Bandwidth Efficient Mixed Pseudo Analogue-Digital Speech Transmission

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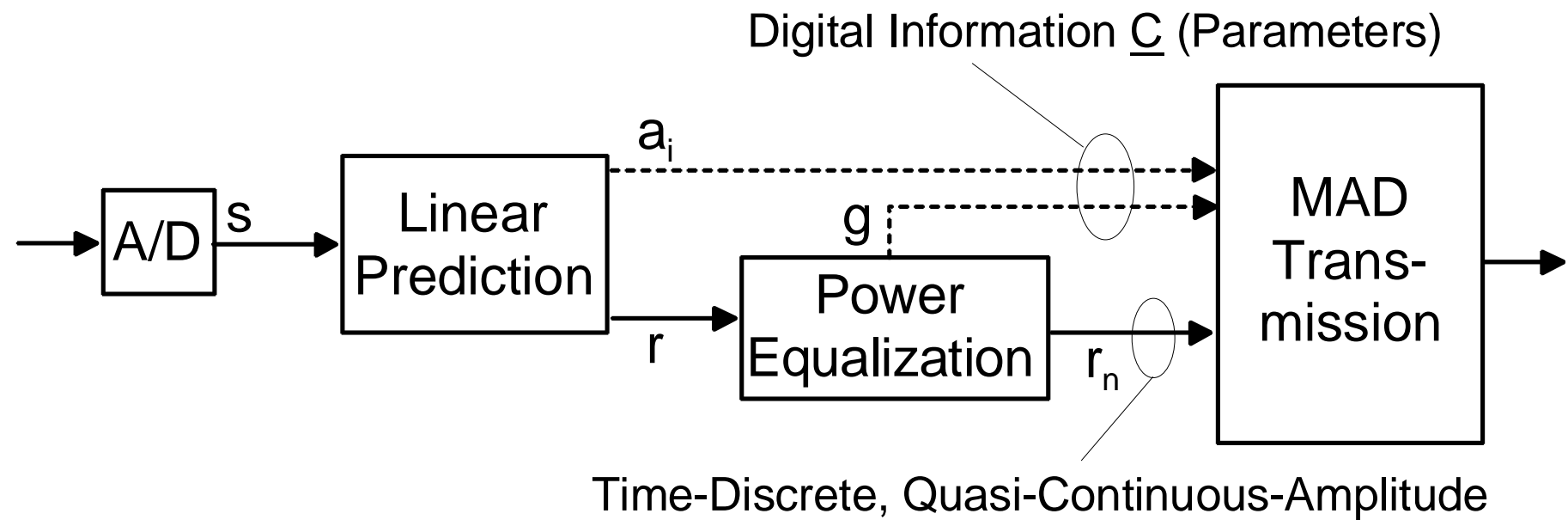Prof. Dr.-Ing. P. Vary**

Outline

- **Introduction**

- **Mixed Pseudo Analogue-Digial (MAD) Transmitter**

- **Channel & Receiver**

- **Speech Transmission**

- **Summary & Conclusions**
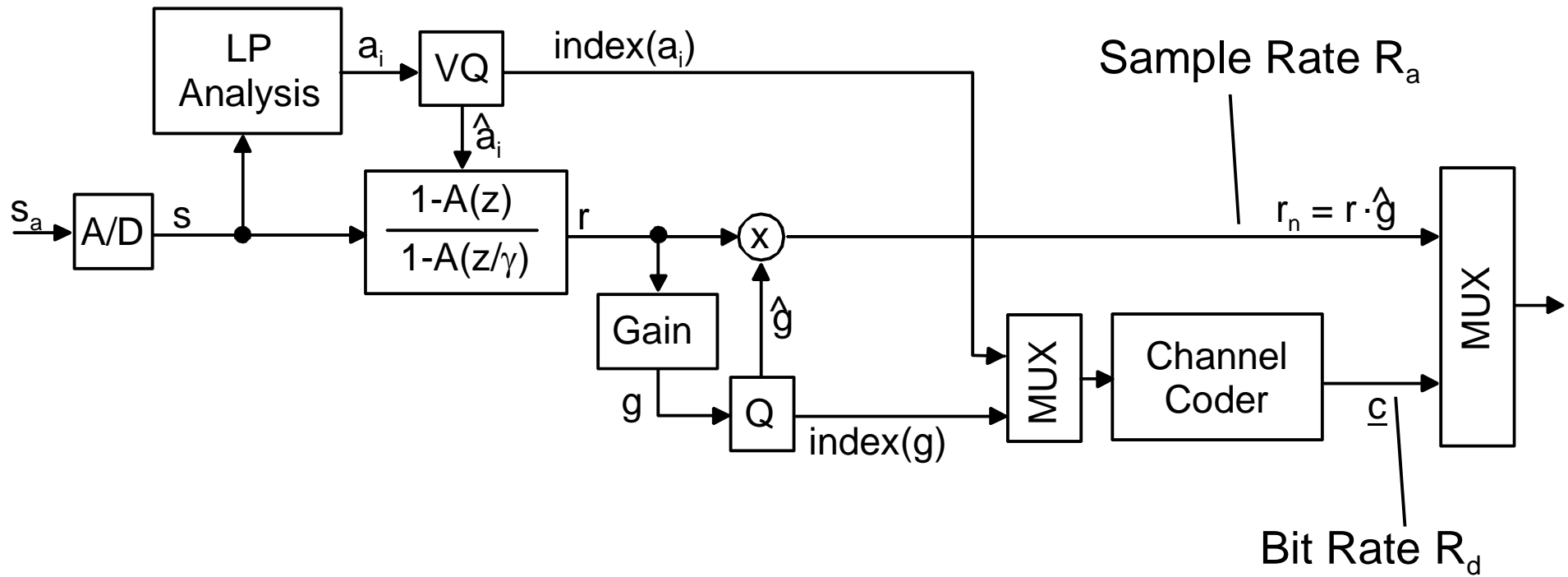
Introduction

- Analogue AM speech transmission:

    - low channel bandwidth
    - highly sensitive to additive noise

- Digital speech transmission:

    - robust channel coding against transmission errors

    - higher bandwidth

    - higher complexity

    - maximum quality defined by the speech codec design

- Mixed Pseudo Analogue-Digital (MAD) speech transmission:

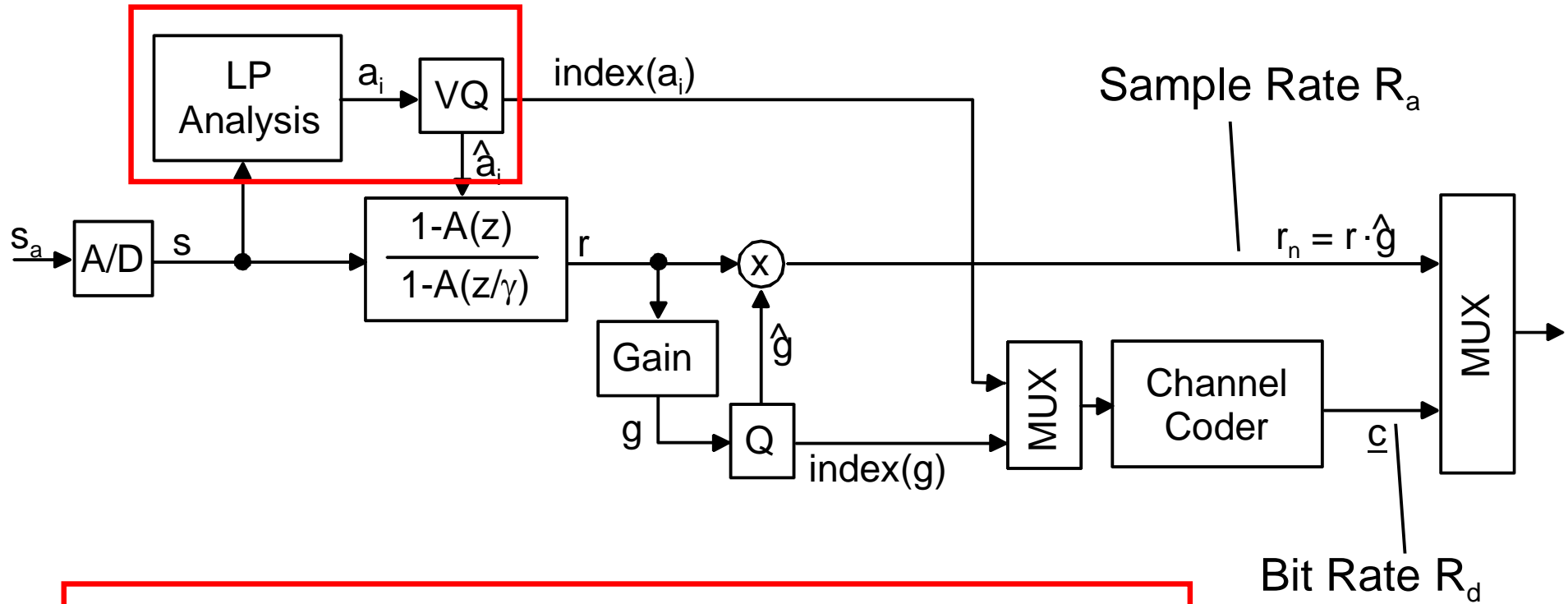   - combine the advantages of both paradigms

Introduction

Principle of MAD Transmission:

Digital Information $\underline{C}$ (Parameters)

a_i

A/D — s → Linear Prediction → r

g

Power Equalization — r_n

MAD Trans-mission

Time-Discrete, Quasi-Continuous-Amplitude

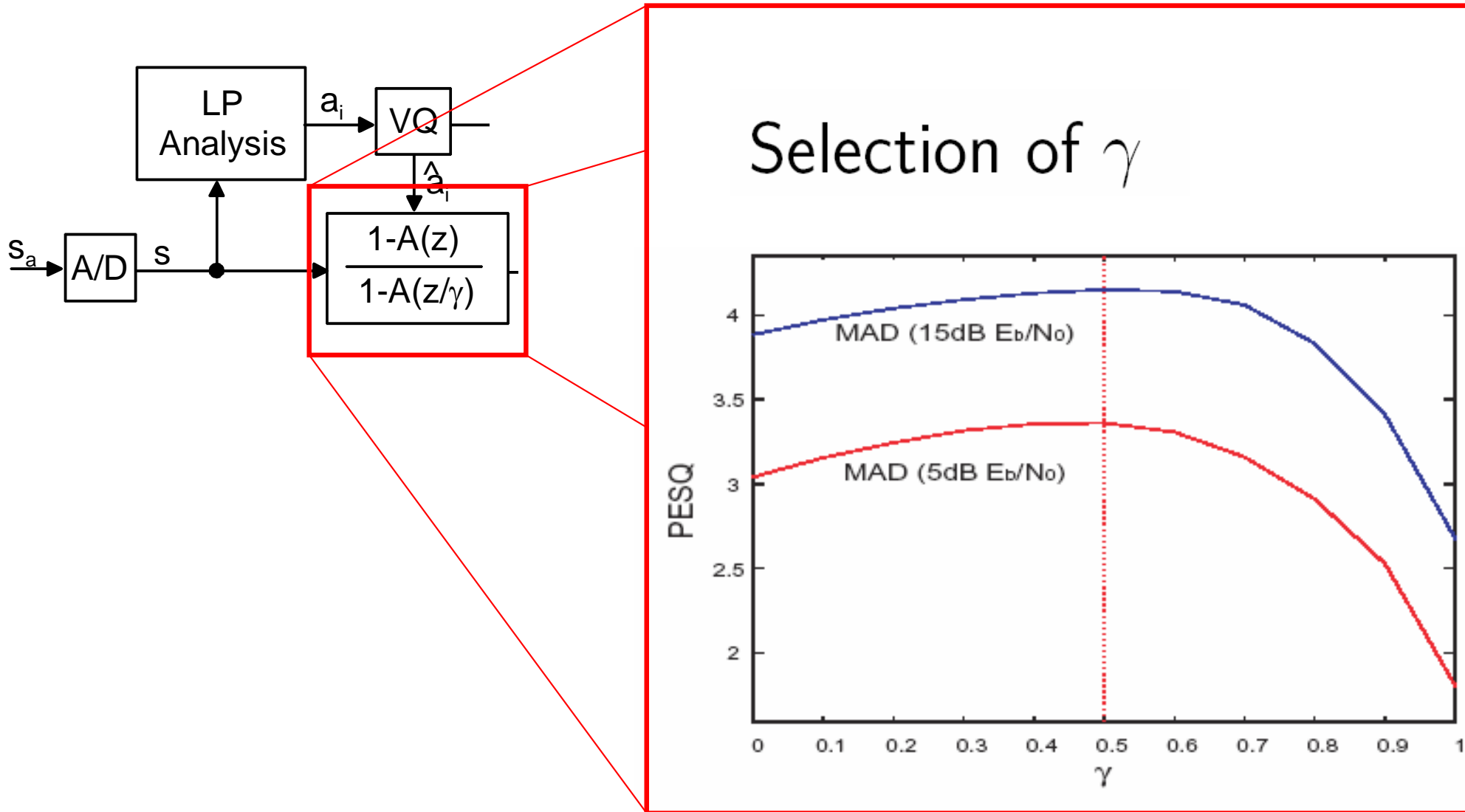# Mixed Pseudo Analogue-Digital Transmission
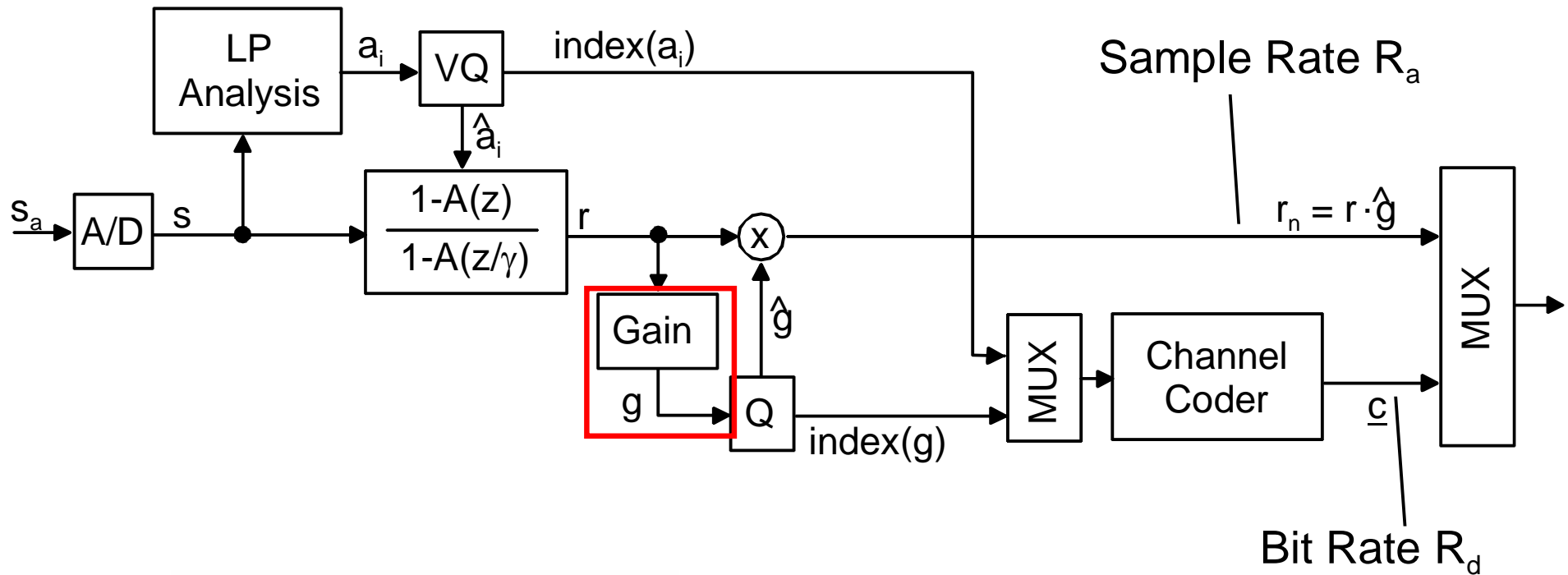
Mixed Pseudo Analogue-Digital Transmission

Calculation and Quantization of LP coefficients with original AMR-GSM modules (Narrowband and Wideband)

Mixed Pseudo Analogue-Digital Transmission

Block diagram: LP Analysis → VQ; A/D with inputs s_a, output s; LP Analysis output a_i to VQ; VQ output $\hat{a}_i$ to filter $\dfrac{1-A(z)}{1-A(z/\gamma)}$.

Selection of γ

PESQ vs γ

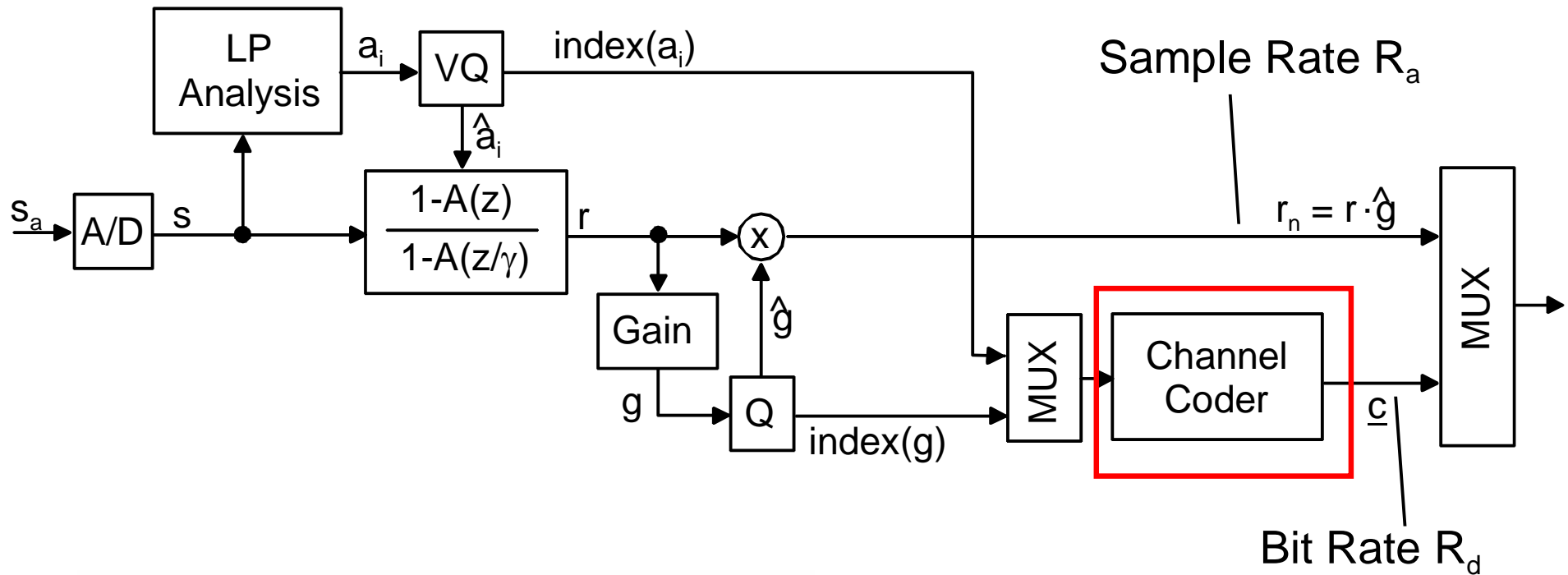MAD (15dB E_b/N_0)

MAD (5dB E_b/N_0)

Mixed Pseudo Analogue-Digital Transmission

$$g = \sqrt{1/\sum r(k)^2}$$
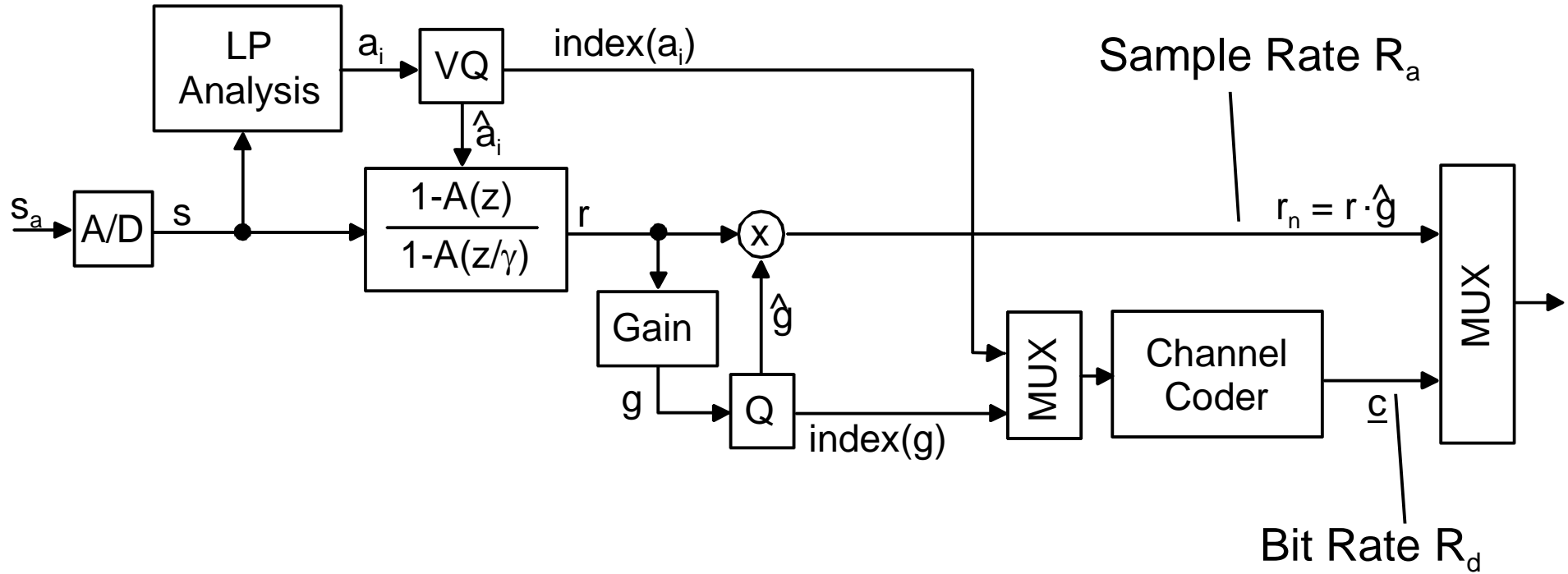
within each 5ms subframe
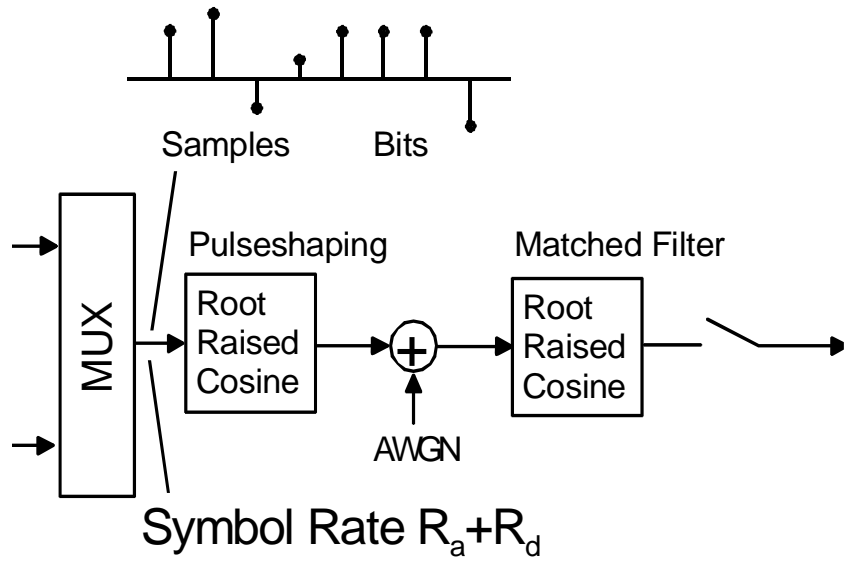
Mixed Pseudo Analogue-Digital Transmission

$$G_0 = 1 + D^3 + D^4$$
$$G_1 = 1 + D + D^3 + D^4$$

Mixed Pseudo Analogue-Digital Transmission

Very low complexity (e.g. no codebook search)

MAD Transmission: Channel & Receiver

Samples   Bits

Pulseshaping   Matched Filter

MUX

Root Raised Cosine $+$ Root Raised Cosine

AWGN

Symbol Rate $R_a + R_d$

Channel

Narrowband Speech Transmission

Channel bandwidth of narrowband transmission (NB)

AMR: $B_{\text{AMR}_{\text{NB}}} = 1.5 \cdot 22.8 \,\text{kbit/s} = \mathbf{34.2 \,\text{kHz}}$

MAD: $\displaystyle R_{d_{\text{NB}}} = (38 + 20 + 4) \,\text{bit/frame} \cdot 50 \,\text{frames/s} \cdot 2 = 6.2 \,\text{kbit/s}$
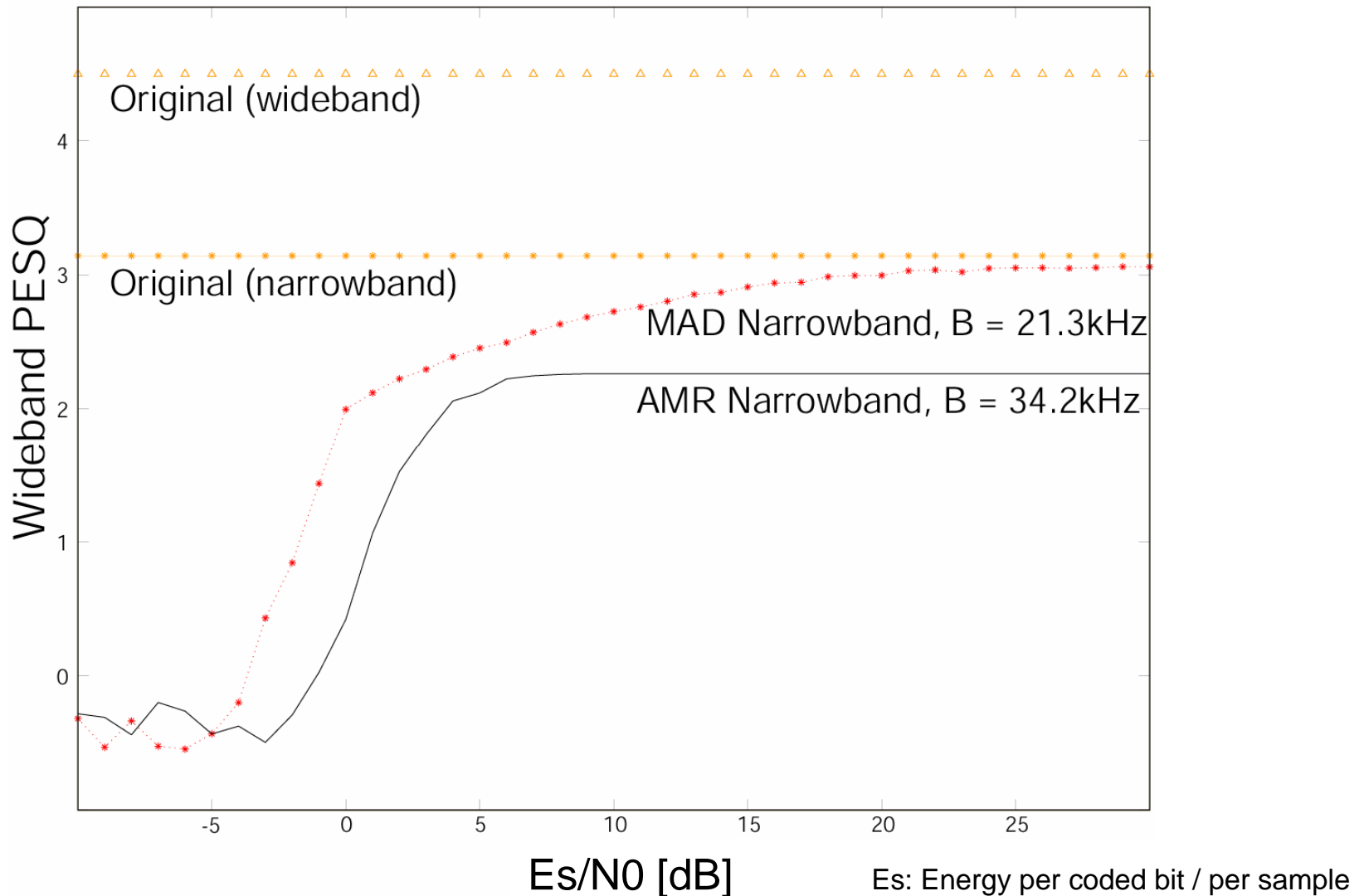
$\displaystyle B_{a_{\text{NB}}} = 1.5 \cdot f_{s_{\text{NB}}} = 12 \,\text{kHz}, \qquad f_{s_{\text{NB}}} = 8 \,\text{kHz}$

$\displaystyle B_{d_{\text{NB}}} = 1.5 \cdot R_{d_{\text{NB}}} = 9.3 \,\text{kHz}$

$\displaystyle B_{\text{MAD}_{\text{NB}}} = B_{a_{\text{NB}}} + B_{d_{\text{NB}}} = 12 \,\text{kHz} + 9.3 \,\text{kHz} = \mathbf{21.3 \,\text{kHz}}$

Narrowband Speech Transmission

• Narrowband speech: 300Hz – 3.4kHz audio bandwidth

Wideband Speech Transmission

Channel bandwidth of wideband transmission (WB)

$$\text{MAD}_{\text{WB}} : R_{d_{\text{WB}}} = \quad (46 + 20 + 4)\,\text{bit/frame} \cdot 50\,\text{frames/s} \cdot 2 = 7\,\text{kbit/s}$$
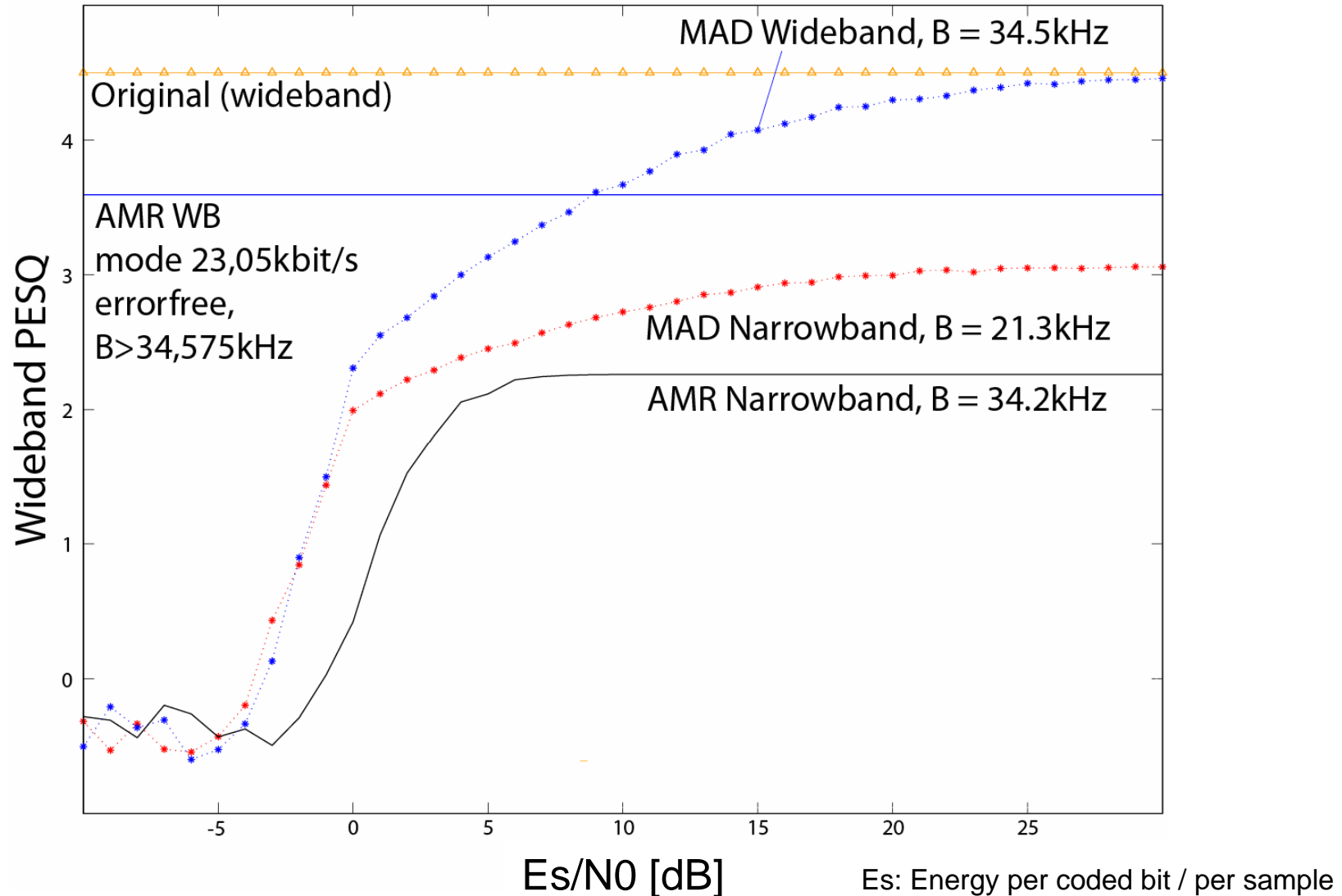
$$B_{a_{\text{WB}}} = \quad 1.5 \cdot f_{s_{\text{WB}}} = 24\,\text{kHz}, \qquad f_{s_{\text{WB}}} = 16\,\text{kHz}$$

$$B_{d_{\text{WB}}} = \quad 1.5 \cdot R_{d_{\text{WB}}} = 10.5\,\text{kHz}$$

$$B_{\text{MAD}_{\text{WB}}} = B_{a_{\text{WB}}} + B_{d_{\text{WB}}} = 24\,\text{kHz} + 10.5\,\text{kHz} = \textcolor{red}{\mathbf{34.5\,\text{kHz}}}$$

Wideband Speech Transmission

- Wideband speech: 50Hz – 7kHz audio bandwidth

Summary & Conclusions

- Mixed Pseudo Analogue-Digital (MAD) speech and audio transmission is an alternative concept of high quality transmission with low complexity, e.g. for wireless microphones and cordless telephones

- MAD speech transmission outperforms narrowband and wideband AMR w.r.t. speech quality, transmission bandwidth, and complexity

- Not being based on a model of speech production, MAD is suitable for speech and audio transmission

Summary & Conclusions

Thank you for your attention

References for Further Information

Introduction of MAD Transmission:

C.Hoelper, P.Vary, "Bandwidth-Efficient Mixed Pseudo Analogue-Digital Speech Transmission", *European Signal Processing Conference EUSIPCO*, Florence, 9/06.

MAD Audio Transmission:

C.Hoelper, P.Vary, "Bandwidth-Efficient Mixed Pseudo Analogue-Digital Speech and Audio Transmission", *Int. Workshop On Multimedia Sig. Proc.*, Victoria, 10/06.

MAD Transmission with 2-Dimensional Modulation:

C.Hoelper, P.Vary, "A New Modulation Concept for Mixed Pseudo Analogue-Digital Speech and Audio Transmission", *International Conference on Acoustics, Speech, and Signal Processing*, Hawaii, 4/07.