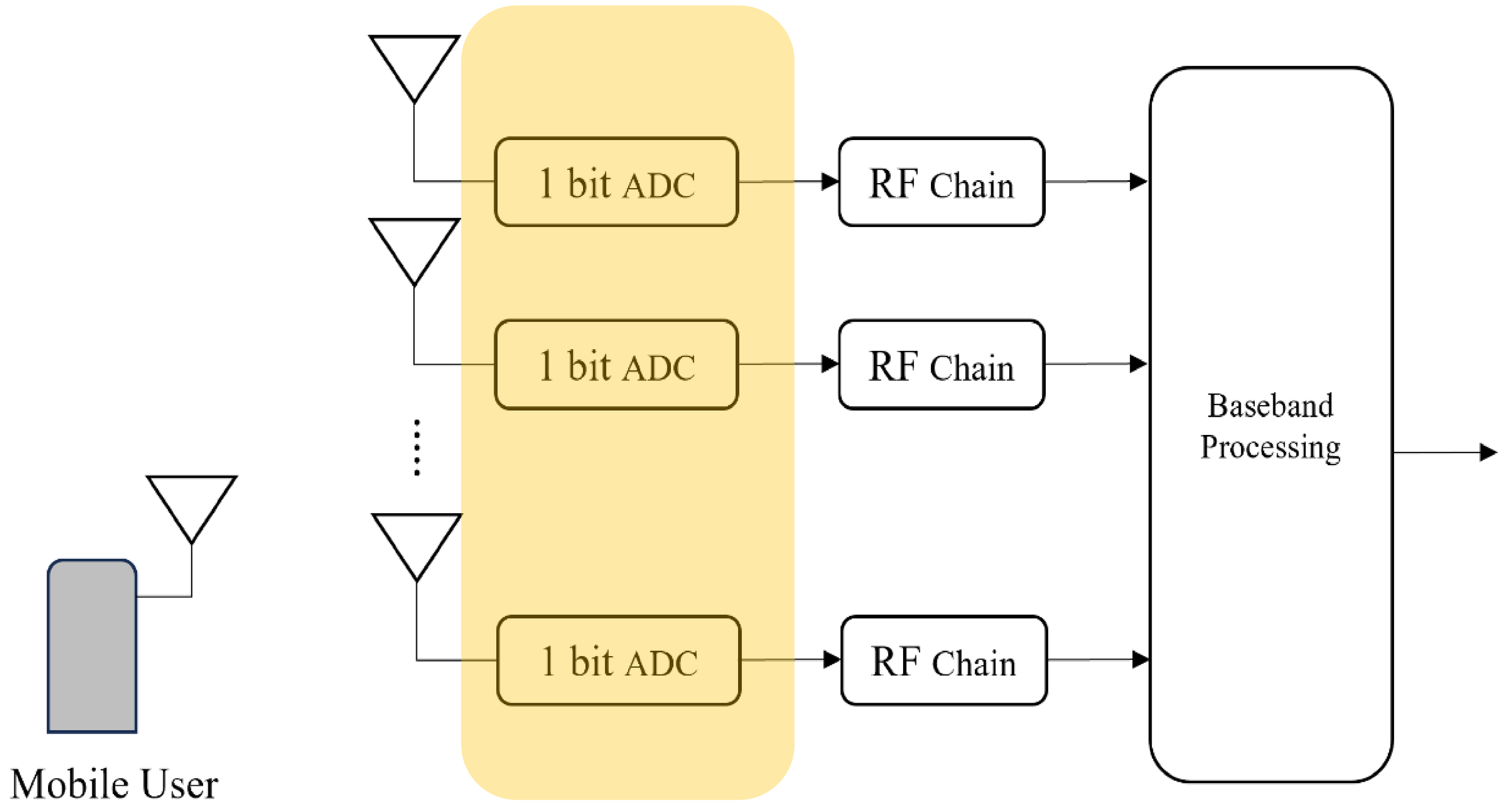
ONE-BIT QUANTIZATION ROBUST TO ANGLE-OF-ARRIVALS FOR UNIFORM LINEAR ANTENNA ARRAY

情報学研究科　王 申健

Osaka Metropolitan University

Introduction

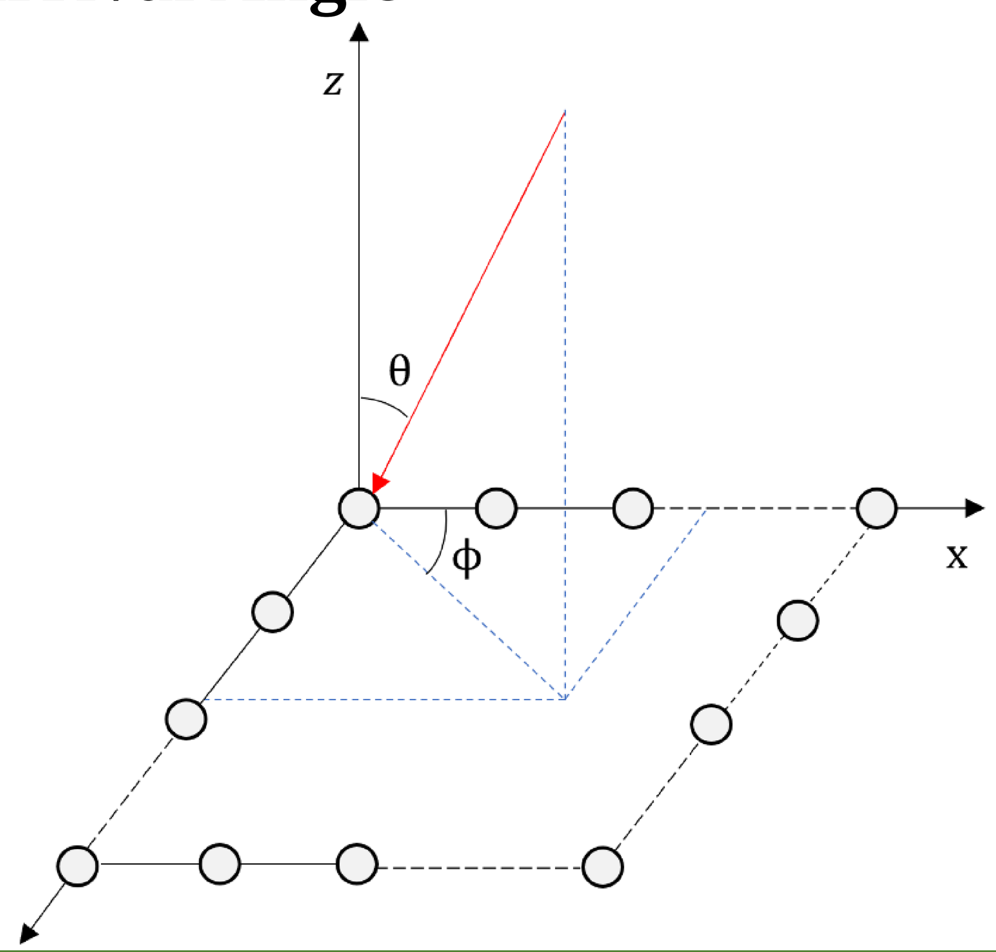


Massive MIMO that equips base stations with very large antenna arrays is key technology for 5G wireless communication systems

It is necessary to reduce hardware cost and power consumption of radio-frequency (RF) font-ends

Our approach leverages error-feedback quantization to dynamically shape quantization noise in alignment with the arrival angle of received signal

Arrival Angle



We consider only one-dimension case:
The range is symmetric with respect to arrival angle 0

Received signal at the base station can be modeled as

$$\boldsymbol{y} = a(\theta)\boldsymbol{s} + \boldsymbol{n}$$

$\boldsymbol{s}$ represents signal with $\sigma_s^2 \boldsymbol{I}$, $\boldsymbol{n}$: additive noise with covariance matrix $\sigma_n^2 \boldsymbol{I}$

where $a(\theta)$ is the steering vector given by

$$a(\theta) = \frac{1}{\sqrt{N}}[1, e^{-j\frac{2\pi d}{\lambda}\sin(\theta)}, \dots, e^{-j(N-1)\frac{2\pi d}{\lambda}\sin(\theta)}]$$

Design Example

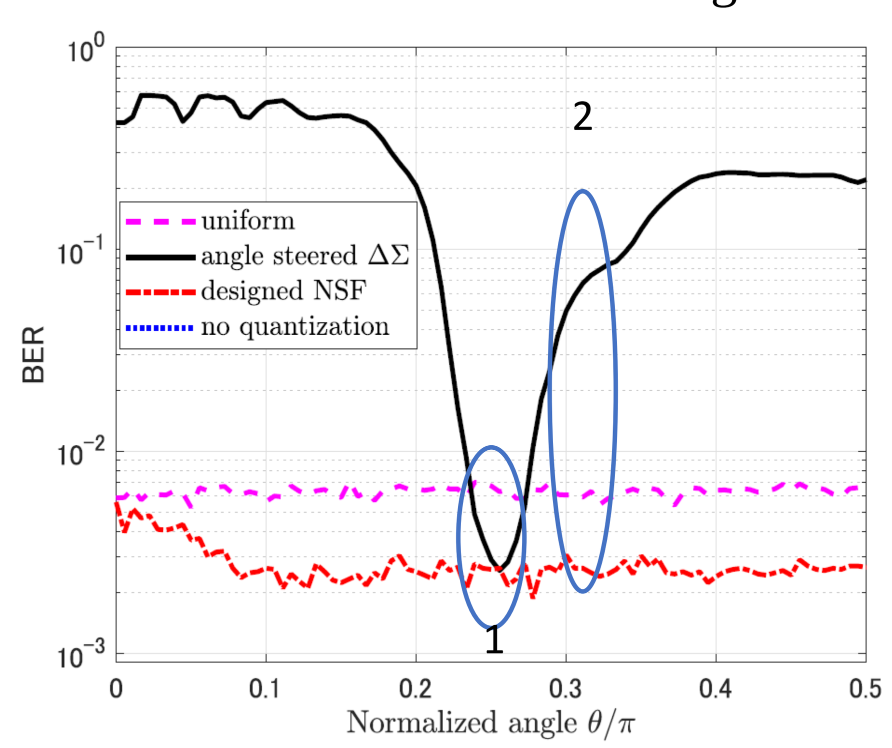
【Parameters】

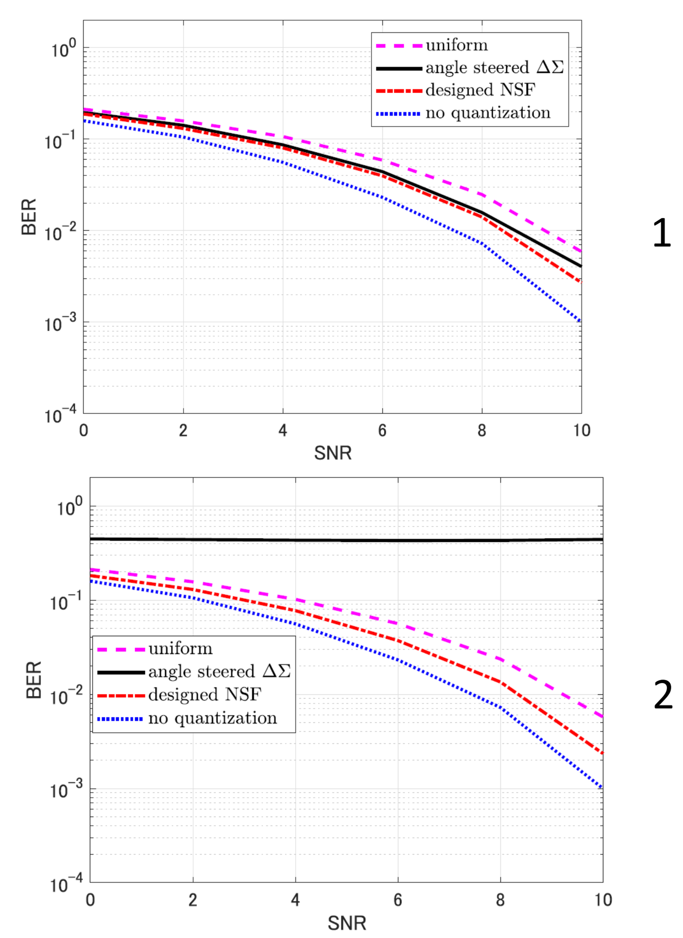
Wavelength antenna distance $\frac{d}{\lambda} = \frac{1}{8}$

Antenna number $N = 64$

SNR $\frac{\sigma_s^2}{\sigma_n^2} = 10dB$

BERs for different arrival angles

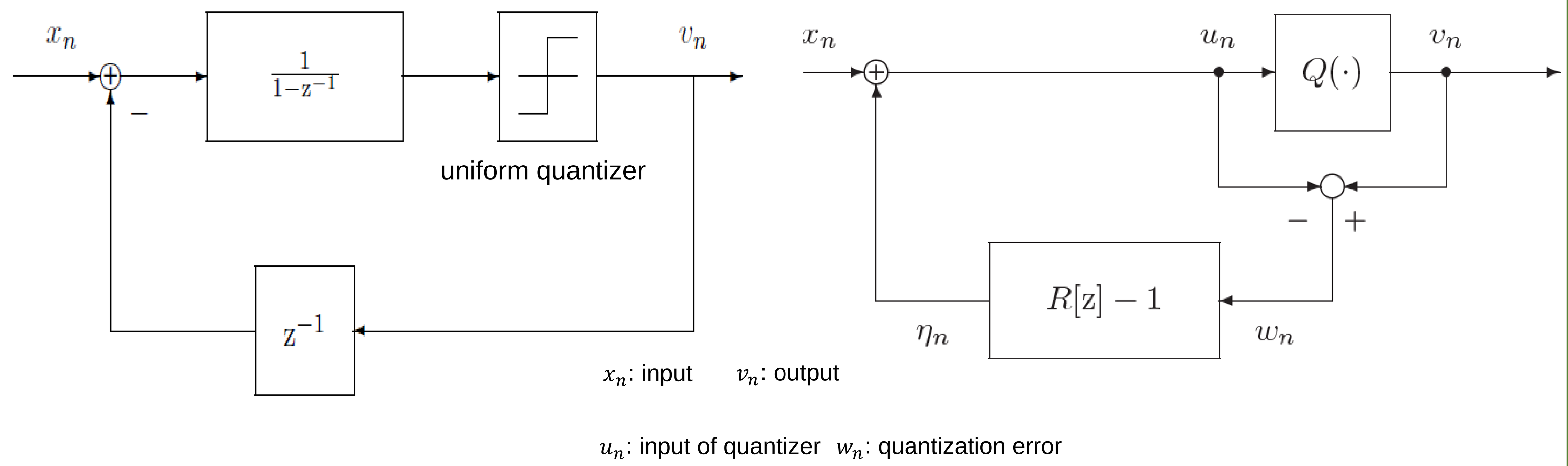




Designed quantizer enjoys better performance than conventional ones, especially for angle far from center angle

Error-feedback Modulator

Note: Stable ΔΣ modulator can be transformed into corresponding error-feedback quantizer

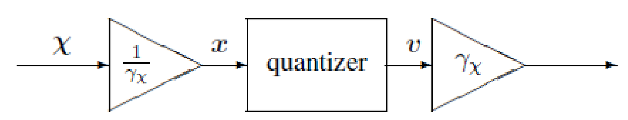


Original $\Delta\Sigma$ modulator　　Error-feedback quantizer

Object : Develop one-bit error-feedback quantizers for massive MIMO systems with uniform linear antenna arrays robust to arrival angles

Formulation

Our quantization schematic



For Error-feedback quantizer

$R[z]$ is called noise shaping filter(NSF) and can be expressed as

$$R[z] = \sum_{n=0}^{n_r} r_n z^{-1} \qquad (1)$$

No-overloading condition is (an overloading occurs when $|u_n| > 2$)

$$\sum_{n=0}^{n_r} |r_n| \leq 1$$

Which is equivalent to

$$\sum_{n=1}^{n_r} \bar{r}_n \leq 1 \qquad -\bar{r}_n \leq r_n \leq \bar{r}_n, \bar{r}_n \geq 0 \text{ for } n = 1, \dots, n_r$$

Our problem can be formulated as

$$\min_{r_1, r_2, \dots, r_{n_r}} \max_{w \in [-\Omega, \Omega]} |R[e^{j\varpi}]| \text{ subject to (1)}$$

Where $\Omega = \frac{2\pi d}{\lambda}\sin(\Theta)$ and $[-\Theta + \Omega_0, \Theta + \Omega_0]$ is arrival angles we are interested

Define state-space matrices$(A, B, C, D)$of $R[z]$ as

$$A = \begin{bmatrix} 0 & 1 \cdots & 0 \\ \vdots & \ddots & \vdots \\ & & 1 \\ 0 & \cdots & 0 \end{bmatrix}, B = [0, \dots, 0, 1]^T,$$

$$C = [r_{n_r}, r_{n_r-1}, \dots, r_1], D = 1$$

By using the generalized KYP lemma, the problem becomes

$$\min_{r_1, \dots, r_{n_r}, \bar{r}_1, \bar{r}_{n_r}} \mu \text{ subject to (1) (2)}$$

$$\begin{bmatrix} M_1 & M_2 & C^T \\ M_2^T & M_3 & 1 \\ C & 1 & -1 \end{bmatrix} < 0, \text{ where} \qquad (2)$$

$$M_1 = A^T XA + YA + A^T Y - X - 2Y\cos\Omega$$

$$M_2 = A^T XB + YB$$

$$M_3 = B^T XB - \mu$$

Conclusion

Our approach leverages error-feedback quantization to dynamically shape the quantization noise in alignment with arrival angle of the received signal

To optimize the system's performance within a predefined range of arrival angles, we focus on maximizing the minimum SNR of the quantized received signal

We formulate design of our quantizer as convex optimization problem

Our numerical results demonstrate that proposed quantizer exhibits robust performance across different arrival angles