Development of 45-inch High Quality LC-TV

Yasuhiro Yoshida, Hiroyuki Furukawa, Masafumi Ueno, Eiji Ikuta, Scott Daly, Xiaofan Feng, Ibrahim Sezan, Yuji Kikuchi, Toshiyuki Fujine, Michiyuki Sugino

SHARP Corporation, JAPAN

Abstract

Sharp has developed industry's largest high-definition LC TV, Aquos LC-45GD1. In this paper, we discuss its 10-bit signal processing as one important enabler of its excellent picture quality. Utilizing 10 bits signal processing, in combination with full-spec High-Definition panel and "Intelligent Environment Illumination Sensor", we have succeeded to realize a beautiful gigantic LC TV.

1. Introduction

Sharp Corporation has introduced into the world- wide market the LC-45GD1 AQUOS 45V-inch High Definition LC TV. It is the industry's largest LCD model with HD-ready input, featuring a full-spec high-definition panel of 6.22 million dots (1920Hx1080VxRGB), industry's highest level in a 45V-inch size. This model has been manufactured at our Kameyama Plant, the world's first integrated production facility for LC TVs – from fabrication of the LCD panel to final assembly.

In this paper we discuss how superior picture quality of the LC-45GD1 is realized by applying new technologies that are based on human visual system (HVS) modeling and combining such technologies with a full-spec HD LC panel.

Table 1. Specifications of the LC-45GD1

LCD Panel	Screen size	45V 98.6cm(H)×55.5cm(V)
	Driving	TFT active matrix LCD
	Picture dots	6,220,800dots(1,920(H) x 1,080(V) x RGB)
	Intensity	450cd/m^2
Power supply		AC100V 50/60Hz
Power consumption		315W
Channels		VHF 1 -12ch、UHF 13 -62ch、CATV13 -63ch、 BS digital 000～999ch、CS digital 000 -999ch、 Digital terrestrial 000 -999ch

2. New-Aquos Platform

We have developed new digital image processing engines that are exclusively developed for the full-HDTV LC TV as "New AQUOS platform" shown in Figure 2.

At the heart of the new-Aquos platform, there are two new engines that were developed separately for high quality signal processing and quality enhancement of the LC panel, in which both of them were optimized for its requirement respectively. The core technology for both engines is the 10 bits signal processing path for each one of R, G and B color channels. The 10 bits signal processing path makes it possible to display four times higher density of gray levels than the conventional LC TV.

(1) LCD Panel Driver Engine: A new engine that is equipped by our original bit depth extension circuit[1]. This unique algorithm is based on the application of HVS such that it can drive full-spec HD panel under visual accuracy of 10 bits for each of one of the R, G, and B channels.

(2) Digital Imaging Engine for enhanced picture quality: An original engine for high quality digital imaging that includes 10 bits signal processing units for all of I/P conversion, scaling, noise reduction, edge enhancement, color management, and active contrast control.

Using 10 bits signal processing, the LC-45GD1 will render extremely high-quality pictures on its large LC screen especially for high SNR signal sources such as digital HDTV broadcasting and DVD movie playback. In addition, with the use of the full-spec HD panel, high definition representation as well as natural representation is realized by LC-45GD1. By taking advantage of both panel and source, even delicate texture of human face can be represented accurately and naturally.

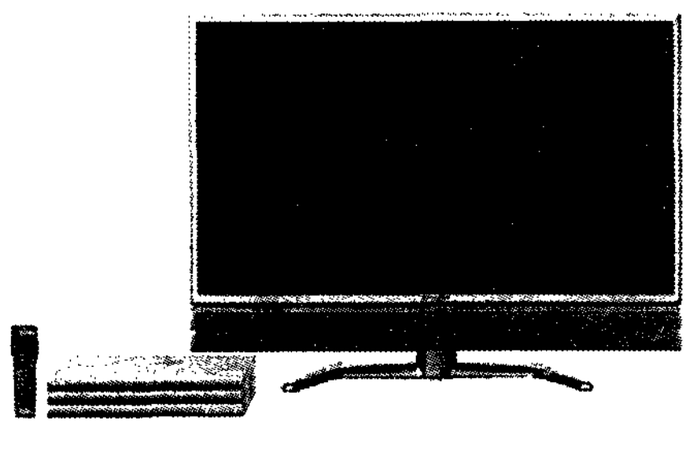


Figure 1. The LC-45DG1

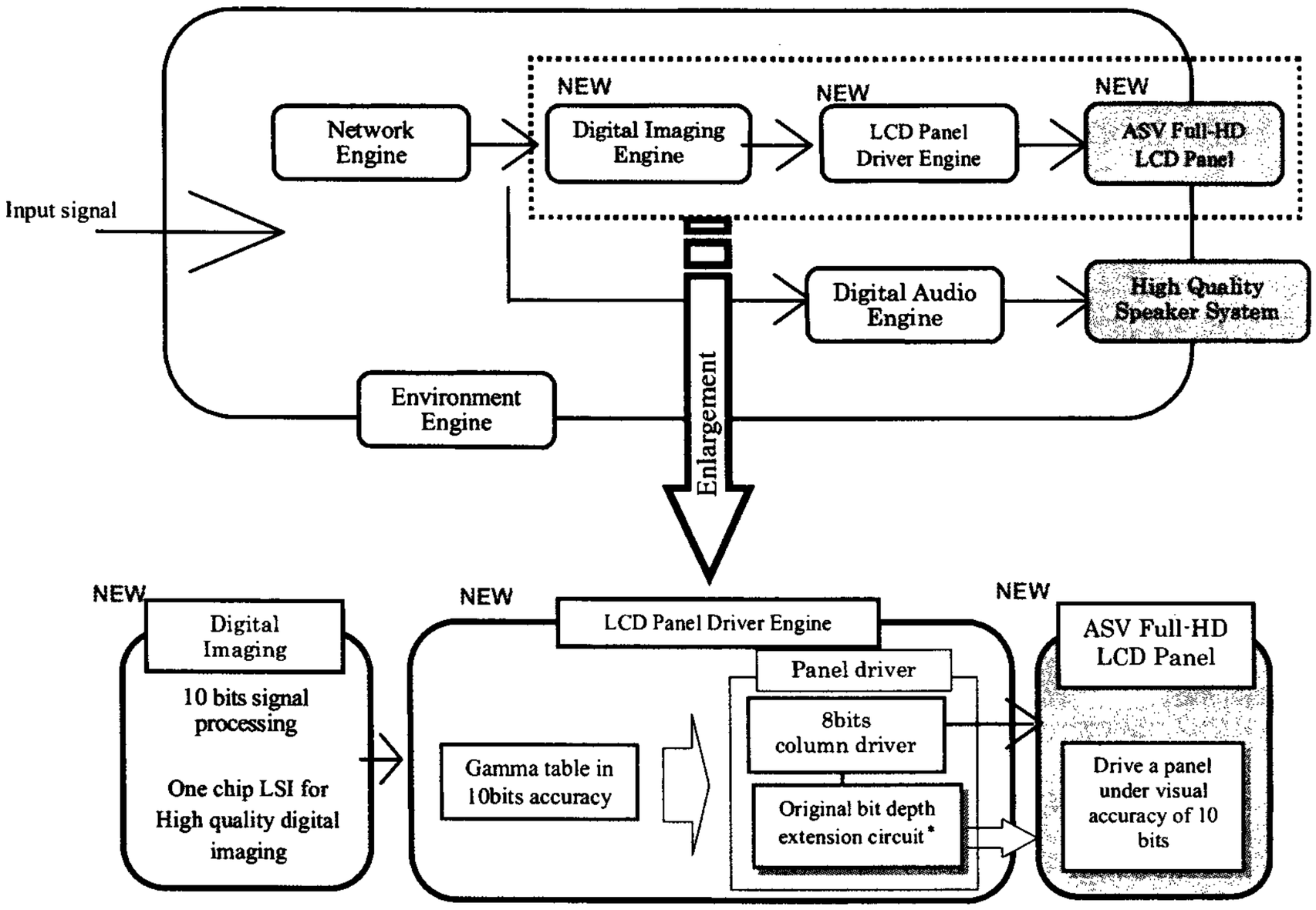


Figure 2. General block diagram of the new generation Aquos platform developing for full-HDTV application.
*Original bit depth extension circuit: This unique circuit is based on an application of the Human Visual System such that it can drive full-spec HD panel under visual accuracy of 10 bits, that is usually limited for 8 bits due to column driver.

3. Key Technologies

One of the new features of the Sharp LC-45GD1 is the 10 bits signal processing circuitry. It reduces the visibility of false contour artifacts significantly. From color perception point of view, Miyahara et al.[2] have reported that a bit depth of R:G:B=10:12:9 bits is needed to keep the color difference due to quantization error below a detectable threshold for a display with 1000:1 dynamic range and γ=3.0. However, since the threshold is affected by (1)step difference in intensity corresponding to quantization error, (2)spatial frequency content of contours, which determines the visibility of the contour by the human visual system, and (3)light adaptation status of HVS. Since the spatial frequency response and light adaptation were not considered at Miyahara's report, we performed a subjective experiment to determine the visibility of contour artifacts at 10 bits under a variety of display and viewing conditions based on the above three attributes[3].

3.1 Preliminary experiment: Deficiencies of 8 bits

It is widely known that the maximum bit depth of the most LCDs is 8 bit per color channel, i.e. R:G:B =8:8:8 bits, so we first initiated a subjective evaluation to determine how much of the contour artifacts are actually visible as a result of 8 bits quantization.

The experimental conditions are listed in Table 2. The LC-45GD1 was set in a room with adjustable lighting system. As shown in Table 2, we have utilized a couple of conditions that relate the above-mentioned attributes. Figure 3 shows a set of test images that we used. The key attributes are zero noise and very low gradient; these ramps span a very limited span of the total. The quantization to 8 bits causes steps to appear in the ideally smooth ramps. These test images are generated at PC and displayed on the LC-45GD1. Observers viewed test images at a viewing distance of three picture heights and used a five-grade impairment scale. The legend is as follows: 5:imperceptible, 4:perceptible, but not annoying, 3:slightly annoying, 2:annoying, 1:very annoying that is shown below.

Figure 4 shows experimental results at the maximum intensity of 320cd/m^2 with 4 different lighting levels. The subjective mean opinion score (MOS) for two observers are reported

Table 2. Experimental conditions

Attributes	Corresponding parameter	Conditions
Amount of quantization error	Maximum brightness	450cd/m^2, 320cd/m^2, 150cd/m^2
Spatial frequency of the contour	Slope of grating	Table.3.
Adaptation status	Illuminating condition	Dark room, 100lux, 600lux, 3500lux

Table 3. Specification of the test images used

Chart No.	Left	Center	Right	Spatial freq. of the bar(cpd)
1	0	127	255	5.6
2	0	31	63	1.6
3	64	95	127	1.6
4	128	159	191	1.6
5	192	223	255	1.6
6	32	39	47	0.4
7	48	55	63	0.4

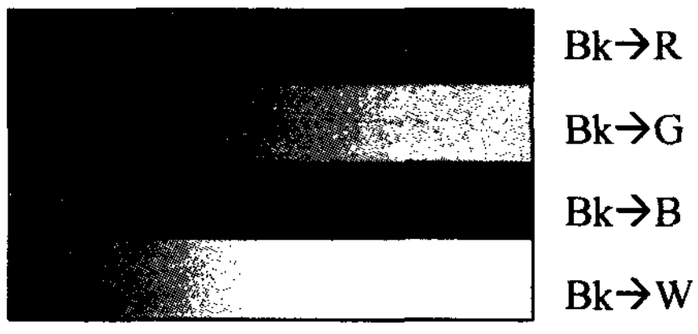


Figure 3. Test image used

at the bar graph. The MOS is dependent on both the lighting condition and the test charts. The false contours of the LCD at R:G:B=8:8:8 bits were clearly visible for most lighting conditions.

3.2 Picture quality evaluation of 10 bits

We increased bit-depth to 10 bits and performed a similar experiment to the previous experiment. Figure 5 depicts the results for the 10 bits case. When compared with the 8 bits case as shown in Figure 4, all subjective scores are improved significantly for all test images under all evaluation conditions. The subjective results show a drastic decrease in the perceived visibility of false contours.

Also we confirmed that the contour artifacts were not visible under all experimental conditions down to the room lighting of 100 lux. Under the dark room conditions, the contours were slightly perceived for the high intensity test images of 6 and 7(*). This means that even in the 10 bits system, there is still a perceptible false contour, according to a mutual relationship between maximum intensity of the display and environmental illumination condition.

However, in other words, this means that LC TVs in which contour artifacts are never perceived (i.e., contour-free) can be realized with 10 bits if only the maximum intensity would be adaptively controlled according to the environment illumination condition.

(*)They have the same spatial frequency content of contours in Table 2, and 1/4th of the brightness difference, i.e., a gentler slope than the previous case.

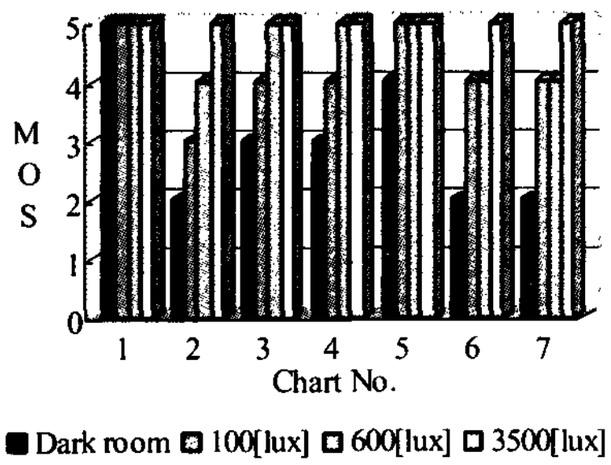


Figure 4. An example of the subjective evaluation results for the bit depth of 8 bits at 320 cd/m^2.

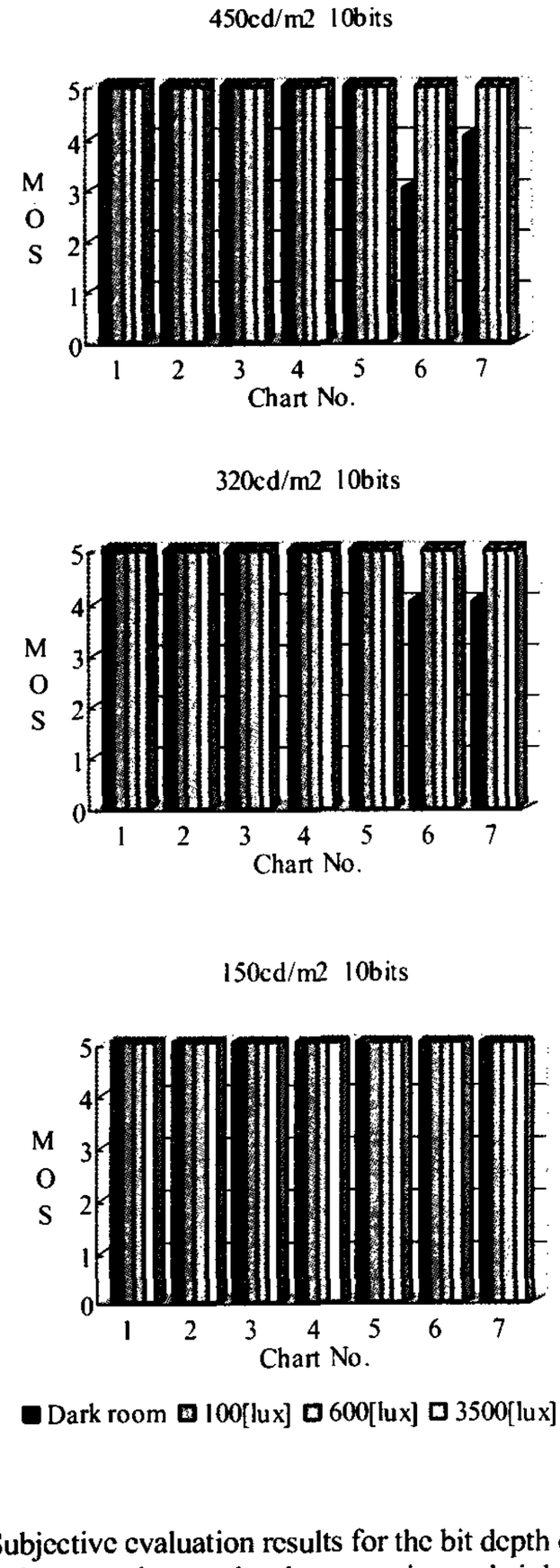


Figure 5. Subjective evaluation results for the bit depth of 10 bits. From top to bottom, the graphs show maximum brightness of 450cd/m^2, 320 cd/m^2 and 150 cd/m^2, respectively.

4. Adaptive Control for Picture Quality Optimization

In order to optimize the picture quality under 10 bits signal processing, the LC-45GD1 is equipped with a picture quality optimization technology called "Intelligent Environment Illumination Sensor", which makes it possible to control the intensity of backlighting system depending on an environment illumination condition. Depending on the adaptation characteristics of the HVS to the ambient illumination condition, the sensor automatically controls a maximum intensity of the LCD screen. Thus the LC-45GD1 has achieved the highest quality picture, without contour artifact. For example, for any possible ambient condition, LC-45GD1 is capable of representing visually optimal pictures, even for a low contrast source picture under a dim viewing condition such as shown in Figure 6.

In addition to the features explained above, the use of 10 bits signal processing has other advantages. The LC-45GD1 is equipped with gamma correction table in 10 bits accuracy for each one of the R, G, and B channels independently. This is very effective for not only accurate gamma correction but also for making it possible to achieve accurate color balance. This in effect improves gray color tracking for the entire gray scale and reduces the visibility of a non-uniformity at inflection points of the gamma curve[4].

5. Conclusion

In this paper, we have explained important features of the 45-inch LC-TV of LC-45GD1. Especially, we have concentrated on improvements to picture quality by means of 10 bits signal processing. The technology that supports these features is being realized at both "LCD Panel Driver Engine" and "Digital Imaging Engine for enhanced picture quality", that are exclusively developed for the full-HDTV LC TV as the main building blocks of the "New AQUOS platform".

By combining a full-spec HD panel and the 10 bits circuit, it is possible for LC-45GD1 to reproduce an extremely fine and smooth representation of the source on the screen.

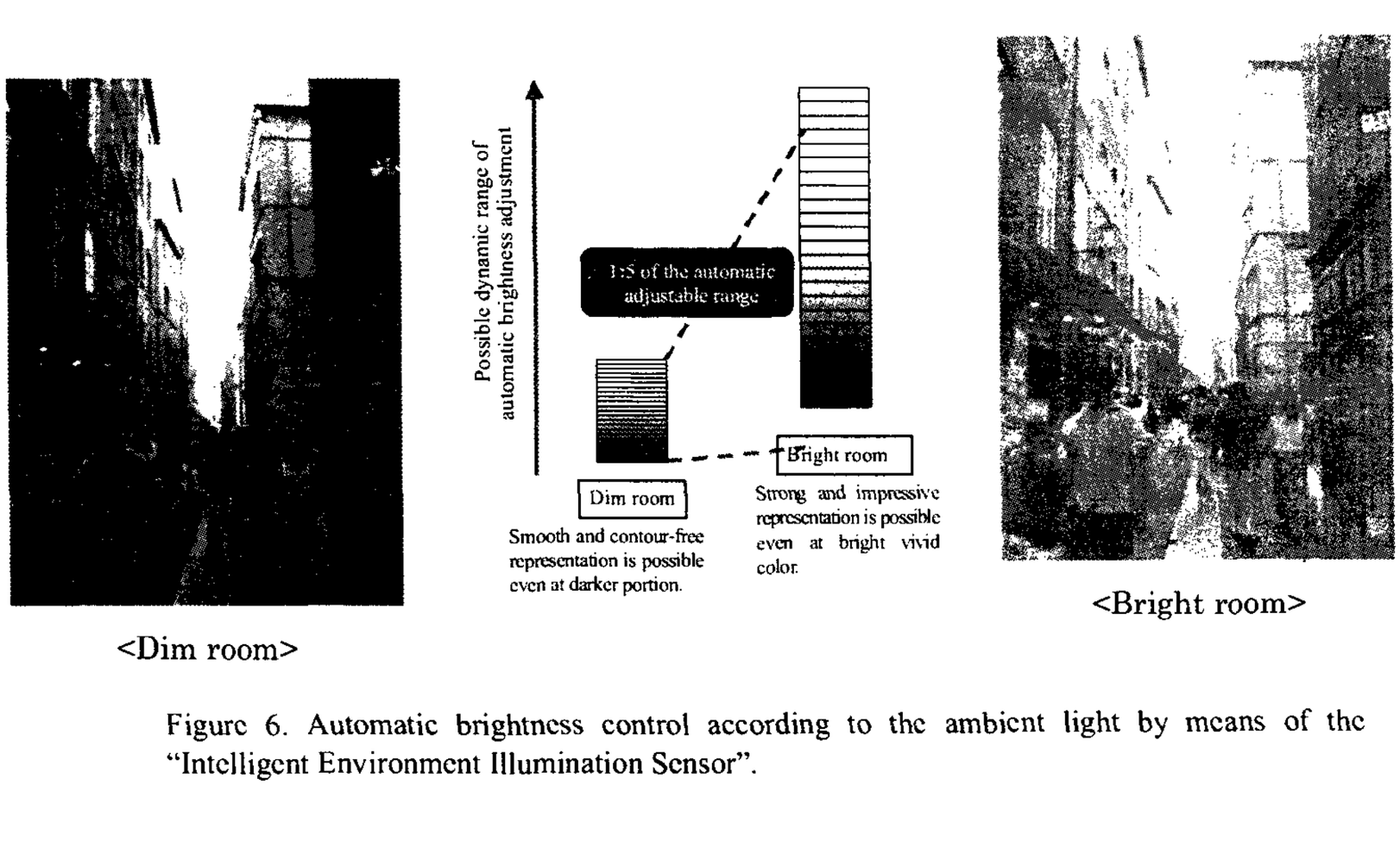
6. References

[1] S. Daly and X.F. Feng: "Bit-Depth Extension: Overcoming LCD Driver Limitations by Using Models of the Equivalent Input Noise of the Visual System, SID Conference 2004, Seattle WA, May 2004.

[2] M.Miyahara, T.Ino, H.Shirai, S.Taniho and R.Algazi: "Important factors to Convey High Order Sensation", IEICE Trans on Commun., Vol.E81-B, No.11, 1966-1973, November 1998.

[3] Y.Yoshida, Y.Yamamoto: "High Quality Imaging System", PICS Conference, Portland OR, USA, April 2002.

[4] Y.Yoshida, Y.Yamamoto: "Beyond 8 bits LCD Imaging System", SID Conference 2002, Boston MA, USA, May 2002.



<Dim room>

<Bright room>

Figure 6. Automatic brightness control according to the ambient light by means of the "Intelligent Environment Illumination Sensor".