GUIDE TO WIRELESS AV CONNECTIVITY

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Introduction

The increasing use of tablets, smartphones, and other portable media and computer devices (also known as Bring Your Own Devices, or BYODs) has, not surprisingly, created demand for wireless display and audio connectivity. You wouldn't want to bring a tablet or ultrabook computer into a meeting room and connect a long cable to its external display connector to share a presentation or a video.

Since all of these devices use digital interfaces based on the High Definition Multimedia Interface (HDMI), DisplayPort (DP), and variations on these two standards, the challenge is to make a wireless display and audio connection with minimal compression of the signals.

It is important to distinguish between baseband video streams and display streams. Video can be compressed using one of several codecs; the most common is MPEG (H.264). The video signal doesn't have to deliver full-resolution color: compressed video is usually transported and delivered in a format (YCbCr) where color information is sampled at half the rate of luminance information. This technique makes it possible to deliver high-definition video in a standard 6 MHz television channel.

In contrast, display connections are always made in the RGB format, with three full-resolution color signals. So the challenge for a wireless AV system is to deliver these signals in an uncompressed or lightly compressed format.

To accomplish this, a wireless display connectivity system must operate on microwave frequencies, where channels are considerably wider than those found in television broadcast bands. The 2.4 GHz wireless "b" and "g" spectrum is a possible candidate – channels here are 20 MHz wide and can be bonded for additional bandwidth – but there is so much Wi-Fi activity on these channels already that they can't be considered reliable for our purposes.

The wireless channels in the SHF 5 GHz "a" and "n" bands are a better choice, as are the new channels allocated in the 60 GHz EHF spectrum. In this guide, we'll take a closer look at wireless systems that use both bands of frequencies.

Bandwidth Requirements

Our bandwidth requirements for a wireless AV system can be determined by first calculating clock rates. To arrive at the required bandwidth, multiply the total number of horizontal pixels (including the blanking interval) by the total number of vertical pixels (again, including the blanking interval). That product is then multiplied by the image refresh rate, resulting in the "clock rate" for the output signal. Most tablets and smartphones will output a 1080p/60 signal when connected to an external display, so we'll use that as an example:

2200 (H) pixels (x) 1125 (V) pixels (x) 60 = 148,500,000, or 148.5 MHz

Next, multiply the clock rate by the color bit depth. In an 8-bit signal, the data "wrapper" adds two bits:

148.5 MHz (x) (8+2) = 1.485 gigabits per second (Gb/s)

This is the data rate for a single color channel. For an RGB signal, the data rate is multiplied by three:

1.485 (x) 3 = 4.46 Gb/s

4.46 Gb/s is a common single-link data rate for HDMI. In addition to streaming display and audio signals, a high bandwidth AV wireless system must also support two-way connection to exchange extended display identification data (EDID) and high-bandwidth digital copy protection (HDCP) keys.

A data rate of 4.46 Gb/s definitely won't fit in a pair of 20 MHz channels – let alone one channel - so light signal compression is needed to make wireless AV practical at 5 GHz and 60 GHz. How that is accomplished depends on the wireless standard in use, but the most common approach involves sampling color information at a lower rate than luminance information, just as the MPEG compression standards do but with much less compression applied.

Wireless AV Standards

Here is a list of wireless connectivity protocols currently in use.

	Bluetooth	ZigBee	Wi-Fi	Wi-Fi	WiGig	WHDI	WiHD
IEEE Standard	802.15.1	802.15.4	802.11n	802.11ac	802.11ad	n/a	802.15.3c
Frequency	2.4 GHz	900 MHz / 2.4 GHz	5.1 – 5.8 GHz	5.1 – 5.8 GHz	57 – 66 GHz	5.1 – 5.8 GHz	57 – 66 GHz
Maximum Bit Rate	1 Mb/s	250 Kb/s	450 Mb/s (typically much slower)	1 Gb/s	> 1 Gb/s	1080p over 40 MHz, 720p over 20 MHz	Up to 28 Gb/s on all four channels
Nominal Range	30 feet	30 - 300 feet	300 feet	300 feet	30 feet LOS	Up to 100 feet	30 feet LOS
# of RF Channels	79	1/10, 16	24 with DFS/ TPC	24	Multiple	24 with DFS/TPC	Multiple
Channel Bandwidth	1 MHz	.3 – .6 MHz, 2 MHz	20 MHz (unpaired)	Up to 160 MHz (paired)	2.16 GHz	20 MHz (720p) 40 MHz (1080p)	2.16 GHz
Modulation System	GFSK	BPSK, OPSK	OFDM	OFDM / 256 QAM	OFDM	OFDM	OFDM / 256 QAM
Suitable for Wireless Display?	**No**	**No**	**No**	**Yes**	**Yes**	**Yes**	**Yes**

Table 1. A comparison of current wireless AV connectivity standards

Bluetooth (IEEE 802.15.1) and ZigBee (IEEE 802.15.4), shown in the first two columns, are both versatile wireless protocols and are widely used to make short-range, low bit rate connections to everything from electronic locks and thermostats to ear buds, cordless mice and keyboards, and speakerphones. Both systems operate in the 2.4 GHz wireless band and have a working range of at least 30 feet. However, the bit rates permitted for each system are too slow for streaming video and display data. Bluetooth is capped at 1 megabit per second (Mb/s), while ZigBee is even slower at 250 kilobits per second (Kb/s).

As we've just seen; faster data rates are required to stream display information. The next five standards – Wi-Fi 802.11n, Wi-Fi 802.11ac, Wireless Gigabit, WHDI, and WiHD – all look more promising for this application. Note that three of them use the 5 GHz Unlicensed National Information Infrastructure (U-NII) "white space" frequency bands in the United States.

5 GHz U-NII Spectrum Allocations

A total of 24 channels are available within this band for low-power, unlicensed wireless operation. However, depending on the sophistication of the wireless equipment, only 9 of these channels may be available for wireless AV operations. Each channel is 20 MHz wide, and channels can be "bonded" as needed to increase bandwidth for higher data transfer rates.

This chart shows the 5 GHz channels currently allocated for wireless AV operation in the United States.

Channel Identifier	Center Frequency (MHz)	FCC Classification	Permitted Use Location	P-P Max Intentional Radiator Power	Number of available Channels
U-NII-1 Low 36	5180				
to		Part 15.407	Indoor only	50 mW / 17 dBm	4
U-NII-1 Low 48	5240				
U-NII-2A Mid 52	5260	Part 15.407			
to		(DFS - TPC REQ)	Indoor / Outdoor	250 mW / 24 dBm	4
U-NII-2A Mid 64	5320				
U-NII-2C EXT 100	5500	Part 15.407			
to		(DFS - TPC REQ)	Indoor / Outdoor	250 mW / 24 dBm	11
U-NII-2C EXT 140	5700				
U-NII-3 Upper 149	5745	Part 15.407			
to		and Part 15.247	Indoor / Outdoor	1W / 30 dBm	5
U-NII-3 Upper 165	5825				

Table 2. 5 GHz U-NII channel allocations in the United States

Ordinarily, channels 36 to 48 and 149 to 165 are available for use by any low-power, unlicensed "white space" transmitters and receivers. This includes Wi-Fi routers, which also use the 2.4 GHz band and can bond channels across both bands as needed.

Operation on channels 52 through 140 is restricted to unlicensed devices that incorporate dynamic frequency selection (DFS) and transmit power control (TPC). The first feature allows the transmitter and receiver to automatically change frequency when another signal is detected on a channel, minimizing interference. The second feature, TPC, automatically sets the minimum power required to maintain reliable communications.

Operating power limits in the Unlicensed National Information Infrastructure (U-NII) 5 GHz bands are 50 milliwatts (mW) for channels 36 – 48, 250 mW for channels 52 – 140, and 1 watt for channels 149 – 165. Note that these restrictions apply to both 802.11 devices and non-standard wireless protocols.

Operating Range for Wireless AV Systems

The maximum operating range of wireless display connectivity devices is determined by many factors, including channel activity, physical obstructions, and the targeted bit rate. In theory, wireless display connectivity systems are limited to in-room use with a maximum range of 30 to 50 feet. However, 5 GHz signals can and do penetrate walls, especially those made from non-metallic material. With unobstructed line-of-sight (LOS) paths, the point-to-point range of these systems can easily achieve 100 feet or more.

In the United States, an additional 7 GHz of spectrum in the EHF band (57 – 64 GHz) has been allocated for unlicensed, low-power “white space” operations. At these frequencies, signal propagation is strictly limited to in-room operation. Even non-metallic walls will bounce and refract signals, creating dynamic multipath.

Accordingly, wireless AV devices that operate in this part of the spectrum use multiple, steerable antenna arrays to process multiple signal paths. Total effective isotopic radiated power (EIRP) for operation at 60 GHz is limited to 10 watts, much higher than the allowable limits for 5 GHz operation.

802.11N/AN/AC/AD WI-FI

These products primarily operate at 5 GHz (some may also bond channels in the 2.4 GHz band). These kits are inexpensive ($70 - $200) and are widely available through brick-and-mortar stores and online retail outlets. While these “wireless HDMI kits” are affordable and easy to connect and operate, they are susceptible to dropped signals or intermittent operation in areas where there is moderate to heavy Wi-Fi activity.

There are two reasons for this. One is the limited number of channels on which these devices can operate, and the other is their use of basic Internet protocols for streaming video. Apple TV and WiDi are two examples of 802.11a/n Wi-Fi systems that can transport high-resolution display signals. As a result, 802.11-based transmit-receive kits introduce latency and must buffer the signals accordingly.

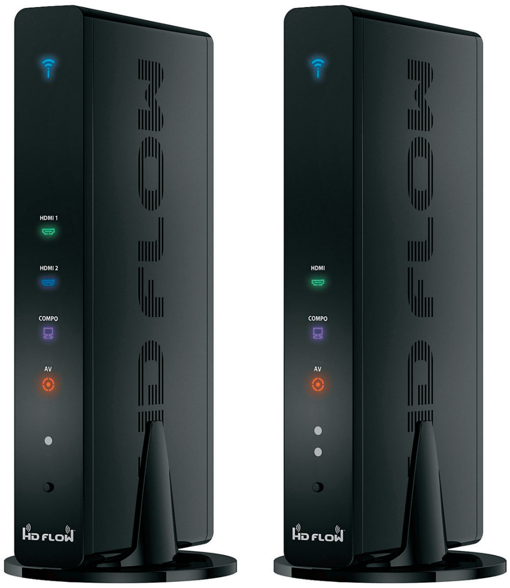

Figure 1. An 802.11a/n wireless HDMI transmitter and receiver kit

Products that use the new Wi-Fi Direct standard (peer-to-peer connection) are more reliable performers when AV connections are made. If the connection distance is short, there will be less interference from other 802.11x devices nearby. Issues with streaming video remain; however.

Yet another standard, 802.11ac, promises even higher speeds by bonding multiple channels to create bandwidths of 40, 60, 80, and even 160 MHz, with multichannel rates of 1 GB/s and single-channel rates to 500 Mb/s. (No 802.11ac wireless display kits were available as of this writing.) Compression must be used to lower the nominal HDMI and DisplayPort bit rates for operation with 802.11-based devices.

At 60 GHz, a new Wi-Fi standard (WiGig Certified) provides faster upload and download speeds through a new class of transmit and receive links (IEEE 802.11ad) that use 2.16 GHz-wide channels. At this frequency, a 1080p/60 signal can be streamed at 3 Gb/s using light compression. Multiple wireless links are enabled with beam steering to prevent interference. No WiGig Certified products have been released to the marketplace as of this writing.

Wireless High Definition (WiHD)

The Wireless HD (WiHD) system (IEEE 802.15.3c) also enables high bitrate wireless display connections. Like 802.11ad, it operates on four 2.16 GHz EHF channels from 57 to 64 GHz and carries audio, data, and video. Like 802.11, WiHD adds a network structure – the wide-area video network (WAVN).

Due to the high absorption factor of nearby objects, WiHD has a maximum range of approximately 30 feet (line-of-sight). However, the full wavelength of a 60 GHz signal measures just .005 meters or .2 inches, allowing for all components in a WiHD radio – including antennas – to be constructed on a single chip substrate that's small enough to be built into tablets, smartphones, and cameras.

The shorter wavelength of a WiHD signal also makes it possible to incorporate beam-steering at the transmitting antenna and employ multiple arrays of receiving antennas. This technique dynamically optimizes the signal path for line-of-sight reception or reflected / multipath reception. Antenna selection / switching cycles take less then 1 millisecond.

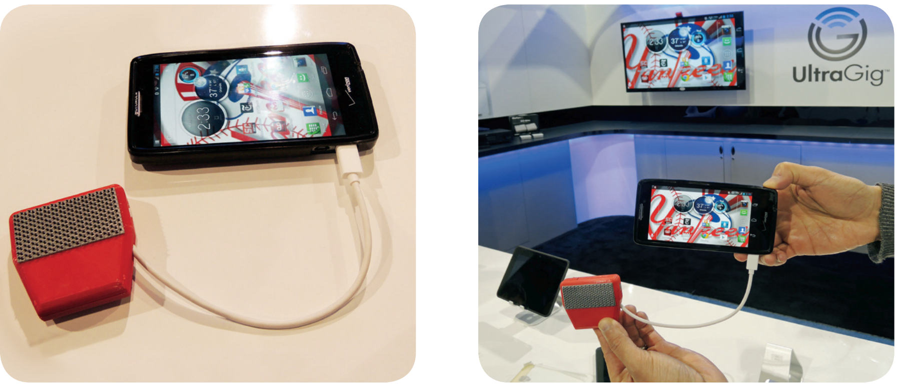

Figure 2. A WiHD prototype dongle, streaming 1080p/60 content from a smartphone to a nearby TV

Silicon Image acquired the original WiHD technology n 2011 from SiBEAM. Even though it has been demonstrated as a wireless HDMI connectivity system, WiHD can also work with DisplayPort and 3G HD-SDI. It can transmit up to four concurrent video streams with a maximum data rate of 28.5 Gb/s – fast enough to enable wireless 4K display connectivity.

The nominal data rate for WiHD connectivity is 3 Gb/s in a single channel, equivalent to a 1080p/60 video stream. According to the current WiHD specification (version 1.1, May 2010), the maximum resolution supported is Quad HD (2560x1440 pixels) with 60 Hz refresh and 12-bit color. At this resolution, the targeted bit rate is 8 Gb/s, with a maximum latency of 2 milliseconds. (8 Gb/s is also the practical limit of HDMI 1.4. However, faster data rates can be accommodated with MIMO.)

A WiHD WAVN uses a Coordinator – typically an HDMI "sink," such as a display or digital video recorder – and one or more Stations, devices that have high-resolution display content to stream or pass along. The Coordinator then selects from the available Stations to establish a wireless connection. Depending on the rate of the physical network layer in use, Stations can conduct bidirectional communications with the Coordinator, exchanging low-resolution video, audio, and metadata.

Wireless High Definition Interface (WHDI)

The Wireless High Definition Interface (WHDI) system is a better choice for professional AV applications than 5 GHz 802.11-based systems. WHDI does not conform to any existing IEEE specification and was originally developed for the U.S. military by Amimon Semiconductor. The technology is now available in both consumer and professional products.

WHDI transmits on 9 or 15 channels in the 5 GHz U-NII band, depending on the hardware implementation. Although WHDI was originally developed to transport HDMI signals, it works equally well with packetized display interfaces like DisplayPort and serial transport streams like HD-SDI. Latency is very low at less than 1 millisecond.

720p-resolution video is transmitted in a single 20 MHz channel @ 166 Mb/s and 1080p video @ 372 Mb/s, using two 20 MHz channels. This is accomplished by assigning weights to bits of the signal, with the most significant bits (MSBs) receiving priority over least significant bits (LSBs).

For example, luminance information receives priority over chrominance information. This process reduces the actual bit rate and is a form of compression, but also functions as a real-time video streaming protocol.

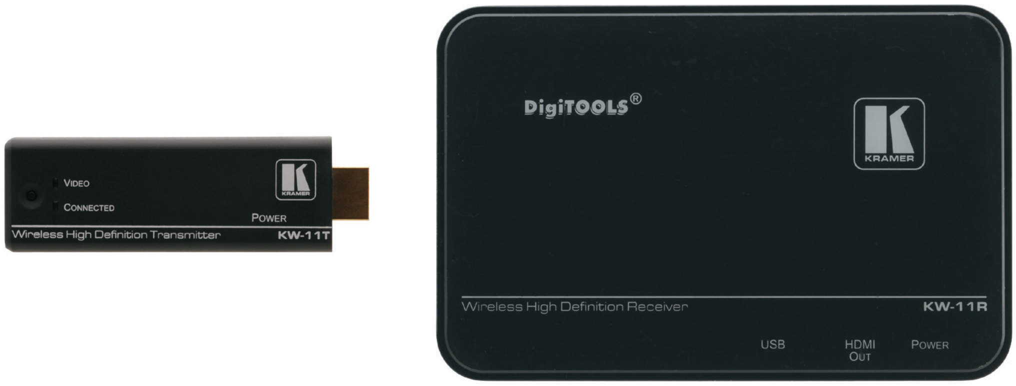

Figure 3. Kramer's KW-11 WHDI 5 GHz stick transmitter and receiver for wireless HDMI connectivity

Kramer's KW-11 WHDI connectivity kit operates on U-NII channels 36 through 48 and 149 through 165 in the 5 GHz band. The small transmitter stick plugs directly into an HDMI jack or connects through an HDMI extension cable. 5-volt DC power for the stick is supplied though a companion wall transformer or a direct connection from a computer to the mini USB jack on the side of the stick.

When powered up, the stick and receiver must first locate a channel and link together. Once that is done, the "Connected" LED will light up. Next, the HDMI signal from the source must be linked, using EDID and HDCP exchanges (when necessary). Once this link is made, the "Video" LED will also light up. Depending on other activity in the 5 GHz band, this linking process can take a few seconds.

Once both LEDs are lit, the KW-11 provides an HDMI connection between the video source and the connected display, switch, or distribution amplifier. The transmitter and receiver do not have to be visible to each other – WHDI links can take place through furniture, walls, desks, tables, and windows. But signal range is greatest when there are few obstructions between the stick and receiver.

Practical Applications for the KW-11

In practical testing at Kramer's Wireless Lab, it was found that a maximum of three KW-11 kits can operate reliably in close proximity. This held true even when two Wi-Fi-based wireless HDMI kits were also in operation close by. In fact, both of the Wi-Fi kits experienced signal drop-out after the KW-11s were connected. That is because the WHDI technology is better able to tolerate in-band interference.

The operational limitation of the KW-11 is a direct result of the limited channel selection for U-NII devices. It takes a single 20 MHz channel to transmit video or computer signals at a maximum resolution of 1280x720 / 1280x800 pixels, while 1920x1080p signals require bonding two 20 MHz channels to establish a link. Three 1080p signals will require six channels out of the nine available to the KW-11.

The KW-11 can be used with any HDMI interface. It has been tested with Chrome OS tablets using HDMI interfaces and Apple iPads with the Apple AV adapter. In addition, the KW-11 has been tested with smartphones employing Micro HDMI and Mobile High-definition Link (MHL) connections. A small, high-capacity battery pack is required to power the transmitter stick when it is used with tablets and phones.

Another practical use for the KW-11 is to connect a presentation switcher to a projector or large flat screen display. The KW-11 stick connects to the HDMI output of a Kramer VP-7-series ProScale™ presentation scaler/switcher, with power provided by the wall transformer. The receiver mounts at the projector or near the flat screen display. Any display and audio signals connected at the stick will be received at the display.

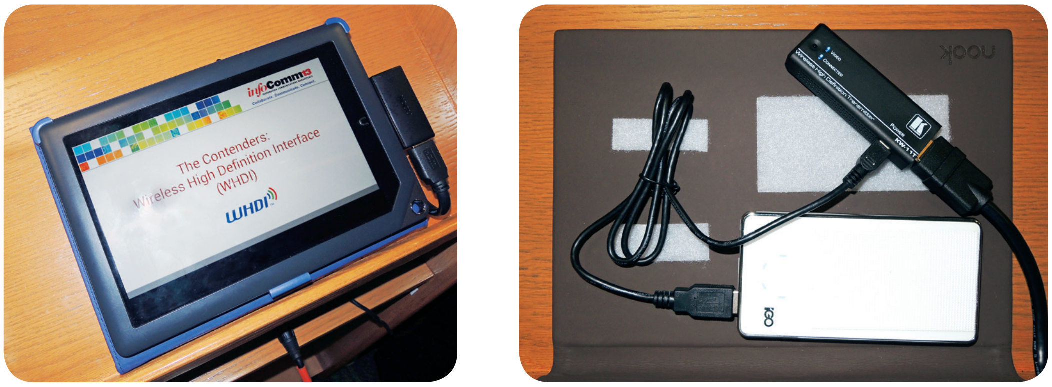

Figure 4. This wireless Nook tablet uses the KW-11 stick and a high-capacity iGo battery for power

Yet another use for the KW-11 is as a wireless HD camera link. Consumer and professional camcorders are all equipped with HDMI outputs for local monitoring as well as USB ports for DC power. The display signal will connect automatically as before, and embedded audio will be passed along to the receiver.

The KW-11 is helpful in unusual staging applications where conventional cables can't be run or attached to room surfaces. As long as the signal can be converted to the HDMI format, it will travel through the KW-11 connection just like any other HDMI signal.

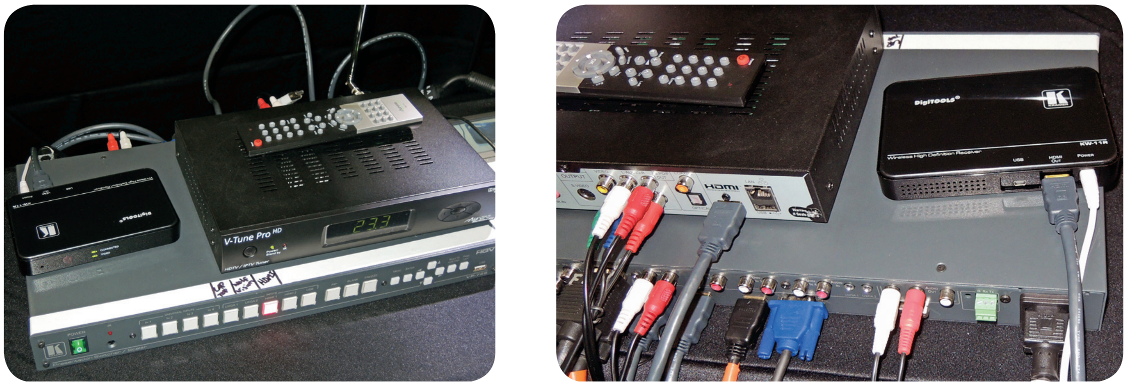

Figure 5. The KW-11 provides a wireless HDMI input to a Kramer VP-728 ProScale™ presentation scaler/switcher

In a unique example, a KW-11 provided a 60-foot wireless video link in a historic 1920s movie theater. The event was a party and fundraiser for a nonprofit theater and was tied into a national movie awards broadcast, attracting over 400 guests.

The theater interior is constructed of stone, marble, tile, and stucco, and it was not possible to drill any holes, install brackets, or tape cables to the walls, ceiling, or floor. A Samsung digital TV tuner located near the entrance was used to receive and demodulate the local HDTV broadcast from channel 6, and the KW-11 stick was connected to the HDMI output of the tuner. (Bottom right photo)

The KW-11 receiver was placed below a 46-inch LCD TV, positioned above the theater box office. (Bottom left photo). The 720p HD signal streamed reliably from the stick to the receiver for the six-hour duration of the event, even though the theater entrance and foyer were full of guests and buffet tables. A similar setup was placed in the refreshment lobby to link a 47-inch LCD TV to a KW-11 transmitter behind the bar.

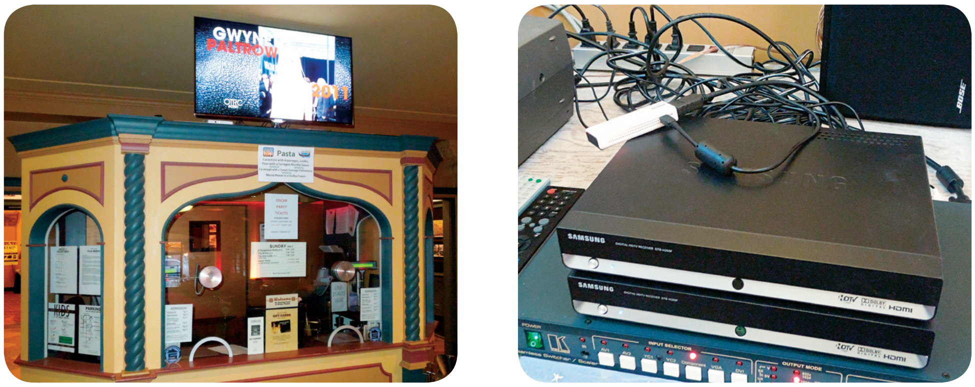

Figure 6. A KW-11 kit connects an LCD TV (left) to a digital TV tuner (right) over a 60-foot path

Operational Considerations for the KW-11

Establishing WHDI links: When using more than one KW-11 stick/receiver set, the best operating practice is to power up each WHDI link one at a time, until channel and video connections are made and verified. Both “Connected” and “Video” indicators on the stick and receiver must be lit for a wireless HDMI link to be established. Bring each additional KW-11 set on-line the same way.

It is not unusual for the 5 GHz WHDI signal to penetrate sheetrock walls, but it will not pass through metal or screened enclosures. Operating range depends on the amount of 5 GHz activity in the area (Wi-Fi or otherwise) and the path between the transmitter and receiver. The nominal maximum operating range for the KW-11 is 50 feet, although distances up to 100 feet have been achieved under ideal conditions.

In areas with very high levels of 802.11 Wi-Fi activity, it may be difficult to establish one or more WHDI links, depending on how many of the nine channels allocated for KW-11 operation are available. The WHDI system is designed to compensate for some degree of in-band interference from 802.11 operations. In this case, it is not unusual for the stick and receiver to take several seconds to connect.

Stick operation: it is not unusual for the transmitter stick to become warm during operation as it is dissipating about four watts of power. Accordingly, the stick should be well-ventilated wherever it is installed. For connections to notebook computers with HDMI outputs, DC power can be directly obtained from any USB port on the computer. Blu-ray players and set-top receivers can be connected in the same way as they also provide power over USB ports.

Battery operation: for portable operation, the stick will require a high-capacity lithium ion rechargeable battery pack, like the iGo shown in the wireless tablet example. These and other makes of portable battery packs come in different sizes and were designed to recharge mobile phones. The capacity of the battery will determine how long the stick can operate.

A battery with a listed capacity of at least 3000 milliampere-hours (mAh) is recommended to power the KW-11 stick in a portable application. This will allow the stick to transmit for 2 – 3 hours. Smaller batteries can be used, but transmit time will be reduced accordingly. A small rig with a 2400 mAh battery and HDMI adapters has been used to connect a smartphone wirelessly to TVs and presentation scaler/switchers.

Receiver mounting: the KW-11 receiver comes with a non-conductive, weighted stand. Use this stand to keep the receiver from sliding or “walking” during operation, particularly if heavy-gauge HDMI cables are being used. The receiver should be positioned (if possible) so it has a line-of-sight path to the transmitter stick, but also will work with signal echoes and multipath. However, the receiver should not be encased in a metallic enclosure, as this will shield the transmitter signal completely.

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