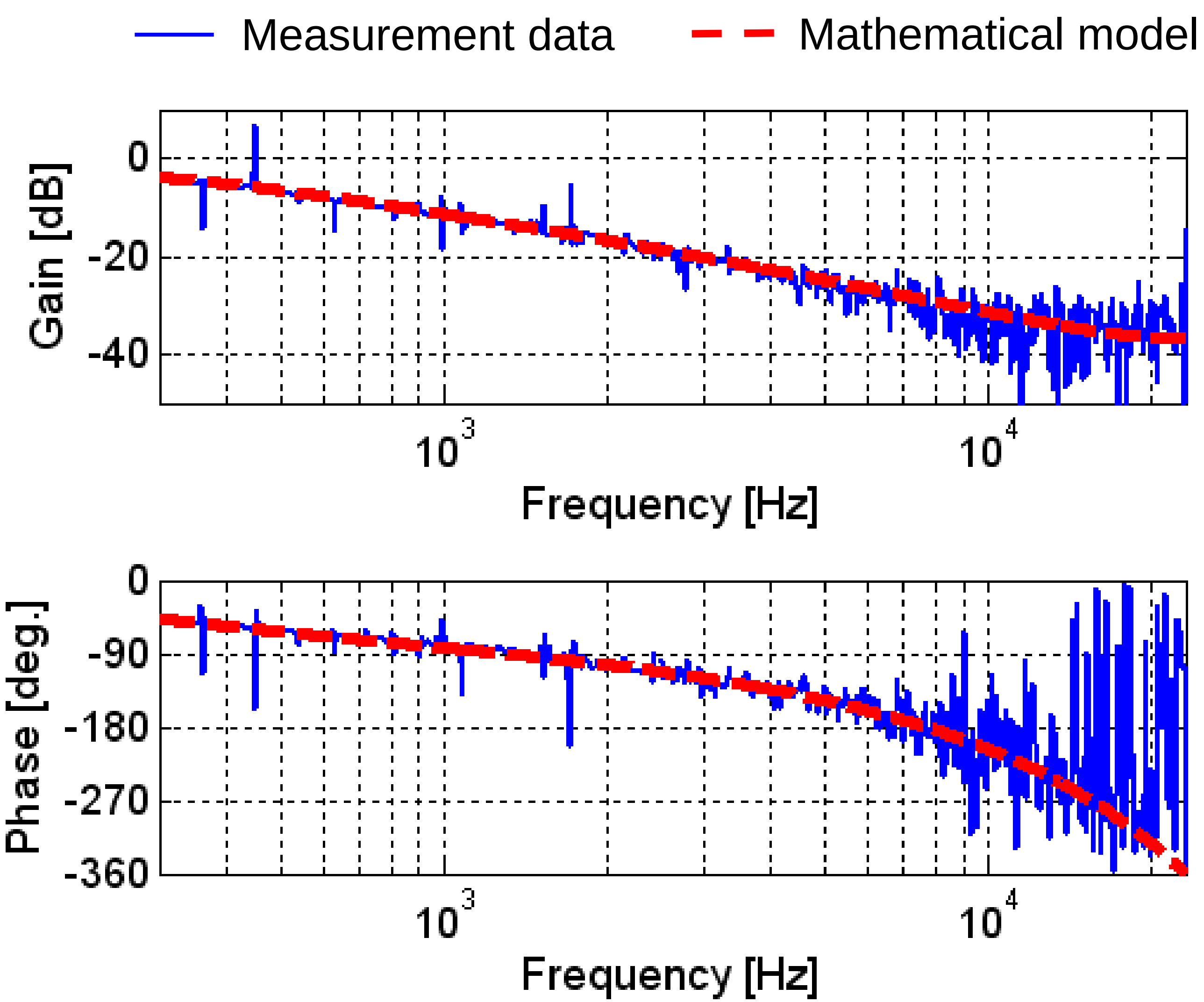


Thermal Actuator



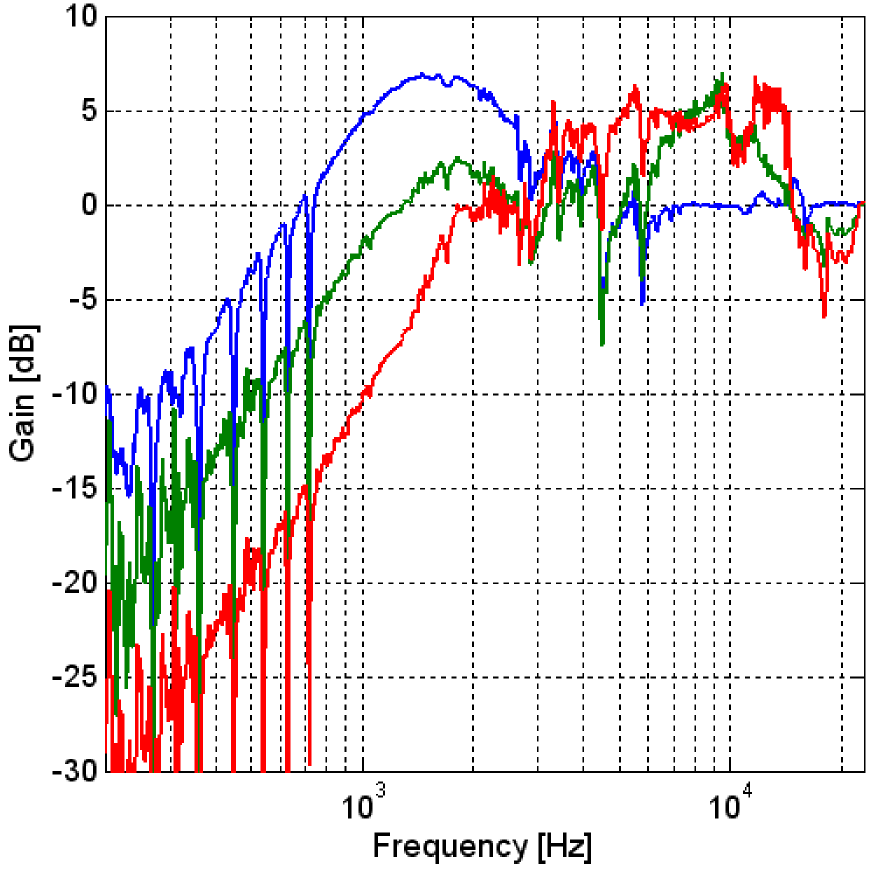

VCM
Disk for mobile HDDs
PZT actuator
Thermal actuator

Frequency Response of Thermal Actuator

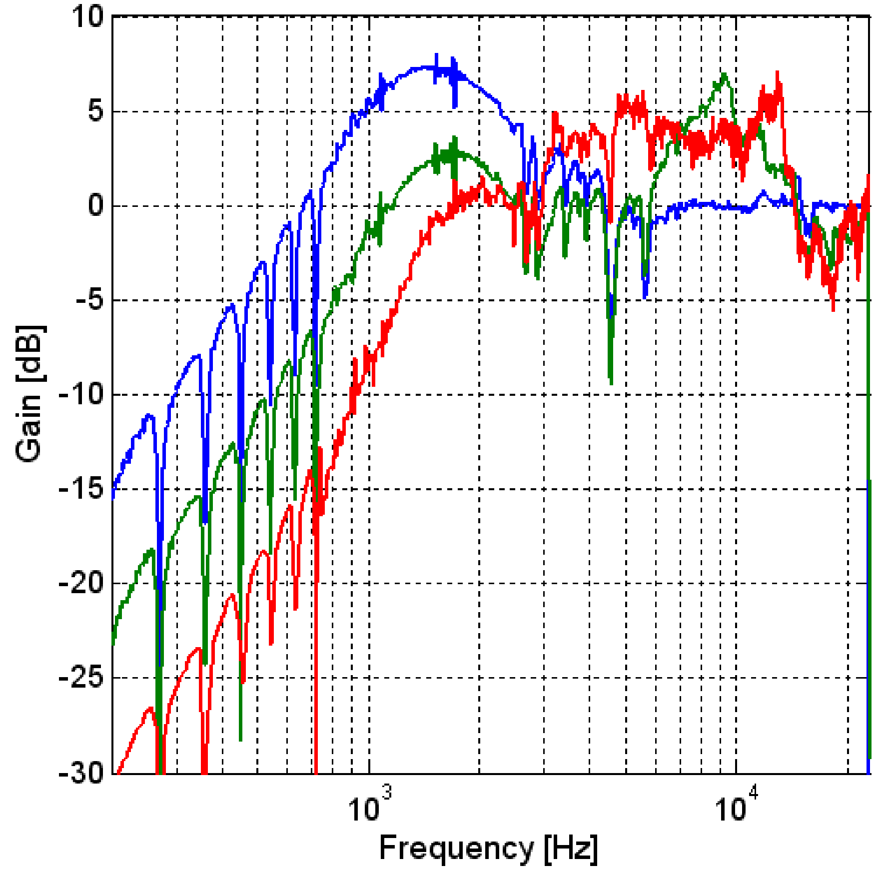


Comparison of Sensitivity Function

Design results



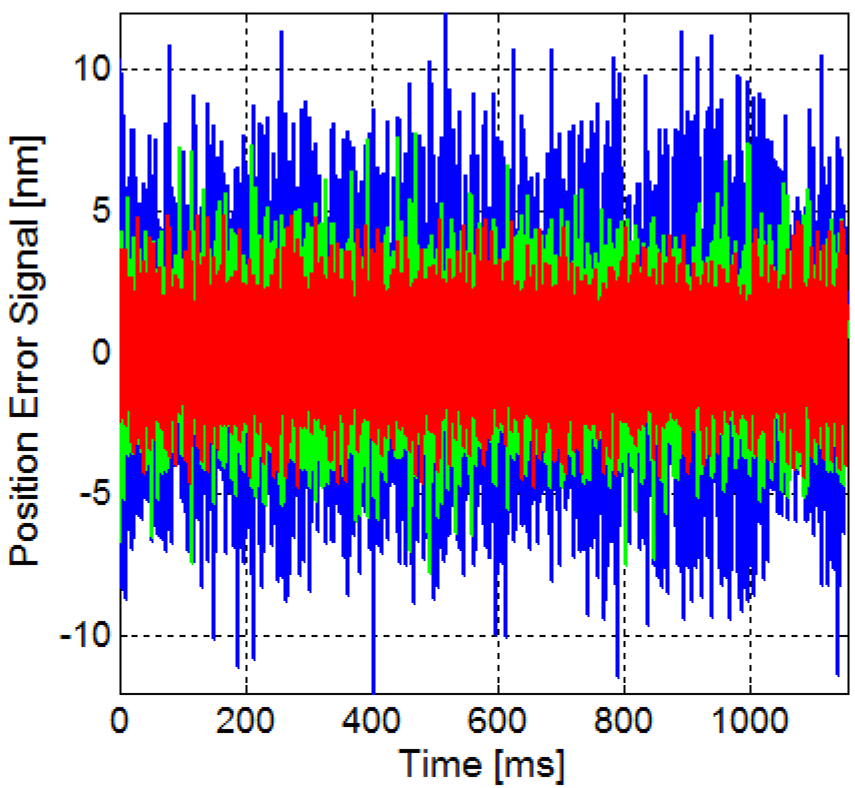
Experimental results



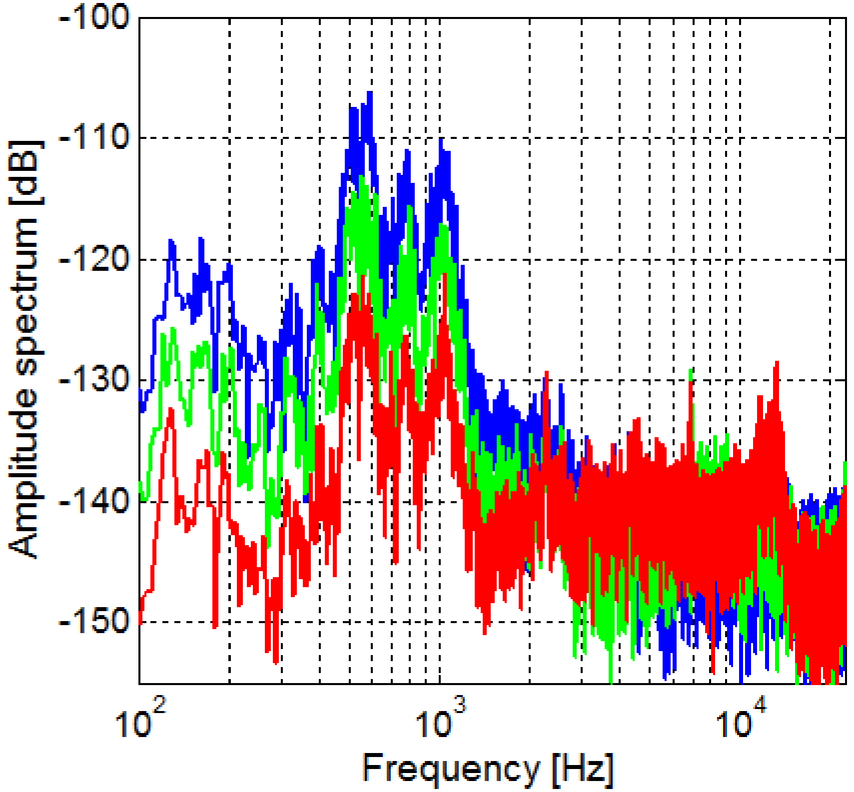
Single-stage actuator (VCM only)
Dual-stage actuator (VCM + PZT)
Triple-stage actuator (VCM + PZT + Thermal actuator))

Comparison of Positioning Error

Time domain



Frequency domain



- Single-stage actuator (VCM only), SD: 3.12 nm
- Dual-stage actuator (VCM + PZT), SD: 1.57 nm
- Triple-stage actuator (VCM + PZT + Thermal actuator)), SD: 0.96 nm

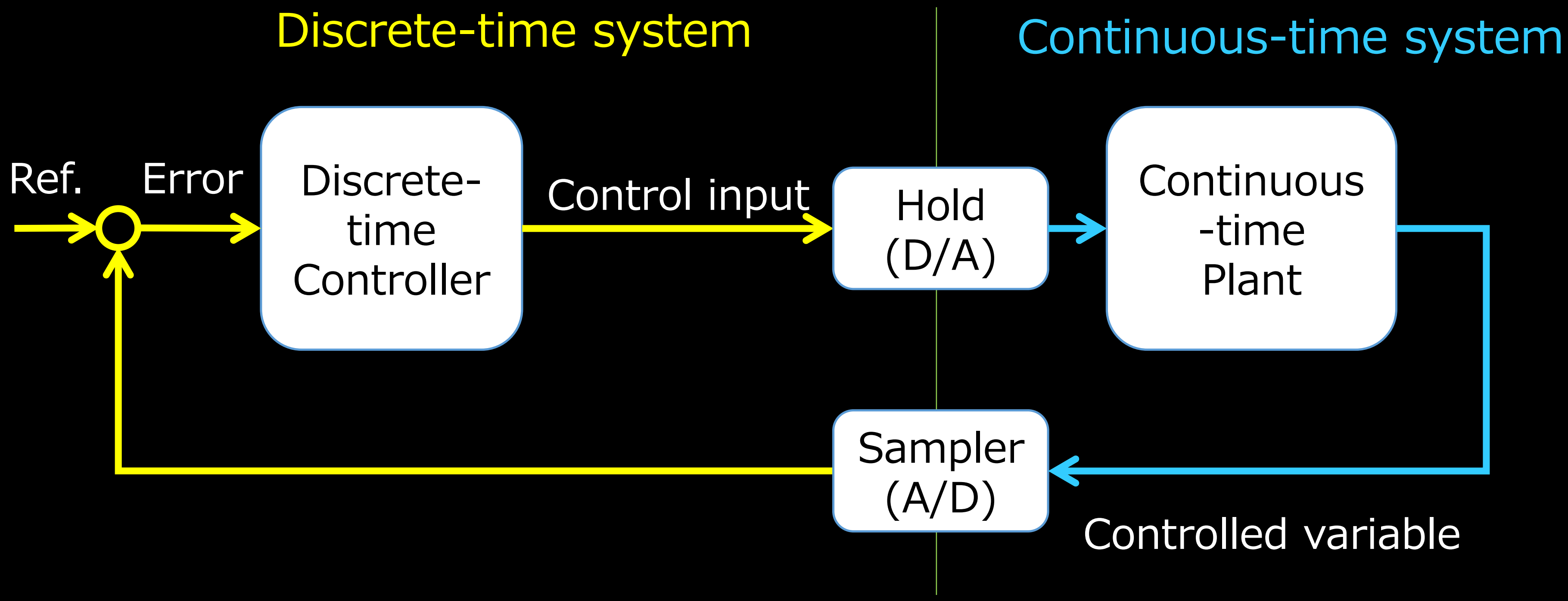
ここ最近の学会発表

The 2nd IEEJ international workshop on Sensing, Actuation, Motion Control, and Optimization
March 8th, 2016, Seikei University, Tokyo

Estimation Method of Unobservable Oscillations in Sampled-Data Positioning Systems

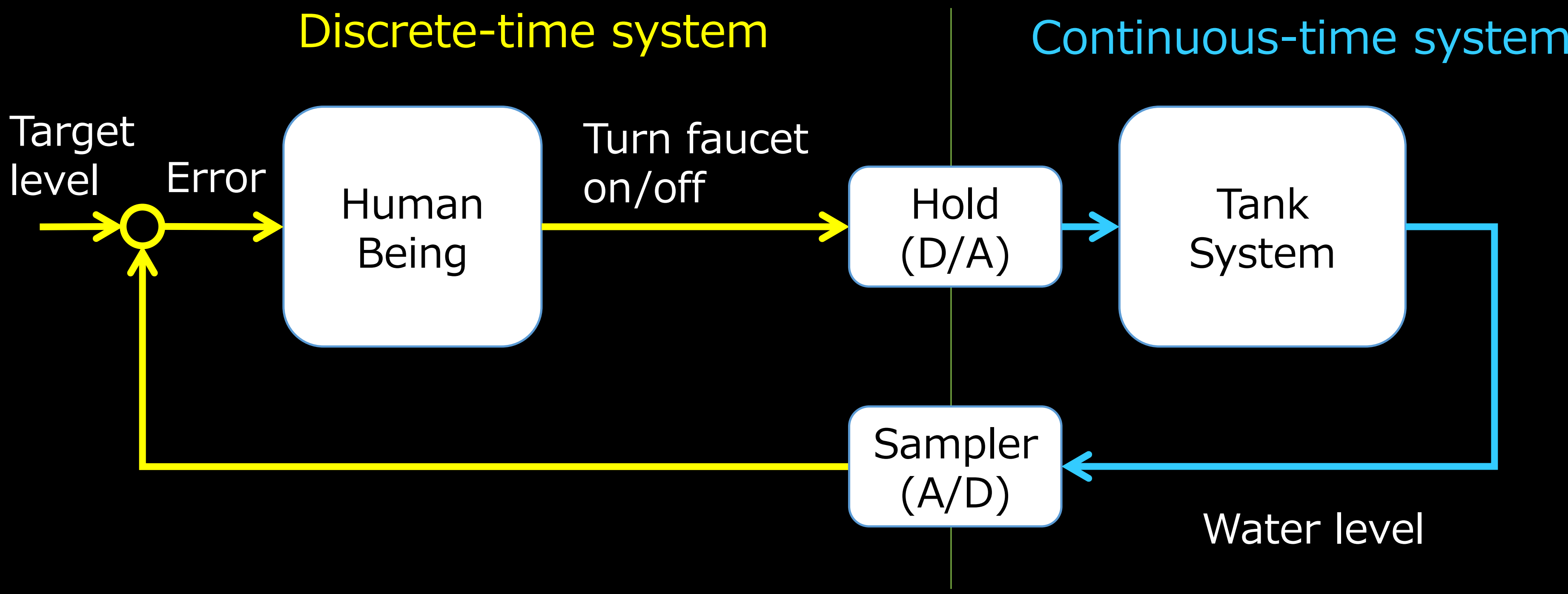
Takenori Atsumi
Chiba Institute of Technology

Sampled-data Control System



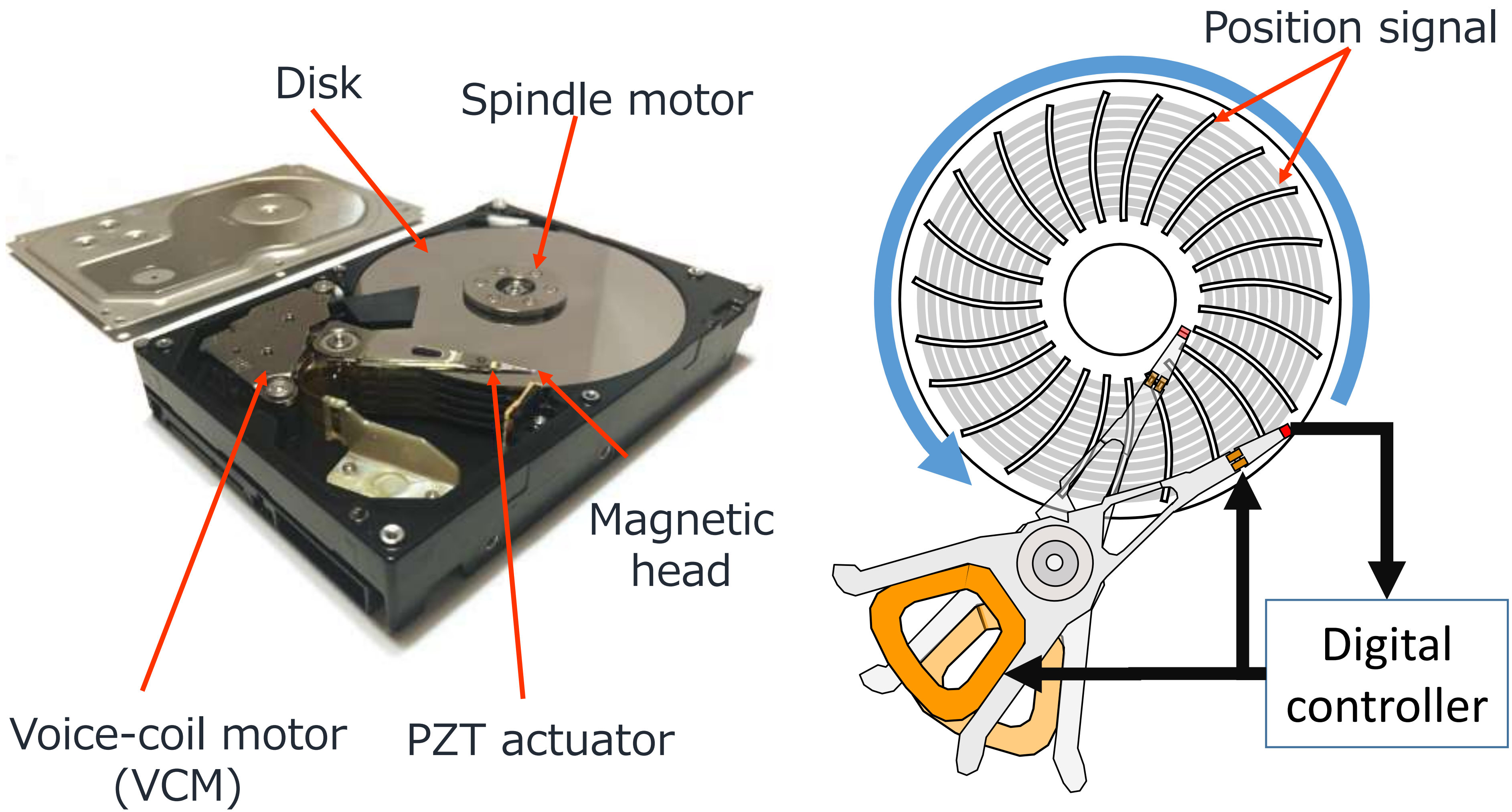
Example: Tank System

Block Diagram of Tank System



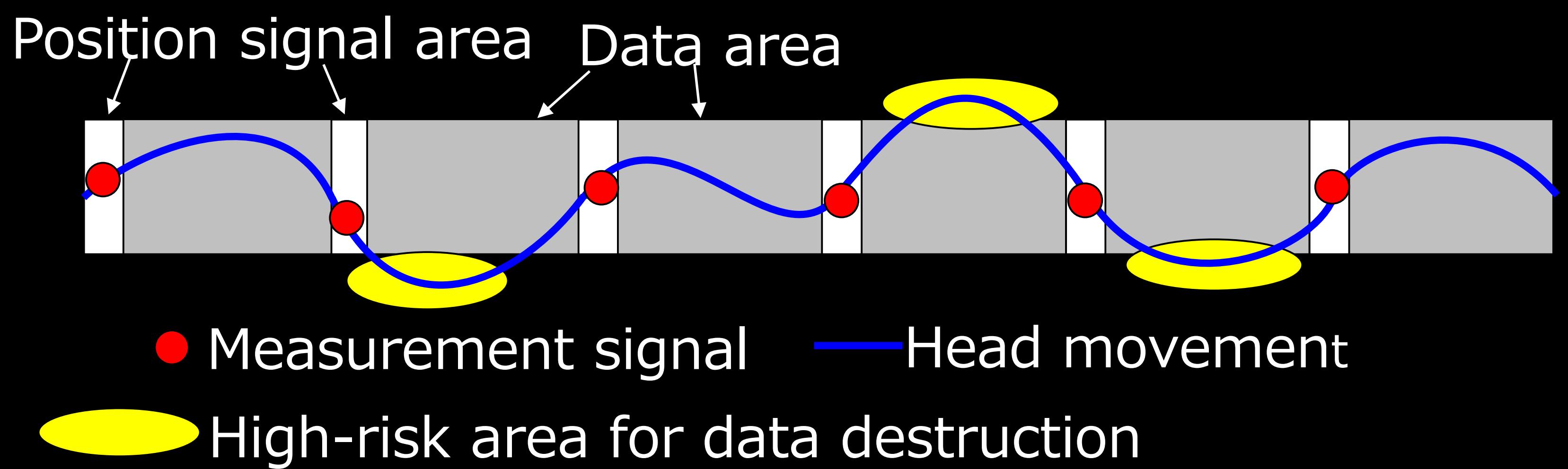
If the sampling time is too long…

Head-Positioning Control System in HDD

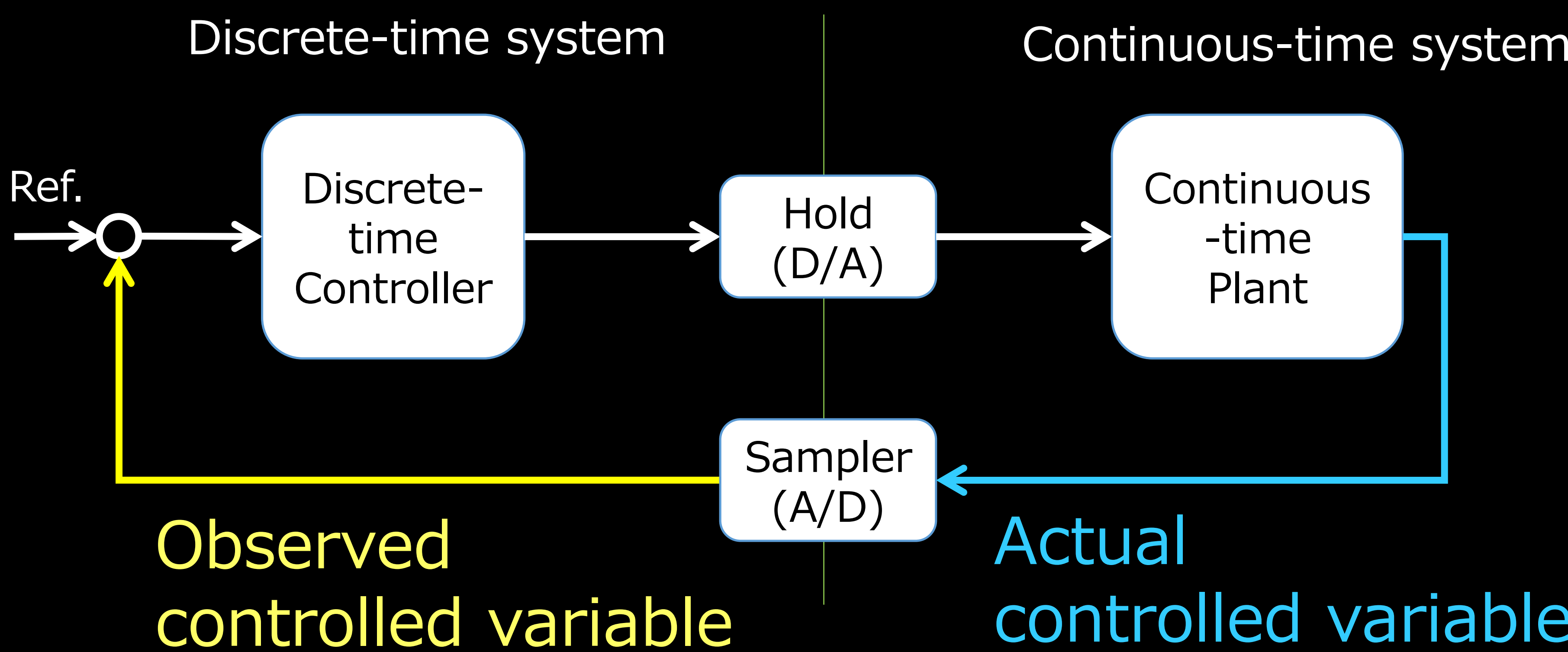


The timing of reading or writing user data corresponds to the time between samples.

The control system cannot “see” intersampling vibrations which cause destruction of users data.

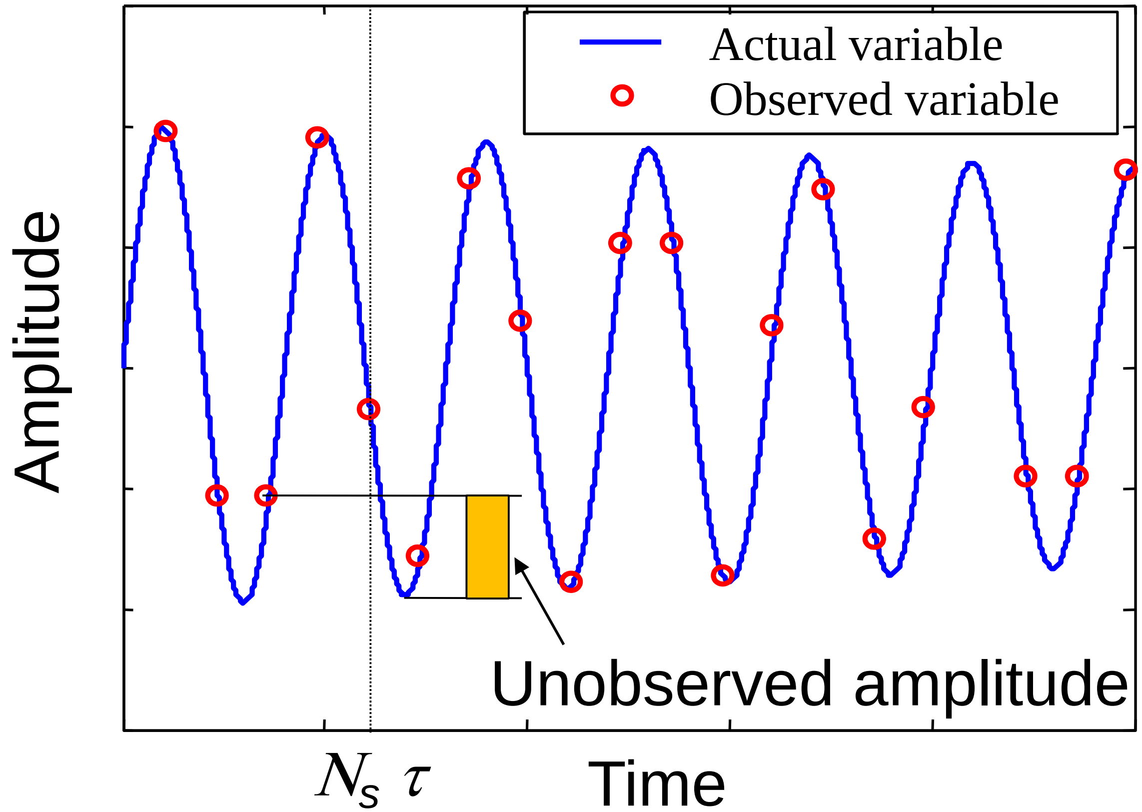


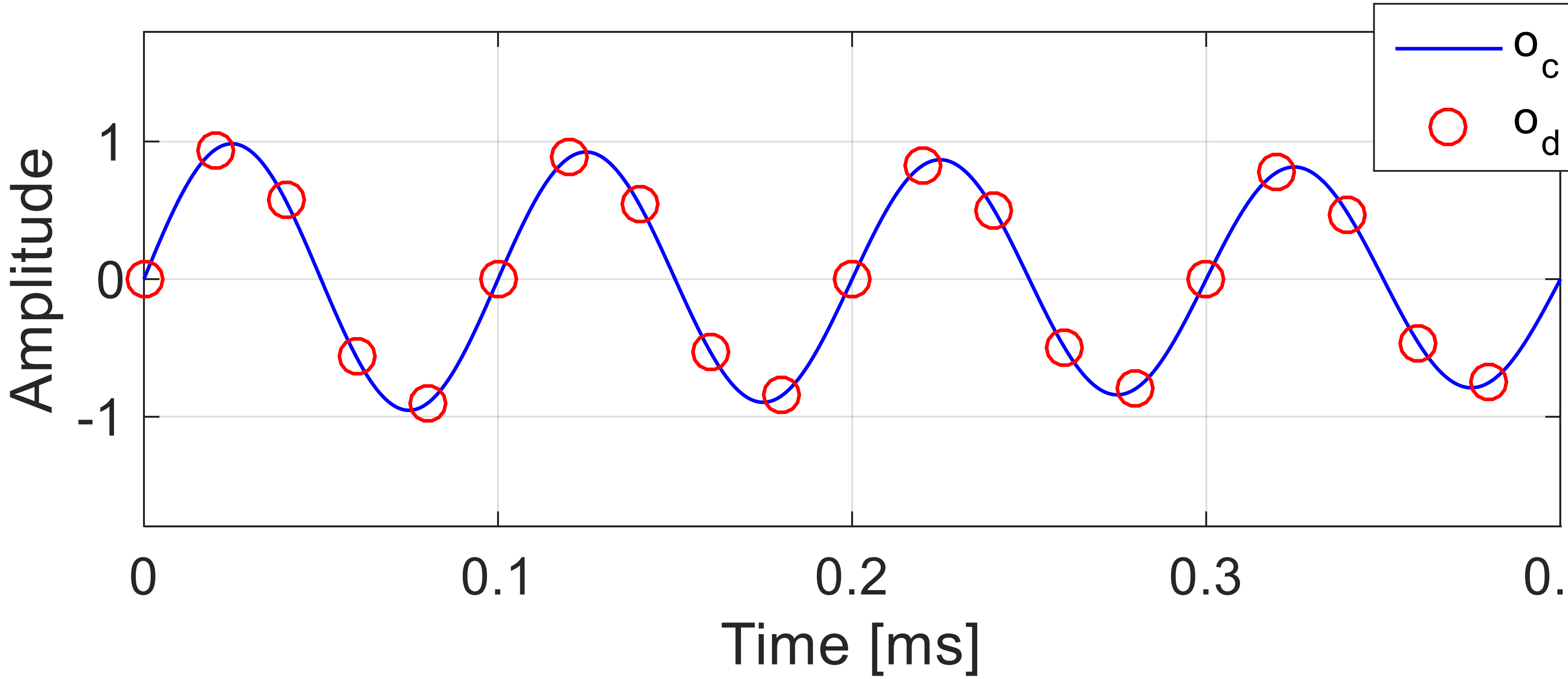
We have to know difference between observed and actual controlled variables



Unobservable Amplitude of Oscillation

N_s: Number of samples for estimation, τ: Sampling time





$$o_c(\omega_d, t, \phi_0) = \exp(-\zeta\omega_n t)\sin(\omega_d t + \phi_0)$$

$$o_d(\omega_d, n, \phi_0) = o_c(\omega_d, \tau n, \phi_0) = \exp(-\zeta\omega_n \tau n)\sin(\omega_d \tau n + \phi_0)$$

$\omega_d = \omega_n\sqrt{(1-\zeta^2)}$: Damped natural frequency, ω_n : Natural frequency,

ζ : Damping ratio, ϕ_0: Initial phase, n : Sample number, τ : Sampling time

$$m_u(\omega_d, \phi_0) = \begin{cases} 0 : m_{ut}(\omega_d, \phi_0) \leq 0, m_{ub}(\omega_d, \phi_0) \geq 0 \\ |m_{ut}(\omega_d, \phi_0)| : m_{ut}(\omega_d, \phi_0) > 0, m_{ub}(\omega_d, \phi_0) \geq 0 \\ |m_{ub}(\omega_d, \phi_0)| : m_{ut}(\omega_d, \phi_0) \leq 0, m_{ub}(\omega_d, \phi_0) < 0 \\ |m_{ut}(\omega_d, \phi_0)| : m_{ut}(\omega_d, \phi_0) \geq -m_{ub}(\omega_d, \phi_0) > 0 \\ |m_{ub}(\omega_d, \phi_0)| : -m_{ub}(\omega_d, \phi_0) > m_{ut}(\omega_d, \phi_0) > 0 \end{cases},$$

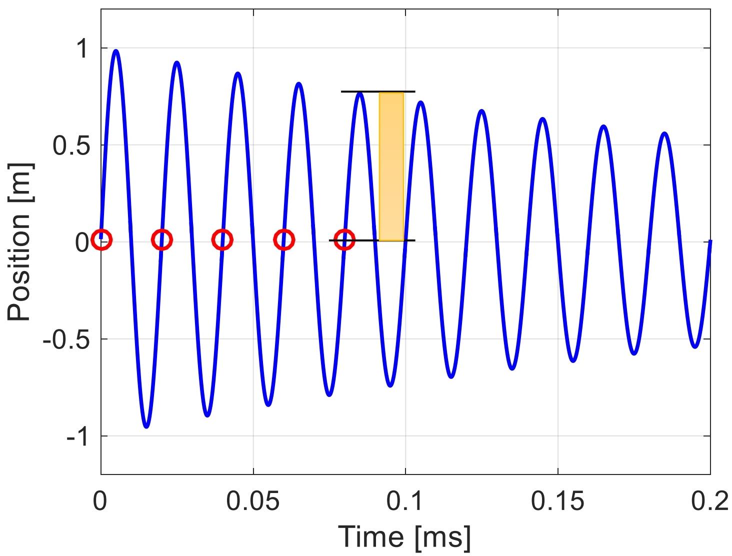
where

$$m_{ut}(\omega_d, \phi_0) = \sup_{t \in [N_s \tau, \infty)} (o_c(\omega_d, t, \phi_0)) - \max_{n \in [1, N_s]} (o_d(\omega_d, n, \phi_0)),$$

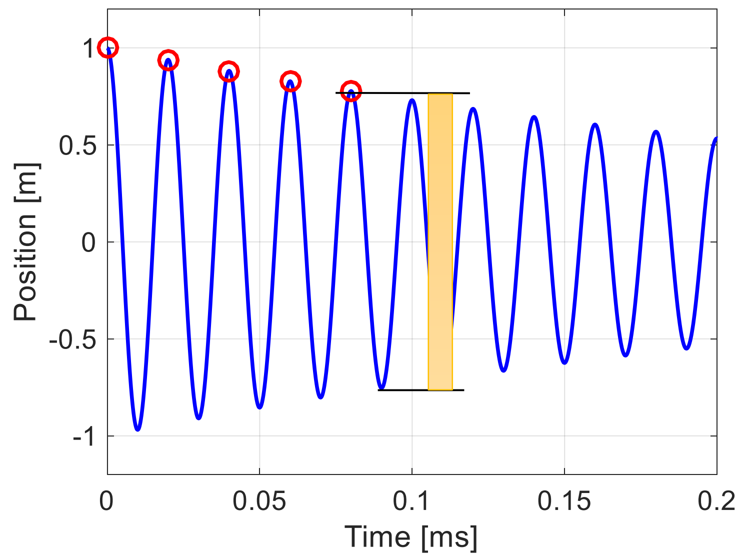
$$m_{ub}(\omega_d, \phi_0) = \inf_{t \in [N_s \tau, \infty)} (o_c(\omega_d, t, \phi_0)) - \min_{n \in [1, N_s]} (o_d(\omega_d, n, \phi_0)),$$

Oscillation at Sampling Frequency

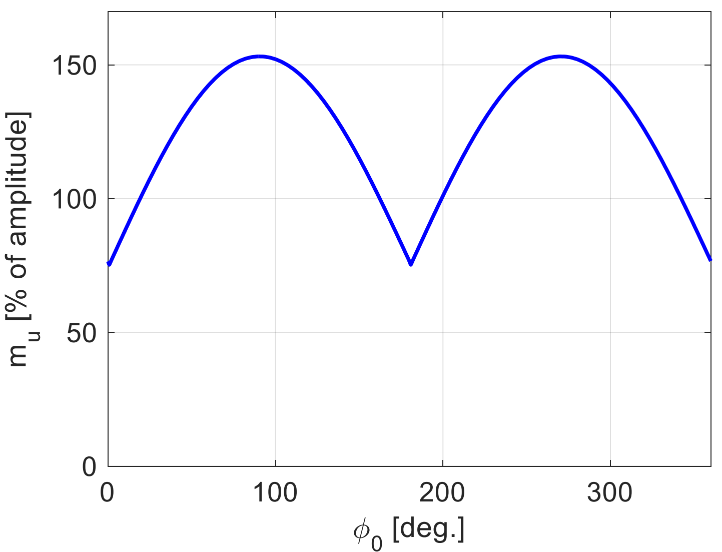
Best case



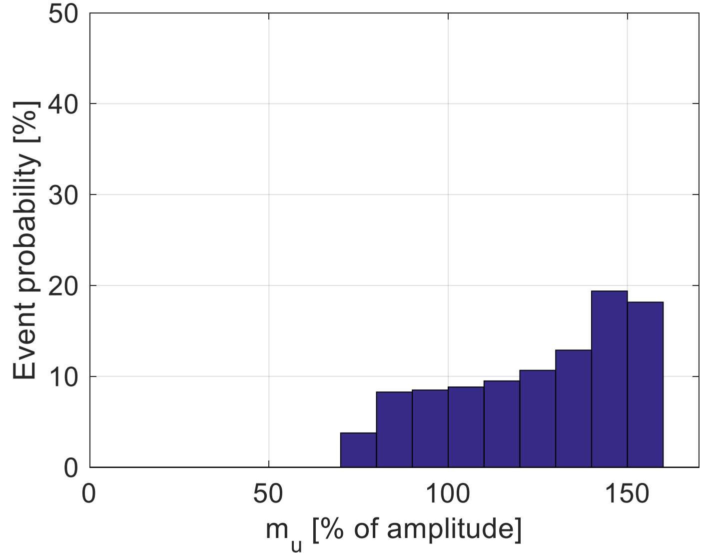
Worst case



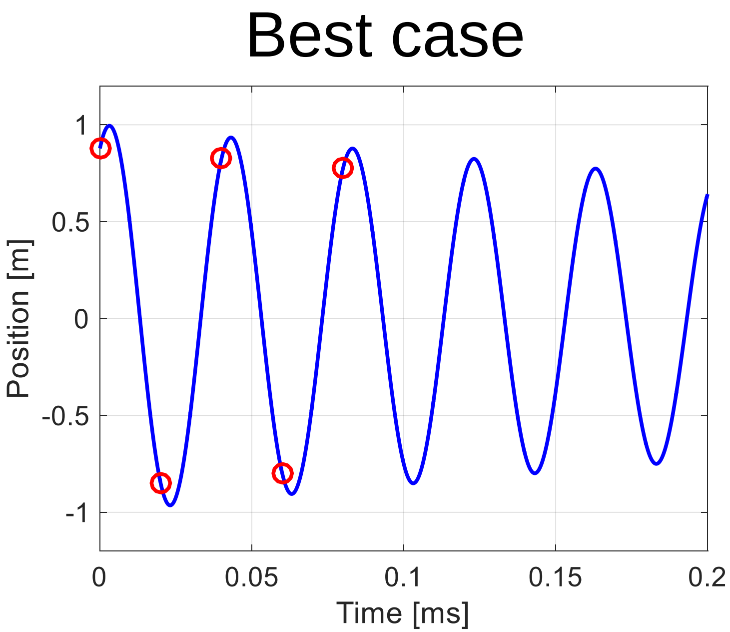
Dependence of m_u on ϕ_0

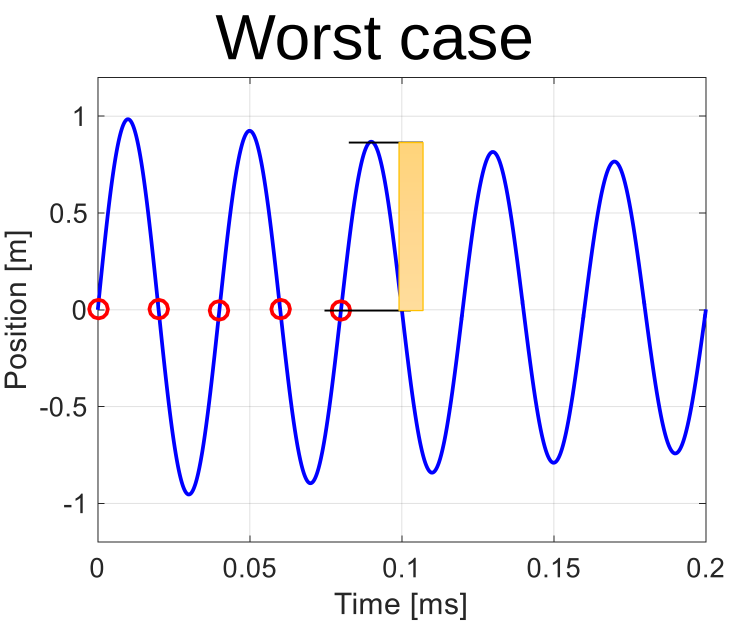


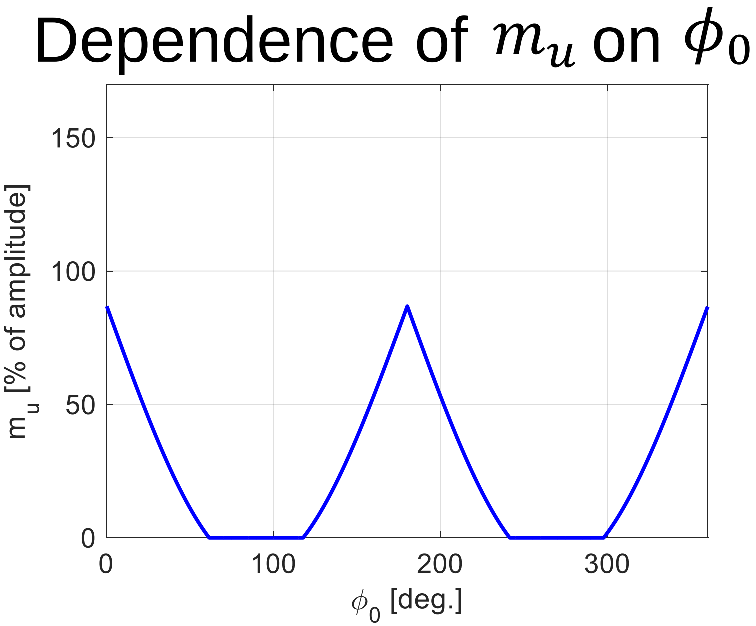
Event probability

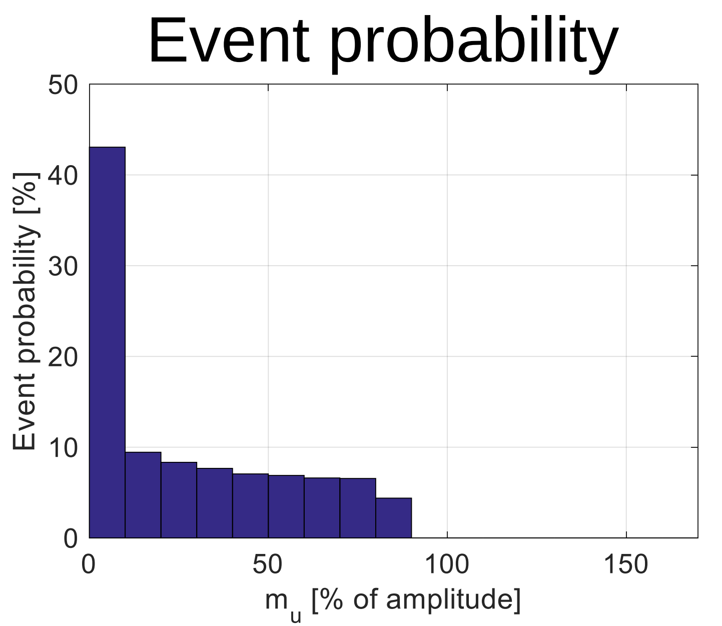


Oscillation at Nyquist Frequency

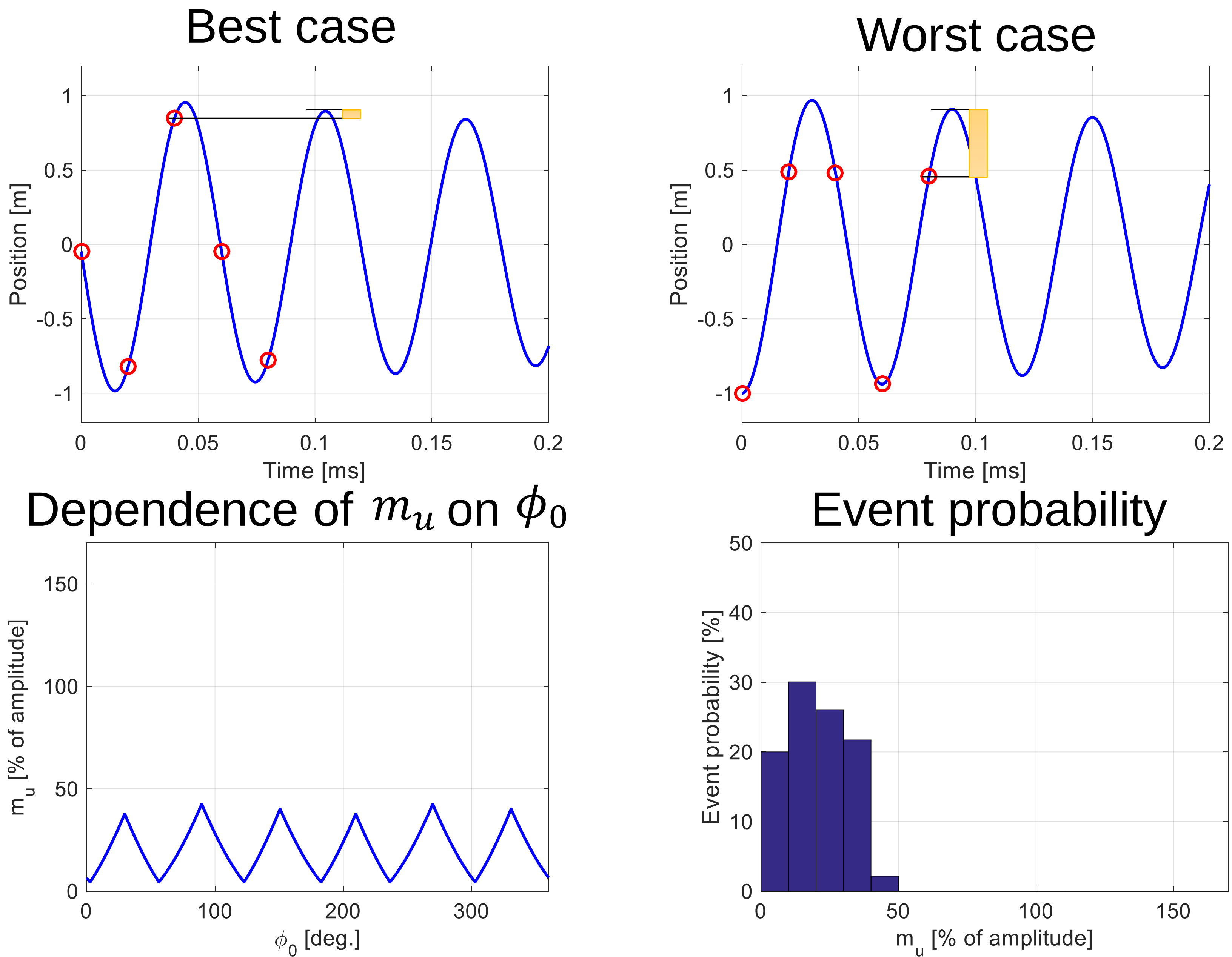






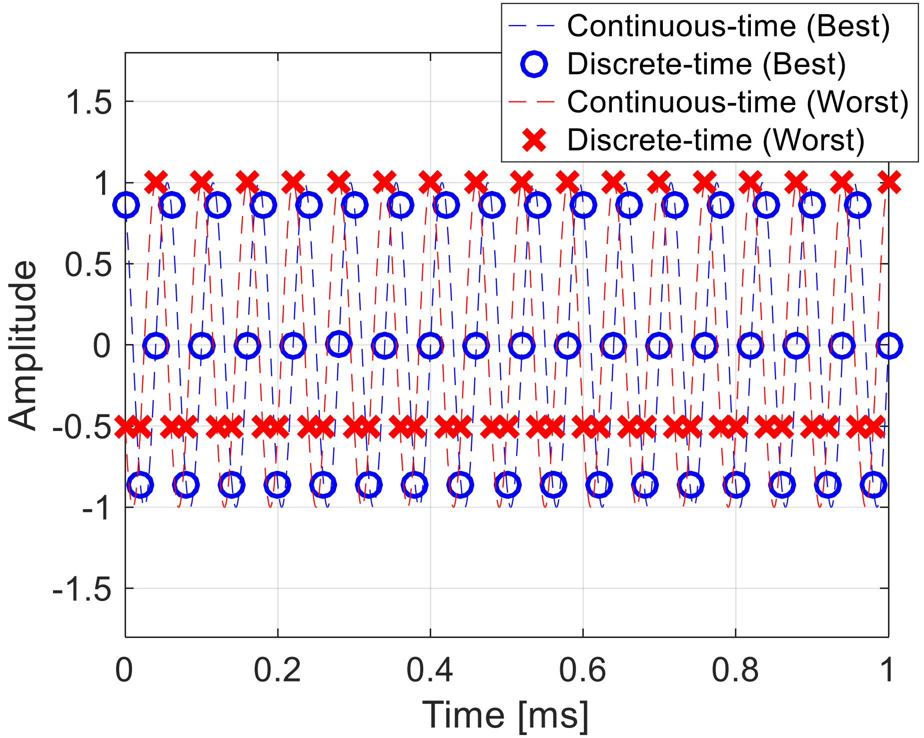


Oscillation at One-third of Sampling Freq.



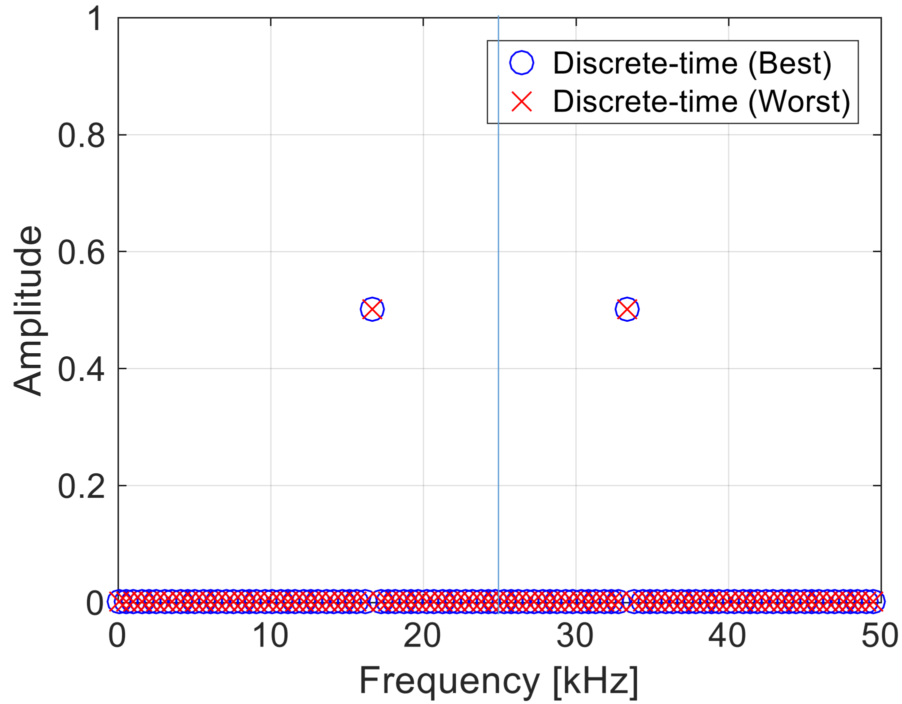
サンプリング定理と矛盾する？

時間領域



Continuous-time (Best)
Discrete-time (Best)
Continuous-time (Worst)
Discrete-time (Worst)
1.5
1
0.5
0
-0.5
-1
-1.5
Amplitude
0
0.2
0.4
0.6
0.8
1
Time [ms]

周波数領域



Discrete-time (Best)
Discrete-time (Worst)
1
0.8
0.6
0.4
0.2
0
Amplitude
0
10
20
30
40
50
Frequency [kHz]

Two Index Values for Evaluation

Maximum value based

$$m_{um}(\omega_d) = \sup_{\phi_0 \in [0, 2\pi)} (m_u(\omega_d, \phi_0))$$

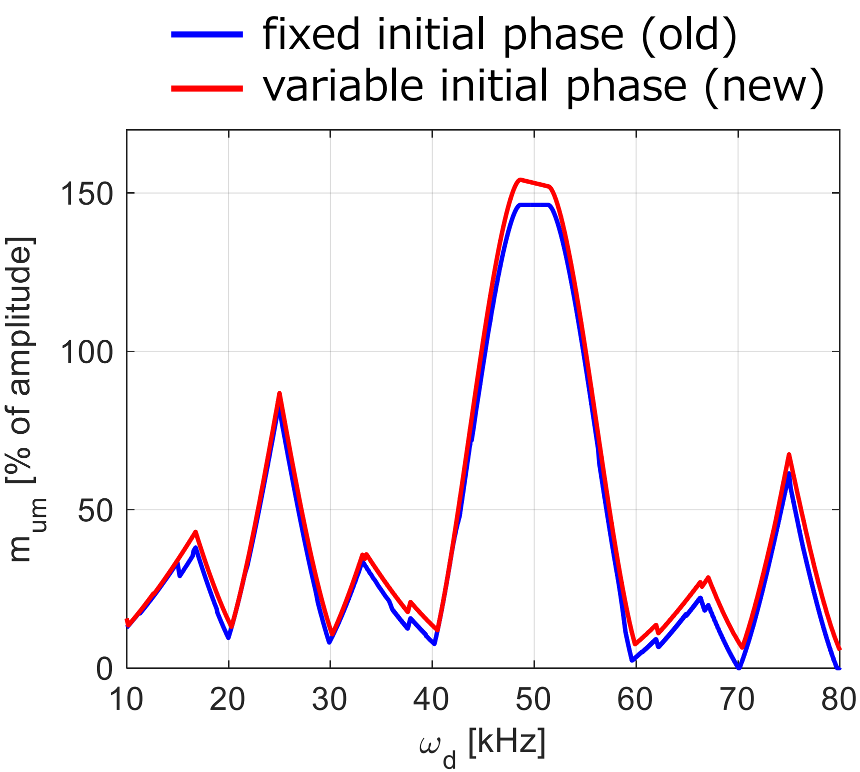
Root-Mean-Square (RMS) value based

$$m_{ur}(\omega_d) = \sqrt{\frac{1}{2\pi} \int_0^{2\pi} \{m_u(\omega_d, \phi_0)\}^2 d\phi_0}$$

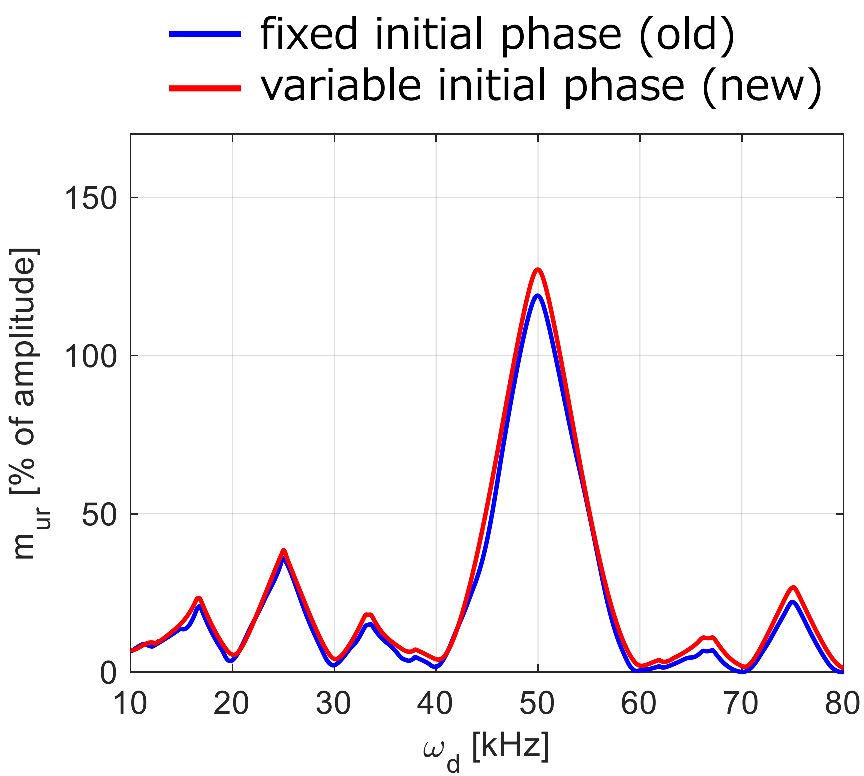
Comparison with Previous Work

T. Atsumi and W. Messner, "Analysis of Unobservable Oscillations in Sampled-Data Positioning Systems," The IEEE Transactions on Industrial Electronics, vol. 59, no. 10, pp. 3951-3960, (2012-10)

Maximum value



RMS value



Estimation Procedure

Set modal parameters

Modal parameters of mechanical system are decided by using measurement results

Calculation of Index value

Index values are calculated by using resonance frequency, damping ratio and number of samples for estimation

Evaluation using Index value

Unacceptable sampling frequencies are estimated by using index values and target of reliability

Example: Hard Disk Drive

Estimation Procedure

Set modal parameters

Modal parameters of mechanical system are decided by using measurement data

Calculation of Index value

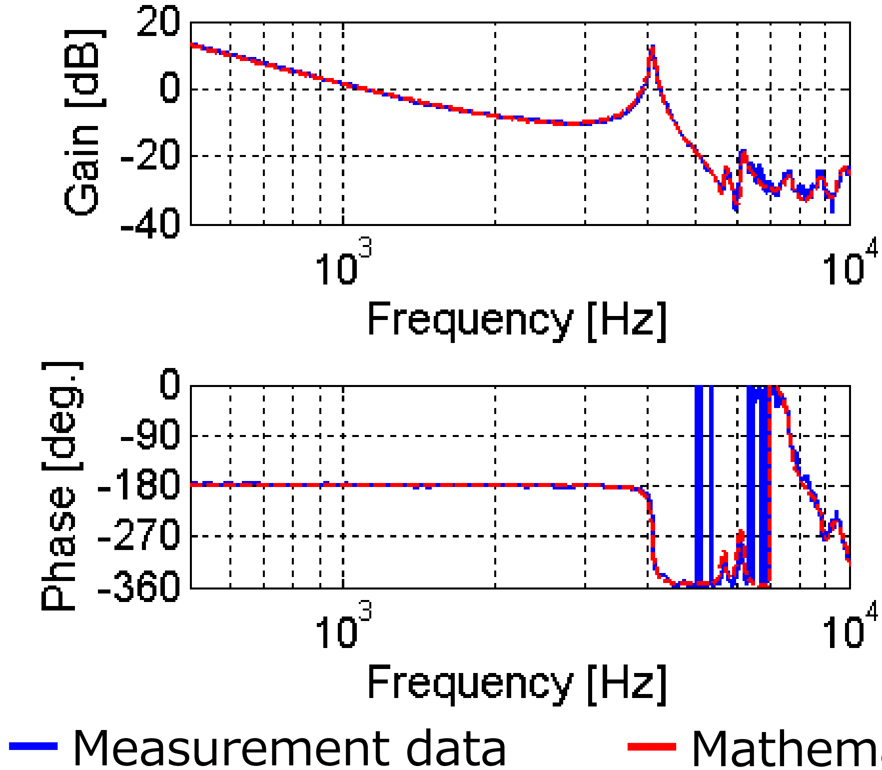
Index values are calculated by using resonance frequency, damping ratio and number of samples for estimation

Evaluation using Index value

Unacceptable sampling frequencies are estimated by using index values and target of reliability

Mechanical Characteristics of HDDs

Frequency response



Mathematical model

$$P_s(s) = K_p \sum_{i=1}^{l} \frac{\alpha_m(i)}{s^2 + 2\zeta_m(i)\omega_m(i)s + \omega_m(i)^2}$$

i	$\omega_m(i)$	$\alpha_m(i)$	$\zeta_m(i)$
1	0	1.00	0
2	$2\pi \cdot 4100$	-1.30	0.01
3	$2\pi \cdot 5700$	-0.03	0.01
4	$2\pi \cdot 6200$	-0.08	0.01
5	$2\pi \cdot 7650$	0.12	0.02
6	$2\pi \cdot 8900$	-0.13	0.02
7	$2\pi \cdot 9800$	-0.35	0.03

Primary mechanical resonance

- Resonance frequency: 4100 Hz
- Damping ratio: 0.01

Estimation Procedure

Set modal parameters

Modal parameters of mechanical system are decided by using measurement data

Calculation of Index value

Index values are calculated by using resonance frequency, damping ratio and number of samples for estimation

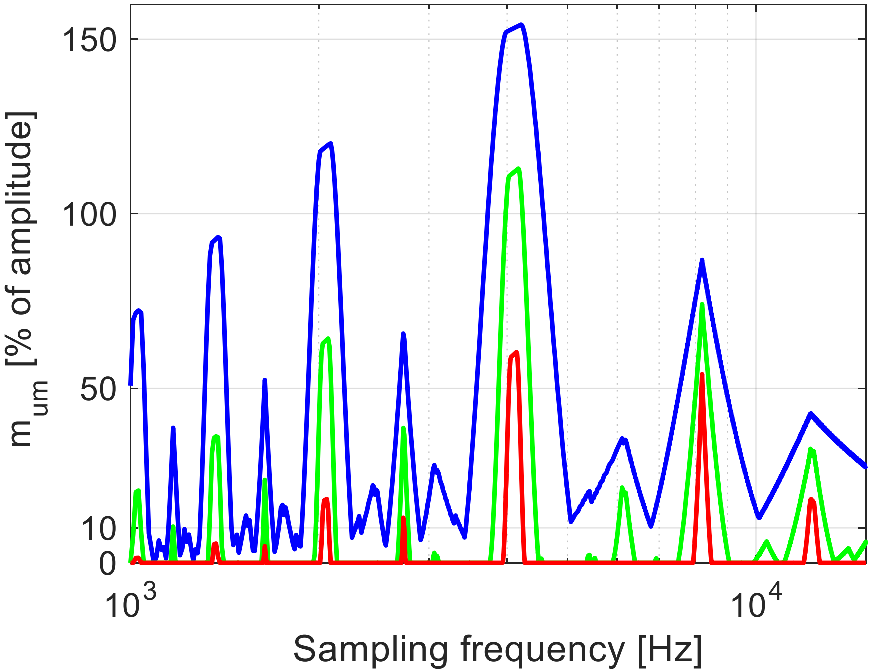
Evaluation using Index value

Unacceptable sampling frequencies are estimated by using index values and target of reliability

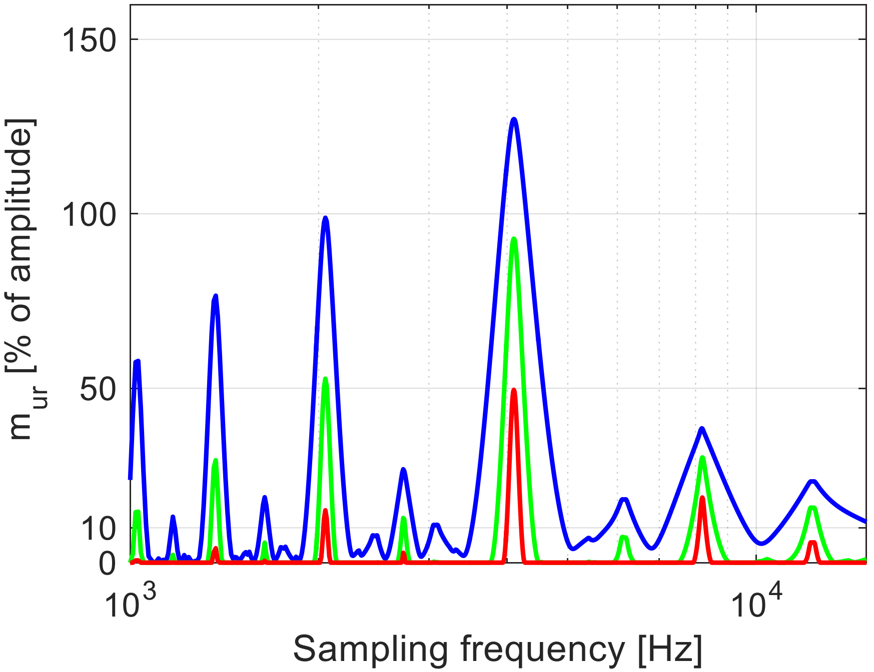
Dependence of Unobservable Amplitude on Sampling Frequency

- Resonance frequency: 4100Hz
- Damping ratio: 0.01
- Number of sample: 5(blue), 10(green), 20(red)

Maximum value



RMS value



Estimation Procedure

Set modal parameters

Modal parameters of mechanical system are decided by using measurement data

Calculation of Index value

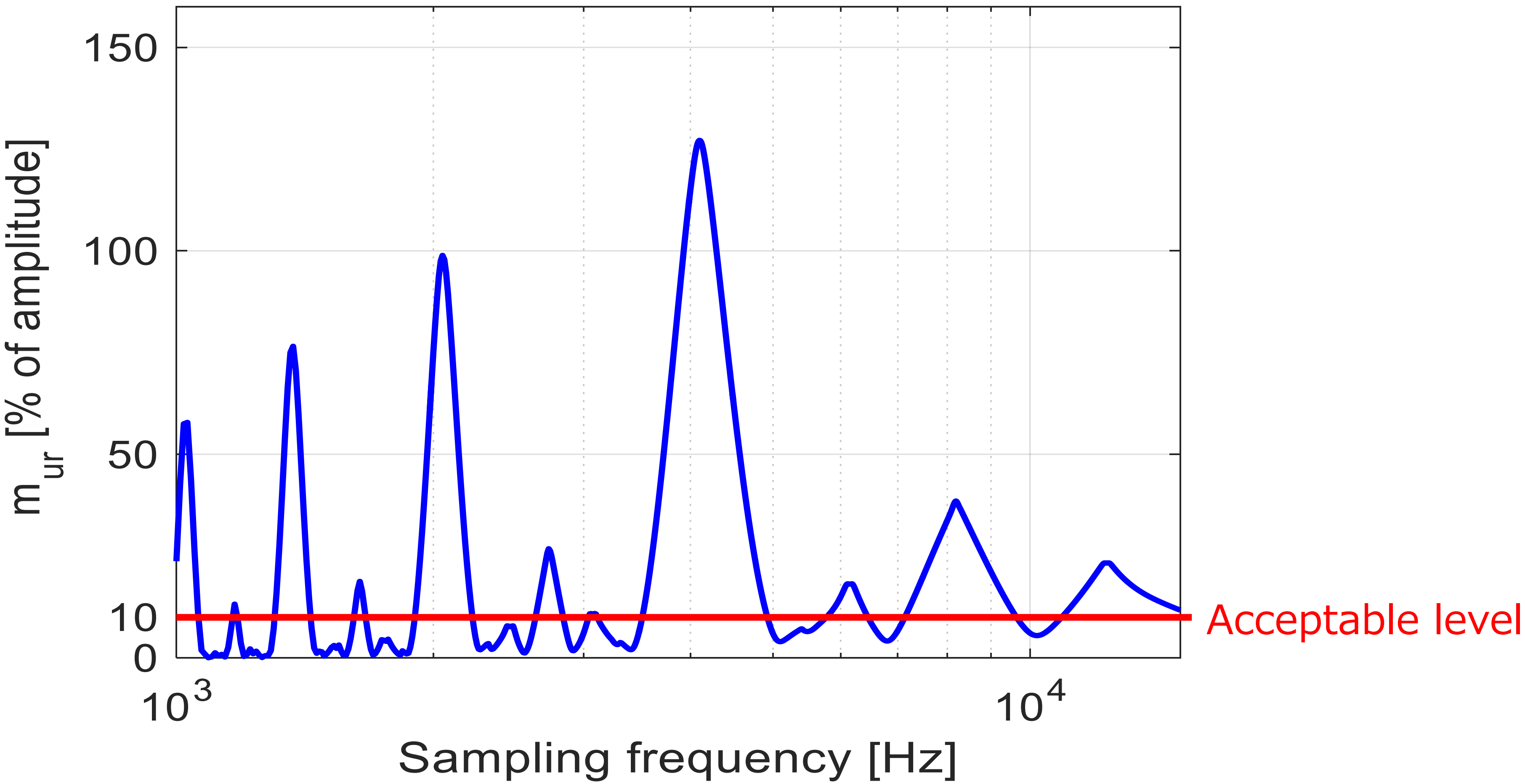
Index values are calculated by using resonance frequency, damping ratio and number of samples for estimation

Evaluation using Index value

Unacceptable sampling frequencies are estimated by using index values and target of reliability

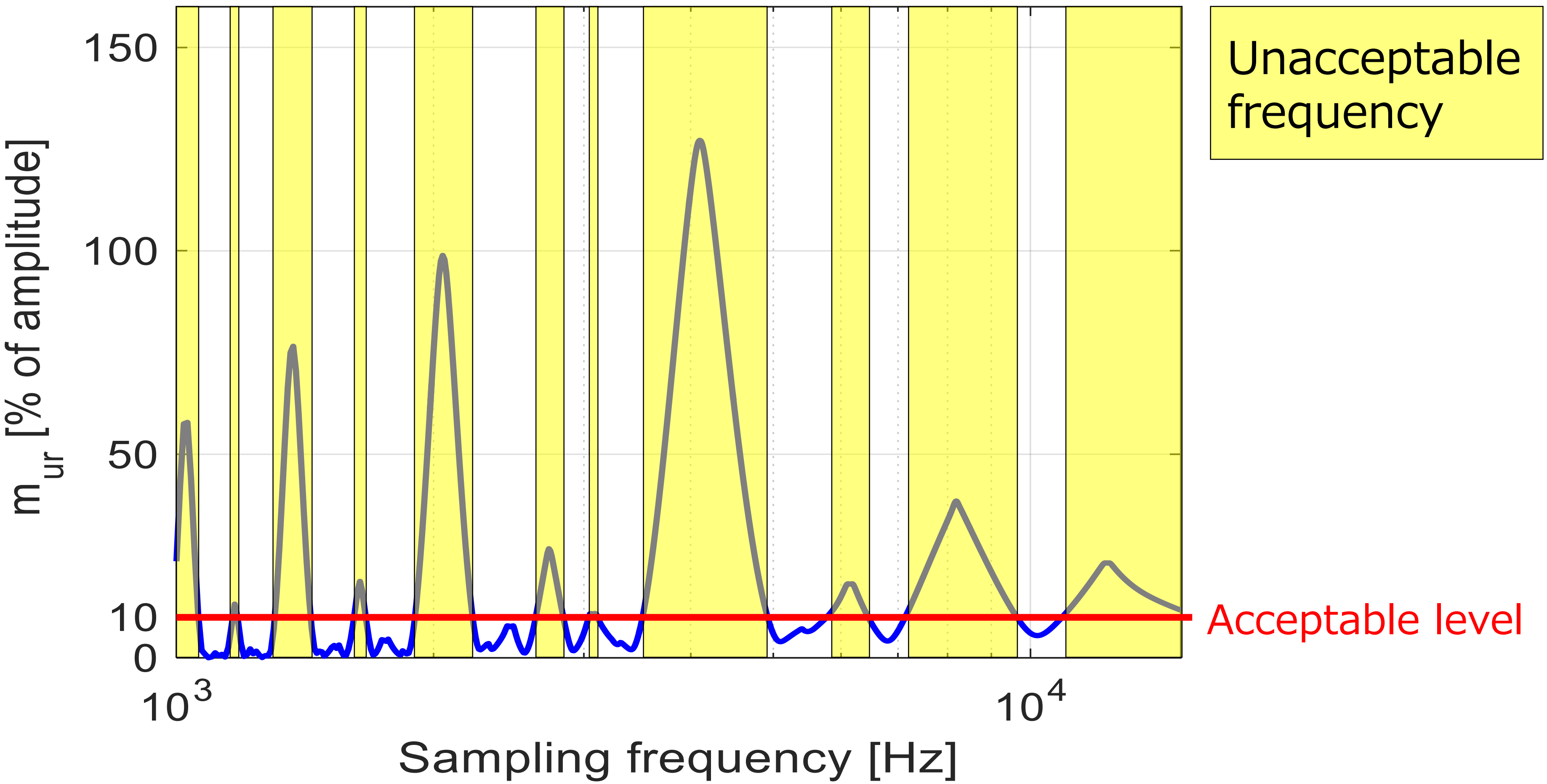
Unacceptable Sampling Frequency

- Mechanical Resonance: 4100Hz/ Damping ratio: 0.01
- Number of sample for estimation: 5
- Acceptable unobservable amplitude (RMS): Less 10%



Unacceptable Sampling Frequency

- Mechanical Resonance: 4100Hz/ Damping ratio: 0.01
- Number of sample for estimation: 5
- Acceptable unobservable amplitude (RMS): Less 10%



Conclusion

Most of positioning control systems are sampled-data control systems with mechanical resonances.

⬇

We should check unobservable amplitude on our experimental systems.

ACC2016@BostonでWorkshop

Loop Shaping in the 21st Century

An ACC 2016 Workshop

Tuesday 5 July 2016

Bill Messner (Tufts University) and Takenori Atsumi (Chiba Institute of Technology)