EBU CODE FOR THE SYNCHRONIZATION BETWEEN FILM CAMERAS AND AUDIO TAPE-RECORDERS

Tech. 3096-E Third edition -March 1985

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Historical note

The classical method of ensuring synchronism between motion-picture film and the accompanying sound, when the latter is recorded on a separate medium, is to use a clapper-board. Other systems have been used, involving a cable connection or a radio link between the camera and the sound recorder, but the operations could be simplified if the precise time when the exposure and the recording were taking place was to be recorded separately on both the film and the sound track since subsequently it would be necessary only to match up the timing information.

This document describes a time code which can be recorded on the film and the magnetic tape in a simple manner and which is so designed that the additional equipment required on portable cameras does not add significantly to their weight. This code has been established on the basis of research initiated by the Institut für Rundfunktechnik at Munich, the development of which was closely followed by Sub-group G3 of EBU Working Party G. Other Members of the EBU which are represented on the Sub-group, in particular the ORTF (now TDF), have carried out experiments and studies into the possibilities of the code.

The Sub-group first examined the general principles of the code and the method of recording it on motion-picture film and their unanimous recommendations were the subject of the first edition of document Tech. 3096. This third edition contains supplementary chapters which give the results of the TDF and IRT studies into the design of methods of recording the code on magnetic media, as well as methods of setting the time-code generators by means of a master clock. Two different solutions for each of these problems have been developed and have been demonstrated to the complete satisfaction of Sub-group G3.

Introduction

Conventional methods of making films with synchronized sound, particularly when operating in locations external to studios, involve the use of 6.25-mm magnetic tape with some means whereby the sound recording may subsequently be transferred to a sprocketed COMOPT, COMMAG or SEPMAG track. There are a number of proprietary systems for achieving synchronism between the picture film and the sound recording, most of which rely upon a cable connection or a radio link between the camera and the sound recorder to convey information concerning the rate at which pictures are being recorded. These are described in EBU document Tech. 3095*[*]. Synchronizing marks are recorded along with the sound and are later used to control the sound transfer to sprocketed magnetic film.

Synchronizing systems of the type described are in widespread use and function very satisfactorily. It is usual to include some method of marking the start of each synchronized recording either by the familiar "clapper board" or by means of some lamp system which marks the film and at the same time records a distinguishing tone on the sound recording. In this way both the frequency and the phase of the picture and sound recordings become controllable. However, the disadvantages of filming with a cable connection between the camera and the sound recorder are fairly obvious and there are problems with radio-link systems where more than one camera is to be operated in connection with a single sound recording.

It is now possible to design crystal-controlled motor systems which will operate independently of any external synchronizing signal to an accuracy of one frame over a period of several hours and if, therefore, the camera and the sound recorder are independently driven by such motors. then the frame frequency of the picture and the sound recording will be correctly related without any interconnection between the two. It remains necessary to provide identification of the moment at which any particular picture recording and sound recording should simultaneously begin.

[*] Review of existing systems for the synchronisation between film cameras and audio tape recorders. EBU document Tech. 3095-E. February 1973.

If a unique time code is recorded on the film in the camera to indicate the start of each separate second and if the same time code is simultaneously recorded on the magnetic tape of the sound recorder, subsequent picture-sound synchronization can be achieved simply by matching the time codes on the film and the tape. synchronization marks will always be found within a distance of 12 frames from any given editing point. If sufficiently stable generators are used in the cameras and the sound recorder, and if they are synchronized before the start of a day's shooting, then no other synchronizing connection of any kind is needed between the cameras and the sound recorder.

The presence of a time code on both film and tape enables the automation of certain production operations to be envisaged, such as the synchronization of rushes and the work of assembling sequences in order before the editing proper. Relatively inexpensive equipment could be designed which would automatically synchronize the sound and the picture tracks or would search for a pre-determined point in the recordings using only the coded time information. This coding system would also enable several cameras to be used in synchronism with a single sound recording. This list is not exhaustive, however, and other applications of this system to facilitate production operations are possible.

A time code suitable for use in filming and the system of recording that code on 16-mm cinefilm have been standardized by the EBU. The attention of the manufacturers is drawn to the two methods of modulation and systems of recording proposed here which meet the fundamental requirements established by the EBU for the recording of the code on magnetic tapes and films (6.25-mm tape and l6-mm film).

CHAPTER 1
Principle of the time code

The use of digital time codes has already been proposed for magnetic video tapes to assist in synchronization, in the search for a particular programme item and in editing, but the number of bits per frame is such that these codes could not be used for motion-picture films since an extremely complex optical recording device would be required in the camera.

It is felt that four readily-available light-emitting diodes could easily be installed within the height of a single film frame, whatever the film format likely to be used (including Super 8); in consequence, a suitable bit-rate for the time code would be 96 or 100 bits per second, depending on whether the film runs at 24 or 25 frames per second.

It is considered to be important that the film-marking system should be decipherable by eye as well as by various code-reading devices associated with editing and synchronization. For this reason the binary-coded decimal system has been chosen, so that one decimal digit fits into one film frame. In film formats where there is one sprocket hole per frame, the perforation will provide a visual reference for the position of each bit in a group of four.

1. Recorded time information

The time information marking on the film and on the magnetic media will be recorded once per second and consists of a synchronizing mark indicating the start of the second, followed by a coded "real time" recording, covering twelve months (10 decimal digits, two for each number, indicating second, minute, hour, day, month). In comparison with an elapsed time recording, the real time recording has the advantage that no additional coded information (e.g. slate or take number) needing a special generator is necessary at the coder. A fixed coding network for the identification of the camera could easily be added.

Each camera and sound recorder belonging to a film crew must be provided with a separate time-code generator, which should remain in synchronism during the whole period of shooting. It may be noted that a stability of one part in 10^6 would allow synchronism to within one frame over a period of 10 hours. Thus all the time-code generators belonging to a film team, after having been synchronized together, will remain in good synchronism for the duration of a shooting day.

The synchronization of the time-code generators is carried out by a master clock. This device is set approximately to local time read from, for example, a wrist-watch and is then used to transfer identical time information to the various code-generators used by the film crew. This time-setting of the code generators can be done either simultaneously or sequentially; in the latter case the master clock operates as a time-keeper. It can be equipped with a display unit and thus can be used to note sequence timings.

2. Additional recorded information

As the synchronizing mark occupies three frames only and the time code occupies ten frames. eleven or twelve frames in each period of one second (depending on whether the camera is running at 24 or 25 frames per second) are available for the recording of supplementary data.

Unlike the information concerning the month, day, hour, minute and second transmitted to the code generator from the master clock, the additional information referred to above would require preset adjustments on the code generators. Indication of the year could, however, be transmitted from the master clock.

The EBU considers that the timing information would suffice in most cases and has decided not to recommend that additional recorded information be mandatory, although the opinion has been expressed that a fixed pre-wired coding network to code the camera number (3 or 4 digits) could easily be built into each camera to facilitate later production operations. It has also been suggested that, where necessary, the last two figures of the year could be recorded and that space should be reserved for this purpose immediately following the time code.

3. Start/stop information

The condition when the camera drive is running up to speed but has not yet reached synchronism with the code generator should be indicated by exposing the film by activating all four light-emitting diodes simultaneously for at least three frames. This information could also be used to recognize or to search for the beginning of new takes. A similar arrangement might possibly be adopted for the sound recording.

CHAPTER 2
Specification of the time code

1. Nature of the code

The code used is a binary-coded decimal code in which each decimal digit (0 to 9) is represented by a group of four binary symbols (0 to 1), called a binary group.

The conversion table is the following:

Decimal	*Binary-coded decimal*	*Decimal*	*Binary-coded decimal*
0	0000	5	0101
1	0001	6	0110
2	0010	7	0111
3	0011	8	1000
4	0100	9	1001

Numbers higher than 9 may be represented in binary form using this coding system but, with the exception of the synchronizing word (see 5), the corresponding groups will not be used.

2. Sense of writing the code

When the medium upon which the code is written is arranged so as to travel from left to right, the four binary symbols constituting a number are written from right to left in the order of increasing significance.

3. Code word

All the coded information will be recorded once per second and constitute one word of the code.

4. Bit-rate

The bit-rate depends on the shooting speed and has been fixed at four bits per frame.

This corresponds to:

100 bits per second	for 25 frames/second shooting,
96 bits per second	for 24 frames/second shooting.

5. Content of the code word

When the medium upon which the code is written is arranged so as to travel from left to right, and the binary groups are numbered from 1 to 25 (or from 1 to 24) from the beginning of a second, then the following items of information will be found in each code word, reading from right to left (Fig. 1) :

a) Synchronizing word

The synchronizing word which also, on reproduction, enables the direction of travel to be determined, occupies binary groups Nos. 1 to 3.

The structure of the synchronizing word is the following:

Binary group numbers	3	2	
Structure of the word	1011	1111	1100
to be read as	(11)	(15)	(12)

b) Real time

The time information consists of two digits for each of the indications of second, minute, hour, day and month, in that order.

The real time occupies the binary groups Nos. 4 to 13, the seconds occupying the binary groups Nos. 4 and 5. The odd-numbered groups contain the tens and the even-numbered groups contain the units.

It should be noted that the year is not considered to be "real time".

c) Additional information

It has been agreed that binary groups Nos. 14 and 15 should be reserved with priority for the optional recording of the last two figures of the year. Similarly, binary groups Nos. 16 to 18 should be reserved with priority for the recording of a number identifying the equipment in use.

Other additional information which would occupy binary groups Nos. 19 to 22 is not subject to any particular specifications. The binary groups Nos. 23 to 25 must not be occupied by any coded information.

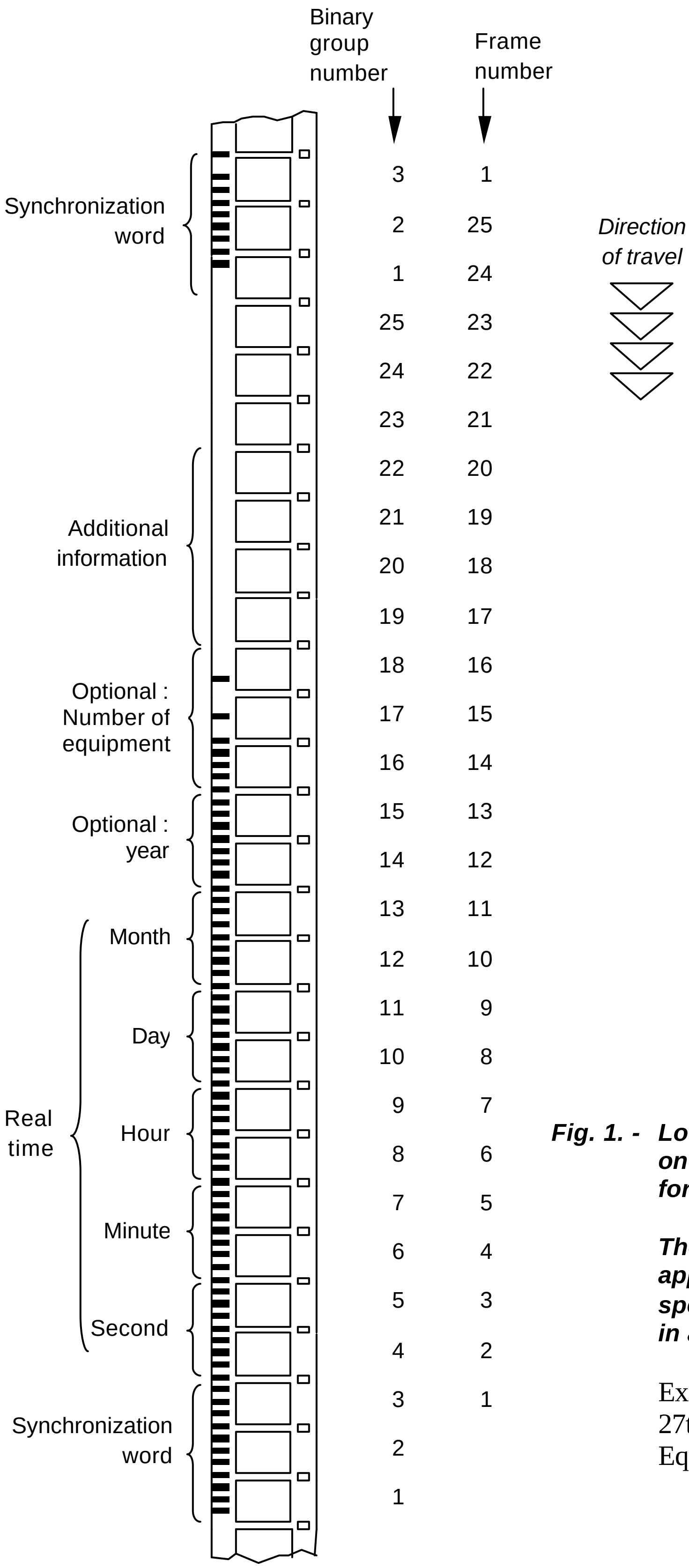

Fig. 1. - Location of the binary groups on 16-mm motion-picture film, for 25 frames/second.

The drawing also shows the application of the preceding specification to the 16-mm film in accordance with Chapter 4.

Example of coding :
27th January, 1981, 14h53min26s
Equipment No.121

CHAPTER 3
Recording of the time code on the picture film

1. Method of recording

Four bits per frame will be marked on the picture film by exposing it by means of four solid-state lamps. This exposure will take place during the period when the film is stationary in the gate, except for the camera start and stop information which is exposed on at least three frames during the period of synchronous running to indicate the start of a new take.

2. Positioning of the recorded time code

The time-code information could be recorded on the film on either side of the picture area but the relative advantages and disadvantages of each position must be carefully weighed before a decision is taken. So far, the EBU has decided on the position for the 16-mm format only.

In this format, the only practicable position is to place it on the side normally reserved for an optical sound track. The only other possible area between the sprocket holes would leave the whole of the useful area of the film intact but this is already used for latent-image edge numbers and other information recorded by the film-stock manufacturer. There is also a danger that the time-code information could be lost in the first layers of film in a daylight-loading spool due to edge-fogging through the sprocket holes. Moreover it would be difficult to install an automatic reading device in current editing tables to operate on the sprocket-hole side of the film.

The position of the time-code information with respect to the frame to which it corresponds has also been standardized for the l6-mm format. For mechanical reasons connected with several types of existing cameras. it has been decided that the exposure will take place two frames below the film gate in the camera. If mechanical considerations affecting camera design make it necessary to vary this position, the code generator will introduce the corresponding correction.

For other film formats, the position occupied by the time-code markings can be decided later.

CHAPTER 4
Recording specifications for 16.mm motion picture film

1. Position of the code

The code is recorded in the area intended for the optical sound track.

2. Position of binary groups

The device that records the time code is placed two frames ahead in time of the film gate. Fig. 2a shows the resulting position.

3. Dimension of binary digits

Each binary group is written within one frame and the limits are com- patible with the use of double-perforated stock.

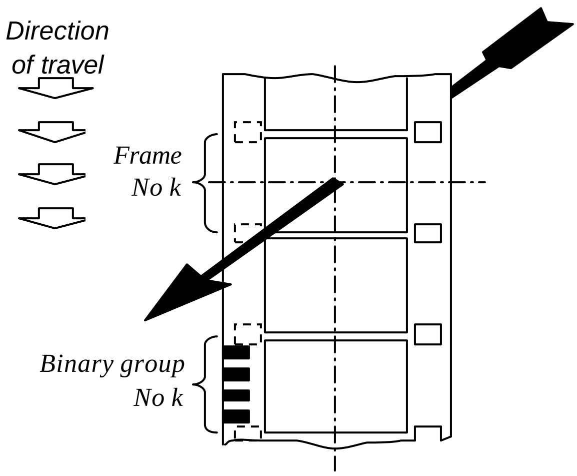

Fig. 2a. - Position of binary groups with respect to the corresponding frames

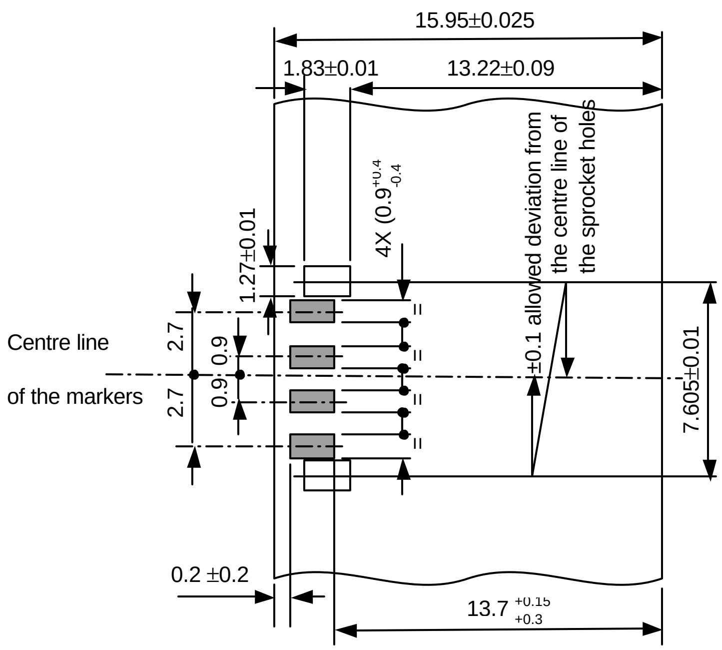

Fig. 2b.- Dimensions, in millimetres, of the binary digits recorded on 16-mm film

Fig. 2b shows the detailed dimensions of the binary digits and of their separation. These dimensions refer to the digits as recorded on the film; the relatively large tolerances specified for the external dimensions of each digit are intended to take account of the fact that in certain films there is an inevitable spread of the picture outside the aperture formed by the film gate.

4. Density of binary digits

Whatever the type of film used when shooting, the binary symbol 1 will be obtained by exposing the film by appropriate illumination and binary symbol 0 will be indicated by the absence of exposure. The difference of density between these two symbols must be ≥ 0.8 measured with a filter combination V_{λ} + Wratten No. 16.

CHAPTER 5
Magnetic recording of the time code

1. General requirements

The time code which is recorded simultaneously on the cinefilm and on the accompanying 6.25-mm sound tape can be recopied onto 16-mm magnetic film to facilitate subsequent production operations. Both recordings should meet the following fundamental requirements.

1.1. Bit sequence

The time code should be recorded in binary-coded decimal form in the same order as that specified for the cinefilm. The 100 (or 96) bits are transmitted sequentially in order of increasing significance, the bit-repetition rate being loo Hz (or 96 Hz).

1.2. Code-clocking

The code should be self-clocking, both on magnetic tape and magnetic film; in other words, it should be possible for the decoder to derive the clock pulses from the code. It should be noted that the sprocket holes on a magnetic film cannot be used as clock pulses for the start of each binary group; there is no relation between the position of the perforations and the position of the recorded pulses since in a magnetic film recorder there is no precise relation between the drum-controlled mechanism and the recording heads.

1.3. Cross-talk

Cross-talk from the code signal should be inaudible in the programme channel during reproduction.

Cross-talk from the programme channel on the code channel should be such as to guarantee a bit error-rate of 10^{-5} at speeds at which reliable operation is required.

1.4. Reproduction of the code

It is necessary to be able to decode the recorded information in whatever sense the heads are connected

1.5. Reliability

Reproduction from magnetic tape and magnetic film should be reliable (bit error rate < 10^{-5}) even at speeds other than normal speed. At the transfer bench the maximum speed to be considered should be 250 frames/second. Lower speeds than normal are desirable but not essential. At the editing table the minimum speed to be considered should be 3 frames/second and the maximum should be 150 frames/second.

2. Track format

On magnetic tape, the code is recorded on a central track. The width of this track should be at least 0.40 mm and the width of each guard band should be at least 0.7 mm.

Fig. 3 shows the position of the tracks as recorded. Track C is used for the recording of the code; tracks A and B are used for programme signals.

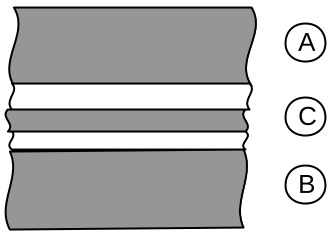

Fig. 3. -Track assignment on the sound tape A and B: programme, C: time code

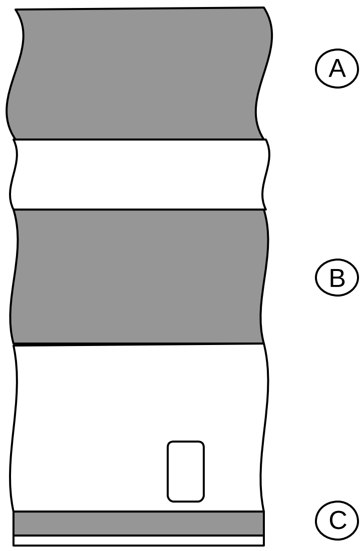

Fig.4. - Track assignment on the sound magnetic film A and B: programme C: time code

On magnetic film, the code is recorded on the control track as specified in Fig. 2 of CCIR Recommendation 265-4. The width of this track should be 0.7 mm.

Fig. 4 shows the position of the tracks as recorded.

The fundamental requirements enumerated above are, in general, satisfied by two methods of modulation; the description of these methods follows.

The method employing pulse-polarity modulation was developed by the Institut für Rundfunktechnik (IRT), at Munich.

The method using differential phase-shift keying was developed by Télédiffusion de France (TDF), at Paris.

3. Pulse-polarity modulation method (PPM)

3.1. Type .of modulation

The recorded signal (the magnetic flux) is produced by modulation of the polarity of pulses of recording current. A binary "1" is represented by positive pulse polarity and binary "0" by negative pulse polarity.

The pulses are of sine-squared form and have a half-amplitude duration of 0.5 ms for magnetic tape and 1 ms for magnetic film. The pulse-repetition rate is equal to the bit rate (100 Hz or 96 Hz).

3.2. Recording on magnetic tape

The PPM signal is recorded with a peak magnetic flux of 900 nWb/m of track width, with bias. The tolerance for the recording level is ± 2 dB.

3.3. Recording on magnetic film

The PPM signal is recorded with a peak magnetic flux of 900 nWb/m of track width, with bias. The tolerance for the recording level is ± 2 dB. The recording current must be adjustable continuously up to the peak value.

3.4. Relative position of the code and the programme signals

Special facilities are incorporated in the editing table to compensate for the separation introduced between the code and the programme signals by

- -the film camera,
- -the audio tape-recorder,
- -the audio tape-replay machine

4. Differential phase-shift keying method (DPSK)

4.1. Type of modulation

The recorded signal is produced by two-state differential phase modulation.

The carrier is a square wave, the frequency of which is twice the bit rate (200 Hz or 192 Hz). The start of each bit coincides with the time at which the carrier passes through zero.

The modulated signal is obtained from the carrier by inverting the phase of the transmitted signal whenever a bit equal to zero occurs (Fig. 5).

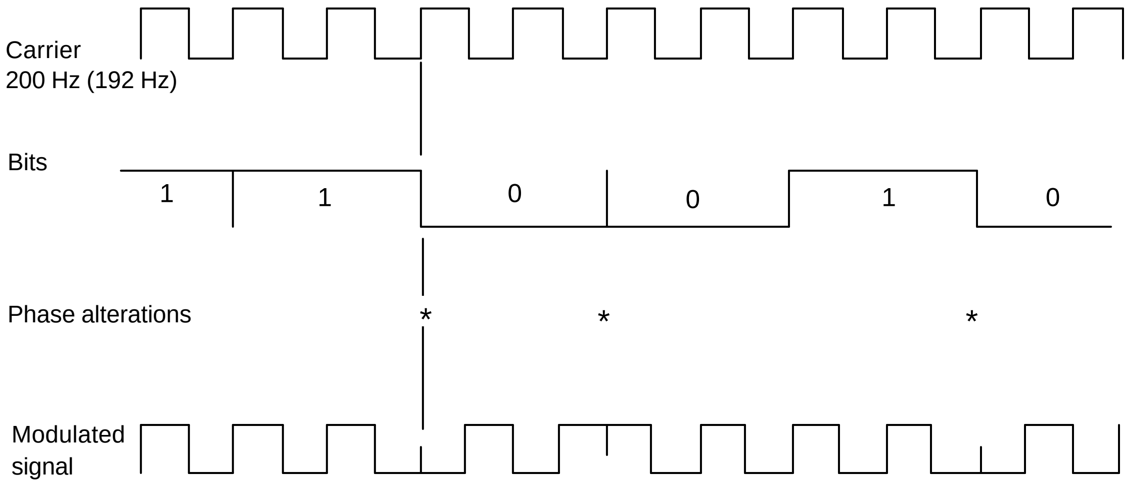

Fig. 5. - Principle of the differential phase-shift keying method

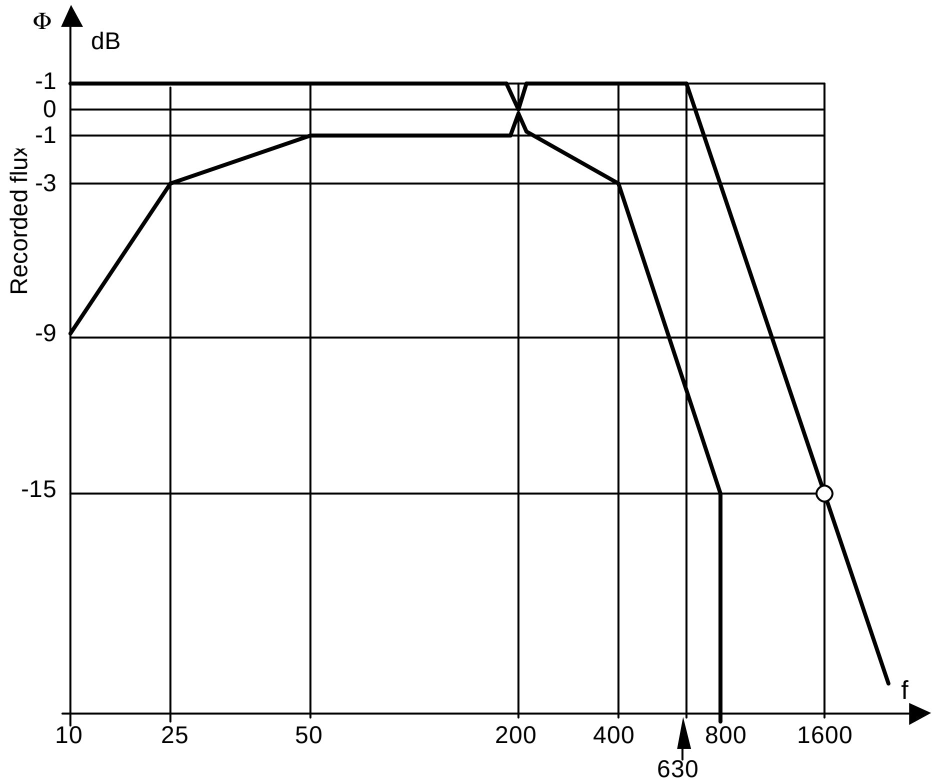

Fig. 6.. Template of the recording characteristic

4.2. Recording on magnetic tape

The DPSK signal is recorded with an RMS magnetic flux of 40 nWb/m of track width, with bias. The tolerance for the recording level is ± 2 dB.

The overall response curve of the recording chain following the modulator as defined above must lie within the values specified by the template shown in Fig. 6.

4.3. Recording on magnetic film

The recording level should be at least 800 nWb/m of track width. It is recommended that bias be used.

The waveform of the recording current should be such that, during reproduction at normal speed, the rise-time of the flux induced in a narrow-gap replay head should be less than 0.3 ms. This rise-time is defined in Fig. 7.

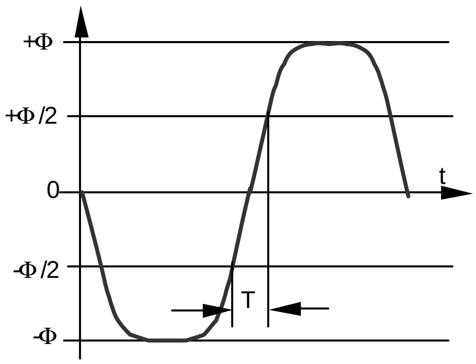

Fig. 7. - Definition of rise-time T

4.4. Relative position of the code and the programme signals

The relative position of the code and programme signals on the 16-mm magnetic film should be that that would be obtained with a direct recording on this medium using head gaps aligned for the different signals.

At the time of transfer, it is therefore necessary to compensate for the separation introduced between the code and programme signals by the relative positions of:

- the record heads in the 6.25-mm audio tape-recorder,
- the replay heads in the 6.25-mm audio tape-replay machine,
- the record heads in the 16-mm magnetic-film recorder.

CHAPTER 6
Presetting the code generators

Apart from the characteristics imposed by the definition of the code word itself, the code generator must be standardised in relation to:

- The signal from the master clock used to set the coder timing,
- The method of changing the date

The first point specifies the arrangements that enable all the code generators used by a film crew to be synchronized to the same master clock. Two methods of doing this have been developed.

- *The first method (presetting by counting) has been designed by the Institut für Rundfunktechnik (IRT), at Munich., the second, (presetting by coded time transmission) by Télédiffusion de France (TDF), at Paris.*

As for the second point, the calendar is not automatically changed in the coders at midnight and the hours counter continues to count beyond 23.59.59 until it is reset by the master clock, or until 39.59.59 when it is automatically reset.

1. Presetting by counting

In this method the code generators are set by a binary signal defined as follows:

- The forty-eight bits of time information (seconds, minutes, hours, days, months and year) are transmitted by two successive groups of pulses over a coaxial cable. One group sets the time, the other the date.

- The number of pulses in the first group should correspond to the time expressed in seconds. The number of pulses in the second group should correspond to the decimal number obtained by taking, successively, the number of the month, of the day and of the year (thus, 12th June, 1975 is set by 061275 pulses). When the year is not coded the last two figures in the number of pulses must be zeros.

- The two groups of pulses are preceded by a reset pulse, the leading edge of which sets the counters in the code generators to zero. The trailing edge corresponds to the seconds transition in the master clock. The duration of the reset pulse should be at least 0.02 second.

- The pulses to set the coder clocks are produced within the 0.35 second following the trailing edge of the reset pulse, taking into account a time interval of at least 0.01 second between the trailing edge and the start of this pulse train. The pulses to set the calendar should be produced within the period between 0.55 and 0.95 second. The interval between 0.35 and 0.55 second should be left free. The frequency of pulses of the two groups should lie between 310 and 550 kHz (the pulses not representing independent binary data).

- The pulses should be of positive polarity and have an amplitude between 4 and 7 V, taking into account a load of 800 Ω .

- The information in binary groups Nos. 16 to 22 is not transmitted from the master clock; it must be entered directly at the time code generators.

- -The relative frequency drift of the time base in the code generators as well as in the master clock should be (i 1.3 in 106 within a temperature range from -10°C to + 40°C. Master clocks that can be preset by a slave clock may have a stability of ≤ ± 5 in 106.

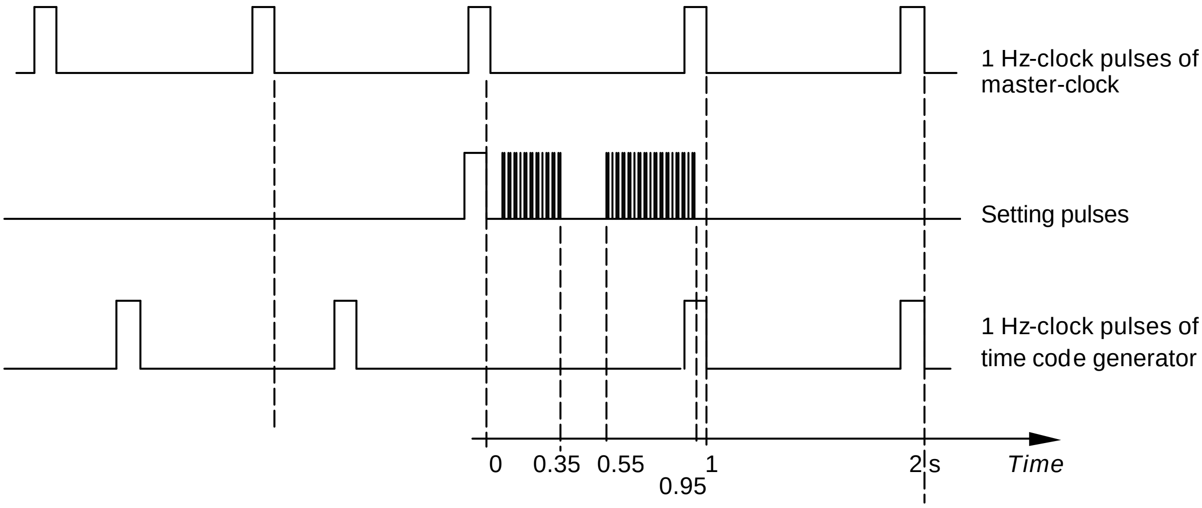

Fig. 8. - Arrangement of the pulses used to set the clock in the counting method

2. Presetting by coded time transmission

The code generators are set in the following way:

- Each second, the master clock produces a train of 2400 bits of equal duration by repeating 50 times, in the order of increasing weight, the 40 bits of standardized time information (seconds,. Minutes, hours, days and months), followed by eight bits which may either be zero or may represent the last two figures of the year.

- The signal transmitted to the code generator is obtained from the previous signal by replacing the last eight bits by a reset pulse, consisting of a negative pulse with a duration of 1/2400 second, which identifies the end of the second (Fig. 9).
- The signal is transmitted via a coaxial cable; the central conductor is at zero potential during the transmission of binary-zero bits, has a positive potential during the transmission of binary-one bits and has a negative potential during the transmission of the reset pulse.
- Connection to the code generator is made by a jack.
- The input impedance of the code generator must be not less than 10 kΩ. The amplitude of the positive and negative pulses transmitted to the code generator must lie between 3 and 15 V.

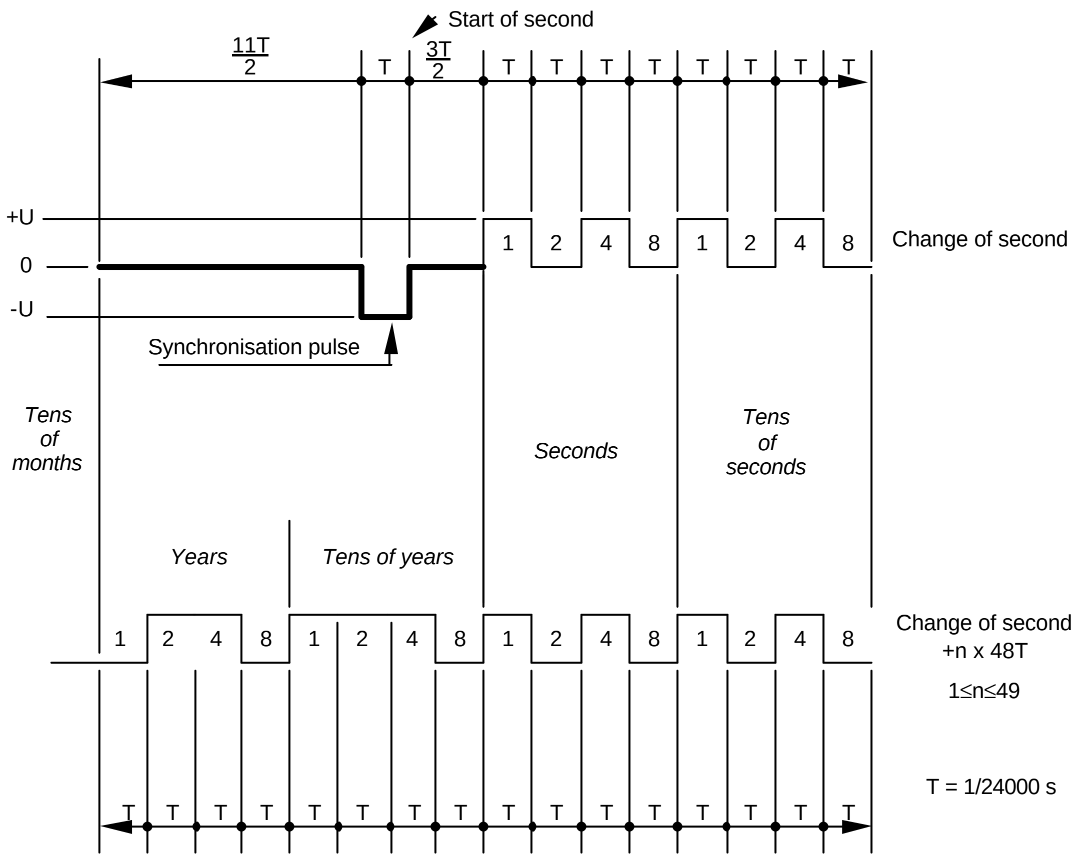

Fig. 9. - Arrangement of the pulses used to set the clock in the coded time transmission method

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D/1985/0299/223

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