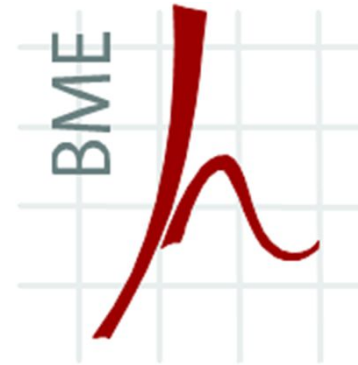




SOUND TRANSMISSION AND RECORDING

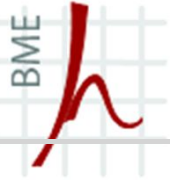
Study aid for learning of Communications Acoustics

VIHIM 000

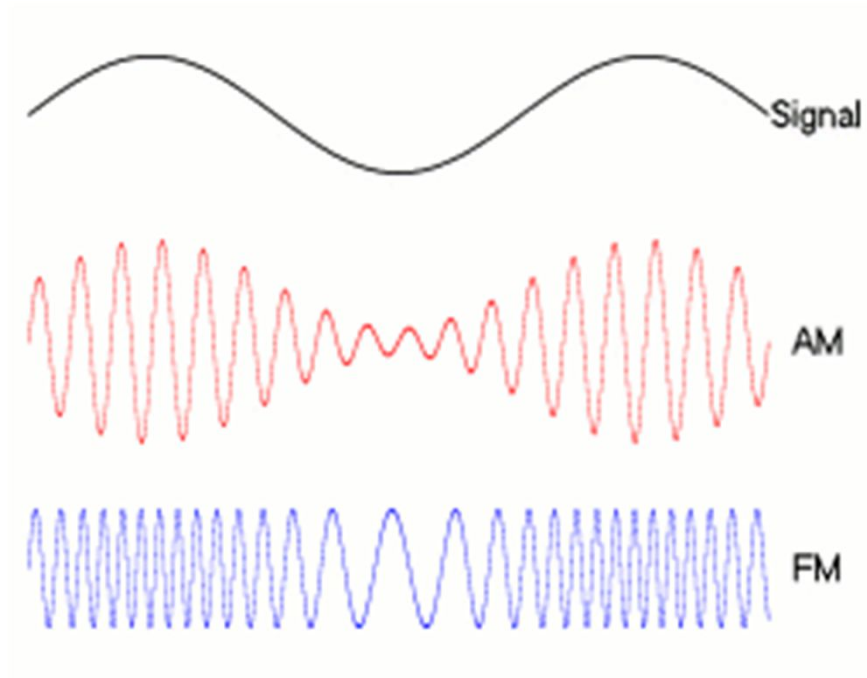
Prof. Fülöp Augusztinovicz
BME Dept. of Networked Systems and Services
fulop@hit.bme.hu



2018. december 5.,
Budapest



Radio transmitting systems



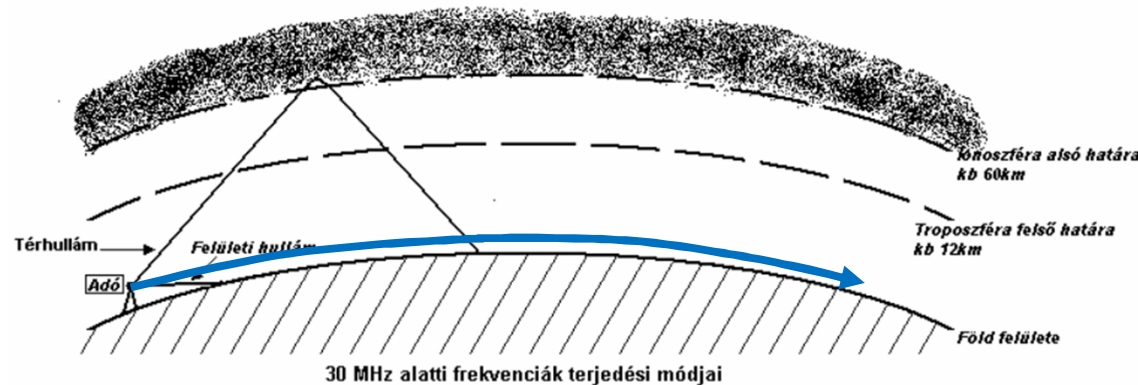
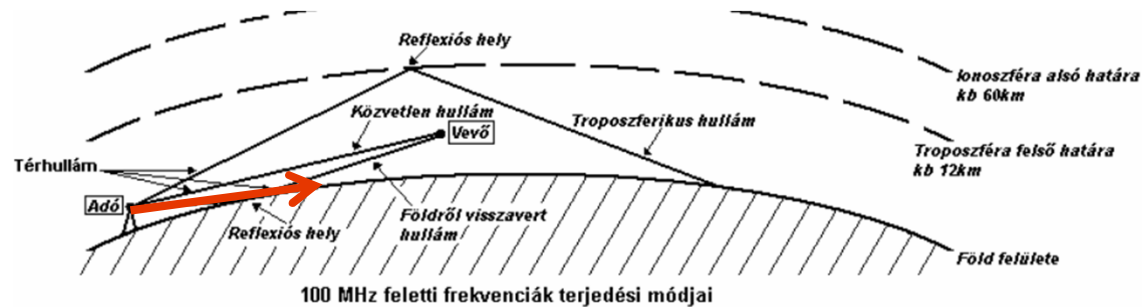
$$20 < f_{\text{sound}} < 20 \text{ kHz}$$

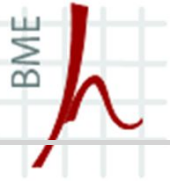
$$f = f_{\text{carrier}} \pm f_{\text{sound}}$$

$$f = f_{\text{carrier}} \pm 75 \text{ kHz (max)}$$

Propagation of radio waves

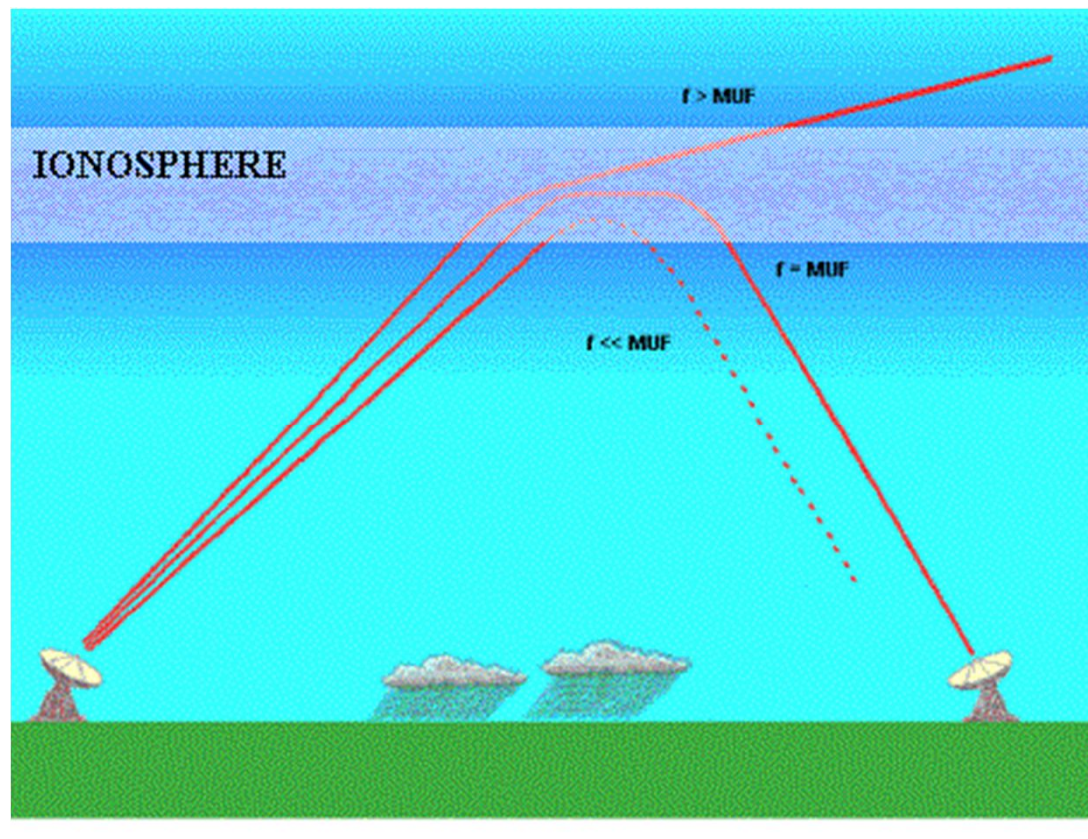
- Strongly dependent on frequency
 - above 100 MHz:** direct, reflected and tropospheric
 - below 30 MHz:** space wave and surface wave

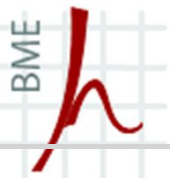




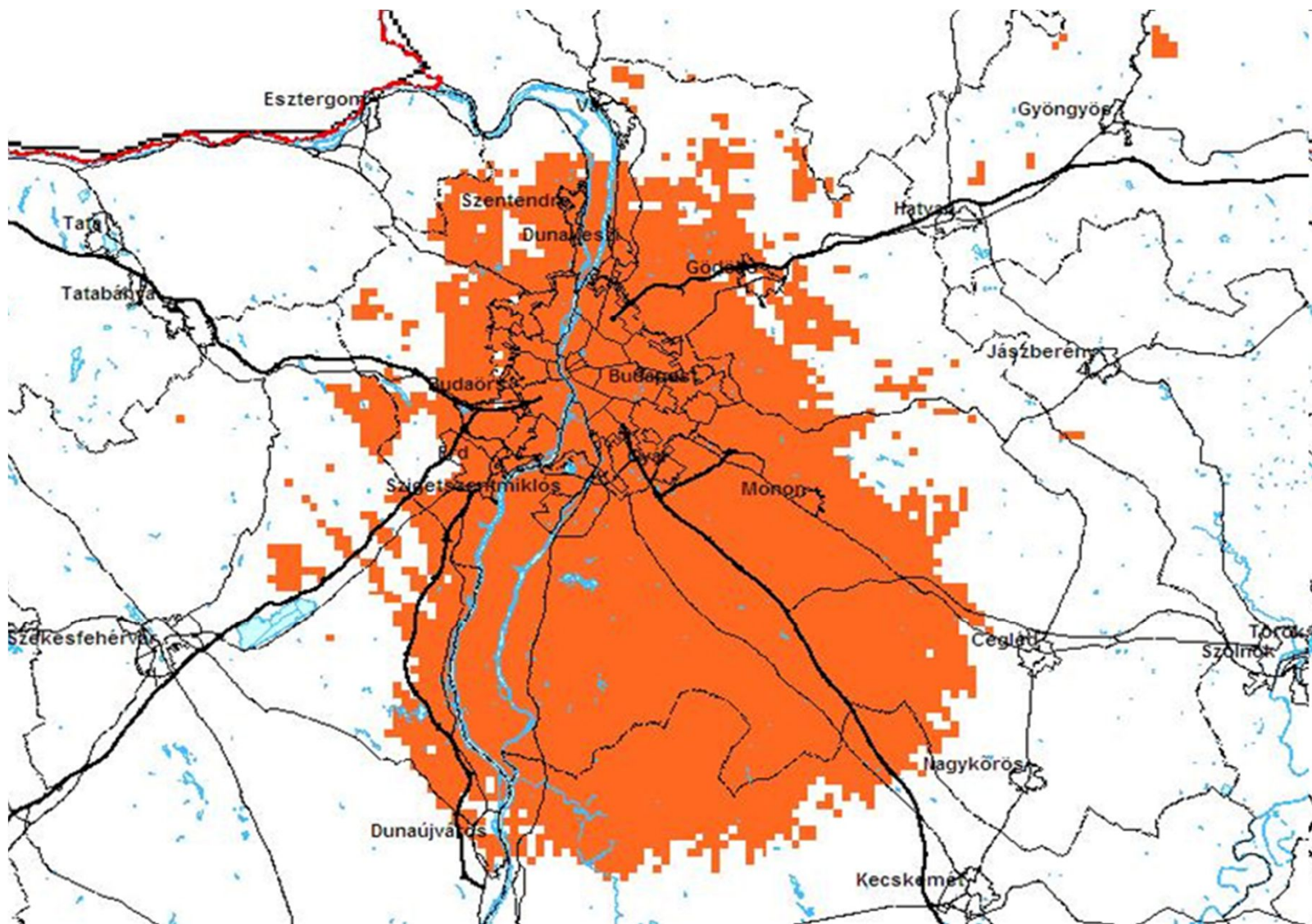
Propagation of radio waves in the atmosphere

- Reflected waves (mainly in the Short Wave band)
 - MUF = Maximum Usable Frequency



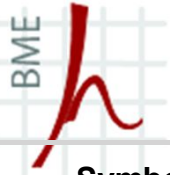


FM broadcasting coverage around Budapest



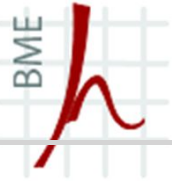
Relief map around Budapest





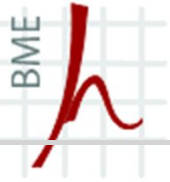
Radio bands

Symbol	Frequency	Wavelength	Applications
ELF	3–30 Hz	10,000– 100,000 km	Directly audible when converted to sound (above ~20 Hz), communication with submarines
SLF	30–300 Hz	1,000– 10,000 km	Directly audible when converted to sound, AC power grids (50–60 Hz)
ULF	300– 3000 Hz	100–1,000 km	Directly audible when converted to sound, communication with mines
VLF	3–30 kHz	10–100 km	Directly audible when converted to sound (below ~20 kHz; or ultrasound otherwise)
LF	30– 300 kHz	1–10 km	AM broadcasting , navigational beacons , lowFER , amateur radio
MF	300– 3000 kHz	100–1000 m	Navigational beacons, AM broadcasting , amateur radio , maritime and aviation communication
HF	3–30 MHz	10–100 m	Shortwave , amateur radio , citizens' band radio
VHF	30– 300 MHz	1–10 m	FM broadcasting , amateur radio , broadcast television , aviation , GPR , MRI
UHF	300– 3000 MHz	10–100 cm	Broadcast television, amateur radio , mobile telephones , cordless telephones , wireless networking , remote keyless entry for automobiles, microwave ovens , GPR
SHF	3–30 GHz	1–10 cm	Wireless networking, satellite links, amateur radio , microwave links, satellite television, door openers
EHF	30– 300 GHz	1–10 mm	Microwave data links, radio astronomy , amateur radio , remote sensing , advanced weapons systems, advanced security scanning

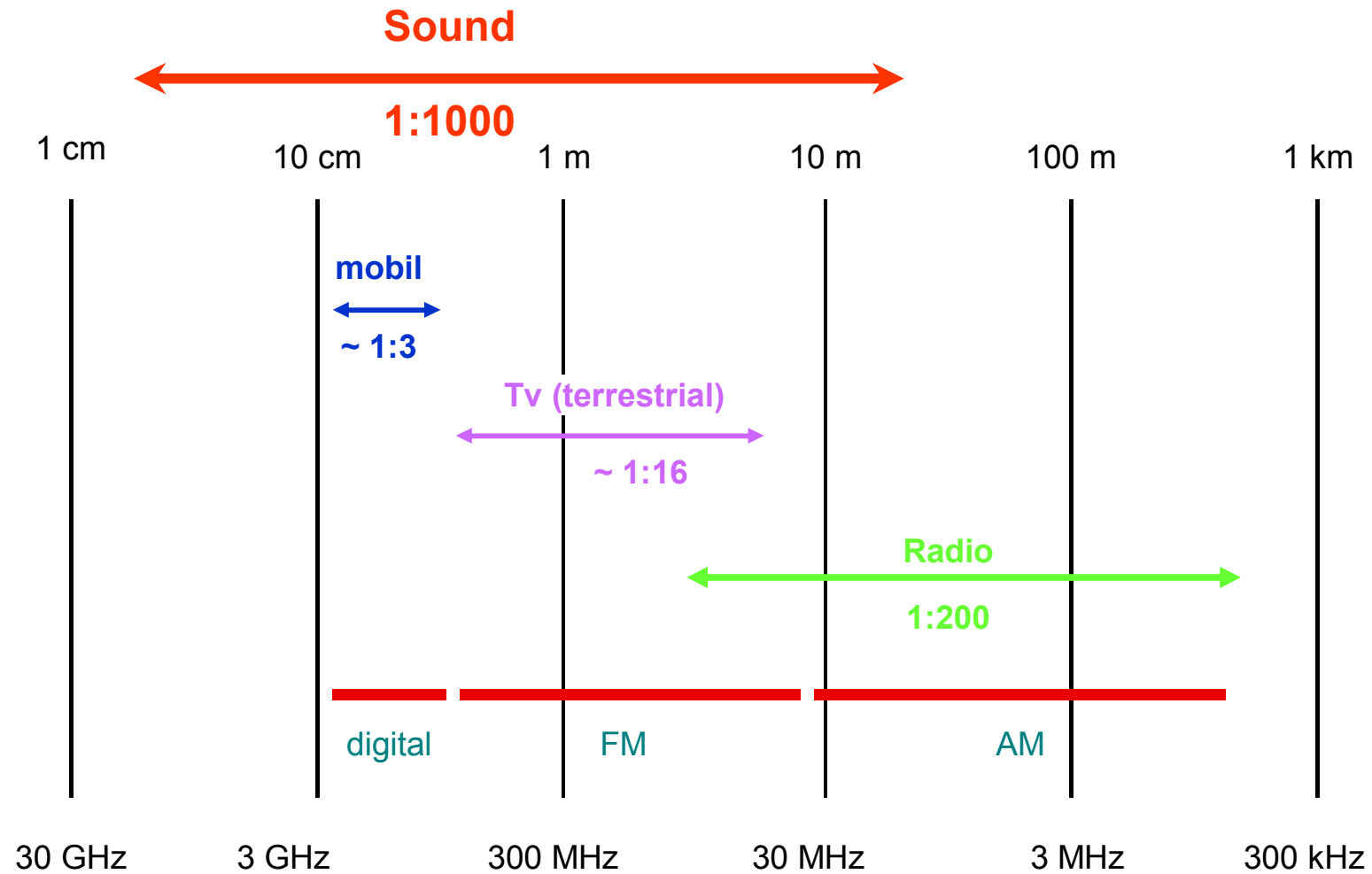


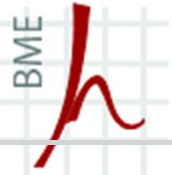
Radio systems

- AM
 - In MW band,
 - Frequencies allocated in 9 kHz distance (E) or 10 kHz (US)
 - Dynamic range 50 dB, bandwidth: 100-4500 Hz
 - Amateur, large distance telecommunication etc.
- FM
 - In VHF band (CCIR), frequencies allocated in 100 kHz distance
 - larger dynamics: 70 dB
 - wider frequency range: 40-15000 Hz
- Digital
 - DRM (Digital Radio Mondiale)
 - DAB, DAB+ (Digital Audio Broadcasting)
 - DVB-T, DVB-S (Digital Video Broadcasting – Terrestrial/Satellite)



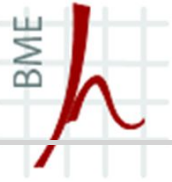
Ranges of wavelength





Frequency bandwidth

- AM, medium wave 100 - 4500 Hz
- FM, VHF 40 - 15 000 Hz
- TV: 40 - 15 000 Hz
- Traditional records
(LP, vinyl or bakelite): 30-10000 (but in new conditions only)
(harmonics up to 30 000 Hz)
- MC (music cassette): 50 - 10 000 Hz
- CD (compact disc): 20 - 18 000 Hz
- SACD (=Super Audio CD): 20 - 200 000 Hz

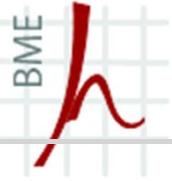


Dynamic range

Ratio of the maximum and minimum transmittable signal components, in dB

Upper limit: distortion, lower limit: background noise

- AM, MW: 40-50 dB
- FM 60-70 dB
- Tv: the same as FM
- Record: 30 - 40 dB
- MC: 30 – 40 dB
- CD: 96 dB
- SACD: 110 dB

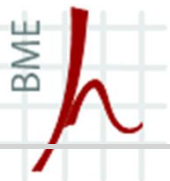


Volume, loudness, saturation, distortion and clipping

- These all together in:

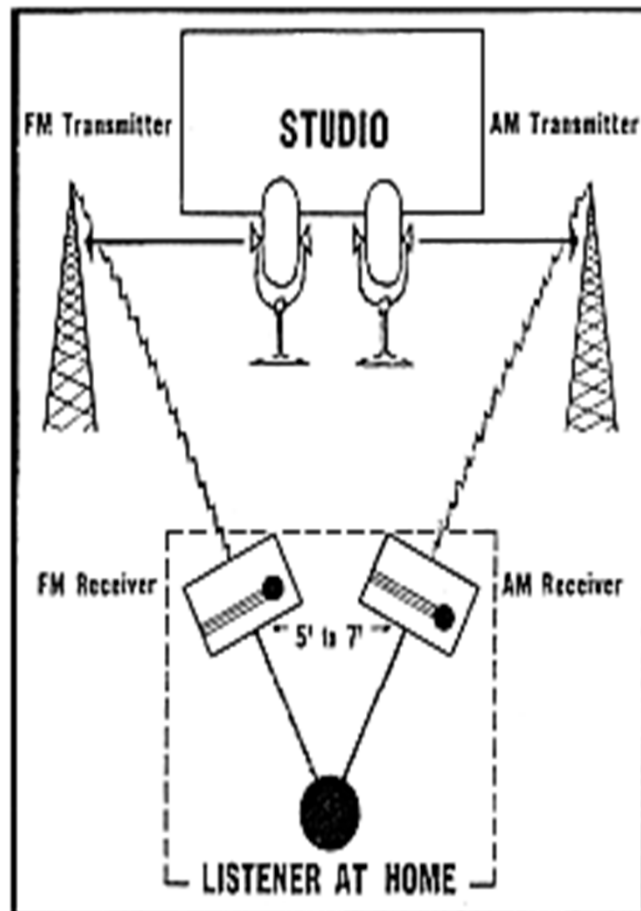
[The Loudness War](#)

http://www.youtube.com/watch?v=3Gmex_4hreQ



Outset of the stereo transmission

- The first stereo radio (1961)



The first virtual audio equipment

- The phonograph of Th.A. Edison
- (patent from 1877)

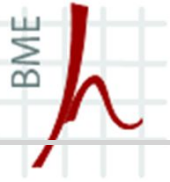


- The telediffusion (on the phone) by T. Puskás, the first coverage from the Paris Opera House (1881)



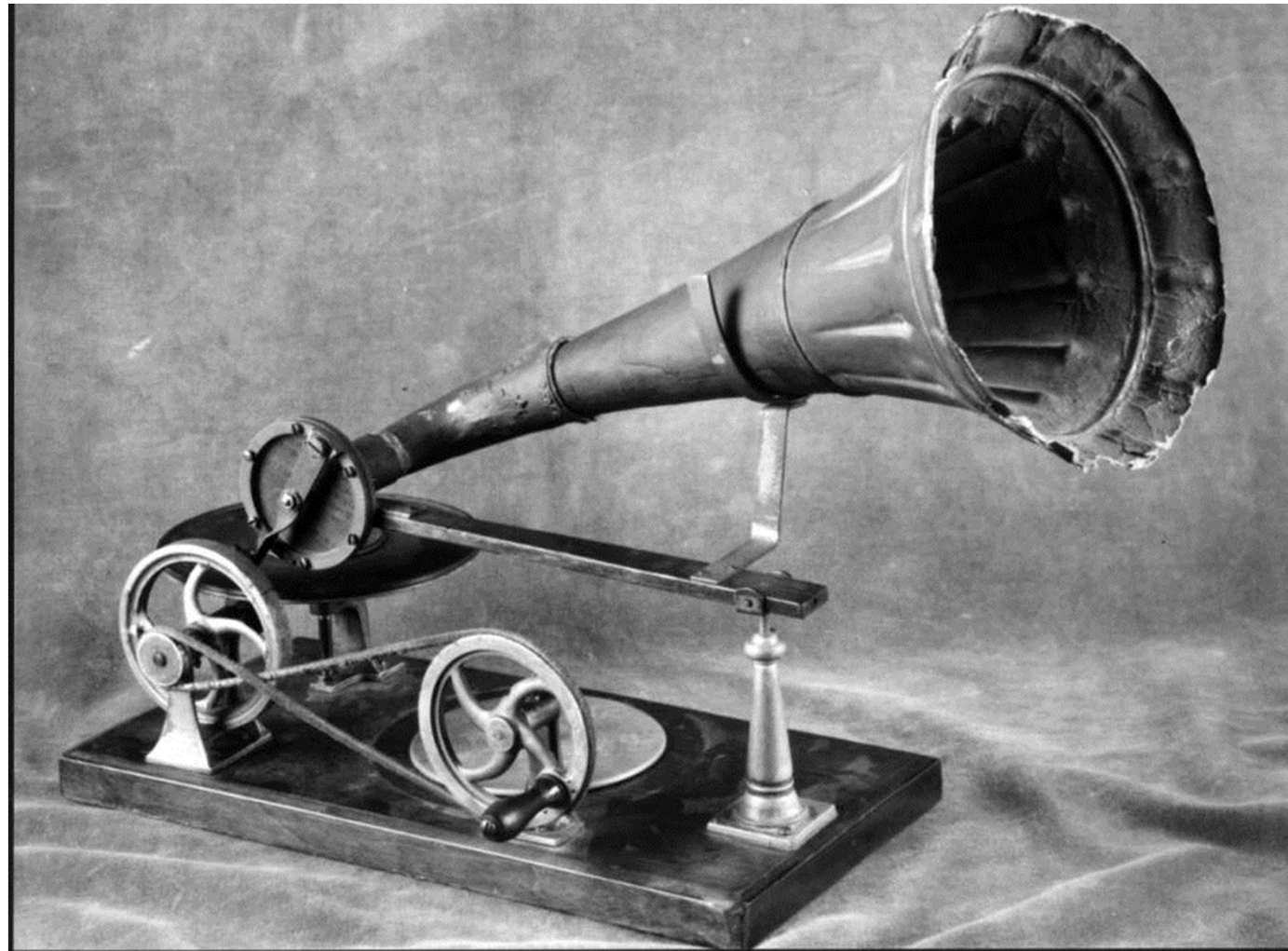
Phonograph cylinders





Development of sound recording technologies

- Mechanical record (Berliner, 1895)



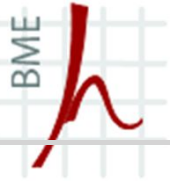


Purely electronic record player

- 45 rpm player (RCA, ~1948)



Enrico Caruso, tenore



Modes of operation

BERLINER
GRAMOPHONE
RECORD

lateral movement
of the needle tip

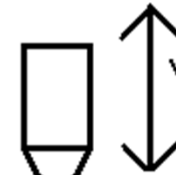


rotation of
the record

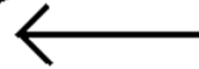


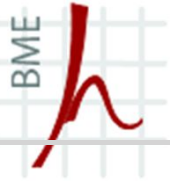
EDISON
PHONOGRAPH
CYLINDER

vertical movement
of the needle tip

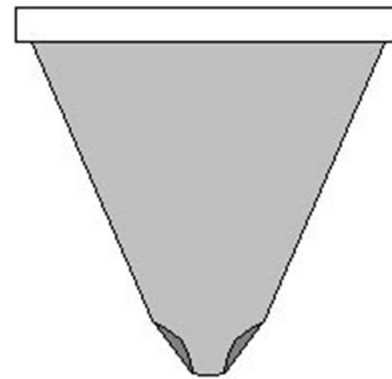
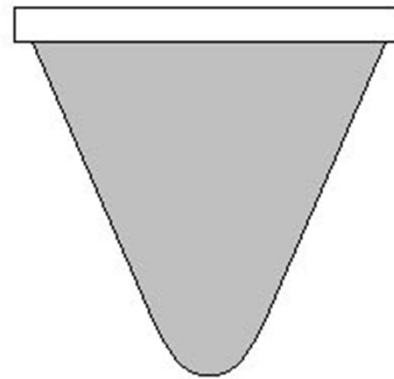
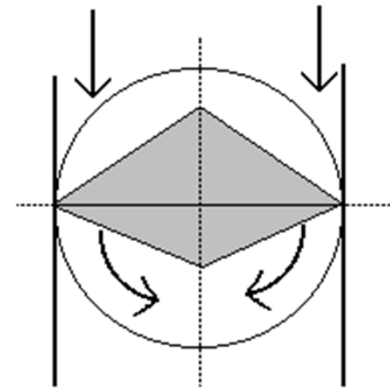
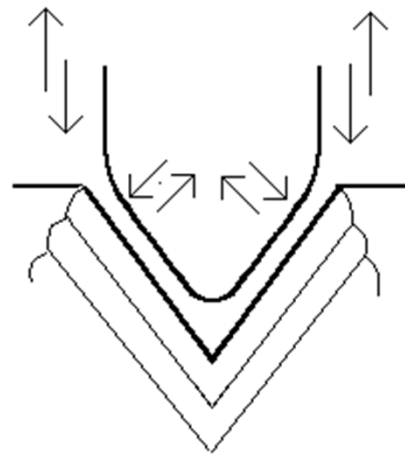


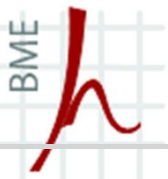
rotation of the cylinder



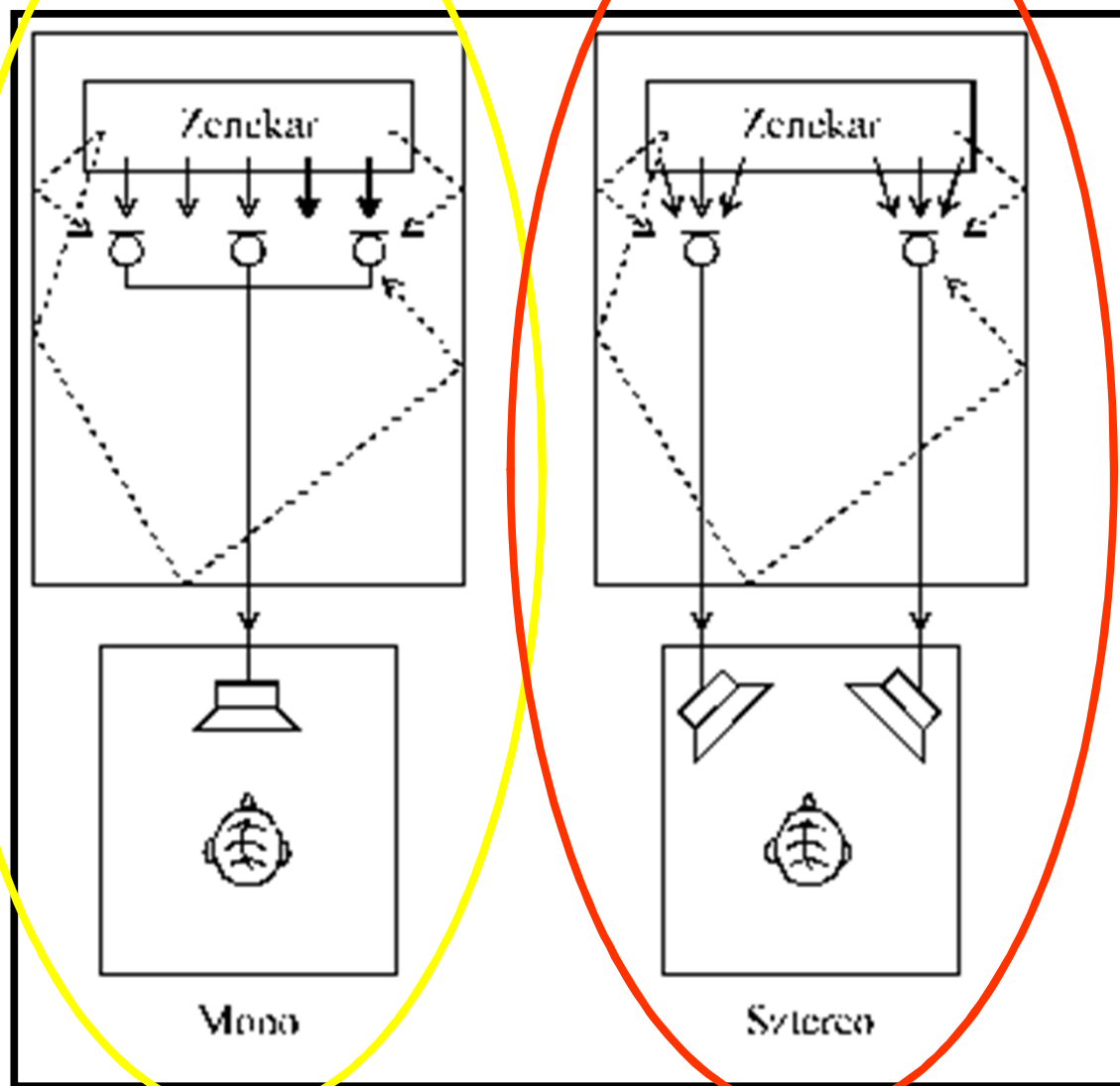


Two channel (stereophonic) LP record





Multichannel recording

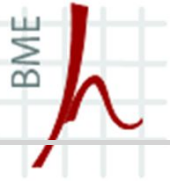


Development of stereo recording

- One of the best:
Sergeant Pepper's Lonely Hearts' Club
(1967, Abbey Road Studio, George Martin, EMI Records)
- <https://www.youtube.com/watch?v=gLIWIfKO0sU>

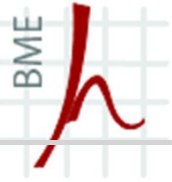


„A defining album in the emerging psychedelic rock style, *Sgt. Pepper* was critically acclaimed upon release and won four Grammy awards in 1968. Acclaimed by critics and publications as one of the most important albums in the history of popular music.”



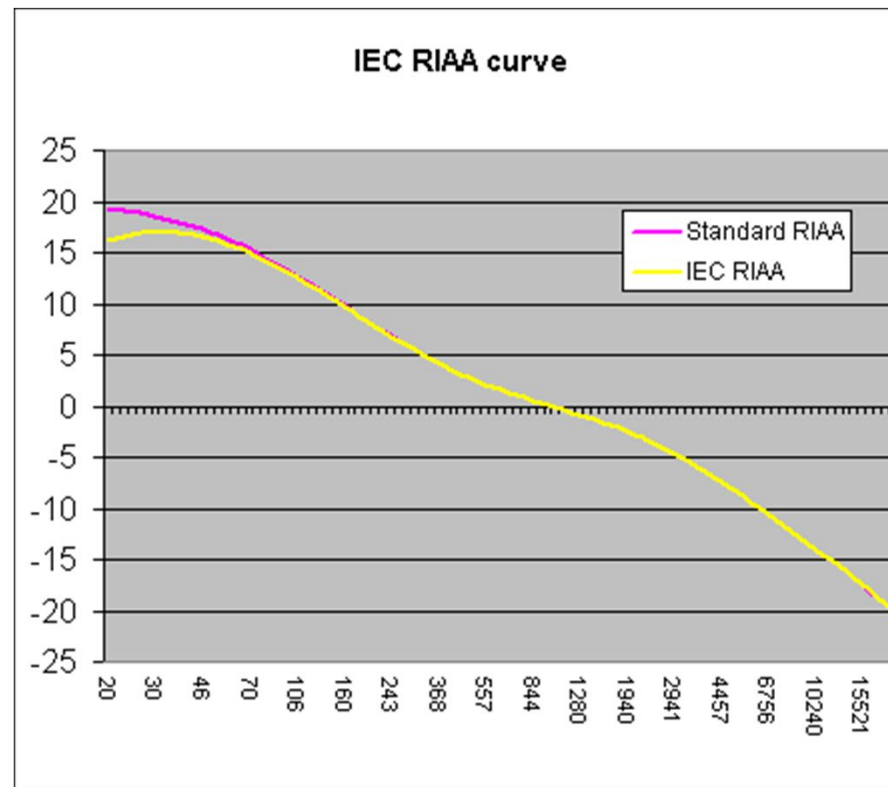
The pickup





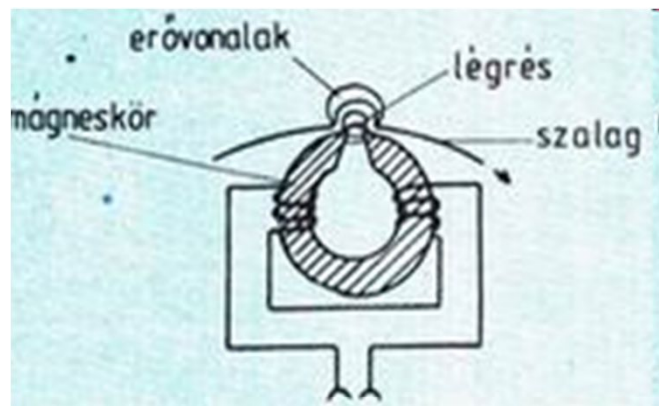
Frequency correction

- Record Industry Association of America - RIAA korrektor





Tape recorder



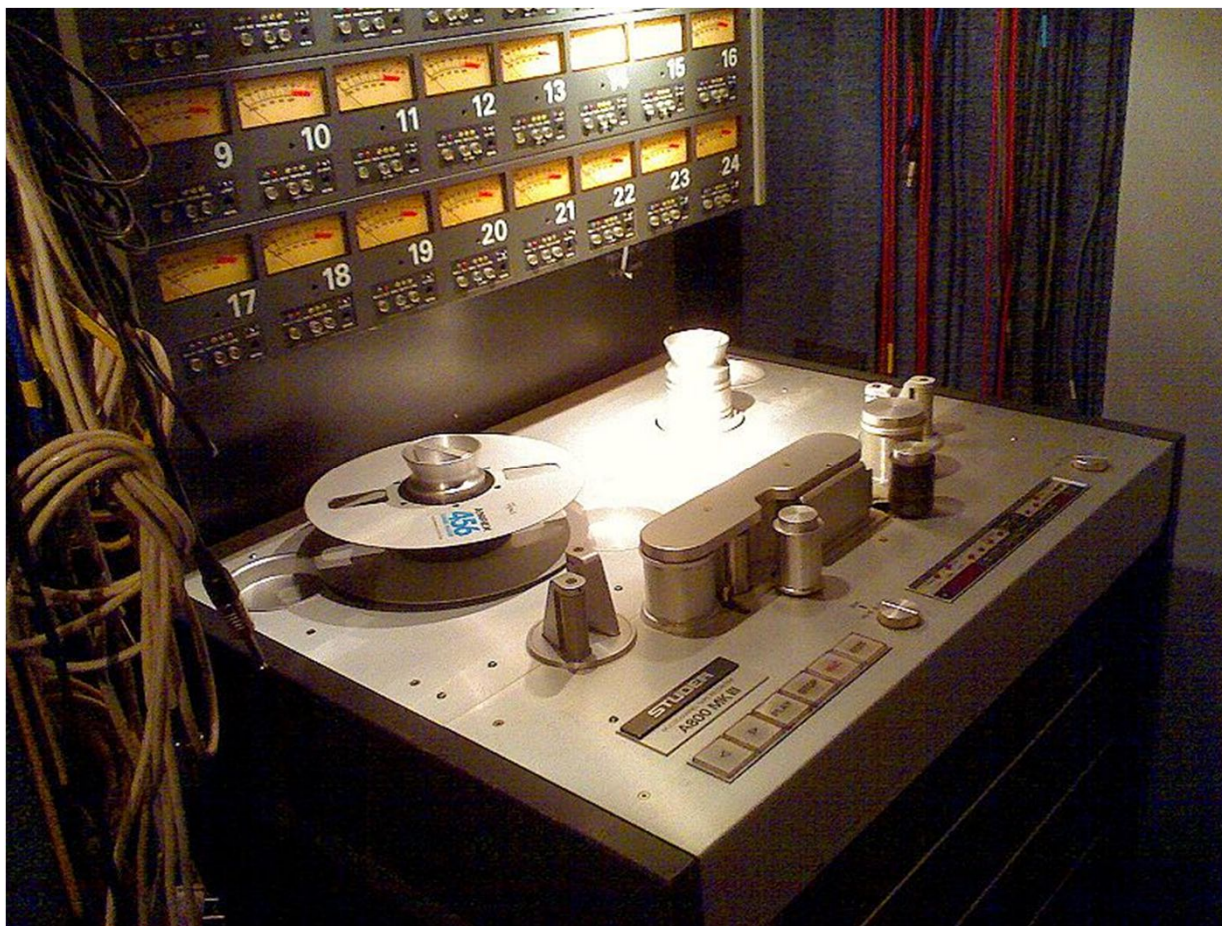
BRG. Vörös Szikra MAGNÓ - 1954

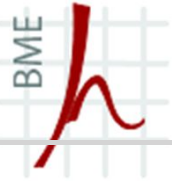


MTMA foto

Studio tape recorder

- Analogue multichannel recorder, e.g. a Studer A800 MK III.

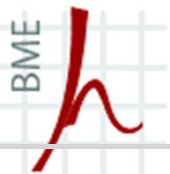




Digital sound recording – why?

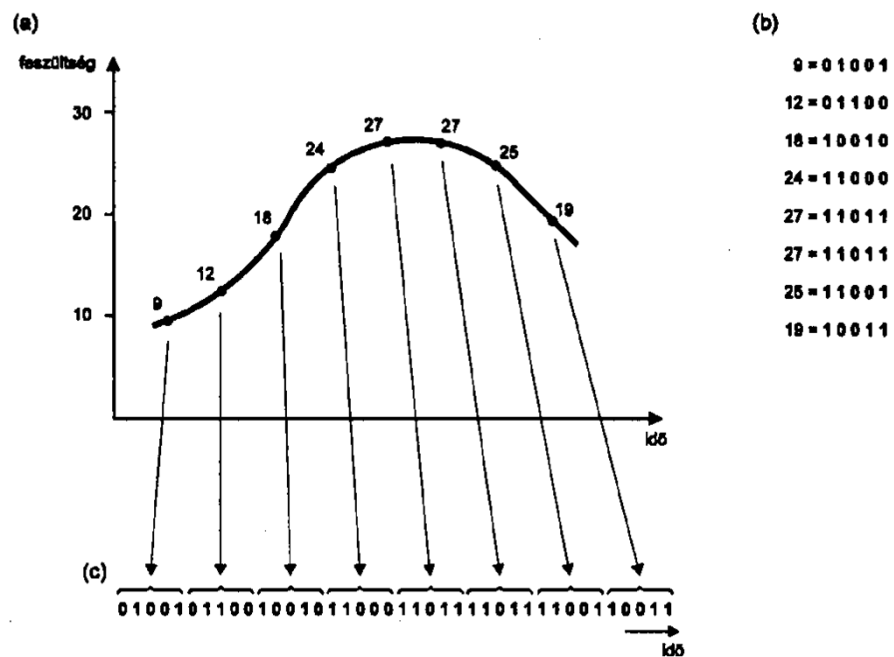
- From **sound quality's** point of view:
 - The quality depends on the A/D – D/A conversion only, independent on the signal carrying medium
 - Recordings can be copied and multiplied without quality degradation
 - Conversion into digital domain opens up new possibilities
- From **production technology's** point of view:
 - Easy to integrate and to miniaturize
 - Cheap

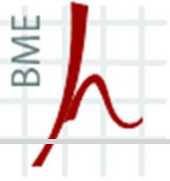




The basics

- Replacement of an analogue wave by a series of numbers:
PCM = Pulse-Code Modulation



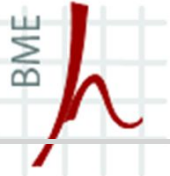


Basics of the binary system

- **10 kinds of people do exist:**
 - one understands the binary system,
 - the other does not

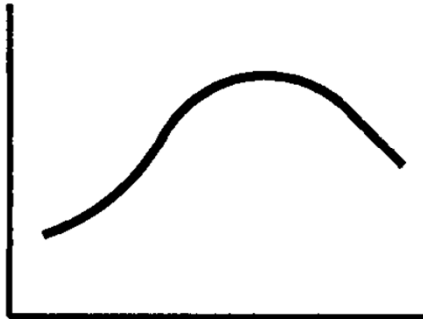
- We have ten fingers, therefore in modern times the decimal system is widespread

- In Babilon the duodecimal system prevailed
 - Some reminiscences are there still today:
 - dozen
 - special words for 11 and 12 in the Indogerman languages (elf/zwölf, eleven/twelve, onze/douze)
 - Computation of time: a day = 2×12 hours, 1 our = 5×12 minutes etc.

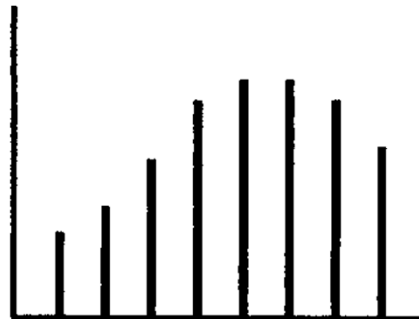


Most common digitizing method: PAM

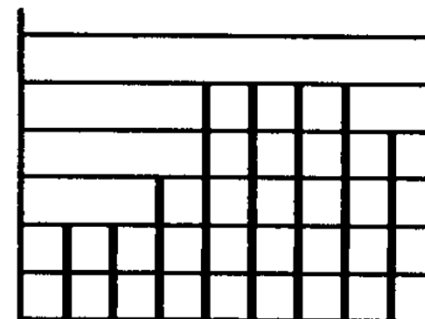
- Principle of the Pulse Amplitude Modulation (PAM)
 - Discretization both in time and frequency
 - Sampling and quantization



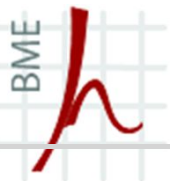
(a)



(b)



(c)

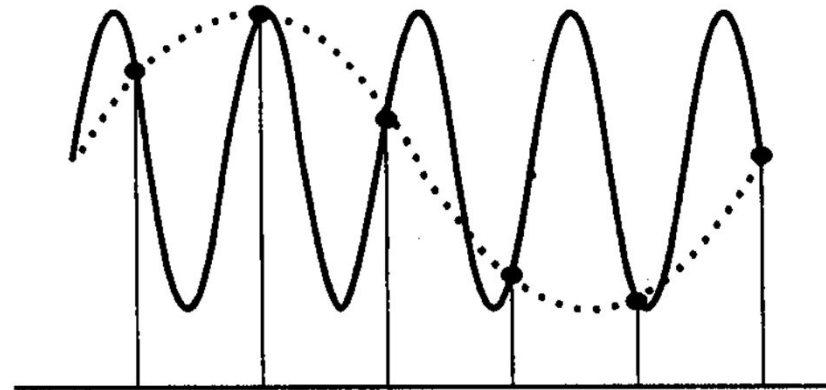


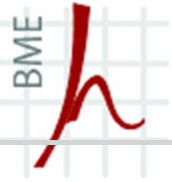
1. step: Sampling

- Sampling frequency should be sufficiently high
 - If not: picket fence effect



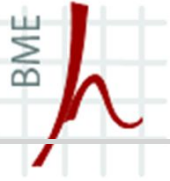
— f
..... f_{alias}





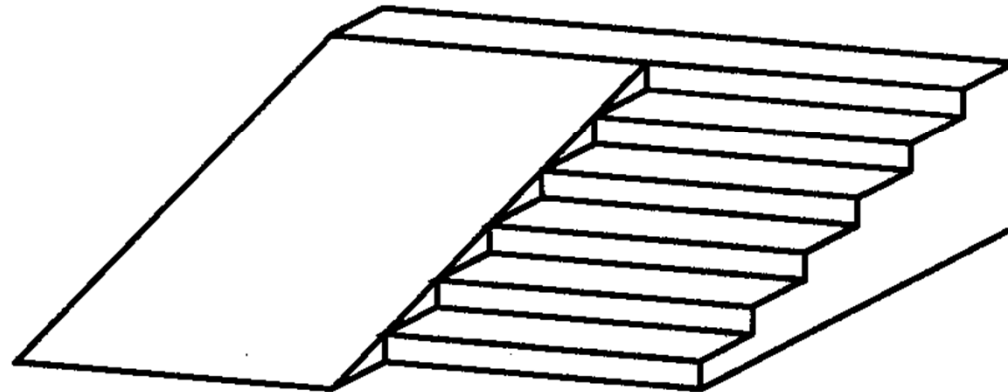
Basic rule of sampling: the Nyquist theorem

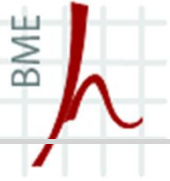
- $f_{\text{sampling}} \geq 2f_{\text{maximum}}$
- If not obeyed: **aliasing**
- In order to meet the Nyquist-criterion:
 - Sufficiently high sampling frequency
 - or
 - Filtering by low pass filter



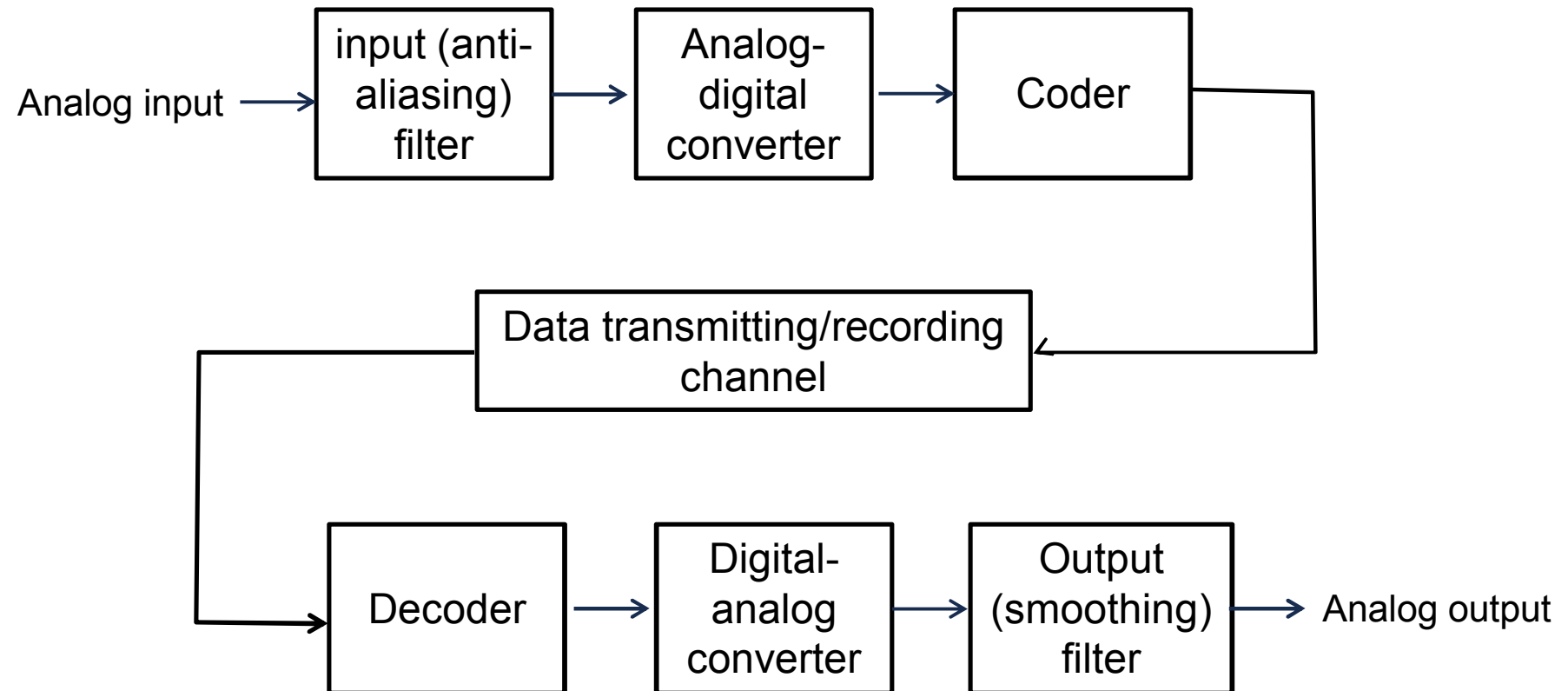
2. step: Quantization

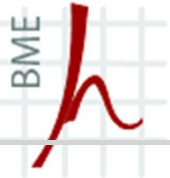
- „stairs” in sampling:
only certain values are possible





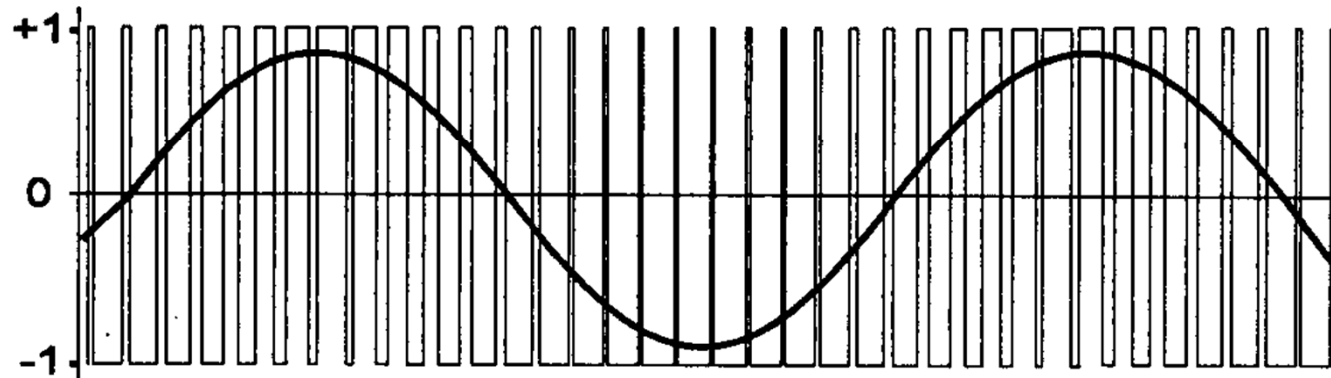
General block diagram of a digital sound transmission/recording system



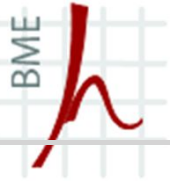


Alternative AD/DA conversion

- Pulse Width Modulation, PWM
 - works in higher quality audio equipment

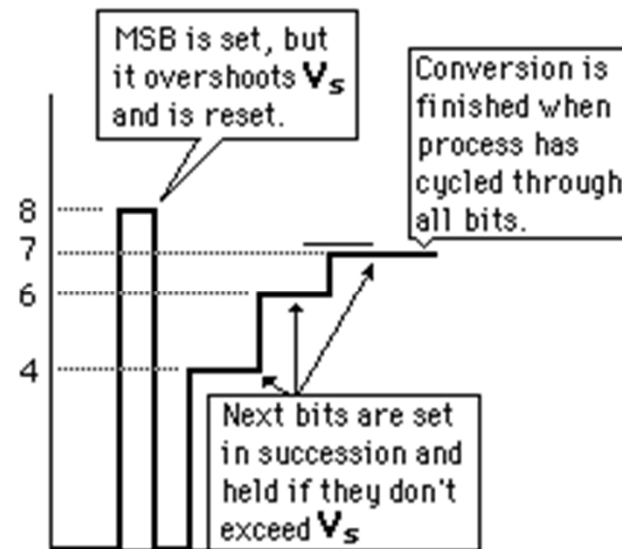
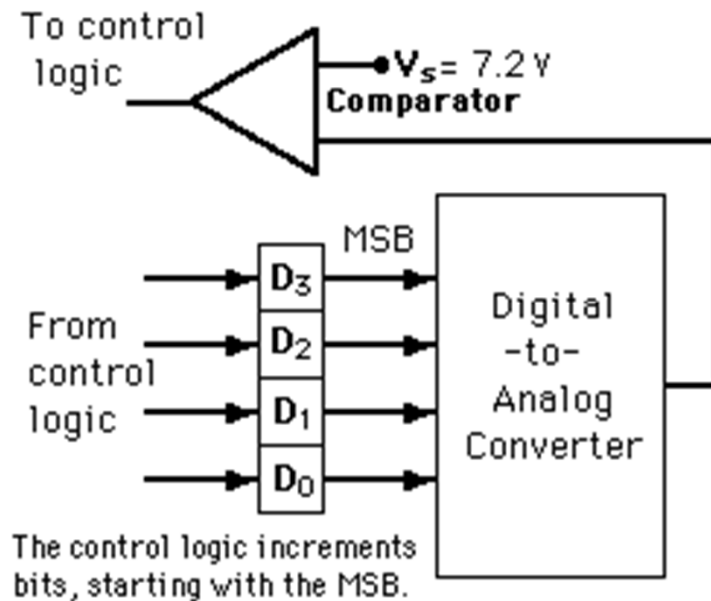


Relationship of the analog wave and the pulse train, generated by a PW Modulator



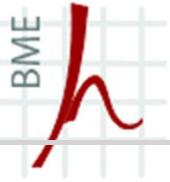
A/D conversion

- Successive approximation A/D converter



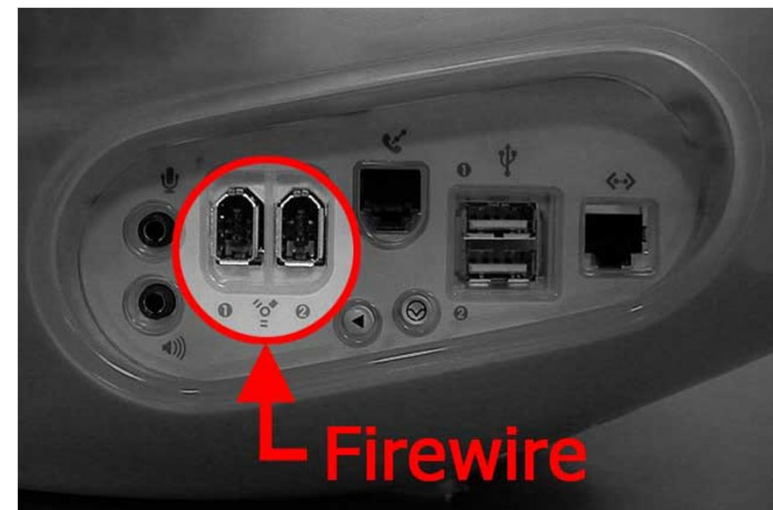
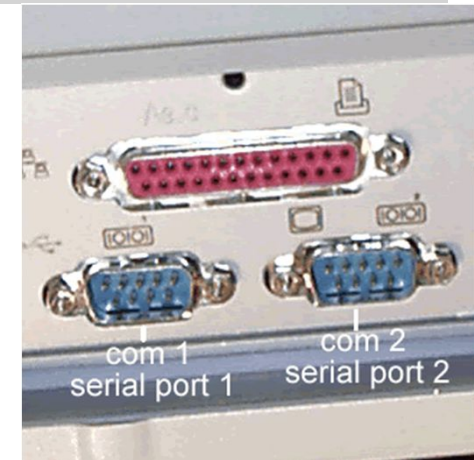
End result: 0111

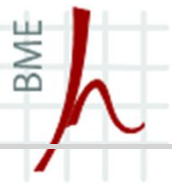
Most Significant Bit: MSB, Least Significant Bit: LSB



Data transmission/recording options

- Parallel transmission
 - eg. the par. printer port (obsolete!)
 - 8-16 data bit + control bits
- Series transmission
 - USB, firewire, optical cable...
 - One pair of cables: data, another pair: control
- Optoelectronic storage (CD)
- Magnetic storage (HDD)
- Purely electronic storage (solid state memory/disk, SSD)



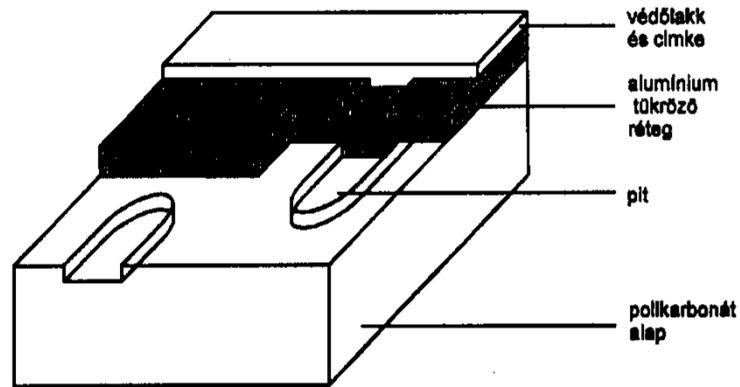


Potential possibilities of digital signal processing/storage

- Volume control
- Compression and limitation of levels
- Data compression
- Equalization of frequency response
- Filtering, noise removal
- Artificial echo / reverberation: effect processing
- Echo removal
- ...and many, many more



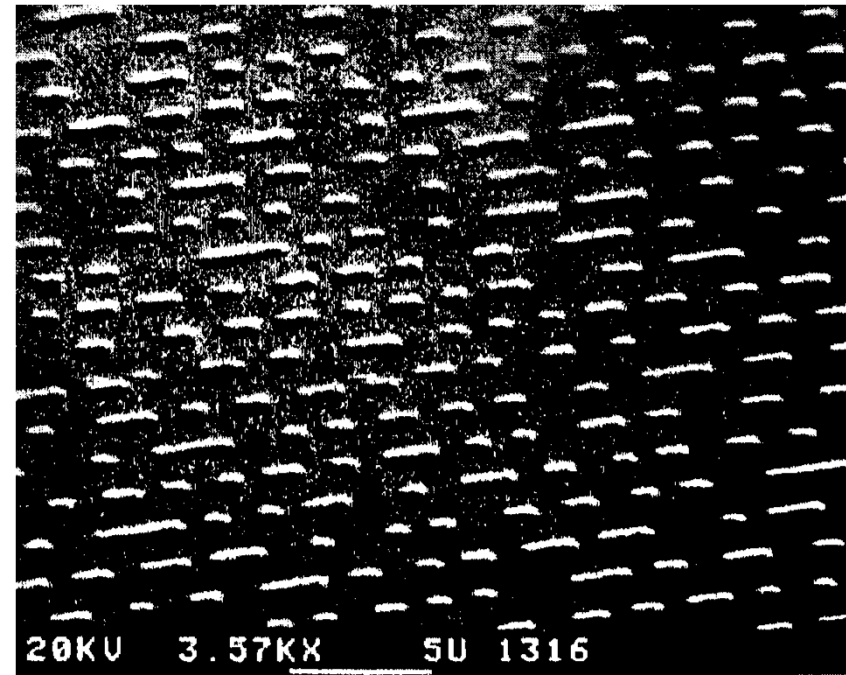
The compact disc (CD)



A SONY/Philips invention

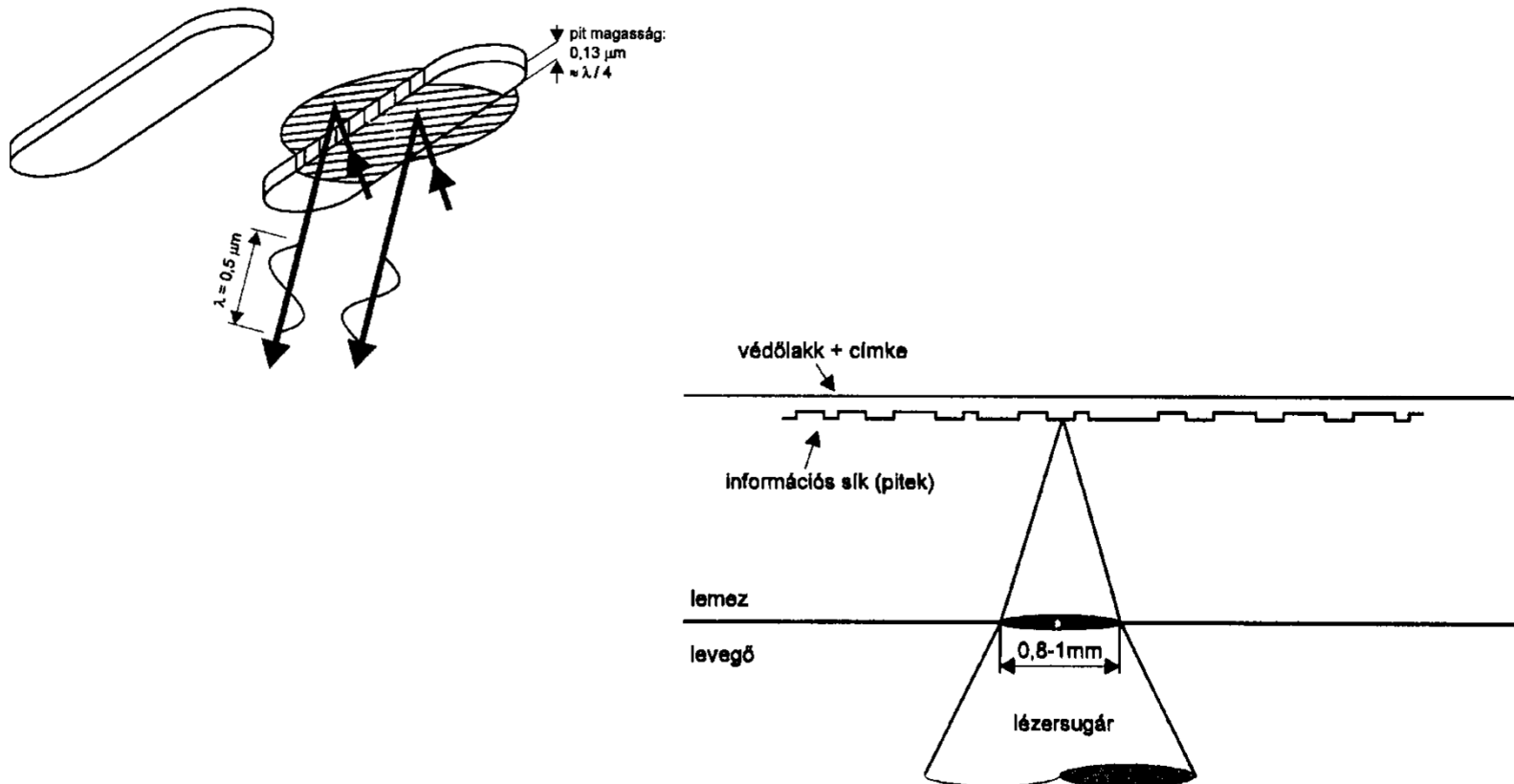
Why 74 minutes?

Why 44,1 kHz?



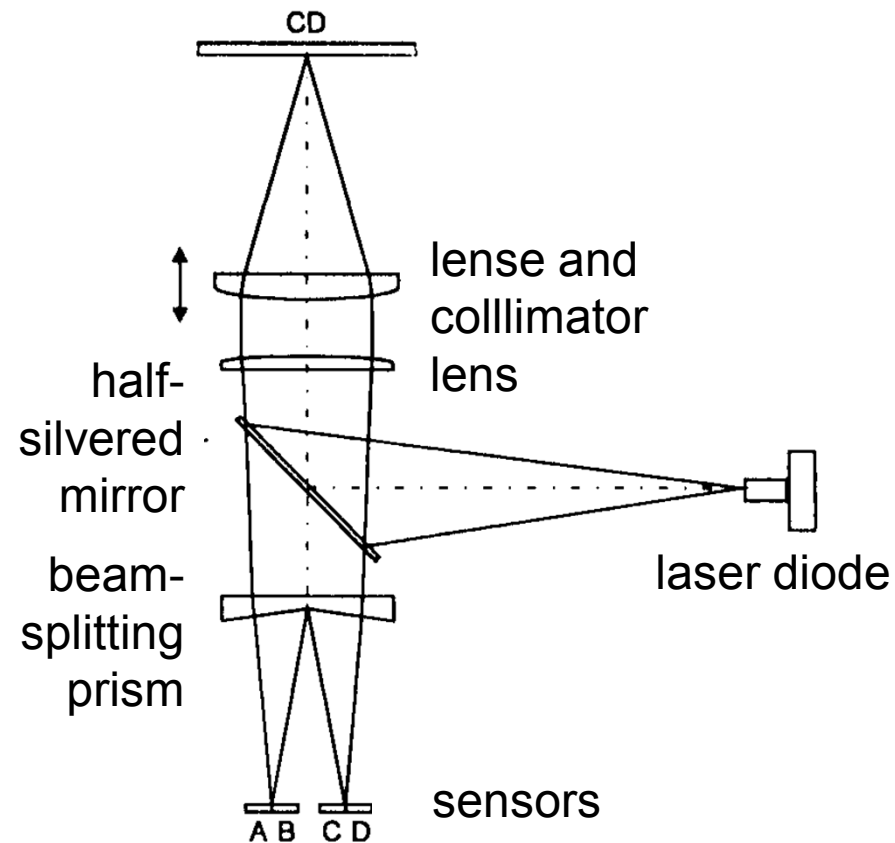
94. ábra. Elektronmikroszkópos felvétel a pitekről. A kép alján lévő felirat alatti vízszintes vonal hossza 5 μm .

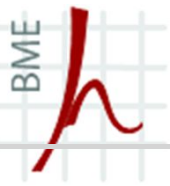
Principle of operation of the CD /1



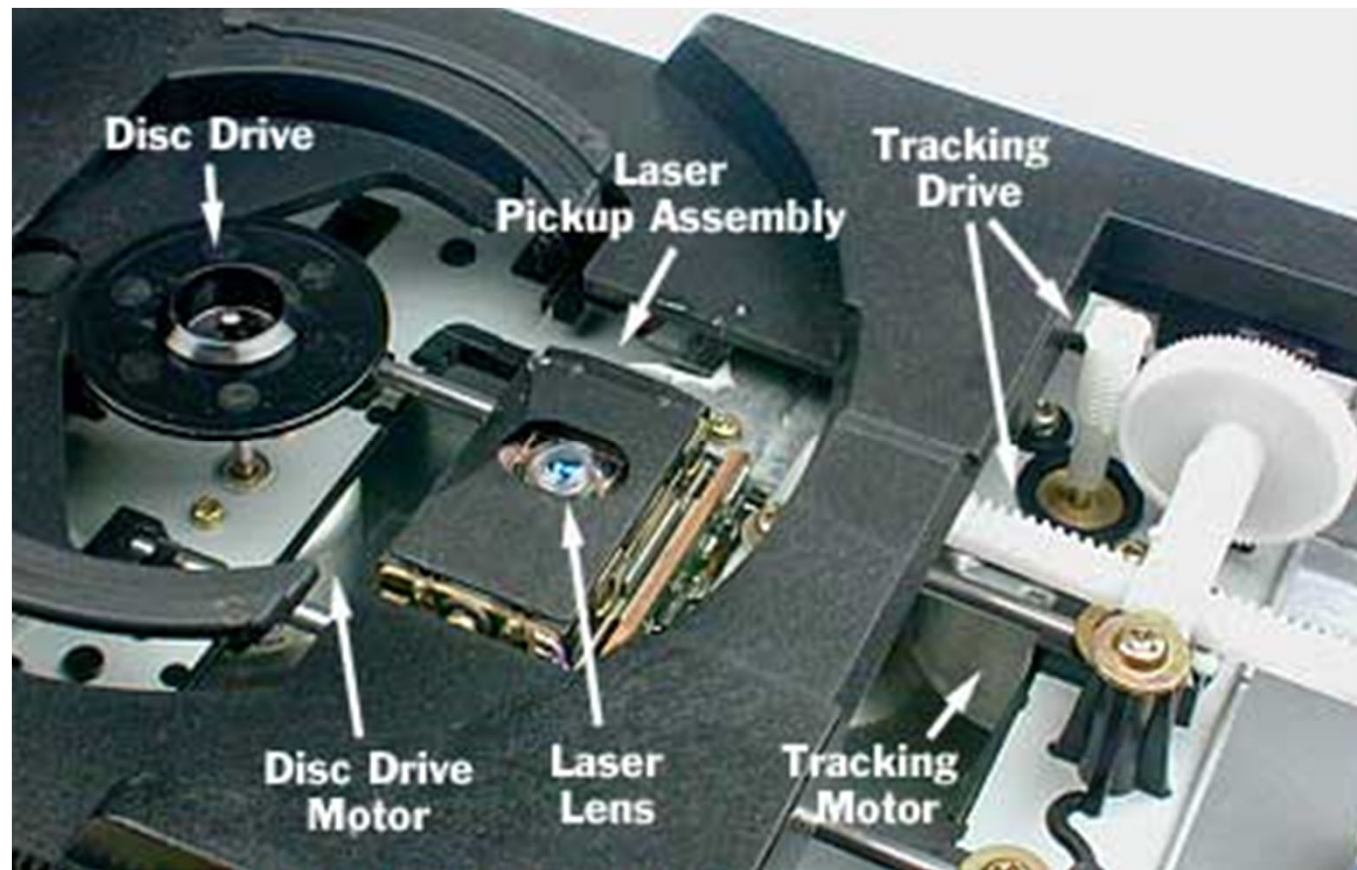


Principle of operation of the CD / 2





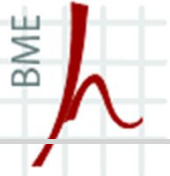
Interior of a CD player



Technical parameters of the standard CD

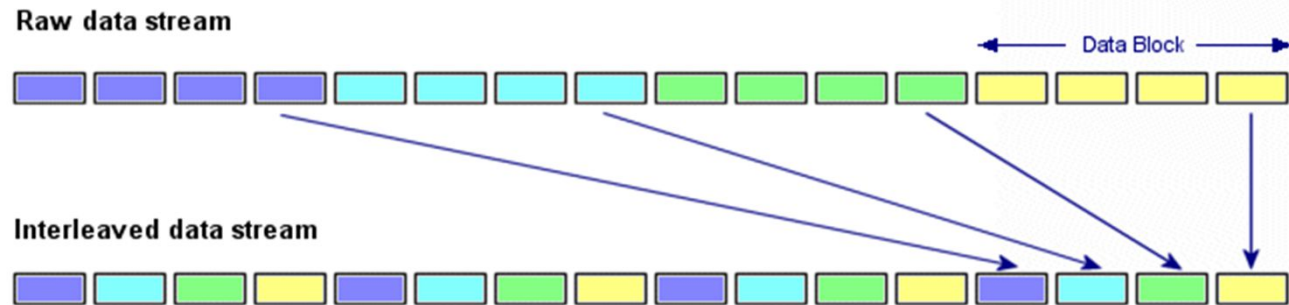
- Program time: max. 74 perc 33 s
- Track speed: 1,2 – 1,4 m/s
- Pit length: 0,9 μm
- Pit depth: 0,11 μm
- Focal depth: $\pm 2 \mu\text{m}$
(if the CD-read speed, this accuracy mm accuracy!)
- Quantizing: 16 bit
- Sampling frequency: 44,1 kHz
- Bandwidth: 20 Hz – 20 kHz
- Dynamics: 96 dB
- Bit rate of the channel: 4,5 MB/s
 - **18 kHz $\Rightarrow$ many MHz!**



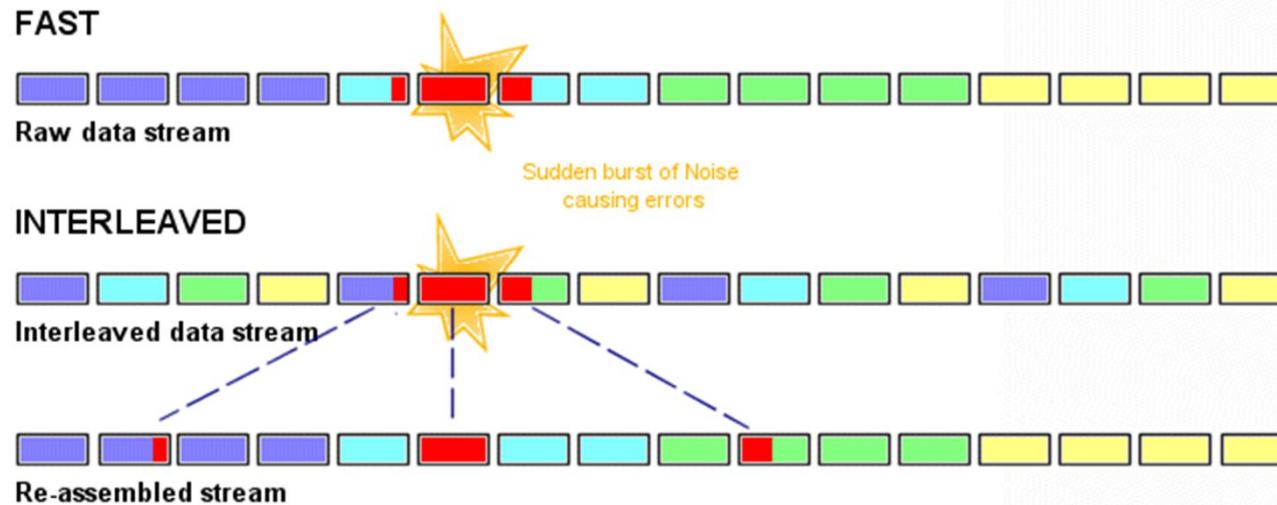


Error protection by interleaving

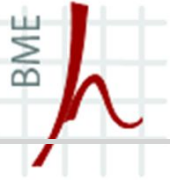
- Interleaving: aims at avoiding kink (clotting?)



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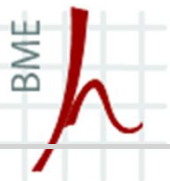
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Sony DAT (Digital Audio Tape) technology

- Since 1989, but
Still around as a
- tool for cheap long-time/professional audio storage





Typical HW recording equipment of today

- Amateur: e.g. Zoom H4n, professional: Marantz PMD 661



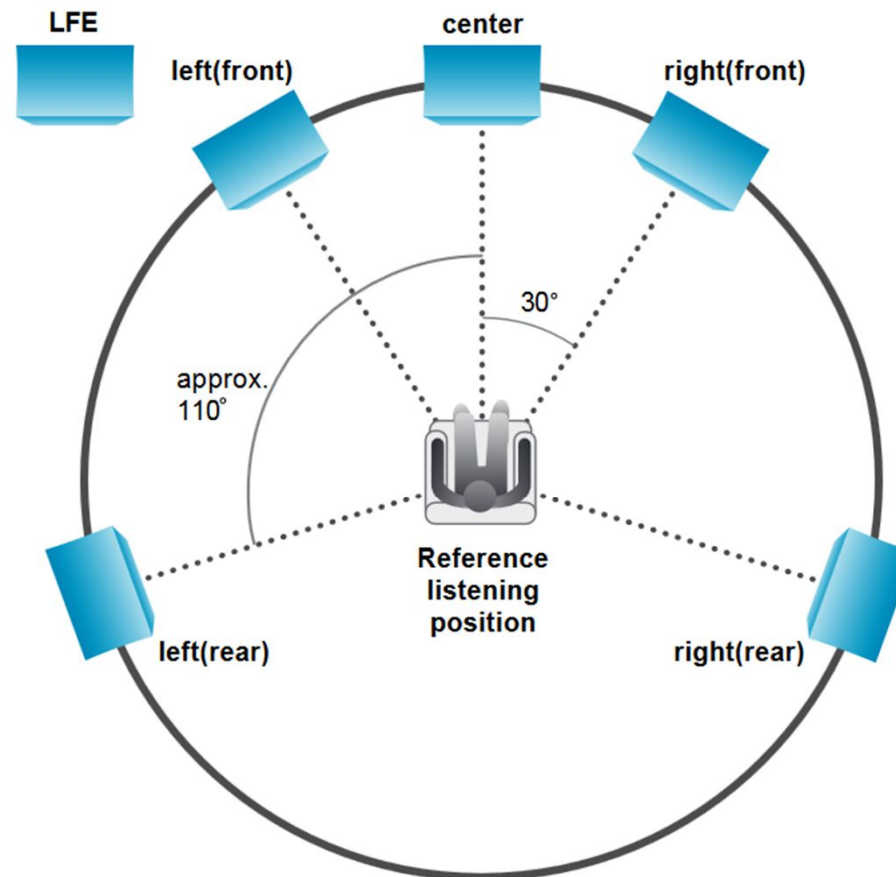
High Resolution Audio

- Problem with data compression and even with CD: limited information content
- Lossless data compressions:
 - WAV (Microsoft)
 - FLAC Free Lossless Audio Codec
 - AIFF (Apple)
- CD is not good enough (?): Super Audio CD
 - Direct 1-bit recording
 - Multiple channels
 - Content protection
- HRA is not a format but a collective notion
 - usually 24 bit 192 kHz audio



Surround sound

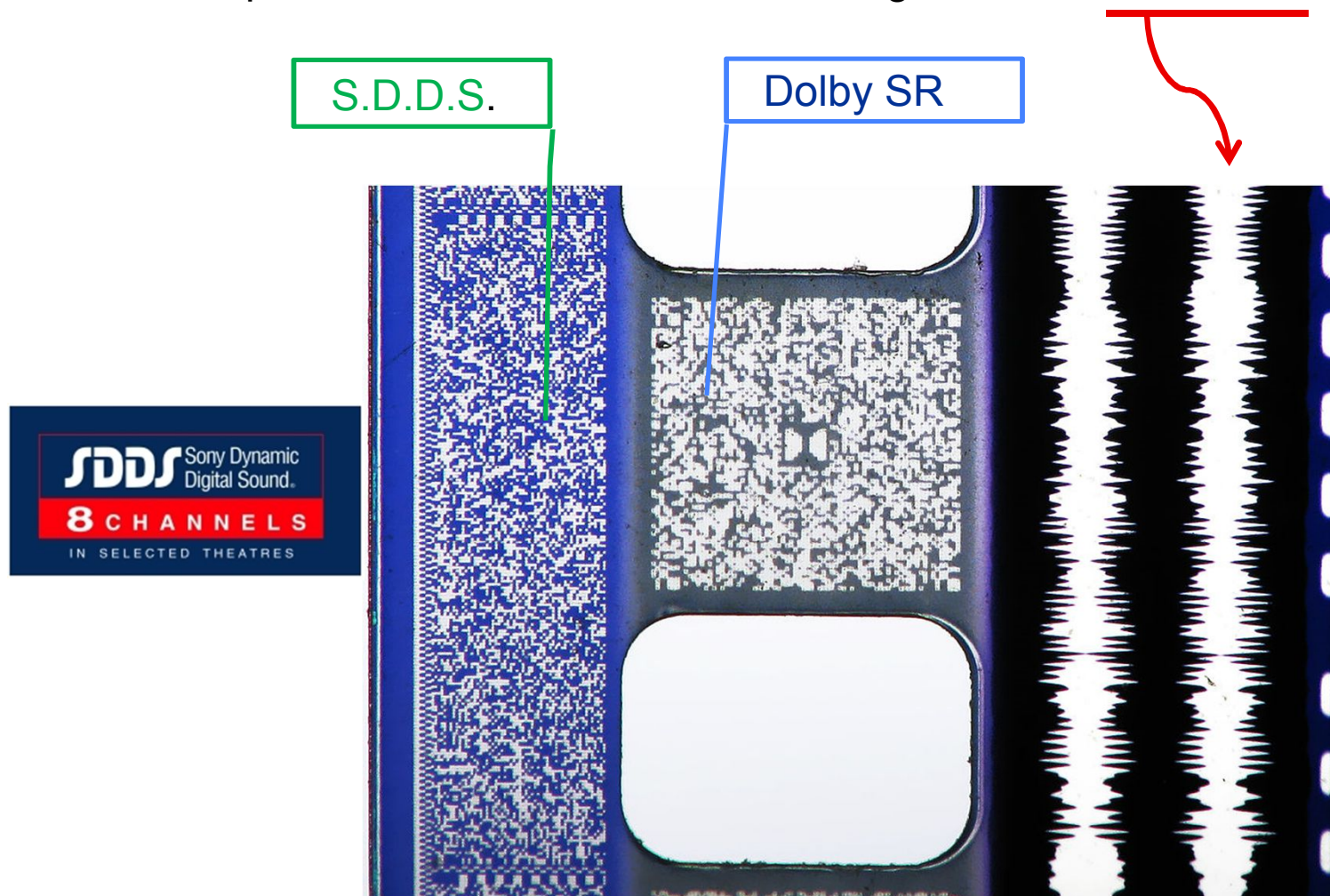
- 6-channel sound recording and reproduction system, mainly used for home cinema



Speaker placement in accordance with the ITU-R BS.775 recommendation: the sixth channel can be optionally used for low-frequency enhancement.

Sound on film

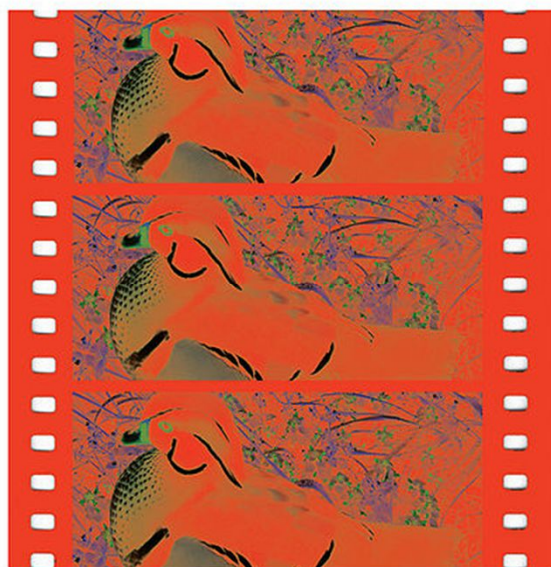
- Optical recording: both analogue and digital
- The optical track can be intensional, longitudinal or transversal



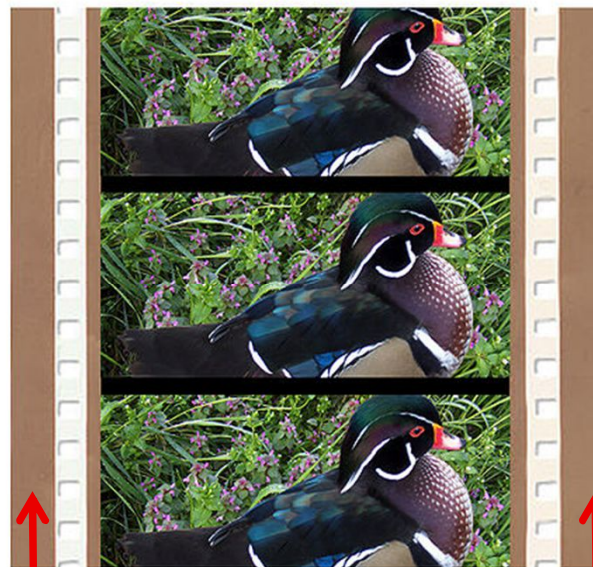
Magnetic sound recording on film

- Originally developed by Dolby Labs for the 70 mm film prints, later on adopted for 35 mm films

Todd-AO process



NEGATIVE 65 mm



POSITIVE 70 mm

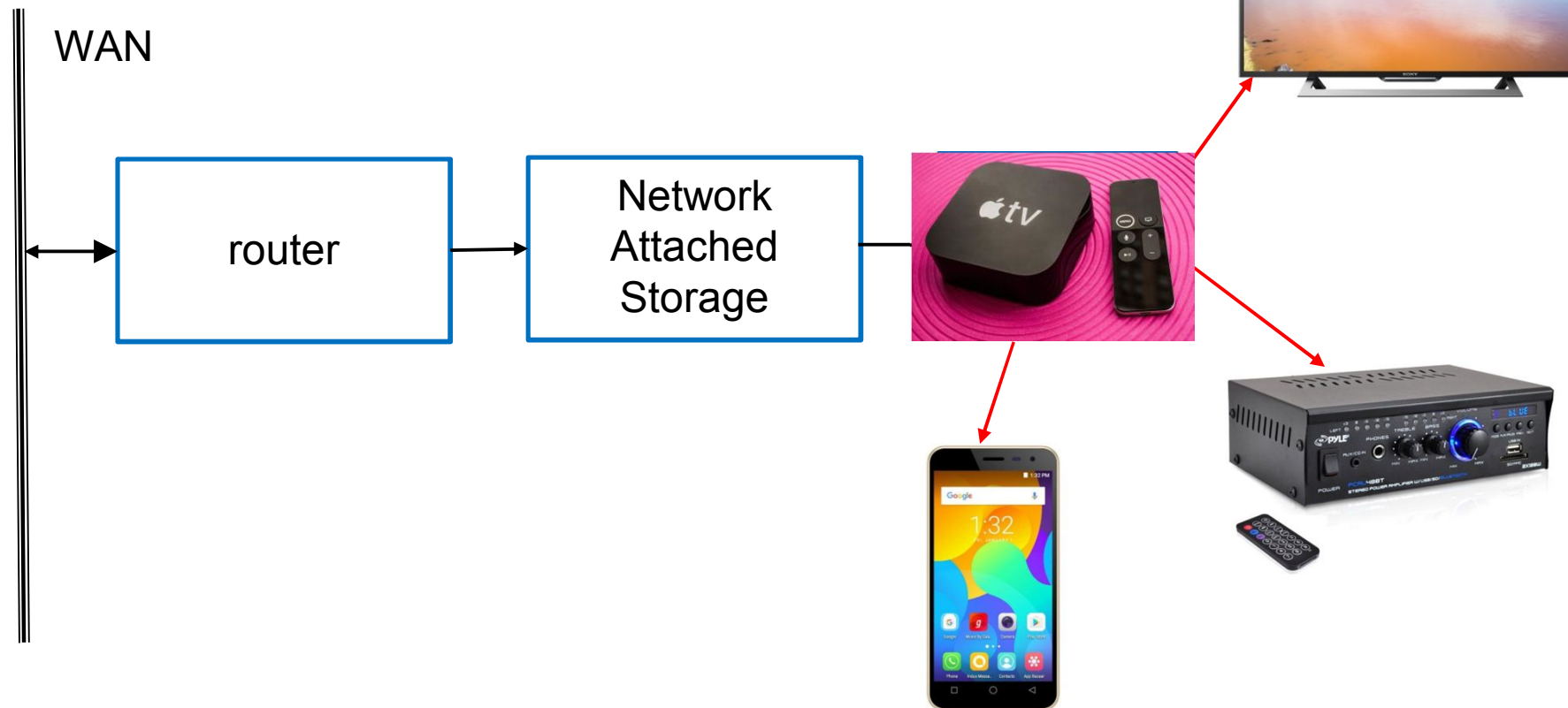
Magnetic track

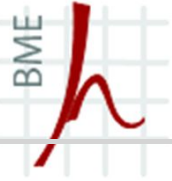
Magnetic track

Other surround systems

- CDS: Cinema Digital Sound
- DTS: Digital Theater Systems (later: Dedicated To Sound)
- THX: a quality assurance system for the acoustics of cinema
- 7.1: two extra surround channel in the back
- Multichannel systems

From broadcast to stream





And this is...

The End