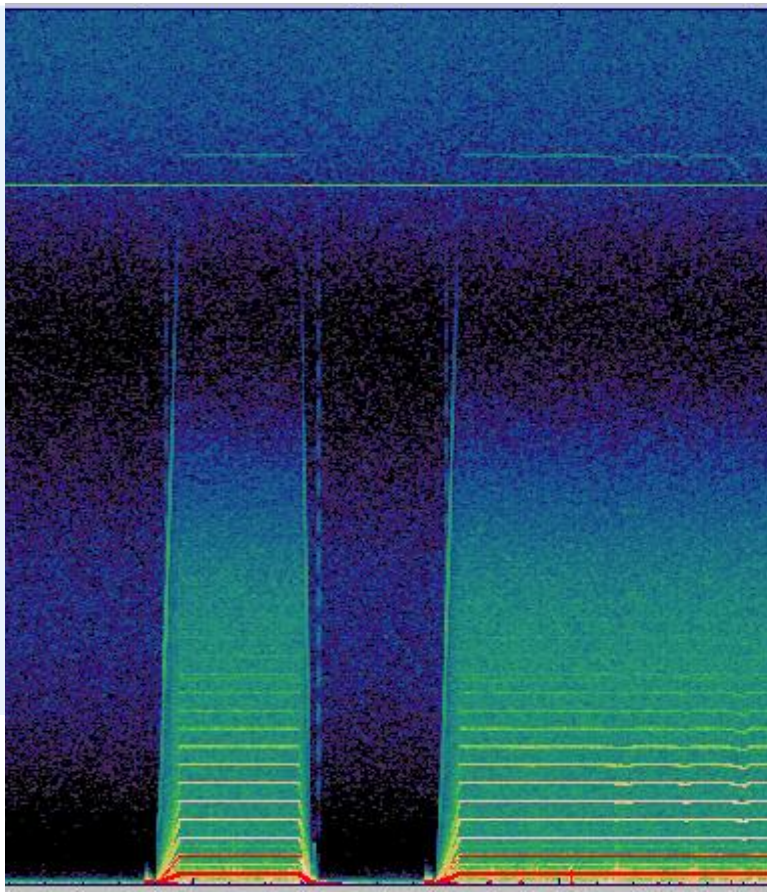
# HF-Bias Signal Pick-Up and Pre-Processing for Wow and Flutter Correction of Analogue Magnetic Tape

## Analyses and Limitations in Practical Application



Nadja Wallaszkovits
Heinrich Pichler

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- Introduction
- Basic theory
- Practical application of HF-bias signal retrieval at original playback-speeds
- Analyses and limitations in practical application
- Alternative approaches
- Conclusion

… Wishes to the industry…

# Introduction

- Standard Archival Workflow:
  - Focus: reproduction of the signal band carrying the primary information (content, “essence”)
  - Due to limitations of standard playback systems: some technical information is lost
    - HF bias signal recorded on the original tape
- Archival community debates the ultimate and exhaustive signal extraction
- Analogue magnetic tape: possible benefits of retrieving the HF bias signal as a reference for the digital correction of irregular speed variations

# Introduction

- Irregular speed variations at slow rates (~0.5Hz):
  - Problems of speed regulation or power supply on the recording process ▸ perceived as pitch changes ▸ correction via change of relative playback speed by means of an electro-mechanical circuit
- Wow & flutter / scrape flutter: Frequency modulation artefacts (>0.5Hz)
  - Speed fluctuations of the driving mechanism:

    Tribology / excentricity of mechanical parts, resonances of vibrating mechanical elements (tape guides, head)
  - Mechanical properties of the tape; damages of the tape due to storage artefacts

- Wow & flutter ▸ spectral sidebands
- Correction on the basis of an electro-mechanical circuit impossible ▸ need of digital signal processing
- Basic idea of digital correction:
  - Both audio signal and HF-bias signal are similarly affected by wow & flutter artefacts
  - Bias frequency is expected to be initially constant
  - Wow & flutter is also reflected in the bias signal
  - Reference for digital correction methods

- Digital correction tools have already been developed:
  - various automated and semi-automated detection routines in combination with non-uniform resampling methods

▸ Focus on the practical retrieval of HF bias signal at original playback speeds to be implemented in a standard archival workflow

# HF-Bias Frequencies – Professional Tape Machines

| Model | Speeds | Bias (kHz) |
|---|---|---|
| Stellavox SP7 | 9,5/ 19/ 38 cm/s | 61,44 |
| Revox G36 | 9,5/ 19 - 19/ 38cm/s | 70 |
| Nagra IV S | *9,5/ 19 cm/s* | 125 |
| AEG Telefunken M15 | 19/ 38/ 76 cm/s | 131 |
| Otari MX55/ MX5050 | 9,5/ 19/ 38 cm/s | 133 |
| Tascam BR 20 | 19/ 38 cm/s | 145 |
| Tascam 34 | 19/ 38 cm/s | 150 |
| Studer div. | 9,5/ 19/ 38/ 76 cm/s | 150 |
| Studer A807, 810, 812, 820 | 9,5/ 19/ 38/ 76 cm/s | 153,6 |
| AEG Telefunken M20 | 9,5 /19/ 38/ 76 cm/s | 205 |
| Sony MCI JH 110 | 38/ 76 cm/s | 210 |
| Ampex ATR 100 | 9,5/ 19/ 38/ 76 cm/s | 432 |

# HF-Bias – Semiprofessional/ Consumer Machines

| Model | ~Year | Speeds | Bias (kHz) |
|---|---|---|---|
| Uher 4000 Report L | 1961 | 2,38/ 4,75/ 9,5/ 19 cm/s | 50 |
| Uher 4200 | 1975 | 2,38/ 4,75/ 9,5/ 19 cm/s | 70 |
| Uher 4400 | 1984 | 2,38/ 4,75/ 9,5/ 19 cm/s | 60 - 100 |
| Revox B 36 | 1956 | 9,5/ 19 cm/s | 70 |
| Revox A77 | 1967 | 9,5/ 19 cm/s | 120 |
| Revox B77 | 1977 | 9,5/ 19 cm/s | 150 |
| Revox PR 99 | 1984 | 9,5/ 19/ 38 cm/s | 150 |
| Tesla Sonet Duo | 1959 | 4,75/ 9,5 cm/s | 50 |
| SABA TG 674 | 1976 | 9,5/ 19 cm/s | 57 |
| Philips N4404 | 1969 | 9,5/ 19 cm/s | 57 |
| Philips N4422 | 1978 | 4,75/ 9,5/ 19 cm/s | 100 |
| AKAI X100-D | 1962 | 4,75/ 9,5/ 19 cm/s | 60 |
| Sony TC 270 | 1973 | 4,75/ 9,5/ 19 cm/s | 75 |
| Toshiba PT 862 D | 1972 | 4,75/ 9,5 cm/s | 85 |
| TEAC A3300 | 1979 | 9,5/ 19 - 19/ 38cm/s | 100 |
| Grundig TK-600 | 1972 | 9,5/ 19 cm/s | 105 |

# Basic Theory: Playback Head Design

- Recorded wavelength of a signal on magnetic tape depends on
  - the frequency
  - the tape speed in the recording state, shown in the equation:

$$\lambda_{med} = \frac{v_{rel}}{f}$$

Low tape speed / high frequency ▸ short wave length

# Basic Theory

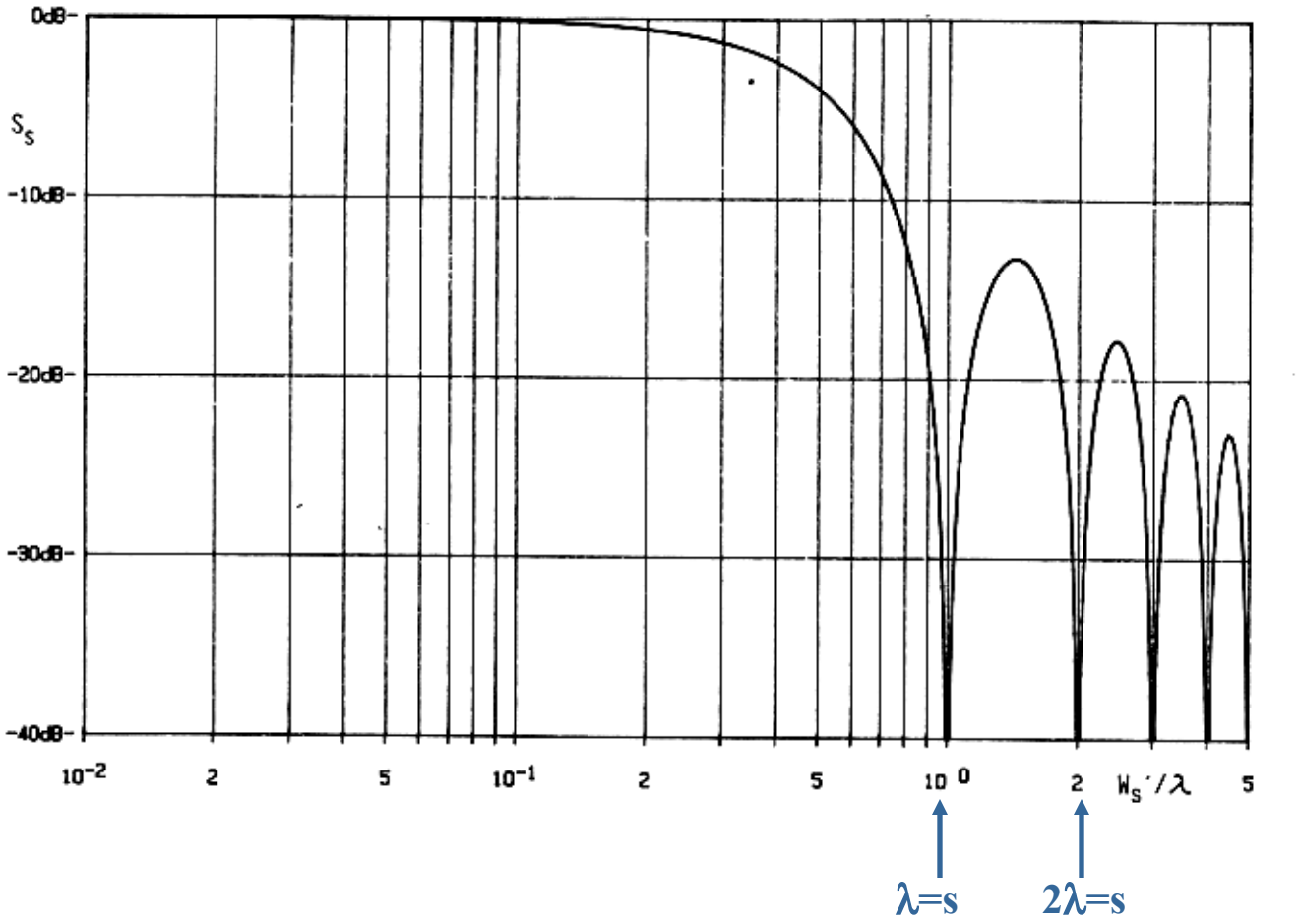
- Gap losses: relation of the wavelength of the bias frequency and the gap width of the playback head
  - If the wavelength reaches a dimension close to the effective gap width ▸ gap losses
  - If the wavelength equals the effective gap width = no head output

$$D_s = -20\lg \frac{\sin \pi s/\lambda}{\pi s/\lambda}$$

$D_s$ = gap loss

Gap loss function

# Head Gap Loss Function



# Practical Application of HF-Bias Signal Retrieval at Original Speeds:

- Focus: Use of **slightly modified** and **inexpensive standard components**
- Readout of the bias signal by use of a sensor head (mounted e.g. instead of the recording head) with minimal available standard gap width

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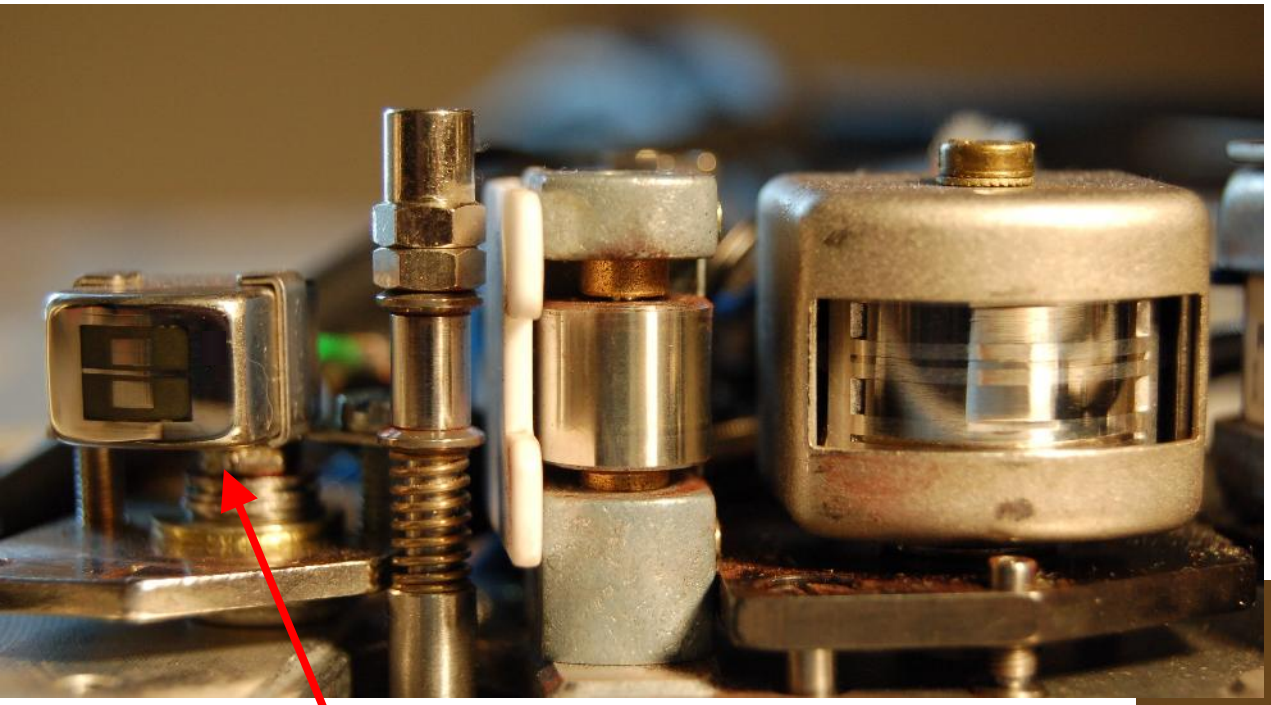
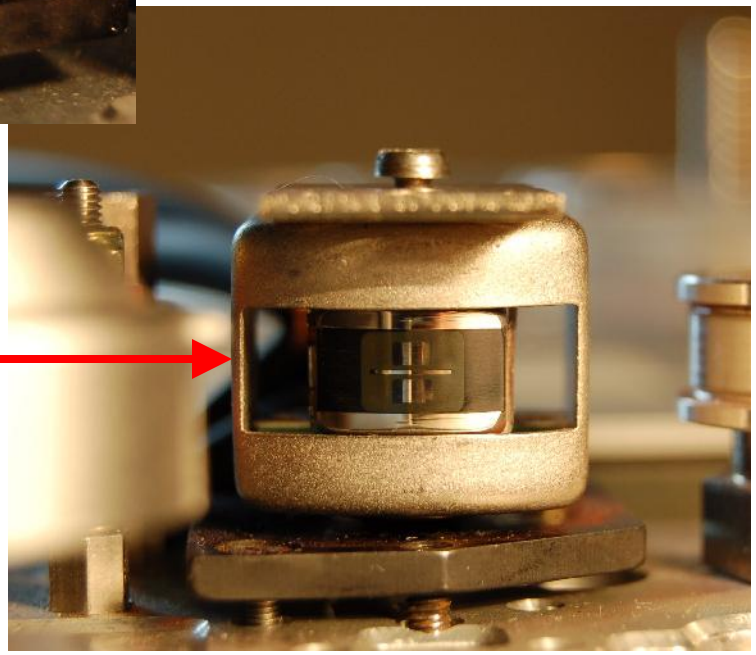
# Practical Application of HF-Bias Signal Retrieval

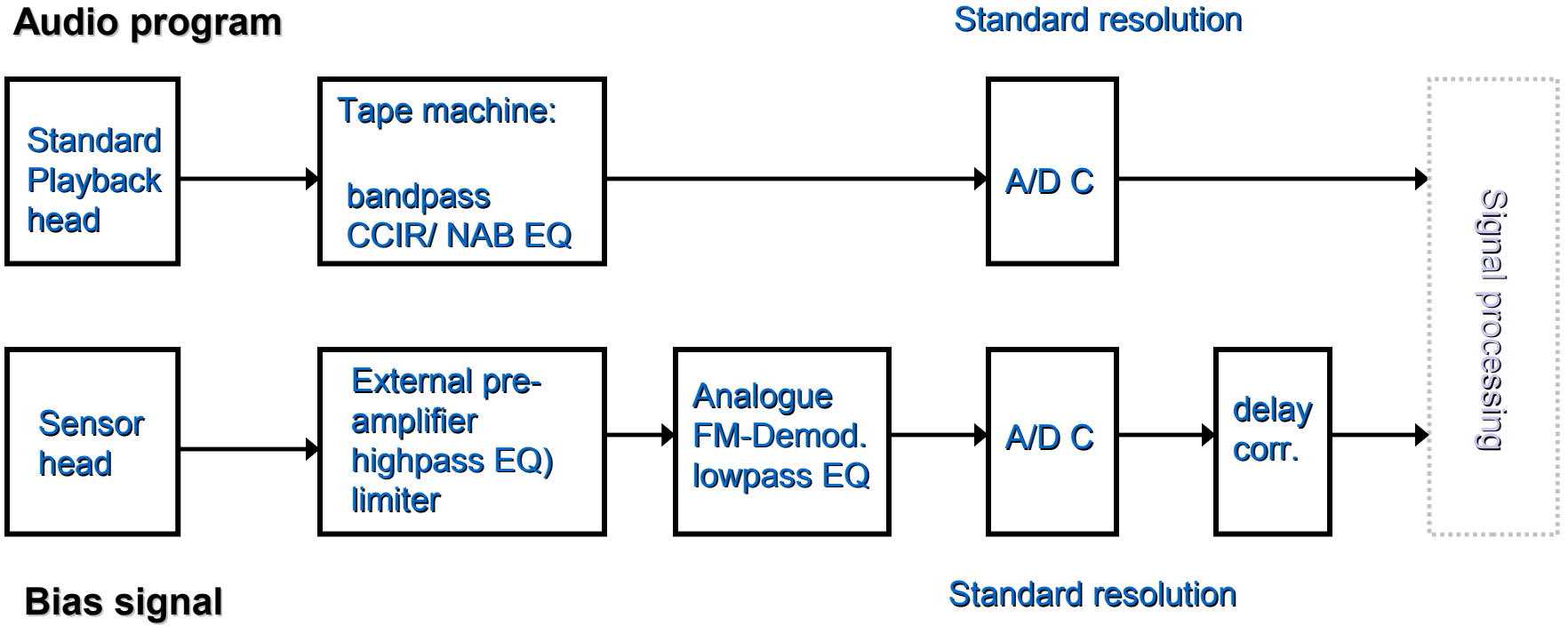
Use of additional HF bias sensor head



Use of cassette head
as additional
HF bias sensor head



# Analogue pre- processing of HF bias signal




- Advantage: standard resolution sufficient – cost effective
- Disadvantage: problems of analogue FM-demodulation:
  Bias frequency not known a priori – special circuit design necessary

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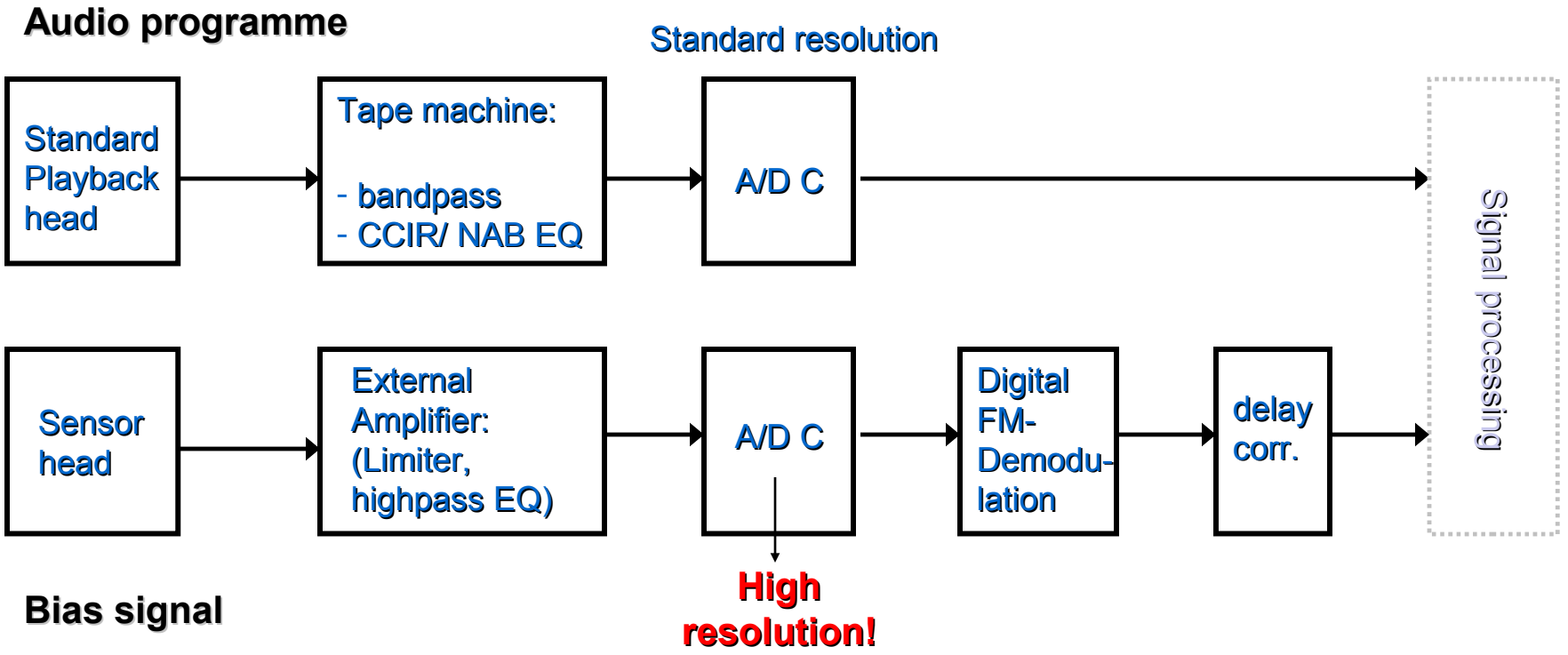
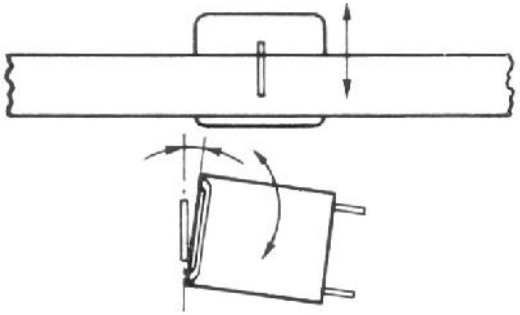
# Digital pre- processing of HF bias signal



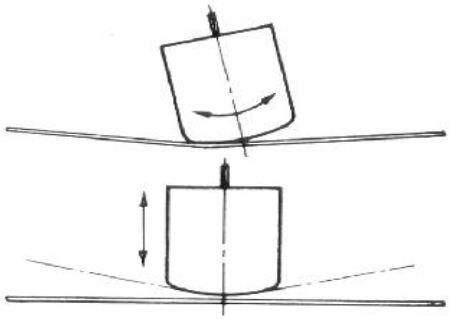

- Advantage: FM-demodulation in digital domain allows signal processing in a 2nd (later, maybe improved) step - to be preferred
- Disadvantage: higher costs, higher storage needs!

# Analyses and Limitations in Practical Application

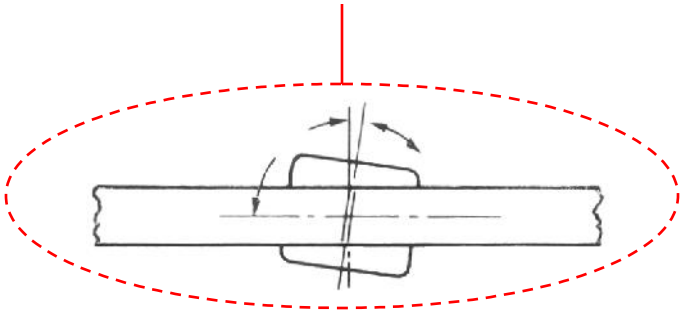
- Availability of dedicated reproduce heads
- Accurate mounting/ adjustment of dedicated repro heads:



**General adjustments**



**Individually per tape!**

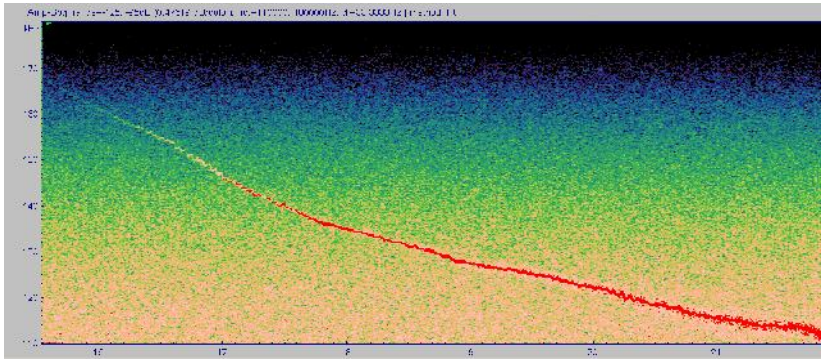


# Analyses and Limitations in Practical Application

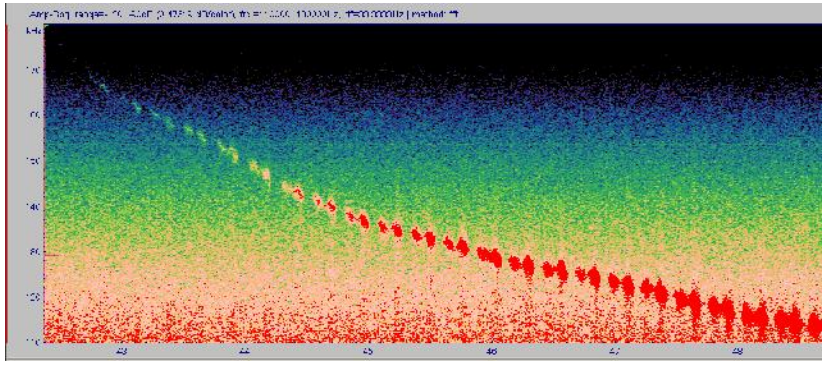
- Practical problems of bias signal retrieval:
- Head mounting: ▸ before the capstan

Comparison of wow performance with sensor heads mounted at different locations along the tape path:

a)

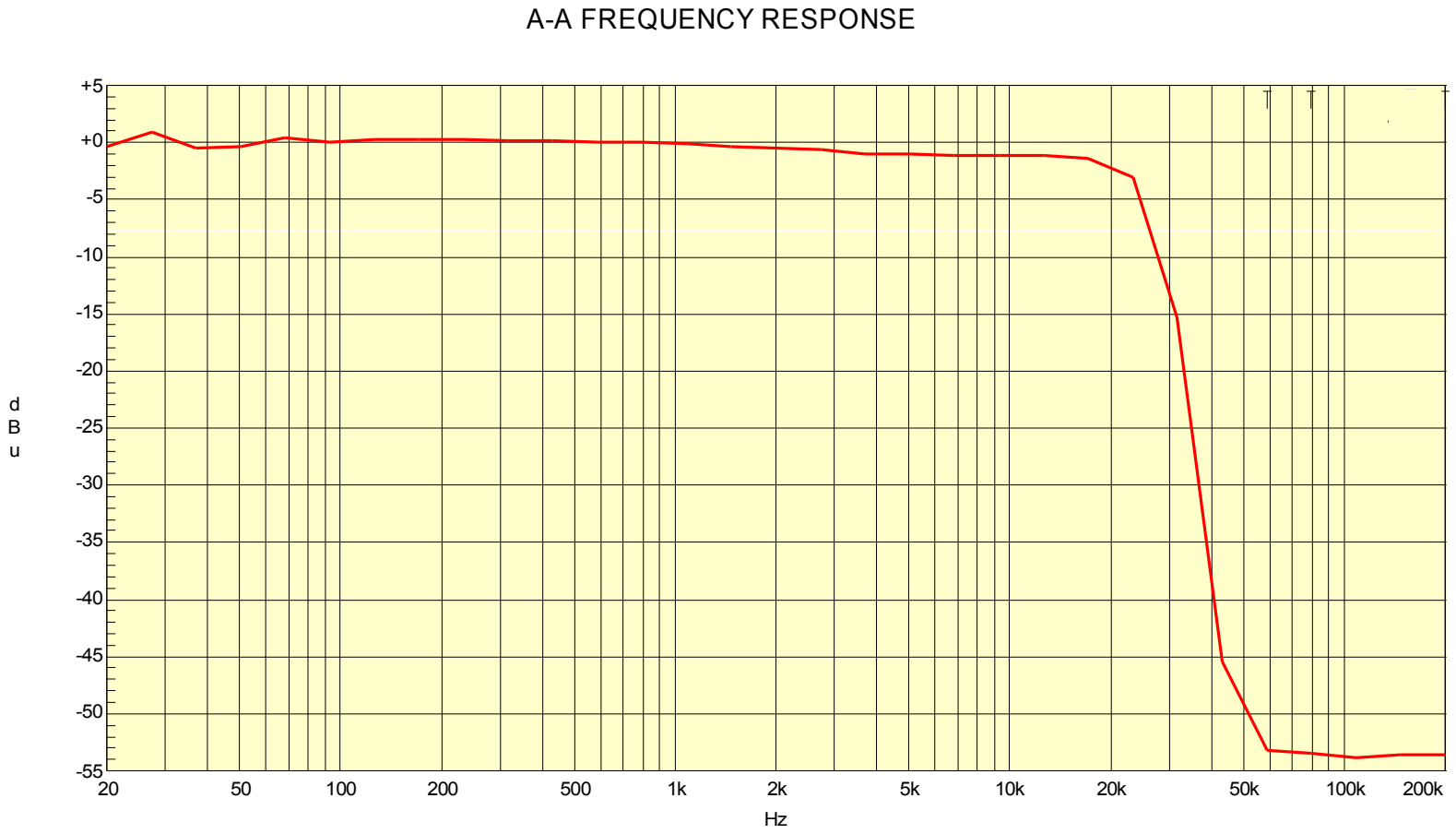


b)



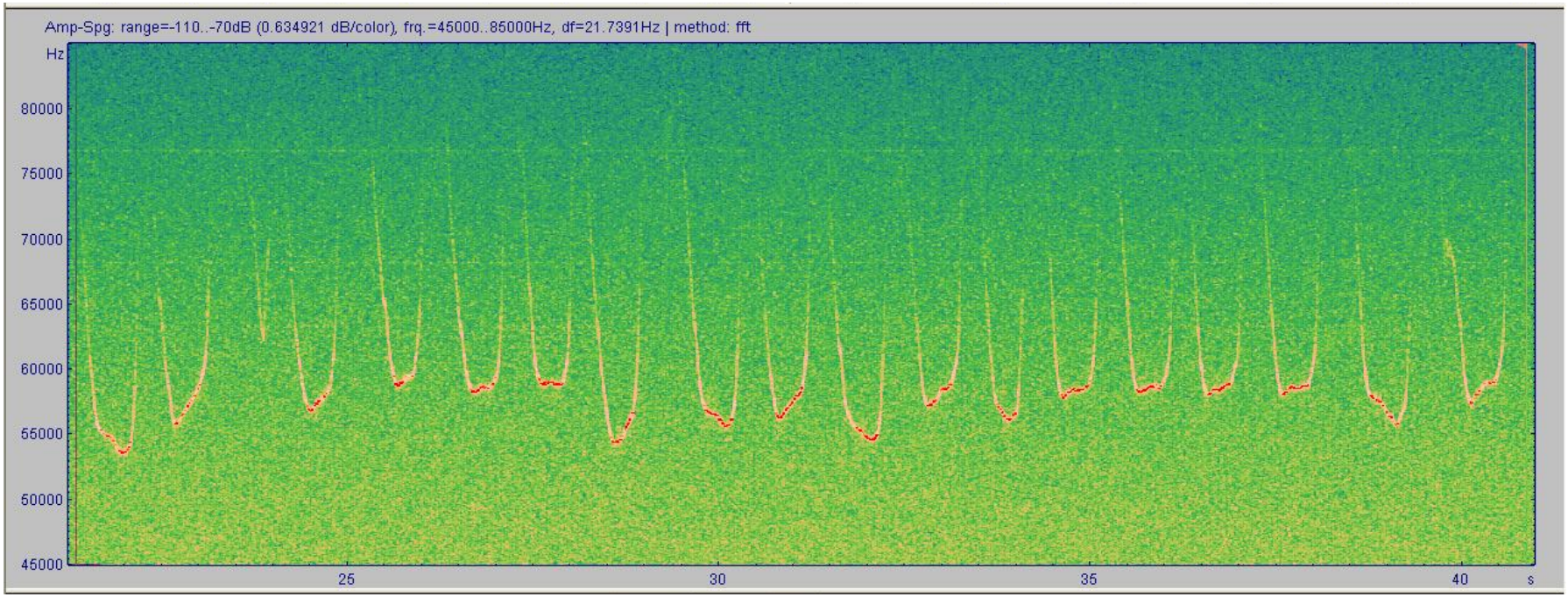
# Analyses and Limitations in Practical Application

- Bandwith limitation of the repro amplifier section of standard playback machines



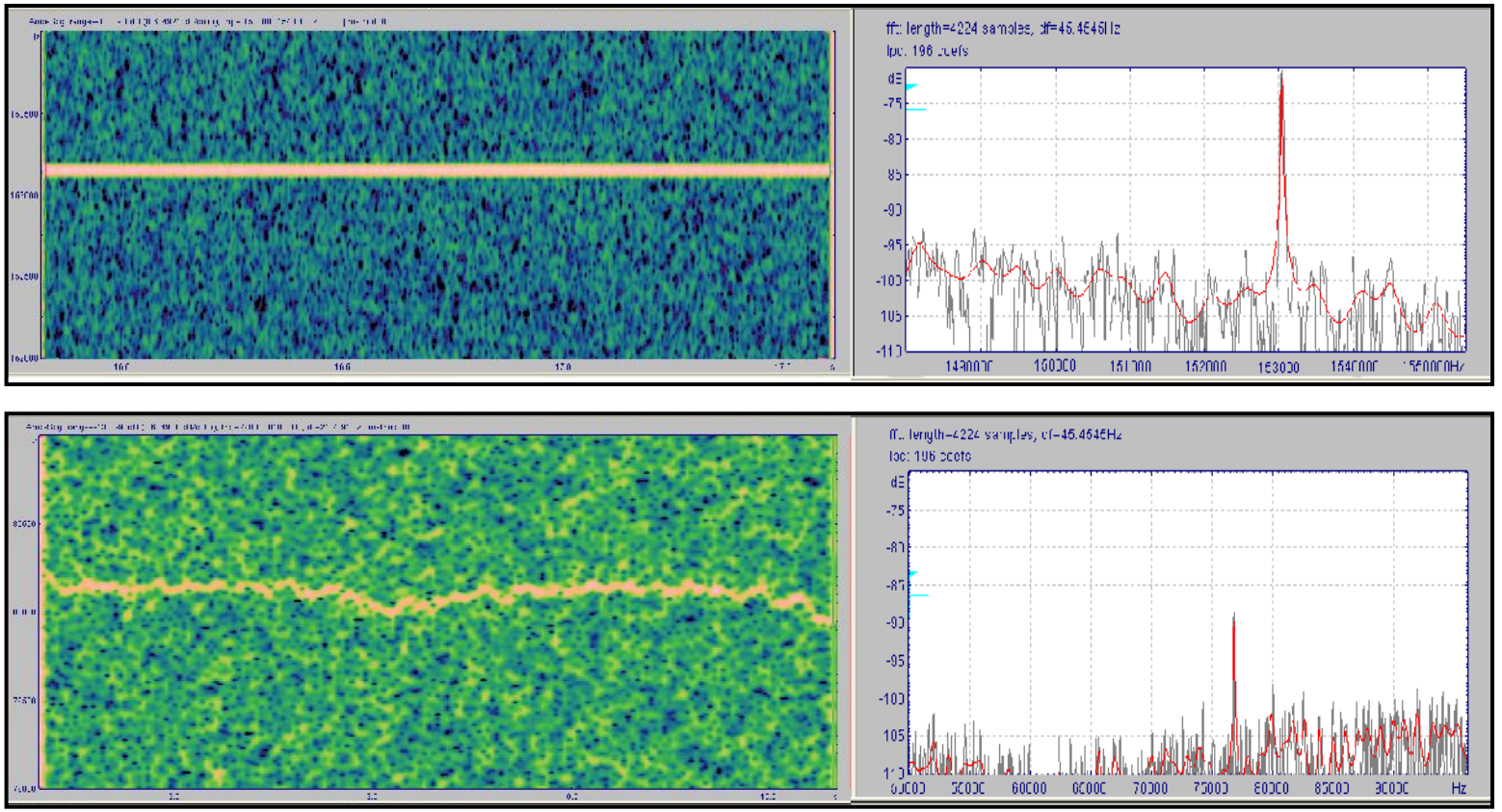
# Analyses and Limitations in Practical Application

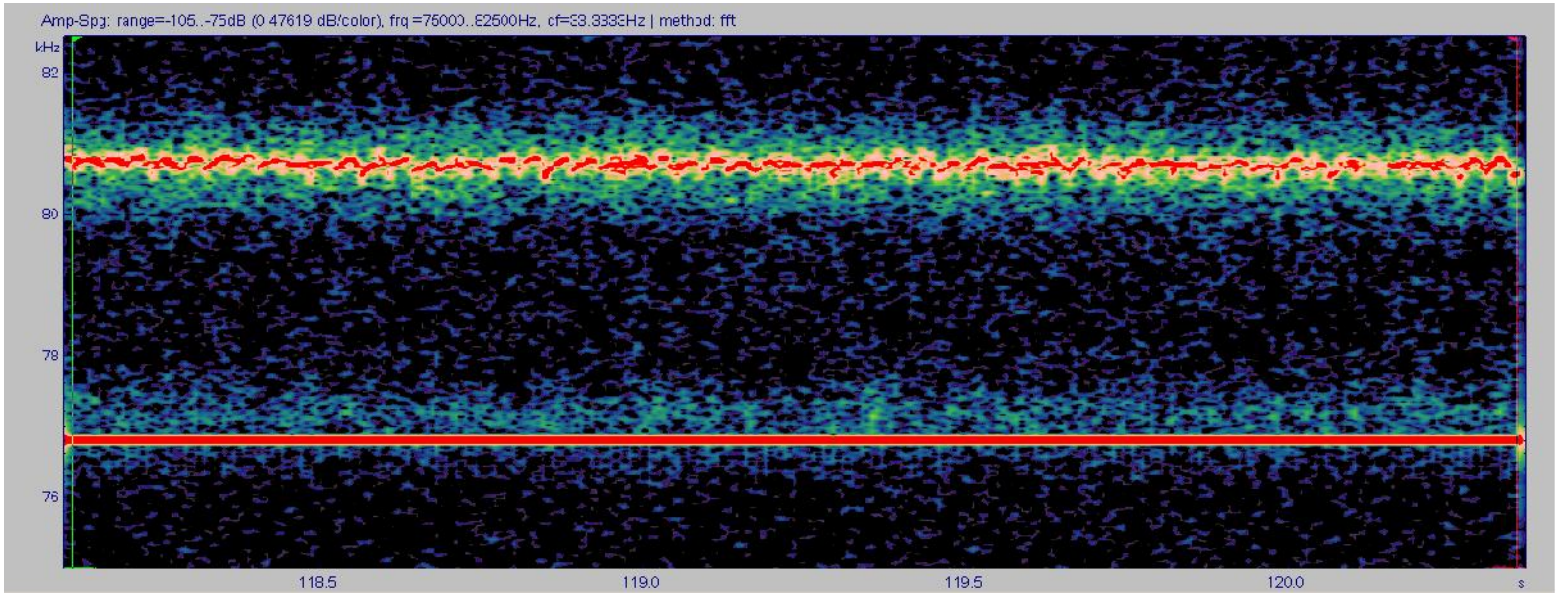
- Level, instability and unknown frequency of the recorded HF bias signal
- Extreme variations mainly with semiprofessional devices of older generations – instability of the bias oscillator

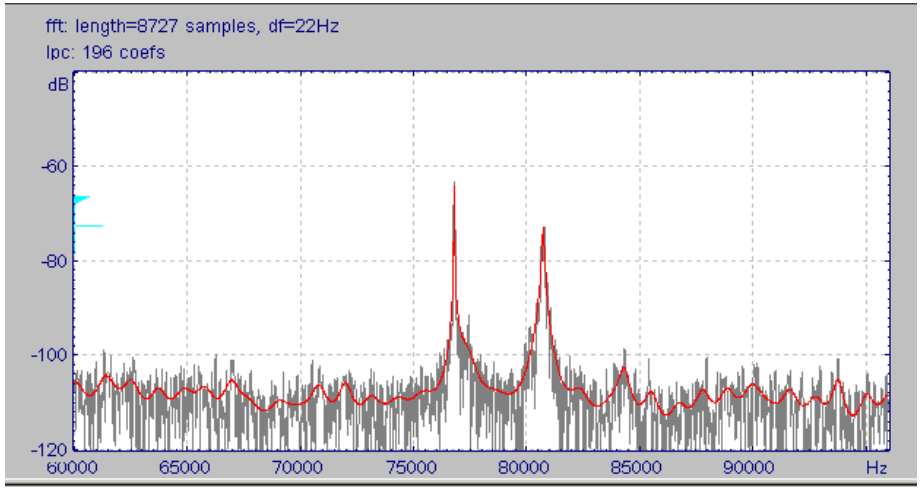


# Analyses and Limitations in Practical Application

- Ultrasonic artefacts: signal interferences of the playback machine

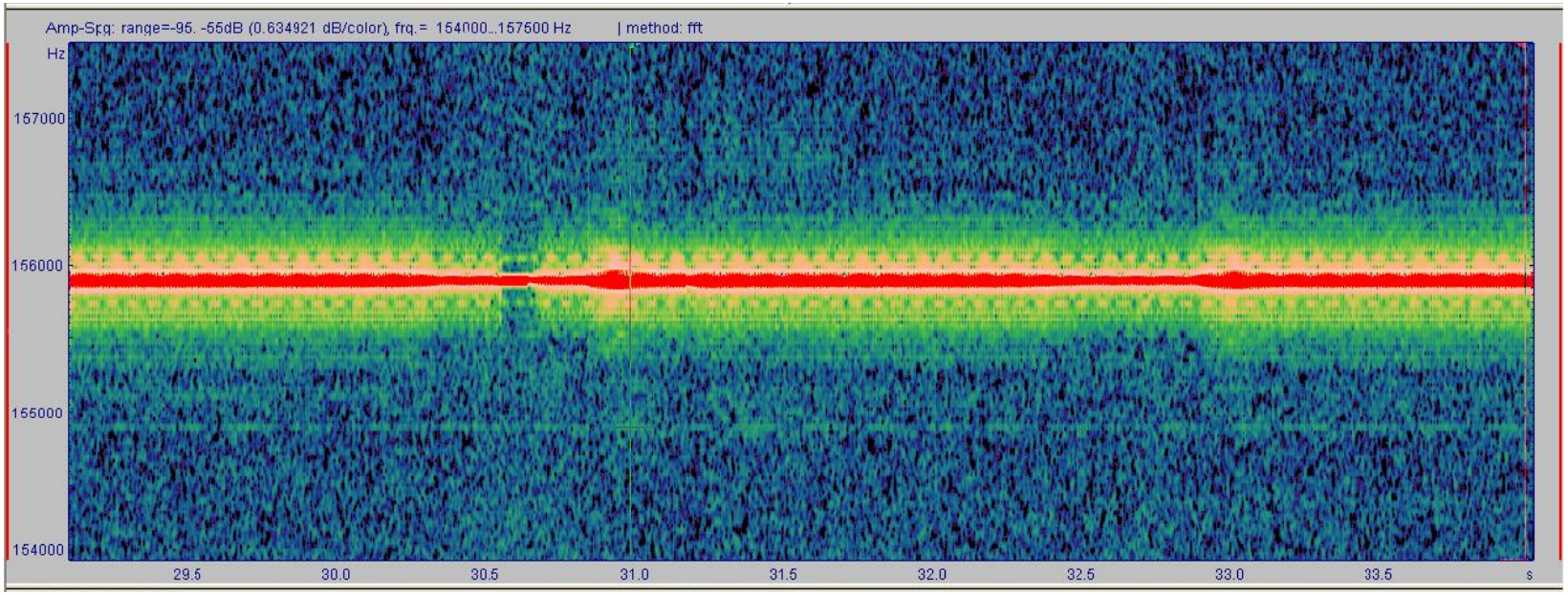


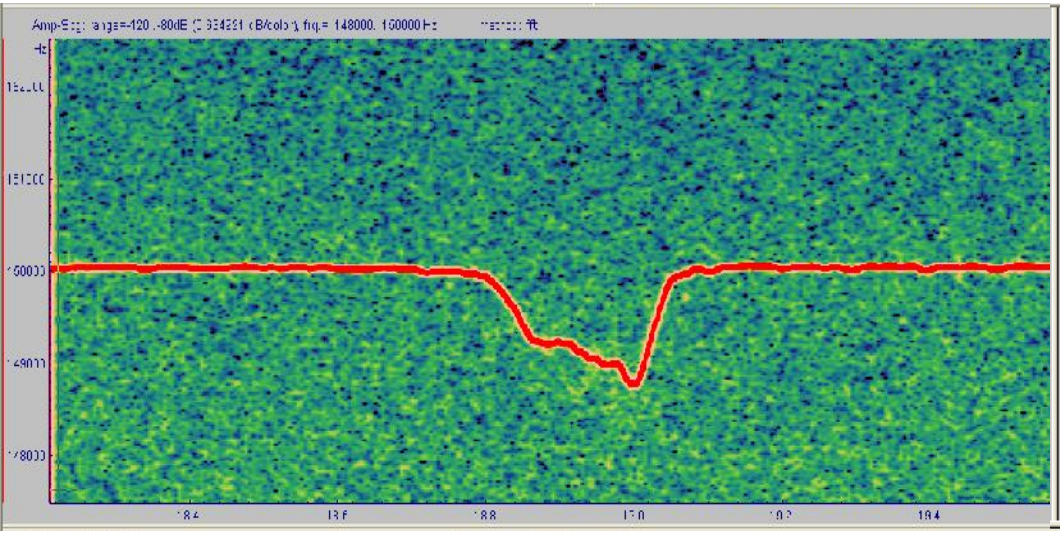

Amp-Spg: range=-105..-75dB (0.47619 dB/color), frq=75000..82500Hz, df=83.333Hz | method: fft
kHz
82
80
78
76
118.5
119.0
119.5
120.0
s

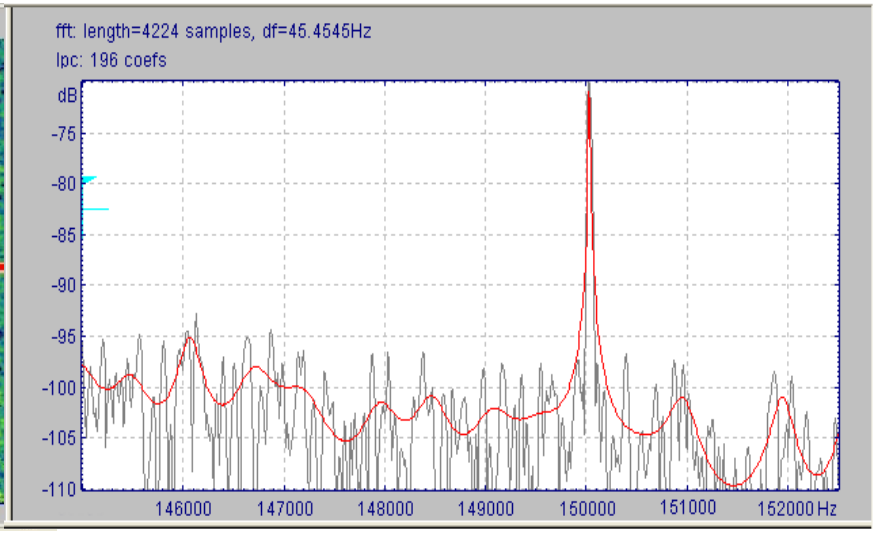

fft: length=8727 samples, df=22Hz
lpc: 196 coefs
dB
-60
-80
-100
-120
60000
65000
70000
75000
80000
85000
90000
Hz

# Analyses and Limitations in Practical Application

- Signal interaction of bias signal and system clock frequency interference as an effect of recording and playing back with the same (processor controlled) tape machine

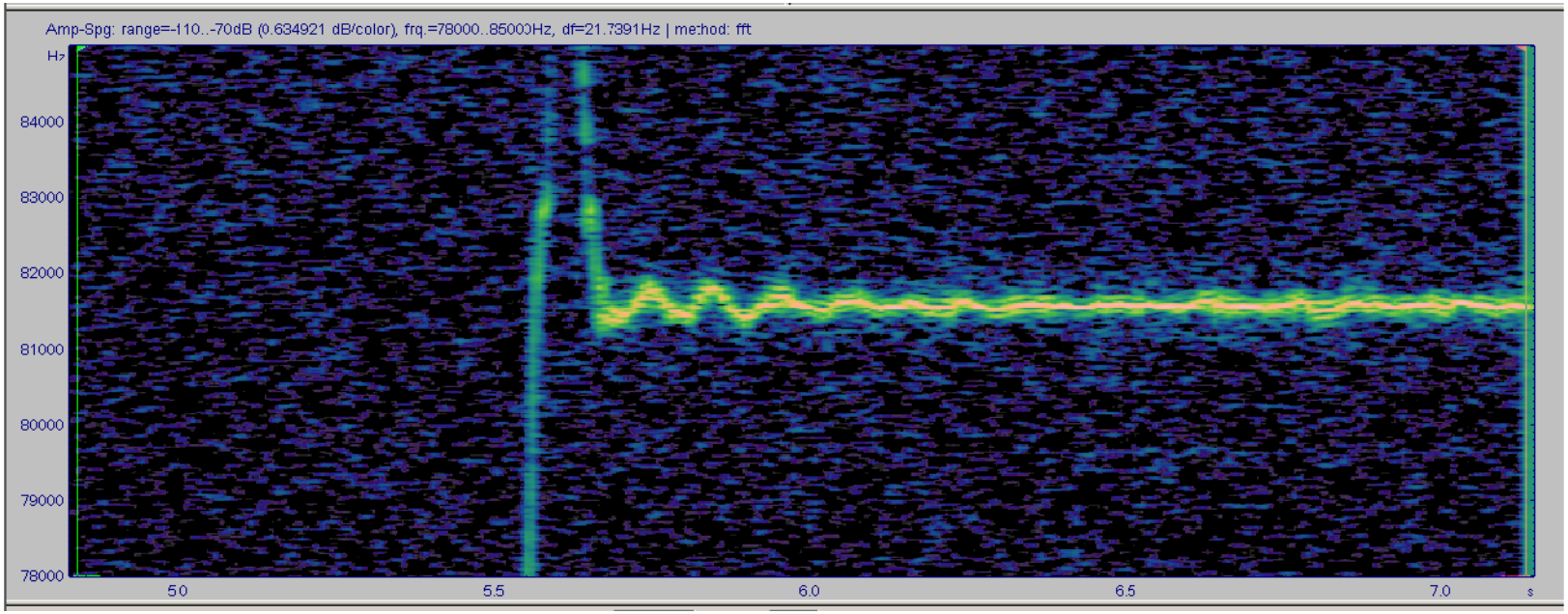







Retrieval of HF bias deviation (wow) at ~ 150kHz by means of an additional sensor head, using external signal amplification

Original recording: 38cm/s, Studer B67
(replay head needs ~2,3µ effective gap width)




Signal attack of the bias signal when starting reproduction from [stop] to [play].
Original recording: Uher 4200, 9,5cm/s
(replay head needs ~1,2µ effective gap width)

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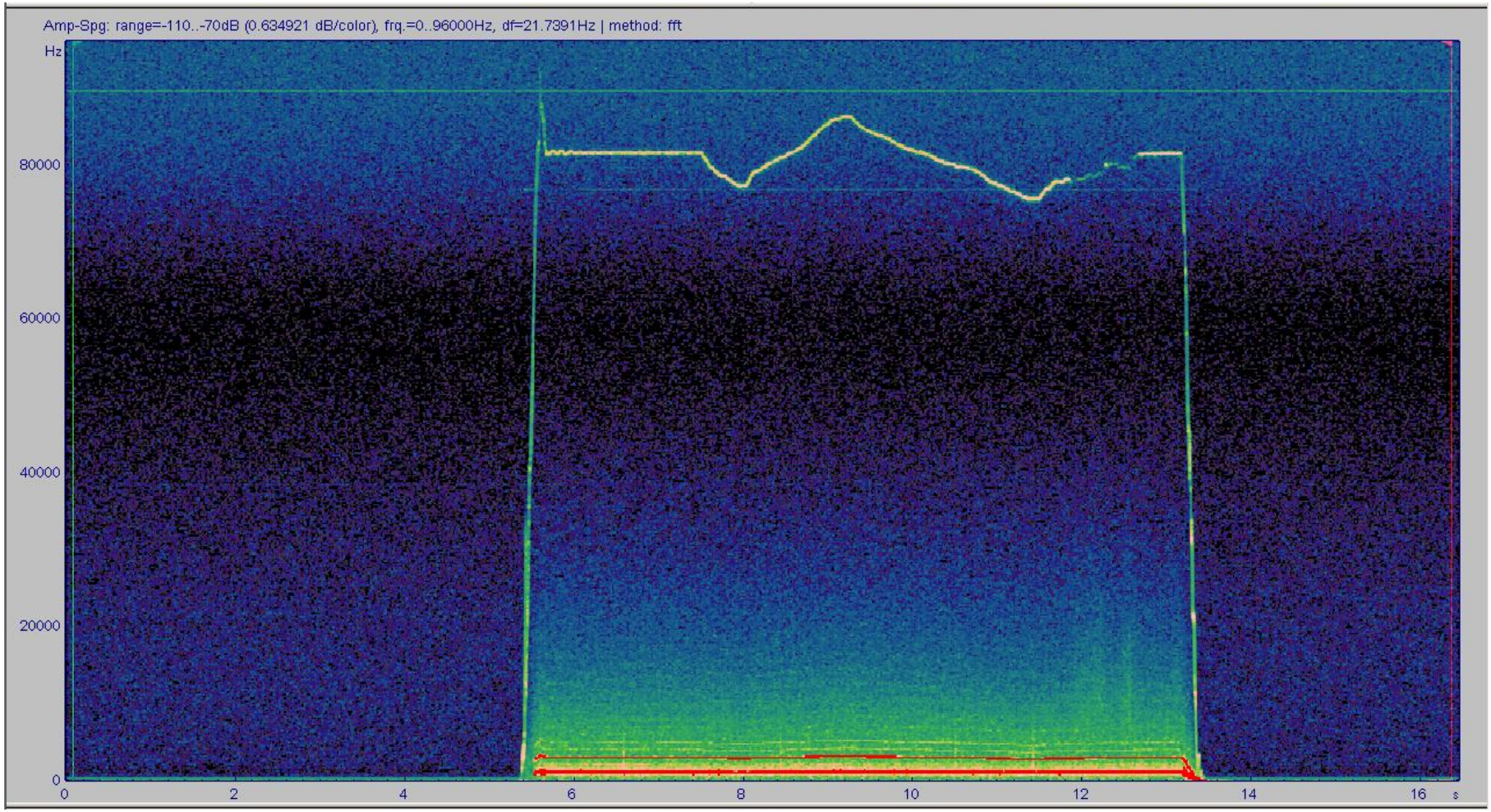
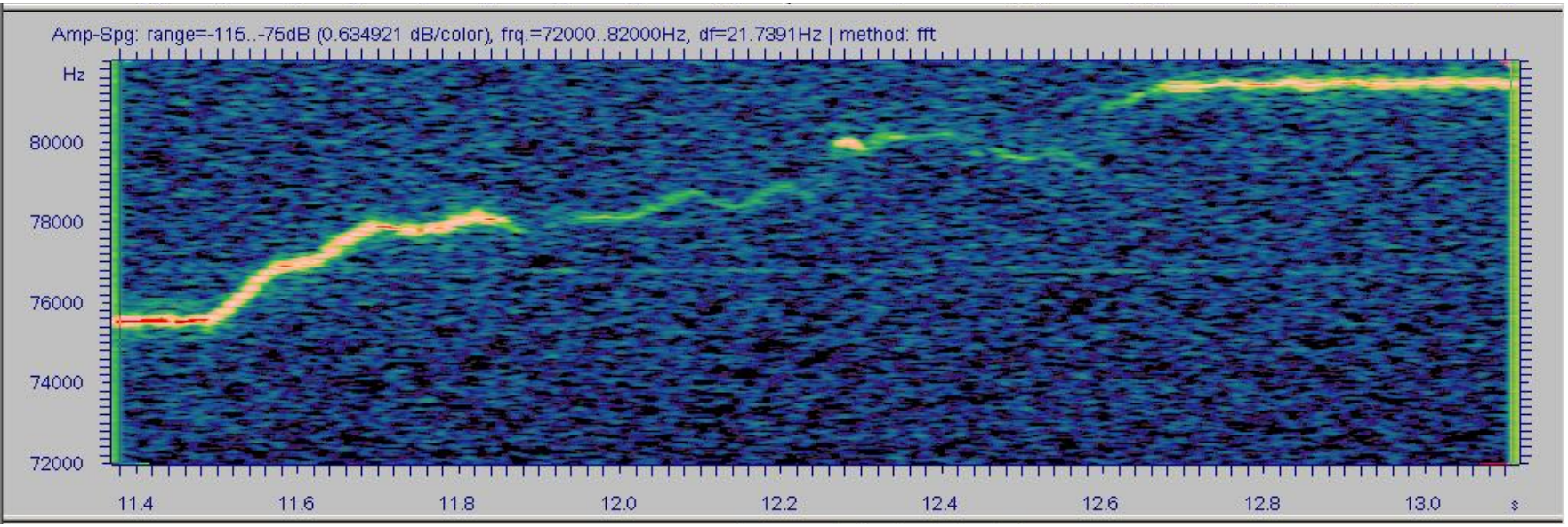
# Full spectrum analysis of previous example:

*Original recording: Uher 4200, 9,5cm/s (~1,2µ effective gap width)*






HF bias deviations in detail

# Analyses and Limitations in Practical Application

- Signal amplification:

  In many cases: bias signal very weak
  - Gap-loss problem
  - Playback on not regularily degaussed machines

# Alternative Approaches

- Playback at lower speeds:
  - Does **NOT** solve the wavelength problem!
  - **Increases** Wow & Flutter of replay machine!
  - Playback equalisation has to be compensated!
  - Time consuming!

# Alternative Approaches

- Simultaneous readout of audio program and bias signal using custom-built wide-bandwidth components
  - Production of analogue magnetic heads is disappearing
  - It is already difficult to replace standard heads
  - Not easy to realise

  - Advantage: audio program as well as the bias signal are retrieved simultaneously, and therefore are already synchronized
  - Scrape flutter & effects caused due to tape friction could be detected

**… theoretically …**

# ... In practice:

All theories are based on an ideal playback machine!

Wow & flutter performance of the playback machine must be **significantly lower** than of the recording device

Signals recorded and played back on high quality last generation devices or even the same device ▸ speed deviation effect is too low ▸ no applicable results

# Conclusion

- Retrieval of HF bias signals within a relatively wide range of combinations of standard bias frequencies and recording speeds is possible

Limitations:

- Problems with recordings produced on semiprofessional equipment:
  - low recording speeds
  - Instable HF
- Problems with distortions & signal interspersions
- Problems with the availability of reproduce heads

- Future applications:

  Forensic audio analysis

  – detection of start and end modulations of analogue magnetic tape and compact cassette recordings

**Thanks to**

Institute of Acoustic Research of the Austrian Academy of Sciences

for updating their analysis software STX up to 2MHz bandwidth due to the authors request

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# Thank you for your attention!

heinrich.pichler@aon.at

Nadja.Wallaszkovits@oeaw.ac.at

http://www.pha.oeaw.ac.at/