Improving Patient Experience with Electrophoretic Display Technology

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Keywords: Digital Paper, Electrophoretic, ePaper, Digital Whiteboard, Door Sign

ABSTRACT

Electrophoretic displays (EPDs) have been used in e-Readers for more than a decade. Such products have been widely adopted by consumers because of the superior user experience enabled by EPDs. Today, hospitals are also evaluating products with this technology due to the improved experience it brings to both patients and hospital staff.

1 INTRODUCTION

Digital paper devices based on reflective EPD with no light emission [1] have become the industry standard for e-Readers. Such devices are widely used in electronic reader devices mainly because of their high quality appearance that is similar to that of printed paper. Their non-emissive feature is appreciated by end users because it can help to reduce eye strains and improve the eye health for the users. [2] Similarly, when EPDs are used inside the hospital rooms, patients can also benefit from the non-emissive feature because it doesn't create blue-light pollution which is can be annoying to patients. [3] Additionally, EPD's superior power efficiency can save US hospitals' significant energy and device installation costs.

2 BLUE LIGHT HAZARD FROM DISPLAY DEVICES

Researchers have found that blue light from artificial light sources may have a negative impact on human's health. [3] In particular, blue light with wavelengths of 446 nm to 477 nm can have an impact on human's circadian system. [4] Thus long time exposure to blue light can negatively affect sleep for patients in hospitals due to the excessive exposure to blue light.

2.1 Digital Paper Reduces Blue Light Hazard

In many hospitals, display devices inside the patient room or patient ward are one of the major sources of light emission since LCD displays are currently the most common choice for such applications. LCD displays have a strong blue emission coming from their backlights such as LED light bars. [5] It is apparent in Figure 1 that the light emission spectrum from a typical LCD display (Fig. 1a) is significantly higher than that of typical fluorescent room light (Fig. 1c) as well as that of natural outdoor sunlight (Fig. 1b). [6] When these LCD displays are inside the patient's room, the patient(s) can be exposed to strong

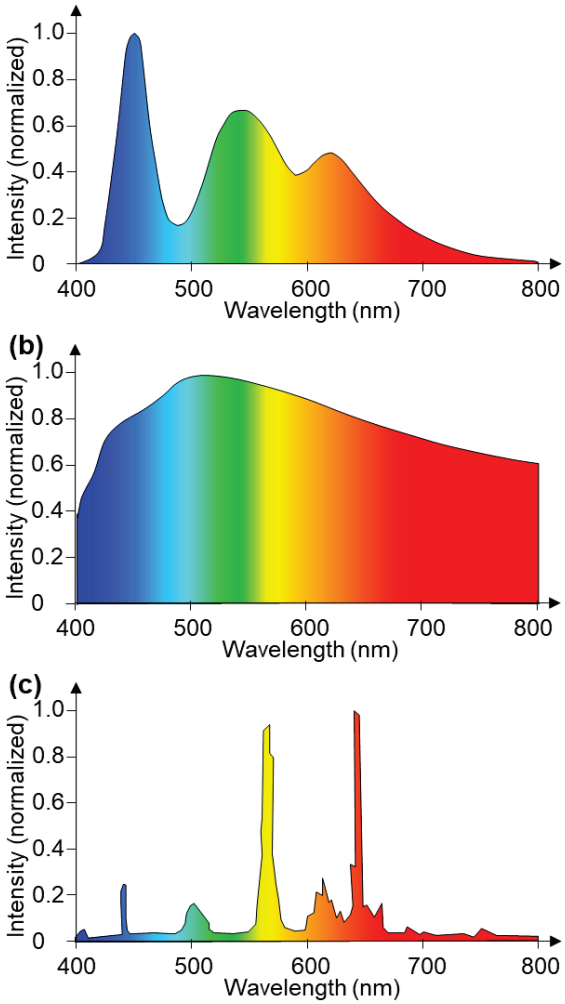

Fig. 1 (a) White light spectrum from a typical LCD screen; (b) Natural outdoor sunlight spectrum; (c) Light spectrum from a fluorescence light bulb

blue light. On the other hand EPDs are reflective, not emissive. Therefore, the light spectrum a patient experiences is similar to the ambient light source. For example, if the EPD is used outdoor, the light spectrum of EPD a viewer will see is similar to natural sunlight as shown in Fig. 1b. In the hospital, a patient will see the EPD's light spectrum more similar to Fig 1c, since the ceiling lights are usually fluorescence light,

Therefore it is apparent that using EPD inside the patient rooms can significantly reduce blue light and blue light pollution, and thus improve sleep for many patients.

2.2 Digital Paper's "Always-On"

One of the key advantages of EPD that can help to improve the patient experience is its "Always-On" feature. EPD is a reflective display. Inside the patient room, when the room light turned is off or at night, the EPD screen can be on but with no light emission by itself. Fig. 2 shows a typical setting at night inside the patient room with one LCD TV and one EPD communication board. As the room light turned off, and the patient is ready to sleep, the EPD device is completely dark, and has no interference with patient's rest. However hospital staff often enter the patient rooms with a flashlight to check on the patients and will still be able to see the EPD without waking the patient up. With such characteristics, the EPD display can be kept on all the time with no need for the patient or staff to manage it's on and off. Such feature is greatly appreciated in the healthcare setting by both the patient and the hospital staff.

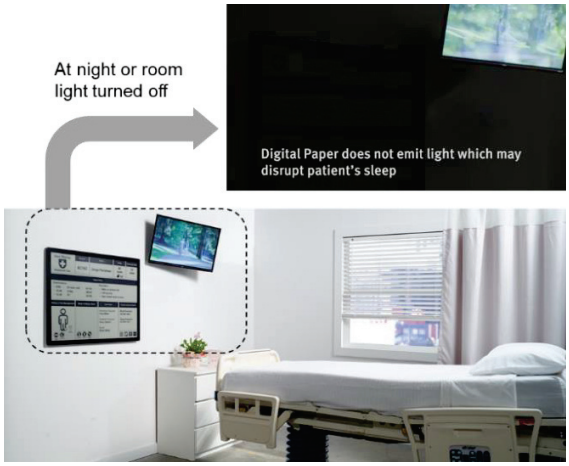

Fig. 2 A typical patient room setting with one LCD TV and one communication board.

3 POWER CONSUMPTION

EPD has extremely low power consumption because of its bi-stable characteristics, EPD panels only consume power when the content is changed. Thus no power is needed to display the existing content. A typical power consumption curve of an EPD panel is shown in Fig. 3. When the EPD panel updates the new content, the power increases. While the EPD screen is on standby status and not updating the content, the power consumption is close to zero. Note that for an EPD device, the standby power consumption is contributed by the controller electronics, not the EPD panel itself. Table 1 shows the power comparison with the LCD counterpart. In this measurement, the EPD screen is flashed with new

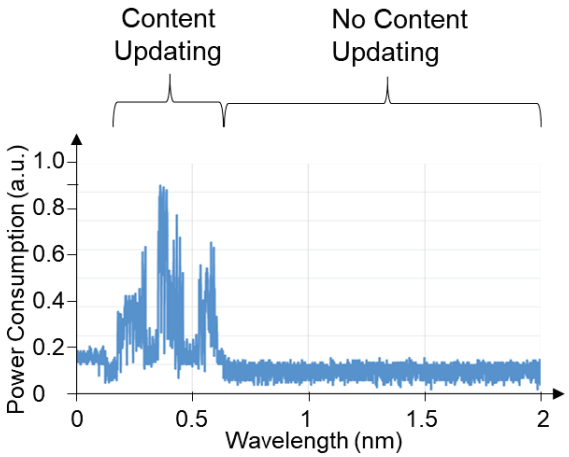

Fig. 3 Typical power consumption curve for an EPD device

content every minute. Both the EPD device and the LCD device were displaying continuously for 24 hours. Total power consumption data of 24 hours were collected and analyzed. An EPD device's power consumption is less than 3% of that for a typical indoor LCD. In applications where the content update is less often, the total EPD power consumption will be even lower.

Device tested	EPD	LCD (32" Indoor)	LCD (32" Outdoor)
Total Power Consumption	X	30·X	120·X

Table 1 Comparison of power consumption between EPD and LCD devices (EPD content was updated every minute)

	Voltage (V)	Current (A)	Power (W)
No Content Update (RMS)	12.1	0.11	1.33
No Content Update (Max)	12.1	0.34	4.14
Content Update (RMS)	12.1	0.23	2.80
Content Update (Max)	12.1	2.20	26.62

Table 2 Power consumption of a 42" EPD for several different status

In Table 2, the power consumption of a 42" EPD device was measured in various screen status. Multiple measurements were made as different content images were flashed. Both of RMS result and the maximum value of the electrical power consumed were recorded. The RMS power of this 42" EPD device during content

update was 2.8W, which was extremely low compared with the LCD display of similar size, which measured about 100W.

3.1 Digital Paper with Long Battery Run Time

Traditionally, battery based display devices usually have very short battery run time. Thus for wall-mount applications, display devices usually need wires or cables to provide the power. An always-on EPD device can be battery powered with long battery run time. This can provide flexibility to the device deployment. Figure 4 shows a 7.8" EPD tablet deployed in a US hospital as a digital door sign outside the patient room. It uses 6 AAA batteries. The device is configured to turn on the WiFi every 15 minutes to receive and display the new data from the server. On the average, the EPD screen has content updates 3 time each day in actual useage. Under such condition, its battery run time will be about 11 months.

Fig. 4 An EPD tablet used as a digital door sign in a US hospital. It is battery powered and wirelessly connected with EMR

3.2 Deployment Flexibility with Low Cost

With such long battery run time, the EPD tablet can be deployed wire free in a practical way. That allows the EPD tablets to be located virtually anywhere in the hospitals without physical limitations, including for example on the regular walls, glass walls, and even attached to mobile units such as patient beds and medical carts. Fig. 5 shows typical hospital deployments. This flexibility allows a digital EPD display portal solution that can be fully optimized for enhanced patient experience. In addition to removing need for wires and cables in device installation, the ongoing cost to hospitals and medical care centers can be significantly reduced.

For large size EPD devices such as the 42" one shown in Fig. 2, the power consumption is low enough that these devices can be powered by Power over Internet (PoE). Compared with the LCD screen powered by an AC wall receptacle, the device installation cost savings for large

Fig. 5 EPD tablets are installed at difference surface in hospitals

size EPD devices powered by PoE can be very significant. In addition, the operational energy cost for a large screen EPD is also much lower than its LCD counterpart. Table 3 shows the comparison of energy consumption and the operational energy cost between an EPD device and a LCD device. The 42" EPD's average power consumption is 2.8W as shown in Table 3. A 75W 43 in. LG smart TV is used as a comparison

	42" EPD (Avalue)	43" LCD Smart TV (LG)
Watts	2.8	75
Annual Usage (kWh)	24.5	657
Annual Energy Cost	$2.58	$69
5-Yr Energy Cost	$13	$345

Table 3 5-year energy cost of a 42" EPD and its comparison with a 43" LCD smart TV

reference. The annual energy cost saving for using EPD instead of LCD screens is calculated to be $66. Assuming the device operational lifetime is 5 years, the total operational energy cost saving using EPD can be more than $300 per device. CDC data shows that US

had about 898,000 patient beds in 2015. [7]. If every patient bed uses one screen as part of the digital solution, the total energy cost saving for using EPD device could be as much as $60 million annually.

4 CONCLUSIONS

In these times of worldwide pandemics and increasing hospital care, it is increasingly important to find ways improve the patient's comfort as well as finding ways to improve the efficiency of hospital communication while reducing hospital operational costs. EPD offers important improvements to each of these needs. Its unique non-emissive reflective printed-paper look with no backlight coupled with its power efficiency is enabling the healthcare community to design and develop digital solutions with improved patient experience.

5 ACKNOWLEDGEMENTS

We thank Jennifer Su, Qi Ming Lin, Stanley Chiang, Tim O'Malley, Paul G. Apen of E Ink Corporation for their contributions and ideas to this paper.

We also acknowledge and thank Avalue Technology Inc. and Foxconn Medical Group for the support to this study.

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