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(10/2010)

**Technologies in the area of extremely
high resolution imagery**

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Technologies in the area of extremely high resolution imagery

(Question ITU-R 40/6)

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1 Introduction

Throughout this Report a hierarchy of spatial resolutions, which is recommended in Recommendation ITU-R BT.1201 and also given in Table 1, is adopted to classify spatial resolution of pictures in extremely high resolution imagery (EHRI). The limitation of available technologies in this area used to force us to stay mainly in still (non-real-time picture) image applications for higher resolutions. Recently real-time systems for higher resolution systems are reported though those are still in the experimental stage. Basically real-time applications in this area can be defined in terms of frame repetition rates independent of the spatial resolution hierarchy.

The attention of the reader is drawn to Table 19 where some questions have been raised that need further study.

TABLE 1

A hierarchy of spatial resolution in EHRI

	EHRI-0	EHRI-1	EHRI-2	EHRI-3
Spatial resolution (number of samples)	$1\,920 \times 1\,080$	$3\,840 \times 2\,160$	$5\,760 \times 3\,240$	$7\,680 \times 4\,320$

The hierarchy is based on the well accepted 16:9 picture aspect ratio.

EHRI-1 to 3 are simple integer multiples of EHRI-0 pixel counts, namely $1\,920 \times 1\,080$, in horizontal and vertical directions, i.e. the multiplier is the suffix value plus 1.

The EHRI hierarchy in Table 1 is in spatial domain and is independent of the temporal axis. In the real-time case, images are classified by specifying the frame rate in the temporal axis.

1.1 EHRI systems under development in Japan

Recent findings on EHRI technology development have proved that real-time systems in the area of EHRI-1, 2 hierarchy defined in Table 1 are possible. They are still under development and dissemination of devices for EHRI and products to support practical applications is considered to be still several years away. However, an advent of a killer application of EHRI will surely accelerate the development of essential devices and thus system components.

TABLE 2
**EHRI hierarchy and major system parameters EHRI systems
under development in Japan (September 2002)**

Affiliation	System parameters						Developed hardware
	EHRI hierarchy	Aspect ratio	Horizontal resolution (pixels)	Vertical resolution (pixels)	Frame rate (Hz)	Scanning	
CRL and JVC	EHRI-1	16:9	3 840	2 160	30/60	Progressive	Camera and display
NTT	EHRI-1	16:9	3 840	2 160	24/48/(96)	Progressive	Display
NHK	EHRI-1	16:9	3 840	2 160	60	Progressive	Camera (developed one year before in 2001)
NHK	EHRI-3	16:9	7 680	4 320	60	Progressive	Camera and display

CRL: Communications Research Laboratory

JVC: Victor Company of Japan

NTT: Nippon Telegraph and Telephone Corporation

NHK: Japan Broadcasting Corporation

NOTE 1 – The experimental systems are reported to ITU-R as a contribution in September 2002.

CRL and JVC have jointly developed a camera and display system with 2 000 scanning lines called Quadruple HDTV. The camera system employs three CMOS sensors of $3\,888 \times 2\,192$ pixels and outputs the video signals in four channels of high-definition television (HDTV) signals. The projector employs three LCD panels of $3\,840 \times 2\,048$ pixels. The light output of the projector is 5 200 lm and the contrast ratio is more than 750:1. The resolution of this system corresponds to 2×2 times of $1\,920 \times 1\,080$ pixels.

NTT has also developed a digital cinema system that can store, transmit, and display images of 2 000 scanning lines, with 10-bit each for *R*, *G*, and *B* components. The projector of the system is the same as that of CRL-JVC. Image sources of the system are 35 mm motion films of 24 Hz and the system operates at a frame rate of 24 Hz or 48 Hz. The projector displays the images with a refresh rate of 96 Hz in order to avoid the flicker disturbance. The resolution of this system also corresponds to 2×2 times of $1\,920 \times 1\,080$ pixels.

NHK has developed an EHRI-3 system including a video camera and a projector display succeeding their previous system based on EHRI-1. In order to realize this system, four panels for both CCD and LCD are employed. As the maximum number of panel pixels currently available is $3\,840 \times 2\,048$ for both CCD and LCD, four panels (two panels for greens, one for red and one for

blue) are combined to realize a resolution of $8\text{ k} \times 4\text{ k}$ pixels. The two green panels are arranged by the diagonal-pixel-offset method to achieve the resolution. The resolution of this system corresponds to 4×4 times of $1\,920 \times 1\,080$ pixels.

1.2 $1\,920 \times 1\,080/60$ Hz progressive technologies in Japan in the year 2003

1.2.1 $1\,920 \times 1\,080/60\text{P}$ current technology status

– Camera system bases on 2/3 inch CCD technology

A $1\,920 \times 1\,080/60\text{P}$ (60 frames/s) camera with three CCD devices for each *RGB* colour, has been developed as an experimental progressive scan HDTV camera in NHK of Japan in 2003. The horizontal and vertical resolutions of this camera are about 1 000 TV-lines each, and the vertical MTF (modulation transfer function) response is about 57% on 700 TVL and 30% on 1 000 TVL.

– 60P display devices available as products

It had been long believed that it is difficult to realize $1\,080/60$ Hz progressive CRT monitors since the response of horizontal deflection of CRT tube needs certain amount of time to settle itself in a stable condition. A novel technique can overcome this problem without changing the response of the deflection circuit of monitors. With a little bit higher response of the video circuit and the use of higher memory readout speed, the picture part of video signal can be squeezed in time domain and will leave a wider horizontal blanking period in the video signal. With this technique $1\,920 \times 1\,080$ 60 Hz progressive scanning is realized. A professional monitor product is available from one of the broadcast products manufactures in Japan using this scheme. The scanning specification of the CRT monitor covers not only 24P but also 60P.

– 1080/60P interface

To make a $1\,080/60\text{P}$ system feasible, interface for the system components is considered to be essential. Fortunately there is an SMPTE standard, SMPTE 372M-2002, to use for the links between the equipment. The title of this SMPTE standard is “Dual Link 292M Interface for $1\,920 \times 1\,080$ Picture Raster”. The SMPTE standard uses two HD-SDI connections to transmit 2.970 Gbit/s data. The specification includes $1\,920 \times 1\,080$ 60P/4:2:2/10-bit interconnections. Here, each link is specified in Recommendation ITU-R BT.1120 and can carry a 10-bit serial data stream defined in Recommendation ITU-R BT.709.

1.2.2 The technologies and products within the foreseeable range

– Projectors available before the end of 2004

The availability of $1\,080/60\text{P}$ projectors is a product planning issue, and not so much a technological issue. The processing speed is a key technological issue for projecting progressive signals. However, this issue is not difficult, and is rather straightforward. It does not require a novel technique to achieve.

The real issue is to develop a projector that meets the demand and the competitive pricing of the market. One of the broadcast products manufactures in Japan is currently planning to release a full $1\,920 \times 1\,080$ projector before the end of 2004. This multi-scan projector covers 50P and 60P projection in its specification.

– CCD and CMOS devices for 1080/60P cameras

For acquisition purposes, it is necessary for us to be provided with 60 Hz progressive cameras to have a genuine 60 Hz progressive environment. It is a well-known claim that an optical sensor for the $1\,080/60\text{P}$ camera will be realized with the refinement of a current CCD device. Around this frame rate the CMOS optical sensor which can provide higher processing speed need not be

required. It is also understood that a camera system with the CMOS device will also be available in parallel with CCD based 60 Hz progressive cameras.

– **Storage devices**

The data rate of $1920 \times 1080/60$ Hz progressive format is two times higher than that of $1920 \times 1080/60$ Hz interlace. In order to record $1920 \times 1080/4:2:2/10$ bit/60 Hz progressive signals on tape it is necessary for a digital VTR to handle approximately 1.24×2 Gbit/s of data for net video only. Compression technology is widely applied to video recording and the picture quality is well accepted. Under the current product line-up of VTRs in several manufactures there are recorders which can record 880 Mbit/s of net video rate. The combination of these technologies makes a recorder for 1080/60 Hz progressive quite feasible. One of the broadcast products manufacturers in Japan has released the specifications of a VTR product which is a portable VTR of the HDCAM series of products. The VTR can record $1920 \times 1080/4:2:2/10$ bit/60 Hz progressive signals with a compression factor of 2.7.

1.2.3 Summary

Japan contributed a progress report to the Radiocommunication Study Group 6 block meetings in the year 2002 on the subject of EHRI. In this Report several EHRI systems are reported to be progressive and have adopted the frame rate of 60 Hz. The systems reported are under experiment but several products which support 60 Hz progressive are already available. As the voices of customers accumulate toward 60 Hz progressive applications, it is a natural tendency that the family of products suitable to those applications should increase. There are clear technology trends to respond to such expectation.

1.2.4 Bibliography

Document 6-9/52, Document 6P/137 – Progress report on extremely high resolution imagery applicable to digital cinema, contribution by Japan.

Contribution Document to AHG on D-cinema in September 2001 – Ultra-high definition video camera, by NHK Science & Technical Research Laboratories.

SMPTE 372M-2002 – Dual Link 292M Interface for 1920×1080 Picture Raster, Society for Motion Picture and Television Engineers.

2 Overview of current EHRI technologies

2.1 Still and picture-by-picture image processing (current practice in programme making)

It is well known that in films of recent release digital film optical effects are often used intensively and the advanced picture processing makes the films very attractive to the majority of audiences. The digital film optical effects, i.e. electronic processing on film, set a new stage for film-making, efficiently replacing the previous film optical processes by the cost-effective and well-established studio post-production techniques. These are compositing with computer-generated graphics, film matting and compositing by blue-screen keyer, retouching of scenes to remove unwanted landscapes and colour and gradation changes for old and decayed films.

There are several such systems available in the market and they are successfully used. The whole system comprises a CCD film scanner, an output film recorder and a signal processing facility based on high-speed workstations. Workstations and relevant software packages are usually used to realize these effects. The equipment can process film quality pictures in the area of EHRI; that is more than 40 times conventional TV signal resolutions.

2.2 Computer graphics (CG)

Various high quality graphic images are generated on computers. The images are generated in non-real-time, and there are no serious problems involved in this technology area. If disk storage capacity to store the images is large enough and a high-speed computer is used, parameters such as spatial resolution, screen aspect ratio, temporal resolution and others, can be set, in principle according to the demands. However, creation of moving images on a real-time basis is difficult to realize with current technology. It depends on the complexity of the image to be produced and the CG technology used. Image generation by a simple CG technology makes some applications, such as virtual reality systems, flight simulators and game machines, possible in real-time.

For current HDTV programme production, approximately 0.25 h is required using an 800 MIPS computer to generate one frame of a human image. If an EHRI-3 level of image is to be produced with the same technology, four hours will be needed to generate a 4×4 times higher resolution image. Availability of huge CPU power in terms of MIPS and an adoption of dedicated graphics engines are always the key for generating high resolution images in CG.

3 Technologies and devices for EHRI realization

3.1 Display devices

The number of HDTV display monitors for high-grade home use in Japan has begun to increase following the successful introduction of digital satellite broadcasting service for HDTV. The price of such monitors is becoming significantly lower compared to the past.

Personal computers are also becoming popular not only in the office but also in each individual home all over the world. The phenomenon has coincided with the wide penetration of the Internet. The GUI for the “Windows” machines requires much higher display capabilities than VGA (640×480), such as XGA (1024×768), and SXGA (1280×1024). Displays for typical workstations hold a resolution of SXGA or UXGA (1600×1200). Toward the year 2005 WUXGA (1920×1200) and QXGA (3200×2400) TFT liquid crystal display (LCD) monitors will be available in the market and will be used in certain applications.

With the advent of multimedia age and especially after the emergence of interactive applications on TV, requirements for a display have changed. Such a display has to have a characteristic of both TV and PC display. Those two are different in the following respects:

- Gamma non-linearity of a cathode ray tube (CRT) display is pre-equalized before broadcasting, while pictures generated by a PC do not have any pre-equalization. Simultaneous display of those two different pictures on the same screen is therefore a compromise.
- Uniformity of picture resolution across the screen is the essential requirement for any PC monitor. On the other hand a TV monitor does not require uniformity but rather requires higher luminosity. Those two characteristics are difficult to maintain on the same display monitors.
- Generally, TV displays have around 10% over-scan. PC displays do not have any. Besides the CRT, there are several other alternative new display technologies available now. Projection-type displays and panel displays have been developed to provide a larger screen size, which is important for sharing common pictures among a large number of audiences. CRT, liquid crystal on silicon (LCOS), and digital micro-mirror device (DMD)

technologies are used for projection-type displays. Plasma display panel (PDP) technology is used widely for flat panel displays. Various sizes of liquid crystal (LC) panel displays are becoming popular. Fifteen inch XGA, 17 inch SXGA, and 24 inch WUXGA LC panel displays are available for computer display. TV display applications of the LC panel are also becoming popular and 28 inch panels are currently available for the applications.

Both CRT and PDP use electro-luminescent effect of G/B/R phosphors. On the other hand, the LC device controls the amount of light which is generated by a light bulb, and the DMD device, by switching mirrors on and off, reflects the light projected on it to a lens block. For colour display, red, blue and green lights are separated from a single light source by “dichroic prism” and are subsequently led to the modulation block of each projector.

3.1.1 CRT displays

For CRT displays with an image size of about 20 inches, a resolution of around 1000 lines is achievable at a shadow mask pitch of about 0.3 mm. In high-level workstations, a pitch of 0.15 mm has already been achieved. The mask pitch depends on many technical factors, like the thickness of the mask and manufacturing conditions. With the present technology level the limit is estimated to be about 0.16 mm in the 40 inch size of CRT. Current spot size of the electron beam is around 1-2 mm. To have higher resolution it is necessary to reduce the size of the spot to around 0.5-1 mm.

It is also necessary to increase the driving speed of CRT deflection circuitry. This is achieved by reducing the width of the deflection yoke wire and by lowering the loss at the core. To reduce deflection errors a digital compensation circuit will be necessary.

Table 3 shows typical high-resolution applications of the CRT display and some of the parameters of available products in the market.

TABLE 3

Some CRT display products available for high-resolution applications

Area of application		Medical	Graphic display	HDTV display monitor
Display	Size	21 inch	32 inch	30 inch
	Aspect ratio		1:1	19:6
Pixel number		2 048 × 2 560	2 048 × 2 048	1 920 × 1 080
Phosphor pitch		None colour continuous (black and white)	0.31 mm	
Contrast ratio		10 bit D/A		
Scanning	Horizontal	186 kHz	126.8 kHz	
	Vertical	72 Hz non-interlace	60 Hz non-interlace	
Physical size	Depth		1 000 mm	
	Weight		100 kg	