



# Content-Dependent, Low-Frequency Watermarking for Motion Pictures

*Sarnoff's Low-Frequency Watermark in Context*

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# Outline

- ◆ DRM and Watermarking
  - Copy Control (DVD)
  - Forensic Tracking (Digital Cinema)
- ◆ Robustness Challenges
- ◆ Low-Frequency Watermark
- ◆ Fidelity Challenges
- ◆ Sarnoff's Content-Dependent, Low-Frequency Watermark

# DRM for Motion Pictures

- ◆ Cryptography and DRM can manage a motion picture while it is in digital form
- ◆ Movie is vulnerable before it is put into the DRM system and after it is removed
- ◆ Movie must be converted to analog signals and then light and sound

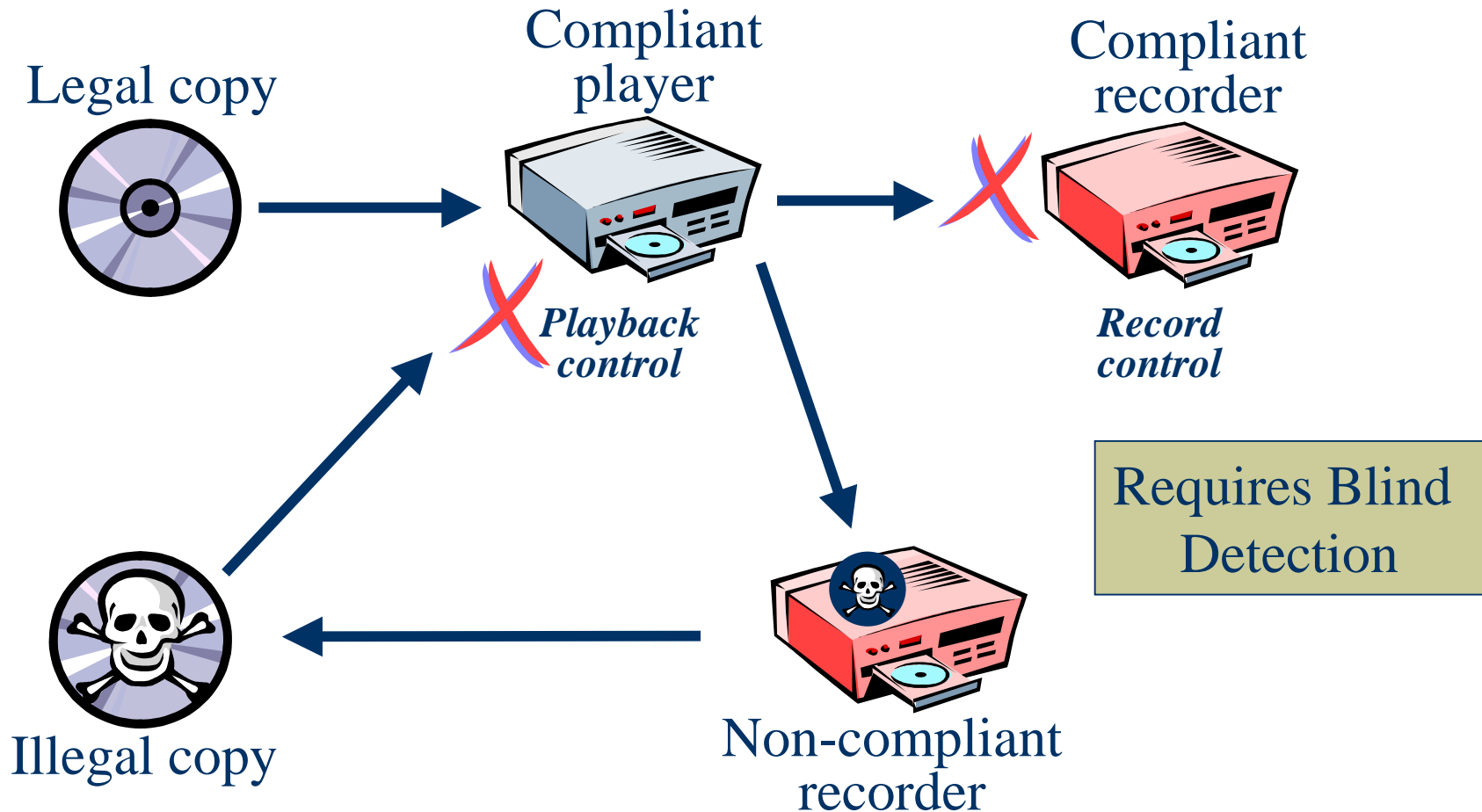
# Watermarking in DRM

## DVD Copy Control

- ◆ DRM holds copy rights
- ◆ Movie will eventually be exposed
- ◆ Watermark indicates copy status
  - No Copy
  - Copy Once
  - Copy Freely
- ◆ Record Control and Playback Control

# Watermarking in DRM

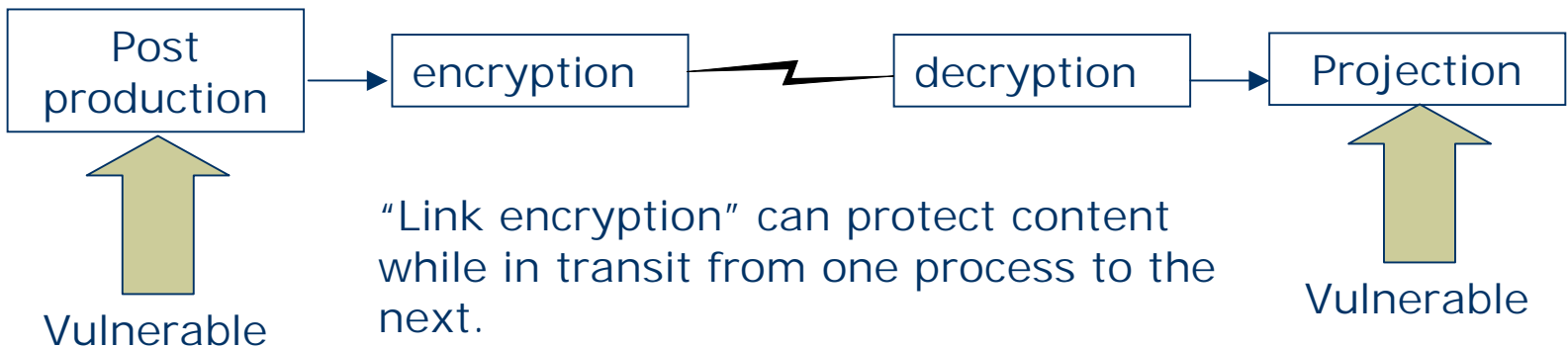
## DVD Copy Control



# DRM for Digital Cinema

## Limitations of Cryptography Use

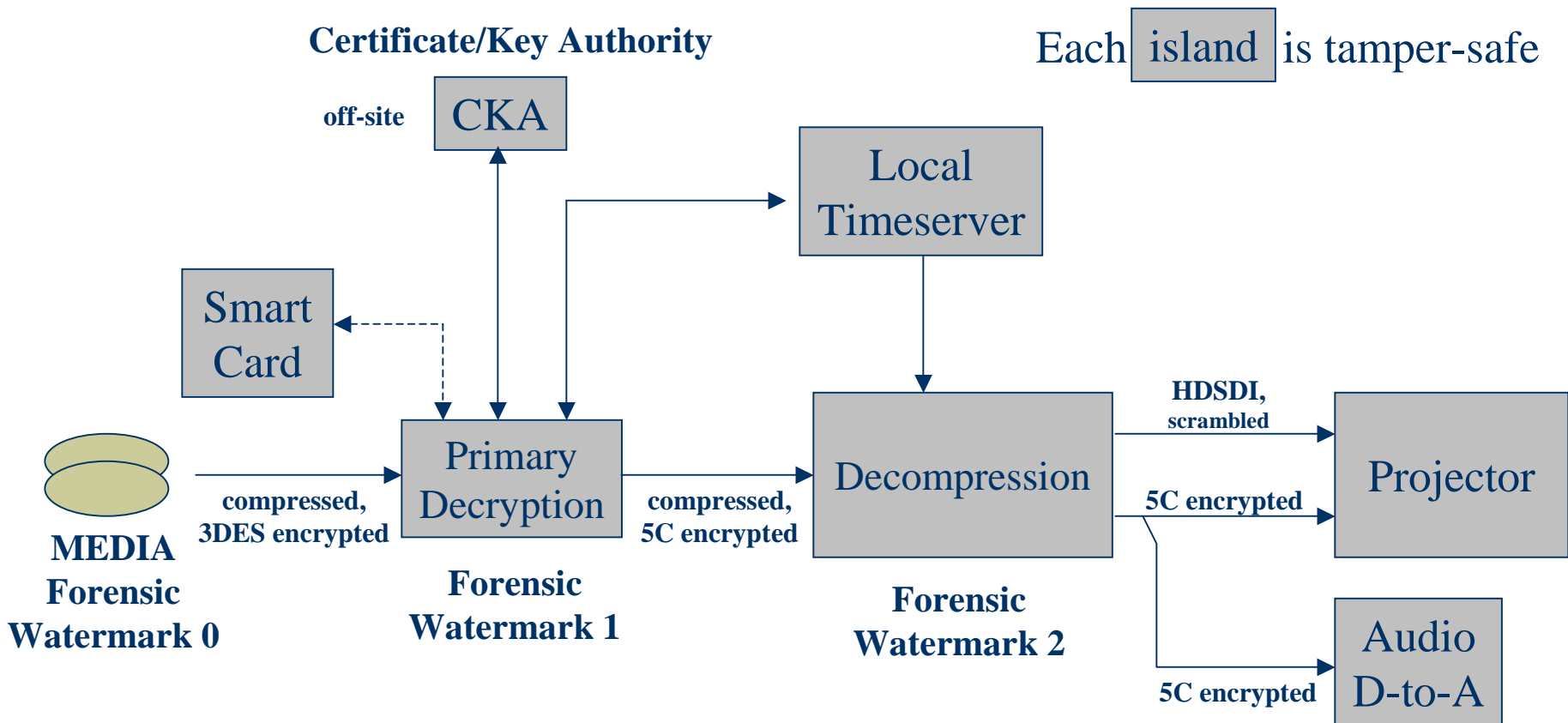
- ◆ Post production and distribution need access to unencrypted content for editing and compression
- ◆ Cryptography cannot protect a movie after it has been decrypted for projection



This relies on the security of each individual process.

# DRM for Digital Cinema

## Example



# Digital Cinema Forensic Watermarks

- ◆ Three forensic watermarks
  - 3DES Decryption key stolen from a tampered device
  - Used to decrypt content from a “borrowed” ROM
- ◆ Forensic Watermark 0
  - identifies the media: distributed to a particular venue
- ◆ Forensic Watermark 1
  - identifies the decryption key used (tampered device)
- ◆ Forensic Watermark 2
  - identifies the specific exhibition: screen, date, time
  - can also be used to identify the operator, GPS coordinates, etc.

# Robustness

## Camcorder Capture and Compression



**Original:** 1280x1024 CinemaScope  
(1.91:1 horizontal), 24 fps, 10-bit)

**Capture:** 720x480, 30 fps, 8-bit

**Resize:** 360x240

**Compress:** MPEG-4, 250kbs, 15 fps

- ◆ Geometric distortion (affine, warping, etc.)
- ◆ Temporal distortion (time shift, change in frame rate)
- ◆ Cropping
- ◆ Occlusion
- ◆ Volumetric distortions (brightness, contrast, low-pass filtering, etc.)
- ◆ Compression for Internet distribution (P2P)

# Robustness

## Camcorder Capture and Compression

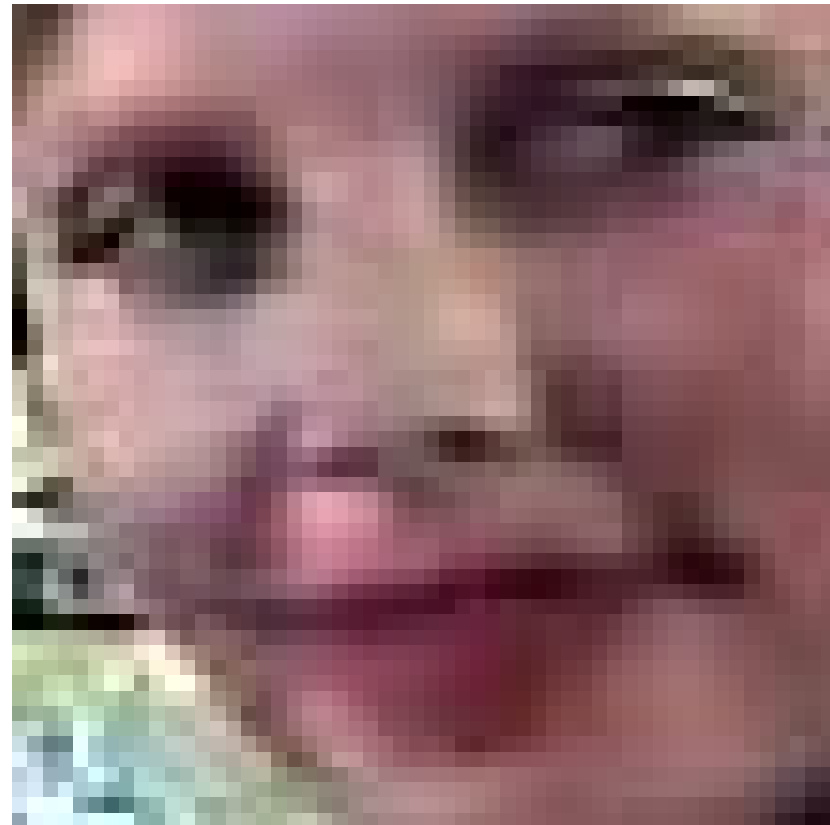


# Robustness Requirements

Original



Camcorder captured and compressed

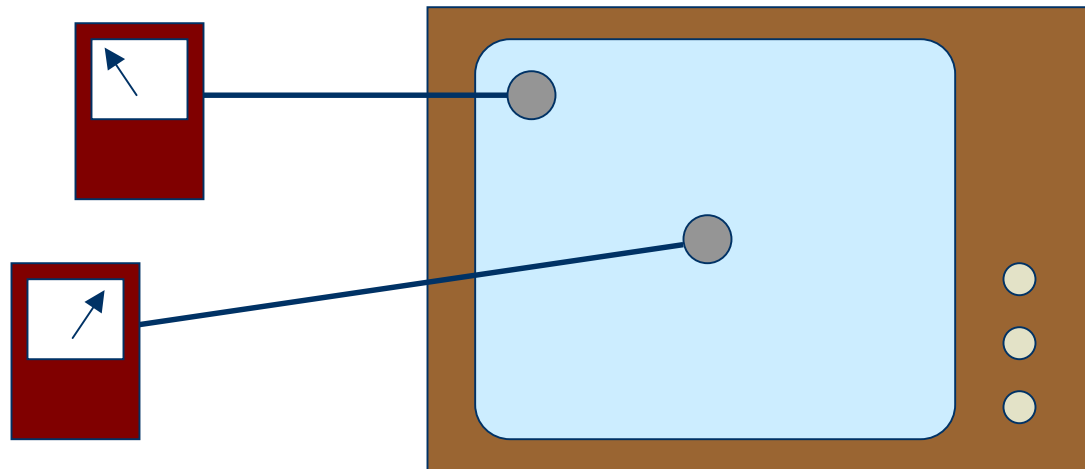


# Low-Frequency Watermarking

- ◆ Sarnoff (*Lubin, Bloom, and Cheng 2003*), Philips (*Haitsma and Kalker 2001*), SUNY Binghamton (*Fridrich 1997, Fridrich 2000*)
- ◆ Recognize that very low spatial or spatio-temporal frequencies survive severe compression and camcorder capture
- ◆ Fidelity challenge as common watermarking “wisdom” states that low-frequency watermarks introduce visible artifacts

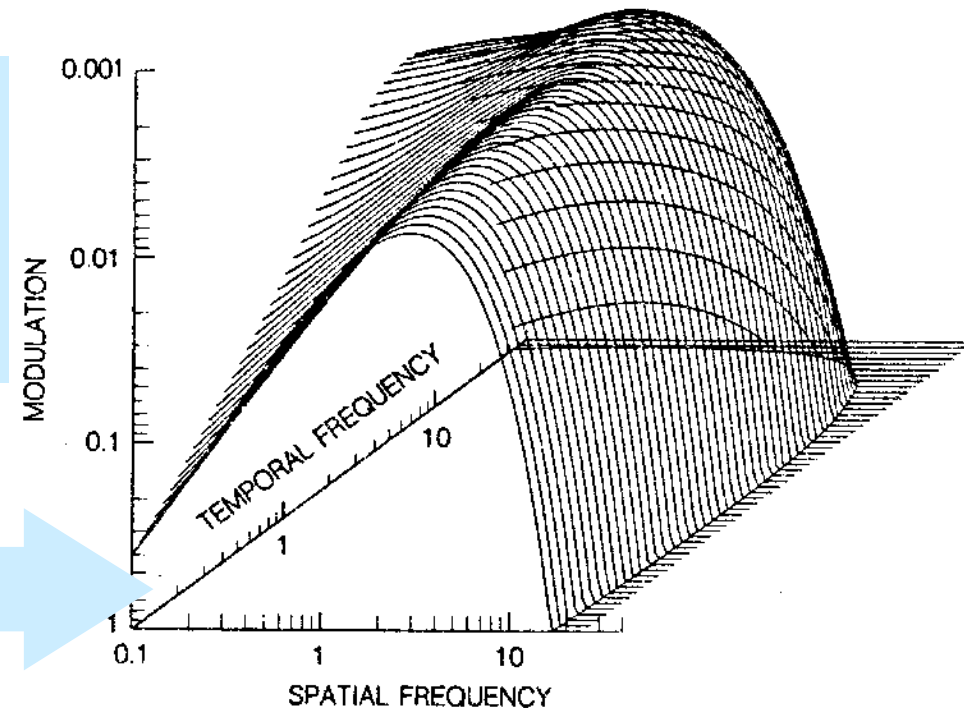
# Fidelity: A lesson from CRT design

- ◆ Center-corner luminance drops up to 25% are easily measurable, but not visible



# Fidelity: Low Frequencies

Human visual sensitivity is low at low spatio-temporal frequencies.



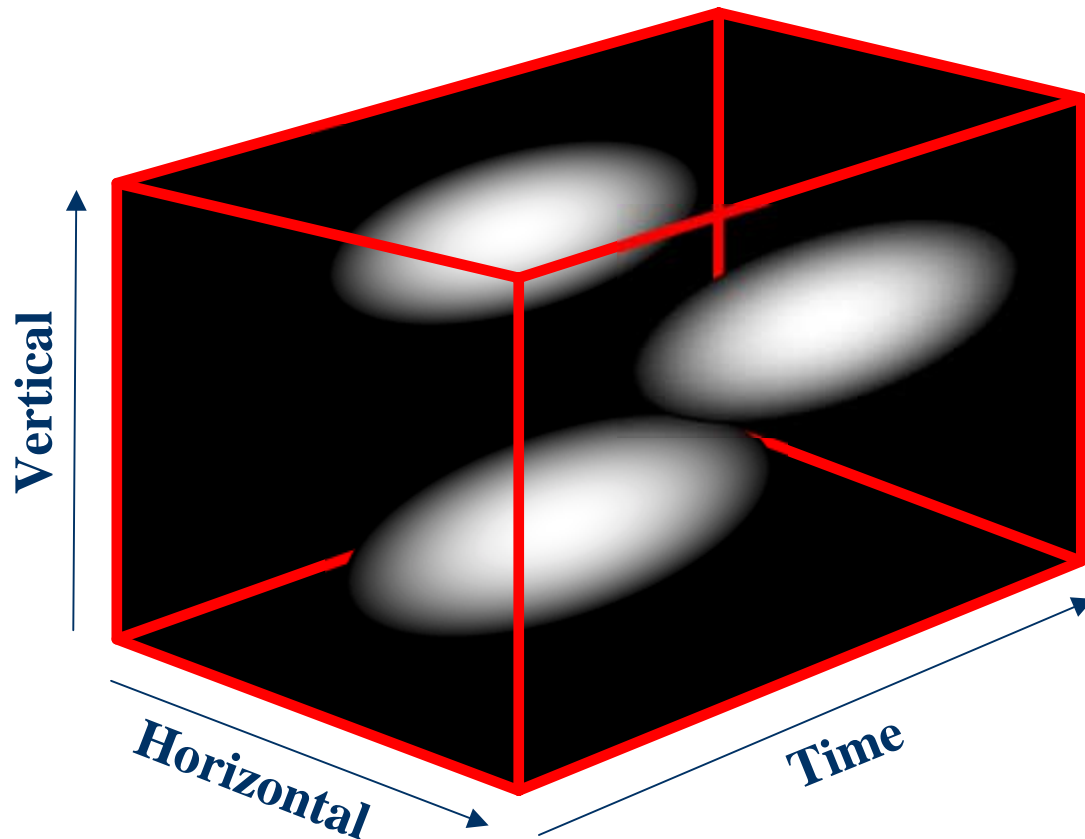
# Sarnoff's Low-Frequency Forensic Watermark

- ◆ Perceptual model used to create content-dependent, low-frequency watermark
- ◆ Exploits opportunity for informed detection
- ◆ Watermark is a spatio-temporal volume
- ◆ 3D watermark is a combination of local, low-frequency carriers
- ◆ Size, shape, and location of individual carriers is determined by perceptual model

# Sarnoff's Watermark Low-Frequency Carriers

- ◆ Carrier = a pattern that varies slowly in time and space
- ◆ Each carrier encodes one bit (bit value determines sign of carrier)
- ◆ Perceptual preprocess determines where carriers can be hidden
- ◆ Arrangement of carriers is provided to detector

# Sarnoff's Watermark Carriers in Time-Space Volume



# Sarnoff's Watermark Informed Detection Process

- ◆ Align original with received video (space, time, and histogram)
- ◆ Subtract aligned original from received video to obtain difference video
- ◆ Apply alignment transform to carrier pattern
- ◆ Correlate aligned carriers with difference video

# Informed Detection

- ◆ Allows removal of cover work noise
  - Dirty-paper watermarking suggests this might be unnecessary
- ◆ Allows detection in the presence of content dependent distortions
- ◆ Allows for content-dependent placement of carriers for improved fidelity

# Summary

- ◆ Watermarking is useful in DRM for both copy control (utilizing blind detection) and forensic tracking (utilizing informed detection)
- ◆ Low-frequency watermarks can provide the required robustness
- ◆ Informed detection allows low-frequency watermarks to be customized to the content thus providing the required fidelity

# References

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