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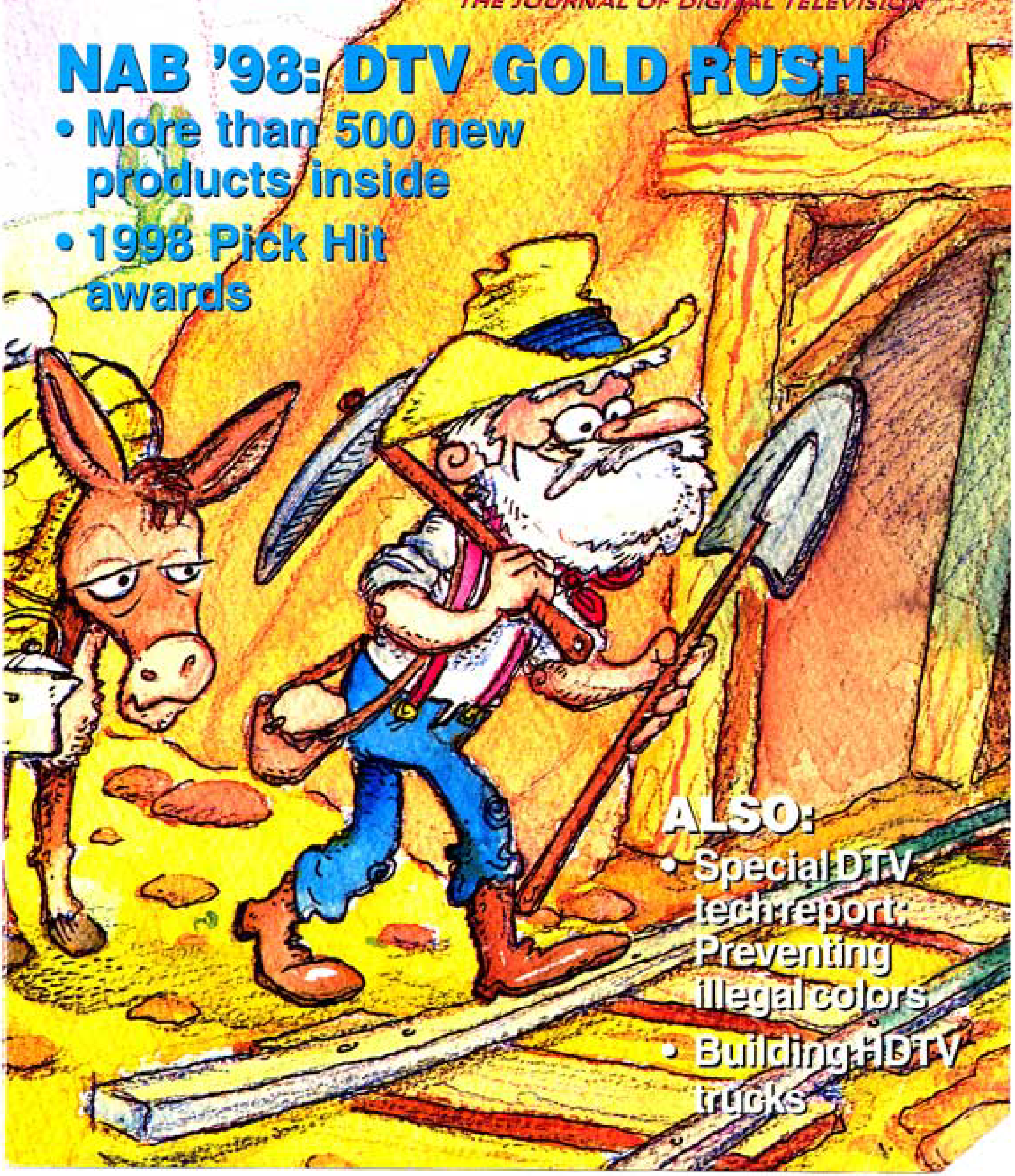

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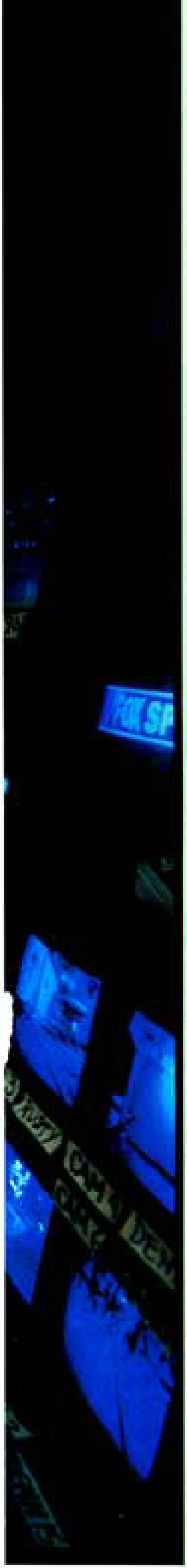


Building HD remote trucks

By Jim Boston

Now that the first wave of DTV stations are moving from the planning to the implementation stage, with air dates this November, thoughts are quickly turning to filling the ATSC programming pipeline. As we all know, stations are wrestling with which entries in ATSC's Table 3 to offer viewers. Looming over these considerations is the fact that Congress has let it be known that they want their HDTV. Network-affiliated stations will naturally look to their networks for cues as to the digital infrastructure they will adopt. In most cases, HD will play some part in these plans.

HD paths imply HD programming. A large inventory of programming shot on 35mm film provides an excellent start for the HDTV roll out. But to provide the same variety in HD as SD (standard definition), it's important to start building electronic HD production facilities. It's generally accepted that HD really demonstrates its value in field production. Until recently, HD field acquisition was an EFP type activity. Now, complete mobile HD production facilities are getting ready to hit the road. These facilities are commonly known as remote or OB (outside broadcast) trucks. A few years ago traditional, analog OB trucks saw their first digital offspring. Now, this digital generation is about to witness another big evolutionary step with the arrival of the higher bit-rate HD digital truck. This article will examine the logistical and engineering challenges facing the builders of these trucks.

Three-in-one

First, let's come to grips with the scope of a project like this. For those who have added digital infrastructure to an existing analog facility, you know the result is generally a digital layer over the existing analog layer. A common lament in this case is that if building from scratch, one could build a digital-only plant. But those who have had the luxury of building a digital facility from scratch will tell you that even in this case, you still end up with both analog and digital layers. The same holds true when building an SD digital truck from scratch.

Many have already surmised what must happen when building an HD truck. You still need an analog NTSC layer, a serial digital interface (SD-SDI) layer, and an HD-SDI layer. To build an HD truck, you really have to build three trucks in one.

Let's look at why this is so. Although most sources will have an HD path through the truck, not

Photo: Remotes will be the first, and probably the most important, source of new HD programming. Trucks like the National Mobile Televisions's DX-4, equipped by Sony, will be reincarnated in HD versions. This story illustrates the design process required to bring an HD truck from concept to reality.

all sources have HD outputs yet. Almost all have SD-SDI, so some sources will also need paths to an HD upconverter. Additionally, just because you have an HD truck doesn't mean you still won't have SD customers. Therefore, many outputs of the truck will have to be downconverted back to SD. Up/down converters are not cheap; they currently top out at over $100,000. This forces a desire to limit the number of these used on a truck. This also means that an SD digital router is required, along with the HD router.

Today's remote trucks often have upward of 150 monitors onboard. Few of these usually need to be high-quality evaluation monitors. So, it makes economic sense to use lower-priced monitors (often with analog inputs) for less critical applications. Because most HD (and SD digital) gear also has NTSC analog outputs, this infrastructure, complete with its own router, is usually desired. Surprisingly, the HD router matrix may be the smallest, and the NTSC router matrix maybe the largest.

In some cases NTSC waveform monitoring still makes sense. Many video operators find that camera balance and matching are easier to perform using NTSC test equipment than SD or HD digital component test equipment. This is because baselines are easier to quantize. Plus, the NTSC test equipment is much cheaper. Generally, the only paths that are solely in the HD layer are those tangential to the production switcher and DME/DVE.

The audio side of the truck undergoes a similar stratification. The main audio layer today is AES, but often a sizable analog audio layer is also present. The two audio layers will generally each have their own routing matrices. A third level will probably evolve over time as 5.1 surround sound, which requires six channels of audio, might have to be encoded into one or two AES channels. Most VTRs today still accept only four separate audio feeds. This leads us back to the video. If a network distribution standard (network to affiliate feed) becomes dominant, this might extend back to the origination truck, or the contribution feed, historically known as the "backhaul." This would mean an ATSC-type signal might need to emanate from and be processed on the truck. Add a machine-control layer to the truck, and we have eight layers of signals, each probably requiring routing capability.

HD means heavy-duty demands

Superficially, we have just stated what fabric needs to be woven into an HD truck. However, the truck has to be deemed useful and worthy of its clients. What amenities must be loaded into the van to accomplish this? Most first-rate trucks today must carry at least 12 cameras, but trucks carrying over 20 cameras ply the interstates. A dozen onboard VTRs is not uncommon and operational space and seating for a couple dozen people is not considered unreasonable. On top of this, it is assumed that the mobile facility will be extremely flexible and highly fault tolerant, hence all the routing and patching on all the layers previously mentioned. And we have to keep the interior warm in the winter, and more importantly, cool in the summer.

As expected, everything about an SD-SDI truck is more than an NTSC truck, and everything in an HD-SDI truck is more than an SD-SDI truck. Let's start with price. To produce the facilities mentioned in the previous paragraph would cost $4,000,000 to $5,000,000 on an NTSC truck. An SD digital equivalent would come in at $6,000,000 to $7,000,000. The HD example could easily approach double the price of an NTSC truck. Most big trucks on the road today have trailers that range in length from 48 feet to 54 feet, and have expandable sides to increase the interior "people" space. A ballpark figure of the weight for an empty trailer of this size is 40,000 pounds. Most trucks this size will end up approaching the bridge weight limit in the United States, which is 80,000 pounds. Generally, an NTSC truck could just make this weight and still carry all its assigned equipment, but SD digital trucks have a harder time accomplishing the same feat.

Many trucks today travel in tandem with utility trucks. Or some of the operations or functions, such as graphics or VTRs, are off-loaded onto a secondary truck. Whereas an NTSC truck might need 20 racks to house the needed equipment in the truck, an SD-SDI truck of similar capability could require up to a dozen more racks. This obviously cuts into the people space, hence the single-, then double-, and now triple-expando trailer.

The first expandable trailers had single-expando sides that came out from the curb side of the trailer. A second

All trucks start out as shells. Here, the NMT HD-1 truck is shown in the Girling Associates factory being modified prior to equipment installation. These modifications included adding "expando" sections, which are needed as much for more people as for equipment.

expandable segment of the trailer was the area where the monitor wall would be in a production compartment turned lengthwise. The third expando trailer area is now out the back of the truck. An HD truck with similar capability to our NTSC example and SD-SDI trucks could require up to 40 racks full of equipment.

There several ways that all this new equipment will place new demands on the truck's design. Where an NTSC truck's rack-mounted equipment would be in the 8,000-pound range, the SD-SDI truck might weigh in at 10,000 pounds, and the HD-SDI truck could add several additional thousand pounds.

More equipment naturally means more power, but digital SD and HD add another element. Component SD-SDI has a clock rate of 270MHz. HD-SDI (all high-definition formats, along with all ATSC formats are component) has a clock rate of up to 1.458Gb/s. High clock rates tend to force equipment to run in high current conduction states a greater percentage of the time, increasing the power draw of that equipment.

The videotape and control area contain nine racks. The first five racks, shown above, contain five HDW-500 recorders and associated monitors. The next four racks provide video control for up to 16 cameras. Note the large black box on the right. It is used to house one of two HDM-20E1U high-definition monitors.

An NTSC truck might consume 75kW to 80kW of power under full operation The comparable SD-SDI truck would require in excess of 90kW. The power requirements of the HD-SDI truck would probably require at least 130kW of service. An extremely small percentage of that consumed power in any facility actually ends up as useful signals, the generated heat is considerably higher in SD-SDI and HD-SDI trucks.

These high current requirements found on digital trucks mean that giving the truck the option of running on single phase is no longer a viable option. Most of these new trucks will require three-phase service. Whereas 10 tons of cooling capability would suffice for the NTSC truck, 15 tons would be prudent on the SD-SDI version, and 20 tons on the HD-SDI version. Actually, the environmental power requirements, lights and air conditioning, usually consume the bulk of the power. Our hypothetical HD truck's tech power would probably be around 50kW. The other +80kW would be to just maintain the internal environment.

There is another reason why the hurdle is raised when contemplating the HD facility. There is energy content in an HD signal that only half jokingly seems closer to light than DC. In an NTSC truck, any energy running through the coax that was higher than 10MHz was noise or spurious harmonics. In an SD-SDI truck, energy over 1GHz down the coax was normal. Now with HD, energy approaching 4GHz is desired.

Why so high? SMPTE 259M and SMPTE 292M (SD and HD serial transmission standards) specify bit-shuffling algorithms designed to create lots of "edges," which are needed in a self-clocking system. In fact, enough edges are created so that for all practical purposes, both signals can be considered square waves. Each bit cell, 1/2706/sec for SD-SDI, and 1/1.5E9/sec for HD-SDI, can be thought of as half the period of that square wave.

What does it take to make square waves? From Fourier's teachings, we know that signals with even symmetry, such as a square wave, require a fundamental sinewave and the odd harmonics to construct. Thus, component SD-SDI requires a 135MHz fundamental sinewave, and the odd harmonics. The third harmonic, which is 405MHz for component SD-SDI, is the most important one. When the third harmonic's amplitude drops below 6dB above the noise floor, the dreaded "error cliff" has been reached, as the SDI signal has effectively stopped being a square wave and has become a sinewave. This prohibits the serial receive circuitry from reliably detecting "edges," and self-clocking at the receiver becomes problematic.

How is HD-SDI different from SD in this regard? Multiply by six and you're there. HD-SDI's fundamental is around 750MHz and its third harmonic is a mere 2.25GHz. This will severely limit your choice in cabling. Keep in mind that this six times differential equates to picture quality also. Whereas a SMPTE 259M SD-SDI picture would have 691,200 active elements in a frame of video, SMPTE 292M HD-SDI has 4,147,200. This means that a wide shot of the ballpark in HD will be nearly as good as sitting in the stands.

Weighty issues

This segues into cable size and weight, another challenge in building the HD-SDI facility, be it on wheels or cement. An interesting corollary is racked equipment weight vs. overall cable weight. They usually are close to each other. On a truck it is imperative to eliminate any unnecessary weight. One way to do this is to use the lightest, and therefore usually the thinnest, cable possible. The trade-off is that thinner cable tends to have greater loss as function of frequency. Thin coax for NTSC tended not to work as it rolled the chroma off. Then it seemed to hit its stride with SD-SDI. However, it still tended to roll off higher frequencies much faster than lower frequencies, but the lengths used on trucks didn't cause the third harmonic in SD-SDI signals to attenuate to a level anywhere near problem levels. This is not so with HD-SDI.

Whereas an SD-SDI signal might travel 600 feet down mini coax with no problem, an HD-SDI signal would be limited to 200 feet down the same coax. So, as far as trucks are concerned, the renaissance of mini cable seems to be in the SD-SDI domain. As alluded to earlier, cable weights for NTSC, SD-SDI, and HD-SDI trucks should be in the 8,000-, 10,000- and 14,000-pound ranges in association with the weight of the racked equipment. Cable weight on an SD-SDI truck might break this rule due to the use of mini cable.

Cable size found on the truck is not only dictated by the flavor of the video coursing through it — audio has similar problems. If AES-3 audio is used over twisted pair, it requires true 110Ω cable. This is because AES audio pumps energy into its cables comparable to NTSC video. Reflections at these frequencies become important. 110Ω cable tends to be larger than 600Ω cable. With analog audio, the upper frequency limit is typically limited to 20kHz.

Even if cable with the wrong impedance is used, the reflections are such a small percentage of overall path length that they are not noticeable. But at AES frequencies, they would cause problems. This means that AES requires the right impedance, and therefore, larger diameter cables must be used. The result is that AES audio adds to the cable weight and space required on the truck.

AES adds complexity in some other ways also. Large AES mixers can be thought of as audio routers with internal digital processing. This means that outputs are not hard-wired to any particular purpose and can usually be specified to be analog or AES.

Deciding which layer AES mixer outputs belong in can be confusing. AES mixers are serious DSP devices, and they tend to be driven by elaborate computer-based systems. This means that UPS power systems need to be employed to ensure that power glitches do not become major audio events. Auxiliary analog mixing systems used as fail-safe backups should always be employed on HD trucks. Equipment with AES interfaces also requires a reference timing signal. This can be either AES's Word Clock or an analog video reference. It is often customary to feed the video reference into the AES mixer, and to use the mixer's AES Word Clock reference output to lock the other equipment.

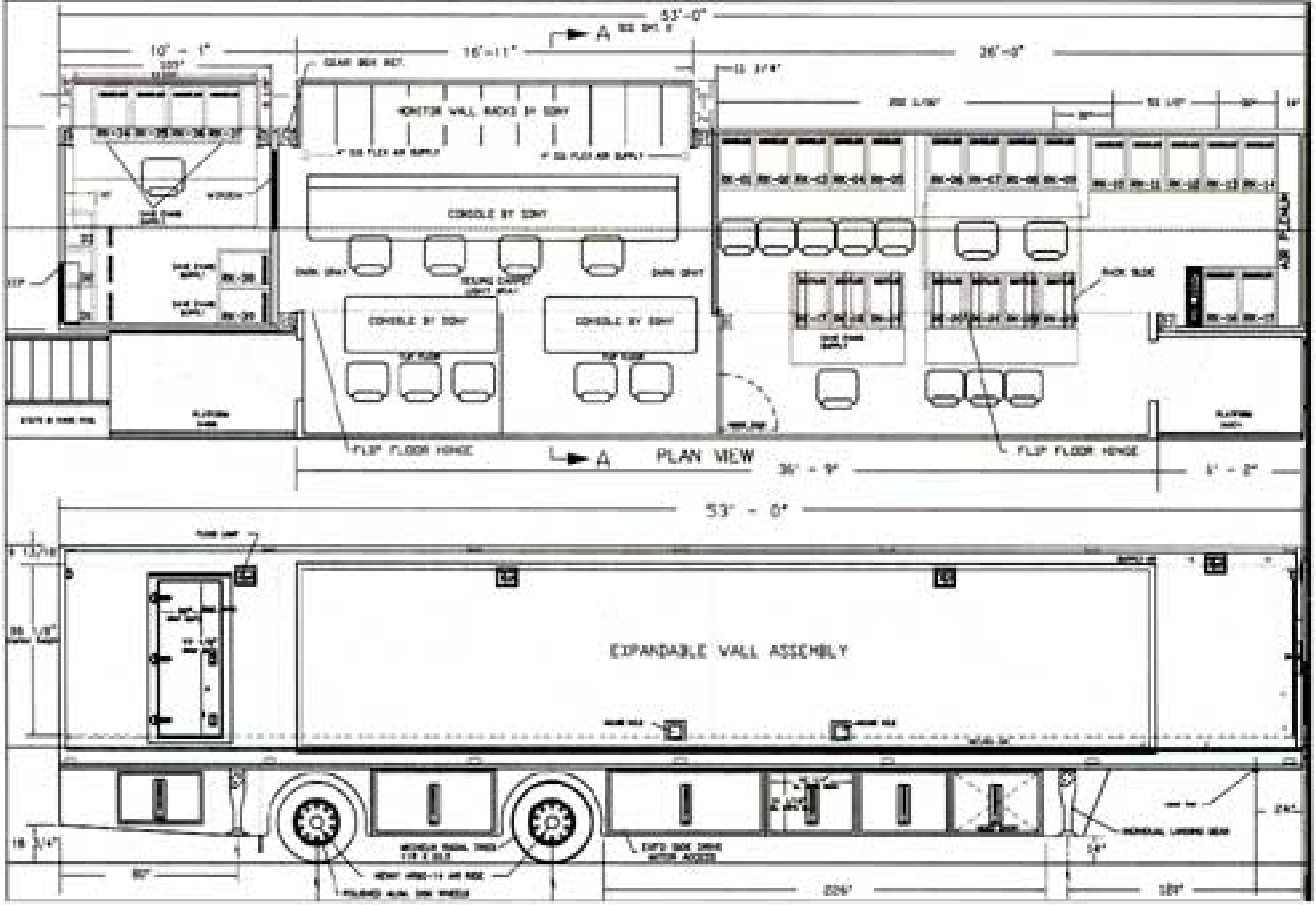
AES allows flexibility not possible with analog audio and it allows audio to be embedded into the video. Up to 16 channels are supported, but the majority of equipment today uses only four channels. Eight-channel use is just now beginning to be accommodated. However, embedding and unembedding this audio adds to system complexity. Plus, routing at the SDI level doesn't tend to support embedded audio breakaway. AES routers are generally smarter about the serial bitstream than SD/HD-SDI routers (AES routers often decode the bitstream, whereas most SDI routers don't). A final consideration is that like HD test equipment, which is more expensive than SD-SDI or NTSC test equipment, AES test equipment is more expensive than analog audio equipment.

Cameras and test

Cameras become slightly different animals in the HD world. The triax camera is no more. Triax is basically coax with an additional shield. Although the losses with triax are slightly less than regular coax, after a few hundred feet, the HD-SDI signal will have fallen apart. Also, as discussed earlier, the HD-SDI signal will consume most of the available bandwidth of the cable. In triax camera systems, we not only need to get HD video from the camera head to the camera-control unit, we also usually want to send control, return video, intercom, and often audio, not to mention power, down the same piece of copper. Triax just isn't going to work for HD. A special fiber/copper cable is needed. This cable has two single mode fibers, two wires for camera control, and four conductors for power. Its diameter is approximately 0.36 inches, and it comes in 50m or 250m lengths. A 250m cable weighs 57 pounds. At least seven of these 250m cables can be connected together, which means camera runs of over 9,000 feet (limited primarily by copper size) are still possible.

Sync and test generators in the HD

The NMT HD-1 truck will be quipped with a full complement of Sony high-definition cameras. Shown here is the Sony HDC-700 being used to record the 1998 Rose Bowl parade.



Note the expanding section shown above is primarily "people space" and adds about 180 square feet of working room. NMT's HD-1 will be the first digital high-definition truck to hit the road. The project was handled by Sony's Systems Integration Center.

realm aren't yet as capable as their SD ancestors. It still might be necessary to use an analog or digital SD sync generator as the absolute reference.

One additional note about monitoring in this new world — truck customers usually want the ability to view all the formats on a video and waveform monitor in three separate positions in the truck during the production. This is insurance that the signal is usable in all worlds. This multiformat monitoring is usually located at the TD/director, shading, and QC positions.

HD integration is like everything else we compared between HD-SDI, SD-SDI, and NTSC. It just takes more planning, more understanding, and more fortitude than the earlier SD formats, not to mention more money. But if we can enlist the viewers to subscribe to the advantages of high-definition viewing, everyone will benefit. ■

EQUIPMENT LIST:

Routing Switchers: NVision Envoy 6464HD serial high definition; Sony DVS-6464B SDI 4:2:2 and DVS-A3232 (dual) AES Audio; Ditech 5881 128x160 NTSC
Production Switcher: Sony HDS-7000 HD digital video switcher
Audio Console: Sony Oxford digital audio mixer
DVE Equipment: Sony HDME-7000 two-channel DME
Recorders: Sony HDW-500 digital HD videotape recorders and DVW-A500 Digital Betacam recorders
Special Effects: eight-channel HD DDR (Vendor TBD); Chyron Infinit! character generators (upconverted to HD)
Audio Effects: 360 Systems Digit-Cart II
Audio monitoring-spot locations: Wohler panels
Audio recorder: Sony PCM-800
Waveform monitors: Tektronix
DAs: Sony digital and analog video DAs and monitor DAs; NVision AES audio DAs; Leitch analog audio DAs
Monitors: Sony HDM20E1U, HDM2830 HD, BVM14F1U SDI/NTSC and PVM series NTSC monitors
Encoder/Decoder Up/Downconverters: Sony HKPF-525 HD downconverters and HKPF-103 HD DA's; Snell and Wilcox HD5050 upconverters and HD2100 Up and downconverters
Cameras: Sony HDC-700 HD studio cameras, HDC-750 HD field cameras and DXC-HD HD POV cameras (model TBD)
Lenses: Fujinon HA66x95ESM high-definition lens and HA20x75ERD HD hand-held lens
Intercom: 80x80 RTS Adam intercom matrix

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