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Adaptive selection of lag-window shape for linear predictive analysis in the 3GPP EVS codec

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Outline

- Lag-window has been used for linear predictive analysis to prevent possible instability of the synthesis filter.
- Lag-window shape has the trade-offs between stability and fidelity.
- Adaptive lag-windowing scheme depending on the periodicity is proposed to obtain good compromise.
- The codec with adaptive lag-window shows better quality by the subjective evaluation.

Introduction

- Linear predictive (LP) analysis is widely used
  - Speech coding: code-excited linear prediction (CELP)
    e.g.) G.729, AMR, AMR-WB, G.718
  - Audio coding: spectral envelope in frequency-domain
    e.g.) TwinVQ, USAC, TCX, AMR-WB+
- New 3GPP EVS codec also uses LP analysis
  - More realistic conversation over the mobile network
  - Lower delay is preferable even for music contents
  - Switching strategy between ACELP speech coding and frequency-domain audio coding achieves excellent quality for VoIP/VoLTE

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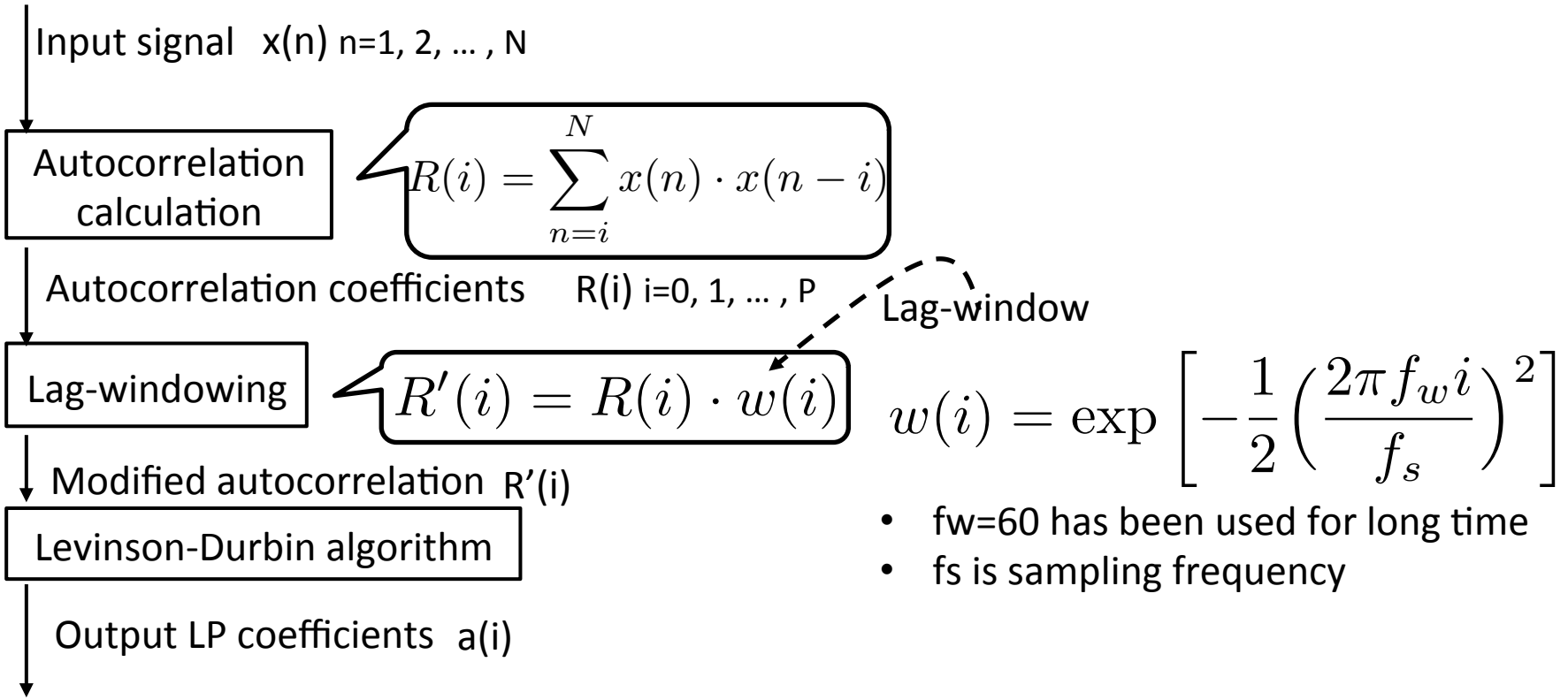
LP analysis by auto-correlation method

- Spectral envelop is estimated by LP coefficients
- Lag-window is applied to avoid instability of filter



- fw=60 has been used for long time
- fs is sampling frequency

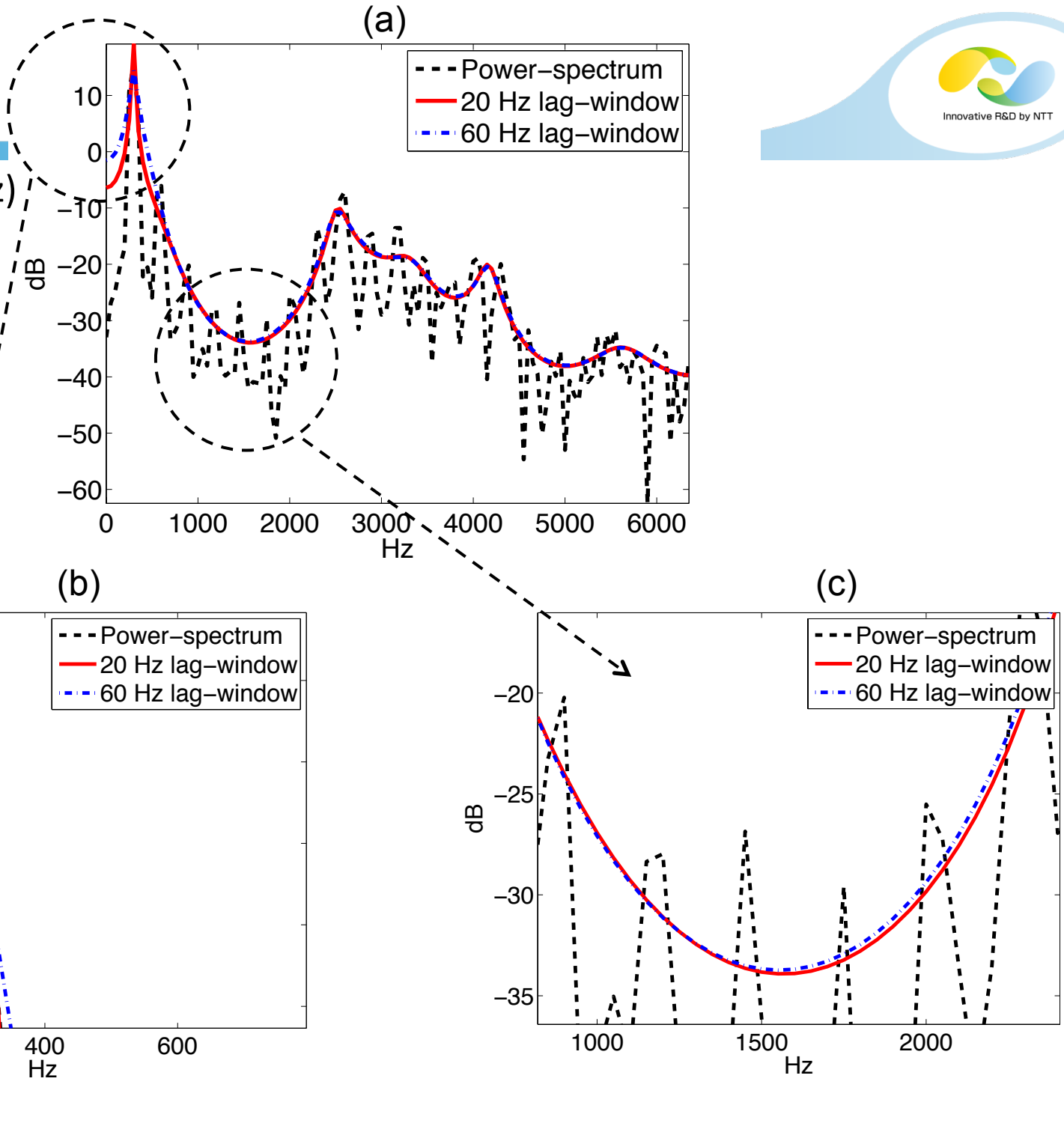
Lag-windowing

- A.k.a. band-width expansion or spectral smoothing
- Preventing instability for LP analysis
  - Simple but efficient, small complexity
- Sacrifice of fidelity of spectral envelop
  - Smaller PARCOR coefficients means whiteness
  - Spectral envelop becomes flatter
- Fixed 60-Hz Gaussian window has been used since early times
- Lag-Window is not needed for some cases
  - Lossless compression without long-term prediction does not use lag-windowing such as G.711.0

Pros: Obtain stable LP coefficients
Cons: Degrade fidelity of spectral envelop

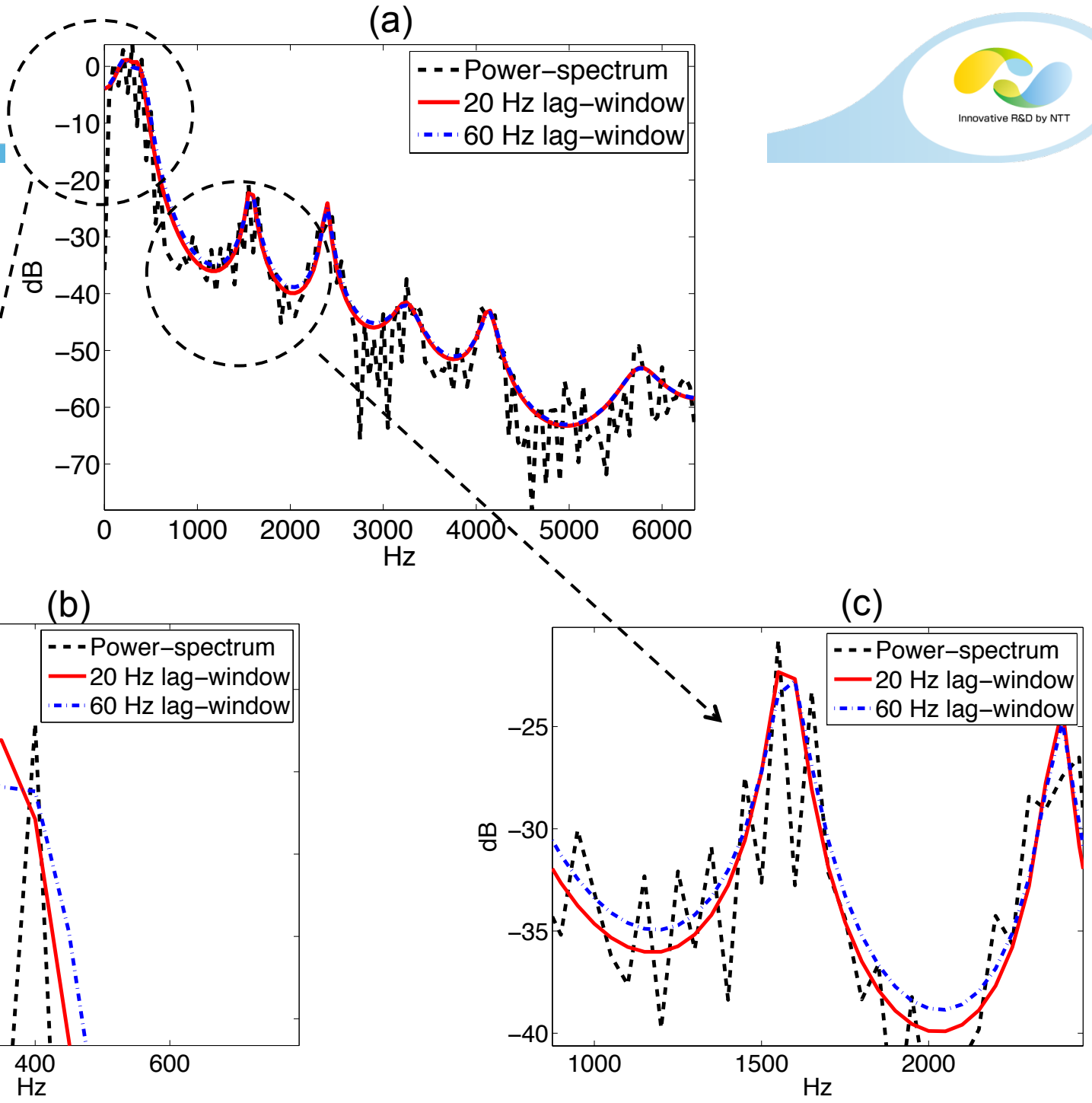
Pros

High-pitch (294 Hz)



Cons

Low-pitch (98 Hz)



Adaptive lag-windowing

- Appropriate control of lag-window shape
- Pilot study
  - Input: Synthesized speech signal to know actual pitch frequency and pitch gain
  - Observed: SNR, segSNR, MOS-LQO by POLQA
  - Results: Higher pitch frequency and pitch gain needs strongly attenuated lag-window, and lower pitch frequency and pitch gain needs weak lag-window
- Lag-window shape should depend on pitch frequency and pitch gain

$$w(i) = \exp\left[-\frac{1}{2}\left(\frac{2\pi(\alpha F_0 + \beta G)i}{f_s}\right)^2\right]$$

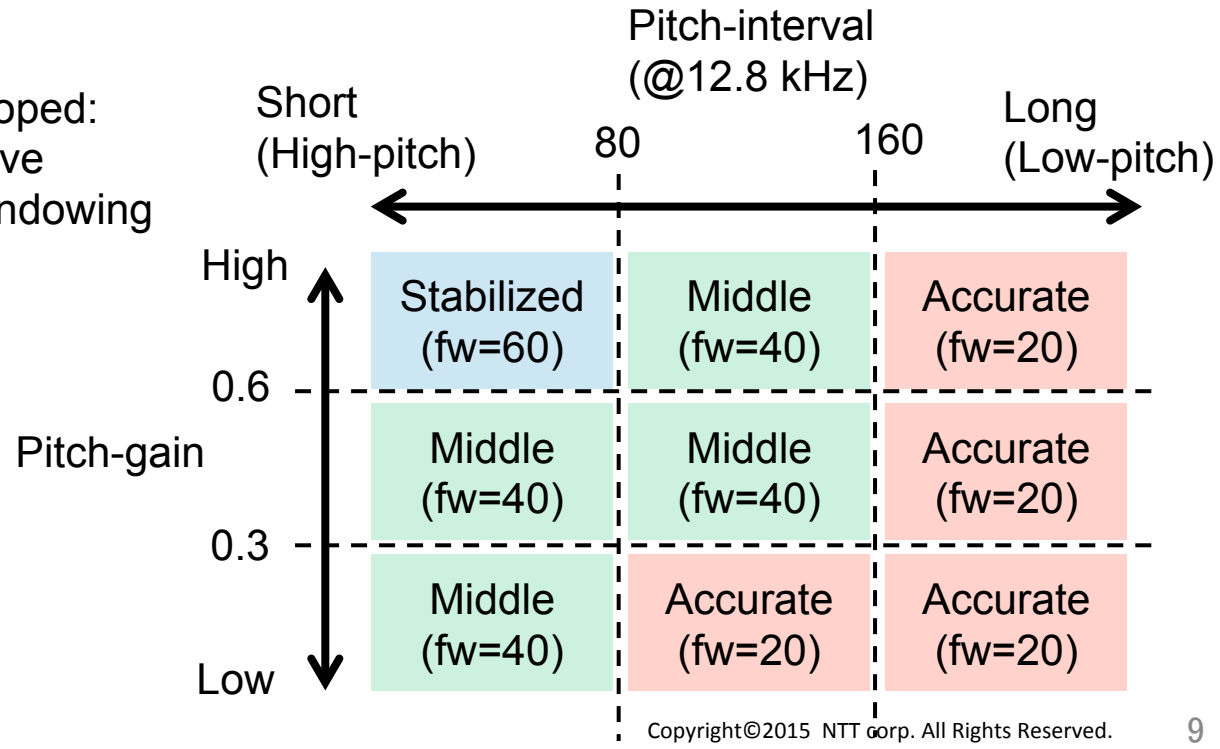
Simplified adaptive lag-windowing

- Selection criterion of lag-window shape
- EVS has enhanced signal analysis tools:
  open-loop pitch analysis, background noise energy estimation, signal activity detection

Conventional:
fixed lag-windowing
(G.729, G.718,
AMR, AMR-WB, etc.)

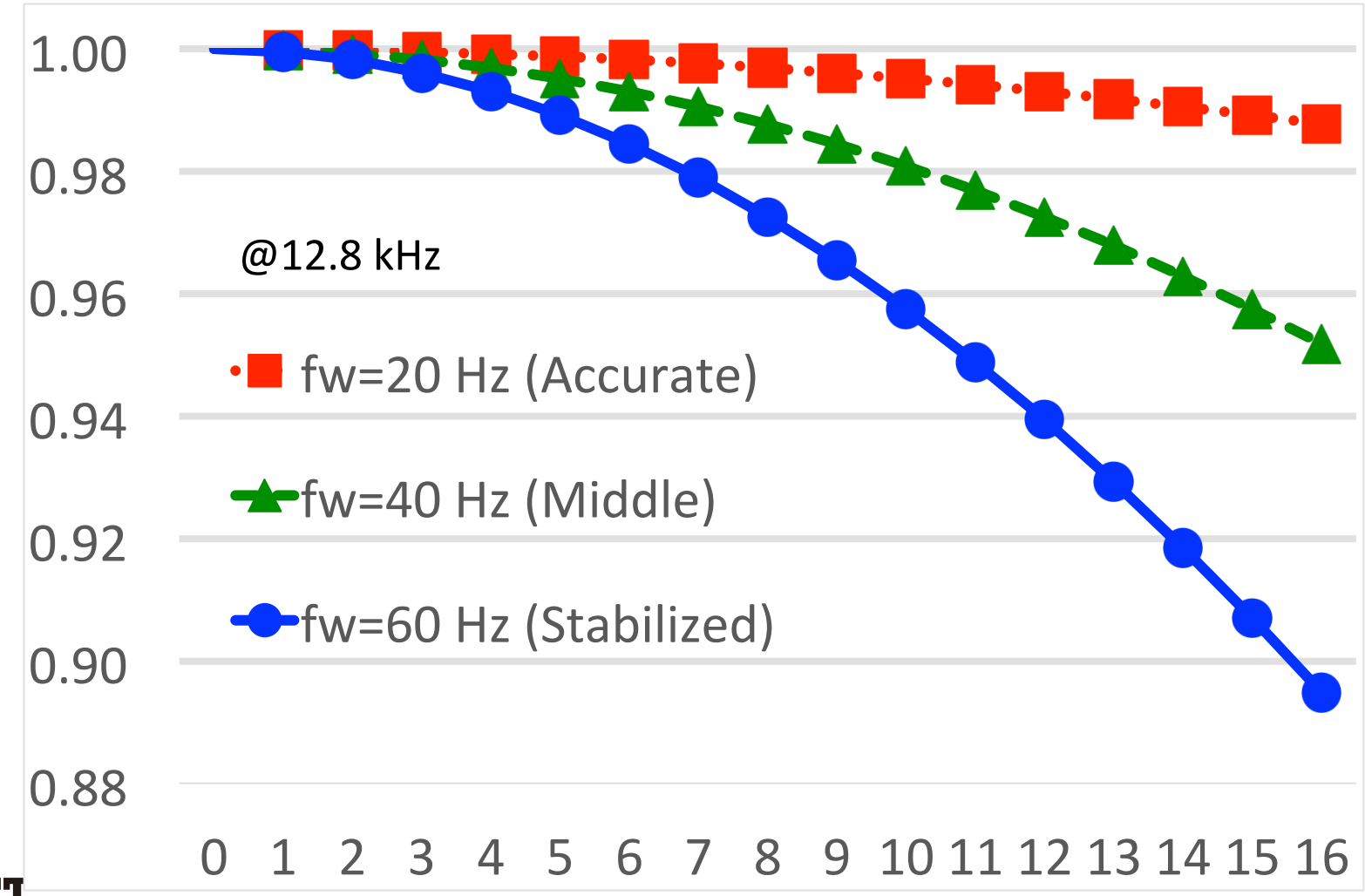
Stabilized
(fw = 60)

Developed:
adaptive
lag-windowing
(EVS)



Shape of lag-window

- Several bytes of ROM, a few if-clause to decide



Subjective evaluations

- ITU-T P.800 & EVS test plan
  - Test items: Wideband (16 kHz sampling), -26 dBov, 8 sec., 4 talkers * 6 sentence-pairs
    - Clean speech (ACR)
    - Noisy speech (DCR) – Car noise @ 20 dB
    - Mixed and Music contents (DCR)
  - 24 naïve and native Japanese listeners, (24 listeners * 4 sentence-pairs = 96 votes)
- Codecs
  - Adaptive lag-windowing (developed) vs. Fixed @ 60-Hz lag-windowing (conventional)
  - EVS: 13.2 kbps, 24.4 kbps, & 48 kbps
  - AMR-WB IO: 12.65 kbps & 23.85 kbps

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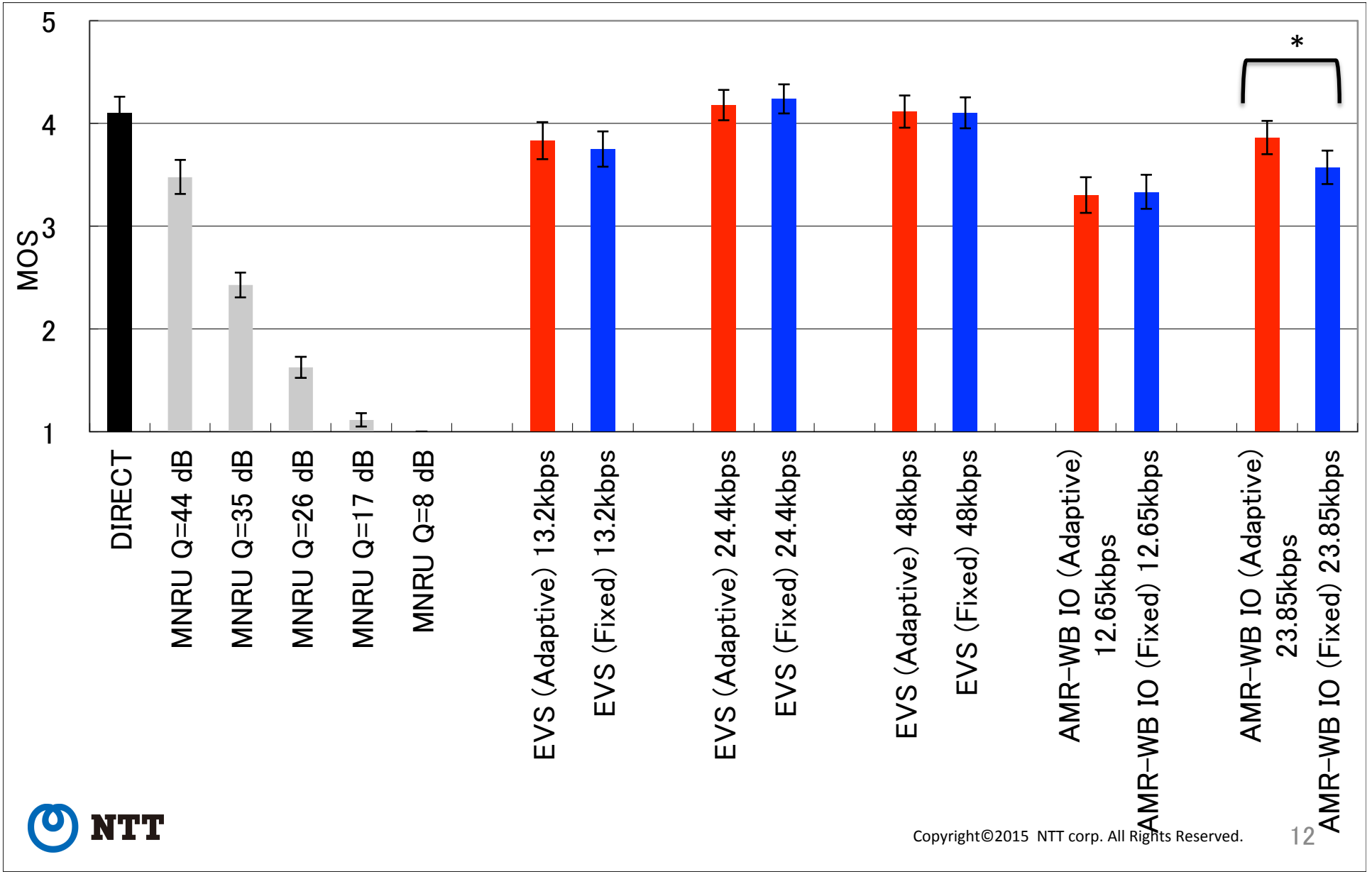
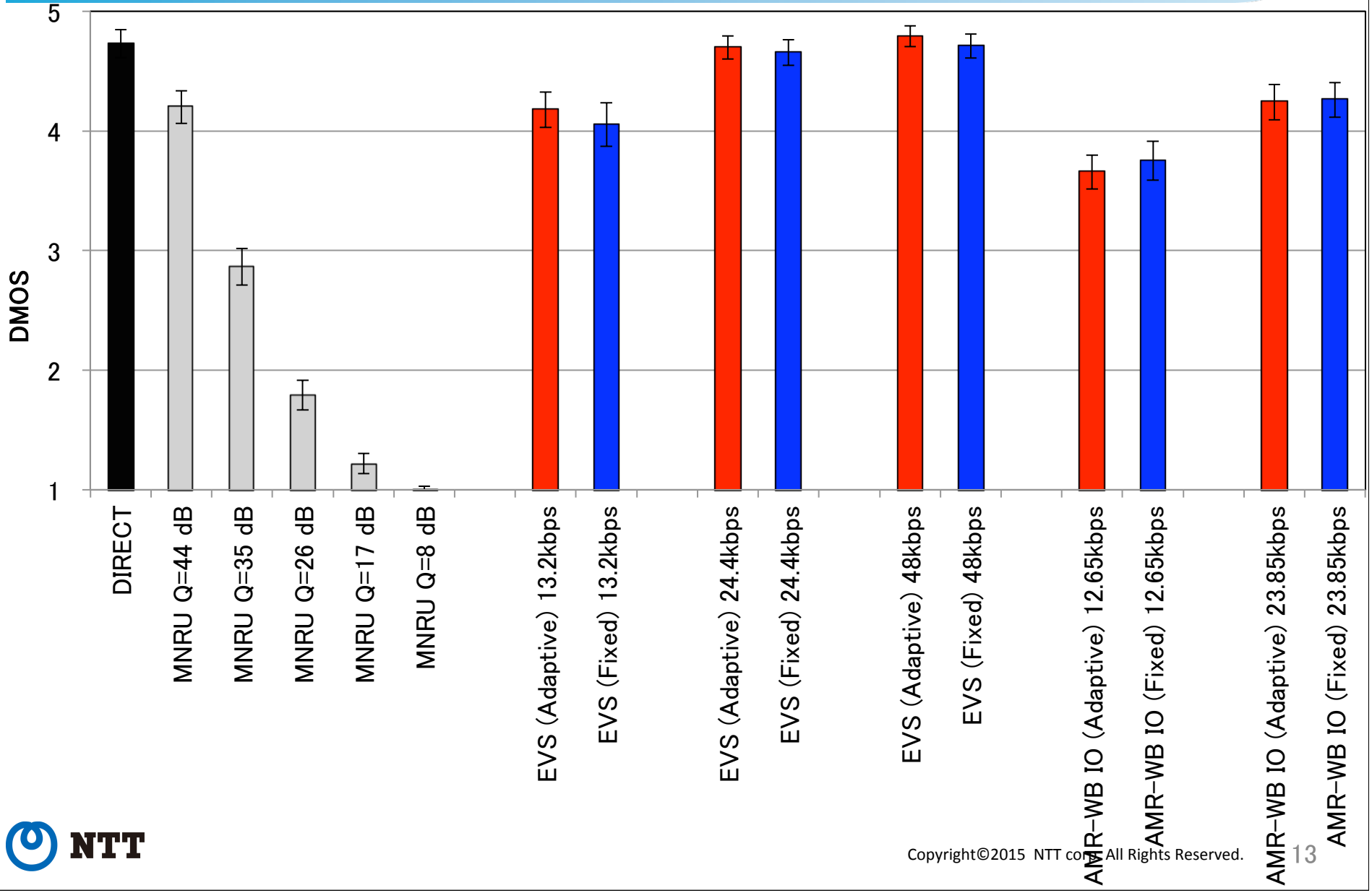
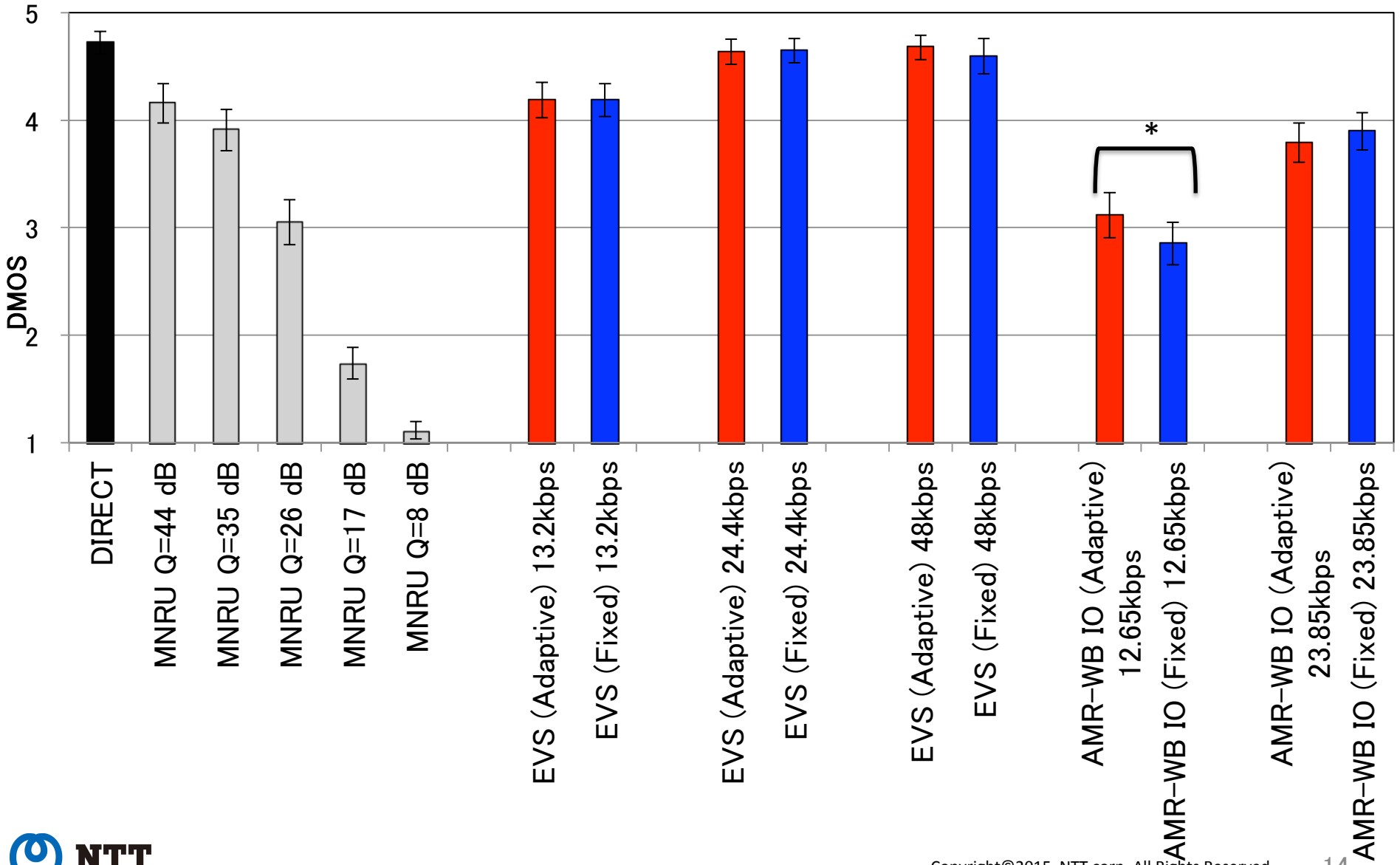
MOS (Clean speech) - ACR



MOS (Noisy speech) - DCR



MOS (Mixed and Music) - DCR



Discussion

- Summary of subjective evaluations
  - No significant degradations
  - Slightly better tendencies
  - Significant improvement for two conditions
- Adaptive lag-windowing enhances the quality of speech and music
  - LP-based codec: IO modes use ACELP, EVS@48 uses TCX
  - Switching LP-based & non-LP-based codecs: EVS@13.2 & EVS@24.4 changes codec strategy frame-by-frame

Adaptive/Fixed	EVS@13.2	EVS@24.4	EVS@48	IO@12.65	IO@23.85
Clean speech	3.8 > 3.7	4.2 = 4.2	4.1 = 4.1	3.3 = 3.3	3.9 >> 3.6
Noisy speech	4.2 > 4.1	4.7 = 4.7	4.8 > 4.7	3.7 < 3.8	4.2 = 4.2
Mixed & Music	4.2 = 4.2	4.6 = 4.6	4.7 > 4.6	3.1 >> 2.9	3.8 < 3.9

Conclusion

- Lag-window has been used for LP analysis to obtain stable coefficients of the synthesis filter.
- Lag-window shape has the trade-offs between stability and fidelity of spectral envelop.
- Adaptive lag-windowing scheme depending on the pitch-lag and the pitch-gain was developed to achieve better compromise.
- The EVS codec with adaptive lag-window showed better quality by the subjective evaluation.
- The adaptive lag-windowing selection method is adopted in 3GPP EVS codec.
- The adaptive lag-windowing scheme may be useful other LP analysis purposes.

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Acknowledgement

- The authors thank all researchers who have contributed to EVS, especially people who kindly checked the performance of the adaptive lag windowing during the standardization phase.