D·I·G·I·T·A·L TELEVISION

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Preface

There are several ways of treating a subject like digital television. One way is to find an author who can personally cover the whole subject. It is hard to find someone who has both access to the detail of the wide range of the essential technologies and who also has the time to write a book. Another way is to invite experts on each of the major topics from various organisations (and countries) to contribute chapters on their own subject. This provides a broad coverage but may lack cohesion.

I have chosen an intermediate approach similar to that which I used on a previous occasion [6]. The material has been covered by a group of specialists who have been working closely together in this field for many years and have themselves pioneered some of the applications of digital techniques to broadcasting. We have therefore been able to compare notes as we went along and have tried to make sure that most areas are covered in a way that hangs together, at least as seen in terms of the requirements of one major broadcasting organisation.

The chapter on digital recording has been treated differently. This has been written by a distinguished broadcasting engineer from Yugoslavia who pulled together the activity in which representatives from industry and broadcasting collaborated on a worldwide basis for several years to produce a common approach to digital recording.

My thanks go to all who have contributed to the book. To the BBC for its enlightened attitude to research and development which enabled much of the work described to be applied successfully. To my co-authors who patiently responded to numerous requests for additional material as the contributions came together. To colleagues in other broadcasting organisations and in manufacturing industry from all over the world who provided material for inclusion in the book, and particularly those in the EBU, SMPTE, and CCIR.

I would like to gratefully acknowledge the helpful discussions with many colleagues in the BBC and to thank Miss Eileen Tasker, Mrs Ann Bennet and Mr Ted Hartwell for help with the manuscripts.

Finally my fond thanks go to my wife Audrey for allowing me to cover large amounts of surface area of our home with paper, particularly at a time when she needed some of the space for the manuscript of her own book!

C. P. SANDBANK,
Broadcasting House,
London.

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1 The Emergence of Digital Television

C. P. Sandbank

INTRODUCTION

In these days when electronics is having such an impact on our lives, mostly by means of devices based on digital circuits using signals in binary form, it may seem surprising that broadcasting, one of the 'founder members' of the electronics industry, is still based essentially on analogue equipment. The relatively late arrival of digital techniques to television can be ascribed to three main factors:

(i) Semiconductor technology has only recently become available in a form compatible with the demanding requirements of television signal processing.

(ii) Analogue electronics are doing a good job in most areas of the broadcasting chain, namely the studios; the distribution networks; the transmitters and the receivers.

(iii) In broadcasting, change is inhibited by the need to be compatible with what has gone before and what is likely to come next.

Indeed, under these circumstances it is remarkable that the use of digital techniques in broadcasting is already quite extensive and increasing rapidly. This is because digital means are often the only practical and cost-effective way of providing some of the new electronic processes which enhance the production of programmes and have become an essential part of the art of television. In the near future, digital techniques will also become essential for bandwidth reduction in distribution and for domestic receiver enhancements. Eventually we will see digital signals in broadcast and recorded form replacing analogue as a means of delivering TV to the public.

The purpose of this chapter is to give the reader some background to the emergence of digital television. It should also help those who prefer to dip into the chapters for items of specific interest to find their way around the book. The subjects of the chapters are not dealt with in chronological order of the developments or in relation to their position in the TV production chain. The order has been chosen with the aim of treating as early as possible subjects which may provide useful background for the subsequent chapters.

PULSE CODE MODULATION (PCM)

Digital television has its roots in PCM which is now accepted throughout the world as the standard means of encoding signals for most modern communications systems. Although this rapid transition from analogue to digital communication has taken place in the relatively recent history of such techniques as microwave transmission or even satellites, it is interesting to note that its invention predates both by a long time. PCM was invented by Alec Reeves in 1937 but it was not until 30 years later that semiconductor devices became available which made PCM a viable proposition for encoding of speech signals. (It was during this period that the author had the good fortune to be able to count Alec Reeves among his close colleagues.) By the time technology made PCM attractive for extensive application to TV a total of 50 years had elapsed since its invention.

It is all the more remarkable that the very detailed description in Reeves' patent [1], published in the UK in 1939, was so far-sighted that it could serve as an accurate description of many of the concepts treated in this book. The aspects addressed in the patent range from quantisation and encoding to consideration of the noise and bandwidth characteristics of the transmission media right through to the relative merits of parallel and serial interfaces — a subject still giving rise to hot international debate in 1989!

The work of Reeves, though directly relevant to current digital TV systems, since it only required modern semiconductor devices to implement PCM as he described it, was motivated by the desire to solve the problems of voice transmission. It is therefore, in the context of this book, worth drawing attention to another much earlier patent granted to Rainey [2] in 1926 which proposed a means of scanning a picture for transmitting facsimiles or 'telephotography' by means of galvanometers, photocells and relays to produce 'a code combination of electrical impulses'. Although this patent is hardly relevant to the systems described in this book Rainey clearly envisaged the concept of encoding an image in digital form when he first filed his patent in 1921.

PCM is well dealt with in the literature [3]. Suffice it to say, at this stage, it provides a means of describing, or encoding, the continuous analogue waveform as a stream of binary numbers. In this form it is more suited for processing by modern electronic circuitry and more amenable to the application of techniques for efficient retention of essential information and minimising corruption by interfering signals (e.g. noise). To produce the PCM signal, the analogue waveform is first sampled periodically to determine its height at each sample time. The higher the sampling frequency the more accurate is this process and, in the limit, an infinite sampling frequency would describe the original waveform exactly. In practice, the waveform of the signal from, say, a TV camera contains a finite amount of information and there is no advantage in choosing a higher sampling frequency than required to convey this limited information to the accuracy required.

The second step in producing the PCM signal is to assign a numerical magnitude to the amplitude measured at each sample period. Again, if this were done with infinite accuracy, the original analogue waveform could eventually be recovered exactly. However, for the same reasons that an excessive sampling frequency is pointless, the precision with which the amplitude of each sample is described (or, in the language of PCM, the number of discrete levels chosen for the quantisation process) should not be higher than needed to convey the essential information about the image which the TV camera is capable of producing.

The processes of sampling and quantisation are described in Chapter 2 dealing with analogue-to-digital conversion. Having converted the original analogue TV signal into PCM, it is then in a form suitable for signal processing by semiconductor circuits which can now be fabricated as large-scale integrated (LSI) devices capable of carrying out complex functions at speeds commensurate with the high information rate of a TV signal. Of equal importance is the fact that the PCM signal facilitates the presentation of the signal in a form similar to that in which the data is processed and stored in a computer. This has enabled the sophisticated hardware developed for the Information Technology industry to be readily adapted for use in television systems.

THE STIMULUS TO USE DIGITAL TECHNIQUES

The need to provide some memory, which is essential for any basic signal processing, provided the strongest initial stimulus to the development of digital techniques. The requirement which first drew attention to this was the need to convert from one TV scanning standard to another. Before the days of video recording or satellites the normal means of international programme exchange was by the use of 16 mm or 35 mm film shot at 24 frames per second. There was thus no need for standards conversion as the film is speeded up slightly to 25 frames per second and scanned at the required transmission standard using the telecine techniques described in Chapter 10.

To a large extent film has remained the basic medium for worldwide programme distribution. However, for a long time there has been a need for scan conversion. It started with the original cross-channel microwave links connecting French and British TV in 1950 when the problem of exchanging programmes made with different scanning standards first emerged [4]. Here standards conversion was simply carried out by pointing a camera at a screen and relying on the inherent memory and integration times of the display and camera devices to perform the basic functions of interpolation described in Chapter 6. When exchange of programmes produced at 50 Hz/625 lines and 60 Hz/525 lines became possible in electronic form, the desirability to achieve electronic standards conversion became evident [5]. Figure 1.1 illustrates the technological difficulty of providing the required memory for a standards conversion before the availability of semiconductor storage in digital form. The device is a precision cut block of quartz with reflecting facets in which the TV signal travels back and forth as an ultrasonic beam until, after passing through 12 such blocks, it has traversed a path length equivalent in time to two fields of television!

The rapid progress made in the technology of semiconductor digital storage described in Chapter 3 is the main reason for the transition from analogue to digital television. It is interesting to note that ten years after the first use of the device in Figure 1.1, it was attractive to use digital semiconductor field stores even at a cost of £3K per field and requiring a power of over 200 W. Today, field stores are feasible using a few chips costing less than £10 and requiring a few milliwatts of power. Soon it may be possible to use three-dimensional solid state memory where the capacity will be measured not in fields, but in minutes of television.

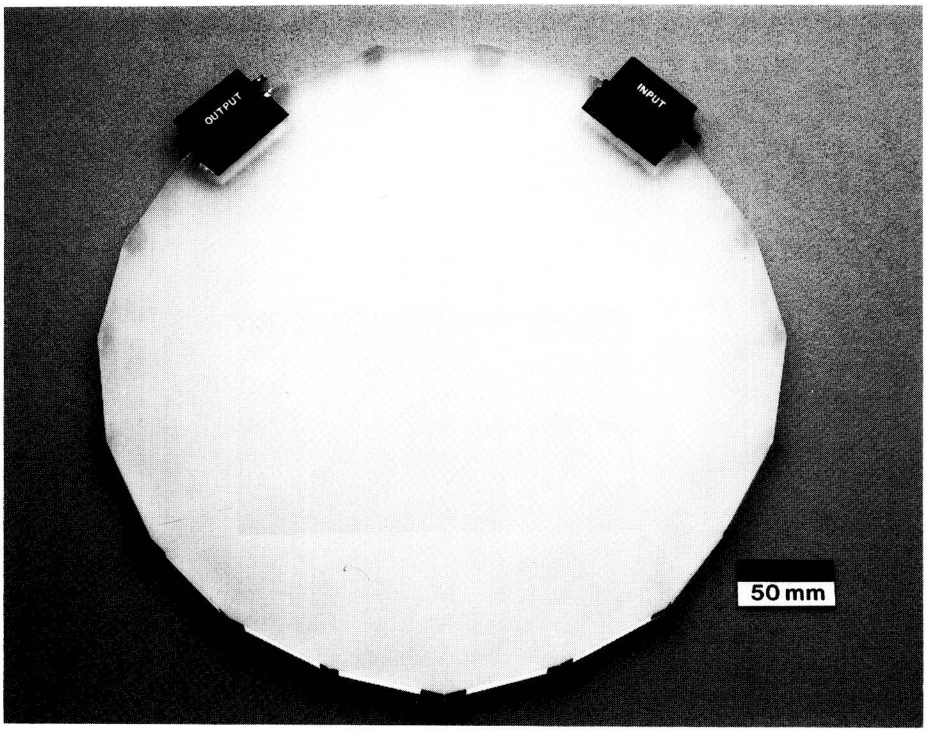

Figure 1.1 Quartz ultrasonic 3.3 ms delay line. It weighed 2.3 kg and 12 of these were used for the picture store in early standards converters

Initially the main application for delay was for timing correction. The two main requirements for this were firstly to correct for the timing imperfections introduced by slight variations in the speed of the tape past the play-back heads in the recorder, and secondly to enable signals arriving from different sources to be locked together in synchronism.

Quite soon after the simple applications of digital delays, more sophisticated digital signal processing techniques began to be introduced to television. A notable example was the use of the digital filtering methods discussed in Chapter 5 for noise reduction at the network output. Also at this time, digital communications were becoming established at bit rates sufficient for the transmission of TV by wide-band media such as optical fibres [6] and satellites [7]. This stimulated the development of digital encoding of TV for transmission, including bandwidth reduction methods, many of which are discussed in Chapter 13 and are only feasible by digital means.

By the end of the 1970s digital TV had become an essential part of production for operational reasons, some of which were mentioned above. The impact on programmes would not have been obvious to the public or even to producers. However, at this time the techniques were beginning to be applied to the art of programme making.

Initially, fairly basic use was made of memory. Producers with access to the stores in the synchronisers started 'grabbing' an occasional frame from the camera and holding it still to heighten dramatic effect. Then there was a combination of storage and image detection used, for instance, by 'teletrack' device [8] used to display the trajectory of objects, such that shown in Figure 1.2. This system detects the position of a moving object in any field by comparing the signal with a stored reference field (e.g. the empty snooker table). The difference represents one 'snapshot' of the moving object. If this is done several times as the object moves about on a stationary background these snapshots of the moving object can all be written into a store and finally superimposed on the original background for display.

Perhaps the digital equipment which first made a great visual impact was that which used a combination of the storage and interpolation processes described in Chapters 3 and 4 to achieve 'special video effects'. The TV industry had long been able to superimpose one image on another either by the traditional means of back projection or by analogue colour separation overlay (see Chapter 11 for an explanation of this process

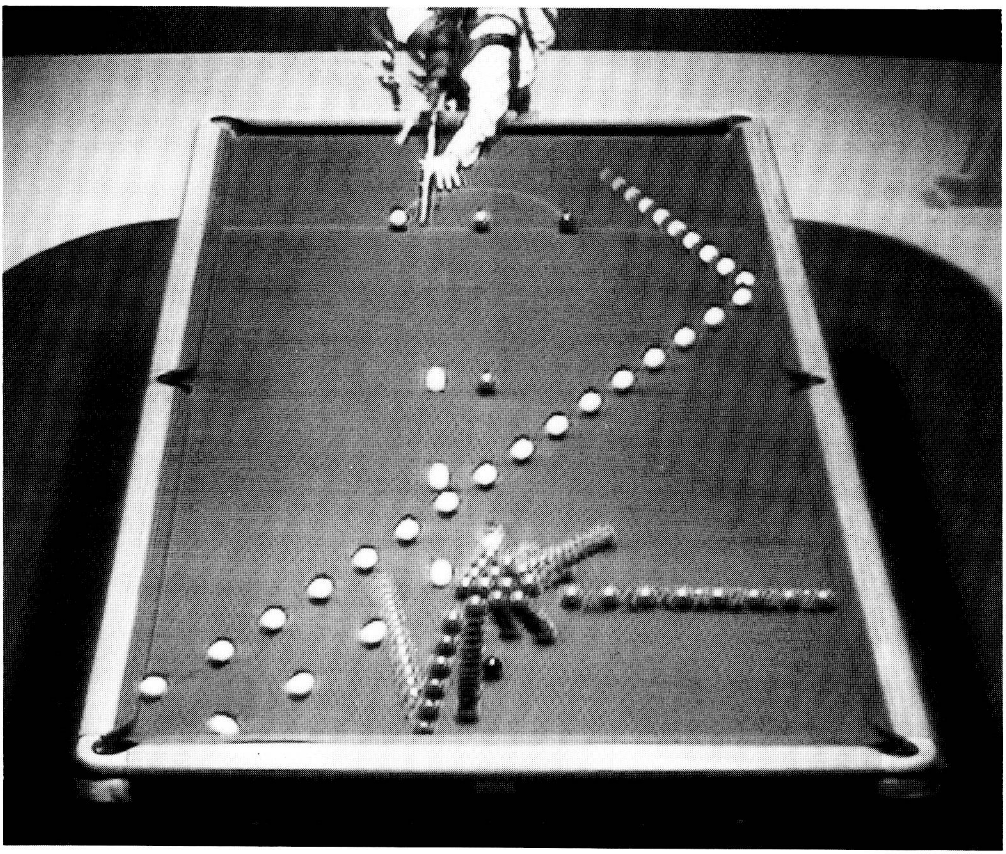

Figure 1.2 'Teletrack', one of the first special effects units to make use of solid state picture stores