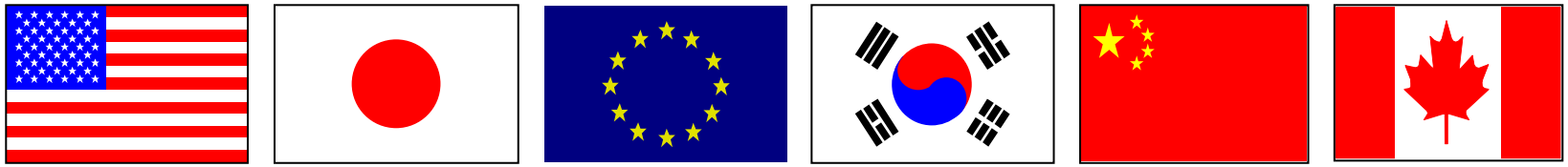
Standardization of the Adaptive Multi-Rate Wideband Codec

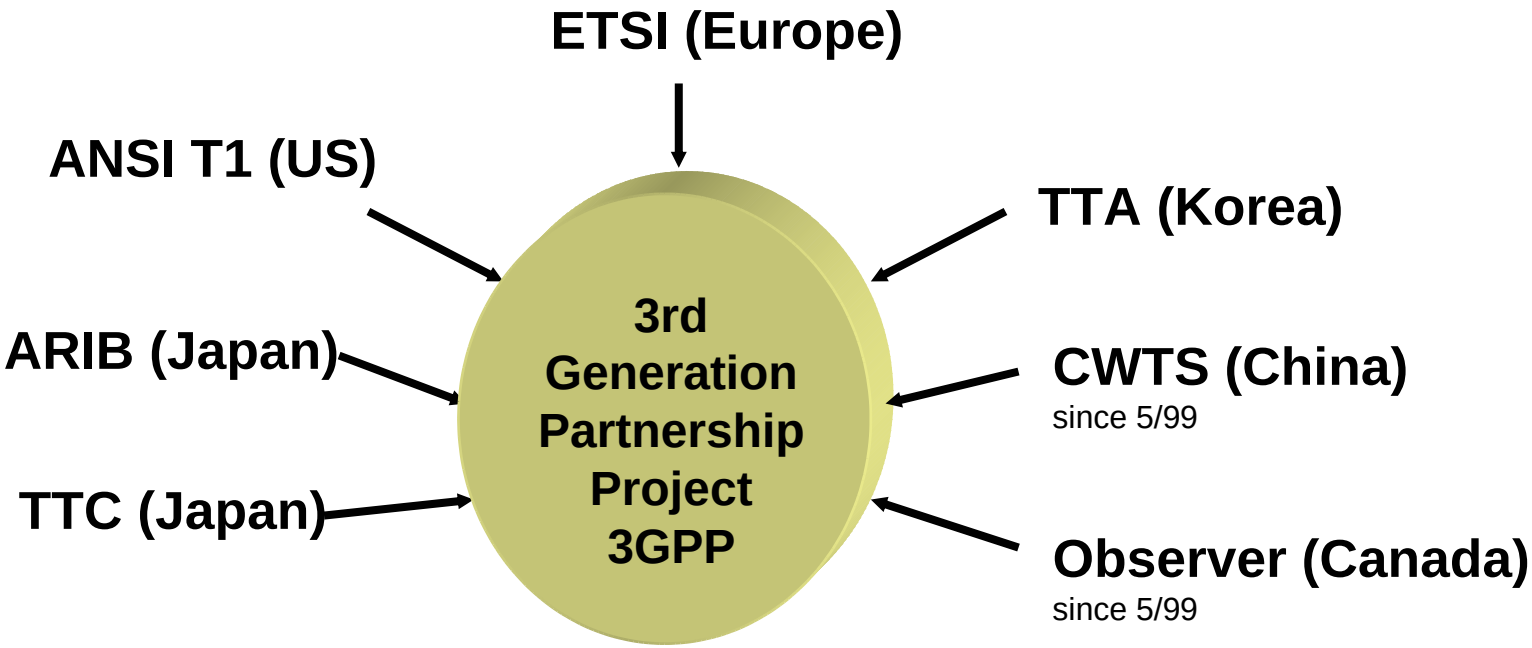
Dr. Imre Varga
Siemens AG
(Served as the Chairman of 3GPP AMR-WB Group)

Index

Standards for Business

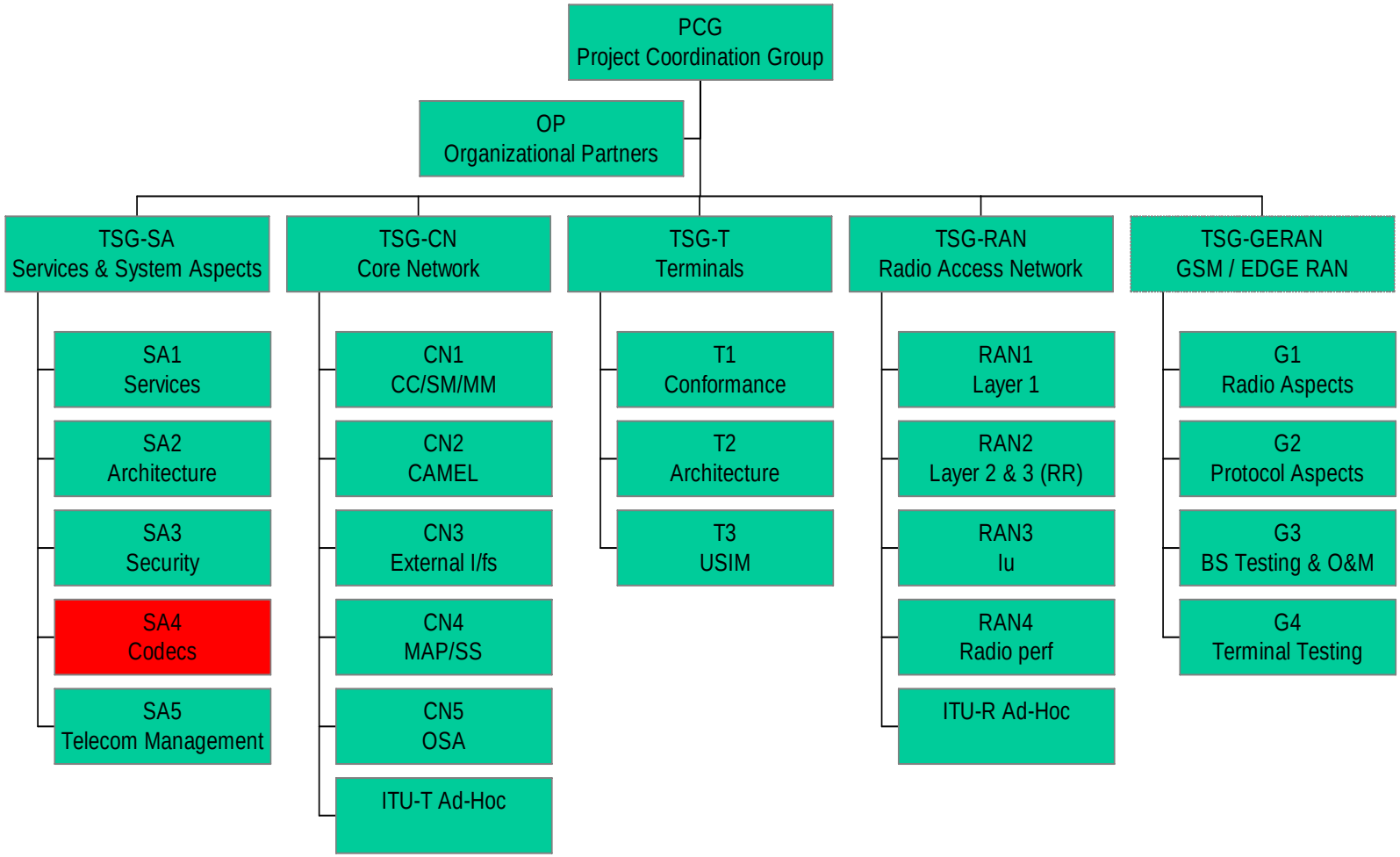
3GPP: 3rd Generation Partnership Project



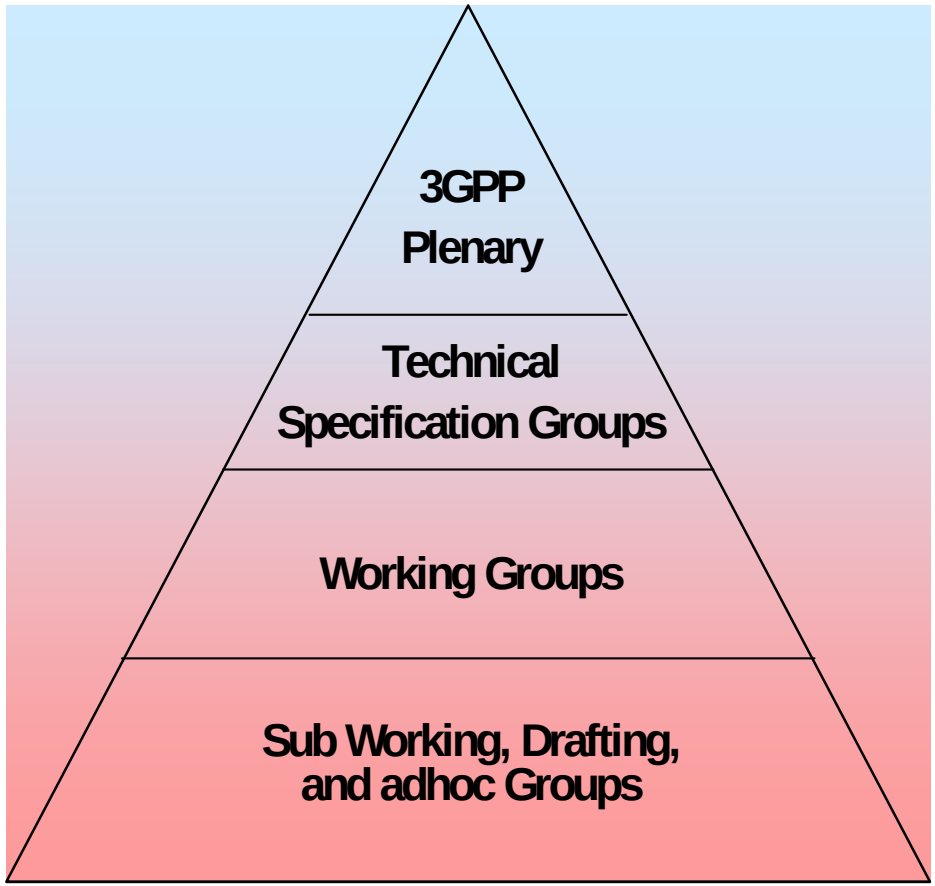


Market Representation Partners:
3G.IP, GSA, GSM Association, IPv6, MWIF, UMTS Forum, UWCC

3GPP Organization



3GPP Organization



- Strategic Impact
- Wideness of Scope

- Detailed Level of Expertise
- Implementation Level

Standards for Business

Index

Introduction - Mobile Multimedia Standardization

AMR-Wideband Project

AMR-Wideband Algorithm

AMR-Wideband Characterization

Discussion: Q&A

Standards for Business

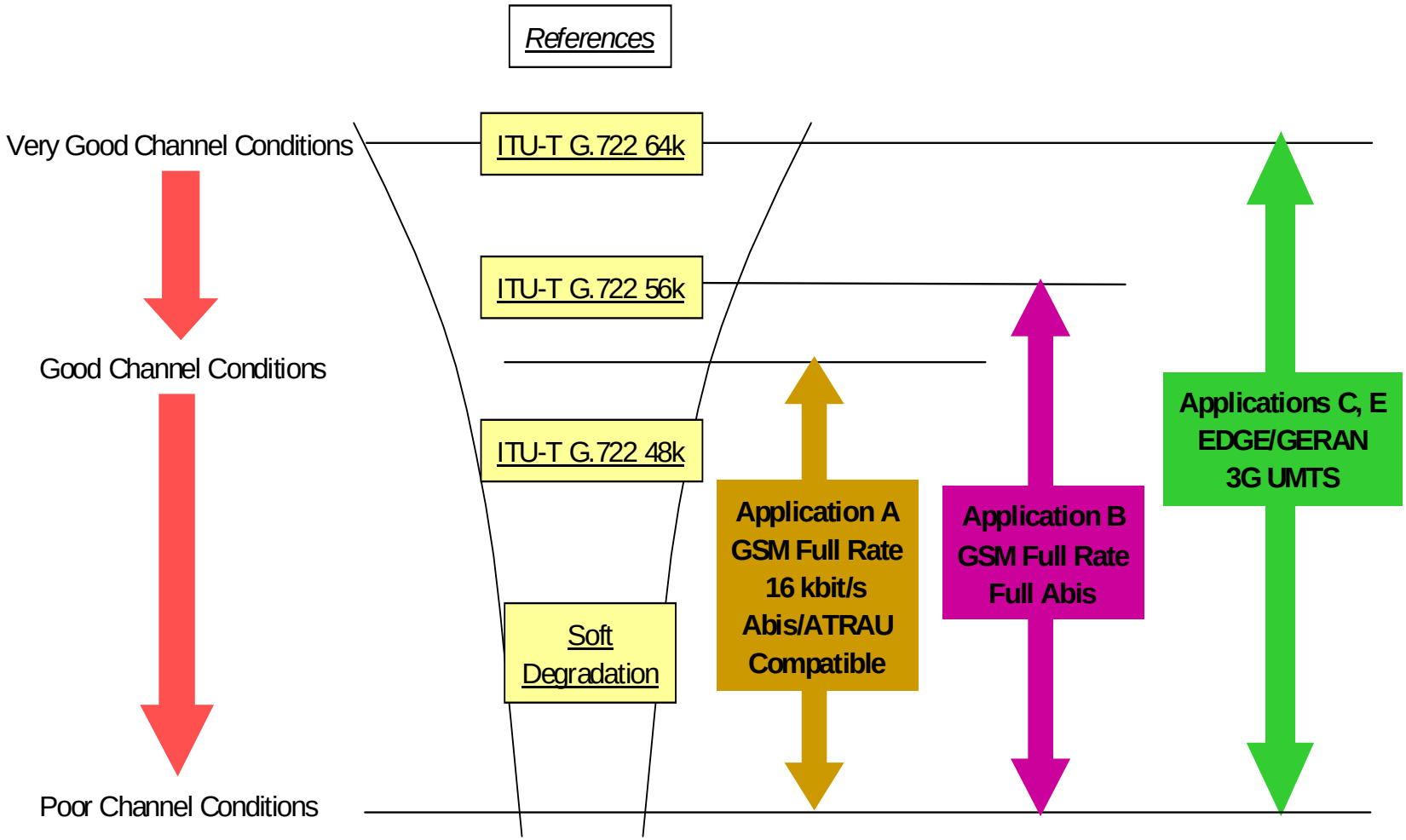
AMR-Wideband Standardization Overview

- **AMR-WB in Networks**
  - Application A: GSM FR traffic channel with 16 kbit/s A-ter sub-multiplexing
  - Application B: GSM FR traffic channel
  - Application C: EDGE/GERAN 8-PSK Phase II radio channels
  - Application E: 3G UTRAN WCDMA radio channel
- **Why AMR-WB?**
  - Improved sound quality through the use of extended audio bandwidth (50-7000 Hz).
  - Increased voice naturalness is expected to be key for hands-free / multimedia applications.
- **Key Project Milestones:**
  - Feasibility Study (ETSI SMG11): Spring 1999; AMR-WB target: Rel4
  - Qualification Phase: Completed in June 2000 (TSG-SA#8)
  - Selection Phase: Completed in October 2000
  - Approval of selection: December 2000 (3GPP TSG-SA#10)
  - Approval of AMR-WB codec specifications: March 2001 (3GPP TSG-SA#11) Rel5
  - Work on network aspects, floating-point: March 2002 (Rel5)

AMR-Wideband Design Constraints

- 16 kHz sampling frequency
- Memory constraints in comparison to AMR-NB:
  - 2.4 x wMOPS (<40 WMOPS)
  - 2.8 x RAM (<15KW)
  - 1.2 x DROM (<18KW)
  - 1.2 x PROM (1.2x4851 ETSI basic operators)
- Reuse of components of AMR-NB codec:
  - DTX scheme
  - Convolutional polynomials shall be reused (05.03) in GSM
  - Rate adaptation scheme
  - Mode change every 20msec in 3G, every 40msec in GSM /GERAN
- Increase of roundtrip delay over AMR-NB with 16 kb/s submultiplexing: max. 6.5 ms

AMR-Wideband Performance Requirements



AMR-Wideband Qualification Phase

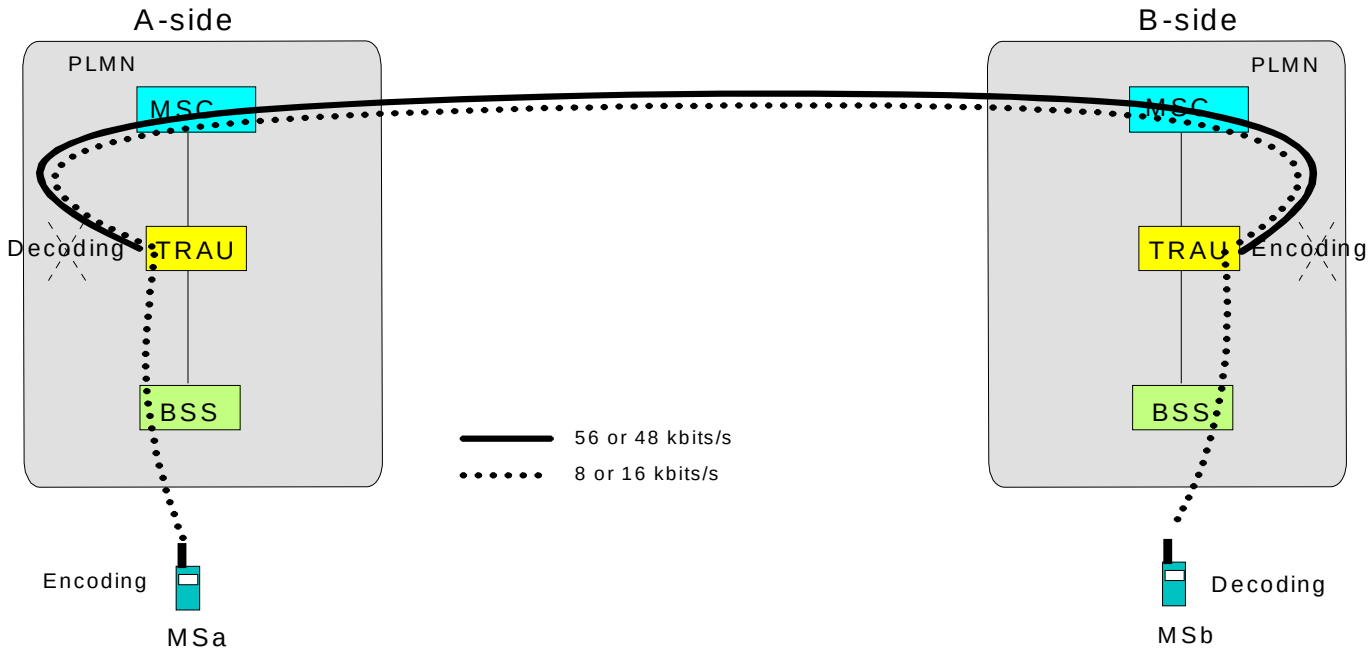
- Formal listening tests based on floating-point code
- Seven candidates
- One candidate failed
- Good overall performance of the other candidates
- Prepared for selection phase

AMR-WB Selection Phase

- 5 codec candidates:
  - Codec 1 = Ericsson
  - Codec 2 = FDNS consortium (consisting of France Télécom, Deutsche Telekom, Nortel Networks and Siemens)
  - Codec 3 = Nokia
  - Codec 4 = Motorola (withdrawn)
  - Codec 5 = Texas Instruments
- Formal subjective listening tests based on fixed-point code
  - 6 independent laboratories (ARCON, AT&T, Dynastat, France Télécom, LMGT, NTT-AT)
  - 5 languages: Japanese, US-English, French, Mandarin Chinese, and Spanish
- Selection details:
  - Selection at 3GPP SA4#13 in October 2000 based on pre-defined selection rules.
  - The failures of all candidates is below the allowed limit in selection rules.
  - Codec 3 meets all the performance requirements and it provides the best quality according to the Figures of Merit. Codec 3 was selected as the AMR-WB codec.

Current AMR-WB Status

- AMR-WB 16-bit fixed-point specifications approved for Rel5
- ANSI C-code is available with test vectors
- Interoperable floating-point version and C code are available
- AMR-WB Tandem Free Operation (TFO) in TS 28.062
- Main use case is conversational telephony service



AMR-WB Speech Codec Specifications

- TS 26.171 AMR WB Speech Codec; General description
- TS 26.173 AMR WB Speech Codec; ANSI C-source code
- TS 26.174 AMR WB Speech Codec; Test Sequences
- TS 26.190 AMR WB Speech Codec; Transcoding Functions
- TS 26.191 AMR WB Speech Codec; Error concealment of erroneous or lost frames
- TS 26.192 AMR WB Speech Codec; CN for AMR Speech Traffic Channels
- TS 26.193 AMR WB Speech Codec; Source Controlled Rate operation
- TS 26.194 AMR WB Speech Codec; VAD for AMR Speech Traffic Channels
- TS 26.201 AMR WB Speech Codec; Speech Codec Frame Structure
- TS 26.202 AMR-WB Speech Codec; interface to Iu and Uu
- TR 26.976 AMR-WB Speech Codec Performance Characterization

ITU-T Q7/16: G.722.2 WB Speech Codec Standardization

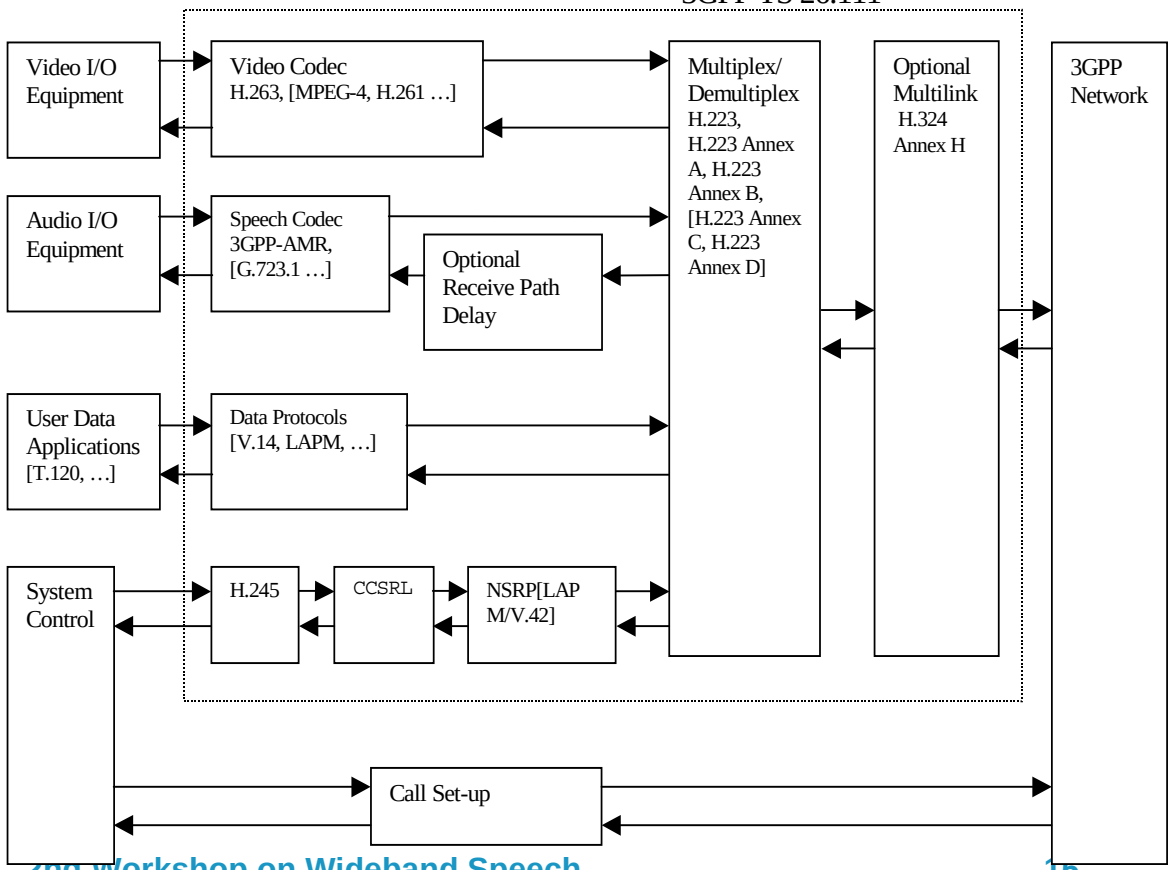
- Objective: “speech-centric” wideband coder
- After selection tests, AMR-WB was selected in July 2001
- Interoperability of wireline and wireless systems is possible without transcoding.
- Additional characterization testing is on-going (e.g. for music signals)

- ITU-T Recommendation G.722.2
- Specification by ANSI C code, harmonization with 3GPP’s AMR-WB

Application Example: 3G-324M Circuit-Switched Videotelephone

- Low-bitrate circuit-switched videotelephony based on ITU-T H.324/M
- AMR speech codec is mandatory instead of G.723.1
- H.263 baseline is the mandatory video codec
- MPEG4 Simple Visual Profile @ Level 0 is optional.
- H.223 MPX
- H.245 cap exchange
- AMR-WB and H.264 (recommended in Rel6)
- Fast call setup

3GPP TS 26.111



Standards for Business

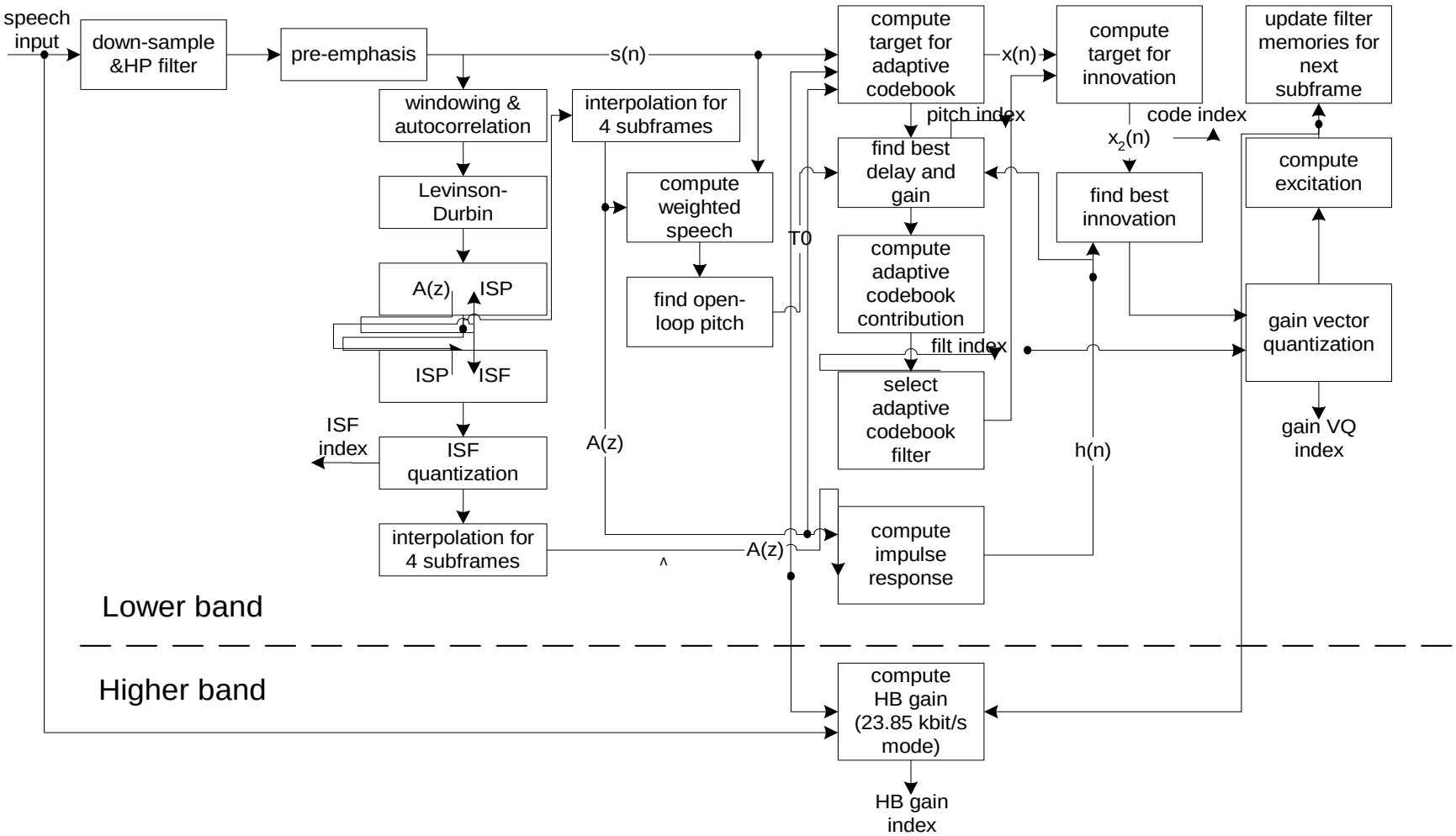
Index

AMR-WB Codec Modes

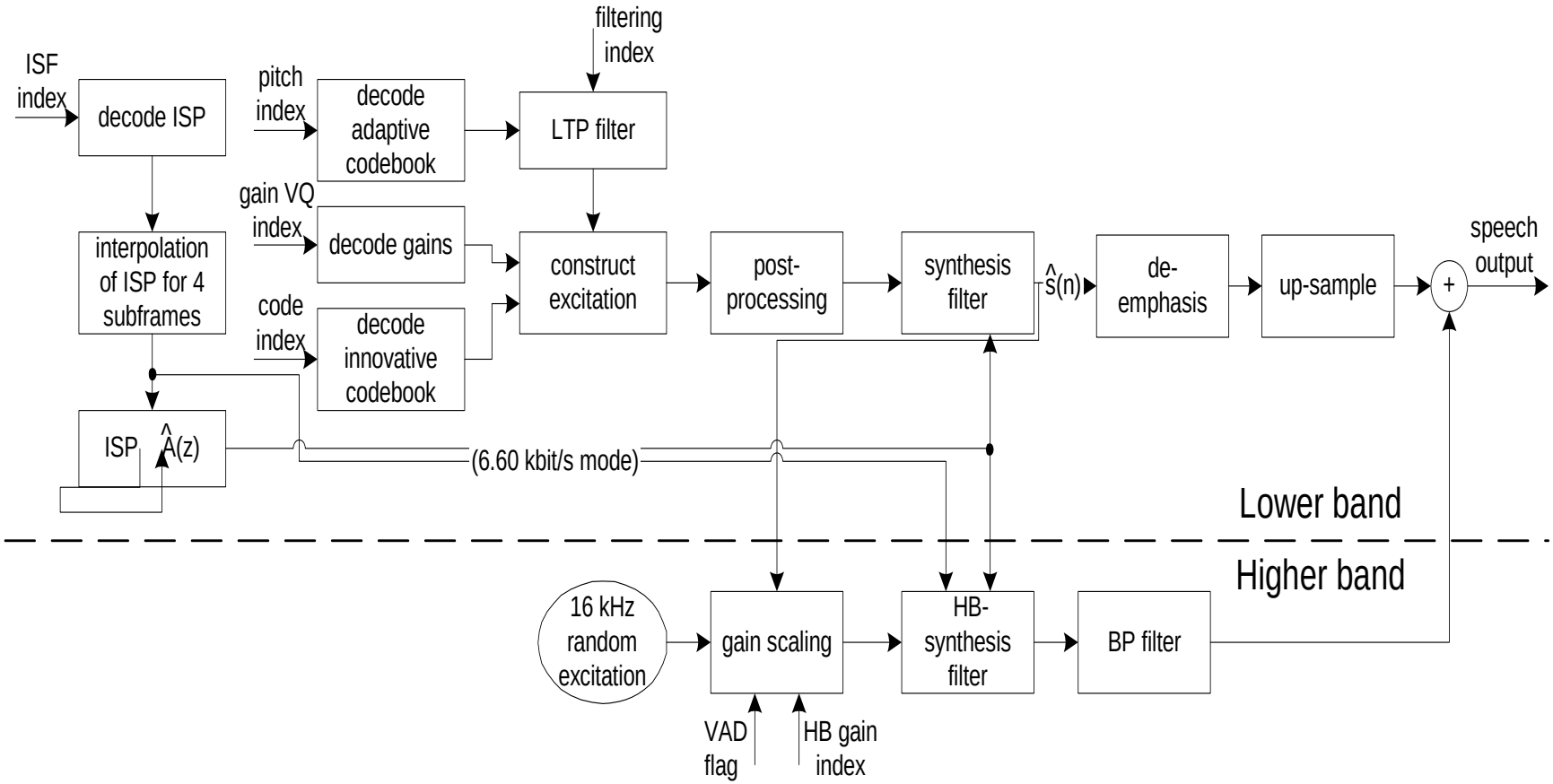
Codec mode	Source codec bit-rate
AMR-WB_23.85	23.85 kbit/s
AMR-WB_23.05	23.05 kbit/s
AMR-WB_19.85	19.85 kbit/s
AMR-WB_18.25	18.25 kbit/s
AMR-WB_15.85	15.85 kbit/s
AMR-WB_14.25	14.25 kbit/s
AMR-WB_12.65	12.65 kbit/s
AMR-WB_8.85	8.85 kbit/s
AMR-WB_6.60	6.60 kbit/s
AMR-WB_SID	1.75 kbit/s *

(*) Assuming SID frames are continuously transmitted

AMR-WB ACELP Speech Encoder



AMR-WB ACELP Speech Decoder



AMR-WB Complexity: WMOPS Figures

WMOPS / Speech Codec + VAD + DTX											
Mode	23.85	23.05	19.85	18.25	15.85	14.25	12.65	8.85	6.60	**TWC**	*WOF est*
Speech encoder	29.07	30.84	**31.14**	30.22	29.41	29.24	26.91	23.59	20.46	**31.14**	-
Speech decoder	6.90	6.89	6.83	6.82	6.79	6.76	6.73	7.47	**7.83**	**7.83**	-
Total Speech	35.97	37.73	**37.97**	37.04	36.20	36.00	33.64	31.06	28.29	**38.97**	*36.13*

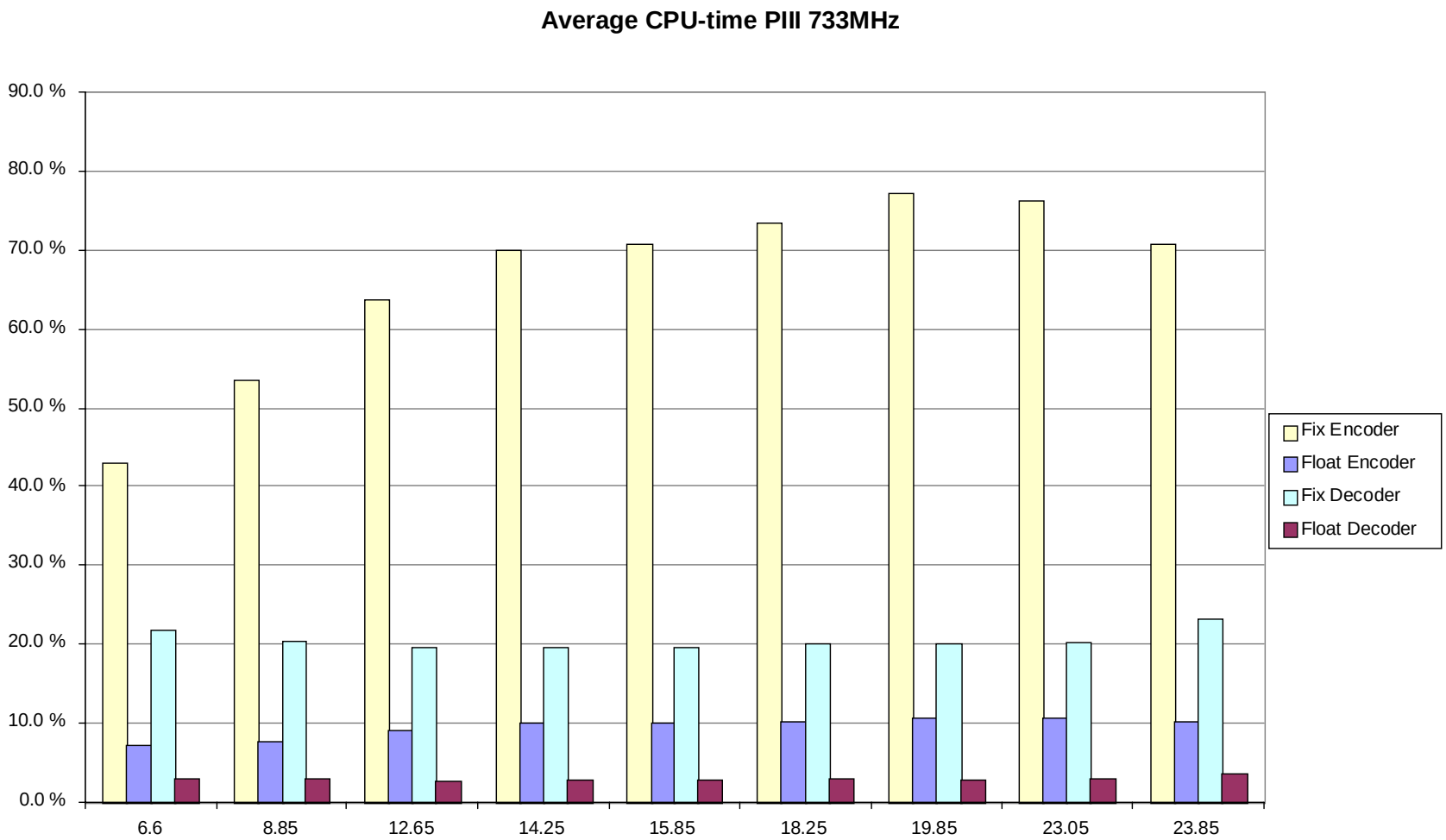
WMOPS / Channel Codec for TCH/WFS											
Mode	23.85	23.05	19.85	18.25	15.85	14.25	12.65	8.85	6.60	**TWC**	*WOF est*
Channel encoder	-	-	0.39	**0.58**	0.51	0.48	0.45	0.42	0.39	**0.58**	-
Channel decoder	-	-	1.32	**3.35**	2.95	2.68	2.42	1.85	1.53	**3.35**	-
Total Channel	-	-	1.71	**3.93**	3.46	3.16	2.87	2.27	1.92	**3.93**	*3.45*

AMR-WB Complexity: Memory Figures

	Data RAM static	Data RAM scratch
Speech Encoder + VAD+DTX	1381 Words	4389 Words
Speech Decoder + DTX	758 Words	
Channel Encoder (TCH/WFS)	229 Words	
Channel Decoder (TCH/WFS)	242 Words	
Link Adaptation	102 Words	
Total	**2712 Words**	**4389 Words**
	Data RAM total 7101 Words	

	Data ROM Tables	Program ROM
Speech Codec + VAD + DTX	9929 Words	3889 basic-ops
Channel Codec (TCH/WFS)	3075 Words	418 basic-ops
Link Adaptation	105 Words	48 basic-ops
Common (log2, oper32b)	--	35 basic-ops
Total	**13109 Words**	**4390 basic-ops**

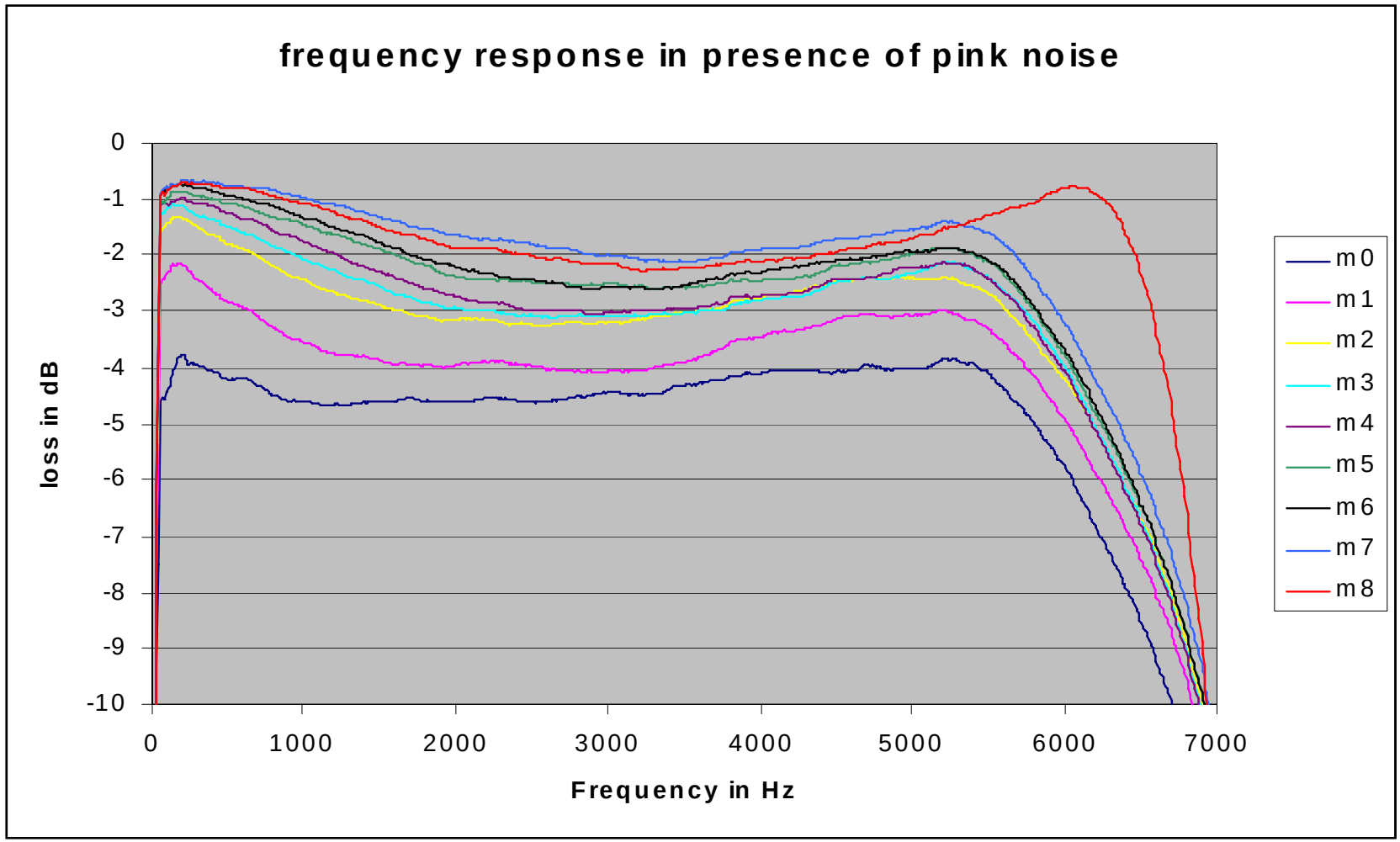
AMR-WB Complexity: Fixed / Floating-Point Versions on PC



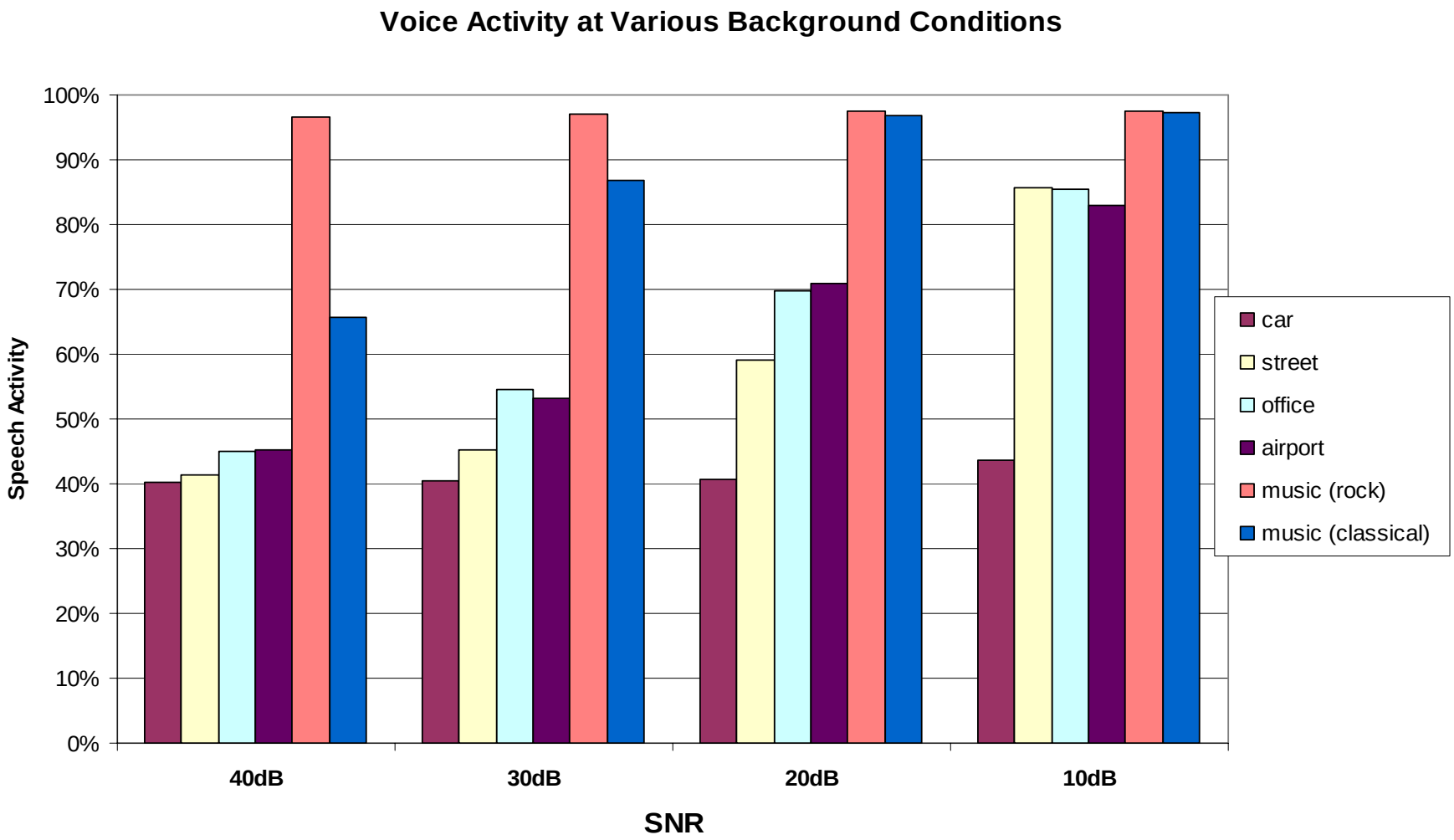
AMR-WB Verification Phase

	Description	Contributing Organisation(s)
1.	Performances with DTMF Tones	BT
2.	Performances with Special Input Signals	Nokia
3.	Overload Performance (objective tests and informal listening)	Matsushita
4.	Muting Behaviour	Nortel Networks
5.	Transmission Delay (Round Trip) (TFO guidance)	Nortel Networks
6.	Frequency Response	France Telecom
7.	Complexity Analysis	Alcatel, STMicroelectronics, Philips Semiconductor
8.	Comfort Noise Generation	Ericsson
9.	Performance with music signals (informal expert listening)	Deutsche Telekom
10.	Switching Performance between AMR and AMR-WB modes (note AMR-WB code does not include this switching capability)	Siemens

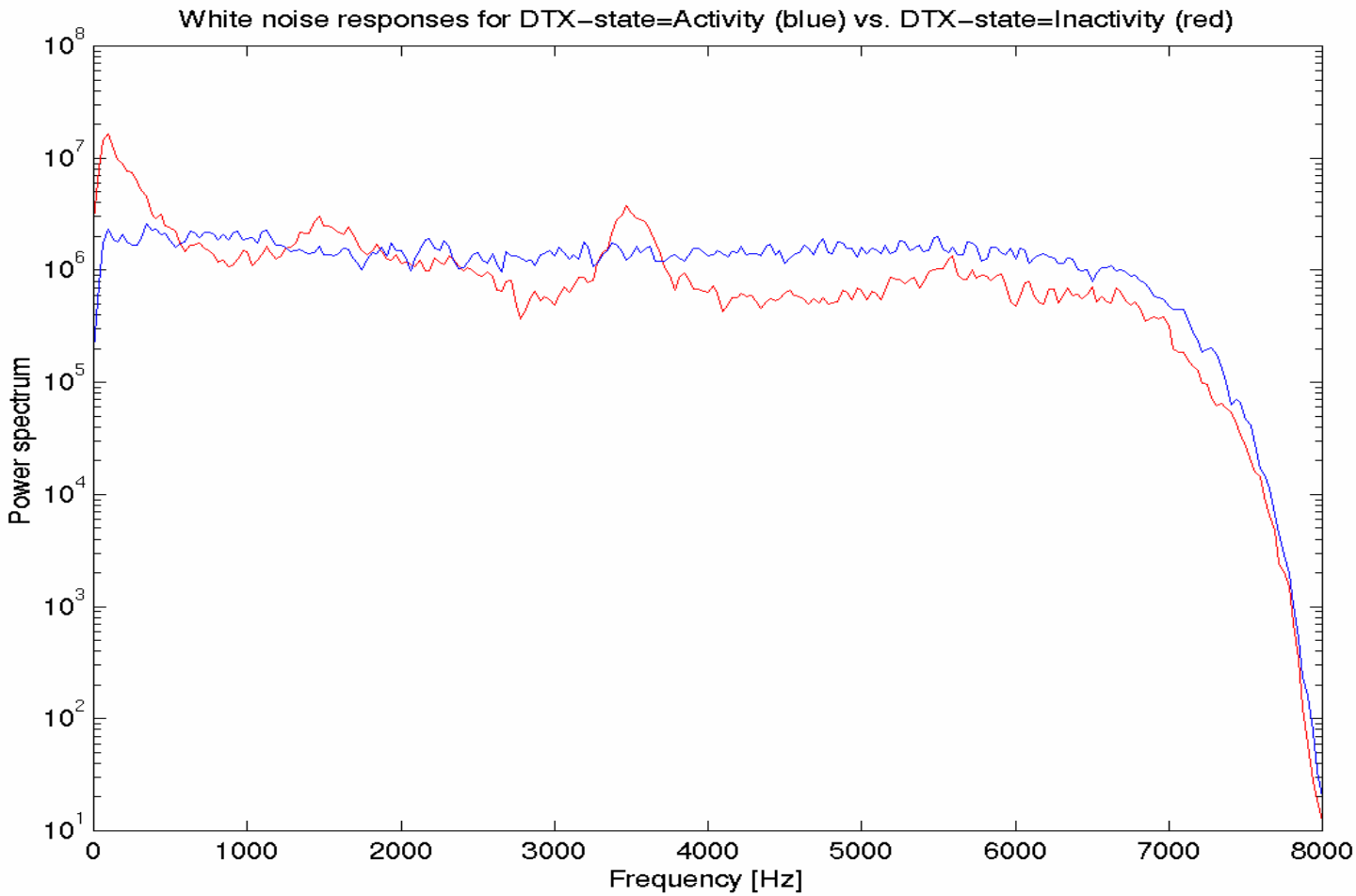
AMR-WB Frequency Response: Method Dependent



AMR-WB VAD Performance



AMR-WB CNG Performance

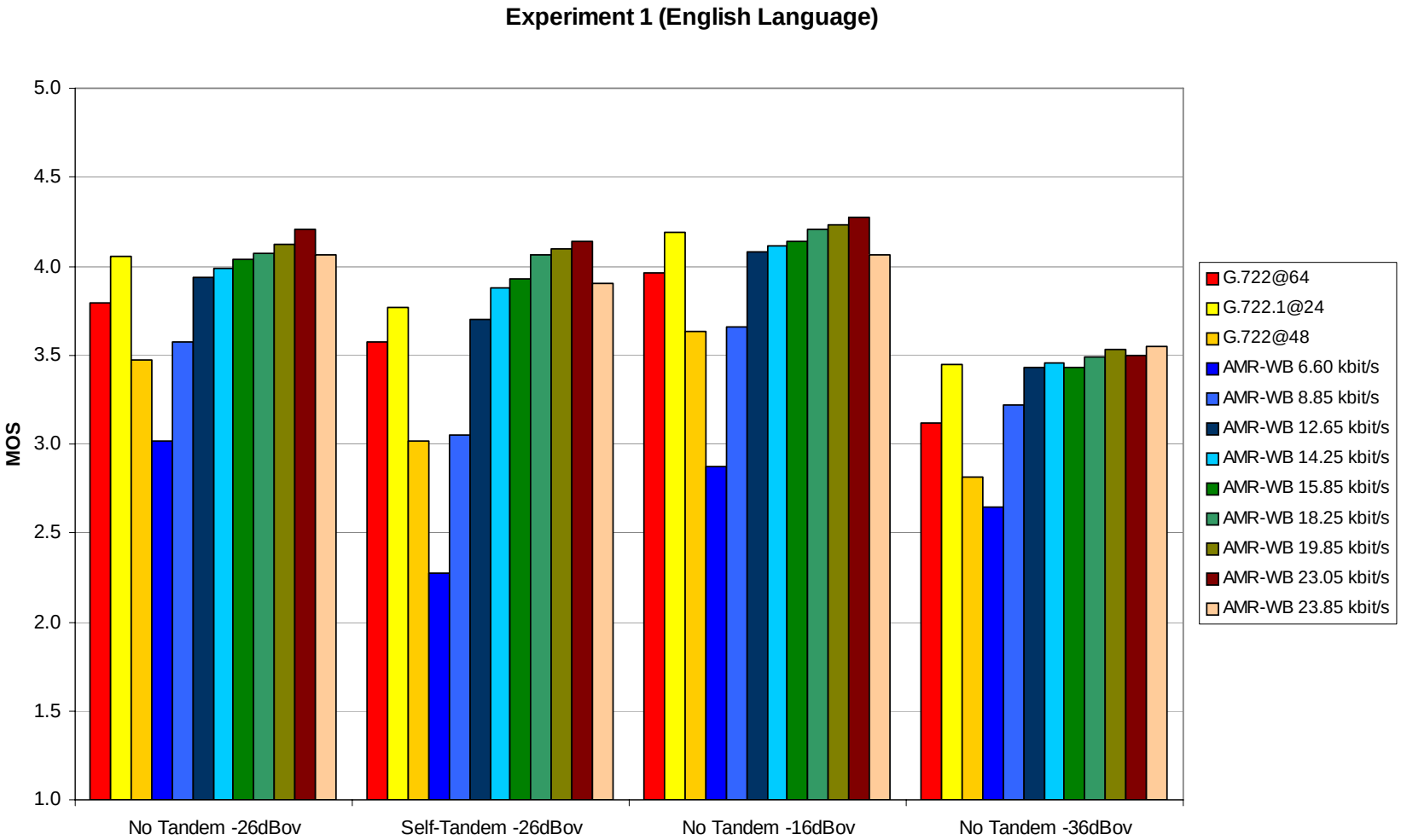


Index

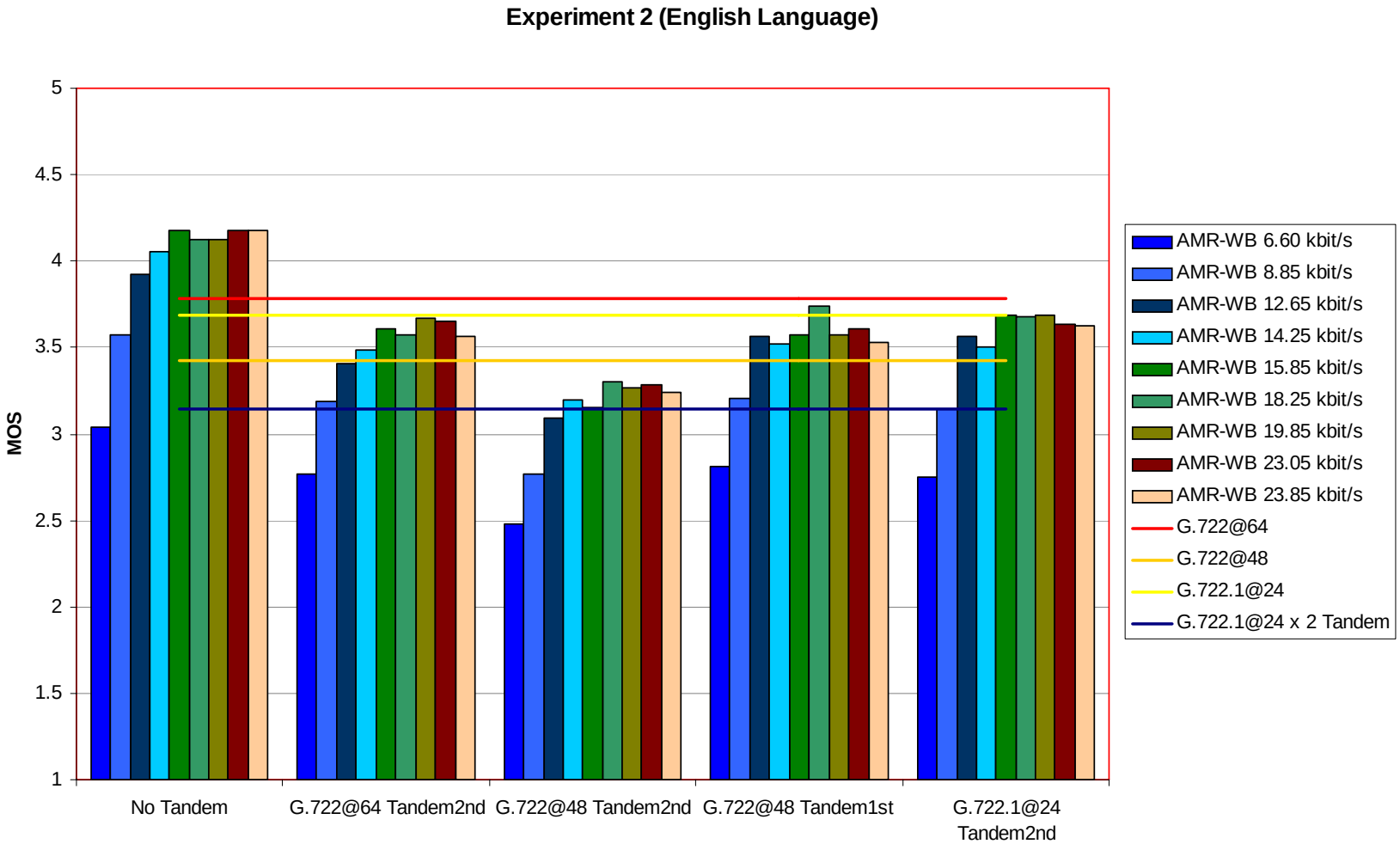
AMR-WB Characterization Phase Organization

- Phase 1A - completed by SA#12 (June 2001)
  - **Performance without channel errors (all applications)**
  - **Performance in GSM FR GMSK channel with channel errors**
  - **6 experiments**
- Phase 1B - completed by SA#14 (December 2001)
  - **Performance in 3G WCDMA channel**
  - **2 experiments**
- Phase 2 – completed by SA#24 (June 2004)
  - **Performance in conversational PSC applications**
  - **2 experiments**

AMR-WB Characterization Exp. 1 (ACR) Various Input Levels and Self-Tandeming (Clean Speech)

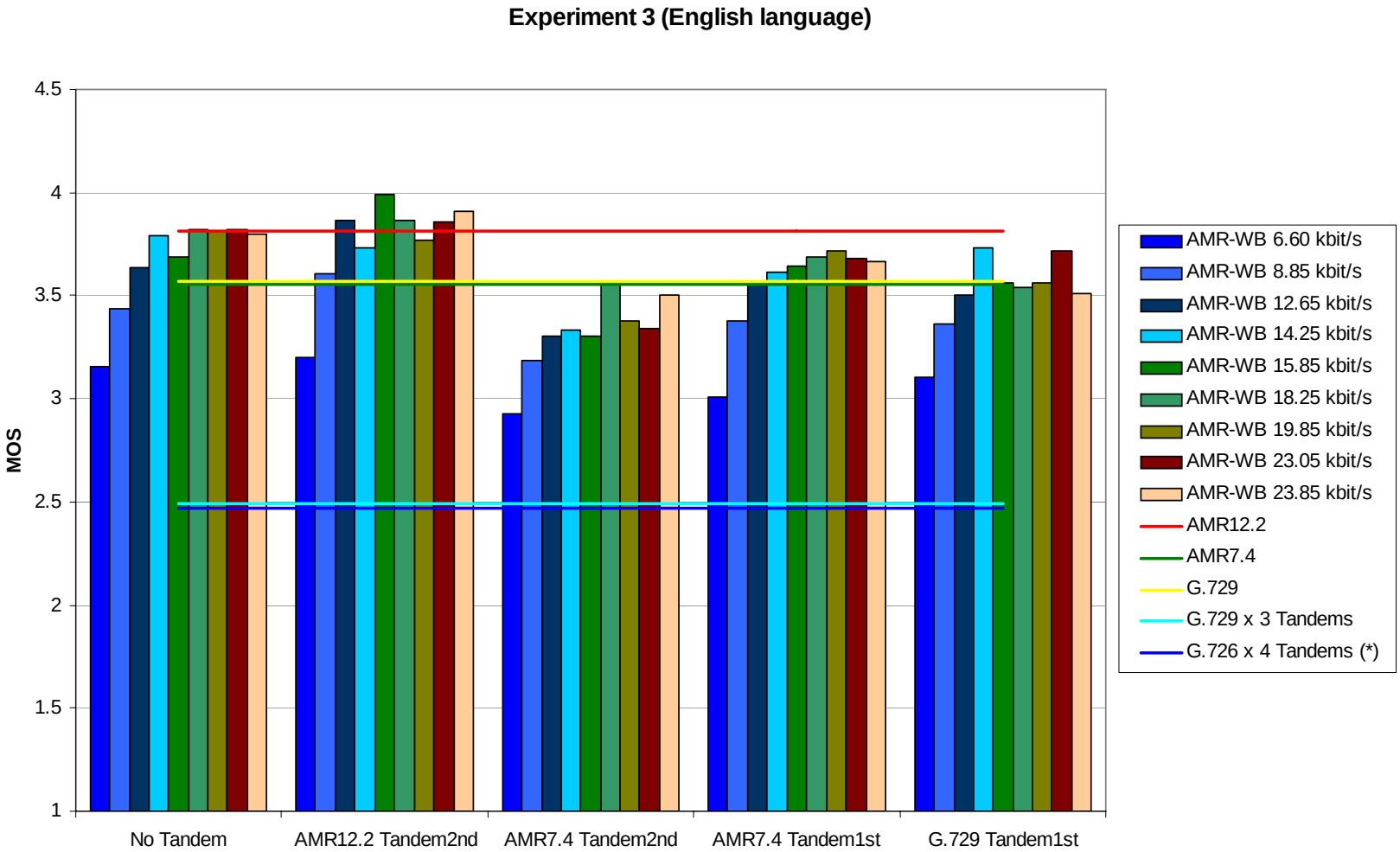


AMR-WB Characterization Exp. 2 (ACR) Wideband Interoperability Performance (Clean Speech)

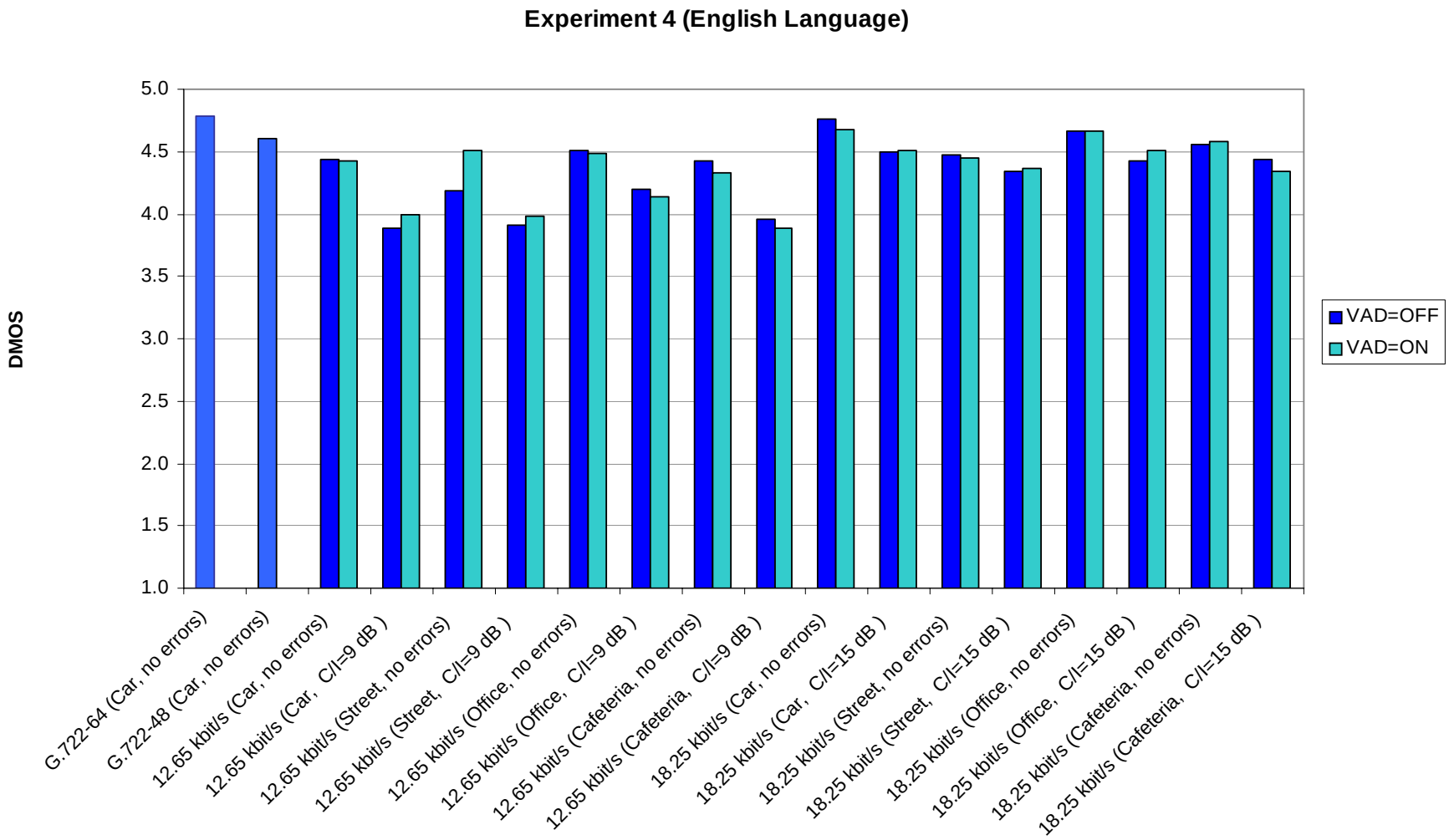


Standards for Business

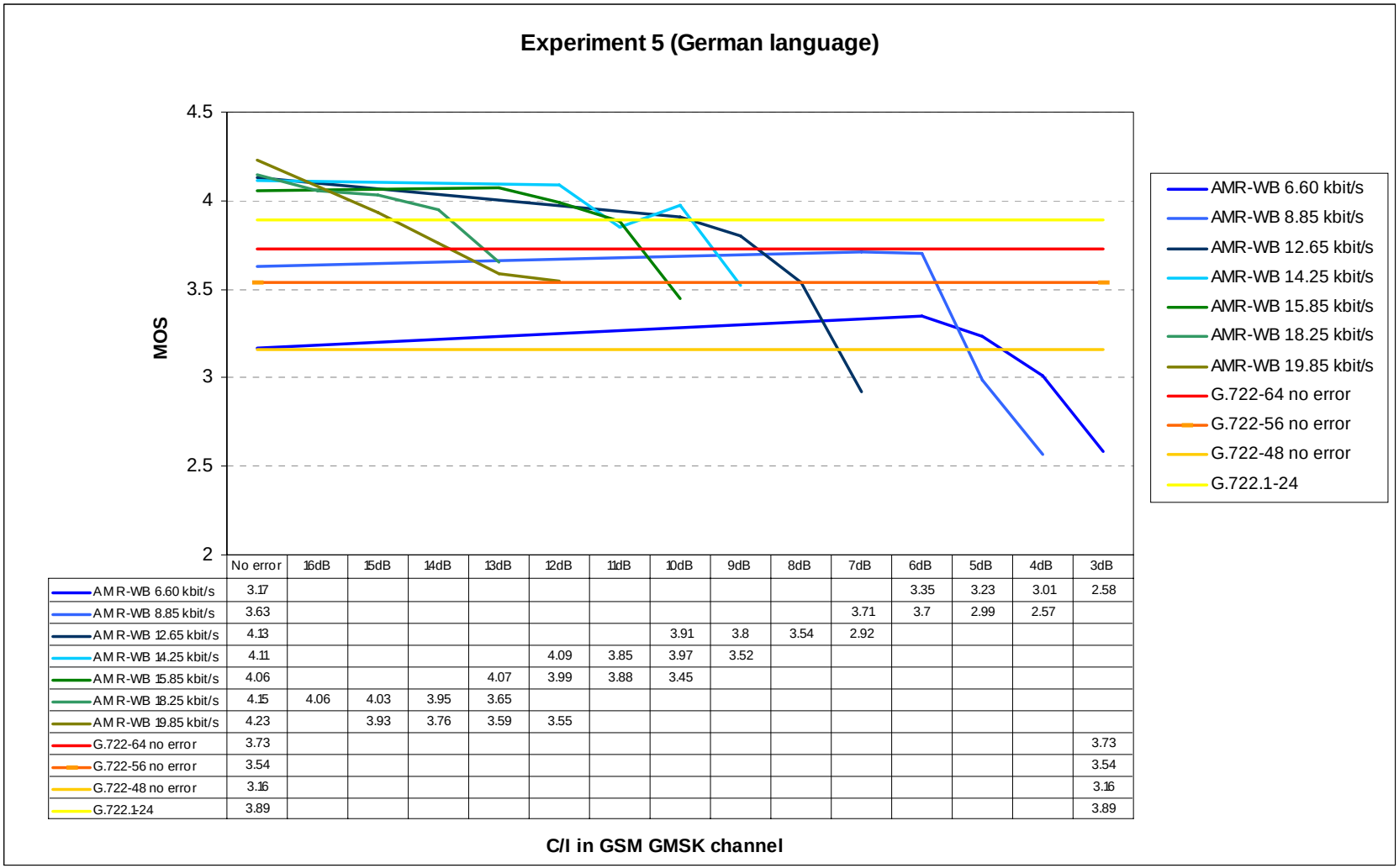
AMR-WB Characterization Exp. 3 (ACR) Narrowband Interoperability Performance (Clean Speech)



AMR-WB Characterization Exp. 4 (DCR) VAD/DTX/CNG Performance (Noisy Speech)

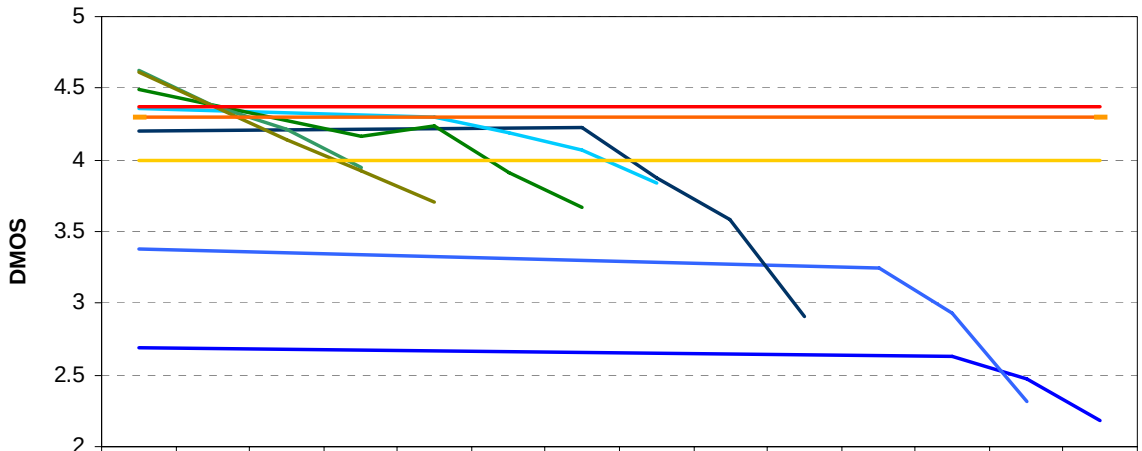


AMR-WB Characterization Exp. 5 (ACR) Static Errors in GSM FR (Clean Speech)



	No error	16dB	15dB	14dB	13dB	12dB	11dB	10dB	9dB	8dB	7dB	6dB	5dB	4dB	3dB
AMR-WB 6.60 kbit/s	3.17											3.35	3.23	3.01	2.58
AMR-WB 8.85 kbit/s	3.63										3.71	3.7	2.99	2.57	
AMR-WB 12.65 kbit/s	4.13							3.91	3.8	3.54	2.92				
AMR-WB 14.25 kbit/s	4.11					4.09	3.85	3.97	3.52						
AMR-WB 15.85 kbit/s	4.06				4.07	3.99	3.88	3.45							
AMR-WB 18.25 kbit/s	4.15	4.06	4.03	3.95	3.65										
AMR-WB 19.85 kbit/s	4.23		3.93	3.76	3.59	3.55									
G.722-64 no error	3.73														3.73
G.722-56 no error	3.54														3.54
G.722-48 no error	3.16														3.16
G.722.1-24	3.89														3.89

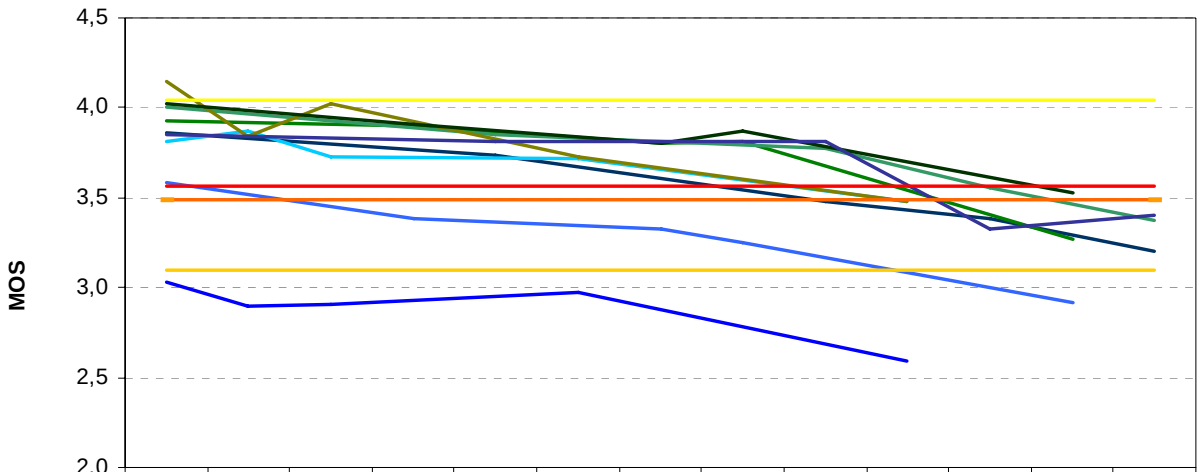
AMR-WB Characterization Exp. 6a (DCR) Static Errors in GSM FR (Car Noise 15dB)



	No error	15dB	14dB	13dB	12dB	11dB	10dB	9dB	8dB	7dB	6dB	5dB	4dB	3dB
AMR-WB 6.60 kbit/s	2.688											2.625	2.469	2.177
AMR-WB 8.85 kbit/s	3.385										3.24	2.927	2.313	
AMR-WB 12.65 kbit/s	4.198						4.229	3.875	3.583	2.906				
AMR-WB 14.25 kbit/s	4.354				4.302	4.188	4.063	3.833						
AMR-WB 15.85 kbit/s	4.49			4.167	4.24	3.917	3.667							
AMR-WB 18.25 kbit/s	4.625	4.385	4.219	3.948										
AMR-WB 19.85 kbit/s	4.615		4.146	3.927	3.708									
G.722-64 no error	4.38													4.38
G.722-56 no error	4.30													4.30
G.722-48 no error	3.99													3.99

C/I in GSM GMSK channel

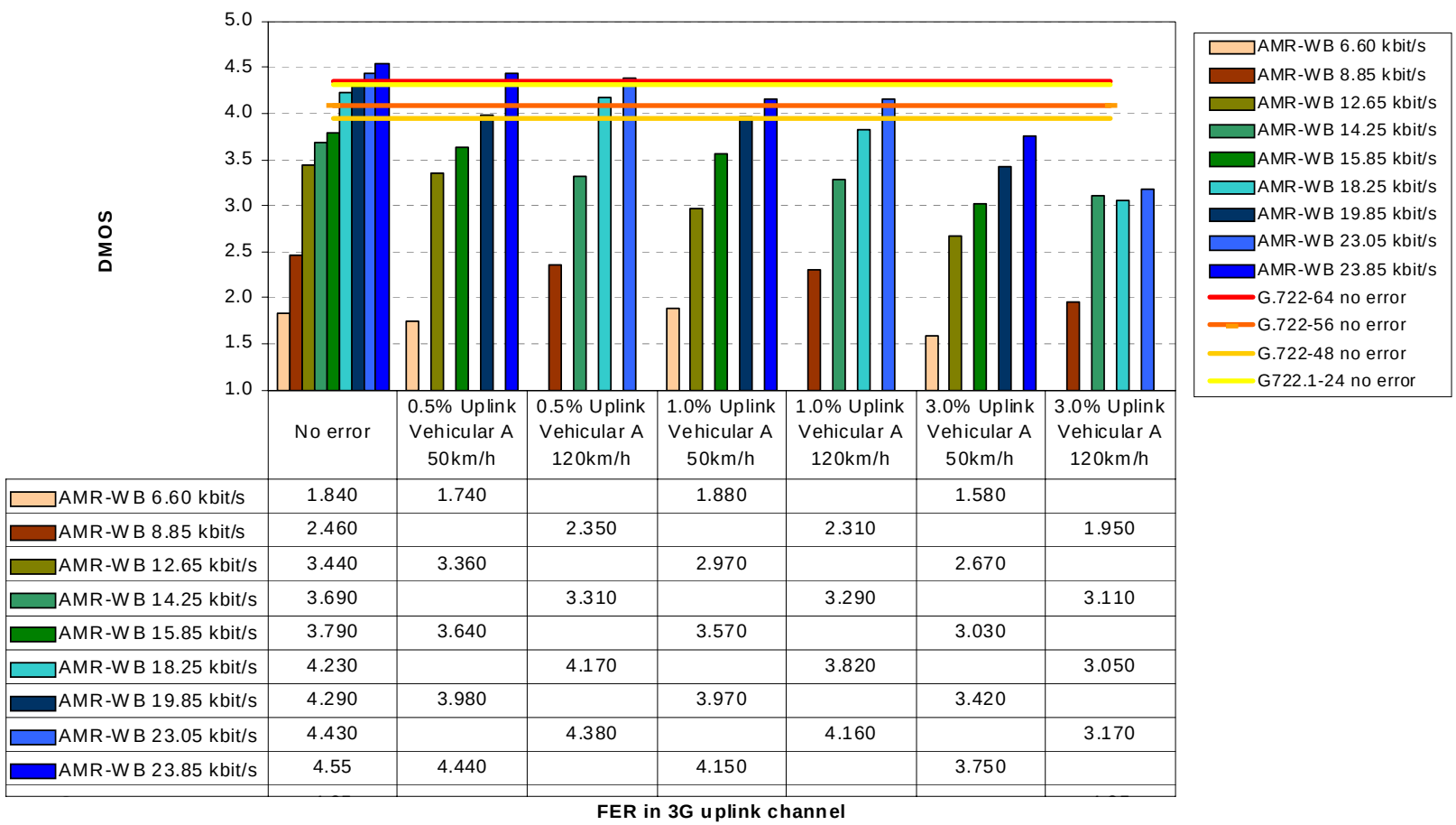
AMR-WB Characterization Exp. 7b (ACR)
Static Errors in 3G DL (Clean Speech)



	No error	0.5%Ve 50km/h	0.5%Ve 120km/h	0.5%Pe 3km/h	0.5%In 3km/h	1.0%Ve 50km/h	1.0%Ve 120km/h	1.0%Pe 3km/h	1.0%In 3km/h	3.0%Ve 50km/h	3.0%Ve 120km/h	3.0%Pe 3km/h	3.0%In 3km/h
AMR-WB 6.60 kbit/s	3,0313	2,8958	2,9063			2,9688				2,5938			
AMR-WB 8.85 kbit/s	3,5833			3,3854			3,3229	3,25				2,9167	
AMR-WB 12.65 kbit/s	3,86				3,7396				3,4792		3,3854		3,1979
AMR-WB 14.25 kbit/s	3,81	3,875	3,7292			3,7188				3,4792			
AMR-WB 15.85 kbit/s	3,9271			3,8958			3,8021	3,8125				3,2708	
AMR-WB 18.25 kbit/s	4,00				3,85				3,7708		3,5521		3,375
AMR-WB 19.85 kbit/s	4,1458	3,8438	4,0208			3,7292				3,4792			
AMR-WB 23.05 kbit/s	4,0208			3,9063			3,8021	3,875				3,5313	
AMR-WB 23.85 kbit/s	3,8542				3,8125				3,8125		3,3229		3,4063
G.722-64 no error	3,5625												3,5625
G.722-56 no error	3,4896												3,4896
G.722-48 no error	3,0938												3,0938
Direct	4,0417												4,0417

FER in 3G downlink channel [Profiles: "Ve=Vehicular", "Pe=Pedestrian", "In=Indoor"]

AMR-WB Characterization Exp. 8a (DCR)
Static Errors in 3G UL (Car Noise)



	No error	0.5% Uplink Vehicular A 50km/h	0.5% Uplink Vehicular A 120km/h	1.0% Uplink Vehicular A 50km/h	1.0% Uplink Vehicular A 120km/h	3.0% Uplink Vehicular A 50km/h	3.0% Uplink Vehicular A 120km/h
AMR-WB 6.60 kbit/s	1.840	1.740		1.880		1.580	
AMR-WB 8.85 kbit/s	2.460		2.350		2.310		1.950
AMR-WB 12.65 kbit/s	3.440	3.360		2.970		2.670	
AMR-WB 14.25 kbit/s	3.690		3.310		3.290		3.110
AMR-WB 15.85 kbit/s	3.790	3.640		3.570		3.030	
AMR-WB 18.25 kbit/s	4.230		4.170		3.820		3.050
AMR-WB 19.85 kbit/s	4.290	3.980		3.970		3.420	
AMR-WB 23.05 kbit/s	4.430		4.380		4.160		3.170
AMR-WB 23.85 kbit/s	4.55	4.440		4.150		3.750	

Index