TI | Developer Conference
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Minds in Motion

Optimizing Speech and Audio Codecs on C55x and C64x DSPs

Claude Gravel
VP Engineering

VoiceAge®
www.voiceage.com
The World's Premier Supplier of Speech and Audio Codecs

Contents

- Introduction
- Speech and Audio Models
- AMR-WB+ Hybrid Audio and Speech Coding Model
- AMR-WB+ Performance Results
- Implementation Optimization on TI Platforms
- Conclusions + Q&A

VoiceAge Corporation – Who are we?

VoiceAge®

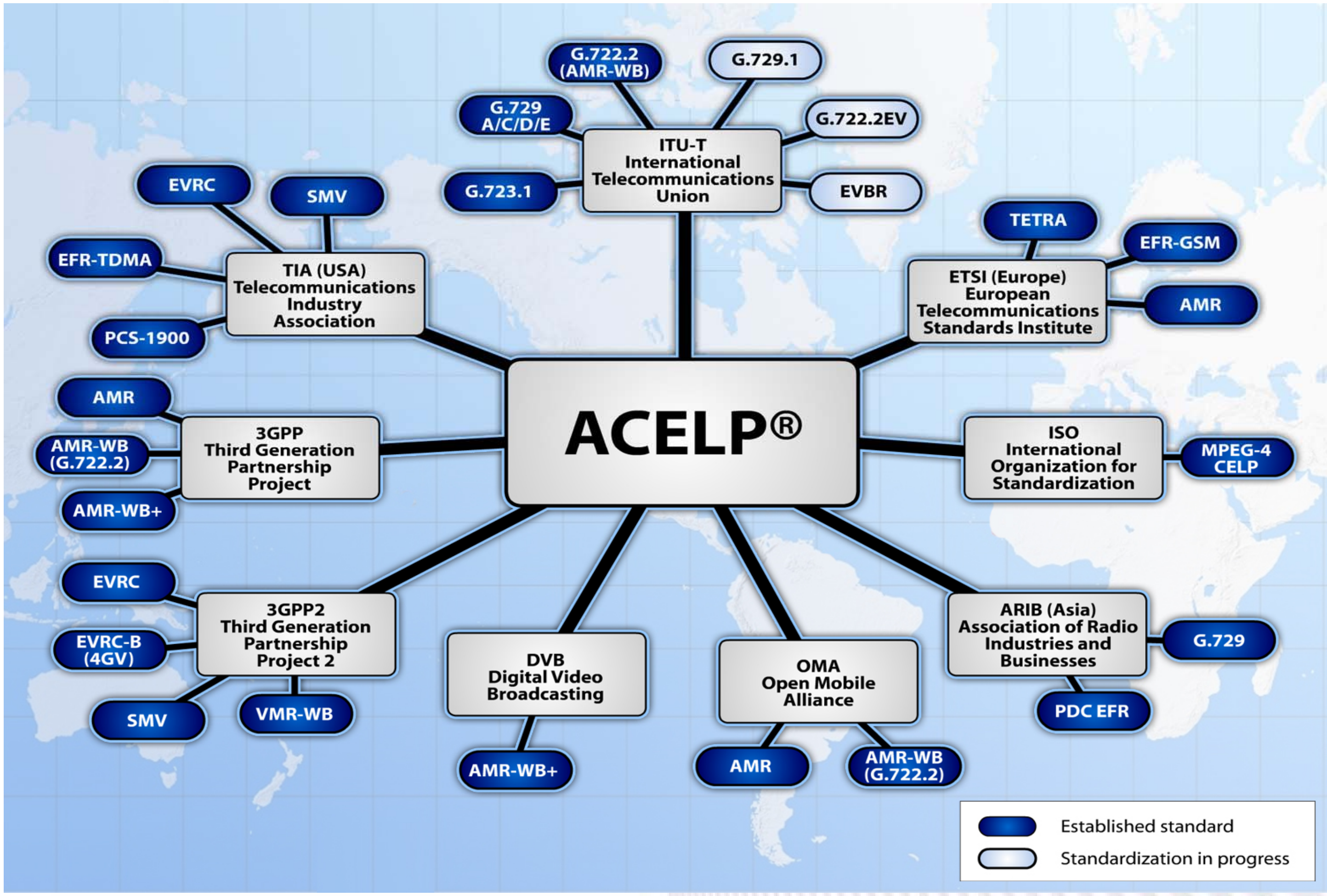
www.voiceage.com

The World's Premier Supplier of Speech and Audio Codecs

Business	**Low bit rate audio compression technologies research, IPR licensing and optimized implementations development**
Headquarters	**Montreal, Canada**
Technologies	***AMR :* 3GPP narrowband voice codec for GSM and WCDMA** ***AMR-WB :* 3GPP, ITU-T wideband voice codec** ***VMR-WB :* 3GPP2 wideband voice codec** ***AMR-WB+ :* 3GPP audio codec**
Achievements	**Won every international audio compression standard for which VoiceAge competed in the last 10 years at 3GPP, 3GPP2, ITU, ETSI, TIA**
Implementations	**World-class optimized implementations and proprietary solutions on multiple O/S and processors/platforms (including TI & ARM based systems)**
Deployment	**More than 1.7B mobile phones and over 500M PCs currently use VoiceAge's technologies**

Minds in Motion

International Standards Using ACELP®



ACELP®

ITU-T International Telecommunications Union

- G.722.2 (AMR-WB)
- G.729.1
- G.722.2EV
- EVBR
- G.723.1
- G.729 A/C/D/E

TIA (USA) Telecommunications Industry Association

- EVRC
- SMV
- EFR-TDMA
- PCS-1900

ETSI (Europe) European Telecommunications Standards Institute

- TETRA
- EFR-GSM
- AMR

3GPP Third Generation Partnership Project

- AMR
- AMR-WB (G.722.2)
- AMR-WB+

ISO International Organization for Standardization

- MPEG-4 CELP

3GPP2 Third Generation Partnership Project 2

- EVRC
- EVRC-B (4GV)
- SMV
- VMR-WB

DVB Digital Video Broadcasting

- AMR-WB+

OMA Open Mobile Alliance

- AMR
- AMR-WB (G.722.2)

ARIB (Asia) Association of Radio Industries and Businesses

- G.729
- PDC EFR

⬬ Established standard

⬭ Standardization in progress

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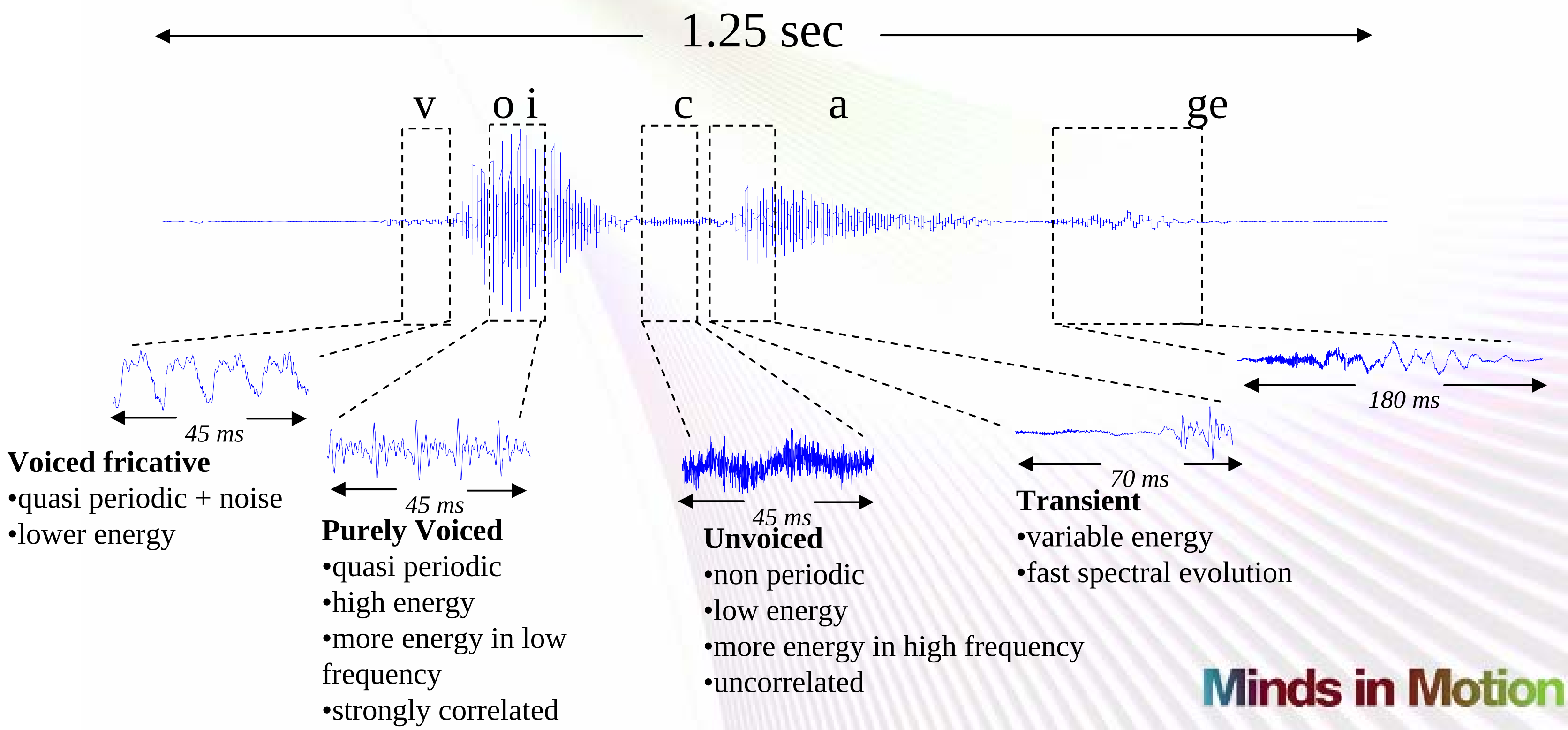
Speech Signal

– Basically, same synthesis model for everyone

– So, speech has a “universal” structure or signature



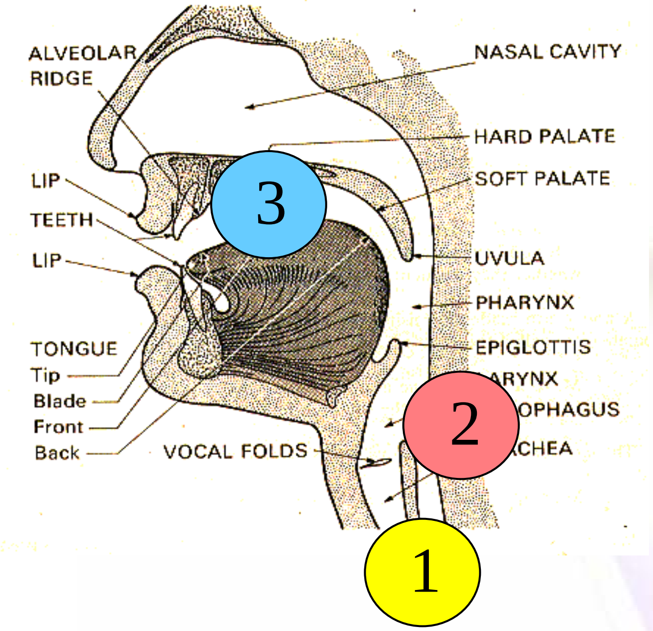
Voiced fricative
- quasi periodic + noise
- lower energy

Purely Voiced
- quasi periodic
- high energy
- more energy in low frequency
- strongly correlated

Unvoiced
- non periodic
- low energy
- more energy in high frequency
- uncorrelated

Transient
- variable energy
- fast spectral evolution

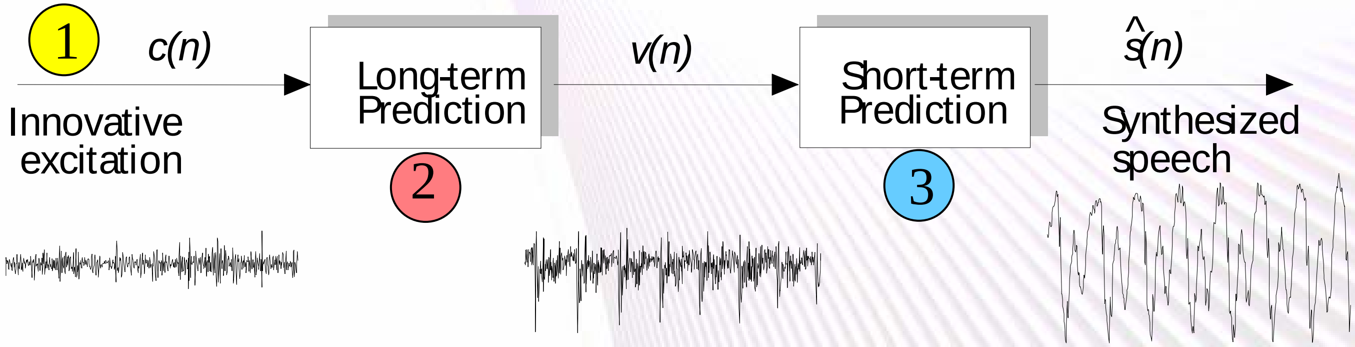
Speech Synthesis Model



1 Air from lungs

2 Vocal chords (periodicity)

3 Vocal tract (mouth + lips)



1 $c(n)$

Innovative excitation

Long-term Prediction

2

$v(n)$

Short-term Prediction

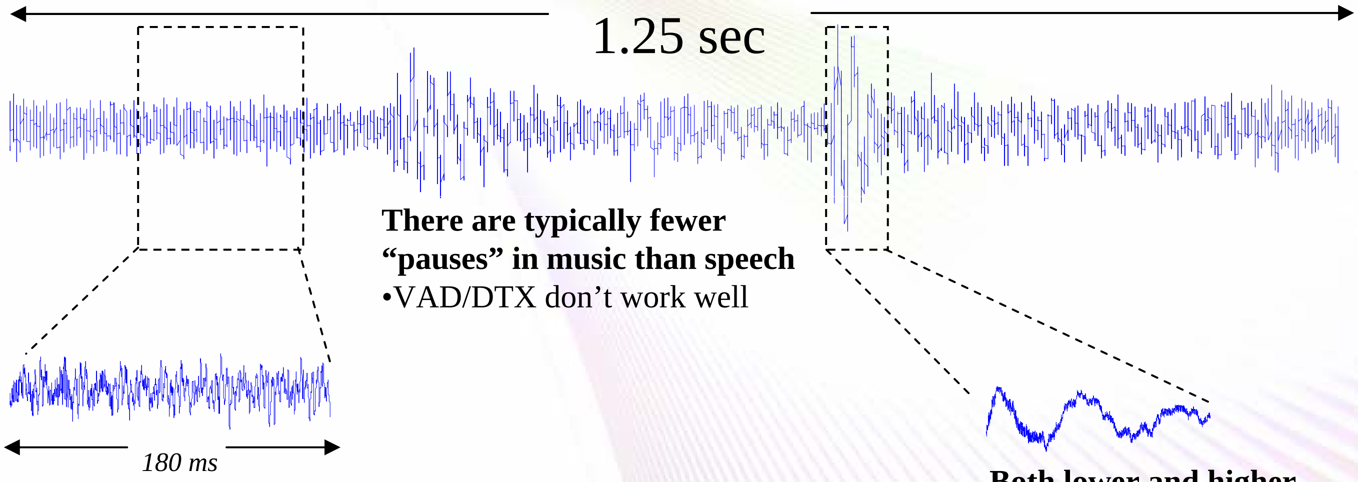
3

$\hat{s}(n)$

Synthesized speech

Audio Signal

- No underlying synthesis model
- What you call music, I may call noise (and vice versa)
- Speech coders not well adapted to music



There are typically fewer "pauses" in music than speech
•VAD/DTX don't work well

Typical audio segment
•More stationary
•More complex (structure less visible than speech)

Both lower and higher frequency content
•More "presence" (LF)
•More "crispness" (HF)
•Larger bandwidth to encode

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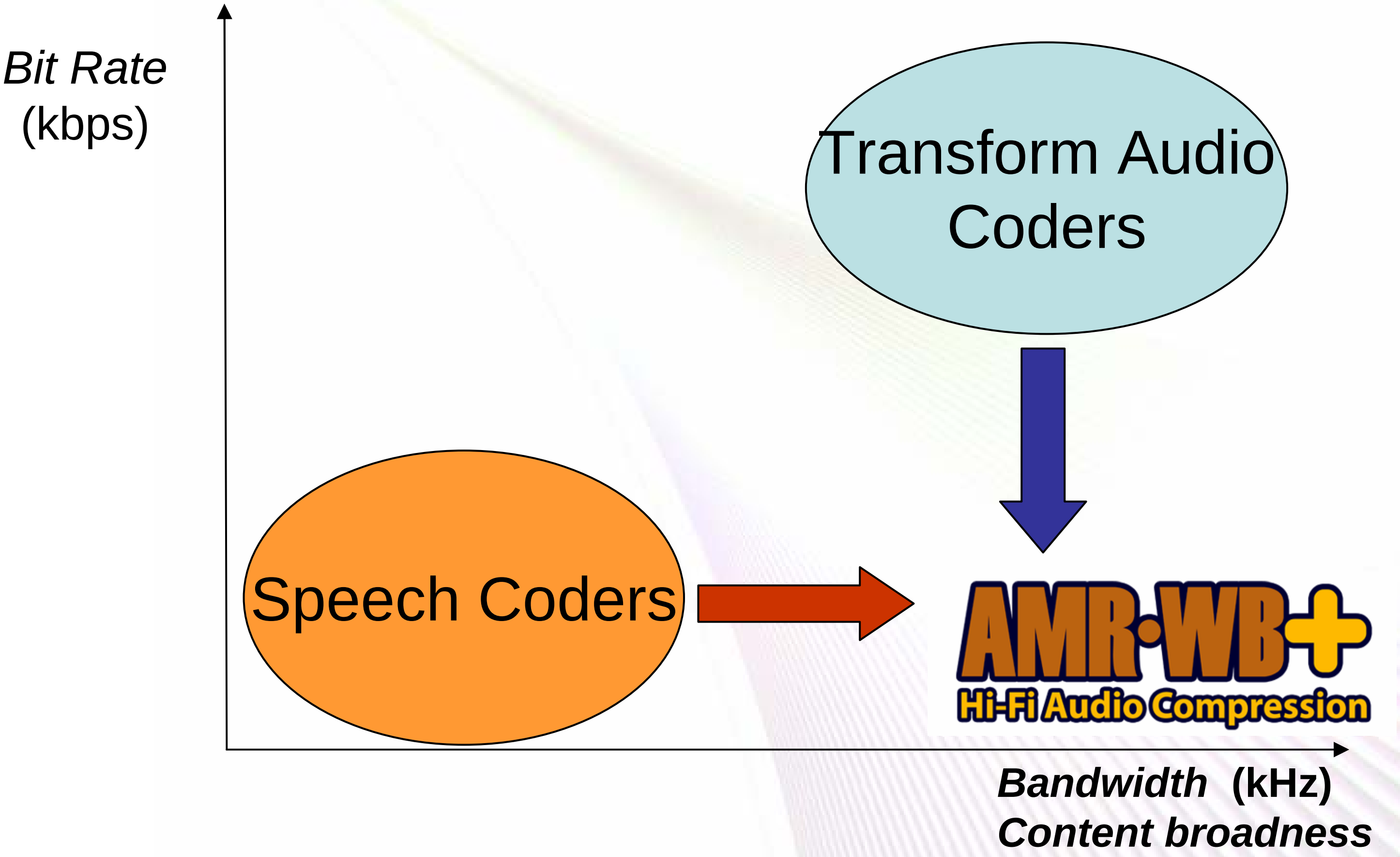
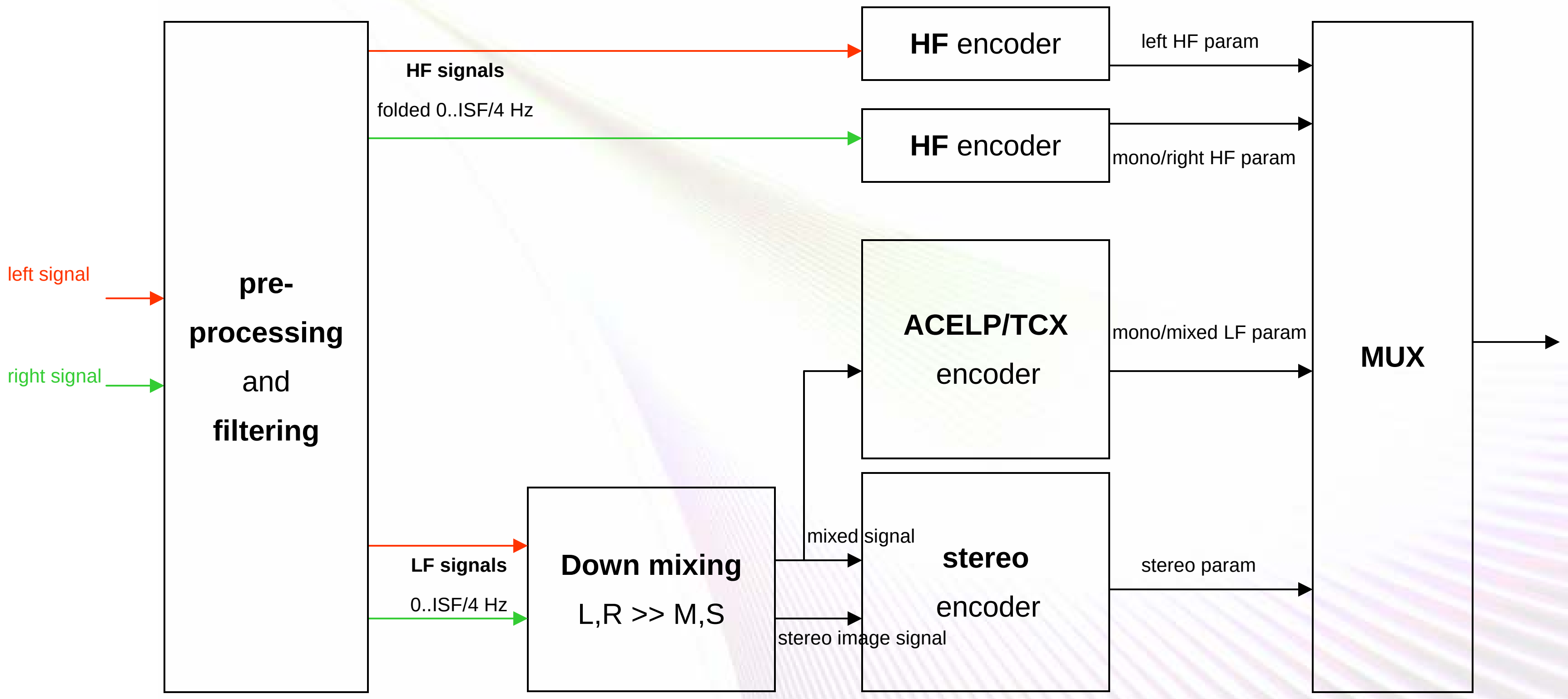
AMR-WB+ Hybrid Approach



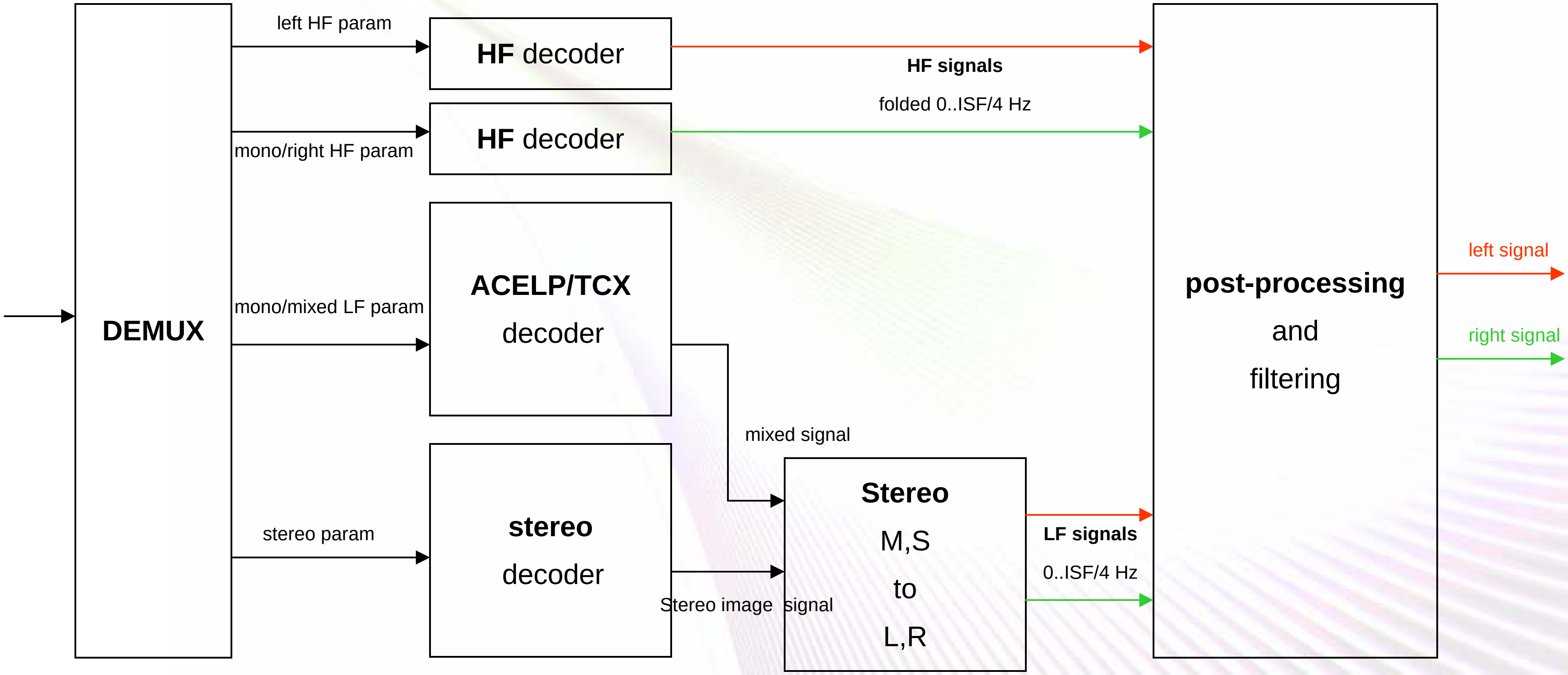
AMR-WB+ Technical Highlights

- Backward compatibility with AMR-WB, the mandatory wideband codec in 3GPP Release 5 specification
- Hybrid ACELP/TCX coding model
  - ACELP (Algebraic CELP)
  - TCX (Transform Coded eXcitation) with Algebraic VQ (AVQ)
- Adaptive window length with superframes of 80 ms
- Closed-loop/ open-loop excitation mode decision
- Bandwidth extension using low bit rate
- Parametric stereo coding (HeHvS)
- Efficient error concealment against packet losses
- Use of over-/underclocking concepts and AVQ features
  - Codec flexibility/tunability
  - Bit rate scalability (6 to 48 kbps)
  - Bandwidth scalability (6.4 to 19.2 kHz)

AMR-WB+ Encoder Architecture



AMR-WB+ Decoder Architecture



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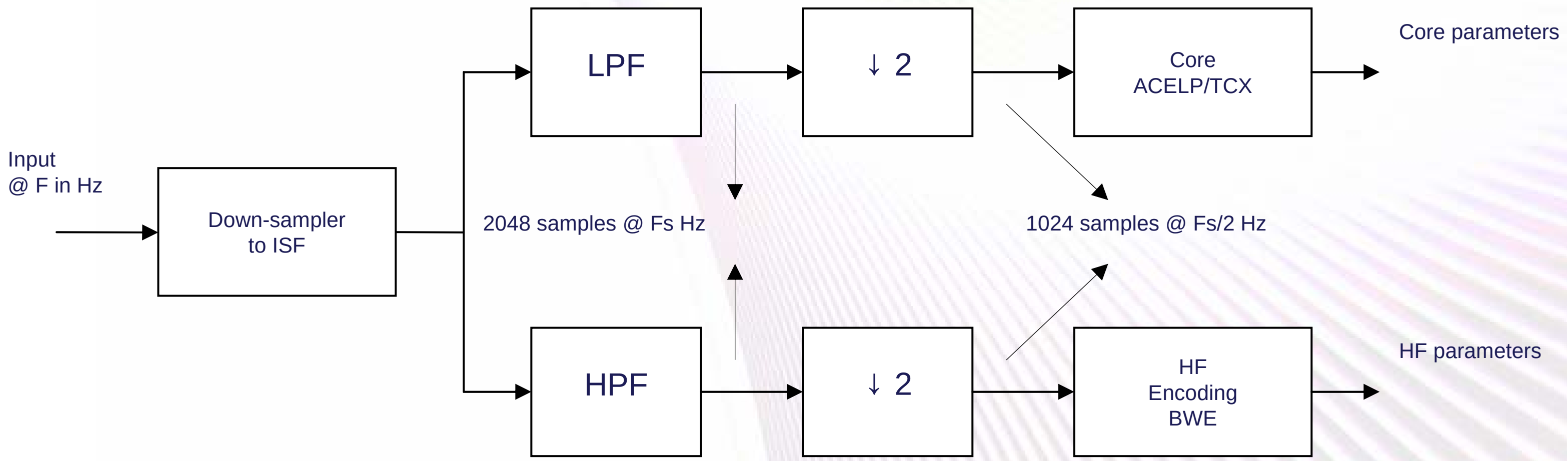
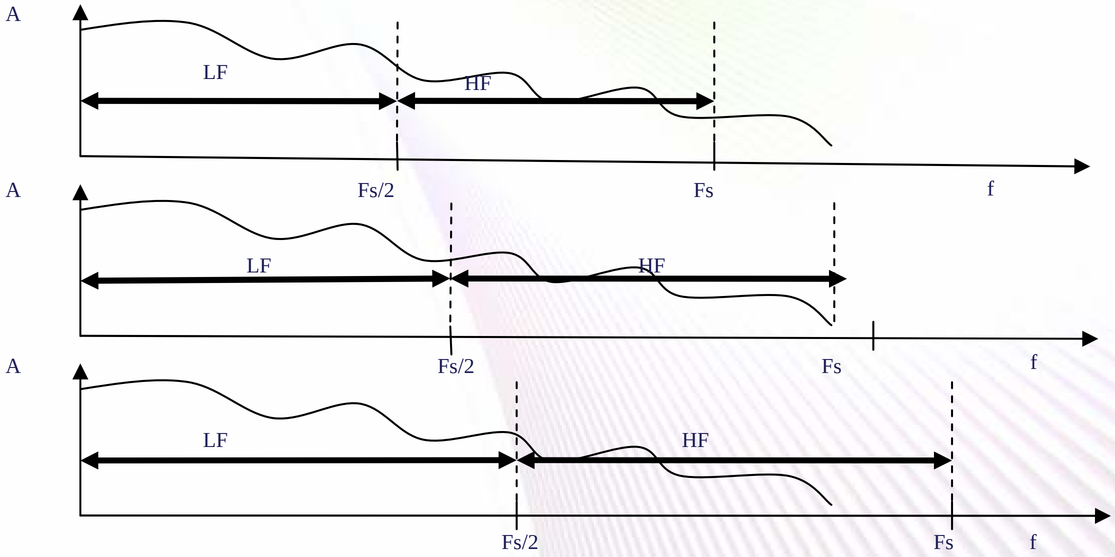
Sampling and Bandwidth

- Input signal downsampled to internal sampling frequency (ISF) [14.4 – 38.4 kHz] (nominal 25.6 kHz)
- Codec operates on 2048-sample superframes
  - [160 – 53.33 ms] (nominal 80 ms)
- The superframe is split into two bands of 1024 samples
  - Low band: 0 – ISF/4
  - High band: ISF/4 – ISF/2

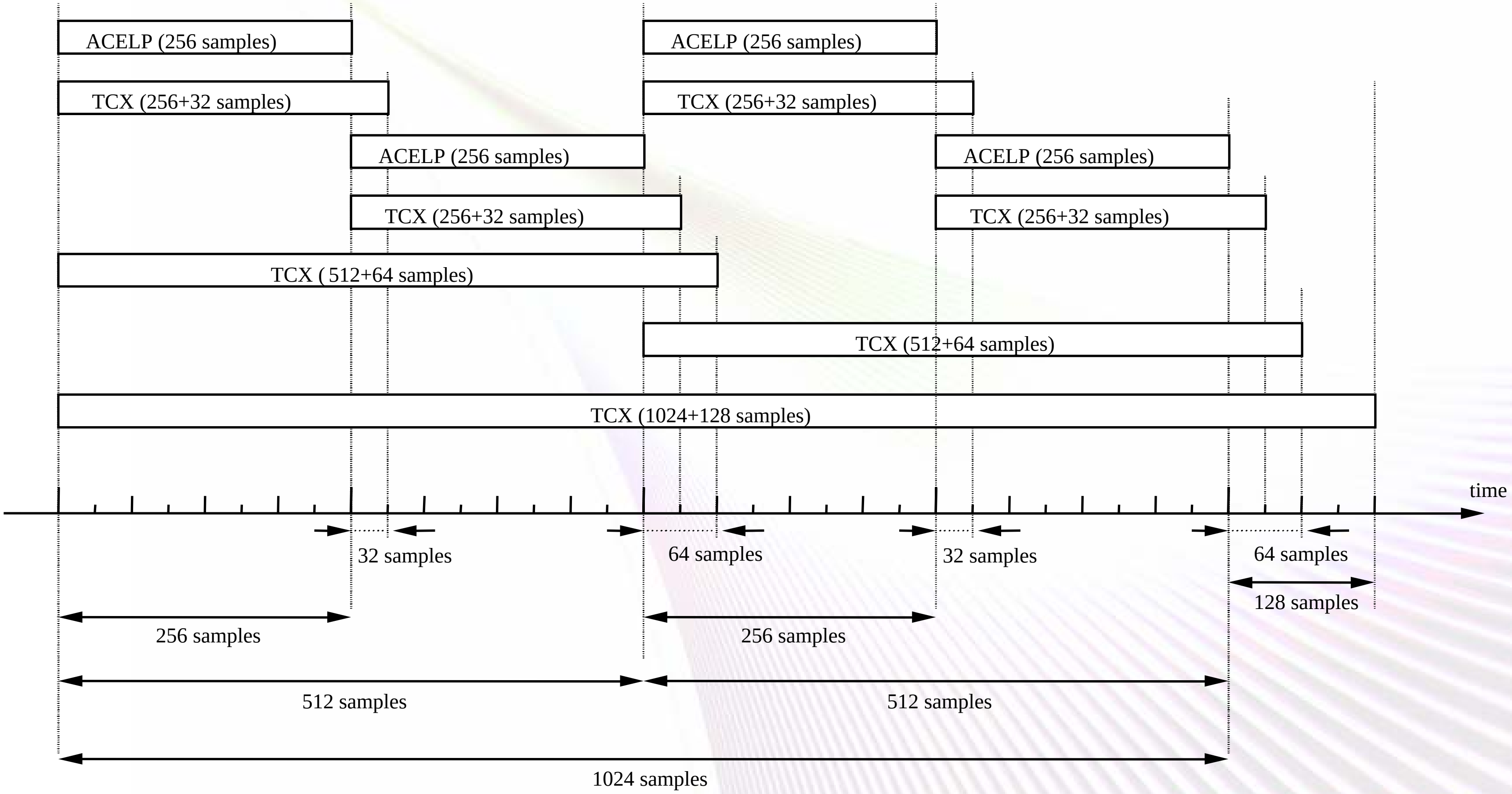


Sampling and Bandwidth

- **ISF can be set to limit the encoded signal when the bit rate is reduced.**
- **ISF can be chosen to exceed the signal bandwidth to maximize the fully encoded band with the core codec.**



Encoder Mode of Operation



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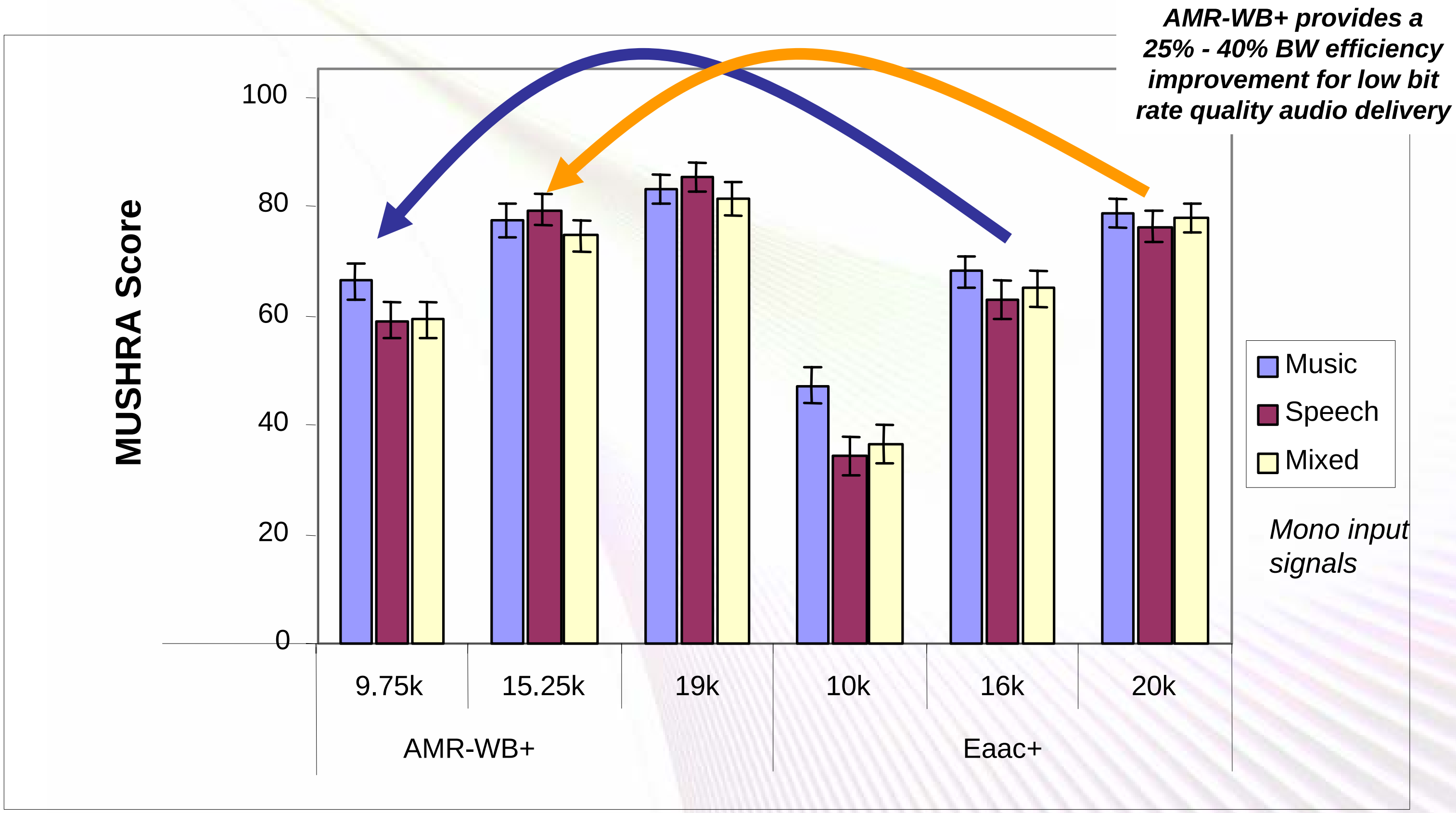
Results from 3GPP Characterization

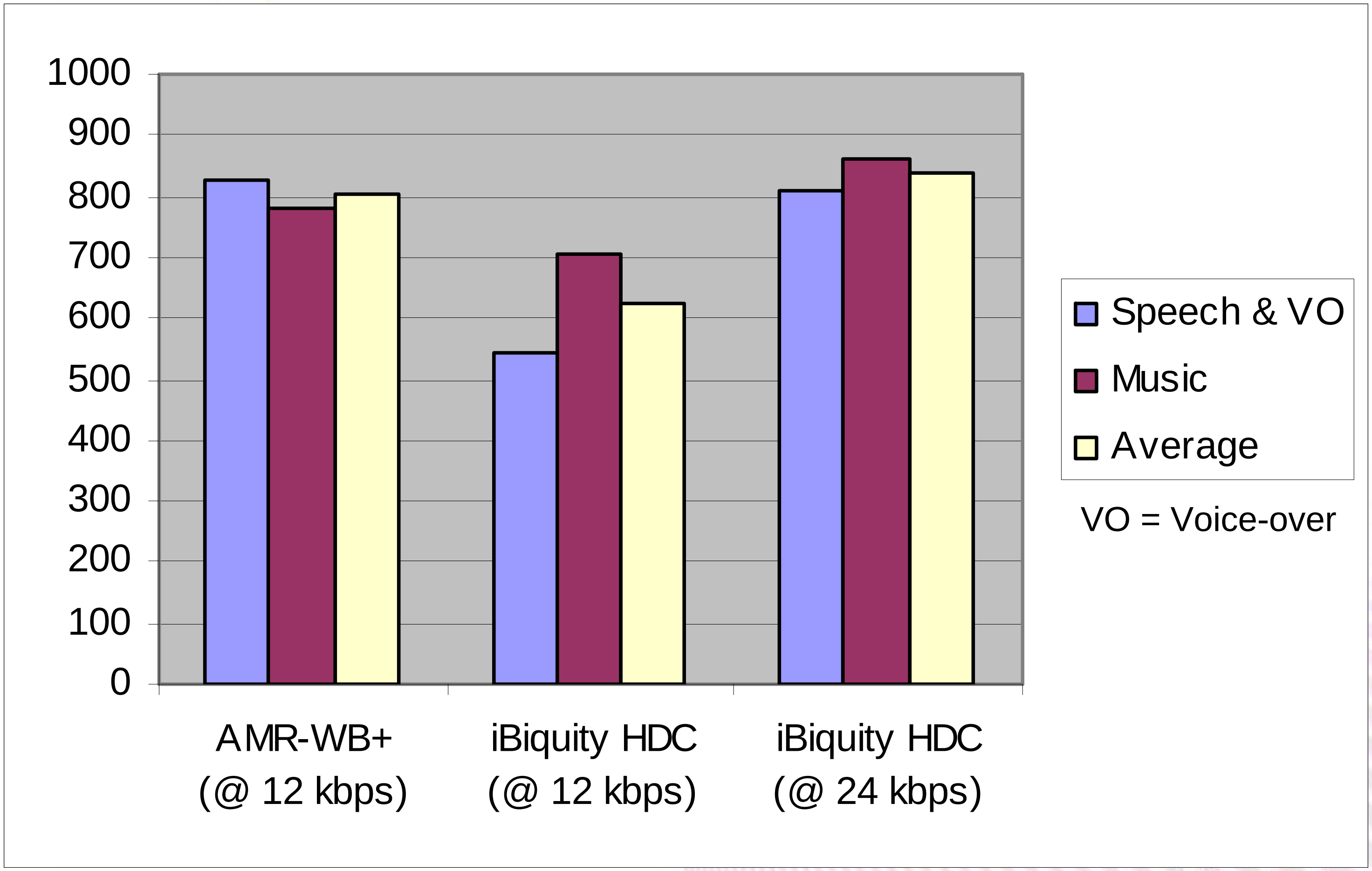


AMR-WB+ provides a 25% - 40% BW efficiency improvement for low bit rate quality audio delivery

Mono input signals

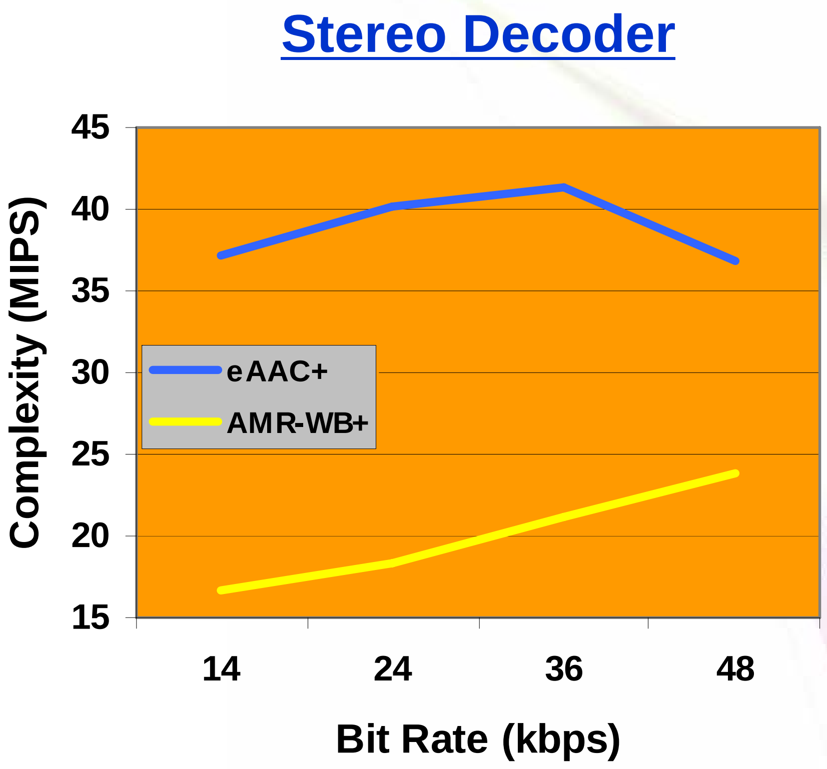
Source: 3GPP TR 26.936
3rd Generation Partnership Project; Technical Specification Group SA WG4;
Performance Characterization of 3GPP Audio Codecs (Release 6)

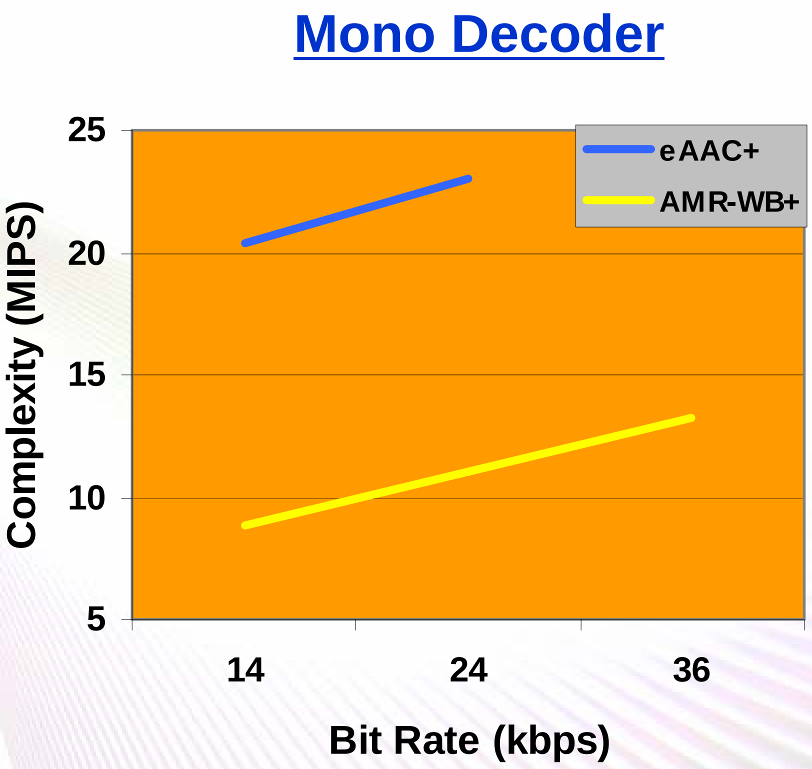
NPR Subjective Testing Results



From : **www.npr.org/euonline/pub/low_bit_rate_coder_report.pdf**

3GPP Complexity Comparison





Source: 3GPP Standardization Specifications

Based on fixed-point implementations

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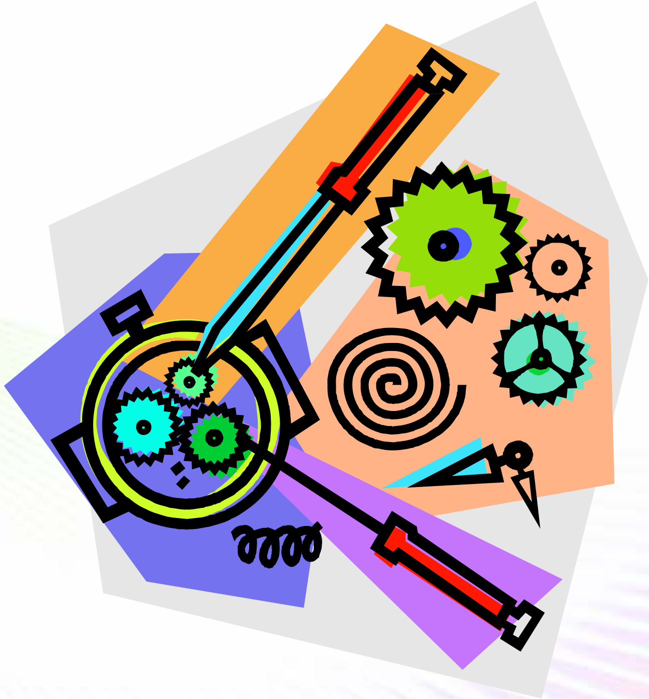
Optimization Challenges

- Codec standards reference code is based on 16-bit operations
- High complexity
- Extensive data usage (quantization tables and filter coefficients)
- Multiple TI platforms



Optimization Overview

Phases

- Conversion from float or basic-ops to “C” fixed point using intrinsic functions
- C code optimization
- Assembly optimization
- Further algorithm optimization (not necessarily preserving bit-exactness)

Conversion to Fixed Point

```
for (i = 0; i < lg; i++) {
    L_tmp = 0;
    for (j = 0; j < L_FIR; j++)
       L_tmp = L_mac(L_tmp, x[i + j], fir_6k_7k[j]);
    signal[i] = round(L_tmp);
}
```

“Basic operators” are a generic set of functions simulating DSP instructions (saturation, normalization, multiply&accumulate, …)

- Replace basic operators by intrinsic arithmetic, +,-,*,/ and shift instructions. Keep saturation.
- For “C” code an “efficient” conversion, recognizing areas where overflow testing can be discarded or moved outside loops

```
Word32 L_mac (Word32 L_var3, Word16 var1, Word16 var2)
{
   Word32 L_var_out;
   Word32 L_product;

   L_product = L_mult (var1, var2);
   L_var_out = L_add (L_var3, L_product);
   return (L_var_out);
}
```

```
Word32 L_mult (Word16 var1, Word16 var2)
{
   Word32 L_var_out;

   L_var_out = (Word32) var1 *(Word32) var2;
   if (L_var_out != (Word32) 0x40000000L) {
       L_var_out *= 2;
   }
   else {
       Overflow = 1;
       L_var_out = MAX_32;
   }

   return (L_var_out);
}
```

C Code Optimization

- Structure C code as if writing in assembler (helps compiler do a better job)
  - Look at the disassembly code generated by the compiler (hint)
- Use "restrict" key word to avoid memory dependencies
- Use unsigned int for loop counters
- Use short data for multiplication inputs whenever possible
- Loop unrolling

C Code Optimization

- Give more information about loops (min, max and multiple of loop counts) to the compiler
- Rearrange the order of code (especially in loop) and introduce more variables to reduce data dependencies and encourage parallelism
- Use 32-bit access to operate on 2X16-bit data (alignment needed)
- Modify the code to use dual multiplication on C55x (axb; axc)
- Modify the code to use dual multiplication on C64x (2X16 bits multiplication)

Assembly Optimization

More effective use of registers, pipeline, parallelism, etc.

- Use additional intrinsic functions (besides the intrinsic / basic-op functions)
- Use pure assembly for complex code
- Decide on the amount of assembly that you want (time vs MIPS)

Optimization Summary

- The overall goals of optimization are to reduce the amount of load & store from memory and make efficient use of data while in registers
- Going from 16 to 32 bits
  - Eases the process
  - Helps reduce overflow and saturation checking
  - Reduces the complexity of those operations
- Compromising bit exactness to reduce complexity

Results

AMR-WB+ decoder complexity (MHz)					
platform	basic-op	compiler optimization	intrinsic functions	C code	assembler
C55X	3212 MHz	1105 MHz	61 MHz	44 MHz	24 MHz
	10 person-days	1 days	10 days	45 days	85 days
C64X	2104 MHz	643 MHz	58 MHz	23 MHz	16 MHz
	15 person-days	1 days	15 days	60 days	85 days

Results

AMR-WB complexity (MHz)					
platform	basic-op	compiler optimization	intrinsic functions	C code	assembler
C55X	2408 MHz	945 MHz	64 MHz	36 MHz	29 MHz
	10 person-days	1 days	10 days	20 days	70 days
C64X	1839 MHz	680 MHz	62 MHz	32 MHz	24 MHz
	15 person-days	1 days	15 days	35 days	50 days

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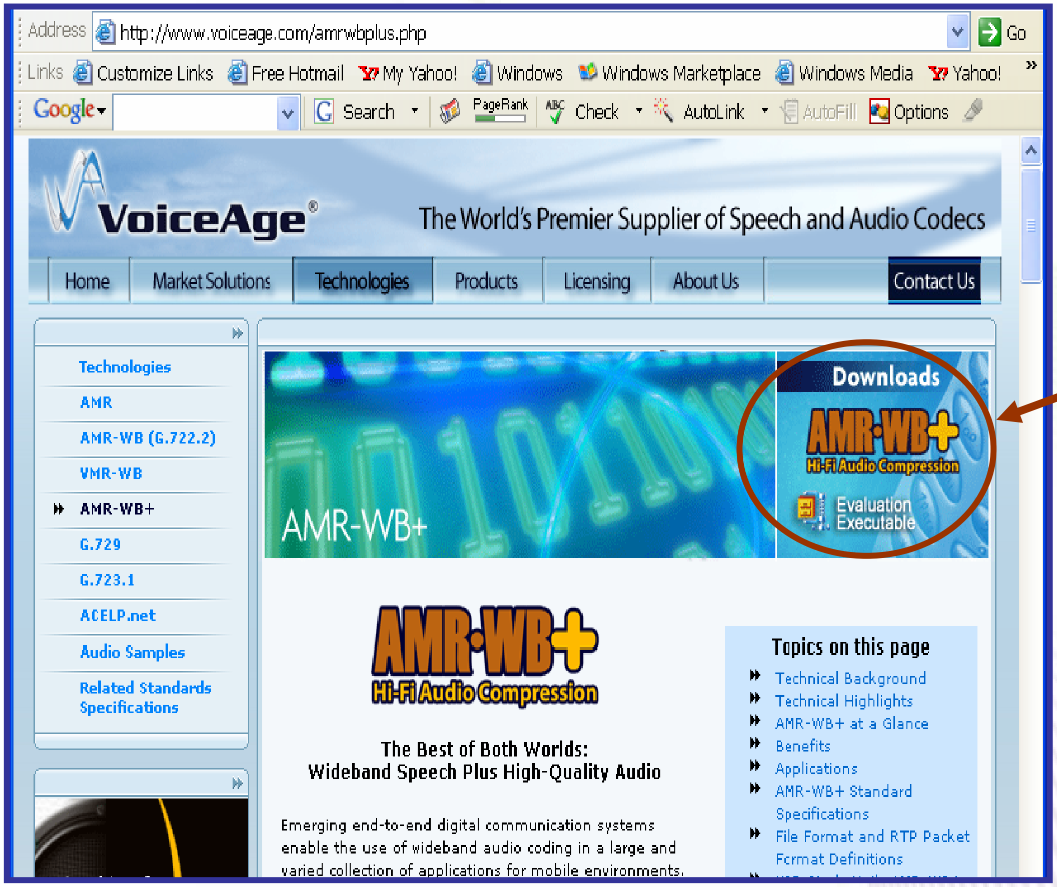
Tools

- DSK for C55 and C64
  - Efficient and inexpensive
  - Code composer debugger and simulator
  - Real-time debugging and testing
  - C std lib library (fread/fwrite) eases the testing
- Code Composer (build tools)
  - Efficient compiler

Conclusions

- Intrinsic functions give you the opportunity to come up with an implementation in a timely manner
- But to get powerful optimized implementations, you need to use assembly language
  - Quite useful on C55
  - Difficult on C64 but compiler already doing a good job
- Can skip C code optimization to jump to assembly directly
- Gain of 2X for C55 and 3X for C64

Thank You!
Download the AMR-WB+ Demo Executable



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The Best of Both Worlds:
Wideband Speech Plus High-Quality Audio

Emerging end-to-end digital communication systems enable the use of wideband audio coding in a large and varied collection of applications for mobile environments.

Topics on this page

- Technical Background
- Technical Highlights
- AMR-WB+ at a Glance
- Benefits
- Applications
- AMR-WB+ Standard Specifications
- File Format and RTP Packet Format Definitions

Go to:
www.voiceage.com/amrwbplus.php

Download the AMR-WB+ demo executable

Generate encoded/decoded WAV files at different bit rates

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