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| Project | **HMD based 3D Content Motion Sickness Reducing Technology**<<http://sites.ieee.org/sagroups-3333-3/> **>** |
| Title | **Display Specifications of VR HMDs** |
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| Re: | Session PM1, NY, USA |
| Abstract | Understand the current display type, resolution and its pixel structure used in currently most popular commercial VR HMDs and discuss how its specification is related to the motion sickness caused by the VR experience. |
| Purpose | Understand the current VR HMD display specifications and discuss any possible correlation between the display specifications and the motion sickness caused by the VR service. |
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<Most Popular Commercial VR HMDs in the market and their specifications>



**Figure 1. HTC Vive, Oculus Rift and Sony PS VR (From left to right)**

Since the acquisition of Oculus by Facebook in 2014, virtual reality has been receiving a lot of industrial attention. In almost any large consumer electronic shows and IT conferences, the presence of virtual reality tech demos was very strong. Especially in 2016, Facebook Oculus, HTC and Sony have released their commercial version of VR HMD and opened an era of affordable consumer VR experience. However, due to the lack of industrial standards, each company has created their own versions of VR HMD with various specifications and this is causing the manufacturing price of VR HMD to rise as the sales of the hardware is still at its early stage. Hence, it would be worthwhile to examine the current specifications of each commercial VR HMD, especially on the display, to enhance the understanding of current status and discuss what would be needed to standardize the hardware specification.

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|  | **HTC Vive** | **Oculus Rift** | **PlayStation VR** |
| **Type**  | Dual low-persistenceSamsung AMOLED(Diamond PenTilesubpixel matrix) | Dual low-persistenceSamsung AMOLED(Diamond PenTilesubpixel matrix) | Low-persistenceAMOLED(RGB subpixel matrix) |
| **Size** | 91.9 mm × 2, 447 ppi | 90 mm × 2, 456 ppi | 5.7-inch |
| **Resolution** | 1200 × 1080(per eye) | 1200 × 1080(per eye) | 960 × 1080(per eye) |
| **Refresh Rate** | 90Hz | 90Hz | 90Hz, 120Hz |

**Table 1. Display Specifications of VR HMDs**

The table 1 shows the information provided by the manufacturers themselves and the understanding of Samsung OLED display technology. In order to produce an immersive visual experience in VR, four elements – display resolution, display quality, optics and field of view – are required and it would be important to understand why the current VR HMDs have chosen the current display types and resolution.



**Figure 2. Subpixel matrix of OLED display used in VR HMDs**

Looking at the table 1, both Oculus Rift and HTC Vive are using the Samsung Display manufactured OLED display and its resolution specification is superior to the display resolution specification of Sony PS VR. However, the display quality difference received by the user using the VR service between the three devices is minimal and this is due to the subpixel matrix. Figure 2 demonstrates how the subpixel matrix of the OLED screen used in PS VR and Oculus Rift & HTC Vive. Normally, it is very difficult to distinguish the subpixel matrix of the AMOLED displays used in the devices like smartphones as the user views from a distance, but a VR HMD screen is magnified with a set of fisheye lenses and it is placed only inches from the viewer’s eyes so the subpixel matrix is much more visible. This is where the Sony PS VR has an advantage as the black area that divides the subpixels is much smaller. Its 1080p screen’s RGB stripe matrix is superior to the PenTile matrix. In a square of four pixels as shown in Figure 2, Sony PS VR screen has more subpixels with even number of each color (red, green and blue) where Samsung PenTile screen has fewer subpixels and more number of green colors. This allows the quality of perceived resolution of PS VR screen when looking at it closely is close to that of the Rift and Vive. The PenTile display used in the Rift and Vive looks grainier when looking at a close distance and produces more pronounced screen-door effect – the grid of the gap between pixels and gradients look worse. PenTile matrix in AMOLED, however, has a price advantage as it costs less to achieve the desired resolution and extends the life cycle of the panel.

<Discussion Points>

1. Does resolution have any relation to the motion sickness caused by the use of VR HMD?
	1. Is resolution alone a factor causing the motion sickness? If so, why?
	2. Is locomotion with higher resolution helps ease the motion sickness problem? If so, why?
2. What is the optimal refresh rate of the screen to minimize the motion sickness?
	1. Is 90 Hz the defecto standards? If so, why?