RTPGE Performance Evaluation Under BCI TEST

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Agenda

- Motivations
- Noises and Impairments
- BER Under BCI
- Examples
- Discussions and Conclusions

Motivations

- Narrowband RFI is the dominant impairment in RTPGE and SNR including RFI is no longer an appropriate performance indicator.
- Requirements of FEC in RTPGE differ from those in broadband noise dominated cases.
- Common terms, preferably, simple ones, are needed in performance description and link budget discussion.

Noises and Impairments

- Broadband Noises
  - Background noise -140dbm/Hz.
  - Xtalks [herman_3bp_01_0713].
  - Residual Echo.
  - Residual ISI.
  - ADC quantization noise (nearly Gaussian due to long FFE, likely the largest broadband noise component).
- Narrowband Noise
  - RFI (100mvpp?)
- Burst Noise
  - Impulse noise
    - Can be narrowband or broadband.
    - Likely far smaller than RFI.
    - Don’t simultaneously appear with RFI in tests.
- Jitter
  - Affects echo cancellation.
  - Reduces eye height.

BER Under Narrowband RFI

- If RFI amplitude is larger than or equal to raw eye height (without broadband noise), there will always be significant BER and no coding with reasonable redundancy (say <10%) will work.
  - Consider a sinusoid signal with frequency exactly a quarter of baud rate, peak-to-peak amplitude equal to the raw eye height, and phase at sampling points being exactly $(2k+1/2)\pi$, the BER without coding is ½.
- IF RFI amplitude is smaller than raw eye height, without broadband noise, there will be no BER.
- Apparently, SNR with RFI included in noise is not a good indicator of error performance.
- BER under RFI can be approximated as

  $BER < 1/2 \times \mathrm{erfc}[sqrt(SBNR/2)]$

  SBNR is the slicer signal less RFI to broadband noise ratio, i.e.

$$S\mathrm{BNR} = \frac{(EyeHeight/2 - A_{rfi})^2}{\sigma^2}$$

and σ is the standard deviation of broadband noise at slicer. *SBNR=16.1 dB is required for BER=1e-10 regardless of modulation size of PAM.*

Examples

- If only Xtalks and background noises are considered, all 3 modulation schemes provide 100mvpp RFI without coding.

Modul.	SNR (*dB*)	Raw Eye Height (mV)	Eye Height @1e-10 (mV)	Noise rms (mV)	Max FFE Gain (dB)
PAM-2	32.1	165	136	2.05	1.4
PAM-3	38.4	183	161	1.80	0.01
PAM-4	40.2	163	140	1.78	0.001

- SBNR with 100mVpp RFI without and with ADC quantization noise 5.2 rms mV (about 5.5, 6.2, and 6.5 ENOB for PAM2, 3, and 4, respectively, if 7.8 dB is assumed for PAR, echo and RFI) are

Modul.	PAM-2	PAM-3	PAM-4
SBNR w/o QN (dB)	21.3	27.3	25.0
SBNR with QN(dB)	12.6	17.5	15.2

With 5.2mV quantization noise, only PAM-3 provides positive margin and PAM-2 needs 3.5dB coding gain.

Discussions and Conclusions

- Further works needed to evaluate Jitter and Impulse noises.
- SBNR is a convenient term that describes performance under BCI and can be directly used to derive the required coding gain.