

Wireless Panel Architecture using Lossless Uncompressed 60 GHz Transmissions

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Abstract

Wireless transmissions have dramatically improved panel placement and interconnection flexibility. In this paper we present a wireless panel architecture where the panel functionality partitioning can be optimized through the use of a 60 GHz high speed wireless link to deliver full fidelity, uncompressed and lossless video at consumer price points. SiBEAM's fully-integrated all-CMOS WirelessHD chipsets enable this architecture via robust transmissions at data rates up to 4 Gbps.

1. Introduction

Interest in, and products featuring, super slim panels have seen a sharp increase due to consumer demand for the most aesthetically pleasing viewing experience coupled with advances in panel design and manufacturing technology. This has resulted in increased attention to the wiring of such systems. From a recent survey conducted by independent firm Survey Sampling International, results show that consumers today are far more attuned to the ease of installation, wiring clutter, and ease of connecting portable devices than ever before. Such concerns point directly to the need for wireless connectivity. In addition, picture quality remains the most important consideration for consumers when buying a new High Definition (HD) TV. As such, recent standards initiatives like the WirelessHD® Consortium have presented new options for introducing uncompressed, lossless wireless connectivity to the consumer's HD experience [1]. How do such new standards and technology find a role in panel architecture and design?

2. Panel Architectures

In a conventional all-in-one television, tuner and panel-specific processing is integrated with the panel as shown in Figure 1.

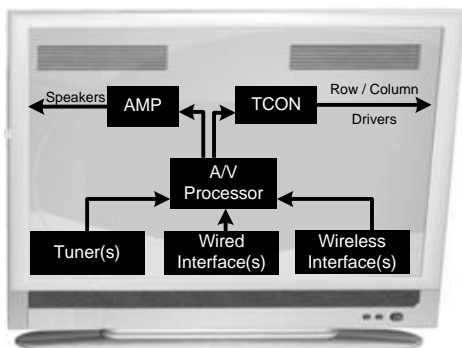


Figure 1 Conventional all-in-one television architecture

Input is received from one or more input sources including tuners and wired and wireless interfaces. Each of these interfaces can support different audio and video formats. In particular, tuners can support both analog and digital formats, from cable or

terrestrial antenna sources. Wired interfaces can include digital and analog inputs, as well as Ethernet inputs, to allow rendering of Internet content. Wireless interfaces can receive compressed content over lower bandwidth interfaces such as WiFi / 802.11 or uncompressed content over higher bandwidth interfaces such as WirelessHD. The inputs are selected and often composited, and then processed in an A/V processor. This processing can include rescaling, de-interlacing, color space conversion, image enhancement, and frame rate conversion. A/V processing can also include On Screen Display (OSD) overlay. The output of the A/V processor is at a fixed panel-specific resolution and format which is then sent on to the panel timing controller (TCON) and audio amplifiers. Thus, there is a significant amount of electronics required in the display, in addition to the panel. This can result in bulkier form factors even when coupled with thin panel technologies.

This has motivated a return to “media receiver box” architectures shown in Figure 2. Here the tuners, wired and wireless interfaces, and panel-specific video processing units are removed from the display panel and placed in a separate media receiver box (MRB). A wired link is used to connect the MRB to the panel. Custom protocols can be used on the link since the two devices are sold in matched pairs. However, in many cases, standard interfaces such as HDMI are used to leverage the volume availability of the link transceivers and cabling. In the MRB architecture, the panel form factor and placement can be optimized by the removal of the majority of the electronics, as well as the interfaces and their associated connectors and cabling. However, a wired MRB to panel connection can be unsightly and costly.

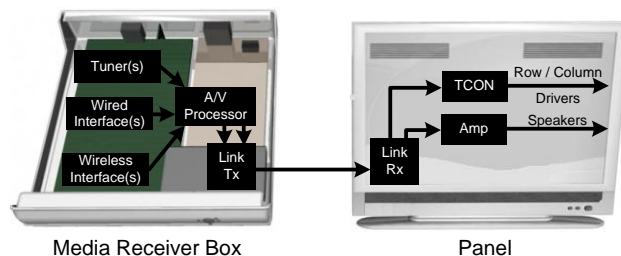


Figure 2 Media receiver box (MRB) architecture

The unsightly, and often costly, cable connecting the MRB and panel can be eliminated through the use of a wireless interface to bridge that link as shown in Figure 3. In this case, the A/V processor still generates the processed panel-specific output video format, but instead of being sent over a wired interface to the panel, it is transmitted wirelessly. This allows the same form factor and placement optimizations of the wired MRB architecture, but eliminates the need for the cable connecting the two devices.

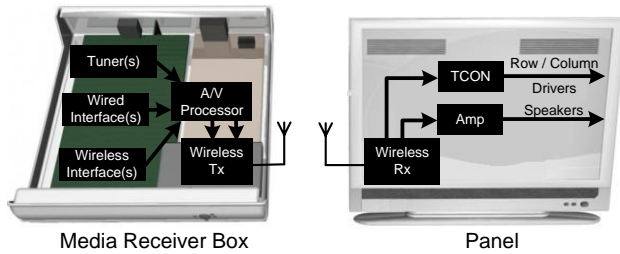


Figure 3 Wireless media receiver box architecture

2.1. Link requirements for wireless MRB architecture

Using wireless transmissions for the MRB to panel link places significant requirements on the wireless link to still provide the full architectural benefits of the MRB architecture without reducing quality of the overall solution:

1. Full native panel resolution (1080p+) and frame rate (60 fps+) transmission to eliminate resolution or frame rate conversion in the panel
2. Low complexity system integration required to avoid reducing panel benefits of MRB architecture; Typically requires baseband video interface to wireless chipset
3. High image quality required
4. Transmission format must be input source agnostic to carry content from any of the input interfaces, tuner, as well as OSDs and composited combinations
5. Wireless technology must allow flexible placement of MRB and panel; Typical home environments translate to 10m Non-Line-of-Sight (NLOS) requirement

Uncompressed and lossless wireless multimedia transmissions using the 60 GHz band are well suited to fulfill these requirements, as described in this paper.

3. WirelessHD consortium and specification

The WirelessHD Consortium (<http://www.wirelesshd.org>) was formed in 2006 to design a next-generation wireless interface specification for HD media streaming and transmission between fixed-location and portable CE devices. WirelessHD includes as members Broadcom, Intel, LG Electronics, NEC, Panasonic, Philips Electronics, Samsung Electronics, SiBEAM, Sony, and

Toshiba. The WirelessHD specification is the first HD digital wireless interface specification for simplified media streaming and HD content portability supported by the CE and technology industries.

The WirelessHD specification's key characteristics include:

- Uncompressed and lossless HD video, audio, and data transmission, scalable to future HD A/V formats
- High-speed wireless, multi-gigabit technology in the unlicensed 60 GHz band
- Smart-antenna technology to overcome line-of-sight constraints of 60 GHz secure communications
- High interoperability supported by major CE device manufacturers
- Device control for simple operation of CE products
- Error protection, framing, and timing control techniques for a quality consumer experience

The WirelessHD specification makes seamless wireless interconnection and interoperability of a wide range of CE devices in a wireless video area network (WVAN) possible. Uncompressed and lossless audio and video allow the highest quality user experience.

4. Uncompressed and lossless wireless video transmissions using the 60 GHz band

Wireless transmission of uncompressed lossless HD video requires data rates of about 4 Gbps for 1080p resolution, far exceeding the capabilities of existing wireless technologies such as IEEE 802.11n and ultra-wideband (UWB), which support only about 0.5 Gbps, as Table 1 shows.

Supporting very high data rates requires either very high spectral efficiency or lots of spectrum since data rate is calculated as:

$$\text{RawDataRate (bps)} = \text{SpectralEfficiency (bps/Hz)} * \text{Bandwidth (Hz)}$$

Increasing spectral efficiency through MIMO techniques such as spatial multiplexing typically leads to higher cost and reduced range and robustness since it requires multiple concurrent paths between the transmitter and receiver and hardware to separate data traveling over these paths.

Increasing bandwidth requires operation in a large frequency spectrum band, which for sufficient range and robustness must allow reasonable transmission power. Fortunately, 7 GHz of

Table 1 Comparison of various high data rate wireless specifications*

Specification	Total spectral availability (GHz)	Maximum allowed transmission power (EIRP**)		Channel bandwidth (MHz)	Maximum data rate (Mbps)	bps/Hz needed for 4 Gbps
		mW	dBm			
WirelessHD	7	10,000	40	~2,000	~4,000	~2
IEEE 802.11n	0.67	160–3,200	22–35	20	289	200
				40	600	100
Ultra-wideband (UWB)	1.5 – 7.5	0.1	-10	520	480	8

* Maximum allowed transmission power and UWB spectral availability vary by regulatory domain.

** Effective isotropic radiated power.

unlicensed spectrum is available worldwide in the 60 GHz band, allowing up to 10W of effective isotropic radiated power (EIRP). If this spectrum is divided into channels of 2 GHz each, a spectral efficiency of only 2 bps/Hz is required to deliver data at 4 Gbps. In contrast, an 11n system requires 100 bps/Hz to deliver the same 4 Gbps data rate even in its wider 40 MHz mode, and a UWB system needs 8 bps/Hz to achieve the same data rate in its 520 MHz channel. UWB is further constrained by regulations to transmit at most only 0.1 mW of power (up to 100,000 times less than is available in the 60 GHz band) and is approved for use only in limited geographical regions. This power limitation severely impacts the obtainable operation range.

4.1. Challenges and solutions for 60 GHz operation

Although the 60 GHz band has significant advantages for obtaining cost-effective, very high data rate wireless communications, it poses several challenges that previously made it unsuitable for use in CE devices [2]. Friis' equation shows that operation at higher frequencies requires higher gain (more directional transmission) to obtain the same range and data rate:

$$Power_{rx} = \frac{Power_{tx} \times Gain_{tx} \times Gain_{rx} \times c^2}{4\pi \times Distance^2 \times Frequency^2}$$

Wireless systems can use high-gain horn antennas to focus in a fixed direction, but they require careful and precise manual alignment as well as line-of sight operation without intervening obstacles such as furniture or people. However, smart-antenna technology can electronically steer a focused directional beam to obtain the necessary beam focus while automatically adapting to the environment to find both direct LOS, and indirect NLOS paths which bounce off objects and walls. This directionality also reduces interference and improves link security.

High-quality, low-latency, uncompressed and lossless HD A/V transmission requires a large number of antennas (more than 10) and dynamic beam steering (less than 1 ms). Although this large number of antennas requires a large area when operating at lower frequencies such as 2.4 GHz, antennas only a few mm² in size can be effective with 60 GHz's shorter wavelengths. Optimized package modeling and design techniques allow the use of standard low-cost, high volume IC packaging processes even at these high frequencies. Because 60 GHz antennas are small, they can be embedded in the same substrate as the radio IC.

The last hurdle is cost-effective manufacturing of 60 GHz radio circuits. Previously, operating frequencies in the 60 GHz range were obtained only with expensive materials, such as GaAs and InP. Over the past decade, however, major advances in digital CMOS and SiGe HBT, have made transistors smaller and fast enough for millimeter-wave operation. CMOS promises the highest integration levels and lowest cost, and SiGe performance is now comparable to, and in some cases better than, other compound semiconductor technologies. Taking advantage of these scaled silicon processes, the novel design and modeling of transistors and passive elements and new circuit design techniques have resulted in silicon circuit blocks operating at 60 GHz [3][4].

Recently, the technology has progressed from individual circuit blocks (oscillators, LNAs, mixers) to increasing integration levels, culminating in fully integrated 60-GHz silicon radios [5][6][7]. The ability to design and manufacture fully integrated millimeter wave radios in standard CMOS now makes 60 GHz radios

inexpensive enough for consumer applications. Applications include consumer electronics as described here, personal area networking (PAN) in the 60-GHz band [8] as well as automotive radar in the 24- and 76- to 77-GHz bands [9].

4.2. Wireless technology for uncompressed HD multimedia transmission

Supporting streaming uncompressed and lossless audio and video at up to 1080p resolution in NLOS ranges of at least 10 meters for in-room applications requires careful system design at all levels. Such a system's PHY requirements include the ability to deliver up to 4 Gbps data rates in a beam-formed directional mode to stream high-speed A/V and data content. The system must also deliver communication at lower data rates omni-directionally for device control and coordination. High-rate PHY modes support the required 1 to 4 Gbps using orthogonal frequency division multiplexing (OFDM). The low-rate PHY modes support command, beacon, broadcast, acknowledgment (ACK), and audio traffic rates of 2.5 to 10 Mbps in omni-directional modes, as well as 20 to 40 Mbps in beam-formed unidirectional modes.

The MAC layer also requires optimization to support high-quality streaming, HD, uncompressed content. A time-division multiple-access (TDMA) core scheduling mechanism enables high quality of service (QoS), which is more difficult to attain with the carrier-sense multiple-access with collision avoidance (CSMA/CA) scheme in 802.11/WiFi. A central coordinator schedules traffic for the WVAN. One of the devices present (typically a display / panel in the network) automatically becomes the coordinator. All devices receive periodic beacons from the coordinator, indicating the access schedule that allows them to precisely time transmits and receives. This helps ensure that required bandwidth is available when needed and also eliminates the overhead of wireless collisions. Even though the coordinator schedules the traffic, all content is sent directly between devices to obtain greater network efficiency and relax coordinator requirements.

Data security and content protection are critical in wireless systems to prevent illicit access to users' data and duplication of commercial copyrighted content. Strong encryption techniques, such as Advanced Encryption Standard (AES) ciphers, thwart illegal or unintended use of data. Leveraging existing Hollywood-approved digital-transmission content protection (DTCP) mechanisms can facilitate the film industry's approval. User data privacy prevents unauthorized users from accessing authorized users' content and devices, so that unauthorized users cannot view recorded content or control or query the devices inappropriately. Additionally, the directional nature of high-speed 60 GHz communications makes it more difficult to capture signals if the device attempting to do so is not in the path between the sender and the intended recipient. Finally, additional proximity controls further ensure that communications are confined.

5. SiBEAM's WirelessHD chipsets

SiBEAM's fully integrated all-CMOS chipsets enable the first WirelessHD-compliant systems in the market, supporting uncompressed and lossless wireless A/V streaming of up to 1080p/60 resolutions and frame rates at 24 bits per pixel with a wired equivalent robustness of less than a 10⁻¹⁰ bit error rate [10][11]. The chipsets support deep color modes having greater than 8 bits per pixel component. They support high-quality audio of up to eight channels at up to 192 kHz sample rates in both pulse code modulation (PCM) and compressed data formats.

Figure 4 shows a chipset in a typical implementation. The two chip sets achieve complete antennas-to-bits integration, requiring minimal additional support hardware for integration into existing A/V sources (Blu-ray and HD DVD players and HD set-top boxes) and sinks (displays). Both all-in-one television architectures (as in Figure 1) and MRB architectures (as in Figure 3) are supported. Integrated device control features allow seamless single-remote-control operation and inter-device communication. The chipsets support DTCP content protection.



Figure 4 Typical reference design. Center chip is the digital baseband/MAC and the chip on the right side is the RF chip with integrated antennas. Other components include minor support circuitry such as voltage regulation and a frequency reference crystal. Actual size is approximately 12 by 3 cm.

The radio chip's packaging includes integrated 60 GHz antennas that ease board and system design by containing all high frequency routing within the CMOS die and chip package. As described earlier, achieving full 10m NLOS coverage at the required data rates requires many independent antennas and partial radio chains. Thus, this fully integrated radio chip, containing all radio chains and antennas, represents a significant advance in the degree of parallelism achieved at the RF level for high-volume consumer wireless communications products. This degree of parallelism requires careful design and implementation at many levels, including system architecture, DSP algorithms, circuit design, and packaging.

Figure 5 shows the digital BB/MAC chip, which contains mixed-signal components (A/D and D/A converters and phase locked loops), digital PHY, digital MAC, audio and video interface unit, and embedded CPU. This chip manages all aspects of A/V and wireless-network operations, presenting direct digital A/V signals to the host device. The digital OFDM PHY encodes and decodes transmissions at data rates up to 4 Gbps. The PHY also controls several functions in the radio chip, including beam former settings

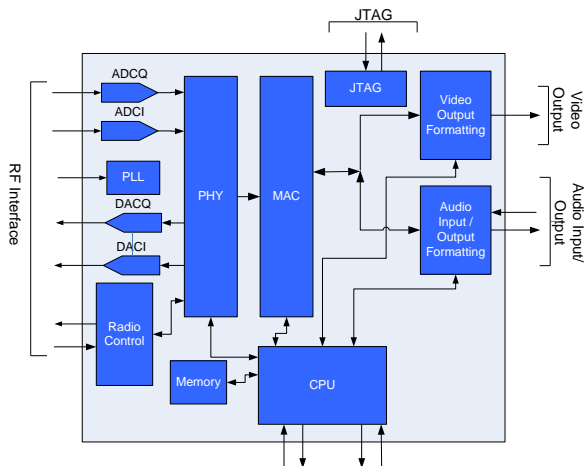


Figure 5 Receiver baseband chip architecture. Simple A/V and system micro interface ease system integration.

for smart antenna operation. The MAC arbitrates access to the wireless medium and controls network operation. The security and content protection unit performs standards-based encryption and decryption. The A/V interface unit packs, unpacks, and processes raw A/V data from the digital audio and LVDS video interfaces into packets suitable for transmission by the MAC. This unburdens the system design of additional A/V logic and allows the chipset to be inserted into the system in a similar manner to existing wired HDMI chipsets. The embedded CPU keeps the host system's load and complexity low by performing A/V network management. The system micro interface allows control information to pass between the internal CPU and the host system.

6. Conclusion

SiBEAM's WirelessHD chipsets enable a "wireless panel" architecture whereby the panel and media receiver box are connected using an uncompressed lossless 60 GHz wireless link. While wireless data rates of 4 Gbps once seemed well beyond the reach of state-of-the-art technology, particularly for NLoS consumer applications, they are now achievable in a cost-effective and robust manner thanks to the wide unlicensed 60 GHz band, advances in high-frequency CMOS circuit modeling and design, and highly scalable, quick-adapting smart-antenna technology.

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