Cutting the Cord

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New Wireless Technology Brings Roving HD Broadcast to Major Events.

After years of waiting for wireless/RF-based HD camera systems to become practical for use as roving cameras in live broadcast situations, the sudden deployment speed of such systems at major events is noteworthy. Prior to late last year, manufacturers, vendors, and broadcasters were still struggling with bandwidth limitations, serious latency issues, signal interference concerns, power consumption challenges, and a host of other obstacles on various embryonic systems. Therefore, they were usually settling for either shooting HD and downsampling it considerably for RF transmission, or shooting SD and up-rezzing it as best they could for broadcast.

The AVS/LinkHD RF system debuted successfully at a Monday Night Football game in December, with the LinkHD transmitter and a battery block attached to a Thomson LDK 6000 camera

Then, in December, European broadcast vendor Presteigne Broadcast Hire for the first time successfully used the LinkHD system from Link Research Limited, of the United Kingdom, married to Thomson LDK 6000 cameras. During a swimming competition at the Third West Asian Games in Qatar, the company incorporated a signal and was able to turn around in less than 50 milliseconds (around 1½-frames latency) from capture to broadcast. Just like that, roving, untethered HD camera coverage entered the broadcast equation as a serious option.

With Aerial Video Systems (AVS), Burbank, Calif., as its lead vendor/integrator in the United States, the LinkHD system was next tested during a Monday Night Football game by ABC. That success convinced the network to hire AVS to set it up for use in sideline reports during its Super Bowl XL telecast.

During this same time period, another HD wireless camera system also debuted at major events. Part of a solution called RF Extreme from RF Central and its sister company, Total RF, in Bensalem, Penn., the system uses the High Definition Messenger Transmitter (HDMT) system manufactured by Global Microwave Systems (GMS) of Carlsbad, Calif., as its foundation. The GMS/Total RF package was also tested successfully during a December Monday Night Football game, and again during the NFC Championship game on Fox in January. Those results prompted CNN to employ it for certain shots during live coverage of President George W. Bush's State of the Union address in January. Soon after, the Academy of Motion Picture Arts and Sciences incorporated it into its Oscar pre-show red carpet coverage, which aired on ABC in March (see the sidebar on p. 20).

TNT also employed the AVS/LinkHD system during its telecast of the NBA All-Star Game in February, while, simultaneously, NBC and Presteigne used LinkHD for a variety of interviews, secondary coverage, and POV shots during the XX Olympic Winter Games in Torino, Italy.

In addition, early this year, a third HD RF system began to see deployment in the field at football games and on New Year's Eve in Times Square. That system was designed by veteran engineer John Porter and is distributed by 3D Wireless, LLC, of Severn, Md. The 3G Wireless system is compatible with various Sony, Thomson, and Ikegami HD cameras, and the company is also reportedly incorporating an optical-link transmission device based on light-beam technology into its HD RF arsenal for certain types of coverage. However, at press time, officials at 3G Wireless declined to discuss specifics about their technology or its applications.

The AVS/LinkHD system was also present on Oscar night — used by E! Entertainment in a fixed-position configuration for its own red-carpet coverage, as well as in the Ameriquest Blimp for aerial POV shots. At press time, ESPN was planning to incorporate both the AVS/LinkHD and Total RF/GMS systems into its coverage of the World Baseball Classic and the upcoming Major League Baseball season. Both systems are being tested for use on major golf tournament broadcasts, and virtually every major network is investigating one or both systems for possible use on other shows in coming months.

“This kind [of coverage] did not exist a month ago,” Randy Hermes, president/CEO of AVS, told *Millimeter* in January, just days after his company successfully combined the LinkHD system with AVS' proprietary fiber-optic antenna system for ABC during the Super Bowl. “A little over a year ago, no one even thought it was possible to broadcast [a wireless HD signal] with ultra-low delay, and now we have it just barely over a one-frame delay. But it's still brand-new — a major addition for major sporting events — and you will see it become commonplace in coming months.”

Figuring It Out

A little more than a year ago, Link engineers began to build on the proprietary MPEG encoding and decoding schemes they had used for some time on standard-def wireless transmitters to come up with an approach that could handle the robust bandwidth of HD. The result was the LinkHD L1403 encoder/transmitter.

The first live test of the LinkHD system on an HD broadcast occurred during the European airing of a swimming event at the West Asia Games late last year.

John Mulcahy, general manager at Link Research, says Link also developed a proprietary modulation codec, dubbed LMS-T. The basic concept behind LMS-T is to move more HD data through a traditional pipe — allowing higher bit rates to be sent without compromising the RF link. Rather than using a 64 QAM (quadrature amplitude modulation) signal, which he says is required to transmit high-quality HD imagery in the standard DVB-T modulation scheme used for traditional microwave transmission in the United States, the system transmits an HD signal through a more robust 16-QAM signal path, with a 9.4MHz wide COFDM spectrum. In other words, he claims that Link's modulation and compression scheme permits transmission of a larger bandwidth, higher-quality HD signal that combines low latency with the power of a traditional SD RF system.

“We worked to optimize the MPEG compression engine to get the best out of HD pictures, and we dismissed the idea of downsampling the signal to send it out over the air before upsampling it on the other end, since you don't end up with the same image you started with,” explains Mulcahy. “What we managed to do was send a contribution-quality HD signal with 18mb as a stream, and send that within a 10MHz RF bandwidth.” He adds that the LMS-T modulation scheme is as robust as a standard DVB-T link, but at HD bit rates.

“This has gotten us to just under the 50-millisecond delay — and, in tests, we have even gotten it to the low 40s,” he adds. “It will probably be difficult to go much beyond that, since we are already at just 1½ frames [latency] at this point. To go lower than that would compromise picture quality or require much more bandwidth, and, from an RF point of view, it would be difficult to get that much frequency. But the point is we have shown this system can maintain a robust RF link with very low delay on major live broadcast events.”

According to president Steve Gansky, Total RF's approach relies on a GMS HD transmitter within the traditional DVD-T modulation scheme, achieving latency of just less than two frames.

“As you get closer to one frame of latency, that can be considered realtime for broadcast purposes, since you get rid of the frame synch and genlock your receiver,” says Gansky. “Our system is also running the 8MHz footprint that is standard in this country.”

Gansky adds that Total RF has also worked to make its system compatible with most broadcast cameras.

“We have already used it with Thomson, Sony, and Ikegami cameras by engineering special brackets for placing the transmitter on HD cameras that were not necessarily designed for RF applications to begin with,” he explains. “None of these first-generation HD cameras have standard camera adapters because no one thought we'd be putting stuff on the back of them and using them as portable cameras. Therefore, every camera we use needs a bracket manufactured for it. It's not a giant engineering feat, but you can't drill the camera itself, so you have to find screws to remove on top and bottom of the camera and attach the bracket without modifying the camera. Especially because, typically, the camera is not ours, we have to find real estate on the back to throw on the microwave transmitter and the battery. In some cases, we've had cameramen wear battery belts. But the point is we have expertise in manufacturing and placing these [transmitter] units onto cameras so that HD cameras designed to be used as tethered cameras can be used for RF applications.”

In the Field

One of the events that used the Total RF/GMS system recently was the president's State of the Union address, for which CNN produced live pool coverage of the speech for all major networks. For the speech, CNN wanted a roving Steadicam to follow President Bush into the House Chamber just prior to his speech and to shoot cut-away shots during his speech for a 1080i broadcast. (This year, since different networks have different HD format preferences, the resulting HD signal was both crossconverted to 1080i and 720p, and downconverted to 4:3 SD and 16:9 SD, as well.)

The GMS/Total RF camera system was used during CNN’s live HD broadcast of President Bush’s State of the Union address in January.

The network researched the LinkHD and Total RF systems and decided that, rather than upconverting an SD signal coming from

the House Chamber as it had done in the past, it wanted a true HD signal to work with. Tu H. Vu, director of broadcast and IT for CNN's Washington bureau, says he researched both systems, but with the only LinkHD system available at the time already committed to the Super Bowl, he chose the Total RF/GMS approach.

Prior to the speech, CNN provided a Sony HDC-930 HD camera to Total RF for testing and interfacing with the GMS transmitter, and Total RF churned out a special bracket to wed the transmitter to that camera over the course of a weekend, according to Gansky. Total RF also set up a dual-diversity antenna system inside the House Chamber to move the signal, with a fiber connection between the antennas and a production truck located outside the chamber, about 800ft. away, according to Vu.

Vu reports, “[The system ended up] delivering beautiful HD pictures on a wireless link from the House Chamber for the first time in history, and this was never before possible.” But, he and Gansky add, with such technology being in its infancy and the cameras involved not designed for such applications, the RF team encountered expected challenges along the way.

“Heat and high battery consumption were two major issues,” says Vu. “Camera-mounted COFDM HD wireless transmitters run hot, and caused occasional thermal shutdowns [in testing]. Total RF rigged a couple of small computer CPU fans as a temporary fix, and this lengthened the duration between power-down [requirements] to between 45 minutes [and] an hour, which worked for our broadcast. Battery consumption is about 20 minutes per charge, so we had to work around all those technical limitations. But as I said, in the end, the system delivered.”

Vu says that, even though he was working with a relatively embryonic system at the time of the broadcast, this approach was actually far less hassle for CNN in terms of incorporating RF material into the rest of the HD broadcast, because networks have been broadcasting the State of the Union speech in HD for the last four years.

“The HD wireless transmission link had low latency, allowing the production staff to inter-cut cameras more freely,” he explains. “A comparable SD wireless system has to go through an upconversion process [for an HD broadcast] in addition to those [delays] inherent in wireless transmission. That adds significant signal delays, which can cause lip-synch issues when cutting between cameras.”

In February, NBC also asked Total RF engineers to figure out a way to make the LinkHD system work with new Sony HDC-1500 progressive scan cameras for its Winter Olympics roving camera coverage. (For a report on NBC's HD storage infrastructure at the International Broadcast Center in Torino, see p. 12.) Until that point, in tests at NFL games and the NBA All-Star Game, the LinkHD system had only been used with Thomson's LDK 6000 cameras. Sony was NBC's lead technology partner for the Olympics, however, and Presteigne was the first vendor in the world to invest in the LinkHD system, so NBC was determined to combine the two for its Olympic RF needs.

“We wanted to see if we could deploy the [Sony] camera with the LinkHD RF system, and that proved to be a little problematic at first,” says Chip Adams, NBC's director of venue engineering at the Olympics. “The 1500 is designed to be used with a fiber transmission system primarily, so we knew we would have to push it. This required [Total RF] to develop a mounting bracket for the microwave transmitter to fit it with the camera, and that made the attempt rather challenging.”

Gansky says that, although his engineers have been able to get an Anton Bauer battery brick onto the back of other cameras at other events, for the Olympics, in the time frame available, it simply made the most sense to fix the microwave transmitter to the camera and have cameramen wear battery belts.

“Normally, we would have thrown the brick onto the back of the camera, but for what they were doing at the Olympics, that would have made it a long and heavy camera,” Gansky says. “So we put the bricks directly onto the camera guys — two on each of them in a battery belt. That let them go A-B on the battery, wasting less time as they switched over as batteries ran out. This didn't make their camera guys super happy, but the new generation of HD stuff throws lots of curves like that at us.”

Of course, marrying the camera, transmitter, and battery together is only part of the challenge in designing a workable HD RF solution. The other key issue is the method of transmission back from the antenna location at a major event. Both systems use diversity antenna configurations to address this issue. Total RF depends on fan beam antennas built by Gigawave in the United Kingdom, while AVS uses a proprietary combined-antenna-and-fiber solution to carry RF signals between the receive location and the mobile unit.

Users of both systems have been tweaking the method of transmission and placement of antennas and receivers ever since they debuted at the end of 2005. During the Super Bowl, for instance, AVS, working with mobile production company NEP Broadcasting, Pittsburgh, set up two sets of diversity antenna pairs near the field and optically transported the signal to a Link L2132 HD decoder, located in an NEP truck just outside Ford Field in Detroit. A few weeks later, for the NBA All-Star Game's pre-game and halftime shows at the Toyota Center in Houston, AVS instead used the LinkHD system in a Steadicam configuration and a single diversity antenna pair, connected by a single TAC-4 fiber cable to the receiver/decoder and data transmission system located inside a production truck outside the arena.

“We ran a fiber cable from the TV truck to the A set, which was the host set position for the shows at center-court of the arena,” Randy Hermes explains. “All signals were RF on glass, meaning we remoted all the antennas with

fiber directly to the truck and only needed antennas and AVS fiber converters to receive and transmit at the host position — no receivers or transmitters were inside the building. This proved very robust; the camera was free to roam anywhere in the arena, and we were able to send and receive a strong signal.

“Before that, at the Super Bowl, we had to locate the camera control transmitter inside the stadium and send data control via a separate modem from the truck, but here we didn't have to do that. This also lessens the equipment required inside the stadium, and instead we can make all our adjustments, such as frequency and power levels, from the TV truck. I believe that having as much hardware and control inside the mobile unit, outside of the actual venue, makes life easier for all concerned.”

Looking Ahead

As networks incorporate HD RF systems into broadcasts, natural questions abound about how much engineers can reduce latency, how to improve transmission configurations, and how to make sure enough frequency bandwidth is made available for such systems to operate efficiently. As Tad Scripter, the Academy's engineer in charge of its Oscar-night production work, points out, “This whole thing is changing so quickly — it's only been a couple of months that we have been able to do this.”

TNT used LinkHD RF technology during pre-game and halftime shows at the NBA All-Star Game, this time configured for Steadicam and transmitting to the receiver/decoder in a production truck outside.

Therefore, he says, there is a lot of uncertainty about what's next for HD RF systems. Scripter says that as systems start to proliferate, dependence on just a couple of vendors with expertise in how to use them, such as AVS or Total RF, will be crucial. But even those most familiar with these systems still have a lot more to learn, Scripter adds, pointing to seminars that have been taking place around the country on this subject in recent months. Shortly before press time in March, the Vitec Group and National Mobile Television sponsored a major event on this topic: the HD Wireless Solutions for Field Production symposium held in Rye on Brook, N.Y. Scripter and representatives of most major networks and vendors, including Total RF and AVS, attended the event, which was designed to have industry leaders witness and discuss the implications and possible applications of the most recent advances in HD RF production-related transmission.

“We're all still learning about it,” Scripter says. “I expect we'll next see improvements in the MPEG encoding process and in antenna systems design. We'll probably be able to soon use antenna deployments similar to cell phone zones. You will be able to create multiple zones and tie those zones together in a pretty large area, allowing us to better deploy these cameras with no breakup. Right now, there is increasingly less bandwidth available as more of it gets sold off to other interests. Therefore, coordination of the remaining space available is an issue. And meanwhile, manufacturers are looking for other spectrums — bands of frequency — that have room available.”

Some of the lessons are fairly simple if broadcasters plan sufficiently, says NBC's Chip Adams, but out on the bleeding edge of pioneering the use of such technology, they might run into a few surprises along the way.

“You have to understand that you can't take these cameras anywhere and expect a strong signal to get back to your antennas,” he says. “We had a problem one time during the Olympics with an interview where our cameraman was standing literally underneath the antenna, and we got a signal back that was breaking up. It was working perfectly prior to that, so we weren't sure what was going on. But then we realized, if you stand under the receive antenna, it just doesn't work as good. So you have to plan and rehearse all of this stuff, and really prep your production people on its limitations.”

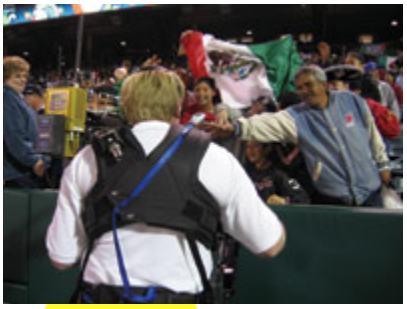
But in terms of their feasibility for use on major broadcasts in place of standard SD RF systems, experts say HD RF's time has arrived.

“The important thing to note is that these two systems have shown the ability to give us about the same latency as we have been achieving for some time with standard def,” says Scripter. “That means [HD RF] is just as practical as digital SD RF in terms of how well it works. What will happen now is the cost will become an issue. As the cost gets closer to the cost of using an SD system and upconverting it, you will see more of these systems out in the field, especially as we see more native HD shows. In any case, for the first time we are now RF- impartial: Certain vendors can do an SD or an HD signal for us without a tremendous penalty in terms of latency, depending on what is best for our show. That's a major change for our industry.”

For a bird's eye view of wireless HD transmission systems in news helicopters, see “HD ENG Takes Flight” in the February 2006 issue of Video Systems *or at* **digitalcontentproducer.com/workflow/video_hd_eng_takes**.

Oscar Night in HD

On Academy Award night, both the GMS/TOTAL RF and AVS/LinkHD systems were in play outside the Kodak Theatre in Hollywood. The Academy of Motion Picture Arts and Sciences, which produced the Oscars show for ABC, had Total RF configure its GMS system with Thomson LDK 6000 cameras for use as celebrities entered the venue on the famous red carpet. Simultaneously, E! Entertainment and AVS were using the LinkHD system, also with Thomson LDK 6000 cameras, but configured with a 33:1 zoom lens at a fixed position on top of the Ripley's Believe It or Not building across the street in a setup designed to capture activity on the red carpet from far away.



The GMS/Total RF system was also used extensively in March during cable coverage of the World Baseball Classic.

“For the Academy-produced pre-show, it's important to see all the elements very well, so ideally, you need a camera physically on the red carpet,” explains Tad Scripter, the Academy's engineer in charge of its Oscar-night production work for both the pre-show and main coverage of the award ceremony for ABC and the Academy. “You don't want to use a wired camera on the red carpet for obvious reasons — it would be a safety hazard if you had a cable there. That takes you to using an RF system, and, for the last three years, we have produced the pre-show in HD. In the past, we used a 16:9 SD camera image and upconverted it to HD from the red carpet. But this year, for the first time, the technology was there to capture those proceedings in native HD [720p, per ABC's preferred HD broadcast format], so we turned to Total RF, since we had worked with them the last four years on the red carpet, and they brought the GMS system into the telecast.”

Scripter adds, “The antenna system hardware — receiver and encoder — were placed out on the red carpet, and we outputted ASI data back via fiber, and then decoded that data in the production truck. Also, don't forget that since the receiver is genlocked, you don't need to use a frame synchronizer, helping to keep latency as low as possible. The only drawback was that, to achieve low latency, we had the slightest diminished chroma bandwidth. But that is not really visible, nor a very big thing in terms of the overall compression scheme, and anyway, it is something that hopefully we will see get better in the future as compression techniques improve and we move away from MPEG to other schemes, such as, perhaps, wavelet-based JPEG 2000. In any case, the overall result was great, and the whole thing went very smooth.”

E!, meanwhile, did not have a camera physically on the red carpet, and was instead peering down at it from a fixed position far away. Yet a wireless camera was still necessary, because production trucks were located on the other side of Highland Avenue, next to the Kodak Theatre, but far from E!'s vantage point on the roof of the Ripley's building. Running cables between those two locations simply was not feasible.

“Our position on the roof included a separate little platform for all the equipment,” explains Brian Quacquarini, E!'s manager of studio and live event operations and the network's technical manager on Oscar night. “It was basically just a small rack unit with antennas and horns on stands, with direct line of sight to the truck farm. [Near the trucks], we had a 10'×10' tent set up with all the receive equipment in it. The HD transmission part of the setup worked great. There were a couple of hiccups, but they were hiccups that are typical of wireless camera systems, such as the data path back to the camera to control iris level was intermittent at times. Resetting the unit fixed the problem, but that wasn't related to the HD transmission aspect.”

Meanwhile, a second AVS/LinkHD system was in use overhead that same evening. An AVS/LinkHD system with a Broadcast Microwave Service 10W, high-power linear amplifier and a Cineflex HD gyro-stabilized camera system operated on the Ameriquest blimp to remotely deliver an aerial POV from high above the Kodak Theatre to E!, KABC (Los Angeles), and TV Guide Channel viewers. Quacquarini says KABC donated the frequency it licenses and normally uses for its HD helicopter in the Los Angeles area to the project, and his team then provided the three broadcast entities with HD imagery from the blimp — some of which was broadcast in HD and some of which was downconverted for broadcast.

Geoffrey Howe, director of engineering for AVS, says his team positioned two receive antennas on the ground, adjacent to the truck farm while the blimp was in the air.

“We put up an omni-directional antenna and a Goldenrod directional antenna, pointed right at the blimp,” he explains. “That got the signal directly to our manned receive site, and from there, it was just regular SDI/HD cable to the truck, which was only about 500ft. away. We've now used [the LinkHD system] in a few aerial applications, and it has always worked smoothly.”
— **M.G.**