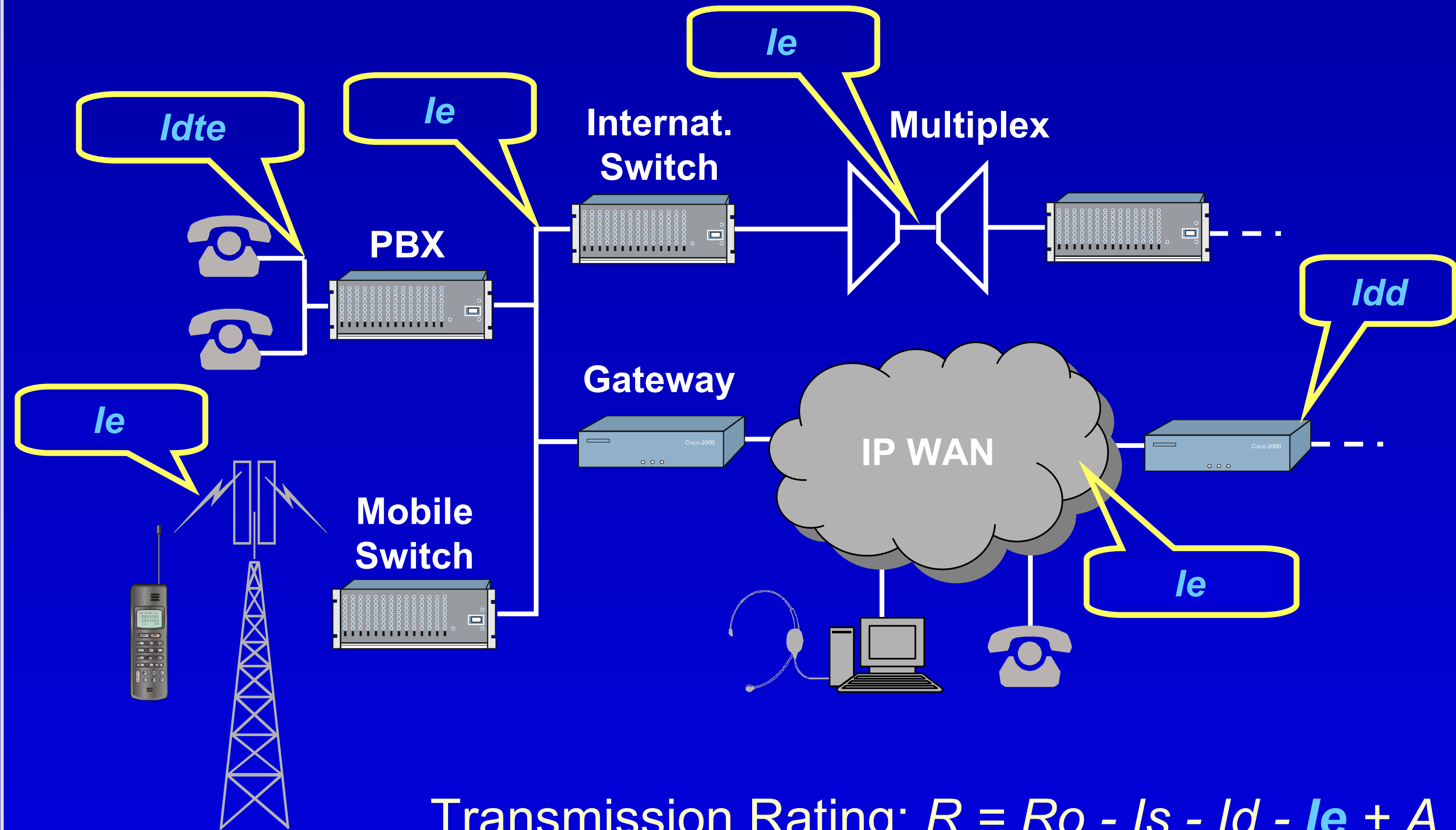
Deriving Equipment Impairment Factors for Wideband Speech Codecs

Sebastian Möller[1], Alexander Raake[1], Vincent Barriac[2], Catherine Quinquis[2]

[1] IKA, Ruhr-University Bochum, Germany

[2] France Télécom R&D, Lannion, France

Speech Communication Network



Transmission Rating: $R = Ro - Is - Id - Ie + A$

Overview

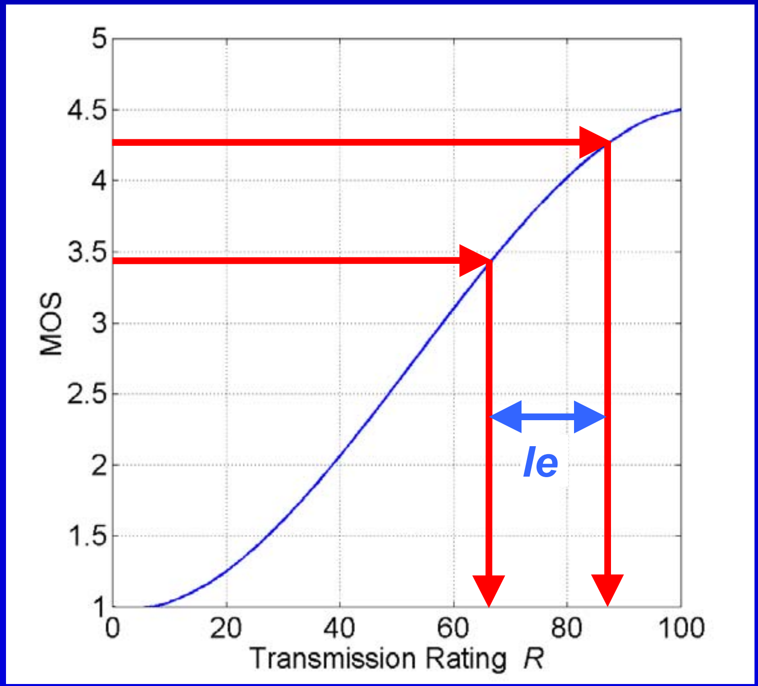
- Derivation of *Ie* in the Narrow-Band Case
  - Methodology According to ITU-T Rec. P.833
  - Problems
- Anchoring on the *R*-Scale
  - Comparison Narrow-Band vs. Wideband Case
  - Definition of an *Ie,wb*
- Derivation of *Ie,wb* for Wideband AMR Codecs
- Additivity Check
- Discussion and Conclusions

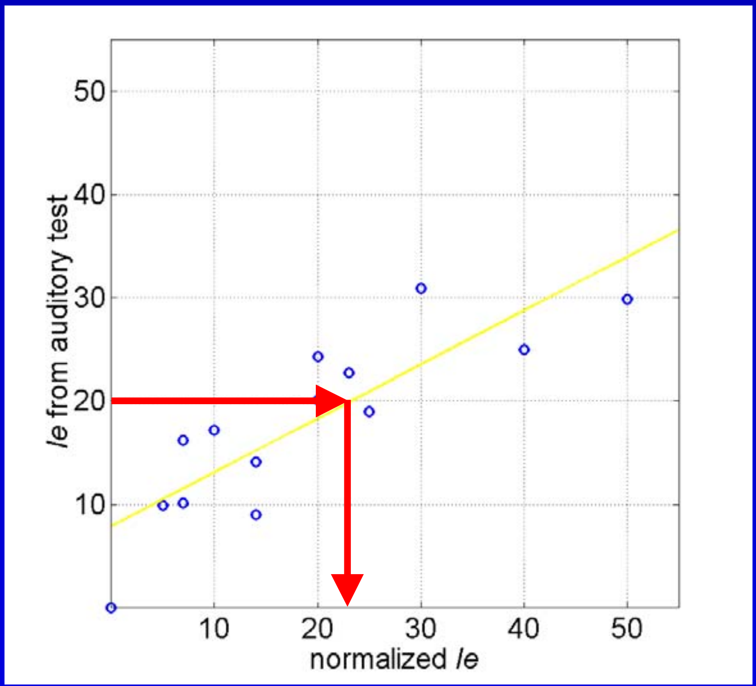
Derivation of *Ie* in the Narrow-Band Case

Methodology According to ITU-T Rec. P.833

Three Steps:

- Step 1: Transformation of MOS to the *R*-Scale
- Step 2: Normalization through linear interpolation
- Step 3: Additivity Check





Derivation of *Ie* in the Narrow-Band Case

Methodology According to ITU-T Rec. P.833

Problems:

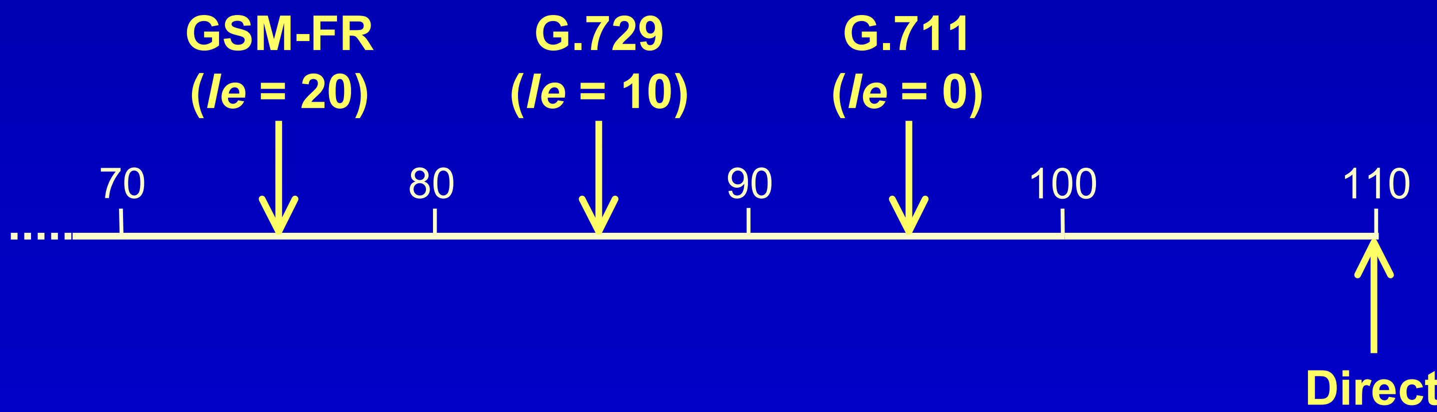
- *R*-scale has been designed for the narrow-band case
- Transformation MOS $\leftrightarrow$ *R* is defined only for the narrow-band case (ITU-T Rec. G.107)
- MOS scale will be used differently when judging narrow-band vs. wideband speech samples

From the previous talk:

- On the *R*-scale, the wideband direct transmission channel corresponds to a value of $R \approx 110$ (at least)

Anchoring on the *R*-Scale

Narrow-Band Case



Wideband Case

$Ie = ?$

Anchoring on the *R*-Scale

Available Test Results:

- 3GPP test on performance of default speech codecs in packet-switched networks (phase 2)
- Conversation test in French and Arabic using headsets
- Included codecs:
  - AMR-WB (12.65, 15.85), G.722 (64)
  - AMR-NB (6.7, 12.2), G.729, G.711
- Results given in 3GPP TR 26.935

Still missing:

- Swedish Telecom test (ITU-T COM 12-11, 1993)
- Test results from Johannesson for ***Ie*** of G.722

Anchoring on the *R*-Scale

Anchoring Procedure:

- Step 1: Transformation of MOS values on the *R* [0;100] scale, using the E-model formula
- Step 2: Expansion of the *R* range from [0;100] to [0;110]
- Step 3: Calculation of *Ie* values as the differences to the G.711 case (***Ie*** := 0)
- Step 4: Definition of a new ***Ie,wb*** as the difference to the direct (wideband) case (*R* := 110)

Anchoring on the *R*-Scale

3GPP Test Results

Phase 2, France Télécom results (French):

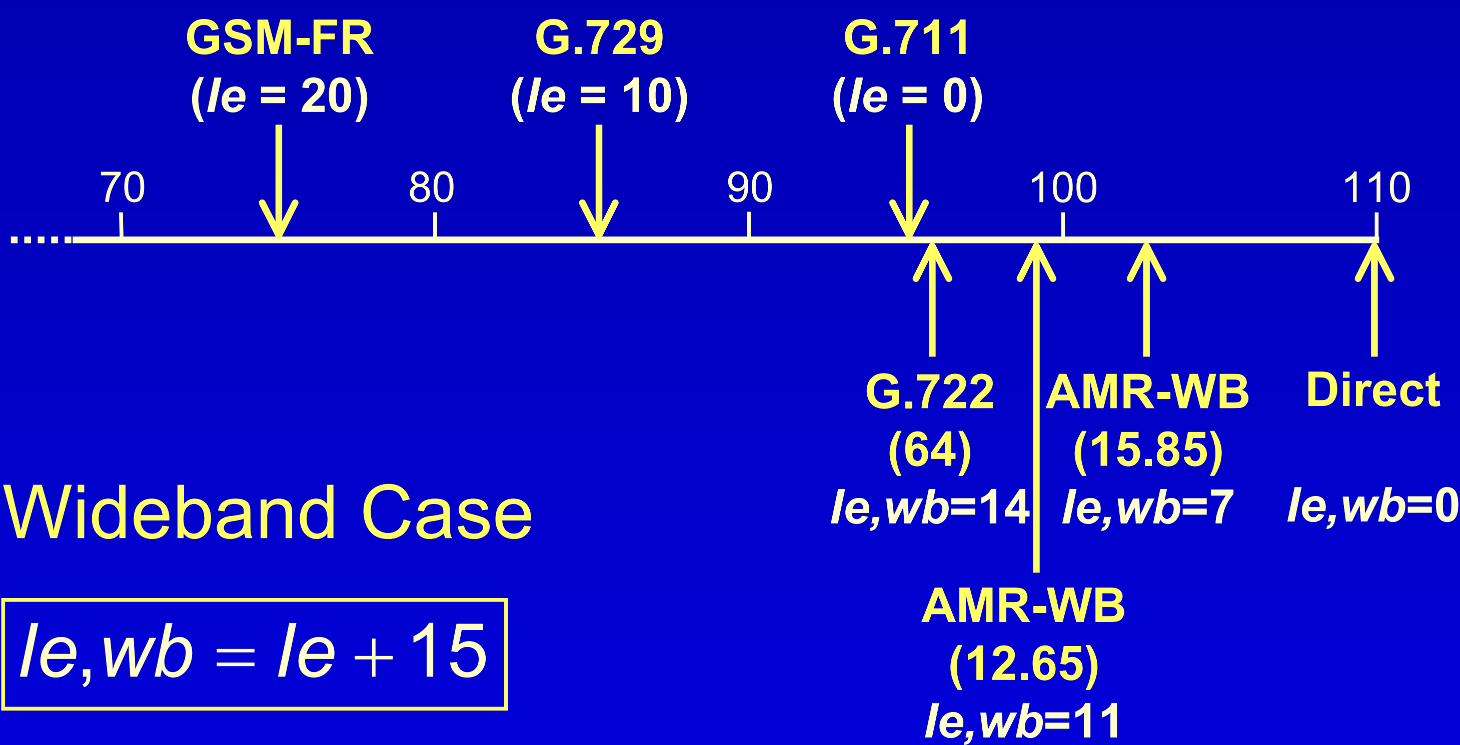
Test Condition	**MOS**	***R*** [0;100]	***R*** [0;110]	***Ie***	***Ie,wb***
direct					0
G.711	4.09	81.8	90.0	0	15
G.722 (64)	4.13	82.9	91.2	-1	14
G.729	3.88	76.4	84.0	6	21
AMR-NB (12.2)	4.06	81.0	89.1	1	16
AMR-NB (6.7)	4.09	81.8	90.0	0	15
AMR-WB (12.65)	4.22	85.7	94.3	-4	11
AMR-WB (15.85)	4.31	88.9	97.8	-8	7

E-Model Formula **x1.1** **-…+R(G.711)** **+(110-95)**

Anchoring on the *R*-Scale

3GPP Test Results

Narrow-Band Case



Wideband Case

$$Ie,wb = Ie + 15$$

Anchoring on the *R*-Scale
Consistency Check

AMR-WB Characterization Test Results:

Test Condition	Exp. 1, BT	Exp. 2a, LMGT	Exp. 5, DT	Exp. 7b, BT	Mean ***Ie,wb***	3GPP, FT
direct	0	0	0	0	0	0
G.722 (64)	10	20	16	12	14.5	14
AMR-WB (12.65)	6	16	5	5	8.0	11
AMR-WB (15.85)	3	8	7	3	5.3	7

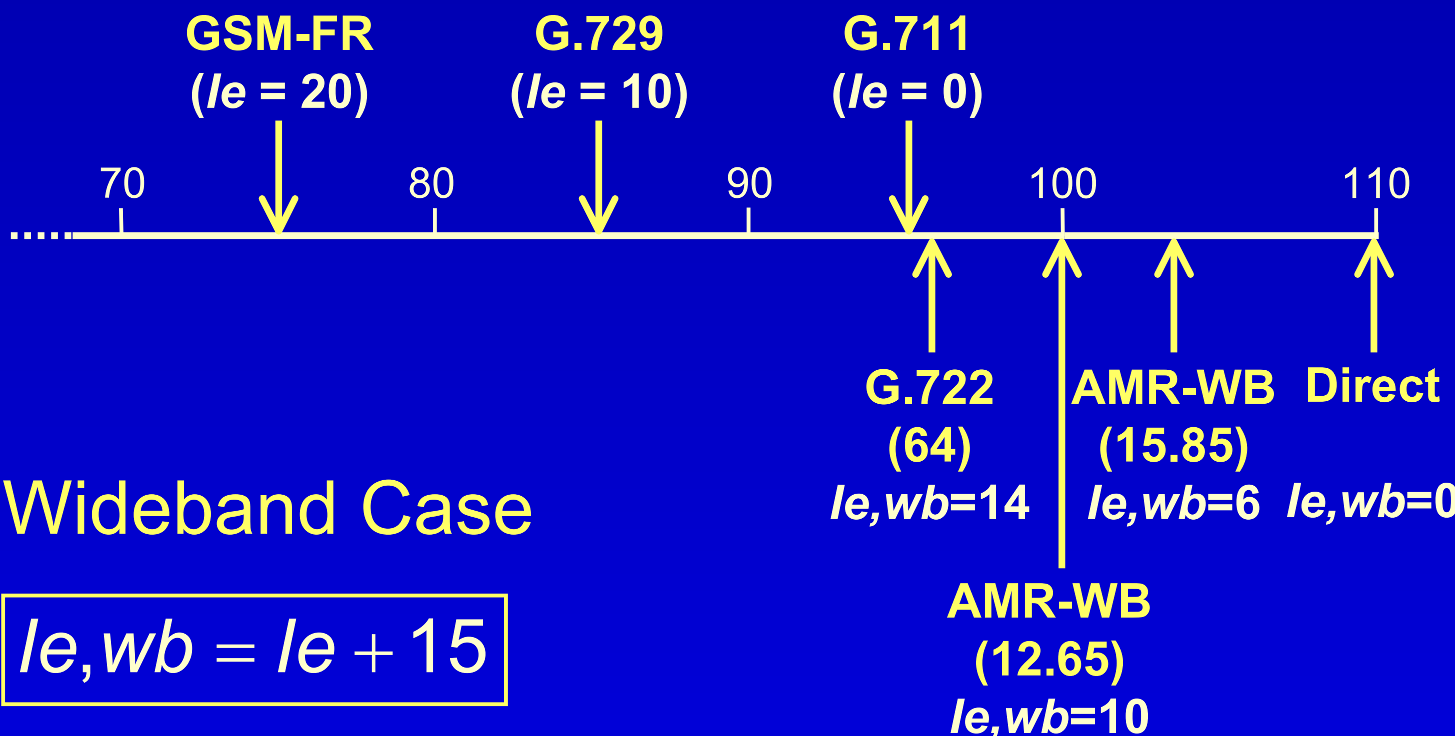
Provisionary definition of ***Ie,wb*** values:

- G.722 (64): ***Ie,wb*** := 14
- AMR-WB (12.85): ***Ie,wb*** := 10
- AMR-WB (15.85): ***Ie,wb*** := 6

Anchoring on the *R*-Scale

Provisionary Definition of ***Ie,wb*** Values

Narrow-Band Case



Wideband Case

$$Ie,wb = Ie + 15$$

Ie,wb for Other Wideband Codecs
AMR-WB Characterization Test Results

Test Condition	Exp. 1, BT	Exp. 2a, LMGT	Exp. 5, DT	Exp. 7b, BT	Mean ***Ie,wb***
G.722 (56)			21	14	17.5
G.722 (48)	17	28	29	23	24.3
G.722.1 (24)	2	22	12		12.0
AMR-WB (6.6)	27	36	29	24	29.0
AMR-WB (8.85)	15	25	19	12	17.8
AMR-WB (14.25)	4	12	6	6	7.0
AMR-WB (18.25)	2	10	5	1	4.5
AMR-WB (19.85)	0	10	2	-4	2.0
AMR-WB (23.05)	-2	8		1	2.3
AMR-WB (23.85)	2	8		5	5.0

Ie,wb for Wideband Codecs
Summary of Provisional Values

G.722 (64):	***Ie,wb*** := 14	(5 Tests)
G.722 (56):	***Ie,wb*** := 18	(2 Tests)
G.722 (48):	***Ie,wb*** := 24	(4 Tests)
G.722.1 (24):	***Ie,wb*** := 12	(3 Tests)
AMR-WB (6.6):	***Ie,wb*** := 29	(4 Tests)
AMR-WB (8.85):	***Ie,wb*** := 18	(4 Tests)
AMR-WB (12.85):	***Ie,wb*** := 10	(5 Tests)
AMR-WB (14.25):	***Ie,wb*** := 7	(4 Tests)
AMR-WB (15.85):	***Ie,wb*** := 6	(5 Tests)
AMR-WB (18.25):	***Ie,wb*** := 5	(4 Tests)
AMR-WB (19.85):	***Ie,wb*** := 2	(4 Tests)
AMR-WB (23.05):	***Ie,wb*** := 2	(3 Tests)
AMR-WB (23.85):	***Ie,wb*** := 5	(3 Tests)

Additivity Check
AMR-WB Characterization Test Results

Exp. 1 (BT), twin tandems:

Test Condition	MOS	*R* [0;100]	*R* [0;110]	***Ie,wb*** tandem	Σ ***Ie,wb*** indiv.
direct	4.15	83.5	91.9	0	0
G.722(64)*G.722(64)	3.57	69.4	76.3	16	28
G.722(48)*G.722(48)	3.02	58.5	64.4	28	48
G.722.1(24)*G.722.1(24)	3.77	73.8	81.2	11	24
AMR-WB(6.6)* AMR-WB(6.6)	2.27	44.1	48.5	43	58
AMR-WB(8.5)* AMR-WB(8.5)	3.05	59.0	64.9	27	36
AMR-WB(12.65)* AMR-WB(12.65)	3.70	72.2	79.4	13	20
AMR-WB(14.25)* AMR-WB(14.25)	3.88	76.4	84.0	8	14
AMR-WB(15.85)* AMR-WB(15.85)	3.93	77.6	85.4	7	12
AMR-WB(18.25)* AMR-WB(18.25)	4.06	81.0	89.1	3	10
AMR-WB(19.85)* AMR-WB(19.85)	4.09	81.8	90.0	2	4
AMR-WB(23.05)* AMR-WB(23.05)	4.14	83.2	91.5	0	4
AMR-WB(23.85)* AMR-WB(23.85)	3.91	77.1	84.8	7	10

Additivity Check
AMR-WB Characterization Test Results

Exp. 2a (LMGT), mixed tandems:

Test Condition	MOS	*R* [0;100]	*R* [0;110]	***Ie,wb*** tandem	Σ ***Ie,wb*** indiv.
direct	4.38	91.8	101.0	0	0
AMR-WB(12.65)*G.722(64)	3.41	66.1	72.7	28	24
AMR-WB(12.65)*G.722(48)	3.09	59.8	65.8	35	34
AMR-WB(12.65)*G.722.1(24)	3.56	69.2	76.1	25	22
G.722(48)*AMR-WB(12.65)	3.56	69.2	76.1	25	34
AMR-WB(15.85)*G.722(64)	3.60	70.1	77.1	24	20
AMR-WB(15.85)*G.722(48)	3.16	61.2	67.3	34	30
AMR-WB(15.85)*G.722.1(24)	3.69	72.0	79.2	22	18
G.722(48)*AMR-WB(15.85)	3.57	69.4	76.3	25	30

→ Tandem order seems to be important

Discussion

Anchoring on the *R*-Scale

Derivation Methodology:

- Fixed relationship between wideband and narrow-band connections (without codecs) was assumed
  - → Extension of the transmission rating scale by 10% (cf. previous talk)
- Transformation rules MOS ↔ *R* apply for the narrow-band case only
  - → Proportional expansion of the range [0;100] to [0;110]
- Use of the MOS scale will differ between narrow-band, wideband and mixed experiments
  - Direct transformation MOS_{wb} ↔ *R* [0;110] possible?
  - Other scaling methods for wideband speech?

Discussion

Anchoring on the *R*-Scale

Problem:

Example: AMR-WB Characterization Test, Exp. 2 (FT)

Test Condition	**MOS**	***R*** [0;100]	***R*** [0;110]	***Ie***	***Ie,wb***
direct	4.85				
G.722	4.60				
AMR-WB (12.65)	4.57				
AMR-WB (15.85)	4.63				

E-Model Formula → no longer applicable!

Discussion
Interpretation of Derived Values

Definition of ***Ie,wb***:

- ***Ie,wb*** is calculated in comparison to the uncoded case
  - → Contrast to ***Ie*** which is compared to G.711
- Provisionary values have been defined for different AMR and G.722 modes
  - → Rough estimation of the overall impact, not exact quality predictions

Additivity:

- Often a worst-case estimation, but not always
- Order of codecs in a tandem seems to play a role
- No information about additivity to other impairment types (delay, echo, noise, etc.)

Conclusions

Summary:

- A new method for deriving equipment impairment factors for wideband speech codecs has been proposed
- The method assumes a fixed relationship between narrow-band and wideband channels on the *R*-scale
- Provisionary values for several AMR-WB and G.722 modes have been derived
- Additivity of ***Ie,wb*** values is not always satisfied

Outlook:

- More thorough testing of the relationship between narrow-band and wideband cases is needed
- Additivity with other impairments → Wideband E-Model?
- Derivation based on instrumental measures (e.g. PESQ-WB)?

Acknowledgement

This study was partly enabled by the EC-funded project INSPIRE (IST-2001-32746).

References

3GPP TR 26.935 (2004). *Packet Switched Group Services and System Aspects; Performance Characterization of Default Codecs (Release 6)*. 3rd Generation Partnership Project, F-Sophia Antipolis.

TD S4(01)0321 (2001). *AMR WB* Characterization *Experiments 2A and 6A - LMGT Results*. Source: LMGT (Author: S. F. Campos-Neto). 3GPP TSG-SA4#17 Meeting, FI-Naantali.

TD S4(01)0326 (2001). *Executive Summary from France Télécom R&D for the ETSI AMR-WB Characterization Phase - Results for Experiments 2 & 5*. Source: France Télécom R&D (Author: D. Pascal). 3GPP TSG-SA4#17 Meeting, FI-Naantali.

TD S4(01)0346R (2001). *AMR Wideband* Characterization *Phase I, Exp 5 - DT Results*. Source: T-Nova Deutsche Telekom (Author: W. Johannsen). 3GPP TSG-SA4#17 Meeting, FI-Naantali.

TD S4(01)0351R1 (2001). *AMR Wideband* Characterization *Phase 1 Listening Tests: Experiment 1 - BT Results*. Source: BT (Author: P. Arden). 3GPP TSG-SA4#17 Meeting, FI-Naantali.

TD S4(01)0354R (2001). ETSI/*AMR WB* Characterization *Experiment 3 - Dynastat Results*. Source: Dynastat Inc. (Author: A. D. Sharpley). 3GPP TSG-SA4#17 Meeting, FI-Naantali.

TD S4(01)0604 (2001). *AMR Wideband* Characterization *Phase 1 Listening Tests: Experiment 7b - BT Results*. Source: BT (Author: P. Arden). 3GPP TSG-SA4#19 Meeting, JP-Tokyo.

ITU-T COM 12-11 (1993). *Difference in Loudness and Speech Quality for 3.1 kHz and 7 kHz Handset Telephony.* Source: Swedish Telecom (Author: N. Gleiss). International Telecommunication Union, Study Group 12 Meeting, CH-Geneva.

ITU-T Rec. G.107 (2003). *The E-Model, a Computational Model for Use in Transmission Planning*. International Telecommunication Union, CH-Geneva.

ITU-T Rec. P.833 (2001). *Methodology for Derivation of Equipment Impairment Factors from Subjective Listening-Only Tests.* International Telecommunication Union, CH-Geneva.

Anchoring on the *R*-Scale

3GPP Test Results; Scale Expansion Towards [0;140]

Phase 2, France Télécom results (French):

Test Condition	**MOS**	***R*** [0;100]	***R*** [0;110]	***Ie***	***Ie,wb***
direct					0
G.711	4.09	81.8	114.5	0	45
G.722 (64)	4.13	82.9	116.1	-2	43
G.729	3.88	76.4	107.0	8	53
AMR-NB (12.2)	4.06	81.0	113.4	1	46
AMR-NB (6.7)	4.09	81.8	114.5	0	45
AMR-WB (12.65)	4.22	85.7	120.0	-7	38
AMR-WB (15.85)	4.31	88.9	124.5	-10	35

E-Model Formula

x1.4

-…+R(G.711)

+(140-95)