MP3 Robust Digital Watermarking

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June 2005

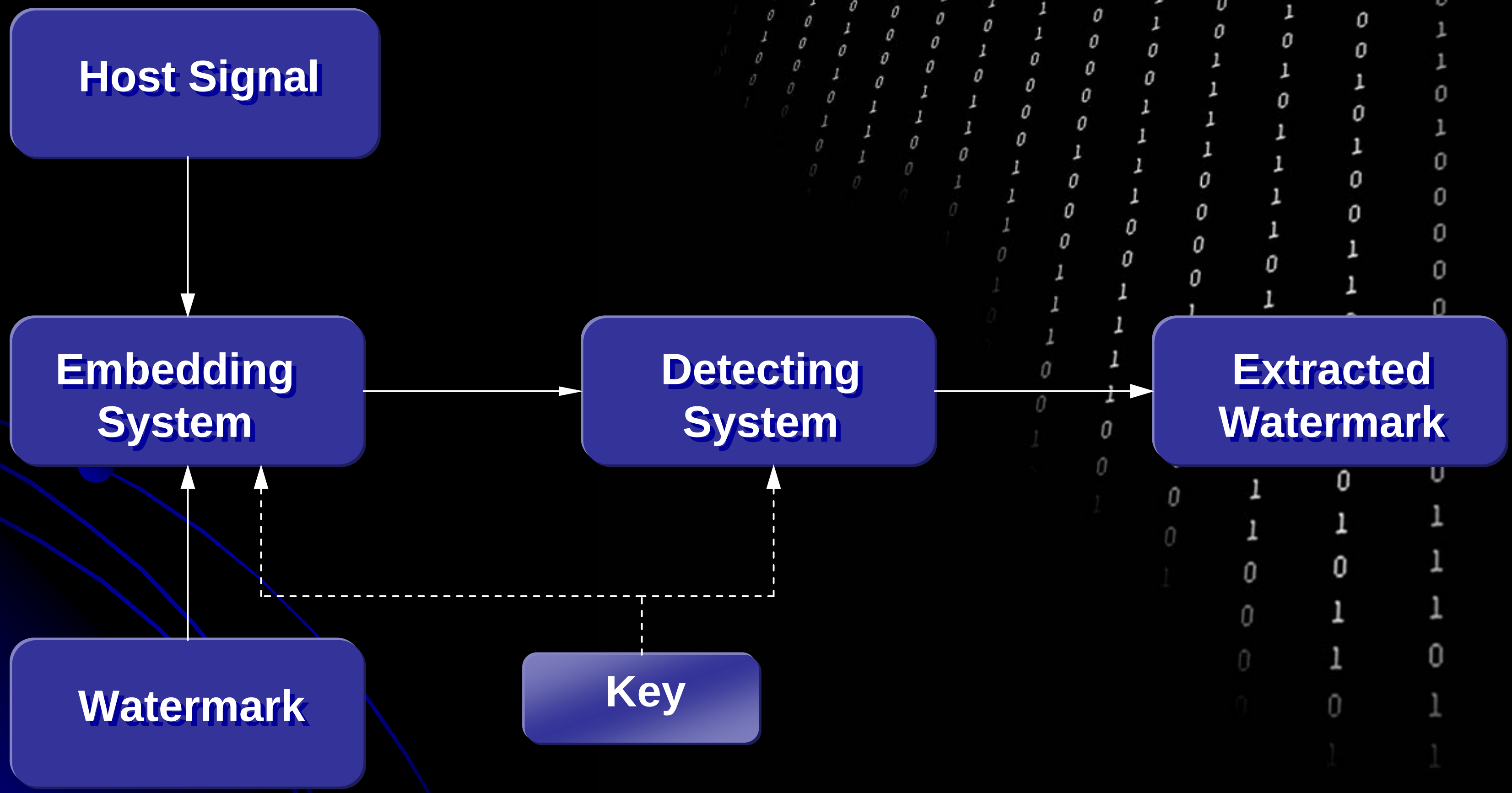
What is Digital Watermarking?

- Digital watermarking/Data Hiding is the practice of embedding data in various digital media types: Images, Audio, Video, Text, etc.
- Provides potential solution to the issue of copyright protection, annotation & identification.

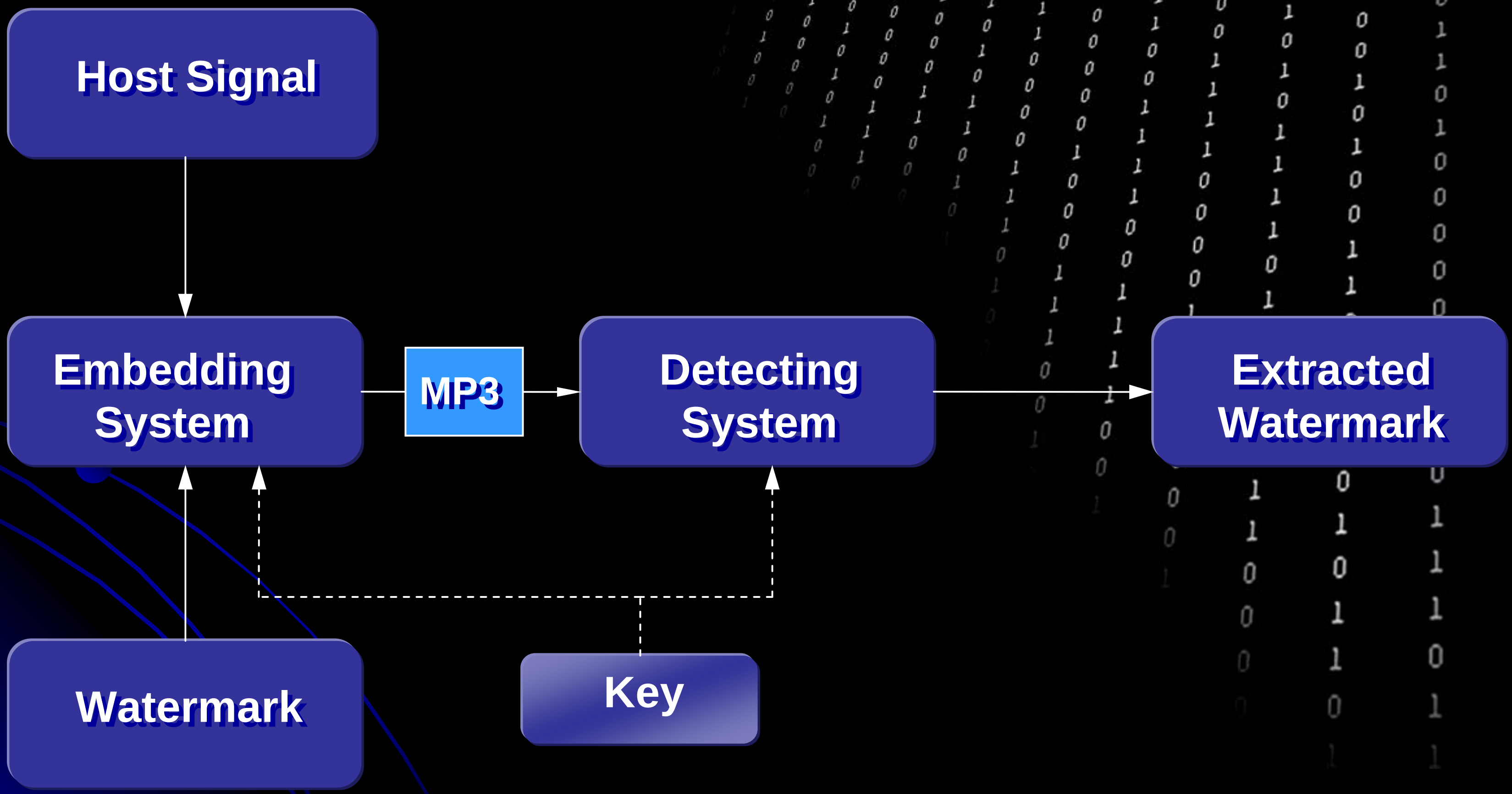
DWM Requirements

- Message embedded within the data itself
- Knowing the watermarking algorithm does not enable to remove the watermark
- Imperceptible, Inaudible watermark
- Undetectable (recommended)
- Resistance to distortions (A/D, Lossy Compression (MP3) , noise, etc.)

General Watermarking Scheme

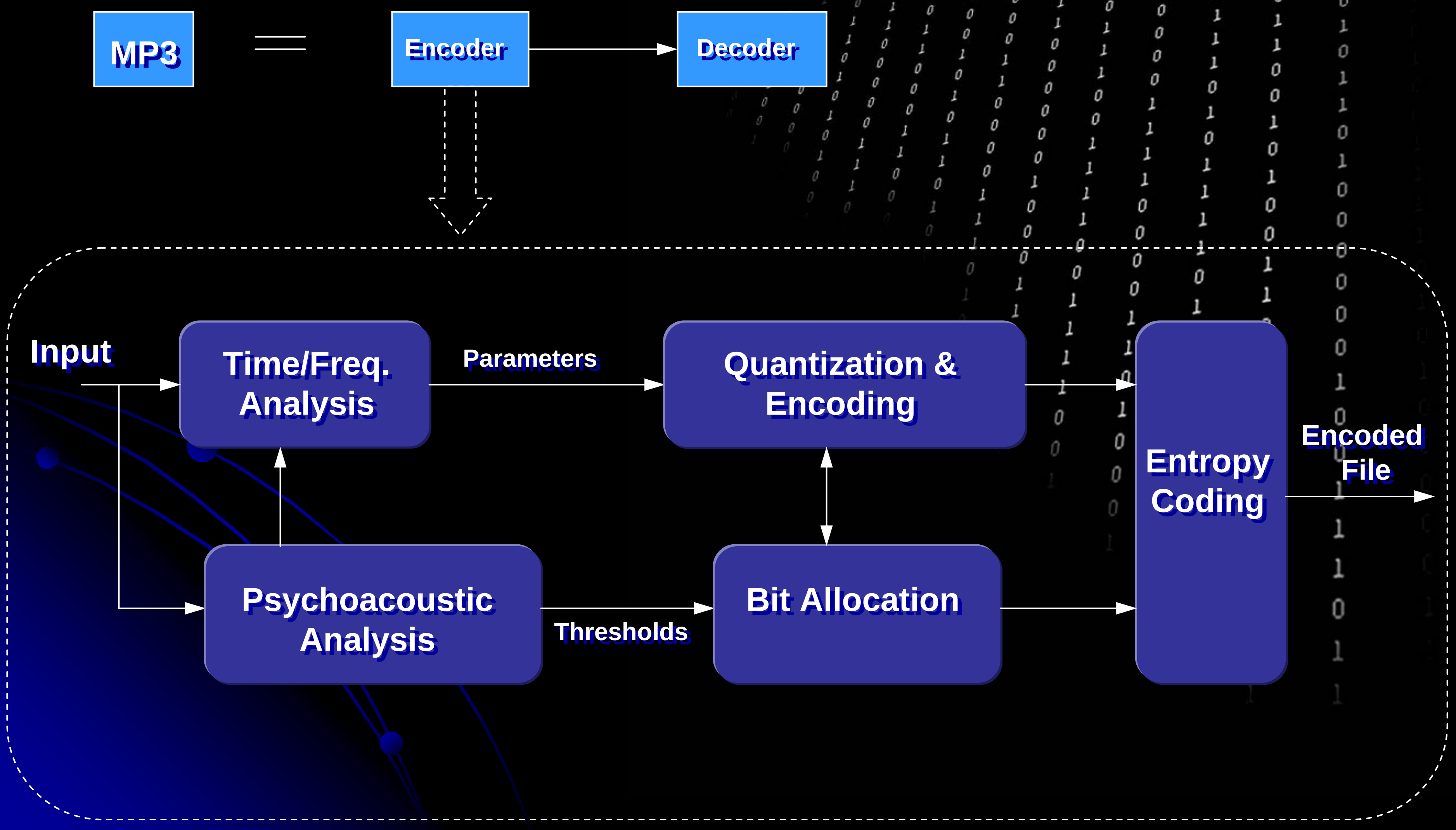


Our Goal



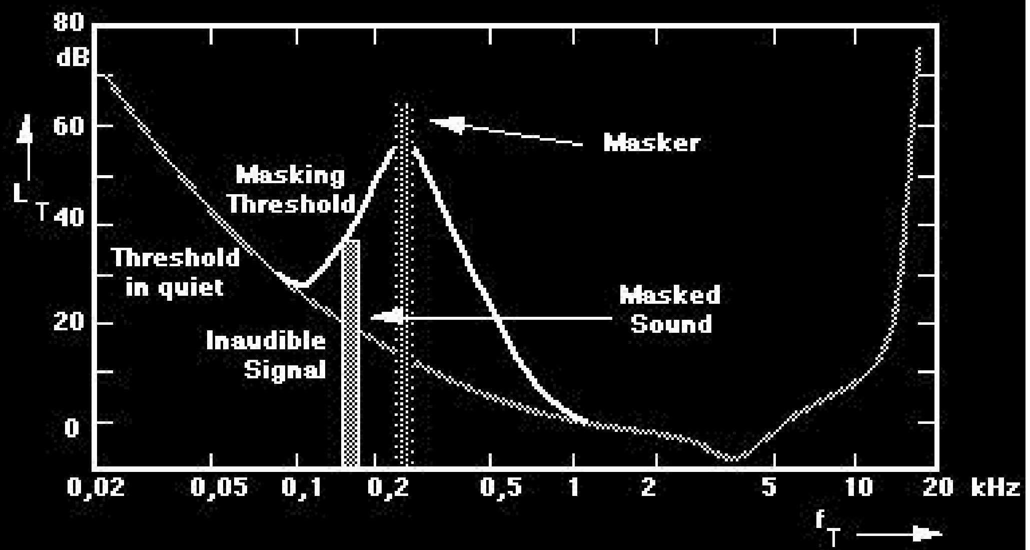
Host Signal
Embedding System
MP3
Detecting System
Extracted Watermark
Watermark
Key

MP3 Coding Scheme



Psychoacoustic Model

- Using the limitations of the hearing system in order to get unperceivable watermarking
- Masking thresholds are calculated & data is being embedded as pseudo-random noise, below hearing threshold.

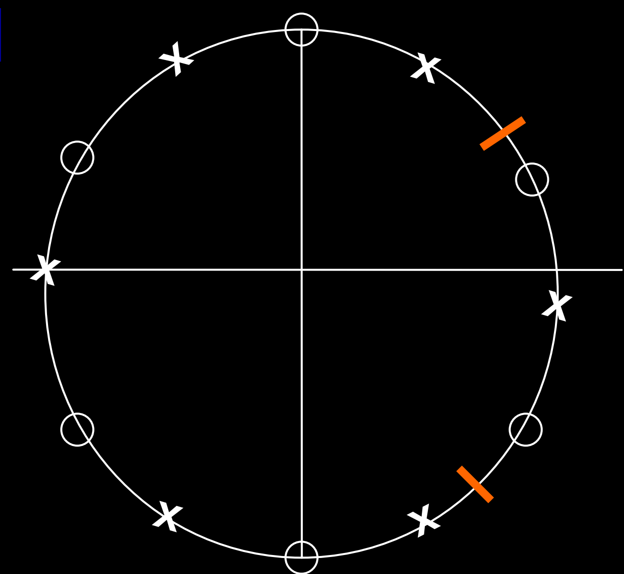


Psychoacoustic Model – Phase

- Phase is thought to be less perceivable than amplitude.
- Humans are more sensitive to phase continuity than to its real values.
- MP3 compression does not affect phase directly – a compression “Hole” we can make use of.

Quantization Index Modulation - QIM

- The signal is divided into segments, proportional to the length used by encoder
- Each segment is transformed to the DFT domain
- Phase and amplitude are extracted
- Phase is being quantized according to the following scheme:



QIM

- Information is being represented by using quantization patterns :

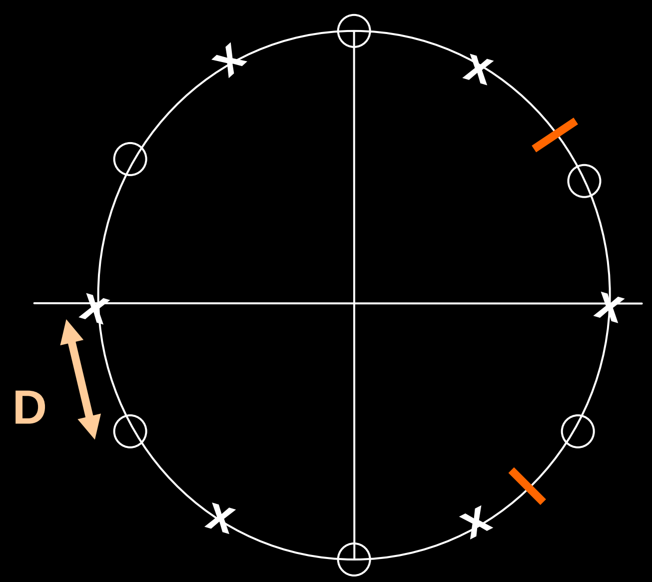
  (xoxo) ≡ bit 0

  (oxox) ≡ bit 1

- D ≡ distance (x point ,o point)

  → Fine quantization for better sound quality

  → Rough quantization for better watermark preservation



QIM

- Decoding:

→ Find the nearest (x,o) points (a_i,b_i) to given phase φ_i

→ Construct two patterns

$u = (a_0, b_1, a_2, b_3)$

$v = (b_0, a_1, b_2, a_3)$

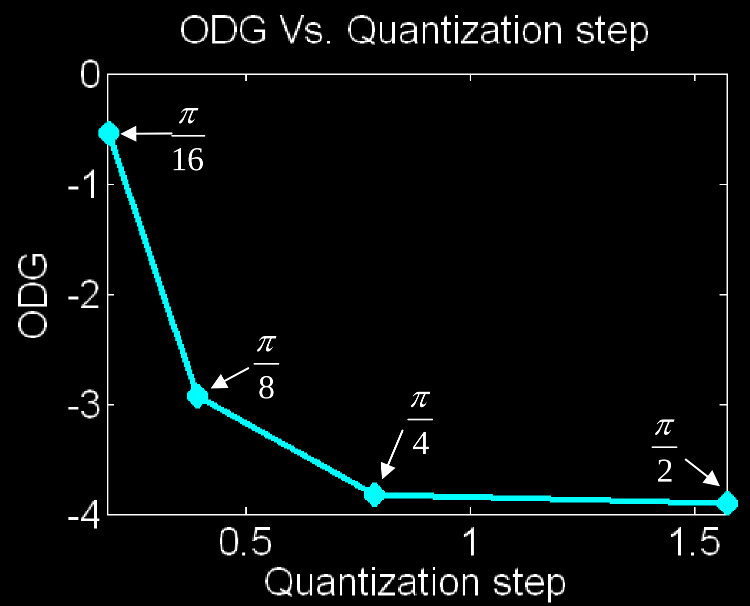
→ If $\sum r_i \cdot (u_i - \varphi_i)^2 < \sum r_i \cdot (v_i - \varphi_i)^2$ the bit is 1,
else the bit is 0.

→ Extending pattern size yields more robust watermark

ODG and Error

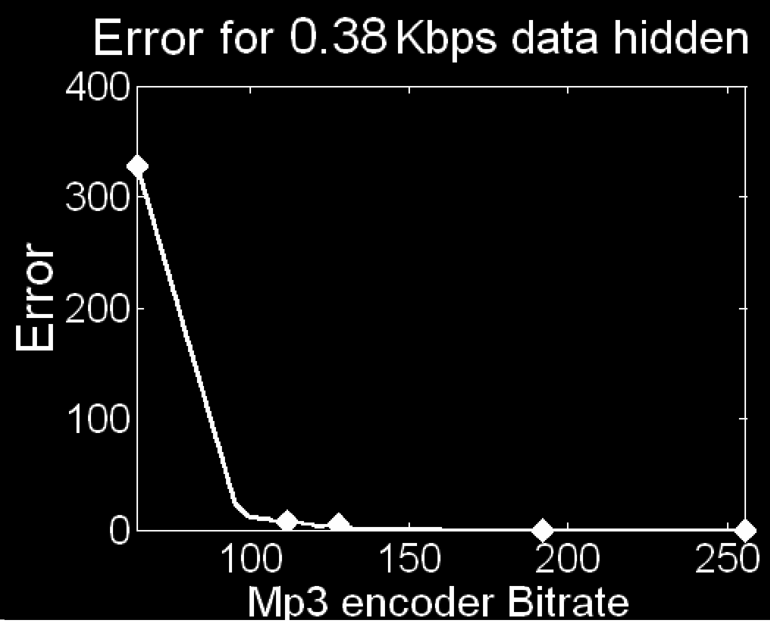
Example Parameters:

- Input Wav: Kern.wav (Before / After)
- Encoder: MP3 (LAME)
- Mp3 bitrate: 128 kbps
- Pattern size: 4
- Watermark bitrate: 0.4 Kbps



- Objective Difference Grade increases with finer quantization

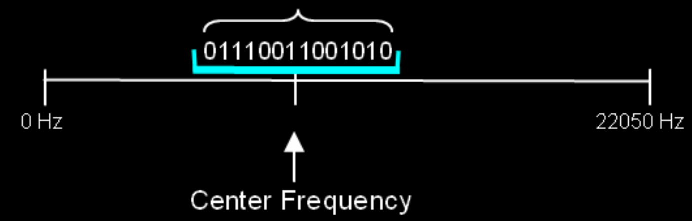
- Error bitrate increases with finer quantization

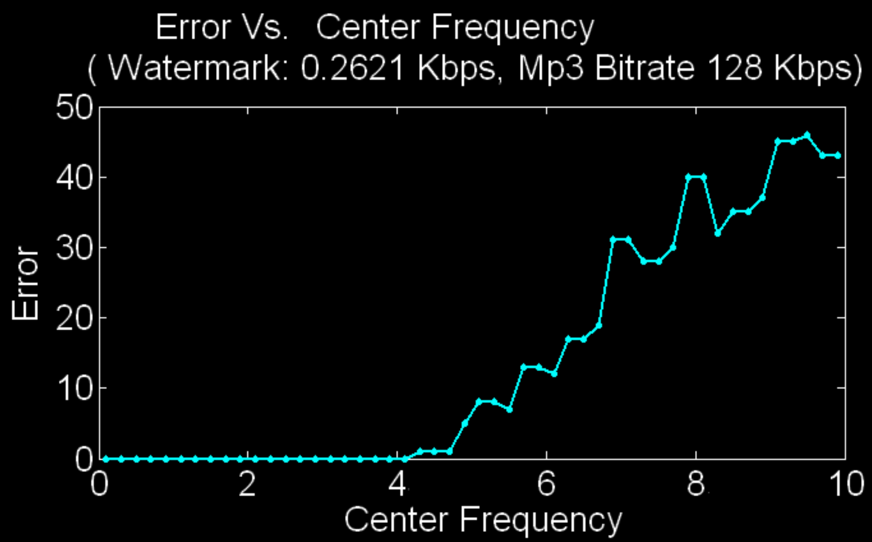


More Results Evaluation

Influence of embedding frequencies:

Embedding bandwidth : 1.225 kHz





- **Behavior suits the hearing threshold model**
- **MP3 damages the watermark & the quality according to the threshold**

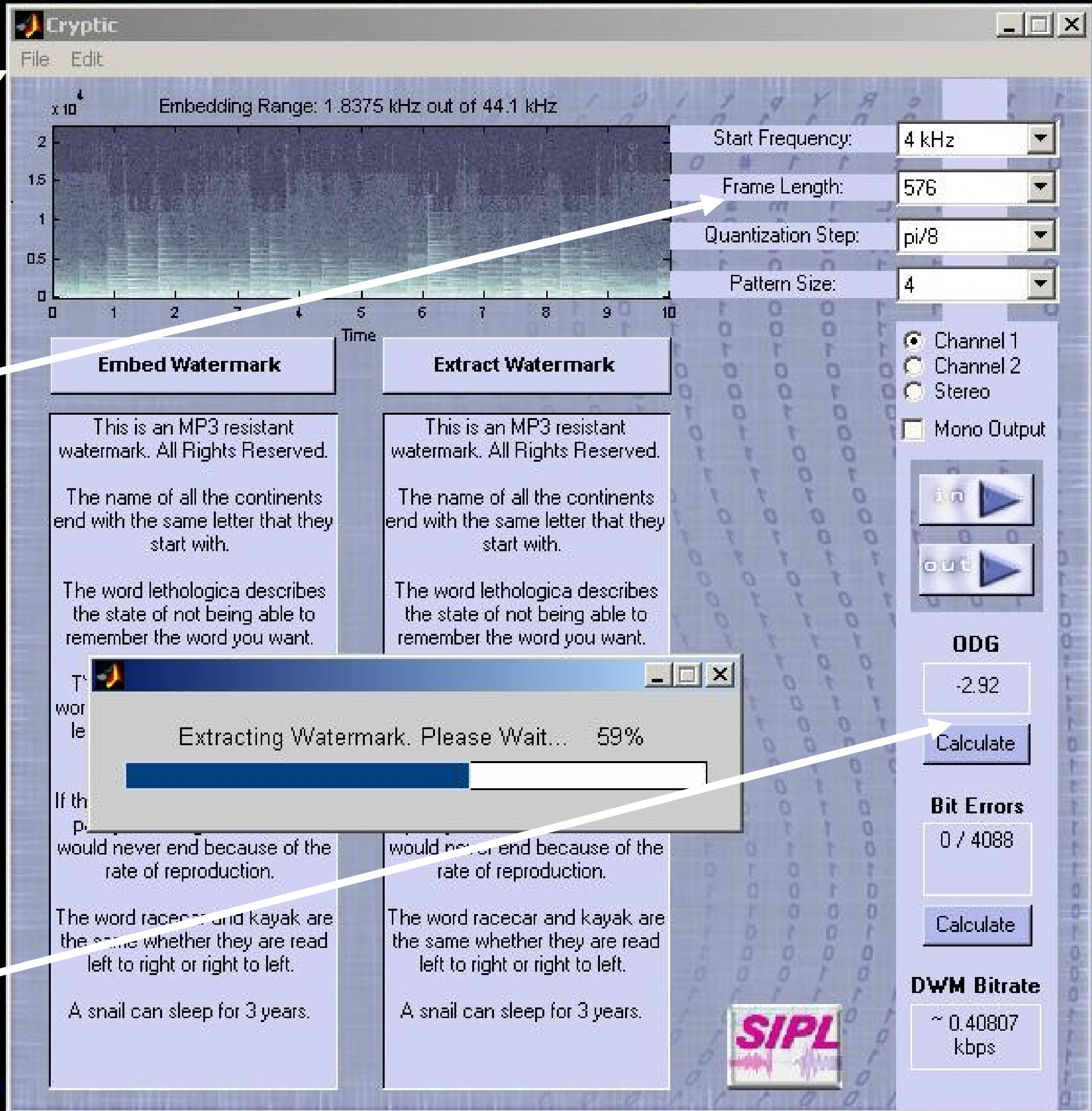
Robustness to New Encoders

- Embedding system shown good results with some more complex & improved perceptual coders:
  - Mpeg 4 AAC
  - Ogg Vorbis
  - MPC – Musepack
- Similar error bitrate performance to MP3 although the AAC, Ogg and MPC use more advanced encoding techniques

GUI Application

Input Parameters:

- Input File
- Input Watermark
- Start Frequency
- Frame Length
- Quantization Step
- Pattern Size



Output Parameters:

- Watermarked File
- Extracted Watermark
- ODG
- Bit Errors
- DWM Bitrate

GUI Application

- Embedding any text information
- Stereo Files - Embedding different DWM in each channel
- Different Codecs available
- Performance analysis easily calculated

Examples

Before

After

Kevin_Kern.Wav

- Encoder: MP3 (LAME)
- Sample Length : 10 sec
- Mp3 bitrate: 160 kbps
- Quantization Step : $\frac{\pi}{8}$
- Watermark bitrate: 0.48 Kbps

ODG : -0.62

Errors : 9/4088

Before

After

Stevie Wonder_As.Wav

- Encoder: MP3 (LAME)
- Sample Length : 8 sec
- Mp3 bitrate: 128 kbps
- Quantization Step : $\frac{\pi}{8}$
- Watermark bitrate: 0.48 Kbps

ODG : -1.57

Errors : 0/4088

The End