

The Future of Audio Recording

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Predicting the future is very difficult, as you probably know. On the other hand, predicting the future of audio recording technology may not be that difficult. One person has been very successful in predicting the future of electronics technology during the last 30 years or so. His name is Gordon Moore, the founder of Intel, which manufactures the electronics used in many computers. As a young electrical engineer, Dr. Moore was one of a team that made the first integrated circuit. This chip contained five to 10 transistors.

Some 30 years ago, Dr. Moore predicted that the number of transistors per square millimeter (or square inch) would double every 18 months. This prediction, now called Moore's law, has been very accurate. For example, in 1980 at the time of the introduction of the Compact Disc, a standard memory could store 16 thousand bits, while current memory units can store approximately 16 million bits. This is a growth factor of a thousand in just 18 years time. Not only has the storage capacity increased by a huge factor, but computer speed has also increased, prices went down, and so forth. The audio engineering industry has benefited a lot from this electronics revolution. In fact it was the driving force behind the digital audio revolution. All kinds of operations can be done in the digital domain much more accurately than was ever thought possible.

The capacity of storage devices such as hard disk drives (HDDs) has not fol-

lowed Moore's prediction. In the early 1980s, HDDs with a capacity of a megabyte were quite common. Now small laptops equipped with HDDs having a capacity of a few gigabytes are commodity products. Again, an increase by a factor of a thousand in 18 years time.

The capacity of optical recording products, say the Compact Disc, has not followed Moore's rule that the capacity would double every 18 months. The capacity of the Compact Disc, which was introduced 15 years ago, is approximately 600 megabytes. The capacity of optical discs changed only once when the DVD was introduced a few years ago. The capacity of the DVD is 4.7 gigabytes, which is a factor of seven more than that of the classic CD introduced 15 years ago. According to Moore's law, one might have expected a growth in capacity of a factor of a thousand instead of seven. Evidently, optical recording is a poor performer in terms of capacity growth. This is not the right setting to discuss the various factors that have played a role in this underperformance, but in the coming years the capacity of optical discs will grow much faster than hitherto.

Let us assume, for the sake of academic interest, that from now on the storage capacity of optical recording will follow Moore's law. What does this mean for the recording industry? What kind of data-hungry formats can we think of that will consume a factor of a thousand more bits than the Compact Disc? The change from CD to DVD gave a slight flavor of what kind of options the audio industry has. This change involved only a small factor of

seven, and the industry came up—very surprisingly—with an increase in resolution and sampling frequency by a factor of two. The industry also came up with the “great” idea of using more channels, usually five instead of the usual two stereo channels. This is a nice beginning to spending the bit budget, but if we have a factor of a thousand to spend, we must try to act as a really big spender. For example, let us think of playing time: we could store a 1000 hours of music on the new disc. That is 40 days of around-the-clock CD-quality music. With eight discs one could play music for a full year. Note that the average Western household owns less than 200 Compact Discs. So with just one “super disc” one could store Mr. Average's repertoire. Unfortunately, the price of such a disc would be, say, \$20,000, which is well above the budget of an average household.

There is a natural limit to the increase in the sampling frequency and resolution. Some people even question whether the average consumer is very much interested in the improved performance that DVD audio is providing in this respect. So we have to think of something more attractive. An increase of spatial resolution may give a radical answer to the technology push of the factor thousand we have to spend. My ultimate audio format would have the following main parameters:

Resolution:	32-bit PCM
Sampling frequency:	196 kHz
Number of channels:	256.

This format would be, for the time being, future proof.

The small technical problem is ⇨

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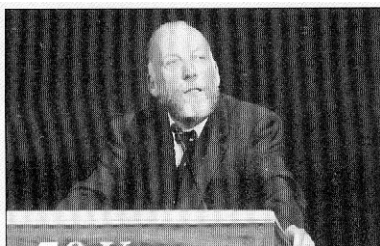
that, apart from a few audio buffs, probably no one would install 256 loudspeakers in the living room.

Clearly, state-of-the-art loudspeakers are ugly, require cables, and so forth. In order to solve this technicality we must (re-)invent the concept of invisible sound or invisible loudspeakers. You may hear them, but you cannot see them. A name for this could be "the emperor's new loudspeaker system." Invisible sound is not science fiction. It is, at least in principle, physically possible to make invisible loudspeakers by using modulated laser light in air using the photo-acoustical effect. There are a few technical obstacles with the cables, in particular the power cables, as evidently batteries cannot provide the required power. So we have to think of alternative power supplies, such as solar power or the beaming of infrared energy. Why not design a micro nuclear reactor, the size of a battery, which could supply the energy. Anyway, it seems like a good idea to ask the Society's

Technical Committee on Loudspeakers and Headphones to take a closer look at invisible loudspeakers.

Let me conclude with the following observation: In the future there will be a proliferation of audio formats, probably mutually incompatible. Since the 1970s we have witnessed a rapidly growing number of recording formats that have been introduced into the market. The average time interval between the introduction of new formats is getting smaller and smaller. After analyzing ample statistical data, I conclude the time is ripe to postulate a new law that simply states that the time interval between two consecutive introductions of new audio formats will halve every 18 months. On the basis of this law, in 2023, at the Society's 75th anniversary, the introduction of an entirely new audio format will occur every hour. Then, fortunately, we will have just enough time to play the new record before both the player and the disc have become obsolete.

THE AUTHOR



Kees A. Schouhamer Immink, a native of the Netherlands, worked at Philips Research Laboratories from 1967 to 1998, and since 1996, has been an adjunct professor at the Institute for Experimental Mathematics, Essen University, Essen, Germany.

He has contributed to the technologies of a variety of digital audio and video recorders such as the Compact Disc, Compact Disc Video, DAT, DCC, and, recently, the DVD. Dr. Immink holds 36 U.S. patents, has authored or coauthored three books, and has written numerous papers in the field of digital audio recording technology. He received many awards for his part in the digital audio revolution. He is a fellow of the AES, IEE, SMPTE, and IEEE, and was honored with the IEEE Edison Medal, the IEE Sir J. J. Thomson Medal, the SMPTE Poniatoff Gold Medal, and the IEEE Masaru Ibuka consumer electronics award. He was elected a member of the Royal Netherlands Academy of Sciences for his contributions to science in 1996. He serves as a governor of the IEEE Information Theory Society and the IEEE Consumer Electronics Society.

Dr. Immink joined the AES in 1980, has been a member of the Review Board of the *Journal* since 1984. He was a committee member of the Netherlands Section from 1986 to 1992 and its chairman from 1988 to 1990. He was elected a governor for the 1995-1997 term, and vice-president, Northern Region, Europe, for 1997-1999. He was made an AES fellow in 1985 and was honored with the Society's Silver Medal in 1992. Email address: immink@exp-math.uni-essen.de.

Upcoming Meetings

1999 April 13-16: *13th European Frequency and Time Forum and 1999 IEEE International Frequency Control Symposium*, Micropolis, the Parc des Expositions et des Congres de Basancon, France. Contact Isabelle Bourgon, tel: 33 3 81 40 28 21 or fax: 33 3 81 88 57 14.

1999 April 17-22: *NAB 99*, Las Vegas, NV, USA. For information, tel: 800-342-2460 or e-mail: register@nab.org, fax: +1 732-544-2888.

1999 April 28: *The American Loudspeakers Manufacturers Association (ALMA) Spring Symposium*, Marriott Nashville Airport Hotel, Nashville, TN, USA. For information contact Carol Bousquet, ALMA executive director, tel: 978-448-5658.

1999 May 8-11: *106th AES Convention*, Munich, Germany, MOC Center, Munich. For information see page 200.

1999 June 23-25: *9th AES Regional Conference*, Tokyo, Japan, Sunshine City Convention Center, Ikebukuro. For information contact: Takeo Yamamoto, convention chairman at tel: +81 3 3489 4760 or e-mail: yamatake@t3.rim.or.jp.

1999 September 2-5: *17th International Conference*, Florence, Italy, "High Quality Audio Coding," Villa Castelletti, Signa, Italy. See page 200.

1999 September 10-14: *IBC99*, Amsterdam, the Netherlands. For information contact Gina Christison, IBC Office, Savoy Place, London WC2R 0BL, UK, tel: +44 (0) 171 240 3839 or fax: +44 (0) 171 240 3724.

1999 September 24-27: *107th AES Convention*, New York, NY, USA. For information see page 200.