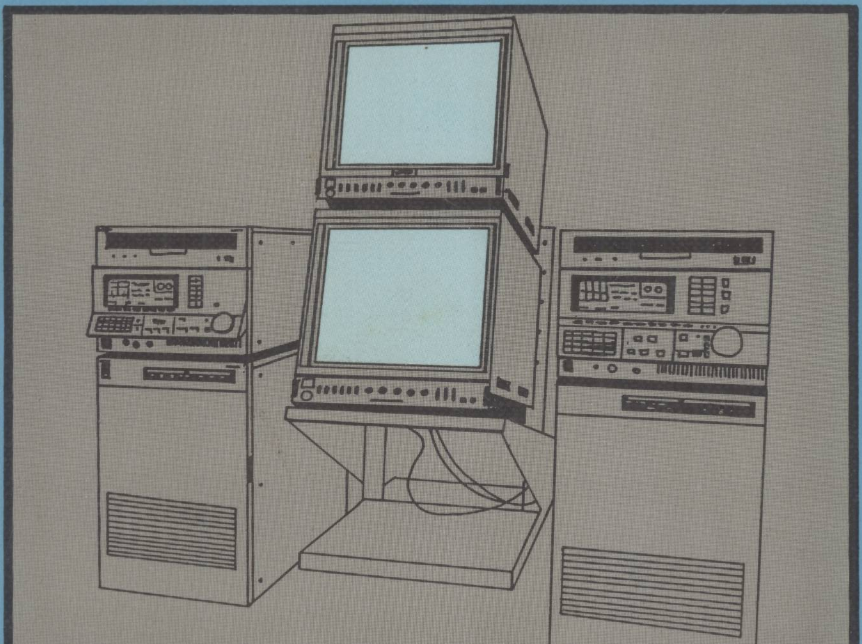
Introduction to the 4:2:2 Digital Video Tape Recorder



Stephen Gregory

Introduction to the 4:2:2 Digital Video Tape Recorder

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with contributions by
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PREFACE

This book has been written mainly for the engineer who will be using DVTR equipment. It is hoped, however, that it will be useful to those who are generally interested both in the overall DVTR format and in the way digital techniques are used in this application.

The book does not provide detailed circuit descriptions, and neither does it concentrate on any particular manufacturer's product, although in the last chapter an introduction is given to the world's first production 4:2:2 format DVTR – the Sony DVR-1000. Instead a wide-range of information is given including the data structure and interconnection method of the video and audio interfaces, the on-tape signal format, video and audio data processing and many other details concerning the internal operations which will need to be carried out by any 4:2:2 DVTR.

A good deal of the information is based on specifications published by the EBU, SMPTE and CCIR, the relevant ones are described in the text and in Appendix C. Since Sony Corporation in Japan and Sony Broadcast in the UK have, over the years, been deeply involved with the development of digital video tape recording, they have both played a large part, together with other manufacturers and broadcasters, in defining the relevant specifications. Thanks to a close association with the Sony designers, it has been possible to include background information in order to give, wherever possible, the reasons behind the choices made.

Although based on the EBU, SMPTE and CCIR specifications this book should not be regarded as a replacement for them. Such documents go through a continuous process of change and updating which is beyond the scope of a book such as this. It is expected and hoped, however, that the depth of treatment given to the subject matter will be sufficient both to quench the appetite for information of a general nature about the 4:2:2 DVTR and also to provide the necessary springboard for the engineer who will be going on to maintain or operate specific products.

Stephen Gregory

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* In 1987 the ITCA changed its name to the Independent Television Association, ITA.

FOREWORD

Digital television has been intensively studied by broadcasters and industry alike since the early 1960's. Very early on it was recognised that the need to record digital video and audio signals was the most significant factor necessary to ensure the widespread use of digital processing for professional television applications.

During the development of digital encoding standards for television signals it was possible, and indeed necessary, to consider in-depth the conflicting requirements for a digital standard in that it must provide an adequate subjective picture quality and yet enable the data to be practicably and economically recorded. This is in contrast to the earlier analogue situation where there was no opportunity to achieve an optimum solution for the video recorder because it had to be designed to cope with an already existing television signal.

On the other hand it is clear that, by its very nature, digital processing demands a more disciplined approach to system design needing many detailed parameters to be specified before equipment design is begun. One needs only to refer to the computer industry to recognise that many systems have been difficult to implement because of poor data compatibility and lack of a common interface between equipments.

Hence the development of the digital tape recorder has been carried out more or less in parallel with that for the encoding parameters and interface specifications for the digital video and the digital audio. Of most importance is that the ensuing standards have received wide international acceptance and ratification by the CCIR, the body responsible for the consolidation of broadcast engineering recommendations, to enable international programme exchange.

A unique feature of this work has been the collaboration between experts from the broadcast industry (the users) and manufacturing industry. The main standardizing bodies have been the European Broadcasting Union (EBU) and the Society of Motion Picture and Television Engineers (SMPTE) in the USA. In both cases these organizations formed specialist committees known, for the EBU by the acronym MAGNUM (MAGnetoscope NUMérique – the French term for a digital magnetic recorder), and for the SMPTE equivalent as the DTTR (Digital Television Tape Recording) Working Party. Also worthy of note is the remarkably close liaison between these two committees resulting in a joint approach to a unified standard that could be put to the 1986 CCIR Plenary Session.

During the development a major question was how radical should the proposals be? We are well aware how rapid progress in technology can make what appears to be extremely difficult to be almost trivial subsequently. Thus, one could search for an ambitious result to avoid early obsolescence, but equally many engineering failures have occurred simply because the technology was ahead of its time. In the generation of the standard for the digital video tape recorder great care was taken to see that forward projections were ambitious but realistic and not based on the principle that something might turn up.

On the other hand simple arithmetic demonstrated very much higher tape packing densities were needed than had ever been envisaged for analogue video tape recorders. To begin with, the total analogue bandwidth specified in CCIR Recommendation 601 for the component signals (comprising a luminance and two colour difference signals) is 13.5 MHz. This is approximately 2.5 times that needed for the PAL I composite signal. Additionally the user opinion expressed in the committees increasingly favoured a cassette recorder rather than an open-reel version. Maintaining equivalent tape packing densities to the one inch type C machines, would result in truly enormous cassettes, even if one ignores the extra overhead in the conversion to the digital form. It was known that increased density could be obtained, without loss of signal-to-noise ratio, by using narrower and, consequently, longer tracks. This in turn demands increased tracking accuracy. Reducing the tape thickness was also seen to be a means by which the size of cassettes may be reduced, but thinner tape requires more careful handling in the tape transport. These and many other interacting factors were central issues in the creation of the standard.

It is unfortunately traditional to assume that audio is treated almost as an afterthought in the design of analogue video tape recorders. Not so in the digital video tape recorder. It was quickly realised that audio quality which could stand comparison with that of the digital video was not likely to be achieved using conventional longitudinal tracks, at least in the foreseeable future. Digital techniques, however make it relatively simple to contemplate multiplexing the digital audio in with the digital video. For editing purposes the video and audio need to be recorded in separate bursts rather than interleaved together, but without losing the attractive feature of being able to use the same record and replay heads for both signals. Comparison of the relative sizes of the video and audio bursts to those of possible scratches and other tape damage led to the conclusion that the audio data should be given the most secure position on the tape. This resulted in the idea (at first sight rather strange) of recording the audio bursts in the centre of the tape.

The realisation of a digital video recorder is, therefore, so very different from its analogue counterpart, in spite of a superficially similar physical resemblance, that it is certain that a great deal of background information must be supplied to those who will experience the new recorders in their professional life. This book is provided as a contribution to the bridging of the gap between the informed expert and interested user and comes from people who have been closely involved in digital video tape recording in its formative years.

In concluding this Foreword, I must mention the names of both Aleksandar

Todorović and Frederick Remley who, via their skilful leadership of the respective EBU and SMPTE committees, were especially important in the creation of the 4:2:2 DVTR format standard. We, at Sony Broadcast, are especially indebted to them for the very valuable contributions they have made to this book.

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CONTENTS

INTRODUCTION – THE 4:2:2 DVTR TELEVISION RECORDING FORMAT: ORGANIZING THE WORK OF STANDARDIZATION

*by Frederick M. Remley, Jr.**

Let us take a moment to examine the structures and roles of the engineering committees that prepared standards for the 4:2:2 component digital video recording format. This format, also known as SMPTE Type D-1, is quite unlike any previous format; it was designed by combining the best ideas of many television experts from many places. As might be expected for work dealing with recording systems, the standardizing committees had some members who were expert in broadcast studio production and post-production practices and others expert in equipment design and manufacture. Important administrative factors leading to successful committee work included the co-ordination of effort and the sharing of results. In this instance, the effort devoted to standardizing the 4:2:2 format was achieved by the co-ordination and co-operation in technical work done by the European Broadcasting Union (EBU) groups in Europe and of the Society of Motion Picture and Television Engineers (SMPTE) engineering committees in North America.

The primary focus of this introduction will be on the functioning of the committee work. This may make it easier to appreciate some of the factors of the standardization process that have led to a 4:2:2 digital component recording standard and to the publication of this book, which serves to describe in detail the technology of the 4:2:2 system.

Active interest in the large scale application of digital technology to television studio facilities developed during the mid-1970s in Europe, North America and Japan. Chapter 1 of this book describes in detail the technical basis for the use of digital video techniques. It was recognized from the start that television recording must be an integral part of any new digital television production system. Accordingly, a time arrived for serious investigation of practical digital video recording systems.

In 1979 active study in the field of digital television recording was begun by the SMPTE when a New Technology Study Group on this subject was formed by the Engineering Vice President of the Society. At about the same time, the Technical Committee of the European Broadcasting Union

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appointed a Specialist Group of magnetic recording experts to study the matter. The EBU group was dubbed MAGNUM, an acronym derived, as noted elsewhere, from the French *MAGnetoscope NUMérique*. MAGNUM was given a very specific charter by the Technical Committee, a charter unique within EBU up to that time, that permitted technical experts from television equipment manufacturing companies to take a direct part in MAGNUM meetings. Of course, most MAGNUM members were delegates of European broadcasting organizations, just as most of the members of the SMPTE study group were potential broadcast users of digital recording equipment. Manufacturers have always participated in SMPTE work, and now the MAGNUM charter allowed full participation of manufacturer experts in the standards work. The EBU and SMPTE engineering groups, and ultimately the 4:2:2 specfication itself, benefited greatly from this direct access to the best technical advice of the equipment manufacturers.

MAGNUM and the SMPTE Group worked energetically in the late 1970s and early 1980s to investigate and discuss realistic attributes for future digital video recorders. The groups maintained close contact over the period by appointing joint members in the two committees – SMPTE members were appointed to MAGNUM and vice versa. Committee work focused very much on defining the parameters considered mandatory by users to allow digital recorders to be fully useful as studio production tools. As a matter of convenience, a general assumption was made that digital recorders should provide at least as much production flexibility as did contemporary analog recorders of the Type B and Type C designs, as well as to exhibit the unique performance improvements of digital technology described in Chapter 1.

By the summer of 1983 it became apparent that studies had progressed to a point where a standardized, universal, component digital video tape recorder format could quite probably be agreed. This seemed a realistic expectation because the CCIR had, ad interim, drafted and approved Recommendation 601, a specification for a universal, 525/60 and 625/50, component digital studio video signal format, applicable the world over. Shortly after the CCIR action on Recommendation 601 was affirmed, the SMPTE Study Group was reorganized into the Working Group on Digital Television Tape Recording (usually shortened to WG-DTTR) reporting to the Technology Committee on Video Recording and Reproduction (VRRT). This reorganization took place in January 1984 in Montreal, Canada. A shift away from *study* to *work* and a reaffirmation of the need to co-operate with MAGNUM were both part of the initial meeting of the new Working Group.

MAGNUM, for its part, continued to hold meetings every few months, to carefully review the work of its own members, and of the industry, and to consider the detailed reports of the work actively underway in the SMPTE WG-DTTR. Much of the work of MAGNUM was carried out in meetings of the committee-of-the-whole. However, subgroups having special expertise often convened separately for sessions separate from the main MAGNUM meetings.

On the SMPTE side of the Atlantic, the assignments of the Working Group were carried forward by a formation of several relatively small groups of users and technological specialists, termed Ad-Hoc Groups. The leaders of the Ad-Hoc groups subsequently reported the results of their work to formal gatherings of the WG-DTTR, meeting at intervals of about two months. MAGNUM received the progress reports immediately.

Ad-hoc groups were formed at various times for specification of mechanical transport parameters, video coding parameters, error detection and correction methods, audio and control track requirements, and the tape and cassette to be used. On occasion, the ad-hoc groups found it necessary to form their own ad-hoc groups, thus leading to the creation of 'ad-hoc-squared' groups focusing on very specific problems indeed! In addition, a Users Ad-hoc group was formed to assist in identifying operational requirements. This group produced a comprehensive set of User Requirements to be met by the evolving 4:2:2 format.

During the two years of most concentrated effort, dozens of meetings of the various ad-hoc and ad-hoc-squared groups were held in Europe, at MAGNUM meetings and during such gatherings as the Montreux Symposium or IBC, and in the United States, Canada and Japan.

As the work progressed, exchanges of documents between MAGNUM and WG-DTTR continued at an accelerated pace. Eventually, final documents were drafted, edited and prepared for submission to the EBU Technical Committee, the SMPTE VRRT Committee and the SMPTE Standards Committee. These unified documents served as contributions to the CCIR Interim Working Party 11D and finally to the Interim and Plenary Sessions of CCIR in 1986 and 1987. In October, 1987, documents identical to those submitted to CCIR were submitted to and processed by Technical Committee 60 of the International Electrotechnical Commission, and an IEC Publication will apply with full international authority to the 4:2:2 system.

These brief introductory comments do not do justice to the thousands of man-hours devoted to experimentation and designs of hardware and software that led to the 4:2:2 format. Tens of thousands of kilometres were travelled to and from Europe, Japan and North America by the WG-DTTR, MAGNUM, and Ad-hoc group members. MAGNUM convened many of its meetings in Brussels, but included many other cities in its venues, as well. Meetings of the WG-DTTR were held in Winchester, England (jointly with MAGNUM), New York, Chicago, Los Angeles, Las Vegas, Miami, San Jose, Redwood City, San Francisco, Toronto and Montreal. The ad-hoc groups met in a variety of other locations in Europe and Japan. The resulting format is generally judged to be fully worthy of the efforts expended.

It was determined through experience that the differing committee structures of the SMPTE and EBU organizations worked in a synergistic manner for this 4:2:2 project; some kinds of decisions were more effectively taken within the EBU procedural structure and others were decided following SMPTE committee practices. This interesting discovery proved a great advantage to the eventual success of the efforts, but tended to compound the problems of communication. The staff engineers of the EBU and SMPTE, and the liaison members of the committees, deserve great credit for expediting the flow of information at all times.

CHAPTER 1

4:2:2 DVTR – REQUIREMENTS AND FORMAT OVERVIEW

*by Aleksandar Todorović**

1.1 TOWARDS THE ALL-DIGITAL STUDIO

Over the past 40 years or so most of the technological advances in electronics have been made in the analogue domain. Recent work has, however, concentrated on improving digital technology especially in the fields of memory and processing circuitry. The advances in digital devices and techniques, developed mainly for the computer industry, have been introduced into television to bring major advances in digital control and processing. The use of digital signal processing in the broadcast television industry has been recognized as the opening of a new era.

It was clear from the outset that the digital approach would permit the creation of new and considerably more versatile production tools. The possibilities for creative programme making would be broadened and the quality of sound and picture would be dramatically improved.

To exploit this new technology to its maximum it is necessary to create and operate a totally digital studio, where the video signal is digitized immediately after the electro-optical conversion and kept in that form throughout the whole programme-making process. The final programme should be stored in digital form, and the digital-to-analogue conversion carried out at the input to the distribution network, or even at the input to the transmitter. In order to achieve this goal, two basic problems need to be solved:

(1) The precise definition of the nature of video and audio signals in their digital form, i.e. to define studio interface signals.
(2) The development of the necessary studio equipment.

It has taken almost 10 years to solve the first of these two problems. The correct definition of the goal and the attempts to reach it went in parallel with a rapid development of the technology. From the initial modest task of converting the composite colour video signal into a digital form in such a way as to obtain a sufficiently low bit-rate (to enable economical trans-

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