Personal digital Recorders

Philip Laven
Director, EBU Technical Department

Video recorders – based on hard disks, rather than on tape – are now being introduced as consumer products. This article suggests that these devices will eventually revolutionize broadcasting by allowing consumers to break free of the constraints of linear broadcasting. Although such technologies will offer many opportunities for broadcasters, there will also be some threats to established business models, such as the use of commercial breaks during TV programmes.

Hard disks have now become so cheap that they can be used to record video programmes. Hard-disk recorders are often known generically as Personal Video Recorders (PVRs) or Personal Digital Recorders (PDRs) to distinguish such devices from traditional tape-based video-cassette recorders (VCRs). This article will employ the term PDR because it emphasizes that such recorders can record video, audio, data or any information available as a digital signal.

Price trends

One of the dominant features of the computer industry over recent years has been the success of Moore's Law in predicting that the number of transistors on a silicon chip would increase by a factor of two, every 18 months. In practice, Moore's Law is often applied more generally to computer hardware, in that prices can be expected to reduce (or performance to increase) by a factor of two, every 18 months.

Fig. 1 shows the prices of hard disks of various sizes. This demonstrates that, for a given price, the capacity of hard disks has increased dramatically over the last 10 years. When a new hard disk is introduced, it initially commands a high price, but the cost falls rapidly. This reduction in price becomes more gradual when it reaches between £100 and £150, before the product is discontinued and replaced by disks of much greater capacity.

The same data is re-plotted in *Fig. 2* in terms of cost per MB, but using a logarithmic vertical scale. It is interesting to observe that a single straight line can provide a good approximation of the diverse curves for hard disks of different capacities.

For reasons of clarity, only a few disk sizes have been shown in Figs. 1 and 2. The lower curve in *Fig. 3* has been derived from a more comprehensive set of data and represents the minimum value of price per MB. This demonstrates that the price of hard-disk capacity has fallen by a factor of two, every 12 months – or even faster, especially in the last few years. For comparison, the upper curve of *Fig. 3* shows the price per MB of random-access memory (RAM). Despite some volatility, the price trend for RAM corresponds to a factor of two, every 18 months.

It may be surprising to realize that the price of hard disks is falling more quickly than the price of RAM. Note that the difference between a factor of two, every 12 months and every 18 months, has important long-term consequences. For example, in 1990, RAM was 10 times more expensive than hard disks but, by 2000, this factor had increased to 100.

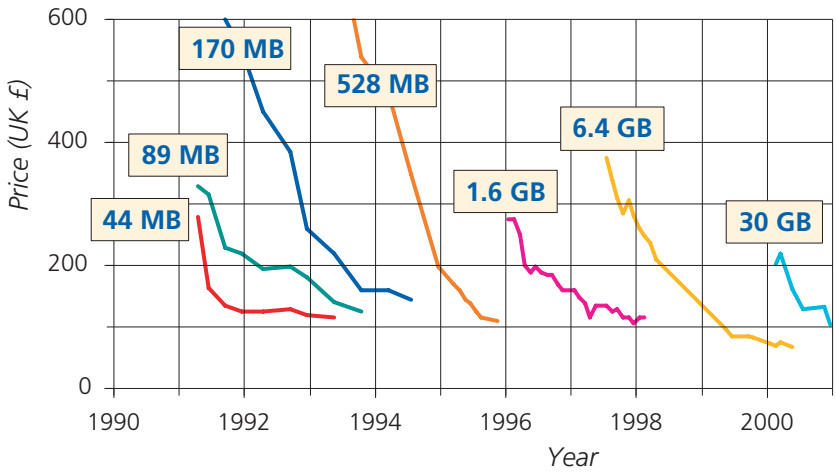

Figure 1
The falling cost of hard drives of different sizes.

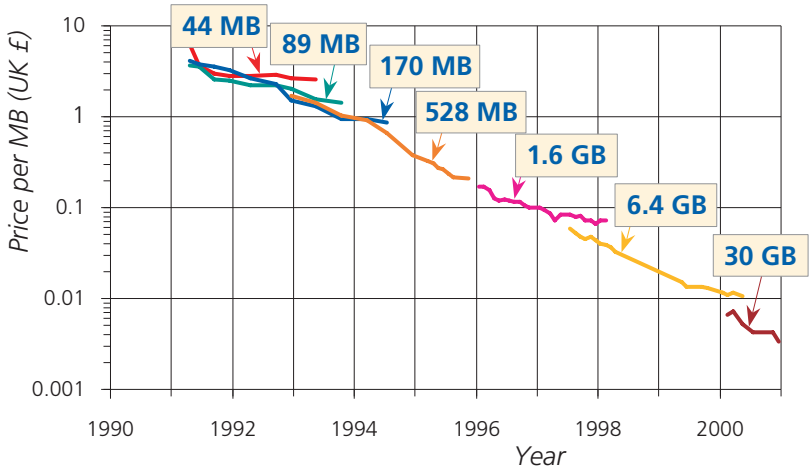

Figure 2
The falling cost per MB, on a logarithmic scale.

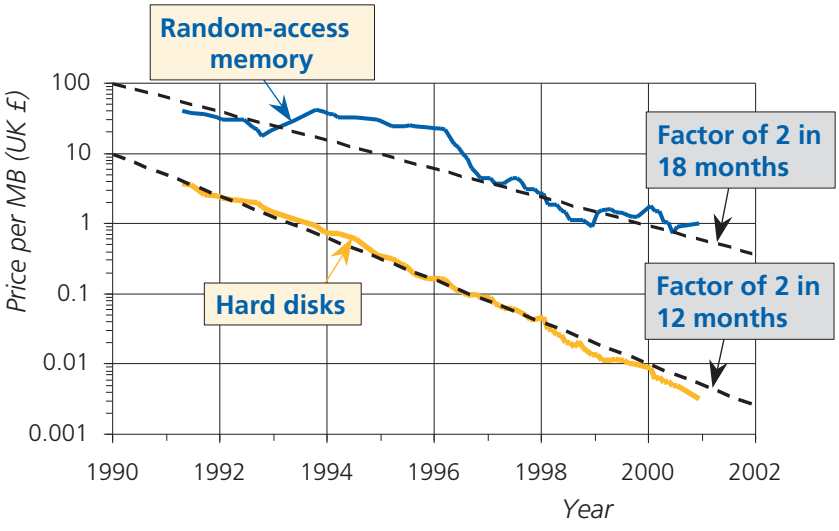

Figure 3
The falling cost per MB of hard drives vs RAM.

The big question is whether these trends will continue in the future. Simple extrapolation of historical trends can be misleading, especially if they involve rapid exponential growth. One good example is that of the Internet: there were about 300 million users at the beginning of 2000. Over the past 10 years, the number of users of the Internet has increased by a factor of 2 approximately every 12 months. *Fig. 4* shows what happens if we assume that growth will continue at the same rate: in May 2004, every man, woman and child in the world would be using the Internet. This prediction is clearly ridiculous: people in developing countries have to deal with much more pressing problems, such as access to water, food and healthcare, than access to the Internet.

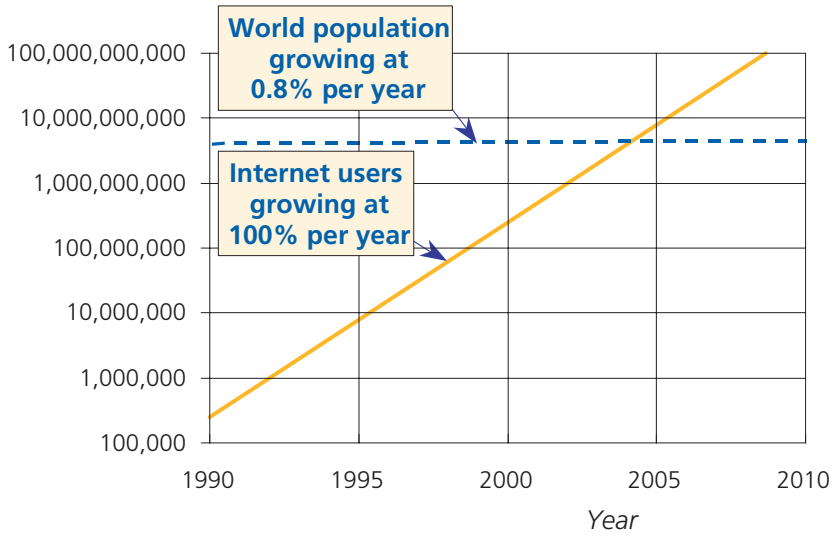

Figure 4
The spectacular growth in Internet use.

It is clearly dangerous to extrapolate on the basis of historical trends, especially if there are hard limits to growth, such as the total population of the world. Nevertheless, we need to understand how the costs of hard disks are likely to change during the next 5 – 10 years. It is, thus, important to identify if there are any barriers to sustained exponential growth in the capacity of hard disks.

One potential problem is the amount of data that can be stored in a limited area of magnetic material. Over the past 10 years, the areal density achieved in hard disks has increased from 0.1 Gbit/in^2 to 10 Gbit/in^2. In 1998, it was suggested that it would not be possible to achieve more that 30 Gbit/in^2 because of the superparamagnetic effect [1], in which the amount of magnetic material corresponding to one bit becomes so small that ambient thermal energy could "flip" the bit from a "0" to a "1" (or vice versa), thus corrupting the data. Recent research suggests that 150 Gbit/in^2 can be achieved and, hence, that the limit due to the superparamagnetic effect is above 150 Gbit/in^2.

Areal density is just one of the many factors in the development of hard disks. Detailed consideration of the design problems of hard disks is beyond the scope of this article. Nevertheless, it seems that the rapid exponential growth in the capacity of hard disks will continue for the next 5 years – and possibly for the next 10 years.

What does this mean for hard-disk video recorders? A 30 GB disk can be purchased today for a retail price of about £100 (€166) and can accommodate about 13 hours of video/audio at a data rate of 5 Mbit/s. The following table summarizes how the capacity of hard disks might evolve over the next 5 years – at a constant price of £100.

	Factor of 2 every 18 months		Factor of 2 every 12 months	
Date	**Disk size (GByte)**	**Duration (hours)**	**Disk size (GByte)**	**Duration (hours)**
January 2001	30	13	30	13
January 2002	48	21	60	27
January 2003	76	34	120	53
January 2004	120	53	240	107
January 2005	190	85	480	213
January 2006	302	134	960	427

From the above table, we can see that hard disks are likely to become viable as a consumer product for the mass storage of video. Note that the above table only relates to the price of the hard disk, not to the total cost of the PDR.

Applications

At first sight, changing the storage medium from tape to hard disks might not seem to be particularly significant. One key distinction is that disks are inherently random-access devices and, hence, they can offer very rapid access to previously-recorded material, whereas tape is a linear medium on which it may take several minutes to locate the required segment. Perhaps, more importantly, PDRs have the ability to record and replay at the same time. It is easy to dismiss this feature as a technological curiosity, but it allows PDRs to offer a new range of facilities that, quite simply, cannot be matched by traditional VCRs.

For example, imagine that you are watching a TV programme as it is being broadcast. If you have a PDR, you will probably also press the "record" button, not necessarily because you wish to preserve the recording for viewing on another occasion but because you wish to use the special features of your PDR. If your viewing is interrupted by the telephone ringing a few minutes after the start of the programme, you can press the "pause replay" button. Although the PDR will continue to record the programme, the picture on your TV screen will remain frozen. When you finish your telephone conversation, you will be able to resume watching the programme from the moment you froze the picture.

Even better, despite the fact that the PDR is still recording the programme, the PDR now gives you full VCR-like controls over playback, allowing you to "play", "stop", "rewind" or "fast forward". For example, you may wish to "rewind" by a small amount so as to remind yourself what was happening on the TV programme just before the telephone started ringing.

Now that you are watching a delayed version of a live broadcast, you can use the "fast forward" feature to skip over any part of the programme that does not particularly interest you. You can even use this feature to "fast forward" through any advertisements! One of the two brands of PDRs sold in the USA has a button that allows you to "jump forward" by 30 seconds – because most commercials are 30 seconds long!

Most of us have great difficulty in pre-setting our VCRs to record a programme automatically. Despite several innovations, such as Programme Delivery Control (PDC), the failure rate remains high – usually because most VCRs and their associated remote controls are too complex. Even if you use a VCR to record a programme that you are watching, you need to label and index every recording to minimize the possibility that it will be inadvertently over-written on a future occasion, such as when you realize that you need a tape with one hour's free space to record a programme that has just started!

PDRs will enable TV viewers to "order" a programme to be recorded by pressing a single button when a programme trailer is being broadcast. PDRs will also offer automatic indexing of recorded programmes, together with a helpful on-screen display of recorded items.

The first PDRs behave rather like "intelligent" VCRs, but subsequent generations will have even more "intelligence". For example, by observing your behaviour, they will learn which programmes

- ⇨ you regularly watch;
- ⇨ you record and watch later;
- ⇨ you record but do not watch.

Using such information, PDRs will automatically record material that you would probably like to watch: for example, programmes in a series, or programmes with your favourite actor or singer. The next time that you use your PDR you will be told about new items that have been recorded and you will be asked whether you wish to keep or delete these items.

Although VCRs have been very successful, few people use them for much more than occasional time-shifting of programmes and for the playing of pre-recorded tapes. Although the bulk of viewing occurs in the evenings, there are many interesting programmes broadcast at less convenient times, such as during the working day or very late at night. The ease of use and the large capacity of PDRs may allow users to construct their own viewing schedules. It has been suggested that if PDRs are successful, they will lead to the death of "prime-time". Such forecasts are almost certainly exaggerated because many people will continue to accept the broadcaster's schedule. In any event, it is improbable that viewers will choose to watch coverage of live events, such as sports, on the following day. Nevertheless, many viewers would welcome the opportunity to watch programmes broadcast at off-peak times, at times more convenient to them. Rather than causing the death of prime-time, PDRs will trigger a slight decline in the importance of the concept of prime-time.

One attractive possibility is that of "segment-jumping" in which users will be able to look at segments of a broadcast programme in any order that they choose. For example, at present, news programmes or magazine programmes are transmitted in a linear format – where the order of the items is chosen by the editor of the TV programme, rather than by the consumer. If such a programme has been recorded on a PDR, it would be helpful to the consumer if an on-screen menu was provided, listing the items included in the programme and thus allowing him/her to jump directly to the segments of particular interest. Effectively, the PDR will allow linear programmes to be consumed in a non-linear manner.

PDRs can be considered as easy-to-use, more-sophisticated versions of VCRs. However, that view underestimates the potential of PDRs. When a cheap PDR is able to record hundreds of hours of video, the user will be able to access a huge range of programmes on demand. For example, the PDR may record many broadcast programmes so that, if desired, you will be able to watch a particular programme transmitted the previous day. Many of us have the experience of going to work and hearing colleagues enthuse about a programme broadcast the previous evening – or reading a newspaper review that says *"If you did not see this programme last night, you missed one of the best programmes of the year"*. All too often, we will have forgotten to watch the programme and not recorded it – neither did any of our friends! With an intelligent PDR, it is quite likely that the programme has been recorded automatically – thus enhancing the value of personal recommendations and, for the first time, allowing reviews of programmes to be really useful.

In addition to recording broadcast programmes, PDRs will also permit broadcasters to download interactive information services over the broadcast channel. These might be similar to web pages, but they will also contain links to clips of high-quality audio and video. Unlike services delivered over the Internet, the multimedia content will already be stored on the hard disk for instant access by the consumer. Such services would be continuously up-dated by the broadcaster, who would ensure that old material would be replaced by new material. Essentially, a PDR user will authorize a broadcaster to manage the contents of a portion of the PDR's hard disk.

By such means, broadcasters could provide a comprehensive on-demand service of news and information. Furthermore, such facilities would have many other applications, such as for the delivery of supporting material associated with a wide range of general programming – ranging from cooking programmes to education.

Abbreviations

ADSL	Asynchronous digital subscriber line	**PDR**	Personal digital recorder
		PVR	Personal video recorder
PDC	Programme delivery control	**RAM**	Random-access memory

Service models for PDRs

All of the above features are possible with PDRs, but they require co-operation between broadcasters / service providers and the developers of PDRs.

Numerous different service models can be envisaged:

- At one extreme, PDRs connected to two-way broadband communications systems (e.g. cable modems or ADSL) could be used to offer video-on-demand services. Several movies might be automatically downloaded and stored on the hard disk – so that they are available on demand. In such circumstances, these movies might be scrambled, even when they are stored on the hard disk – and unscrambled only when the service provider has been paid the appropriate fee. If the available downstream bit-rate is not sufficient for high-quality video, material could be transmitted slower than real time for subsequent viewing via the PDR.

- At the opposite extreme, PDRs could operate without any form of return channel – simply by relying on the broadcast services to deliver the appropriate content.

- In between these two extremes, broadcast services might be used as the downstream delivery mechanism, with a telephone line to provide an interaction channel. For example, a pay-TV operator might encourage the use of PDRs to record scrambled movies and use the telephone line to enable the unscrambling of the requested movie.

Electronic programme guides for PDRs can be delivered by telephone lines or by broadcast systems. The first generation of PDRs use telephone lines and proprietary systems, because they were designed to operate with analogue TV services, for which there is no agreed mechanism to deliver the necessary metadata. This mode of operation also permits the PDR "service provider" to charge a monthly fee for the electronic programme guide and related services.

The TV-Anytime Forum [2][3] has been established to encourage the development of TV and related multimedia services, based on the use of persistent local storage irrespective of the manner of service delivery. This Forum is developing technical specifications that will meet the needs of all participants in the business chain, such as content owners or producers, service providers, network operators, software developers, hardware manufacturers and end-users or consumers. An essential element of the Forum's work is to enable interoperability and end-to-end system integration.

The work of the TV-Anytime Forum is likely to lead to the development of "horizontal" markets in which broadcasters will be able to deliver services to PDRs from many different manufacturers in the knowledge that interoperability is guaranteed. It is important to recognize that the development of incompatible proprietary solutions might be satisfactory for "vertically-integrated" pay-TV operators, but it would lead to

chaos for free-to-air broadcasters who might be obliged to transmit several different sets of metadata, appropriate for several types of PDRs

The threat to advertising

The ability of PDR users to skip commercials has struck fear in the hearts of advertisers and of broadcasters funded by commercials. It is certainly an attractive feature with consumers: market research from the USA suggests that 88% of the owners of such recorders regularly use them to skip commercials on "live" broadcasts. However, we need to recognize that the behaviour of early adopters could be atypical of the population. Furthermore, as many broadcasters in the USA transmit more than 15 minutes of commercials per hour, it is not surprising that there is a demand for a technology that reduces the impact of commercials. Hence, experience from the USA may not be replicated elsewhere in the world where commercials are less frequent and less intrusive.

Although PDRs are a threat to the traditional commercial break, they also offer new opportunities for advertisers. Consumers with PDRs can view the TV programme directly with the default commercials included in the viewing schedule (as anyone without a PDR would do) or they can skip the commercials. However, the ability of PDRs to store content locally means that the default commercials could be replaced with targeted commercials previously stored on the PDR's hard disk. For example, there is little value in advertising cat food to homes with a dog but no cat. Hence, in such homes, commercials for cat food could automatically be replaced by commercials for dog food.

Commercials for expensive products, such as cars or holidays, cannot provide much real information within the confines of a 30-second slot. Before purchasing such products, most people request additional information in the form of printed brochures or even videotapes. With a PDR, it would be possible to offer much more information, such as 10-minute video packages, instantly from the hard disk.

Conclusions

PDRs based on hard disks will offer low-cost mass storage in the near future. This raises the prospect of new ways of viewing traditional TV broadcasts, as well as new types of content designed to benefit from the features of PDRs. In considering the future role of PDRs, it is important to emphasize that technological feasibility should not be confused with commercial viability. The advent of new technologies does not necessarily mean that consumers will purchase them. History is littered with commercial failures of "excellent" technologies. The key to success is to find features or services that interest the public to the point where they will spend hard cash to obtain the

necessary technology or services. In the case of PDRs, a wide range of features could be made available at prices that are likely to be attractive to consumers.

The key selling point for PDRs is that they will allow consumers to "watch what they want, when they want". PDRs will not be an overnight success, but they will eventually revolutionize broadcasting by:

- ⇨ allowing consumers to "break free of the constraints of linear broadcasting";
- ⇨ combining the immediacy of television with the flexibility of the Internet.

PDRs undoubtedly threaten some established business models, but they also offer new and potentially important opportunities for broadcasters – as well as empowering the consumers.

Bibliography

[1] **Avoiding a Data Crunch**
Scientific American, May 2000
http://www.sciam.com/2000/0500issue/0500toig.html

[2] TV-Anytime Forum:
http://www.tv-anytime.org/

[3] J.-P. Evain: **TV-Anytime metadata – a preliminary specification on schedule!**
EBU Technical Review No. 284, September 2000.