A BROADCASTER'S GUIDE TO DTV

Snell & Wilcox Offers Advice to Broadcast Station Engineers Facing the Transition to DTV

With the FCC deadline approaching for the introduction of digital television broadcasting, station engineers are planning the first major rebuild of the American television system in half a century.

The challenges ahead are daunting, but the opportunities in the digital future are rich and exciting. Snell & Wilcox is among the world's leading manufacturers of professional equipment for standard and high definition television. Its engineering team has done pioneering work to develop the new all-digital broadcasting system that will serve American television viewers in the next century.

In this round table discussion on the eve of NAB'98, three of the top engineers at Snell & Wilcox discuss important issues that broadcast engineers will be facing in the coming months.

The participants are **David Lyon**, technical director; **Peter Wilson**, head of HDTV and advanced technology; and **Martin Weston**, principal research engineer.

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1. Though Digital 601 or HDTV television plants are clearly preferable for DTV broadcasting, most medium and small market television stations in the United States still operate analog NTSC plants. What kind of quality can these stations expect if they up-convert their current programming for SD and HDTV transmission?

Wilson: The quality depends on how well the analog plant is lined up and the condition of the equipment. If the plant is fairly new and the correct mathematical relationship, of the subcarrier to line rate for example, exists throughout the whole plant, a high quality decoder can do a good job of decoding the NTSC. If the plant is in less than optimum condition and it goes through things like color-under VTRs, it's not so easy. Once you've lost the true subcarrier/horizontal relationship that you get from a professional camera, it becomes very hard to properly comb filter it. So you fall back to simpler decoder modes and you'll find more artifacts.

2. Say a station in this situation uses an upconverter on its existing NTSC signal and just leaves it on in an automatic mode around the clock. What kind of results will they get?

Wilson: Variable. Very good and very bad at times . It really depends on how the station is put together and what kind of material that's being played.

Weston: The big problem might be people expecting perfection when a lot of what we are trying to do is impossible. Some people think that noise reducers are so good now that you don't have to have a clean feed. Or that upconverters are so good there's no point in going to HD. We are narrowing the gap and keeping up. We are doing things in this company today that I thought were fundamentally impossible when I joined it seven years ago. But you'll never get as good an upconverted picture as you will with original HD.

My biggest question would be what is the level of performance of the plant? How close to its limit is it performing at any given time? If you intend to use an NTSC composite plat, it has got to be working very well. Each piece of equipment in the chain is going to become more important than you had previously perceived it. This is one of the financial and technical balances one makes between purchasing new equipment and continuing to use the existing infrastructure. How much maintenance of your existing plant are you willing to do?

3. Even with a perfectly maintained NTSC plant, there are things we can't control. For example, programs from archives recorded on older color-under VTRs. It seems you are saying that even at best case we should expect uneven performance from such a facility?

Lyon: I would think that's almost certainly going to be true. Some of the answers won't be engineering-driven. They will rest with how the Producers present that material. If you know you are showing archival video, you are in a similar situation as you would be today in showing a piece of fifth generation VHS material shot in a war zone. You would do it, but do it in a way that fits in with your content.

For example,one thing we've seen with upconverters is you can show an upconverted picture in less than the full area of the screen by making use of the screen in some other way, say with graphics or some additional information. Visually that bit of picture looks better than if it were shown full screen because it's nearer its natural resolution.

4. For the engineer planning a move from analog NTSC to a new plant, would you recommend going to Digital 601 or 1080i?

Lyon: Well,it depends on the type of programming you do. I would think that small and medium market stations would do well to keep a very close eye on what happens in the next 12 to 18 months. My personal belief is everyone will need the higher quality of DTV to sell television again in a new marketplace. But the point that high definition equipment costs come down to be on a par with standard definition equipment is still too difficult to predict. I'm confident it will get there if there's a combination of supply and demand. But as always these things can take a while.

5. Some manufacturers are now offering integrated down-converter modules in their high definition cameras. Snell & Wilcox sells stand-alone, outboard down-converters. What are the performance differences between these different types of down-converters?

Wilson: The real issue is related to filter size. The bigger filter you've got, the more control you've got. I have not seen every new on-board camera down-converter. But generally when you put a down-converter on a single board, the first thing you do is reduce the memory in the size of the filter. That gives you less potential control of the video image in terms of bandwidth, frequency response, vertical and temporal aspects. Some of the video from built-in down-converters I've seen - when upconverted - exhibits 'jaggies' because the vertical response is not tailored properly. On a 525 monitor it might not be very visible. But if you want to put that through your 525 plant and upconvert it to DTV, it would become an issue. In a 525-only plant, if you are not too fussy, it might work .But don't think of using it on DTV.

Weston: If the board has a single frame filter, it will be a compromise between resolution and jagging. Basically, in a down-converter, you have to remove all the detail from a high definition signal that would cause trouble when you resample from the output. Because the output rate is interlaced, you need to remove things that will cause an artifact called 'twitter'. Twitter is seen as edges vibrating at 30Hz.

If you put too much detail into 525, then the edges will come alive. So you have to filter off the frequency components that cause that effect. Using a down-converter, as opposed to a camera, you can incorporate a filter that sharply cuts to the point where detail becomes damaging. The objective is to preserve all the wanted information and throw away the unwanted.

Another thing you want is for the filter to make that cut whether the picture is moving or still. When the picture is still, the twitter at 30Hz isn't very visible. You can have quite a lot of resolution before it starts to twitter. When the picture moves, however, those twitter components can be strobed out so they start to move very slowly and they become much more visible. When things move, you actually want to reduce the resolution in order to get rid of those components that cause twitter. That's what we achieve with our down-converter. It uses a three-field aperture. It doesn't just filter at a fixed cutoff frequency. The cutoff frequency depends on the temporal frequency. So as things move, the cutoff is reduced and the picture goes slightly softer. But it doesn't twitter.

A single field converter, which is less expensive, is not going to be able to do that. So with a single field converter you either have too much twitter when things move or not enough resolution when they are still because you can't vary the cutoff.

6. In a studio environment - say with a person on a news set - could you get away with a single field converter since there's not much motion in the picture ?

Weston: Well, it's a strange thing, but when I talk about motion I don't mean rapid motion. One of the most noticeable effects of this would be the news reader, where you get twitter and jaggies on the slope of his shoulders. When he's sitting perfectly still, it's fine. But when he shifts in his chair, you see patterns running up and down his shoulder. Subtle movements cause this problem.

7. My station has just received delivery of a new upconverter. What's the main thing that I, as the station engineer, need to know in operating this device?

*Weston:*The biggest issue is aspect ratio conversion. It's here the broadcaster must make a choice. You've got a 4:3 image going in. You can put out a 16:9 window with black curtains down the side, which is pretty unacceptable, or you can stretch the image horizontally so everybody looks short and fat, which is also unacceptable.

Or you can make the picture bigger. But when you do this it's too tall,so you have to chop something off the top or bottom or both. You can wind up losing the tops of people's heads and their toes. That can be unacceptable as well. So you might end up needing to pan and scan, but that must be done manually, and it's expensive because you need a pan and scan operator. The alternative is to shoot your 4:3 programming framed loosely or with an anamorphic lens.

8. Wait a minute, guys! I'm a small station. I can't afford a staff of pan and scan operators. I have no control over what comes in the door. In fact, I want to preset my upconverter and run it around the clock without an operator. Which is the least offensive method of aspect ratio conversion I can use?

Lyon: The human visual system will not accept the severe distortion of the aspect ratio of an image. The only way to make an image fit a display of a different shape is to by zooming that image. 4:3 to 16:9 is probably the worst because the only way to get an entire 4:3 picture in a 16:9 frame is to show it in the middle of the screen with black bands on the side. That painfully demonstrates to the audience that it's not 16:9.

So if you zoom the image in to get rid of the black bars at the side, inevitably something gets lost at the top or the bottom or both. I've experimented with old cameraman's rules about where the eyelines are in a picture. If you lose about two-thirds off the bottom and about one-third off the top - assuming the eyeline is roughly two thirds the height of the picture you've probably got a reasonable compromise.

Wilson: That's what I do as well. I always set it full width and then turn the picture down so the heads are not chopped off. This is done on a personal theory that losing some feet is less objectionable that losing half a head.

9. Let's say we've preset our upconverter in this mode and then along comes a properly framed 16:9 program. How does the upconverter know the difference?

Wilson: In the U.S. to date, there is no automatic way of knowing. The upconverter will have to be set manually by hitting the 16:9 button. There are discussions going on now about devising an automated way of accomplishing this and our boxes could easily be adapted to accommodate such a function. But there's not yet a standard for doing this.

Weston: When people start using 16:9 the least they should do it write 16:9 on the tape box. This way the operator is aware of how the program was shot.

10. In the DTV era, the upconverter becomes an essential part of the broadcast chain. You literally lose your air signal if it fails. What's the recommended strategy for backup of this device? Do you need to buy a second upconverter for redundancy?

Lyon: It's a tricky thing to predict what the failure rate of something like this is. Redundant power supplies are often something people go for. Redundant power supplies, however, are very difficult to implement in ways that actually increase the reliability of a system.

What you are trying to predict is failures. Well, if you could predict the failures, you'd design them out in the first place. You have to look at where the complexity is in a box like this. In a sense, the power supply is the most simple component in the system. There is a huge amount of far more complex processing electronics that the signal will go through. For end users, spare board assemblies are the most viable and practical way of servicing something like this and protecting against failure.

Weston: I agree. You don't need an entire second upconverter for backup. The best strategy would be to keep a spare card set.

Wilson: Keep in mind that the two main reasons for buying our products is they are engineered for reliability and there's been extraordinary attention to detail in their design.

Weston: One reason our upconverters are so reliable is they aren't thermally stressed. Our HD5100 upconverter, for example, is not heavily populated with circuit cards. It doesn't use high density production methods or thin wires. Basically, there's a fairly relaxed layout on the boards. In operation, it stays cool.

11. Can you offer some advice for stations who want to ensure that their locally-produced programs have adequate production value in the DTV era?

Wilson: My general advice is go to the highest possible spatial resolution that your budget allows. In the video world, that's HDTV. Yes, it's going to be a bit more expensive to re-equip. But prices are coming down and 1080i is the best mastering format now available.

12. For the station using formats like Betacam SP or DV, what quality of upconversion can be expected?

Wilson: One thing often not understood is that 525 interlaced cameras actually record 40 per cent more vertical resolution than we can see on a standard monitor. When that video is upconverted, you release that 40 per cent of vertical information. And, because we are upconverting into an oversampling domain, the viewer perceives all of that extra 40 per cent of resolution. That's why when you do a direct one-to-one upconversion, the 525 picture looks a lot better than you might have expected.

13. With DTV, the home viewing environment changes. Screen displays will be much larger, sound will be digital and ambient room lighting is likely to be lower. How will these new viewing conditions impact the television broadcaster?

Wilson: First of all, I recommend that every broadcaster should have at least a high quality, professional 28-inch or larger monitor. Don't use anything smaller. Professional monitors are needed because HD cameras can capture a very wide contrast ratio.

For multi-camera shoots, remember that using small monitors for switching can result in the director seeing the images as television and cutting too fast for display on larger screens. You can linger much longer on a HD shot than you would on a scene for viewing on a smaller TV display. Also, it's important that care be taken in mixing images that vary in resolution. Indiscriminate back and forth use of high and low resolution pictures can be jarring for the viewer. It's also important that exposure, and black and white levels be consistent on a scene-by-scene basis. Otherwise, the viewer will be very aware of inconsistencies between shots on a large screen display.

14. Typically audio has been a low priority in broadcast television plants. However, in the era of DTV, the audience will receive multichannel digital sound in a dramatic new way. How will better sound delivery impact the station engineer?

Wilson: We mentioned before the implications of mixing high and low definition video. The problem with sound will be the same. If a station plays a movie in multichannel surround sound and they follow that with a local news item in mono, the change will be jarring.

Just look at the way sound is mixed on feature films today. The film's sound designers work in a full size mixing theater with a 150 channel sound console connected to an audio server. They mix down the surround audio so it sounds right in the cinema auditorium. The home cinema audio systems that you buy now are arranged to try to make your living room sound like the cinema. So film soundtracks and home multichannel audio systems are complementary.

On the other hand, a TV station has no equivalent to the mixing theater. It's a different level of operation. Local sound is generally analog mono. I predict the differences in sound will be very apparent to the home viewer.

Lyon: I think audio will be among a huge number of surprises that will come when we enter this transition. The jump from the Hollywood movie to the local news will be very disconcerting. Let's say you're home with the screen the size of a wall and a very impressive multichannel sound system. You're suddenly faced with a piece of 25 year old analog NTSC material with a very noisy mono soundtrack replayed off a poorly maintained VTR. The disconcerting effect on the viewer will be considerable. This is a production problem as well as an engineering problem. It must be determined how to present this kind of material to the viewer in the new environment.

15. As we begin the transition there are many equipment interfaces not yet standardized. This could present an interoperability problem between devices from various manufacturers. What strategy would you recommend to engineers in dealing with this lack of standardization?

Wilson: Interface issues depend on which equipment you are talking about. In the baseband domain, SDI and HDSDI should be OK. There are a few remaining issues to be worked out with STDI. When you get into MPEG (which is the connection between the output of the encoder and anything else) as far I know there are about 30 physical interfaces. None of which are truly standardized. It would be very easy to end up in a situation where they don't even plug together.

To deal with this - at least in the beginning - I think the station engineer would make a contract with a systems supplier that would encompass the encoding and transmission in one package. The engineer that decides to buy a box from one guy and a second box from another guy might be in trouble. This is a new area and it's very complex. It's interesting to note that two of the largest transmitter manufacturers in the United States have set up systems divisions to reverse engineer the studio. This is a new model, one where you start with the antenna and build backwards.

16. We've been repeatedly told that noise is the enemy of compression. In the station environment, is it best to use noise reduction only on the material specifically needing it, or is it best to put a noise reducer in the chain to process the entire on-air feed?

Lyon: My suspicion is most people will put a noise reducer permanently in front of the compressor. There are units available that will sense the noise floor and automatically adjust for it. It will offer a benefit most of the time. There may be some cases with archive retrieval where you'll want to manually adjust it. But that would be in a tape-to-tape, post-type operation.

17. Won't you take a hit in resolution using the noise reducer in an automatic mode?

Lyon: A noise reducer can only take something out of the image. Inevitably it will take a few things out with the noise that you wish it didn't take out. It may not be resolution. A recursive noise reducer in a still picture will do nothing to the resolution but it will introduce some motion blur. As with most processing, there are tradeoffs.

18. Mezzanine compression is a concept born out of the idea, a few years back, that 1.5 gigabit routers would be prohibitively expensive. But now the cost of those routers is falling. The idea of mezzanine compression, however, remains. Why is that?

Lyon: I fail to see the driving force behind it. If we assume we are going to high definition broadcasting, that means we are going to replace our cameras, our production switchers, DVE devices and most VTRs. In a typical studio, that doesn't leave much other than the routing system. If we are replacing this vast amount of the studio, I have to question maintaining one tiny little piece of it, the router. If you have to add a lot of mezzanine compressors and decompressors to continue using that router, it raises the bigger question of why? Cost may be a factor if you have a huge investment in a router, but that by definition would be an extremely large router. I suspect most people starting with HD will begin with much smaller subsystems and islands.

19. Another concept out there is 480 progressive, which got strong support from the computer industry last year. From your perspective, what are the arguments for and against it?

Lyon: Today 480p only exists in the computer industry, where bandwidth is not a problem. You are only going from a computer box to a monitor a few feet away. In a broadcast infrastructure, you have to think of how you move the signal.

There are now two 480p proposals. One makes use of two 270 megabit streams, because essentially the uncompressed bandwidth is doubled. The other proposal makes use of a subsampling technique to reduce it to 4:2:0, in which case you can squeeze it down a 360 megabit link.

If you are going to use 360 megabits and if your router will accept it, there is the possibility you could actually move 480p around an existing cabling infra structure. But nothing else in the plant works. Rule out current cameras, switchers, VTRs and monitors... none of them will work. You can only move signal around the cabling. And remember, there are quality objections to the multi-generation use of 4:2:0 video in a post-production environment.

If you go to 540 megabits, then the video will not travel around any existing cable infrastructure. This begs the question. If you are going to double your data handling rate, is it that much more difficult or expensive to go one step further and build a 1.5 gigabits infrastructure? One of the issues here - as with mezzanine compression - is why do people continue to think they must use standard definition routers? There is almost a fear of 1.5 gigabits. I'm not being dismissive of it, but the same would have been true ten years ago when the idea of sending 270 megabits down coaxial cable was considered to be extremely difficult and was going to demand a huge amount of care. Most people today don't think twice about it. It's now actually easier than routing analog. People's view of digital has changed.

20. Sony has announced that it's supporting a five-year goal of implementing a 1080 progressive video system. Other manufacturers have stated that 1080 progressive is the ultimate goal of an HDTV broadcast system. A 1080p plant would require 3 gigabit routers for baseband video. With this goal known, is it wise to build an expensive 1080 interlaced plant with a 1.5 gigabit routing system over the next couple of years when this might be a transitional technology?

Lyon: Is 1.5 gigabits transitional? I'm not sure I know the answer to that. I guess in a way all technology is transitional. The data rate in 1080 progressive is 3 gigabits whether you like it or not, however you move it. If you wish to manipulate the image, you have to do it at three gigabits. If you are going to compress it, you are back to the issue of desirability of compression in a studio environment.
I can see the case where you could use 1080p cameras and with a little bit of careful prefiltering it would be perfectly possible to manipulate those images in a 1080i environment and provide an extremely respectable output. Even if we accept the fact that 1.5gigabits may be transitional, I think it will last many, many years as being very capable of giving exceedingly good cinema-grade pictures.

Wilson: A big question is whether the whole plant is 1080p or only parts of the plant. As I see it now, the most beneficial place to implement 1080p is in the home receiver. Remember, 1080i has 40 per cent more information than you can see. But when you turn it to progressive it becomes available to your eyes. So if you can get a very good rendition of the 1080i to your home and the receiver upconverts it into progressive, suddenly you've got 40 per cent more resolution anyway.

I don't think it's practical to turn a television plant into three gigabits within five years. The moving of the three gigabits can be done rather easily - the telcos do it now. The problem is the processing power you need for the video. It would be double. Available devices to do 1.5 gigabits are just becoming available now.

Weston: There are those that argue that progressive is twice as good as interlace. That's not true. It's maybe 40 percent better. I think the main advantage progressive has is it's easier to understand. Interlace is an efficient way of compressing signals. It saves you half the bandwidth for the cost of 40 per cent of the resolution.

You could argue that when we move to digital compression - with about a 40-to-1 ratio - that interlace will no longer be needed. In that case, you wouldn't need 1.5 gigabits anyway. Going to 1080p compressed in a studio might be a sensible thing to do.

What we need is a form of lossless compression that's cheap to implement and can be put on a single chip. Then you can compress and decompress to your heart's content. At that stage you don't care.

21. Peter, back to your comment about the processing power needed to handle HD video. What about Moore's Law - the idea that computing power doubles every 18 months. Won't the issue of processing power be gone within five years?

Wilson: Moore's Law only applies to computers. We've looked at Moore's Law as it applies to television. But we've found it doesn't really work. We do things very differently from the way it's done in computer architecture. With computers, the clock speed doubles so they can get more instructions per second. Many of our algorithms are far too complex to operate on one basic computing system. The amusing thing to me about Moore's Law is that, as the speed of hardware doubles every 18 months,the speed of the operating system slows down because it becomes more complex and takes away 90 per cent of that processor speed increase. So your net gain is very little.

Video is a serial process. You capture video with the camera and display it at the receiver. In between, we do one task followed by another task followed by another task. With our hardware, we make every building block processor specific. We design every part of the box to do a single job very well. And, because it's video, every process must be as close to real time as possible.

22. On the viewer side, what about the fear of no DTV reception in urban areas where you can't use an outdoor antenna? Is the cliff effect going to be a problem for broadcasters?

Wilson: I don't know the real answer to your question, but my feeling is rabbit ears in many locations won't really cut the mustard. I think the engineers are rightly concerned about this issue.

Lyon: Nobody in the world has any real experience with this yet. The only people radiating digital transmissions to any degree at this moment are using satellites. There have been studies on the effects of precipitation and foliage on transmission parameters. The broadcaster can do as much work as he wants. But he's going to have difficulty controlling the customer's home antenna installation, which is frequently less than optimum. The customer may have adapted to watching a very poor analog picture. Now, he may get no picture at all. No matter what the broadcaster does, I think he will face quite a few problems from the typical viewer on this issue. There's an education process that needs to take place to inform consumers that they will receive very much better pictures most of the time, but that we are now into a new environment where it's 'go' or 'no go' on reception. This knowledge must become part of the public consciousness.

23. These are complex times for station engineers. What's your message to them as they prepare for the transition?

Lyon: To a certain degree, if engineers face up to high definition processing, many of their problems will hopefully disappear. It might actually be more difficult maintaining an analog facility, which might be a false economy in the long run. If we can get to a digital processing system for HD, most day-to-day tasks for station engineers will diminish.

On the other hand,there will be a huge effect on the production people who will have to learn - in effect - how to use a new medium. People used to making small screen television are suddenly being handed something capable of making large screen, cinema-like pictures. That's a big jump.
