HIGH DEFINITION TELEVISION:-THE TV SYSTEM OF THE FUTURE

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This paper describes the fundamental principles of production and accomplishment of High Definition Television (HDTV)-the television system of the future. It looks at the fundamental parameters of high definition television (HDTV), and shows how the values of these parameters can be derived from consideration of the performance of the viewer's visual system. Bandwidth requirements for various TV and HDTV systems are compared, and a number of optical fibre transmission techniques are considered for HDTV. In conclusion it is stated that the large bandwidths demands of uncompressed HDTV can be met by emerging technology in optical fibre transmission systems-in particular, wavelength division multiplexing (WDM). The paper is as a result of a project study conducted by the author and a colleage when he studied for his degree at Essex University, England. It makes no reference to the development and relevance of HDTV in the African context.

1. INTRODUCTION

Civilisation has developed to a level as we know it today largely due to the human ability to exchange information and ideas by the natural senses of sight and hearing, and by the written word using some form of accepted language or code.

People have constantly searched for means of passing information beyond the normal range of human vision and hearing. We are all familiar with such methods as the Indian smoke signals, beacon fires, and semaphore flag signalling. To quote from P.C. Smale who notes in his book ," Introduction to Telecommunication Systems " that the word 'tele' is derived from the ancient Greek for "at a distance ", "phon" means sound or speech, "graph" means writing or drawing, the following well-known terms have emerged [1]:

Telecommunication--	communicating at a distance
Telephone--	speaking at a distance
Television--	**seeing at a distance**
Telegraph--	writing at a distance

Telecommunication systems are thus concerned with the transmission of information, or messages, from one point to another. As adapted from J.J. O'Reillly [2] an illustrative communication link is shown in figure 1. The message source forms the origin of the message and the destination forms the sink.. This paper primarily deals with the current development of television, particularly high definition television (HDTV).

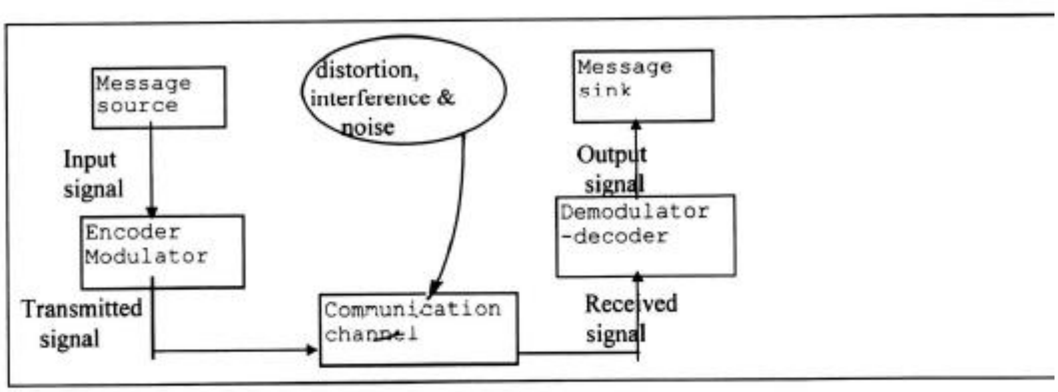

Figure 1 An illustrative Communication Link

2. HISTORICAL BACKGROUND

The term high definition television (HDTV) is used to describe new television systems which are capable of offering a performance and definition sufficiently superior to present day broadcast systems that they are deemed to create a 'new viewing experience '. It is proposed that HDTV must provide pictures with wider formats(much similar to modern day cinema), and have twice the vertical and horizontal detail resolution of present day television systems. These proposals have typically a fivefold increase in source signal bandwidth, and consequently the network and transmission considerations to get these wideband signals to the home are of crucial importance to service providers and network operators such as the South African Broadcasting Corporation (SABC) and the Zambia National Broadcasting Corporation (ZNBC) to name a few.

2.1. HDTV in Japan

HDTV has been under development in Japan for some 20 to 25 years now. The system is known as 'High vision', and a number of manufacturers have already produced a considerable amount of compatible production, transmitting, recording and display equipment. The system has been developed to be truly 'a new viewing experience 'by making it incompatible with the existing television systems requiring expensive equipment to be purchased, both for production in the studio and the future reception or video tape playing in the home.

2.2. HDTV in the USA

In the USA, the New York Institute of Technology has proposed a compatible HDTV transmission system [7]. A standard broadcast television channel is containing the extra resolution and picture information required for high definition. Existing television receivers are able to view HDTV programme material via the standard channel Consumes are still required to invest heavily in the purchase of expensive extra equipment to take advantage of the picture improvement information in the augmentation channel. Despite this, in the North American continent, there is strong support for the Japanese High vision, which has some characteristics convenient for conversion to and from the existing television standard in America and Japan.

2.3. HDTV in Europe

In Europe there is activity in Eureka Project EU-95 on HDTV. This is an industrial project within the European Commission's 'Framework' organisation for collaborative research and development in the economic community [7]. The projects aims are built on the market forecast that in Europe the next generation of standard consumer television receivers will be capable of displaying the multiplexed analogue components (MAC) of the television signal, as transmitted via direct broadcast by (DBS) services. In the short term, European HDTV will utilise the same transmission format as DBS ensuring compatibility of new services for the consumer, and a single television receiver for both DBS and HDTV.

3. IDEAL SCENERIO

The ideal scenario would be one whereby the picture parameters of an HDTV system should match the most sensitive powers of resolution and perception in the human visual system. Although such a system may, at this point in time , present difficulties to manufacturers of source, transmitting and display equipment, advances in the field will undoubtedly enable technology to catch up one day. Additionally, as the performance of optical fibre into the communications networks of the world increases, so the real possibility arises of almost unlimited bandwidth available for wideband services. Hence it is of interest to derive parameters for an HDTV system optimised to the human visual system, and compare transmission requirements to the present and proposed television technologies.

4. PARAMETERS OF HDTV AT ISSUE

The HDTV system can be considered to be an information source of picture samples arranged, according to system parameter specifications, in both spatial (horizontal and vertical) and temporal dimensions, as shown in figure 2, adopted from D I Crawford [7]. The viewer must be presented with sufficient number of television picture lines (vertical resolution), N, so that he/she can resolve adequately high frequency vertical details in the source picture and not detect any line structure due to the scanning process at the source and display. Similarly, along each line, the receiver requires enough samples to match the vertical resolution-which for a picture aspect ratio of (width to height) of 2, will require 2N samples (horizontal resolution). Besides adequate horizontal and vertical spatial resolution, the pictures must be presented to the viewer at a fast enough temporal rate (1/T) to ensure continuity and realism -especially for motion.

There are many other parameters to be considered in an HDTV system, however, besides the basic sampling regime. For the home viewer, various picture aspect ratios and formats have been proposed. Generally, wider, larger picture displays are presumed necessary to complement the improved definition of the system. Some consideration has to be given to interference that may arise from lighting sources with electrical power frequencies that 'beat' with the television picture rate.

Other parameters to be taken into account- particularly in present television systems are the subjective effects of line scanning itself and scanning line interlace. This latter technique of interlacing can be used to reduce the demands on both source and display equipment technology and transmission bandwidths. However, looking to the future, this reduction may be irrelevant in equipment not employing electron beam scanning and transmitting over fibre optic networks where bandwidth compression may be unnecessary. The effects of these parameters which are presently outside the scope of this paper, can be listed down as follows:

4.1. The Kell Effect and Interlace:

This is a direct result of the electron beam scanning processes-which are done at the source and display and causes some subjective viewing effects which have to be considered in any television system. Typically it's value is quoted as 0.7

4.2. Temporal Resolution:

Visual responses to flickering lights and picture repetition rates have been the subject of numerous studies[6]. The special parameter of interest usually quoted is the **critical fusion frequency (CFF)**, which is the modulating frequency at which an amplitude modulated light stimulus appears steady to the viewer. A viewers CFF is a function of a large number of variables, including -stimulus size, luminance intensity, luminance duty cycle, colour, background parameters, scanning method, eye movement etc. Typically, an HDTV picture viewed at a distance of three times the picture height (3H) would subtend a visual angle horizontally of about 30°, and typical white picture luminance level of 100 cd/m would produce a retinal illumination resulting in a CFF of about 60 Hz for the viewers response.

4.3. Spatial Resolution

The spatial response of the human visual system takes the form of a low pass filter. The response is approximately equal in each dimension with a slight reduction in the viewer's resolving power for diagonal spatial frequencies. The cut-off frequencies are termed the observer's **visual acuity**, and are approximately 60 cycles /degree in each dimension for a high brightness and contrast ratio display. The response depends upon a number of parameters including temporal frequency of stimulus presentation (if not steady-state), lighting conditions etc. For a viewing distance of four times the picture height (4H), a visual acuity of 60 cycles/degree represents a vertical frequency of 850 cycles/picture height, and a requirement for 1700 active picture lines. For a viewing distance of 3H, the observer's acuity requires approximately 1150 cycles/picture height and 2300 lines. These requirements are presently considered excessive, and researchers have derived [4] some more manageable figures, which are subjectively only slightly inferior.

4.4. Picture/display requirements

Some subjective tests [4] suggest that an optimal viewing distance for high resolution large-screen pictures is 3H - 4H. For large display with motion, subjects preferred 4H; for mainly static scenes (less intimidating), subjects preferred 3H. Similar tests by various researchers for the best picture aspect ratio at the source/display have suggested ratios with horizontal to vertical dimensions of 5:3, 5.33: 3 (16:9) and 4.85:3 (Fibonacci's Golden Ratio of 1.618 being the limiting value of the ratio between consecutive terms in the Fibonacci series and often found in nature).

4.5. Source lighting

An unfortunate historical result is that television field frequencies derived from the main electrical power supply frequency as evidenced by the current 50 field/s television systems in Europe and 60 field/s television systems in Japan and North America. Occasionally, a situation can arise where 60 Hz field rate equipment is required to operate under 50 Hz lighting conditions (or vice-versa). In the TV studio, DC-powered and incandescent lighting can be used. This alleviates the problem somewhat, as the source lighting does not contain any strong components at multiples of the power source frequency. However, in future situations, HDTV video-conference equipment (for example) with 60 Hz field rate operation, may be required to run in a 50 Hz power environment under fluorescent or gas-discharge lighting. In this case the lighting will flicker at 100 Hz, due to the light peaks during both positive and negative power half cycles.

4.6. Bandwidth requirements

The maximum video frequency, and hence the required luminance channel bandwidth for balanced horizontal and vertical resolution can be worked out by halving the total number of video samples per second, and is given by:

Bandwidth = 0.5 x K x I x N/V x N/H x A x f Hz.
where:

K = Kell effect (0.7)

I = interlace effect (0.65)

V = vertical active picture line fraction (0.95)

H = horizontal active picture line fraction (0.8)

[factors V and H make allowance for the vertical and horizontal scan flyback times required for the source and display process]

N = number of active lines

A = aspect ratio (5.33:3)

f = picture frequency

Assumptions are given in brackets ( ) and bandwidths of about 40 MHz for sequential scan and 49 MHz for interlaced scan have been tested [5].

5. TRANSMISSION

Much of the work on experimental HDTV transmission systems has been concentrated on satellite and radio technology. Optical fibre forms a most suitable transmission medium for wideband services such as HDTV, because of its relatively small size, its wideband capabilities and low-loss characteristics. In particular single mode optical fibre (SMOF) can offer almost unlimited bandwidth, large power budgets, a wide range of components and extensive multiplexing capabilities [7].

5.1. Components

In optical fibre transmission a light source device converts electrical signals into light power, and at the receiver a photo detector is used to reconvert the light into electricity.

At the transmitter, typically a light emitting diode (LED) or semiconductor laser diode (LD) is used. At the receiver, PIN photo diodes (PD) and avalanche photo diodes (APD) are used.

Although an LED's modulation bandwidth may only be narrow, the spectral occupancy after modulation is very broad. Hence the optical coupling efficiency is low into the desired transmission window, and the available transmission bandwidth is limited to 100s of MHz due to material dispersion. Material dispersion occurs when the fibre material causes wavelength-dependent speed changes in the propagating signals. Edge emitting LEDs offer improvement in optical coupling and spectral bandwidth. LDs can be modulated up to 1 or 2 GHz and produce a very narrow spectral width of high directivity for coupling. These devices are suitable for long distance wideband transmission. Both PIN-PD and APD detectors at the receiver can operate up to several GHz. An APD has a high sensitivity as it employs electron multiplication, and is suitable for long distance digital transmission where the signal/noise ratio (SNR) may be low. When a high SNR is essential, as in analogue systems where information is not so robust, a larger received optical power budget is usually allowed for, and a PIN-PD often suffices.

5.2. Fibre

Optical transmission can be achieved via multimode (MM) or single mode (SM) optical fibre (OF). In the former, the larger core size simplifies splicing and power coupling, but the manufacturing process is more difficult and (now) more costly. SMOF offers low losses and almost unlimited bandwidth potential at the lower wavelenght windows, but requires careful splicing, coupling and connecting.

5.3. Networks

The larger bandwidth demands of uncompressed HDTV signals can be easily accommodated by the enormous bandwidth potential of SMOF systems. Full exploitation of SMOF would undoubtedly require extensive multiplexing of HDTV channels. Various systems can be implemented, depending upon whether analogue or digital transmission is required and wavelength division multiplexing (WDM) or time division multiplexing (TDM) is being employed.

5.4. Single HDTV channel

It can be noted with reference to section 4.6 that uncompressed HDTV components can occupy a bandwidth between 17 and 49 MHz, according to the system parameters.

Typically, allowing for today's technology and cost limits, a component analogue bandwidth of 20 - 30 MHz is assumed. Similarly, for digital transmission, time division multiplexing of the component data streams results in serial bit rates of 1.8 Gbits/s (for RGB tristimulus components). The simplest transmission scheme for uncompressed HDTV would appear to be RGB analogue channels over three fibres or in a three wavelength WDM over one SMOF. However, in considering the relatively small modulating bandwidths, the problems of matching three separate channels, the non-linearities, the poor receiver sensitivity and cost, these methods are suitable only for transmission within the HDTV studio, where it is important to preserve the absolute integrity of the signal. A better alternative for transmission in the network is frequency modulation (FM) or phase modulation (PM), which will enable better linearity and sensitivity to be achieved The uncompressed three analogue HDTV components could be frequency division multiplexed (FDM) to combine the components into a single (say) 120 MHz channel, and its electrical signal made to modulate the frequency of the LD optical transmitter. For digital working, the same optical equipment would be used and would be modulated by the 1.2 Gbits/s digital data stream (for example).

5.5. Multiple HDTV channels

Multiple HDTV channels can be multiplexed for transmission by either TDM or WDM techniques. In terms purely of power budget considerations, WDM is always capable of supplying more customers at any bit rate, than TDM. This is because WDM is only limited by the small fixed loss in the WDM components. At this point in time, TDM appears to be more effective for large number of subscribers at the lower bit rates. High bit rate services such as HDTV appear better served by WDM. Future development of WDM coherent technology will further enforce this result, despite the development of electronic multiplexing and switching above 565 Mbits/s

6. CONCLUSION

It can be stated in conclusion that HDTV picture quality will not be permanently restricted due to present-day technology limitations. Existing systems, requiring 17-25 MHz luminance bandwidths, may be superseded by future systems matching the human visual system's most stringent demands, and requiring 40-50 MHz luminance bandwidth. The addition of chrominance information could increase the total source bandwidth to a figure well in excess of 100 MHz.

The enormous bandwidth requirements of uncompressed HDTV signals can be met by the emerging technology in optical fibre transmission systems. In particular, wavelength division multiplexing appears to offer particular suitability for multiple channel HDTV services.

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