9 – Sound recording & reproduction

Mechanical (or „acoustical“) recording until ~1920

Thomas Edison‘s cylinder phonograph, 1877

Emil Berliner‘s disc phonograph, 1889

Short history of the sound recording

The initial idea of sound recording/reproduction is the following: The sound is caught by a large diaphragme that converts the sound into mechanical motion of a stylus that engraves the signal in a soft material like tin foil of wax. Then the recorded signal is transformed to a harder material and records are produced in commercial numbers. The reproducting device (phonograph, grammophone, etc.) also uses a stylus that reads out the engraved signal from the rotating record into mechanical motions that are then transported to a large diaphragm the produces the sound.

Thomas Edison, the inventor of phonograph (1877), used cylinders as the recording media. However, Emil Berliner‘s disc recording technology (1889) proved to be superior for many reasons and won. Disc records, played on turntables, remained dominant as commercial products until the advent of CDs in 1983.

Since around 1920 purely mechanical recording was replaced by technologies using electric signals at the intermediate stages of the processes of recording and reproduction. The main idea remained the same but the quality of recordings essentially improved.

Magnetic-tape recording (invented in Germany in the 30th) transformed the recording industry after the WW-II. In the period 1950-1980 most of recordings were mastered on magnetic tapes. Magnetophones (tape recorders) were also used as consumer recording and listening equipment. The role of pre-recorded magnetic tape as a commercial products remained insignificant.

Stereo was under development since the end of the XIX century, the first practical stereo was demonstrated by the Bell Labs in 1937, but only after the WW-II stereo gradually became a standard in commercial records. At the level of professional recording technology, stereo has to compete with multitrack recording.

Invention of digital recording in 1983 changed everything. Recording was done onto the digital audio tape (DAT), mastered numerically, and then printed on digital compact discs (CDs) as consumer products. Mastering (editing) of the recorded material was done on huge expensive digital machines.

MiniDisc developed by SONY (1992) that uses magnetic storage with data compression took the place of a cheap consumer replacement for DAT. Around 2005 SONY developed a MiniDisc without data compression (that is, with a full CD quality) but it was too late to compete with the emerging hard drive and flash storage.

With the progress of computers in 90th, recordings could be done directly onto the computer‘s hard drive and mastered on the computer, with a much more ease and a much better visualization of the wave shapes that was possible on the earlier dedicated editing machines. Computer editing made high-quality (at least semiprofessional) recording accessible for everybody.

New consumer record media emerged at the end of XX century are DVDs and different kinds of audio discs with a digital resolution better than CD, such as super audio CD (SACD) and DVD-audio. However, it seems that the new types of digital audio discs do not have commercial success. The reasons are: They require new expensive audio reproduction systems; There is a battle of formats (SACD vs DVD-audio), so that the consumer is unsure; Many available recordings, including those of a high artistic value from the past, are not good enough to hear the difference between different types of digital resolution; Many listeners are unable to hear the difference, and for them CDs are good enough.

XXI century brought flash cards as the best compact storage of digital information. Recording on small flash recorders is more convenient (at least for live recordings) than recording on the computer‘s hard drive.

On the music reproduction side, it seems that different new types of digital audio discs have no future because music will be mostly played from hard drives of computerized audio reproduction systems at home and from digital audio players in the outdoor setting. Commercial music products will be files that are not bound to any particular data carrier. On the other hand, it seems that video that requires storage of much greater volume of information than audio, will still require new high-capacity disc carriers such as Blue Ray DVD etc.

Of course this brings up huge problems since many buyers do not believe that pure intellectual products such as files that are so easy to steal (copy and share) are real products that are worth their money. This shows how materialistic is our world: People think that the value of a CD is located in the piece of plastic out of which the CD is manufactured, in the jewel box, in the paper of the booklet with liner notes, rather than in the bits of digital information on the CD.

The ensuing problem of protection of intellectual rights in the digital age is a huge problem that has not been satisfactorily solved up to now. Some people even claim that intellectual rights cannot be protected and intellectual products should be free. However, this will lead to devalueing of the intellectual and further materialisation of our life.

MIDI recording vs sound recording

„MIDI (**Musical Instrument Digital Interface**) is an industry-standard electronic communications protocol that enables electronic musical instruments, computers and other equipment to communicate, control and synchronize with each other in real time. MIDI does not transmit an audio signal or media — it simply transmits digital data "event messages" such as the pitch and intensity of musical notes to play, control signals for parameters such as volume, vibrato and panning, cues and clock signals to set the tempo“ – This is what is written in the Wikipedia.

In simple terms, MIDI is recording of the motions of the piano keys rather than recording of the piano sound. Having a MIDI recording, one can reproduce the music piece on a MIDI-enabled piano 1 to 1 „without the pianist“. Of course MIDI is much more efficient in recording keyboards than in recording string or wind instruments.

Since mechanical pianos and music boxes playing automatically without a musician were popular during many centuries, MIDI recording is not less old than sound recording. At the end of XIX and beginning of XX centuries different kinds of „piano rolls“ have been produced to archive performances of famous pianists. The technology used specially constructed pianos where hitting the keys by the pianist produced engravings in the rotating and axially shifting rolls covered by soft materials like wax. Recently many piano rolls have been played back and a number of historical piano roll CDs have been released. However, as the old recording technologies were imperfect, the piano-roll CDs are not 100% truly reproducing the actual playing, so that many audiophiles dismiss them.

In 2006 an interesting development in restoring historical piano recordings has been done. The original sound recordings have been analyzed by a specially developed computer program and the key motions have been identified and stored. That is, the sound recordings were converted into MIDI recordings. After that the MIDI recordings were played back on a modern MIDI piano (Yamaha Discklavier) and new noise-free sound recordings were produced and CDs were released. The similarity between the playing on the original historical recordings and restored recordings was striking, so that one could say that the restored recordings were pretty true. On the other hand, the recordings partially lost their flavor that was coming from the surface noise, small dynamic and frequency range, another (historical) piano and mono signal. The restored recordings sounded much less original.

MIDI can be used in a modern recording studio but it is not actually used. The reason is that MIDI does not record the acoustics of the hall and the microphone placement that belongs to the wizardry of recording engineers. There are a few case, however, in which MIDI recording proved to be useful. In one case a pianist gave a recital in a stadion, of course with a very bad acoustics. The performance was recorded into MIDI, then played back in a studio with a good acoustics and recorded in a usual way.

Modern recording setup

Modern recording setup includes (as the signal goes)

- Microphones
- Preamplifier
- Analog-digital (A/D) converter
- Digital recorder (computer fed via USB or FireWire or a Flash recorder)

Microphones convert the incoming sound into electric signals.

Preamplifier (preamp) amplifies the weak electric signal produced by the microphones up to the standard signal of the voltage amplitude around 1.5 V (the so-called line signal). Because of the weakness of the input signal, preamps should satisfy strict requirements on the noise that makes them expensive.

Both the electric signals produced by the microphones and those after the preamplifier are the so-called analogue signals, to distingiush them from the digital signals.

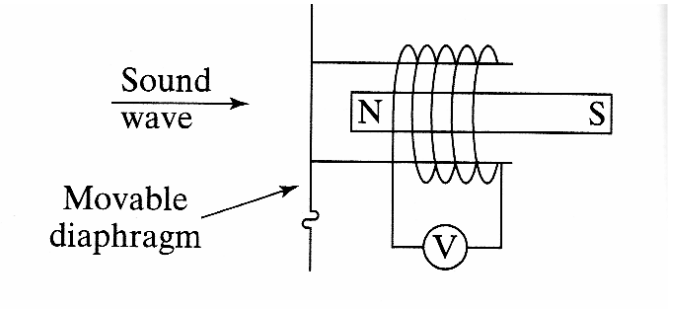
A/D converter converts the analogue electric signal into a digital signal, in which the sound (as well as picture in videos) is represented as a sequence of numbers.

In practical devices the A/D converter may be integrated with the preamp so that one cannot separate one from the other.

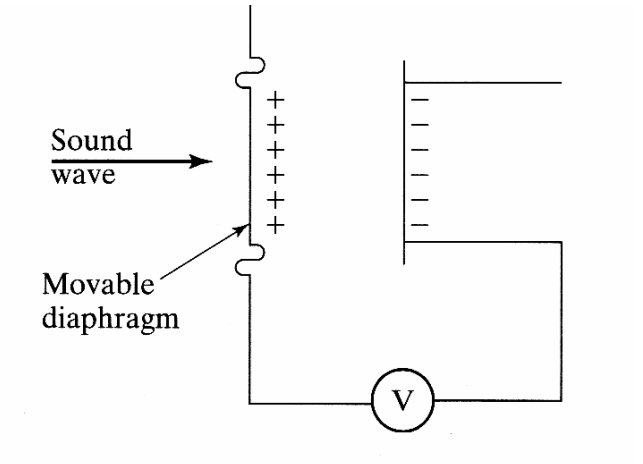
Microphones

Microphons are the most important and the most expensive component of the recording process. The two main types of the microphones are dynamic microphons and electret condenser microphones.

Dynamic microphons use the law of electromagnetic induction discovered by Faraday. A coil of wire rigidly connected to the diaphragm moved by the soud wave is moving past permanent magnet and, as a result, the electromotive force (EMF) is generated in the coil. This EMF creates an electric current with a small voltage V that is passed to the preamp.



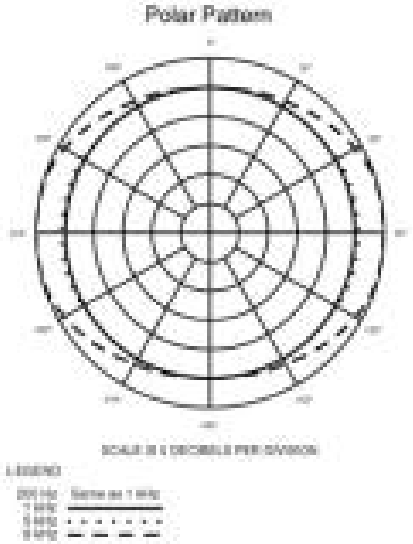
In electret condenser microphones the motion of the diaphragm results in the change of the voltage on a capacitor V via modulation of its capacitance C that depends on the distance between the plates. The charge Q on the capacitor is constant because the charges are provided by a special materials electrets (analogues of permanent magnets). Change of the voltage makes other (unbound) charges flow through the cirquit.



Electret condenser microphones are better than dynamic microphones. In particular, their moving parts are lighter and thus they provide a more accurate response to fast transient sound signals.

Microphones differ by their directional pattern (polar pattern) that shows how sensitive they are to the sound coming from different directions. Directional patterns can be omnidirectional (omni) that picks up the sound from all directions equally well, cardioid that is more sensitive to the sound coming from the front than from the back, unidirectional (or shotgun) that can isolate the sound coming from a particular direction only, etc. Some microphones have switches between different polar patterns. Below are polar patterns of an AudioTechnika switchable electret-condenser microphone. Note that polar patterns depend on the frequency.

AT4050
(Omnidirectional)

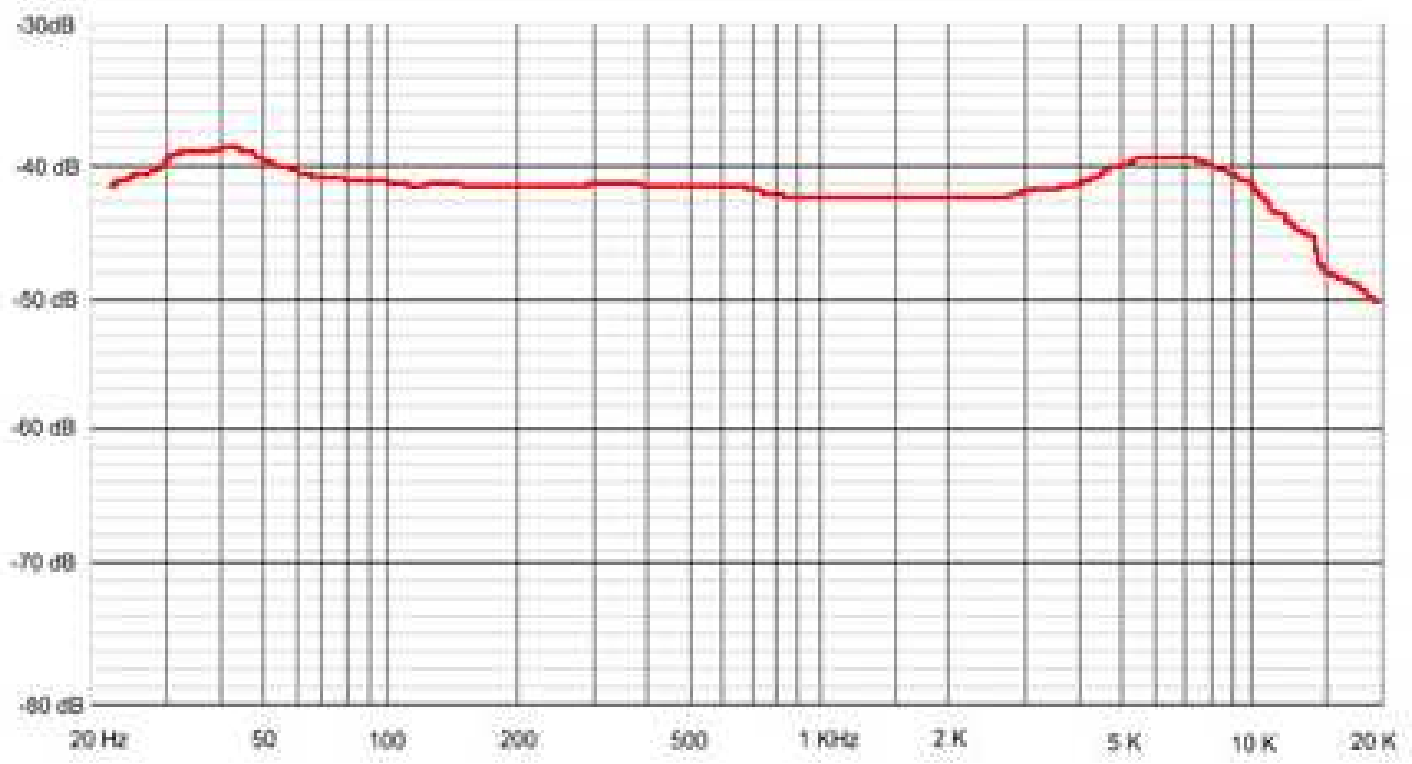


AT4050 (Cardioid)

AT4050
(Figure-Of-Eight)

According to sound engineers, omnidirectional microphones sound most beautiful.

An important characteristic of a microphone is its frequency response. Good expensive mikes have a flat frequency response in the range 20 Hz – 20 KHz. Cheaper microphones become irresponsible to the sound of low and high frequencies, and their frequency response can contain peaks at some resonance frequencies that distort the recorded sound.



Preamplifiers also should have a good frequency response. In addition, the impedances (that play the role of resistance for the alternating current) of the microphone and preamp should be in the same range, otherwise they do not work well together.