Progress on Super Hi-Vision Image Sensors

8k Super Hi-Vision (SHV) is a high-presence broadcasting system consisting of ultra-high-definition video with approximately 33 mega-pixels (7,680 x 4,320 pixels), and 22.2 multi-channel 3D audio. Till now, development of SHV has aimed for a frame frequency (number of frames per second) of 60 Hz with progressive scan. However, fast moving subjects cannot always be reproduced with good image quality at a frame frequency of 60 Hz. For this reason, the International Telecommunication Union – Radiocommunication Sector (ITU-R) has recommended that a frame frequency of 120 Hz be added to the video parameters. In order to obtain video in this new format, NHK STRL is conducting R&D on an SHV image sensor with 33 mega-pixels, a frame frequency of 120 Hz, and 12-bit quantization. This article describes the progress we made in developing this image sensor.

1. Introduction

SHV is a next-generation broadcasting system that will have 33 mega-pixel (7,680 x 4,320 pixels) ultra-high-definition video and 22.2 channel 3D sound. It is able to convey strong sense of presence and realism through its wide horizontal field of view (100° at a viewing distance of 0.75H[*1]). In fact, the pixel structure of SHV is imperceptible at a viewing distance of 0.75H.

In order to reproduce natural images, not only the resolution of the images must be increased; so must the image quality of video showing motion. So far, SHV systems have used progressive scanning at a frame frequency of 60 Hz , but it has become clear that a higher frame frequency is needed to improve the quality of video depicting motion[1)2)]. In response to this need, the ITU-R has published recommendation BT.2020, which adds a frame frequency of 120 Hz to the earlier 60 Hz specification for SHV[3)]. Table 1 shows some of the parameters of SHV video, as specified in ITU-R BT.2020. For the remainder of this article, the 120-Hz, wide-color-gamut version of SHV will be referred to as *full-spec SHV*.

Table 1: SHV Video parameters (from Rec. ITU-R BT.2020)

Item	Parameter
No. of effective pixels	7,680 (H) x 4,320 (V)
Frame frequency (Hz)	120, 60
Scan format	Progressive scan
Quantization	12-bit, 10-bit
Color system	Wide gamut RGB

With the goal of meeting the full-spec SHV parameters, we are engaged in R&D on a 33 megapixel, 120-Hz frame frequency SHV image sensor with 12-bit quantization.

2. The need for 120-Hz frame frequencies[1)2)]

Factors that degrade the quality of motion video include (1) motion blur, (2) strobe effects, and (3) flicker.

[*1] A distance that is 0.75 times the height (H) of the screen.

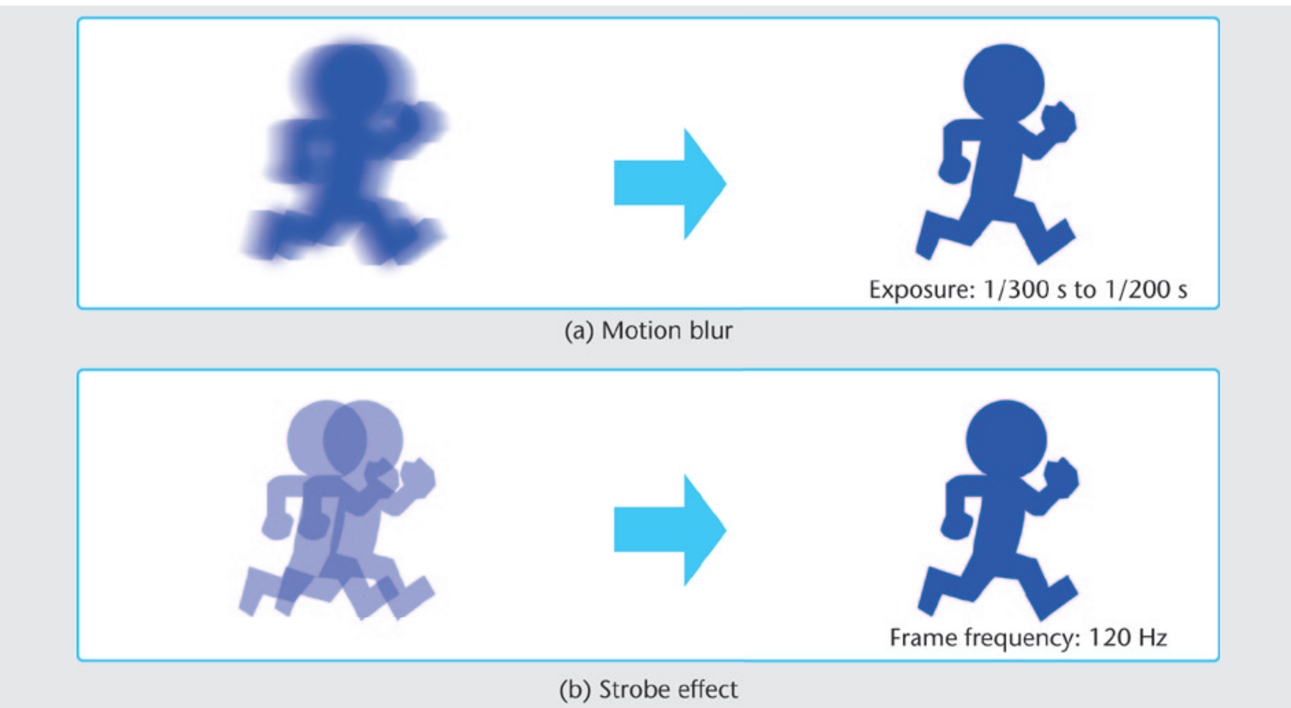

Figure 1: **Examples of factors degrading motion picture quality (motion blur and strobe effect)**

Motion blur occurs when the exposure time (storage time) of the image sensor is too long, and it affects the resolution of the depicted motion (Figure 1 (a)). Motion blur is particularly noticeable with SHV, because of its high definition. To avoid it, the exposure time in the image sensor must be set in the range of 1/300 s to 1/200 s. A strobe effect occurs when the frame frequency is low and a shutter or other device is used to shorten the exposure time. It appears as though the motion video has multiple exposures (Figure 1 (b)). A frame frequency of 100 Hz or higher must be used to reduce the strobe effects to an acceptable level for SHV. Flicker occurs when the brightness of the image appears to fluctuate. Flicker is perceived by the peripheral vision, so it becomes even more noticeable on a display occupying a wide field of view. A frame frequency of 80 Hz or greater must be used to ensure that flicker is not noticeable in SHV.

The subjective improvement in motion video quality had by increasing the frame frequency was evaluated on a five-step scale, and it was measured to be 0.46 in going from 60 Hz to 120 Hz[4]. By comparison, the improvement was measured to be only 0.23 in going from 120 Hz to 240 Hz. After looking at the overall factors degrading quality and the degree of improvement in motion-video quality, 120 Hz was chosen as an SHV frame frequency.

3. Developing a full-spec SHV image sensor

A full-spec SHV image sensor requires outstanding levels of performance especially in terms of operating speed, power consumption, and other factors. Generally speaking, image sensors requiring high data rates convert analog signals from pixels into digital signals in parallel by using analog-to-digital (A/D) converters set on each column of pixels, and they read out this digital data at high speed. Figure 2 illustrates the basic structure of such an image sensor and the performance values required for a full-spec SHV image sensor as regards its pixels, column-parallel A/D conversion circuits, and high-speed output circuits.

The output signal from each pixel must have low noise, and because of the huge number of pixels in an SHV image sensor, each pixel must be very compact.

The SHV column-parallel A/D converter circuits consist of 7,680 individual*2 A/D converters, each converting the signals from the pixels of one column into digital signals. This means, for each column, 4,320 pixels*2 must be scanned at 120 frames per second, so the conversion time must be no more than 1.92 μs (1/(4,320 x 120)). The precision of the conversion also needs to be 12-bit or more. Moreover, each circuit must consume as little power as possible since there are 7,680 A/D internal converters.

The output circuits must send the digital data produced by the column-parallel A/D circuits out of the image sensor at high speed. In fact, the data rates must be at least 48 Gbps.

Although high-definition, high-frame-rate image sensors already exist for digital cinema, the available circuit technology does not provide sufficient performance for a full-spec SHV image sensor.

Thus, we began our development of a full-spec SHV image sensor by researching the A/D conversion circuits, and in collaboration with Shizuoka University, we built a high-speed, two-stage cyclic A/D converter circuit*3. We also parallelized the output circuits to make them faster. With these technologies in hand, we were able to develop a 120-Hz, 33-mega-pixel, 12-bit-quantization SHV image sensor with an output data rate of over 48 Gbps[5]. The sensor is also power efficient (less than 2.5 W).

To evaluate the performance of the image sensor, we prototyped a three-chip color camera incorporating three such image sensors[6] and confirmed that the camera could capture good color video while operating at a

*2 The developed image sensor has a total of 7,808x4,336 pixels, and 7,680×4,320 effective pixels.

*3 For details, see the feature article "A 120 Hz Super Hi-Vision Image Sensor," in this issue.

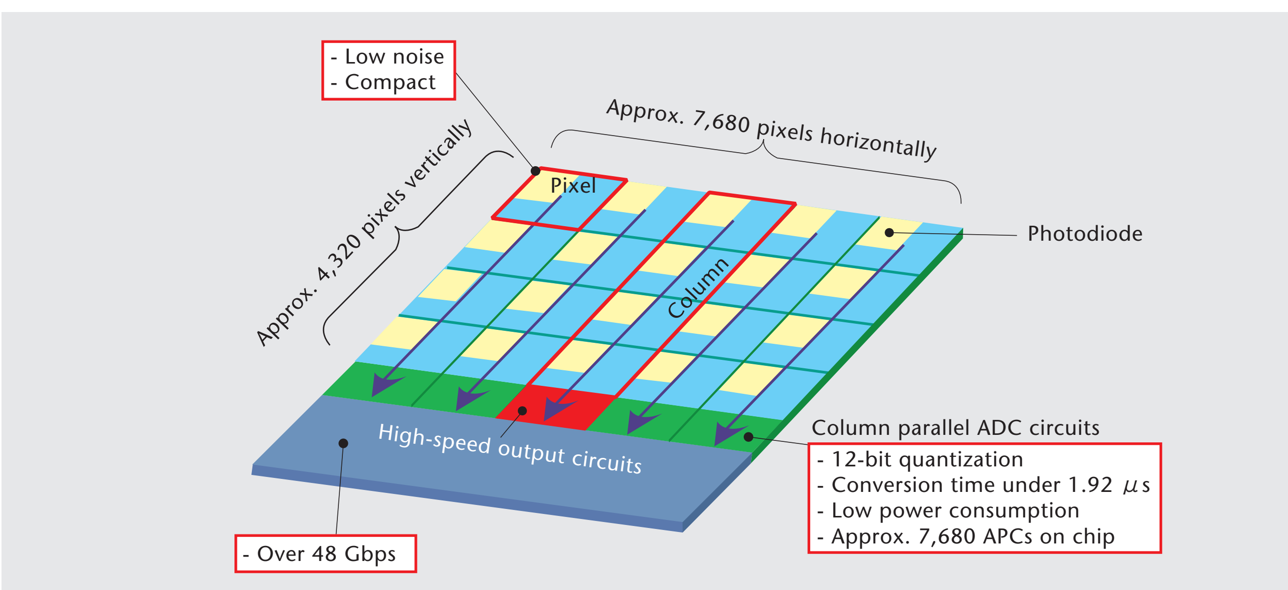

Figure 2: **Basic structure and required performance of 120 Hz frame-frequency SHV image sensor**

frame frequency of 120 Hz. The image sensors and color camera were exhibited at the NHK STRL Open House and broadcasting equipment trade shows overseas, and it has been seen by over 40,000 people to date.

4. Conclusions

Our research and development on SHV has yielded a 120-Hz, 33-megapixel, 12-bit-quantization image sensor. This sensor is based on ITU-R recommendations. In the future, we will develop a camera, and contribute to development of recording, encoding/compression, transmission, and display devices for SHV. We anticipate that the new sensor and camera will be used in the SHV test broadcasts planned for 2016 and will spur development of SHV video content and its applications in medicine, academia, and other fields.

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