THE APOLOGIA OF MAGNETIC RECORDING

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Contrary to the title of this article, it is not so much the protection of analog formats that prevails here as an attempt to objectively criticize the prevailing opinion about the absolute superiority of digital sound recording. I would like to identify areas of application in which analog technology has a clear advantage. Despite the recent emergence of a number of new digital formats, magnetic recording cannot be completely replaced by them and remains relevant for high-quality sound reproduction. Nevertheless, in the near future, magnetic tape will cease to be a mass medium, but due to the reasons considered here it will be able to maintain its place among professionals and recording enthusiasts.

1. An Excursion into History

As you know, the founder of the magnetic recording technique is O. Smith, who published in 1888 a description of both the apparatus itself and the carrier based on silk or cotton fabric, with steel filings spun into it. The first working device, called "Telegraphone" and recording to steel wire, was made and demonstrated by W. Paulsen in 1898. Later, he proposed using steel tape as the recording medium. But only in the mid 30-ies of XX century in Germany, BASF developed a technology for the production of magnetic tapes on paper or plastic basis with a working layer of powdered iron. At that time, AEG-Telefunken launched the production of magnetic recording equipment for broadcasting called "Magnetophone", which later became a household name. After the introduction of the method of high-frequency bias in the early 40s, magnetic recording in its quality sharply exceeded all sound recording methods known at that time. Then, for the first time, it was possible to create serial samples of equipment, using which the listeners could no longer distinguish the broadcast of a "live" concert from its recording.

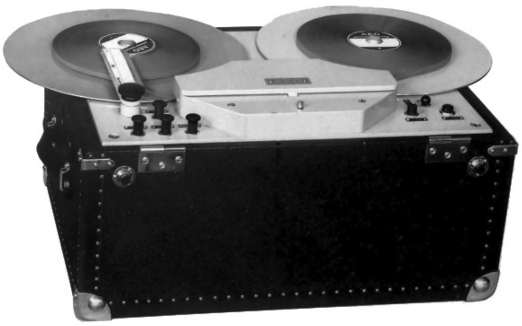

Fig. 1 – The world's first serial tape recorder AEG K1

The wide distribution of magnetic recording in other countries began only after the end of World War II and the export of appropriate technologies from Germany. Further development of this equipment was associated with the development of new magnetic tapes, which allowed to significantly reducing the speed of the carrier. In 1951, a method of dynamic bias was proposed, and at about the same time, improved designs of magnetic heads appeared, which made it possible to optimize the recording and reproduction processes.

I must say that until the 60s the number of manufacturers of high-quality tape recorders was very limited. In Europe, the German firms AEG-Telefunken and Uher, as well as the Swiss Studer / Revox and Nagra; in the USA, Ampex, which created in 1956 the first serial video recorder; in Japan – Sony, which in 1956 first released a fully transistor tape recorder. However, with the advent of stereo phonograph records in 1956, competition began between manufacturers of stereo tape recorders, which were originally developed for professional sound recording. Thanks to this competition, it was possible to optimize the technologies used, which, in turn, led to the development and widespread distribution of household magnetic recording equipment.

Fig. 2 – Elcaset Sony LC-60 FeCr. For comparison, shown with a compact cassette Sony C-60 FeCr

Then, cassette mediums begin to appear, primarily to simplify the handling of household tape recorders. Although the first cassettes for wire spools were used back in the late twenties by the German company Schaub Elektrik-Lorenz, mass distribution of cassettes took place only in the 60s. Then it was proposed many incompatible formats of cassettes for magnetic tape. At the same time, cassettes with two reels of tape were distributed in Europe: Compact Cassette from Philips, DC-International from Grundig, Unisette from BASF and others. In the USA, cartridges with one reel of tape glued into a ring were preferred: Fidelipack, Lear-Jet, Orrtronics, etc. Such cartridges were intended mainly for car players, but at the same time it was possible to record quadraphonic phonogram on them. However, for a number of reasons of a commercial and subjective nature, out of the whole variety of proposed formats, only one compact cassette survived, which was originally developed for recording speech.

Against this background, in the early 70s, Sony proposed a higher quality and more expensive format – Elcaset (***Fig. 2***). But he also could not stand the competition, since at the same time chrome dioxide tapes and Dolby companding noise reduction system appeared on the market, using which a compact cassette could provide sound recording with quality that would satisfy the needs of most consumers. Over time, many of the technologies that were originally developed for open-reel tape recorders were transferred to cassette decks. However, in order to achieve a truly high-quality sound from a cassette deck, it still requires either doubling the speed of the tape while using dynamic bias, or using expensive and prone to oxidation metal powder tapes in combination with unique magnetic heads and special signal processing to reduce distortion. In both cases, manual or automatic adjustment of the recording channel for a specific tape and the use of companding noise reduction systems are required.

Also in the mid-60s, digital processing and recording of signals began to develop. The first public demonstration of digital sound recording with pulse-code modulation was held in 1967 by the Japanese broadcasting corporation NHK. In this case, the medium was a magnetic tape that was played on a VCR with a helical scan recording method. The use of VCRs as an existing equipment for recording digital signals turned out to be very successful, and the first digital tape recorders were developed as two-unit ones containing the VCR itself and a digital sound processor.

For the first time in the world, such a processor for domestic use, having a sampling frequency of 44.1 kHz and 13-bit level quantization was proposed by Sony in 1977 (***Fig. 3***). After the demonstration of this equipment, the industry, which worked on the audio market, begins to actively develop a new area of technology. So in 1977, on the basis of an analog video disc, a Digital Audio Disc (DAD) was developed, but various companies offered their own formats for this medium. Everyone understood that the new disc would quickly become popular, so it was decided to reach an agreement on its standardization as soon as possible, which led to the emergence in 1982 of the well-known CD format.

Fig. 3 – Digital sound processor Sony PCM-1

2. Analysis of the Modern Market of Recording Media

Over the past decades, the most popular recording medium has remained a compact cassette. Thus, according to the Japan Electronic Industry Association for 1995, three out of four sound mediums sold in the world are compact cassettes, as blank or pre-recorded. During this period, the global production of compact cassettes exceeded 6 billion pieces per year, which is three times the volume of production of compact discs and phonograph records combined. All other recording media accounted for less than 1% of world production.

Fig. 4 – Compact cassette Sony Super Metal Master 90

Table 1 – Global demand for blank recording media (million pcs) [12]

Year	Compact-Cassette	Mini-Disc	Audio CD-R	Data CD-R[1]	CD-RW[1]	DVD-R[1]	DVD-RW[1]
1988	1766						
1989	1907						
1990	1897						
1991	1885						
1992	1896						
1993	1893						
1994	1891	6					
1995	1869	12		24			
1996	1842	35		79			
1997	1742	66		203			
1998	1546	125		629			
1999	1308	187		1900	49		
2000	1130	225	106	3282	121	3	
2001	929	243	169	5016	236	14	
2002	758	219	246	5880	282	115	23
2003	614	208	290	7048	306	345	82
2004	491	196	303	7683	303	1192	177
2005	390	144	289	7144	290	3643	289

Note:

1. Including discs for recording data and video.

Despite negative forecasts, in 2005 the global production of compact cassettes exceeded 1 billion pieces. But it should be noted here that the general decline in production observed in recent years is caused by the cessation of the production of the highest quality and most expensive models of compact cassettes with magnetic tapes based on chromium dioxide (IEC-II) and metal powder (IEC-IV).

This is due to the general movement of the analog media market towards mass products of low quality. Thus, it is from here that the main threat to the existence of high-quality magnetic sound recording equipment comes from.

3. Comparison of a Compact Cassette and a Compact Disc

To begin with, we will compare the most common recording formats today: Compact Cassettes (CCs) and Compact Discs (CDs). Thanks to the characteristics declared in the specifications of these formats, it has been established that the compact disc provides a greater dynamic range than the compact cassette. Moreover, the formula for calculating quantization noise is given as the main argument:

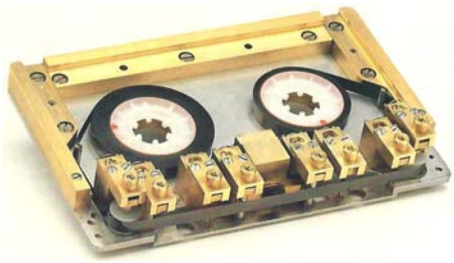

Fig. 5 – BASF reference compact cassette used for mold control in industrial applications

N_q=6.02·Q+1.76 [dB]

Where Q is the number of quantization bits.

For the CD, Q=16 is assumed; therefore, the theoretical quantization noise level is 98 dB. Usually this value is taken as its dynamic range. Considering that the best compact cassettes have a signal-to-noise ratio of about 60 dB (without noise reduction systems), it is concluded that the CD is won by 40 dB.

However, we must not forget that the principles of analogue and digital sound recording are fundamentally different; therefore it is completely incorrect to use the measurement methods adopted for compact cassettes to evaluate the dynamic range of a CD. The dynamic range of the compact cassette from below is determined by the noise level, and above by the total harmonic distortion (THD), the threshold of hearing which can be taken in 3%. In the case of the CD, the situation is completely different. ***Fig. 6*** illustrates typical THD dependencies as a function of signal level for given media. Of these, you can notice that in an analog recording, with a decrease in the signal level, THD monotonically decreases, while in a digital recording it increases, tending to 40% (since the relative size of the quantization step increases).

Wherein, in the analog recording in the spectrum of nonlinear distortions the 3rd and 5th harmonics prevail, which are not very irritating to the hearing. At the same time, a nonlinear distortion of a digital signal is manifested in the form of a multitude of combinational components that do not form a harmonic series familiar to hearing. Therefore, their effect becomes noticeable already at THD about 1%. It is easy to make sure that at signal levels of the order of -50 dB and below, the distortion of the CD signal goes over an acceptable threshold of 1%. Thus, from below, the dynamic range of the CD is not limited by quantization noise, but by nonlinear distortion. In this regard, of the claimed 98 dB, only 50 dB remains on the CD.

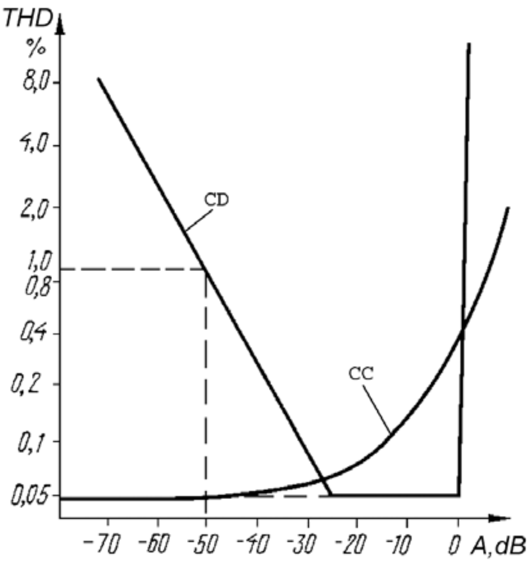

Fig. 6 – THD of Compact Cassette (CC) and Compact Disc (CD) [3]

In addition, during magnetic tape overload, the resulting nonlinear distortions are proportional to the square of the recording level, so their short-term appearance at the signal peaks is almost imperceptible to the ear. On a CD, when the nominal input level of an analog-to-digital converter (ADC) is only 2 ... 3 dB higher, the nonlinear distortion increases by several orders of magnitude, so in digital equipment the signal level should be 12 ... 15 dB (peak factor of real music signal) less than the maximum input level for the ADC. As a result, a CD of theoretical 98 dB of dynamic range still has, at best, 38 dB real, which is 22 dB less than a compact cassette.

Thus, the only advantages of the CD are its operational properties, such as ease of storage, quick access to the necessary recording and the absence of mechanical wear.

4. The Advent of New Digital Formats

All of the above, regarding the dynamic range of the CD, fully applies to such digital formats as R-DAT, DCC and MD, using 16-bit level quantization. Moreover, in the last two formats, data stream compression algorithms with information loss are used. The main method for implementing such compression is the use of masking effects and psychoacoustics of hearing, as well

Fig. 7 – DCC-cassette BASF DCC Maxima 90

as the removal of redundant signals using special mathematical algorithms. Obviously, the sound quality in this case directly depends on the degree of compression. Thus, DCC and MD fundamentally less accurately reproduce the original signal than CD. The same can be said for the proliferated CDs recorded in MP3 format. The MPEG Audio Layer 3 compression algorithm used here reduces the digital data stream to 32 ... 320 kbps (depending on the encoder setting).

5. High Resolution Digital Formats

As can be seen from ***Table 2***, only high-resolution digital formats such as SACD and DVD-Audio can really compete in the quality of sound reproduction with analog magnetic recording. In fact, they have much in common – the same physical structure of disks with a diameter of 12 or 8 cm and a logical data structure that serves as the basis for creating disks. Both formats support multichannel sound (up to six channels) with ultra-high resolution, CD player compatibility and the ability to use graphic and text material.

The idea of improving the sound quality of a CD by increasing the sampling frequency and increasing the bit depth is obvious, and when technical capabilities appeared, it was implemented in DVD-Audio format. However, it should be understood that as the sampling frequency and the bit depth of the signal increase in systems with pulse-code modulation (PCM), real sound quality improvements become less noticeable. The reason for this phenomenon, which consists in filtering the signal, is also known. In the PCM system, filters with a very steep characteristic are required at the input to suppress frequencies equal to half the sampling frequency or exceeding it. The disadvantage of such filters is not only a frequency limitation, but also a negative effect on the phase response of an audio signal.

Table 2 – Comparative characteristics of digital audio formats (in dual channel mode)

Characteristics	Compact-Disc (CD)	Rotary-Head Digital Audio Tape (R-DAT)	Digital Compact-Cassette (DCC)[1]	Mini-Disc (MD)	Super Audio Compact-Disc (SACD)	Digital Versatile Disc – Audio (DVD-A)
Year	1982	1987	1992	1993	1998	1999
Developers	Sony, Philips	Group of companies	Philips	Sony	Sony, Philips	Group of companies
Frequency Response, Hz	5 … 20000	2 … 22000	20 … 20000	5 … 20000	0 … 100000	0 … 96000
Dynamic Range, dB	96	96	92	96	120	144
Recording time, min	74	120	120	74	110	74
Sampling frequency, kHz	44.1	48	48	44.1	2822.4	192
Sampling Interval, μs	22.7	20.8	20.8	22.7	0.354	5.2
Number of Quantization, bits	16	16	16	16	1	24
Data format	Pulse-Code Modulation (PCM)	Pulse-Code Modulation (PCM)	Pulse-Code Modulation (PCM)	Pulse-Code Modulation (PCM)	Direct Stream Digital (DSD)[2]	Pulse-Code Modulation (PCM)
Data compression algorithm	-	-	Precision Adaptive Subband Coding (PASC)	Adaptive Transform Acoustic Coding (ATRAC)	Direct Stream Transfer (DST)[3]	Meridian Lossless Packing (MLP)[3]
Error correction method	Cross Interleave Reed-Solomon Code (CIRC)	Cross Interleave Reed-Solomon Code (CIRC)	Cross Interleave Reed-Solomon Code (CIRC)	Advanced Cross Interleave Reed-Solomon Code (ACIRC)	Reed-Solomon Product Code (RSPC)	Reed-Solomon Product Code (RSPC)
Flow rate, Mbps	1.4	2.46	0.384	0.292	6.5536	9.6

Note:

1. Variant of Stationary-Head Digital Audio Tape (S-DAT);
2. Variant of Sigma-Delta Modulation (SDM);
3. Data lossless compression algorithm.

An increase in the sampling frequency facilitates the operation of the filter, but a simple increase in the frequency cannot solve the problems of the appearance of quantization noise during analog-to-digital and digital-to-analog conversion. With this in mind, of particular interest is the SACD format, which uses a single-bit data stream – DSD, which avoids some signal distortions characteristic of PCM.

An interesting feature of the DSD format is the fact that after decoding, the digital stream can be fed to the amplifier directly through a low-pass filter. Another reason for abandoning multi-bit PCM sound recording systems is the need for complex processing (decimation and interpolation) of the signal, leading to more complex circuitry and poor sound quality.

In addition, due to the high sampling frequency in the DSD signal, the noise spectrum is shifted to higher frequencies (***Fig. 9***). These frequencies are in the inaudible part of the spectrum and can be easily filtered. This situation is different from linear PCM when the noise has a constant level determined by resolution. In reality, this approach requires additional attention to the analog part – high-quality circuitry should be used here.

Fig. 8 – SACD player Sony SCD-1

Since in a single-bit format any bit carries the same amount of information, the effect of each error does not depend on which bit is erroneous. In this case, one-bit errors have the same effect as errors in an analogue record. Regardless of their location, they will be better processed by correcting codes and less degraded, since the influence of errors will take the form of a linear function.

The effect of sample delay (jitter) for the DSD signal is also insignificant, since the delay of several samples (for the highest frequency of the signal) is only a small part of its period. Moreover, in multi-bit systems, a delay of one count, for high-frequency components of the signal, can reach half its period.

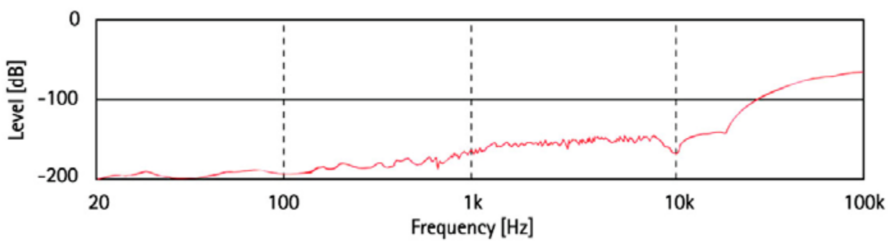

Fig. 9 – Delta Sigma Modulation Noise Spectrum [11]

6. Limitations of the New Digital Formats

In numerous reports and discussions at the congresses of the Audio Engineering Society, opinions were expressed that further progress in improving "transparency" and creating a "sense of presence" can be achieved by increasing the resolution of digital sound recording systems and expanding of the frequency range beyond 20 kHz.

However, an analysis of the knowledge gained in this area shows that this is not enough. Given the complexity of the sound signal and the characteristics of the human auditory system, it can be argued that this requires an increase in the resolution of the equipment in all areas (time, spectral, spatial and dynamic). At the very least, it is now becoming obvious that in order to ensure sound transparency, high resolution in the time domain is the most important.

Recording a real reverberation process without loss of information is associated with enormous difficulties. For example, in a room with a volume of 1000 m3, the number of reflections of sound, one second after the start of the reverberation process, is more than 511,000 reflections / sec. This means that the reflected waves will arrive at the listener with an interval of less than 2 μs, causing corresponding changes in the microphone output signal. Naturally, even with a time interval between samples of 5.2 μs (for DVD-Audio), these changes cannot be registered.

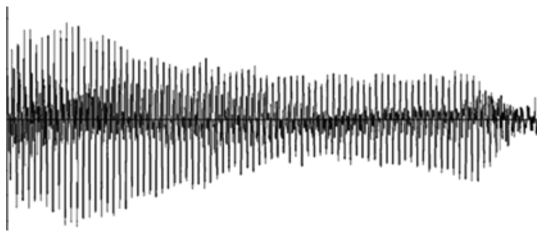

Fig. 10 – The time structure of the violin sound [7]

Careful measurements showed that in these reflected signals there are fast amplitude and phase shifts and fast irregular changes in frequency (frequency jitter). When two or more microphones are distributed in a room and multi-track recording is performed, these complex temporal relationships between frequency modulated signals, when binaural listening, create shifts in the time domain. As it turned out, the human hearing aid is very sensitive to such binaural shifts (binaural jitter), even if they are fractions of microseconds!

The sampling frequencies used in modern formats turn out to be insufficient to “grasp” these subtle time shifts, which lead to inaccurate localization in the peripheral zone and the loss of “environmental sensation” and “depth sensation”. The music performed indoors creates a complex sound signal that is perceived by an extremely thin and complex human hearing aid. Thus, the equipment for recording sound should have a resolution that matches both the given signal and the capabilities of human hearing.

In addition, the loss of information about the original sound in digital systems is associated with an erroneous interpretation of the Kotelnikov sampling theorem (Nyquist–Shannon sampling theorem) on the possibility of accurate restoration of the original signal. Often, designers lose sight of the fact that this sampling theorem was formulated only for discrete signals, to which the principles of the theory of linear systems are applicable, while the digitized signals do not form of linear space. In addition, this theorem is valid only for cases when the spectrum of the original signal is strictly limited. The limitation of the spectrum of broadband signals using low-pass filters cannot provide this condition. Therefore, for systems containing analog-to-digital and digital-to-analog converters, the Kotelnikov theorem can serve only as a theoretical model for rough calculations.

Fig. 11 – Open-Reel tape deck Studer A807 Mk II

Thus, despite all the advantages provided by the new high-resolution digital formats, it would be incorrect to consider them as a complete replacement for high-quality analog recordings.

7. Analysis of the Current State of Magnetic Recording Technology

Currently, analog magnetic recording equipment has reached a level of development above which the growth of its quality indicators can be achieved only at a disproportionately high cost, which will lead to a significant increase in the price level (***Table 3***).

As an example, we can recall the prototype of the Luxman X-3K cassette deck (***Fig. 12***). An uncompromising design with an external path of tape movement could not provide him with a clear advantage, being too

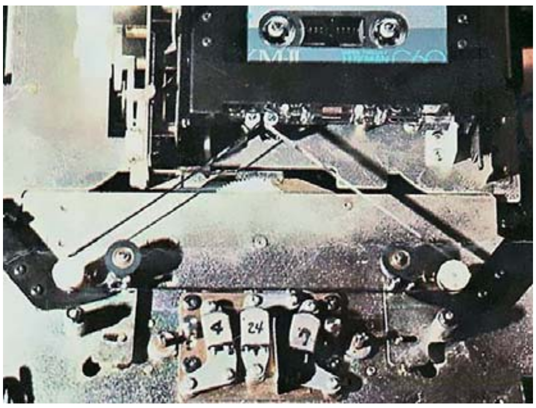

Fig. 12 – Tape transport of prototype Luxman X-3K

bulky, too expensive, inconvenient to operate and ultimately unprofitable.

The paradox of the situation is that it is the complexity of the further development of analog technology that pushes its manufacturers to switch to new digital formats that are easier to promote on the market, and they, in the end, are cheaper.

Table 3 – Technical characteristics of modern professional tape recorders

Characteristics	Open-Reel tape decks	Cassette tape decks
Tape width, mm	6.25	3.81
Tape thickness, microns	52 … 56	12 … 18
Tape speed, cm / s	38.1	4.76
Wow & flutter (IEC)	±0.05%	±0.04%
Frequency response (0 VU)[1], Hz	30 … 24,000 (±3 dB)	20 … 16,000 (±3 dB)
Signal-to-noise ratio (IEC-A)[2], dB	71	61
Total harmonic distortion (0 VU, 1 kHz)	0.8%	1%
Channel separation (0 VU, 1 kHz), dB	>55	>45
Erase level (+10 VU, 1 kHz)[3], dB	>75	>65

Note:

1. To assess overload capacity, the frequency response is given at the recording level of 0 VU. In accordance with current standards, it is customary to indicate this range at the level of -20 dB, which is 15 ... 34,000 Hz and 15 ... 24,000 Hz for reel and cassette recorders, respectively;
2. Using modern compander noise reduction systems, the signal-to-noise ratio can be improved by 30 dB in the entire frequency range. However, this reduces the overload capacity of the tape at medium and high frequencies;
3. When using special demagnetizing devices, the erasure level of modern magnetic tapes exceeds 80 dB.

8. Advantages of Analog Tape Decks

- To date, only analog tape decks can fully convey the time characteristics of audio recordings, which are essential for maintaining spatial sensations. None of the common digital formats are capable of providing the necessary resolution for this;
- With the advent of new technologies, it becomes possible to solve the long-standing problems of magnetic recording at a sufficiently high level. First of all, the parameters of magnetic tapes have been improved, which is reflected in all the quality indicators of tape decks. New

Fig. 13 – Cassette deck Nakamichi 1000ZXL Limited

materials for magnetic heads can increase their wear resistance and parameter stability. The use of magnetoresistive heads can reduce signal loss during playback, increase the signal-to-noise ratio and expand the range of reproduced frequencies. The use of adaptive dynamic bias systems expands the range of recorded frequencies and increases the tape overload capacity. The stability of the tape speed is provided by brushless motor with quartz frequency stabilization, which provides a wow & flutter below the auditory threshold;

- Professional studio tape recorders are characterized by a high degree of reliability and maintainability. With proper care and timely prevention, these devices can work 10 hours a day for 10 or more years. At the same time, the moral aging of analog equipment is an order of magnitude lower than any digital equipment, so that their economic efficiency (taking into account the higher cost of both the devices themselves and the recording media) is comparable to digital recorders;
- Modern magnetic tapes, subject to certain conditions, retain their properties for up to 50 ... 100 years. Qualitative indicators of magnetic recording allow both direct reproduction after 100 years of storage and subsequent restoration using the latest (at the time of restoration) algorithms. No digital format has such advantages, as digitization leads to an irreparable loss of information about sound. In addition to this, an economic efficiency (at the cost of storage) alternative to magnetic tapes has not yet been found. Their information capacity also remains unrivaled. For example, a cartridge with a tape of the new standard SAIT-4 (Super Advanced Intelligent Tape) can accommodate up to 4 TB of data without compression. The write / read speed are 120 MB / s.

9. Disadvantages of Analog Tape Decks

- One of the main disadvantages of modern tape decks is the high consumption of expensive magnetic tape, which is due to high demands on the quality of sound recording. The higher the tape speed, the higher the maximum recorded frequency. The wider the recording track allocated on the tape for recording one channel, the greater the signal-to-noise ratio and the lower the level of harmonic distortion;

Fig. 14 – Sony SAIT-1 500

- The development of electronic circuitry has provided uncritically low noise levels in the electronic path (with the exception of low-frequency interference), but problems with the magnetic tape were unsolvable. The nature of the noise of the tape is explained by the heterogeneity of its structure, the existence of agglomerates of particles of magnetic powder and the microroughness of its surface. Please note that the noise of a magnetic tape is close in nature to white noise and in most cases is not perceived by listeners as annoying. For example, medical scientists assign a pronounced therapeutic effect to white and pink noises. At the same time, it was found that the level of noise caused by digital distortion, which begins to annoy listeners, is lower than the level of white noise masking them by 20 ... 25 dB;

Fig. 15 – Tape manufacturing at TDK's factory

- Compander noise reduction systems (Dolby, dbx, etc.), although they significantly increase the signal-to-noise ratio, they require high stability of the recording-playback channel parameters. In addition, these systems lead to dynamic distortions of abruptly changing sound signals and increase parasitic amplitude modulation of the useful signal;
- The use of various kinds of noise reduction systems cannot eliminate the effect of modulation noise (its level in modern tapes is below -60 dB). Modulation noise is a type of noise of a magnetized carrier and is caused by the inconsistency of the tape-head contact, transverse vibrations of the tape, and the heterogeneity of the magnetic layer of the tape;
- Each subsequent dubbing of an analog phonogram onto a magnetic tape increases distortions by about one and half times and worsens the signal-to-noise ratio. On the other hand, digital dubbing technology is also not absolutely error-free. For example, optical path losses, to some extent recoverable by the Reed-Solomon code, can reach 20%, and the instability of the phase of digital samples further reduces the quality of the phonogram;
- As a result of the magnetization of adjacent turns in a roll of recorded magnetic tape, a copy effect occurs. Its value depends on the recording level and signal frequency, as well as on air temperature, storage time and thickness of the magnetic tape. However, the copy effect is manifested rather slowly, and by periodically rewinding reel with tape, its effect can be significantly weakened.

10. Conclusions

Fig. 16 – Portable cassette recorder Sony TC-D5 ProII

Experience shows that in order to achieve the best digital recording performance in digital formats, a large number of problems have yet to be resolved. The main one is to theoretically substantiate and experimentally confirm the characteristics of the psychoacoustic perception of digitized stereo sound. Based on this, it is necessary to develop new measurement techniques that allow us to objectively assess the quality of digital sound recording channels.

Thus, by far the most advanced technology for storing stereo phonograms remains analog magnetic recording. Despite the mass of specific shortcomings, it is this format that most carefully treats the preservation of the characteristics responsible for the natural sound (transmission of directions and the depth of localization of sound images in space).

Analog technology to the maximum extent corresponds to the human hearing aid, adapted precisely to such signals. Even the distortions that it introduces with the signal are perceived as something harmonious and in some cases allow masking artifacts of digital sources when dubbing phonograms.

11. 2018 Remarks

This article was written over 12 years ago. Over the past time, the situation with magnetic sound recording has been predictably complicated. Although the issues discussed above remain valid, it is necessary to make a few comments.

Fig. 17 – Athan's polyurethane pinch roller with brass bushing and two rolling bearings

- Existing magnetic recording equipment, created at the peak of the popularity of this format, will remain out of competition for a long time to come for enthusiasts. Moreover, there is now a revival of a certain interest in analog technology. And here it is important to note that, in contrast to modern, disposable products, this equipment is repairable. That is, it was originally designed with the expectation of durability;
- The recent difficulties with the availability of spare parts and consumables can be solved by the manufacture of specific parts to order. It is also possible to purchase similar equipment for disassembling for parts. Of course, such parts will cost much more, but you will be sure that you can always restore your equipment to its original state;
- Today, the only real restriction for the further use of magnetic recording is the lack of high-quality media in the public domain. And while stocks of previously released cassettes still cover declining demand, their prices are constantly rising. Against this background, a message appeared that the French company “Recording The Masters” has resumed production of magnetic tape and compact cassettes using technologies from AGFA and BASF;
- The good condition of magnetic tapes, including those recorded more than 30 ... 40 years ago, is surprising. Even without special storage conditions, these recordings still sound great! And archival professionals involved in magnetic recording confirm the long-term reliability of analog media is much higher than any digital!

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