Tripal

A transmission format for analogue colour television signals

by Dr.-Ing. Ernst F. Schröder

Prologue

In May 1970, I started my professional career as a development engineer in the Basic Development Laboratory at Telefunken in Hannover. One of my tasks there was to support presentations on colour television technology, namely the PAL colour TV system. These "PAL demonstrations" were regularly held for various groups of visitors by Professor Walter Bruch, the head of Basic Development Laboratory.

In the building rented by Telefunken in Hannover in Vahrenwalder Strasse, there was a large "demonstration room" with television monitors and other technical equipment, as well as several rows of chairs. To the side were tables with a few black-and-white video recorders on them. These were the standard devices of the time, with 1/2-inch wide magnetic tapes, open reels and helical-track recording with FM modulation. As far as I can remember, they were from JVC, Panasonic, Philips and Sony.

These devices had been prepared by the engineers at the Basic Development Laboratory some time before I arrived, so that they could be used to record and play colour television signals. Towards the end of a demonstration of the advantages of PAL, these video recorders and their colour signals were typically shown. The pre-recorded sequences usually consisted - as in the PAL demonstrations - of the standard colour bar signal, some test slides and finally one or more short films. I particularly remember a film entitled "Palettes of Fashion", which had obviously been produced with particularly intense colour effects.

When preparing for a planned technical demonstration in front of guests, all the equipment was always extensively tested and adjusted. I still remember the high quality of colour video reproduction from these simple video recorders. However, I always noticed that on one or two of these devices the colour reproduction of the colour bar test signal was slightly different. The vertical green bar in particular was somehow darker and not as brilliant as on the other devices, and there was obviously less noise in the picture.

Naturally, I asked my mentor and colleague at the time, Hans-Juergen Kluth, about it. I was told that the colour signal on almost all devices was recorded using the so-called "colour-under" process, but that these conspicuous ones were using the "Tripal" process.

This didn't mean anything to me at first, but I sat down and tried to find out the technical details of this answer.

This was rather simple for "colour-under": It was simply not possible to record the original PAL colour television signal with a signal bandwidth of around 5 MHz on these video recorders. Due to the limited bandwidth of these video recorders, which had only around 3 MHz, there would be a complete loss of colour information. Therefore, the colour signal was first separated from the composite colour television signal, i.e. the frequency range around the colour subcarrier (4.43 MHz) was brought into a lower frequency range (approx. 0.5...1.5 MHz) by downmixing. This signal was then recorded additionally and below the spectrum (hence "colour-under") of the black and white signal recorded as an FM signal on the video tape. The constant carrier frequency for the mixer was generated by synchronization as certain multiples of the line frequency. Playback works the other way round. There are no special secrets to understand here. The later VHS video recorders also worked according to this principle.

With "Tripal" this was different ... and its history goes back to at least 1960.

Prehistory

On 28 January 1960, Telefunken Patent Department filed an application with the German Patent Office for an invention by Walter Bruch, which was later granted under DE1126443 [1]:

A video signal with a bandwidth that is too high for tape recording, is divided into two narrower frequency ranges, which are recorded sequentially, i.e. in line-by-line time-division multiplex, and after appropriate frequency transposition. During playback, only one signal with half the frequency bandwidth is available in each line; the missing signal parts are provided by delay devices (cable, ultrasound) with a one-line delay.

A little later, on 7 March 1960, Sony filed an invention in Japan, which was later also granted in England under GB952487 [2]. Here, a colour signal is recorded by alternately recording the luminance signal Y and a chrominance signal consisting of I and Q, line by line. During playback, a one-line delay is also used to recover a continuous signal.

On January 3 1963, Walter Bruch presented the PAL colour television process, for which a patent application had been filed by Telefunken in December 1962, to experts from the EBU. This process subsequently became the standard for wireless transmission of colour television signals in many countries. Characteristic and important for this process is, among other things, that a delay device is necessary to realize the reception circuits. A delay device that allows for a signal delay of exactly one line of the television picture. This delay was established with the help of a piezoelectric and ultrasonic device made of glass.

Apparently, after his success with PAL, Walter Bruch continued to work on a solution for recording colour signals on simple video recorders. Thanks to the PAL system, delay devices for exactly one television line were now available. Finally, on 9 April 1966, Telefunken filed an application for an invention by Walter Bruch, which was granted under DE1256686 [3]. This invention can be described as the "Original Tripal", and it uses two of these delay devices.

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Original Tripal

Figure 1 shows how the separate colour signals R, G and B, coming from a colour camera or an image scanner, are selected line-by-line in multiplex switch (4) and then recorded sequentially on the (black and white) video recorder (7). During playback, the sequential signals are de-multiplexed with three multiplex switches (13, 14, 15). Three simultaneous colour signals R, G, and B are recovered. In each recovered line, one of the three colour signals is directly available (8) with the full bandwidth of the tape recorder, typically 2.5 … 3 MHz. The other two colour signals (11, 12) are each provided by two delay elements (9, 10). These delay elements are typically designed to have a lower bandwidth of about 500 kHz.

It was obviously clear to the inventor that with the steps described the basic problem of colour signal recording on simple video recorders had not yet been satisfactorily solved. Various sub-claims do reveal approaches for possible improvements.

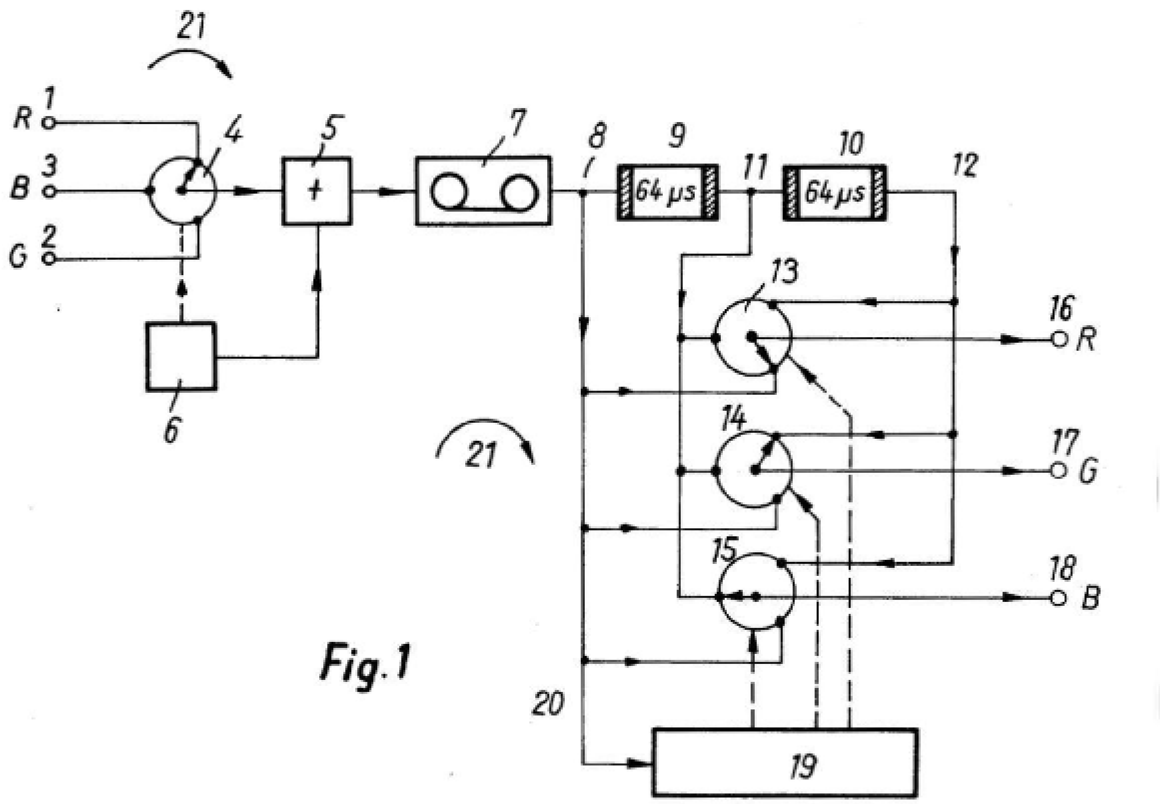

Figure 1: Signal processing in the Original TriPal, Fig. 1 from DE1256686 [3]

This idea was certainly built and tested in hardware at the time. Slide and film scanners with RGB output and monitors with RGB input were available in the laboratory. And the ultrasonic delay device was now a standard component in television receivers designed for the PAL system.

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To estimate the expected quality of the described process, a software simulation was carried out. A suitable colour test image was tri-sequentially encoded according to the specifications in Figure 1, limited to a bandwidth of approximately 3 MHz of the recording device (7) and then decoded according to Figure 1. A bandwidth of 500 kHz was assumed for the two delay lines (9, 10). Figure 2 shows an enlarged section of the result.

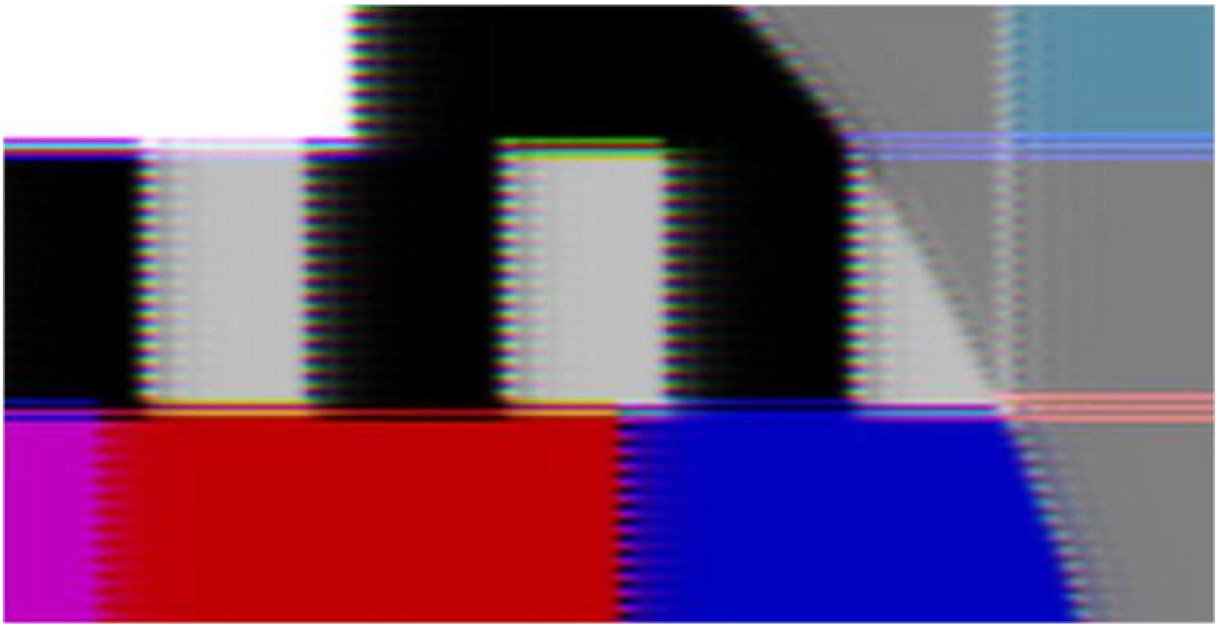

Figure 2: Extract from the result of a simulation according to Figure 1

Two problems can clearly be seen:

1. In vertical direction, complex coloured contours are created at horizontal signal transitions. For example, the three red and three blue lines in the right-hand part of the image are created by the fact that there is only one single white horizontal line in the original image. The combination of the sequential colour transmission process, the double delay (9 and 10 in Figure 1) in the decoder, and the general interlaced vertical image scanning, results in three horizontal coloured lines, each separated by an uncoloured line.
The vertical transition from black to white within two lines of the original image, in the top centre, leads to similarly complex results. In the decoded image we see a sequence of coloured lines with black, green, red, cyan, yellow and white.

2. In horizontal direction, so-called "mouse teeth" appear at vertical signal transitions, where black/white or coloured transitions have been in the original image. These effects result from the fact that the direct signal (8 in Fig. 1) has a bandwidth of 3 MHz and therefore shows a fast slope transition, while the two delayed signals (11 and 12 in Fig. 1) only have a bandwidth of 500 kHz and therefore have a significantly slower slope transition. When these signals are combined with each other, errors occur due to the different slopes.

This effect is further illustrated in Fig. 3 below. Herer only the signals of one field are shown. The visible lines are separated by black lines belonging to the other field not shown here.

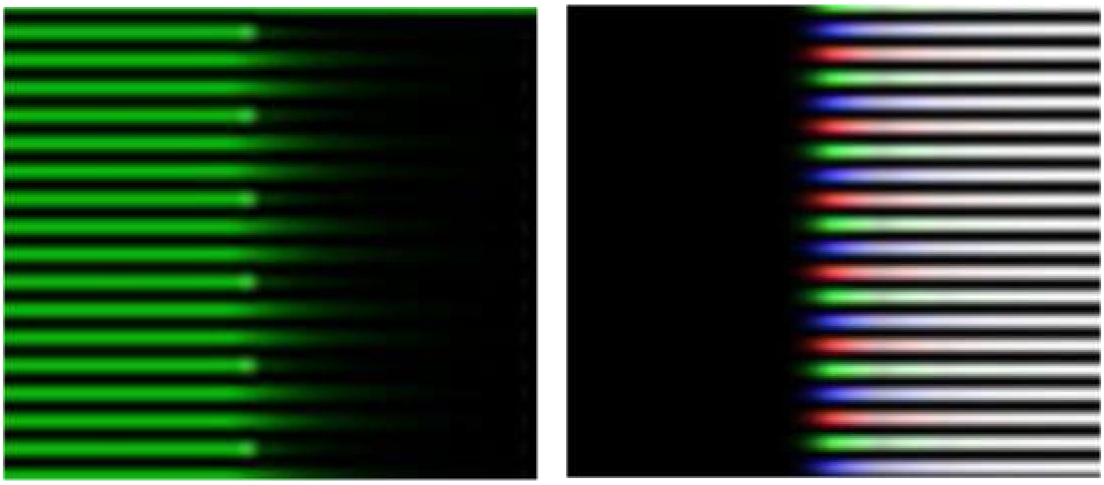

Figure 3: Enlarged section of the result of a simulation according to Figure 1, only signals of one field are shown
on the left: Transition green > black
on the right: Transition black > white

The enlarged display on the left clearly shows that a signal transition from green to black results in a fast slope transition in one line (direct signal 8 in Fig. 1), followed by two lines with a lower slope transition (signals 11 and 12) due to the lower bandwidth.

On the right it is shown for an original transition from black to white, how first a direct signal (8) appears with a fast slope, causing the line to briefly and alternately adopt one of the primary colours R, G or B. A little later, in horizontal direction, the two signals (11, 12) with lower slope are added, causing the line to then take on the correct white colour.

Overall, the image quality of the method shown in Fig. 1 is therefore unsatisfactory, especially for test images with structures that greatly change from line to line.

With real television images supplied by a flying-spot slide or film scanner, however, the problems at horizontal transitions are not necessarily so obvious. This is because the scanning spot has a finite extension and may even be set to have an elliptical shape to achieve a certain smearing or low-pass effect in the vertical direction.

In addition, both the horizontal and vertical resolution on the screens of shadow mask display tubes at that time were significantly lower than on the computer LCD screens used here to reproduce the simulations.

But perhaps things already could be made better back then?

First improvement: mixed highs

Just six months later, on 14 October 1966, Telefunken filed an application for an invention that actually represented a significant improvement:

In DE1261876 [4], Walter Bruch describes the basic features of the so-called "mixed highs": basis is the knowledge already used in the development of the NTSC and PAL colour television processes. The human eye does process colour signals with a lower resolution as compared to processing of luminance signals. Therefore, a bandwidth of 600 kHz or less is sufficient for processing colour signals in a TV transmission system. Bruch writes: "The invention consists of recording a signal combination that alternates line by line between only the low frequencies of the colour signals and a luminance signal containing the high frequencies in each line."

This idea of "mixed highs" apparently goes back to work on the development of "electronic" colour television that was "compatible" with black-and-white receivers, which was carried out at RCA in Princeton/NJ in the 1940s and 1950s and ultimately led to the introduction of the NTSC colour television process.

In his US patent 2,554,693 [5] filed on 7 December 1946, Alda Bedford precisely describes this division into low-frequency and high-frequency signal components. However, his application uses simultaneous transmission in parallel channels, not the sequential transmission in one channel as described by Bruch in [4]. When designing his PAL process, Bruch certainly must have studied the related, older NTSC process in detail and probably also came across the idea of "mixed highs".

The application of "mixed highs" on the encoder side of a line-sequential colour transmission system is shown in Fig. 4. This example from [4] does not start with the three colour signals R, G and B, but with a colour signal representation using a luminance signal and two colour difference signals (Y, R-Y and B-Y). In the NTSC or PAL colour television systems such a representation is commonly used, and these signals can be easily derived from the three colour signals R, G and B.

In the system shown in Fig. 4, the two colour difference signals R-Y and B-Y are first band-limited by low-pass filters (1, 2). Then a matrix (3) is used to establish three signals (4, 5, 6), which consist of low-pass-limited R, G and B components and high-pass-limited Y components. These signals are then sequentially recorded on the video tape recorder (13) via line-sequential switch (10).

The content of matrix (3) is not described in detail in the patent, but can be easily deduced.

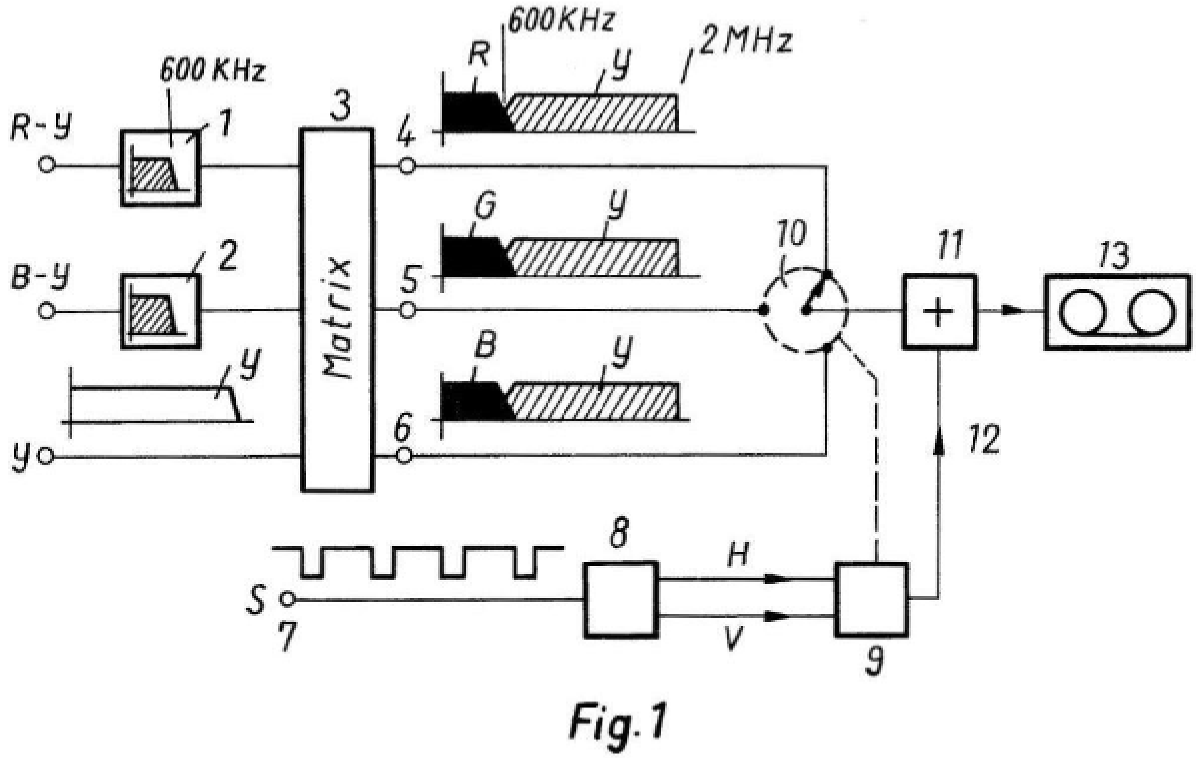

Figure 4: TriPal mixed highs encoder, Fig. 1 from DE1261876 [4]

On the decoder side, as shown in Figure 5, the respective low-pass-limited colour signals C_L (either R_L, G_L or B_L) and the high-pass-limited luminance signal Y_H are first separated from each other in a filter circuit (14). Two delay circuits (16, 17) are provided to have all three low-pass-limited colour signals available at the same time, direct C_L, once delayed C_{L-1}, and twice delayed C_{L-2}. Then the signals are combined in such a way that all three colour signals are alternately present in each line together with the respective luminance signal Y_H.

Because of the sequential recording, the actual colour signals at output 14 and at the adders (20, 21) change with each line. As already shown in Figure 1, this can be corrected using three switches (23, 24, 25) that rotate together and synchronized with switch (10) in the encoder.

Finally, three combined colour-luminance signals (R_L +Y_H, G_L+Y_H and B_L +Y_H) are available for further processing and display.

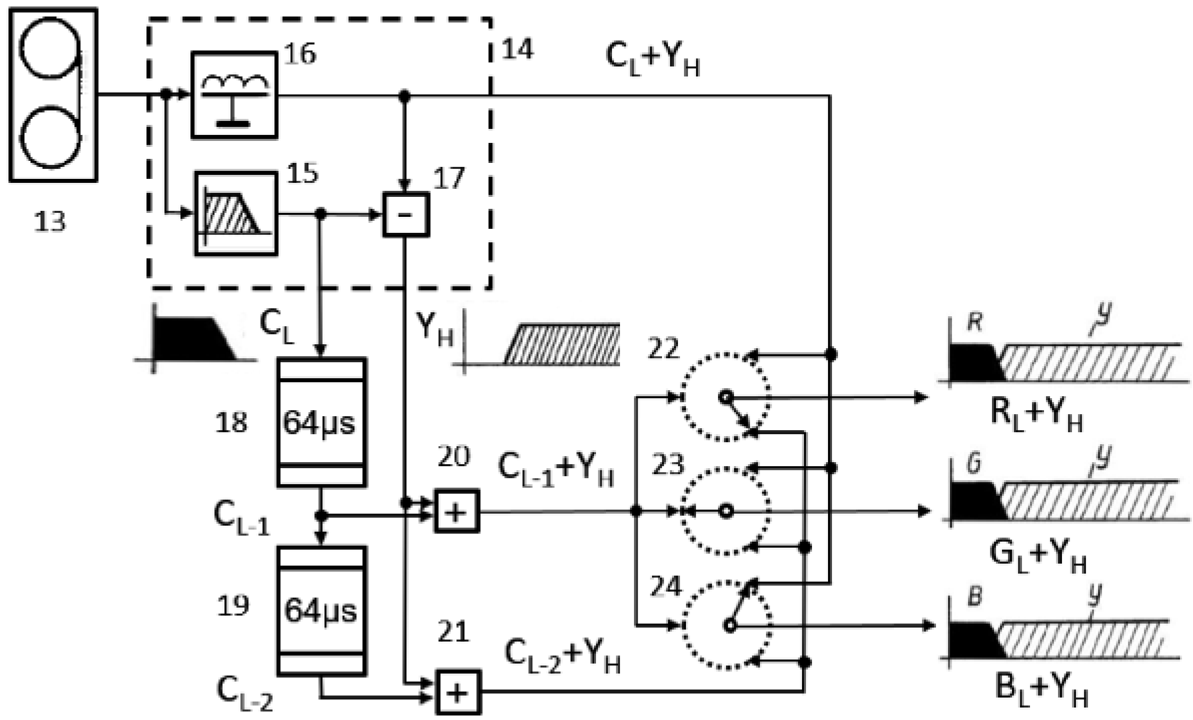

Figure 5: TriPal mixed highs decoder according to DE1261876 [4]

In December 1966, Walter Bruch finally published the results in radio-mentor-electronic magazine [6]. This publication is apparently based on a presentation held at the 14th annual conference of the Fernseh-Technische Gesellschaft FTG in Heidelberg.

For this presentation, one of the first video recorders intended for home use was used, a Philips EL3400A from around 1964 with 1 inch wide magnetic tape. This video recorder still used a large number of electron tubes for signal processing.

Bruch writes in [6] that although certain edge structures were visible, all colour values were reproduced correctly.

To estimate the expected quality, this system according to DE1261876 was also simulated. The corresponding result can be seen in Figure 6.

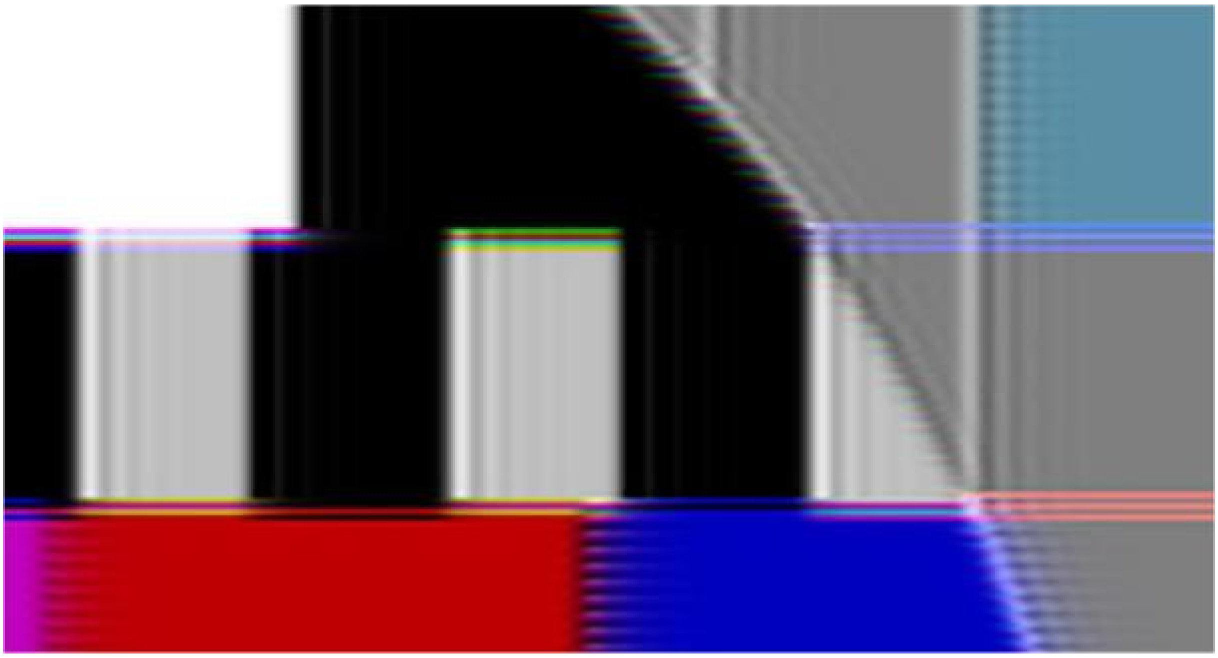

Figure 6: Extract from the result of a simulation with "mixed highs" corresponding to Figures 4 and 5

Figure 7: Simulation result as in Figure 6, photographed from the screen of a shadow mask display tube

When you compare Figure 2 and Figure 6, you can see that there are still a lot of problems, but the horizontal transitions at vertical black and white structures no longer have coloured edges. This is a direct result of the application of the "mixed highs" principle.

Figure 6 shows the reproduction of the simulation on a modern LCD screen. At that time, however, only displays with shadow mask tubes were available, which had a significantly lower vertical and horizontal resolution. Figure 7 therefore shows the same simulation on the screen of a shadow mask tube. In comparison to Figure 6, it can be seen that the multiple structures in the vertical direction are much less noticeable.

For the time being, this line-sequential colour transmission process had been named "Trisec" to reflect its triple-sequential structure. And with presentation at 14th FTG conference and publication in [6], the development had come to rest.

Further improvements: Werner Scholz

Apparently, however, work had not been stopped completely. Almost three years later, on July 11 1969, an invention was registered at the patent office, naming Dipl.-Ing. Werner Scholz as the inventor. At the time, Scholz was an employee in the Telefunken Basic Development Laboratory headed by Walter Bruch. His invention was later granted under DE1935212 [7].

Scholz set himself the task of generating a standard-compliant and thus easily processable FBAS signal in the PAL colour television standard, from the output signals of the available "Trisec" decoder, and that as simple as possible.

The available delay lines had been designed to be used in a PAL colour signal decoder. It was known, that the delay lines had to be fed with carrier-frequent signals, typically using the standard colour subcarrier frequency for PAL at 4.43 MHz. Scholz solved his task by extending the carrier-frequent signal transport through the delay lines to the entire colour signal processing within the Trisec decoder.

To generate a standard-compliant output signal, the two in-quadrature, PAL colour signals F_U and F_V must be formed at carrier-frequency. They are normally generated from the B-Y and R-Y colour difference signals, but there is no Y signal in the low-frequency range of B and R at the output of the Trisec decoder (Fig. 5). The same low-frequent luminance signal component Y_L is missing in the previously only high-frequent Y_H signal.

According to Scholz, the solution is to generate the missing low-frequency component Y_L of the luminance signal with the aid of a Y matrix (25) from the low-frequent colour signals R_L, G_L and B_L, which are present behind the rotating switches. The output from matrix (25) can directly be used in (27, 28) to form the band-limited colour difference signals R_L - Y_L and B_L - Y_L, and in (26) to form the full-bandwidth luminance signal $Y = Y_H + Y_L$. This finally provides the signals required to form a standard PAL-FBAS signal.

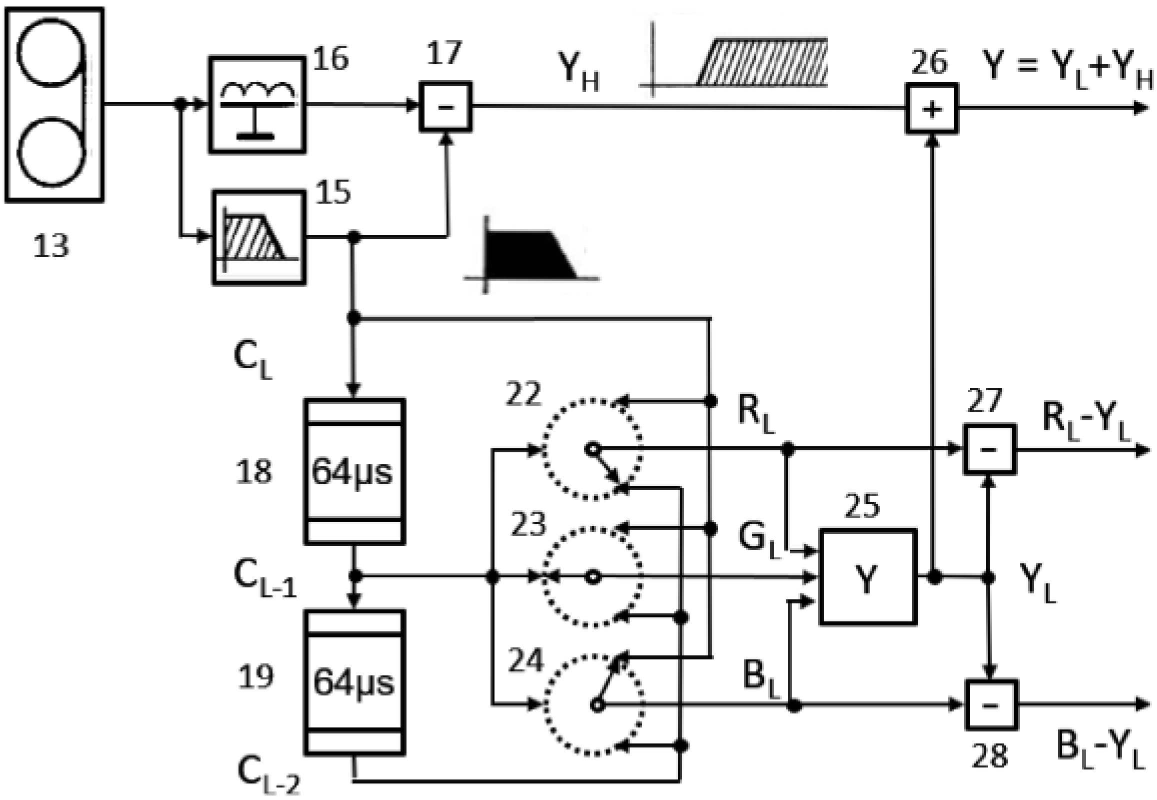

Figure 8: Trisec mixed highs decoder for PAL-FBAS according to DE1935212 [7] (without representation of carrier frequency processing, redrawn for easier comparison with Figure 5)

Unfortunately, Werner Scholz did not tell us in his patent specification how exactly the signals in the matrix (25) are processed. He only mentions the "necessary amplitude ratio". However, he almost certainly must have referred to the usual matrixing of the luminance signal from the individual RGB colour signals according to CCIR Rec. 601 with:

$$Y = 0.299\ R + 0.587\ G + 0.114\ B \qquad (1)$$

One of the advantages of this version of a Trisec decoder, as shown in Fig. 8, appears to be that, in contrast to the version shown in Fig. 5, only low-frequency signal components (index L) are transmitted via the arrangement of the rotating switches.

Just seven days later, on 18 July 1969, another invention by Walter Bruch was registered [8] (DE1936594). It is characterized by the fact that the low-frequency luminance signal Y_L can apparently be obtained in a much simpler way. The signals involved are taken directly from the delay lines and do not have to pass through any of the rotating switches. This also reduces the number of switches from 3 to 2.

As a consequence, however, the new matrix (29 in Fig. 9) does not form the actually correct signal Y_L, but a slightly different signal M_L with:

$$M_L = 0.33\ R_L + 0.33\ G_L + 0.33\ B_L \qquad (2)$$

As the output of the delay lines does not determine whether an R, G or B signal is present, it should actually be written this way:

$$M_L = 0.33\ C_L + 0.33\ C_{L-1} + 0.33\ C_{L-2} \qquad (3)$$

This matrix according to (3) is referred to as "M-matrix". It had similarly been described by Alda Bedford in the aforementioned US patent 2,554,693 [5]. And this fact also solves the mystery of what "M" actually stands for: it is simply derived from the mixed signal in the mixed highs.

Bruch mentions as an advantage that M-matrixing somehow averages the luminance signal in the vertical direction, which does lead to a smoother image reproduction, especially on horizontal or slightly slanted edges.

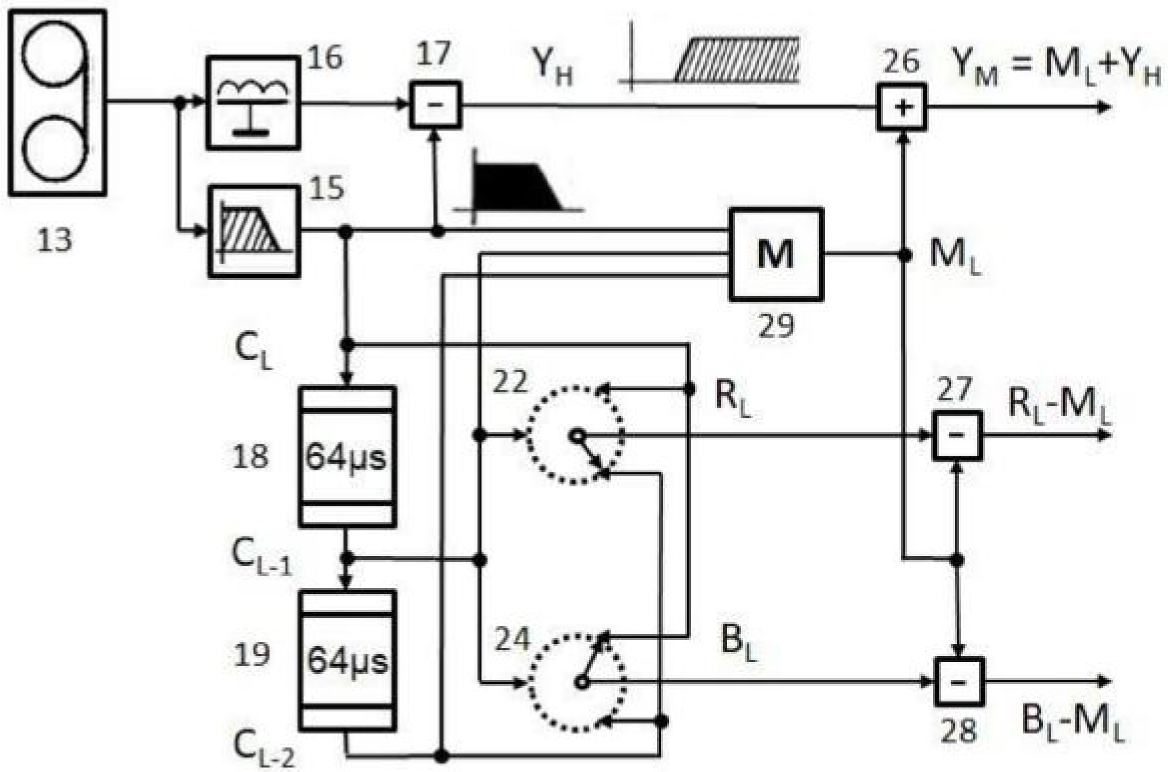

Figure 9: Trisec mixed highs decoder with M-matrix according to DE1936594 [8]

However, it quickly became clear that M-matrixing in (29) does work for the low-frequency components of the luminance signal and can lead to an improvement in image reproduction. But when this signal is used to form the colour difference signals U = B_L-M_L and V = R_L-M_L in (27) and (28), then clear errors do appear in the colour signal reproduction.

Just one month later, therefore, a supplement or correction followed: on 28 August 1969, the later DE1943672 was registered for the inventor Walter Bruch as an addition to DE1936594.

The solution can be seen in Figure 10 below:

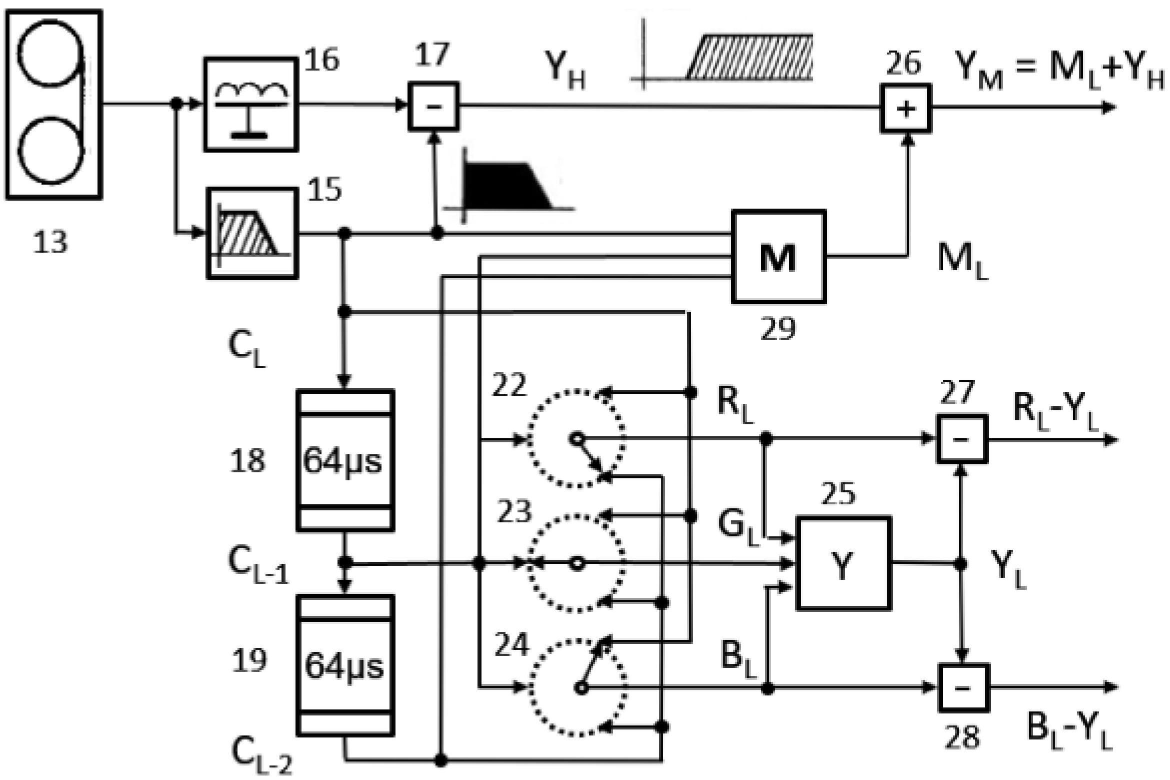

Figure 10: Trisec mixed highs decoder with M and Y-matrices according to DE1943672 [9]

The M-matrix in (29) is retained for the luminance signal, but the familiar Y-matrix (25) from Fig. 8 is re-inserted to form the two colour difference signals. And the third rotating switch that had been saved had to return.

Now one of the mysteries from the prologue can be solved: Due to the actually incorrect M-matrixing in (29) according to formula (3), the green bar in a standard colour bar test signal must appear darker than normal, as it only contributes with a factor of 0.33 instead of 0.587 to the luminance signal Y.

But not only the green bar does appear different, all resulting changes in brightness compared to a correct colour bar test signal are shown in Figure 11.

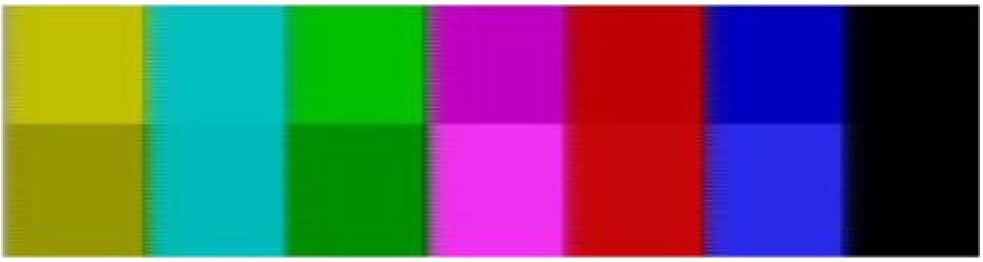

Figure 11: Changes in brightness with different matrices
top: correct colour and brightness values
bottom: MY-Trisec. The yellow and green bars are too dark, the magenta and blue bars are too bright

In the text of DE1936594, Bruch argues in favour of M-matrixing: "This reduces unwanted colour errors at horizontal edges, for example, which occur as a result of the tri-line sequential transmission".

Can this statement be verified?

For this purpose, an image with not particularly high colour contrast and with horizontal structures was encoded using the trisec-mixed-highs method and decoded, once according to Figure 8 and once according to Figure 10. Enlarged sections of the result are shown side by side in Figure 12.

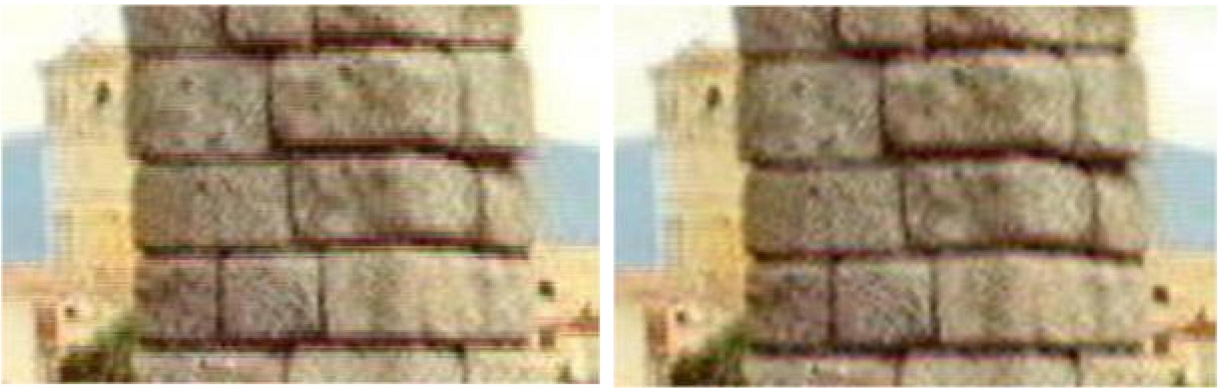

Figure 12: Enlarged sections of picture decoded according to Figure 8 and to Figure 10
left: Decoding according to Trisec mixed highs (Fig. 8)
right: Decoding additionally with MY matrix (Fig. 10)

It can be seen that the coloured horizontal structures at the wall joints are actually somewhat less visible. However, some colour fringes are still clearly visible.

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Further on, work on Trisec continued with minor problem solutions or even just attempts to solve them:

On 31 October 1969, DE1954876 [10] was filed for Werner Scholz, but was not granted.

The disclosure refers to the fact that a composite colour television signal does not only contain luminance and chrominance components, but also signals for synchronization. When these are applied to the decoding circuits presented so far, inaccuracies and smearing occur as a result of averaging over three lines. Scholz suggests to switch off the three-line averaging, especially during the vertical blanking interval, i.e. during the transmission of the synchronization signals.

At the 18th annual conference of the Fernseh-Technische Gesellschaft (FTG) in Mainz in 1970, Walter Bruch gave a presentation on "Experiments with colour recordings on simple magnetic tape recorders". A summary was printed in radio-mentor-electronic [11].

In his presentation, Bruch goes back to the publication from 1966 [5] and now refers to the process presented at that time and "gradually perfected in the meantime" as "Tripal". The renaming from Trisec to Tripal must therefore have taken place in the meantime. In detail, [11] presents the process shown in Fig. 10 in accordance with DE1943672 [9] and refers to it as "MY-Tripal" because of the two different M and Y matrices.

Bruch then also mentions that work on the "colour-under" process has continued with good results. He even comes to this conclusion: "So you don't necessarily have to re-code for home video recording, you can stay with PAL".

At the time, this solution had already been established by other developers of colour-capable video recorders. Sony presented their U-Matic system as early as 1969 and launched it on the market in 1971. Philips and Grundig developed the consumer-type VCR system, which was launched on the market in 1972.

Tripal seemed to be finished for the time being. But now there was another interesting development.

The TED picture disc

In the spring of 1970, a group of developers presented the TED video disc to managers from AEG-Telefunken, Decca and Teldec: a mechanically scanned "picture disc" that could be duplicated by stamping, just like a vinyl record. After the success with PAL, AEG-Telefunken urgently needed another cash cow that would generate license income. The managers were enthusiastic.

The picture disc system was soon presented to the public at a press conference in Berlin on 24.06.1970, still in a very simple version, in particular without colour. But already by late summer 1971, a colour-capable version with five-minute playing time was presented at the IFA radio exhibition in Berlin.

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Finally, on 11 October 1972, Walter Bruch reports on the specially developed Tripal-D version (the D probably stands for 'Disc') at the FTG annual conference in Braunschweig.

The production-ready version of the Telefunken-Teldec TED picture disc with colour and using Tripal-D with a playing time of 10 minutes is finally presented on 31.10.1972 at the AEG-Telefunken Technical Press Colloquium TPC in Frankfurt.

At the following IFA in Berlin in late summer 1973, the system was actually ready for market launch. However, the launch was prevented by an incompatibility of the thin stamped disc with the cardboard carrier pocket in which it was normally stored. After only a short period of storage, slits in the cardboard pocket intended for automatic handling were leaving impressions on the disc material, and this led to intolerable image distortion.

This problem delayed the market launch until spring 1975, when the TED picture disc was finally launched on the market for around 400 days before being largely discontinued. Only in a small market segment for educational videos it was continued for a few years.

As early as December 1972, W. Roth reported on the status of the picture disc system and Tripal-D in Funk-Technik [12]. The block diagram of the signal processing in the TP1005 playback device (Fig. 13), which can often be seen but which is largely incorrect, probably originates from this publication. The actual playback circuit that was later realized is significantly different.

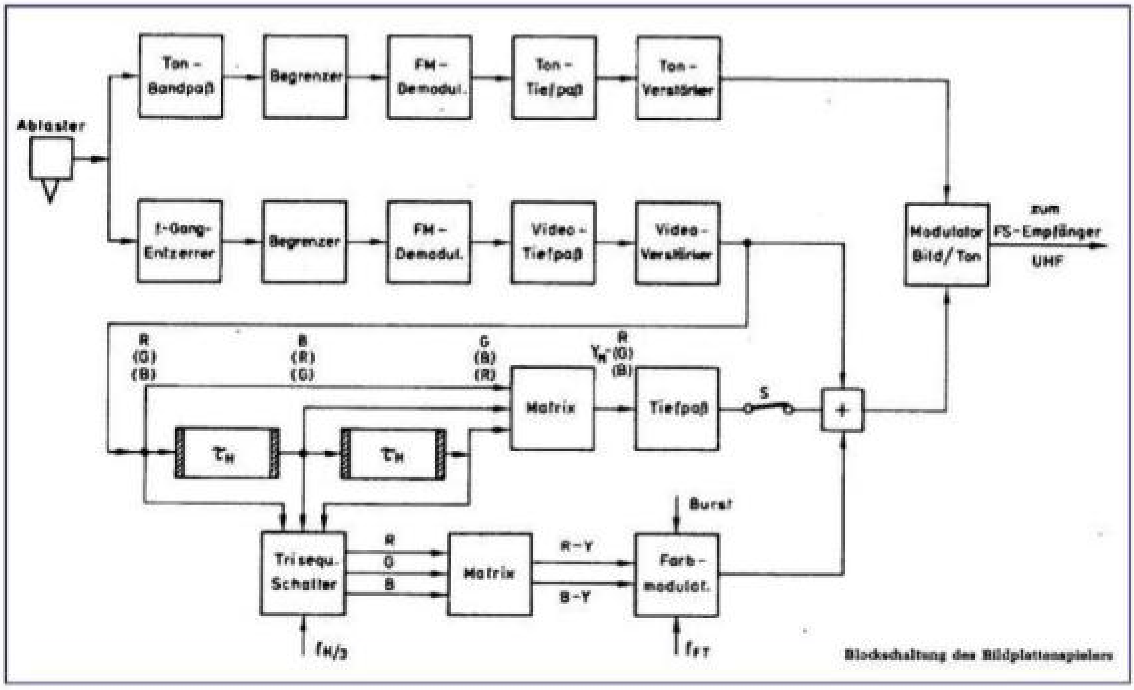

Figure 13: TED playback device: Block diagram from Funk-Technik 23 (1972) [12]

The period between mid-1970 and mid-1973 therefore remains for the development and implementation of Tripal-D. What can we learn about Tripal-D from the patent applications during this period?

The first innovation came on 19 November 1971 as a patent application for Werther Hartmann, an engineer at Teldec in Berlin, the later patent DE2158218 [13].

Hartmann recognizes that M-matrixing is somewhat advantageous in the playback circuit, but distorts the luminance signal. He therefore proposes a way to compensate this on the recording side.

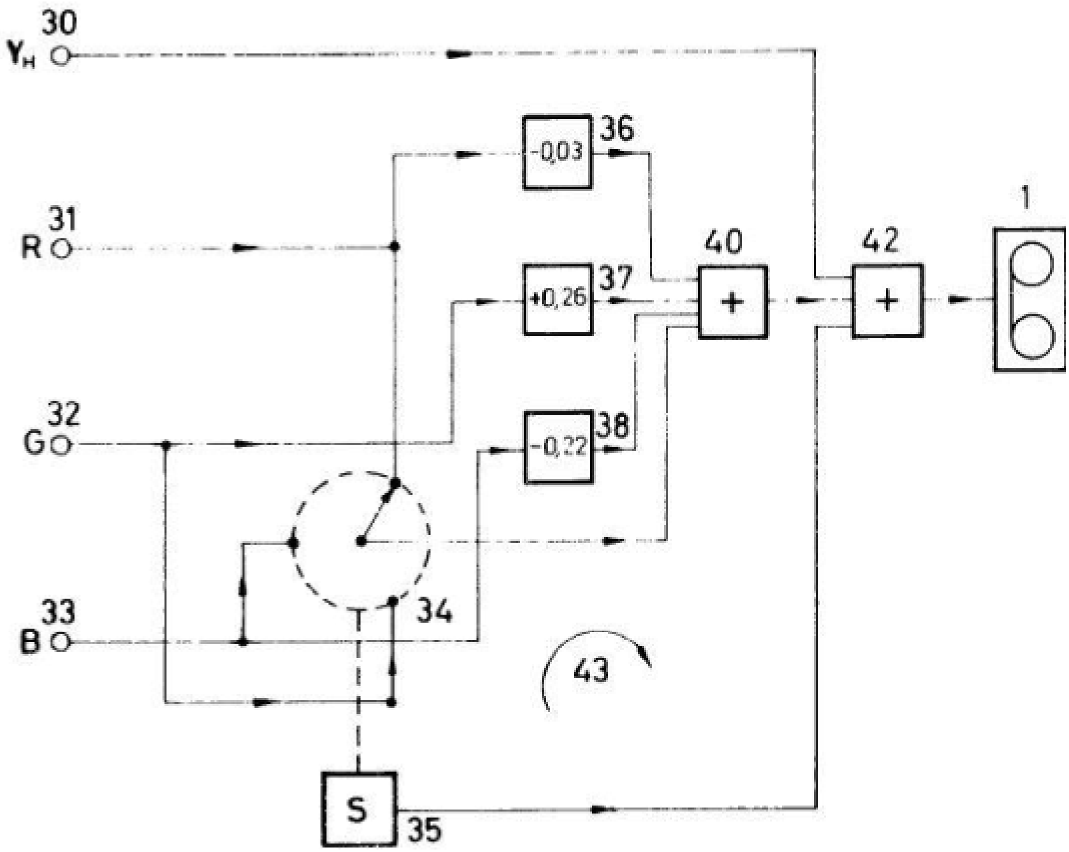

Fig. 2

Figure 14: Correction on the encoder side for M-matrixing in the decoder, Fig. 2 from DE2158218

Only a few days later, on 9 December 1971, Werner Scholz solved the same problem in his usual and precise manner: In the later DE2161106 [14], he showed that the compensation of the luminance error due to M-matrixing was much easier to achieve.

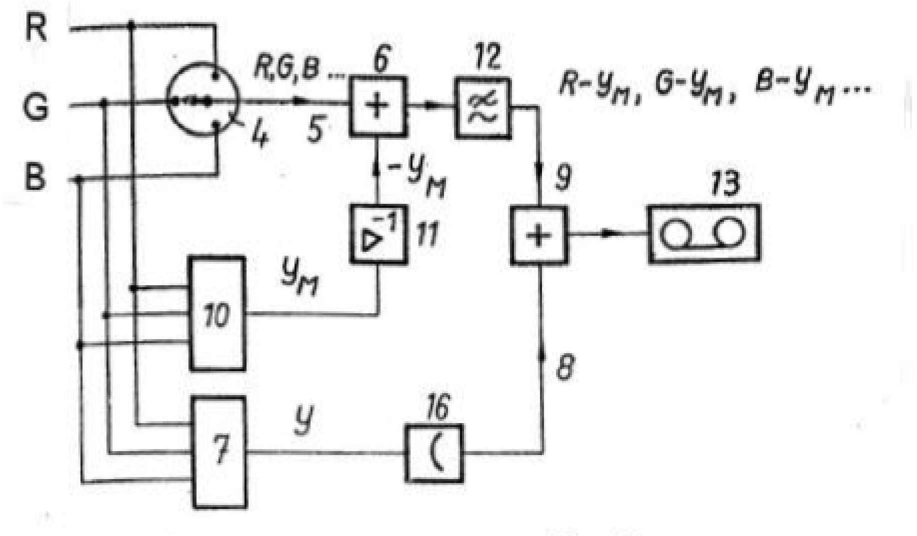

Figure 15: Correction on the encoder side for M-matrixing in the decoder, Fig. 1 from DE2161106

A comparison of these two patent applications shows that the solutions are ultimately identical.

On 27 December 1971, this idea by Walter Bruch was registered (DE2164801):

To improve flicker phenomena on horizontal edges, the luminance signal Y should be delayed by one line during recording, see Fig. 16.

It can be seen, that the delay of one line must be applied the luminance Y signal with full bandwidth. This could not have been achieved with the available ultrasonic delay lines. But, as the mechanical cutting of a stamp master for a TED video disc had to be performed at a speed reduced by 1/25 and thus with a correspondingly reduced frequency range, only a signal bandwidth of around 140 kHz would have been required. However, for the same reason, the signal delay must also be increased by 25 times, from 64 µs to 1.6 ms.

Unfortunately, it is no longer possible to determine whether this idea has actually been used.

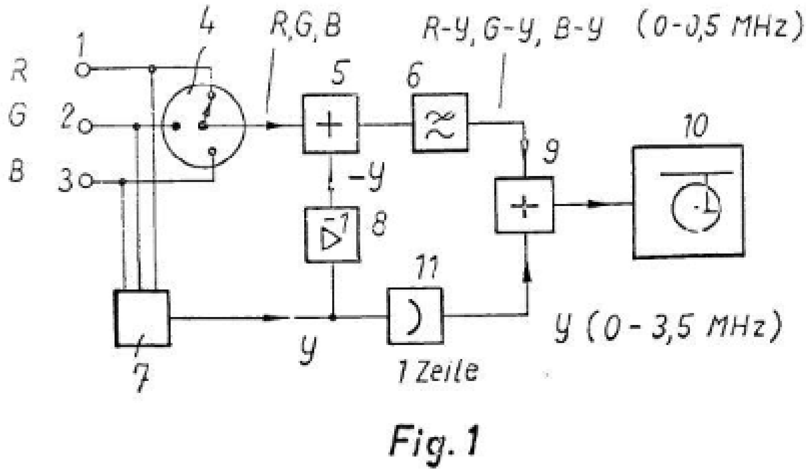

Figure 16: Encoder circuit with mixed highs and additional delay (11), Fig.1 from DE2164801

On 15 February 1972, an invention by Werner Scholz was registered, the later DE2207021 [15]. This represented a significant step forward.

On the recording side, Scholz initially kept the actually incorrect M-matrixing, without his previously described correction circuit (compare with Fig. 15).

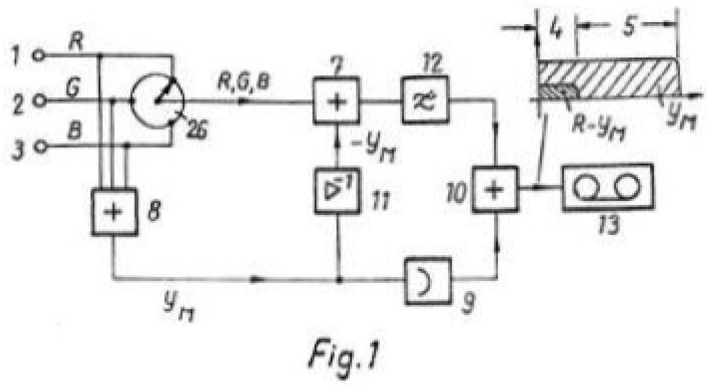

Figure 17: Tripal encoder with mixed highs and additional delay, Fig. 1 from DE2207021

But something crucial changes during playback:
The signal path (16...26) for the luminance signal no longer contains a high pass filter and the difference stage (17) has disappeared. This also eliminates some of the previous problems, including the smearing of the synchronization signals.

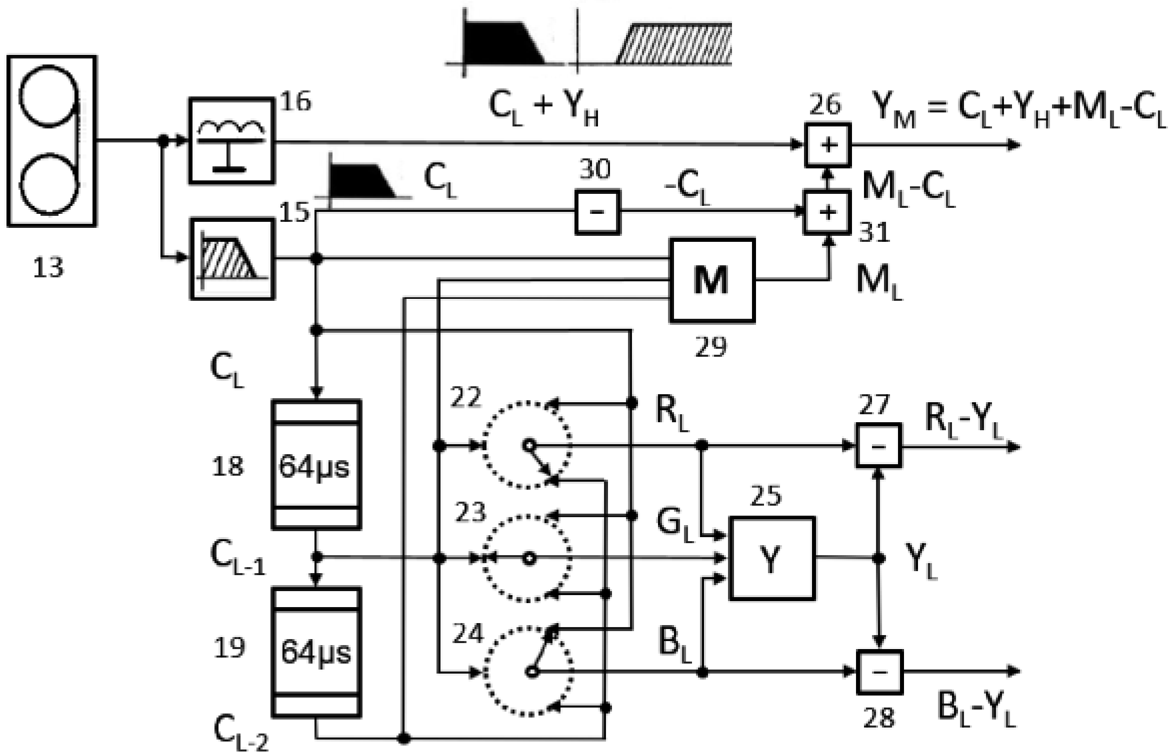

Figure 18: Tripal decoder, Figure 1 from DE2207021, redrawn for better comparison with Figure 9

Another simplification can be seen in Figure 18: The current low-frequency color signal C_L reaches the addition stage (31) via both the inverter (30) and the M-matrix (29). Surely that can be simplified?

In fact, in Figure 7 of the patent disclosure, Werner Scholz shows how to do it:

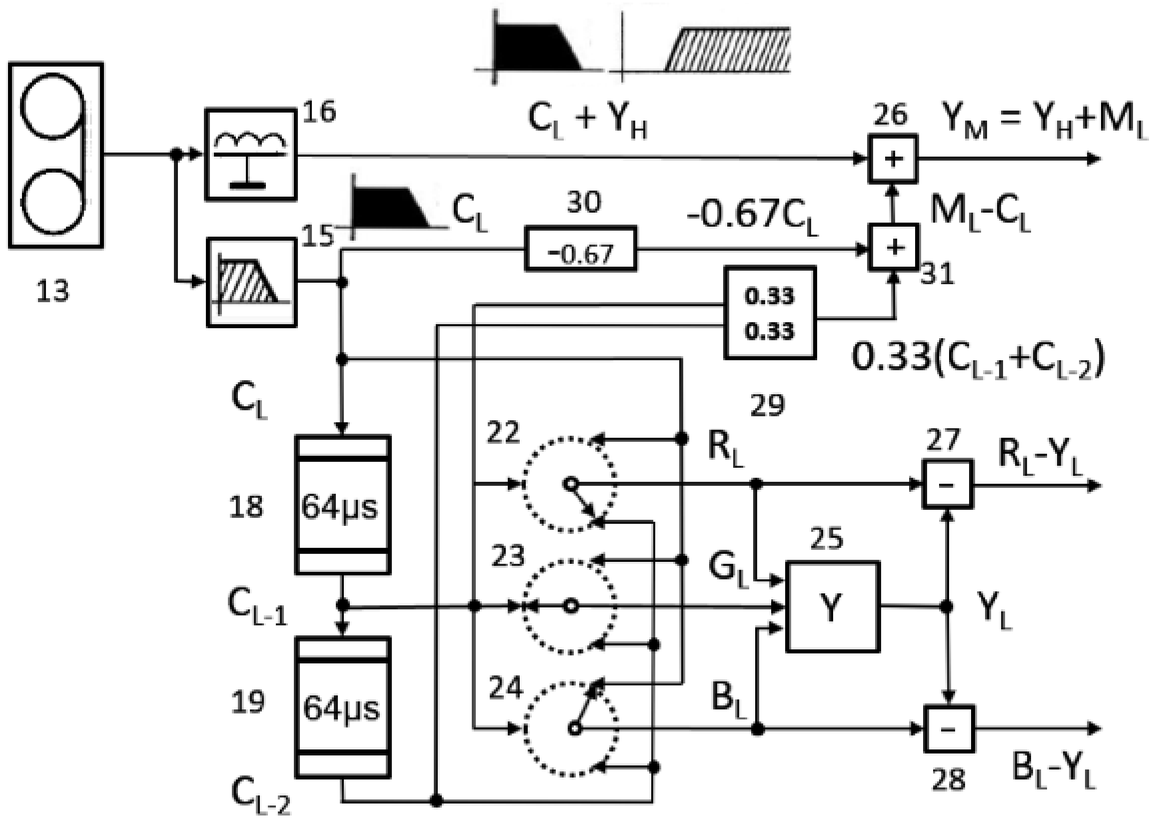

Figure 19: Tripal decoder, Figure 7 from DE2207021
redrawn for better comparison with Figure 9 and Figure 18

In fact, deeper analysis shows that the circuits implemented in the TED TP1005 video disc player were designed according to this Fig. 7 from DE2207021. And this also confirms the author: Werner Scholz.

What was not implemented in the TP1005 circuits is the consistent carrier frequency representation of the color signals in Fig. 7 from DE2207021. Here the actual circuitry of the TP1005 differs significantly.

This means that it can be determined with high probability that Tripal-D must be characterized by these two improvements over Tripal-MY:

- precompensation in the encoder for the error caused by the M matrix
- simplifying the signal flow in the decoder according to Figure 19

The following block diagram in Figure 20 was derived from the circuit actually implemented in the TP1005 (*).

* Two of these devices were kindly provided for investigations by Mr. Thomas Udert.

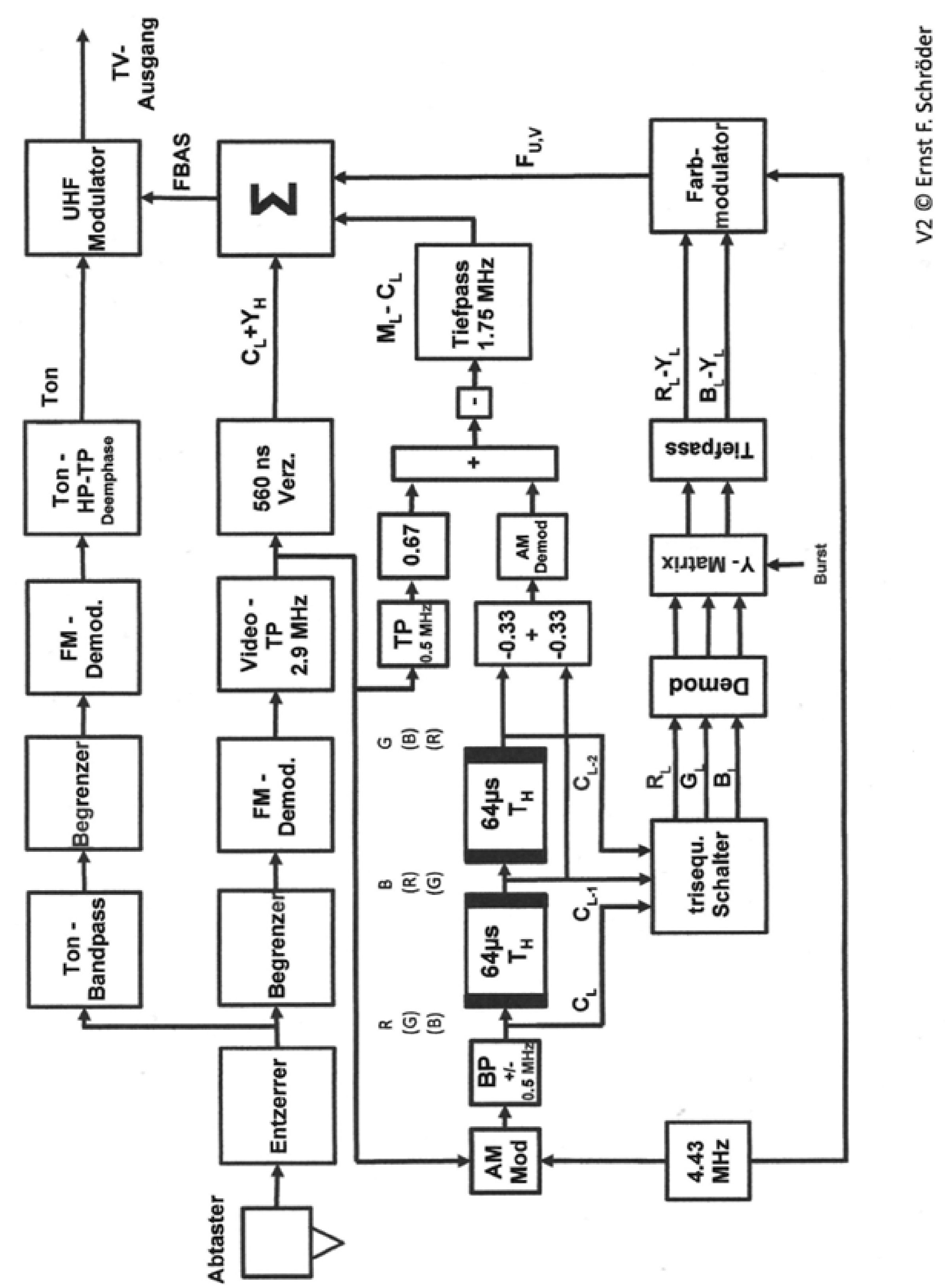

Figure 20: Block diagram of TED Video Disc Player TP 1005

Further attempts to improve the system

There are a number of other and later patents for TED, but they apparently have nothing to do with the "production-ready" version from 1973.

Telefunken and Teldec had now started a worldwide licensing program for the TED video disc, which was aimed at Europe on the one hand, but particularly at Japan and the USA on the other. However, the local standards for television signals defined a higher frame rate of 60 Hz, in combination with a lower number of just 525 lines. The basic change in signal processing from 50 Hz to 60 Hz and from PAL to NTSC was actually quite easy to achieve. However, the lower vertical resolution of only 525 lines was much more noticeable in connection with Tripal than was the case with the 625 lines of the European television systems.

Therefore, intensive theoretical work has been done to improve vertical encoding and decoding for Tripal, which can be seen in a number of patent applications. However, it can be assumed that few or none of these ideas have actually been built and tested. Some of the required components or building blocks were simply not available, such as delay elements for one video line with full video bandwidth.

The later DE2228910 [16] was registered for Walter Bruch as early as on June 14, 1972. Improved encoding for vertical signal transitions should be achieved by carrying out a separate decoding process already in the encoder. By comparing the decoded signal in the encoder with the original signal, a correction signal can be obtained that can be added to the encoded and recorded Tripal signal.

In particular, this is intended to prevent, for example, that one or more colored lines arise from a single white line, as could already be seen in Figure 6. Bruch writes: “This actually results in a distortion of the signals... however, the error is distributed more evenly over several lines and visibility is therefore smaller.”

Unfortunately, the patent specification is not very detailed with regard to the exact functionality, it only describes the procedure using a single white line against a red background. The single white line falls on the part of the tri-sequence where an R signal is transmitted. During normal processing with Tripal-MY, and after transmission, this signal would be interpreted as coming from an originally red line and would therefore completely disappear against the red background.

A simulation with Tripal-MY and DE2228910 is shown in Figure 21 below.

The proposed correction means that during transmission the two lines between two R lines, i.e. the G and B lines, also should carry a signal. As a result, you first get one yellow line, then two white lines, and then another magenta line against the red background. Because of the interlaced image scanning, there is a red line from the other field in between these lines.

Figure 21: greatly enlarged section of a simulation with correction according to DE2228910. Left: Original, Middle: Normal Tripal-MY, Right: with correction

The resulting image impression is certainly better than the complete absence of the single white line, but the strong widening of the horizontal structure is unlikely to significantly improve an image.

Shortly afterwards, on June 16, 1972, the later DE2229393 [17] was registered for Walter Bruch, Horst Redlich and Gerhard Dickopp.

In order to improve encoding in the event of vertical signal transitions, this patent specification recommends adjusting or deforming the scanning spot when scanning images or films with a flying-spot scanner so that the vertical resolution is lower than the horizontal one.

Another solution proposed is to subject the RGB video signals to some sort of averaging in the vertical direction before the Tripal coding process is applied, possibly even with different weighting factors for the averaging.

This is certainly a sensible approach. Sequential coding is a form of subsampling and should be preceded by corresponding low-pass filtering in the vertical direction.

When reading the patent, however, one gets the impression that those involved were still very much stuck in the analog world and the concept of digital filtering according to the FIR principle as well as its interpretation and calculation had not yet found its way into general considerations.

This also applies to DE2258867 [18], which was registered for Walter Bruch on December 1, 1972 as an addition to [17] and was not issued separately. Here Bruch is also concerned with improved encoding in the vertical direction and suggests that "the signals of the preceding and following lines are added with amplitudes according to a statistical distribution curve. The distribution curve can be, for example, a Gaussian function."

Bruch practically proposes a vertical FIR filter with degree n=3 and coefficients [0.5, 1.0, 0.5], and he also suggests that the coefficients could be adjustable and that the degree of the filter could also be increased to, for example, n=5.

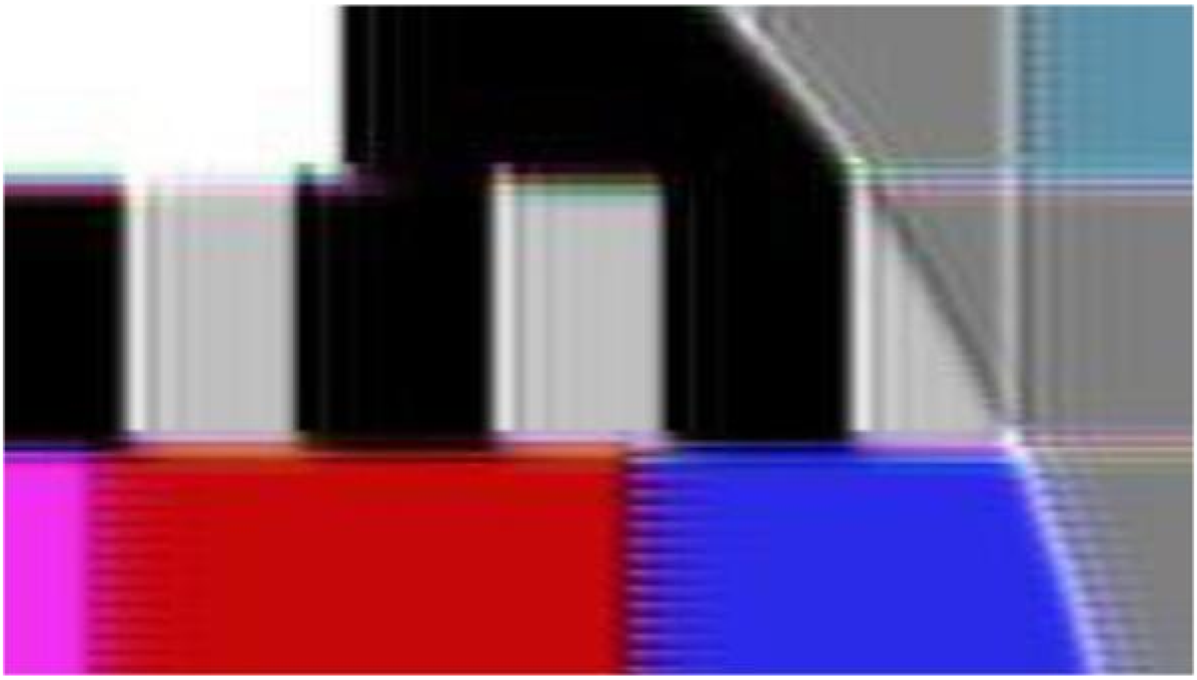

Figure 22: Enlarged section of a simulation with vertical FIR filtering according to Bruch / DE2258867 [18]

Based on this patent application, another simulation was carried out, the result can be seen in Figure 22. First of all, it should be noted that the coefficients [0.5, 1.0, 0.5] proposed by Bruch "according to a statistical distribution curve" are unsuitable because their sum does not result in a value close to or equal to 1.0, which results in a significant overload at the bright parts of the image. Therefore, the coefficients were corrected to [0.25, 0.5, 0.25] and used as such.

When comparing Figure 22 with Figure 6, it can be seen that the horizontal, colored triple structures resulting from single white lines in the original picture are less clearly visible, but still appear significantly wider. However, the structures at the vertical transitions between the white or black areas and the red or blue areas are still present in a disturbing manner. There is therefore no real improvement in image reproduction in the vertical direction.

Decca in England, which was involved in the TED picture disc, was also not idle: on September 28, 1973, an invention was registered for F. A. Griffiths, which was later also granted in Germany as DE2446376 [19].

Griffiths apparently uses the mixed-highs MY decoder according to [9] and according to Figure 18, and adds another delay line (20), the output signal of which is again added to the first delay line, reduced by the factor α (Figure 23). In addition, a second M signal, delayed by one line, is formed (29') and, after multiplication by different factors (x4 or x5), is subtracted from the first M signal (29).

This is obviously an attempt to reduce the color errors in the decoder by using a recursive IIR filter that works in the vertical direction. Furthermore, the vertical transitions in the luminance signal should be sharpened by forming the difference.

Unfortunately, the description in the patent text does not completely match the published Figure 1 of the patent. The obviously more correct solution shown in Figure 23 was also simulated. One result is shown in Figure 24.

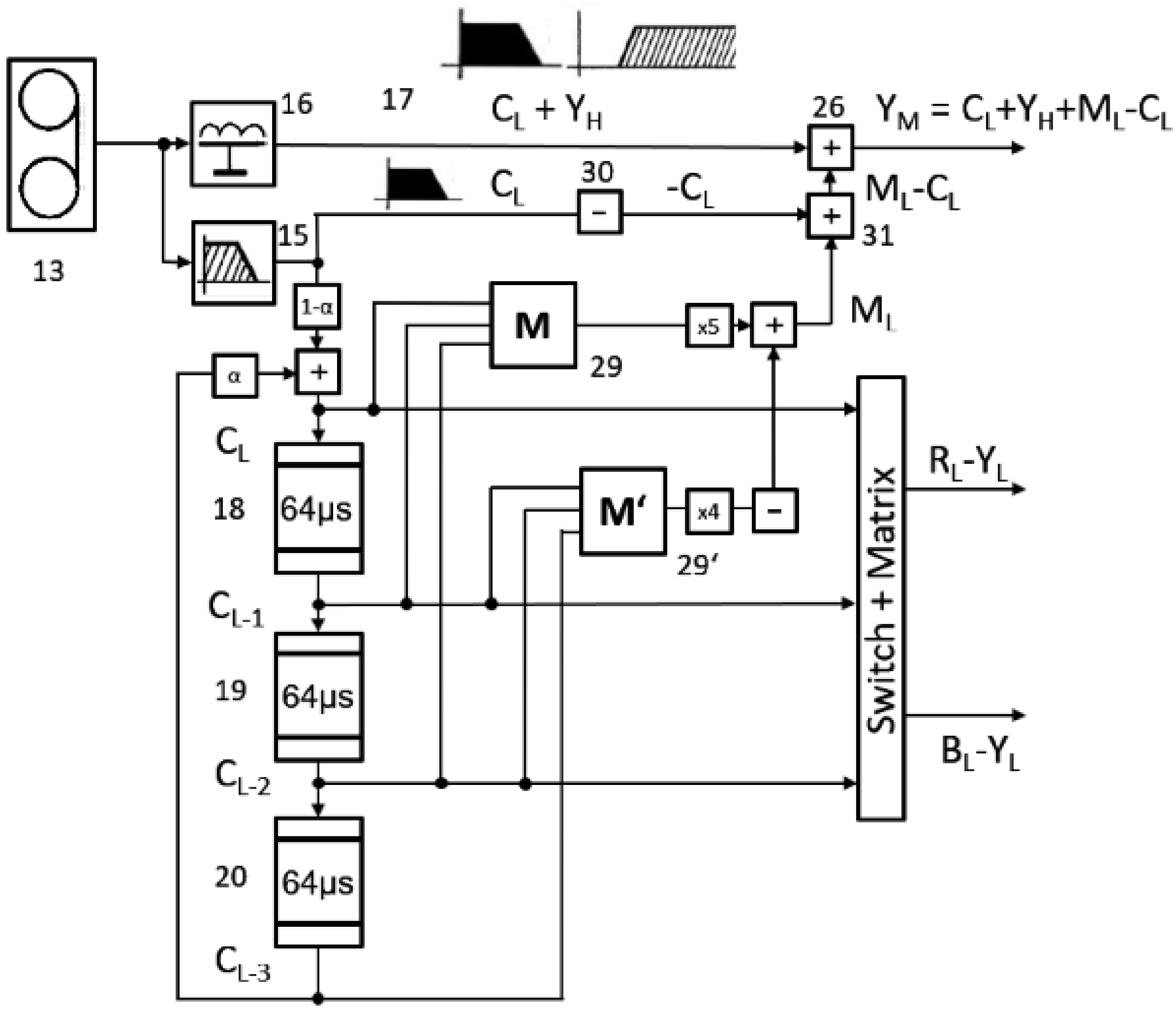

Figure 23: Tripal decoder according to Griffiths, DE2446376 Fig. 1, redrawn for better comparison with Figure 18

The influence of the recursive IIR filter can be clearly seen; the vertical transitions from a black or white surface to a colored surface show a clear, downwardly decreasing “train” of signal repetitions. It is also noticeable that the individual white horizontal lines in the original image are actually reproduced as individual white lines, albeit with considerable 'ringing' in the vertical direction.

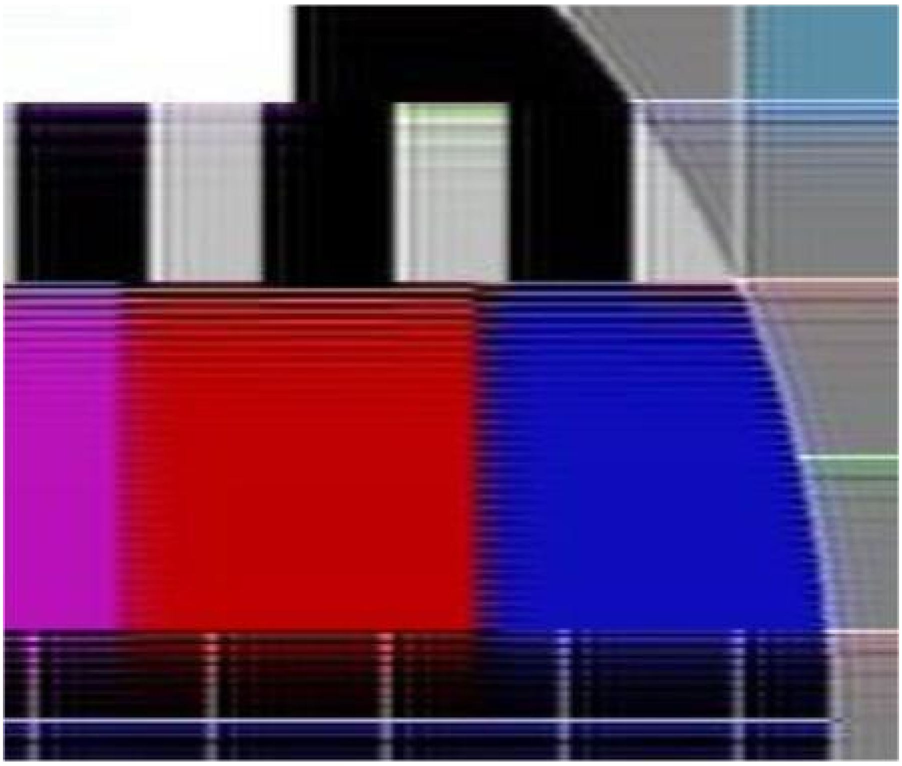

Figure 24: Enlarged section of a simulation with vertical IIR filtering according to Griffiths / DE2446376

On September 17, 1975, DE2541348 [20] was registered for Werner Scholz. Scholz also uses 3 delay lines in the decoder and achieves practically the same result as Griffiths, but - as is often the case - a little more elegant and with significantly less effort.

On March 11, 1976, two more inventions were registered for Werner Scholz. DE2610090 [21] specifies the statements in DE2541348 [20], but does not bring any other noticeable advantages.

The DE2610091 [22] practically dispenses with the recursive IIR filter, which means that the long decay of this filter disappears. Unfortunately, this does not produce a significantly better overall impression. See Figure 25 in comparison with Figure 24.

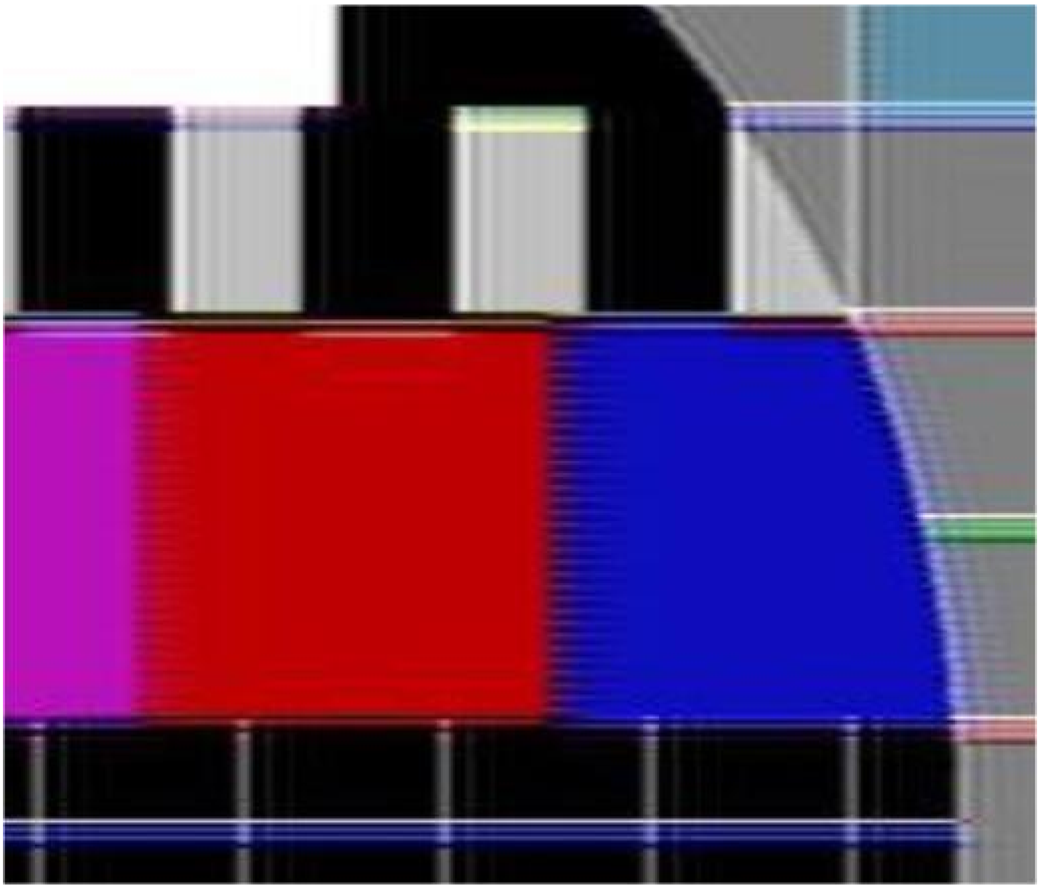

Figure 25: Enlarged section of a simulation according to Scholz, DE2610091

In the patent application for DE2446376, Griffiths also mentioned suggestions for improved encoding, but these no longer appear in the patent that was ultimately granted. To improve the vertical structures, he suggested subjecting the color difference signals to vertical FIR filtering with a filter length of n=7. Unfortunately, he didn't give any values for the coefficients. It must also be doubted that such an arrangement was actually created and tested. The hardware effort for a vertical FIR filter with n=7 would have been considerable at the time.

Nevertheless, an attempt was made to carry out a corresponding simulation. For this purpose, several sets of coefficients were determined and applied. The result of what is still the best solution is shown in Figure 26. Unfortunately, the comparison with Figure 6 as well as Figure 24 and Figure 25 shows that no real improvement is achieved.

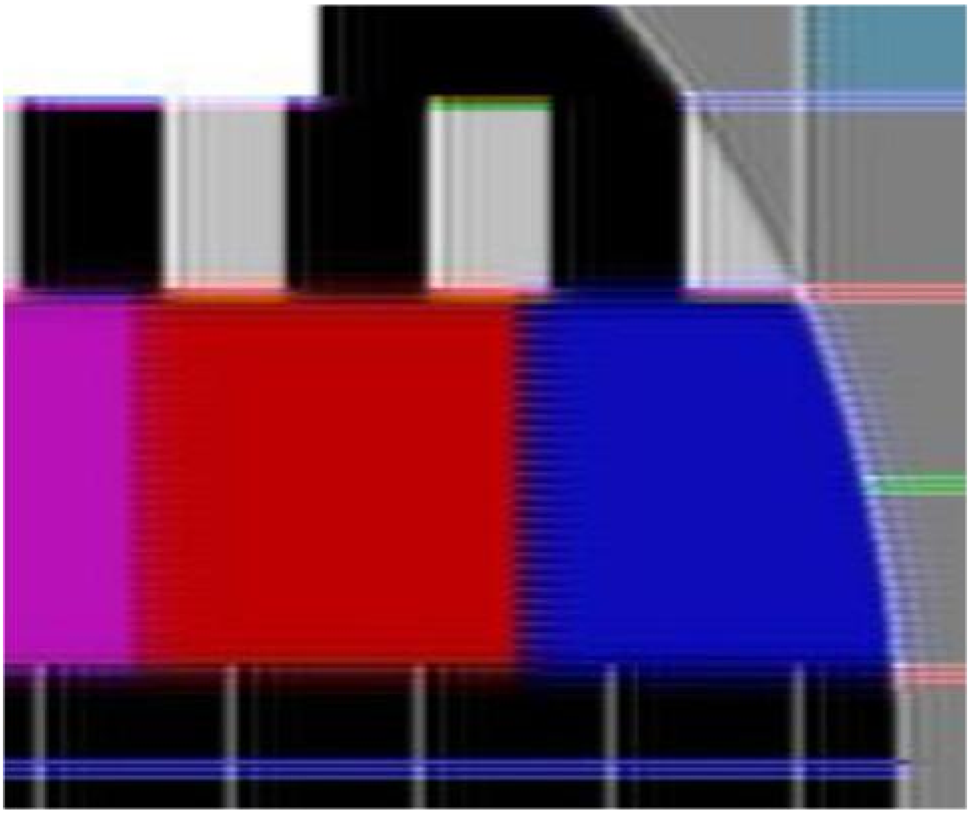

Figure 26: Enlarged section of a simulation with vertical filtering in the encoder according to Griffiths, DE2446376

On March 25, 1976, the later DE2612619 [23] was registered for Gerhard Dickopp, Gerhard Mahler and Werner Scholz, as well as the unissued DE2612620 [24] for Gerhard Dickopp, Gerhard Mahler.

Here, the already known versions with three delay lines from Griffiths [19] and Scholz [20] are first repeated and reasoned for the decoder side. Then, for the encoder side, the low-frequency components of the luminance signal Y (8) are processed using an FIR filter in a circuit according to Figure 15, and the sequential color difference signals (9) are each averaged over 3 lines.

In Figure 27, an improvement can be clearly seen compared to all previous representations: the horizontal white lines are recognizable again, even if they are accompanied by color fringes, and there are various colored transitions in the vertical direction, e.g. white-black and black-white almost disappeared.

However, it remains to be seen that this relatively small improvement in quality would have required a very high amount of hardware.

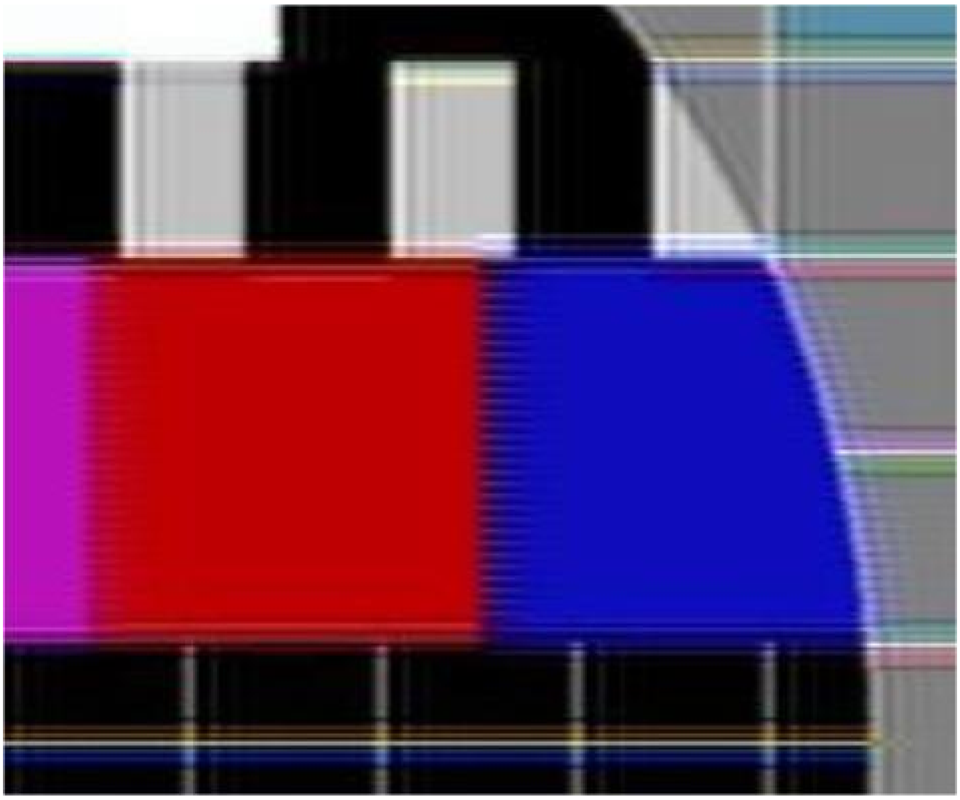

Figure 27: Enlarged section of a simulation with encoding according to Dickopp/Mahler/Scholz DE2612619 and decoding according to Scholz DE2610091

There were a number of other patent applications from those already mentioned, but these did not deal with an overall improvement in quality, but rather with a few peripheral problems.

Since the TED video disc no longer had a future from 1976 onwards, the Tripal color encoding process was no longer needed. Especially as the “color-under” process now was well established for magnetic video tape recorders using FM modulation and helical tracks.

Bibliography

[1] Bruch, Walter: German patent DE1126443B, filed on January 28, 1960

[2] Sony Corporation: English patent specification GB952487, first filed in Japan on March 7, 1960

[3] Bruch, Walter: German display document DE1256686A, filed on April 9, 1966

[4] Bruch, Walter: German display document DE1261876A, filed on October 14, 1966

[5] Bedford, Alda V.: US Patent 2,554,693, filed December 7, 1946

[6] Bruch, Walter: Attempts at recording color images on magnetic tape with simple video recording devices for home use; radio-mentor-electronic (1966) issue 12, pp 987-989

[7] Scholz, Werner: German patent DE1935212B, filed on July 11, 1969

[8] Bruch, Walter: German patent DE1936594C, filed on July 18, 1969

[9] Bruch, Walter: German patent DE1943672C3, filed on August 28, 1969

[10] Scholz, Werner: German disclosure DE1954876, filed on October 31, 1969

[11] Bruch, Walter: Experiments with color recordings on simple magnetic tape recorders; radio-mentor-electronic (1970) issue 12, pp 833-838

[12] Roth, W.: State of development of the video disk system; Funk-Technik (1972) Issue 23, December

[13] Hartmann, Werther: German patent DE2158218 filed on November 19, 1971

[14] Scholz, Werner: German patent DE2161106 filed on December 9, 1971

[15] Scholz, Werner: German patent DE2207021 filed on February 15, 1972

[16] Bruch, Walter: German patent DE2228910 filed on June 14, 1972

[17] Bruch, Redlich, Dickopp: German patent DE2229393 filed on June 16, 1972

[18] Bruch, Walter: German disclosure DE2258867, filed on December 1, 1972

[19] Griffiths, Frank Anthony: German patent DE2446376, first filed in Great Britain on September 28, 1973

[20] Scholz, Werner: German disclosure DE2541348 filed on September 17, 1975

[21] Scholz, Werner: German disclosure DE2610090 filed on March 11, 1976

[22] Scholz, Werner: German disclosure DE2610091 filed on March 11, 1976

[23] Dickopp, Gerhard; Mahler, Gerhard; Scholz, Werner: German patent DE2612619, filed on March 25, 1976

[24] Dickopp, Gerhard; Mahler, Gerhard: German disclosure DE2612620, filed on March 25, 1976