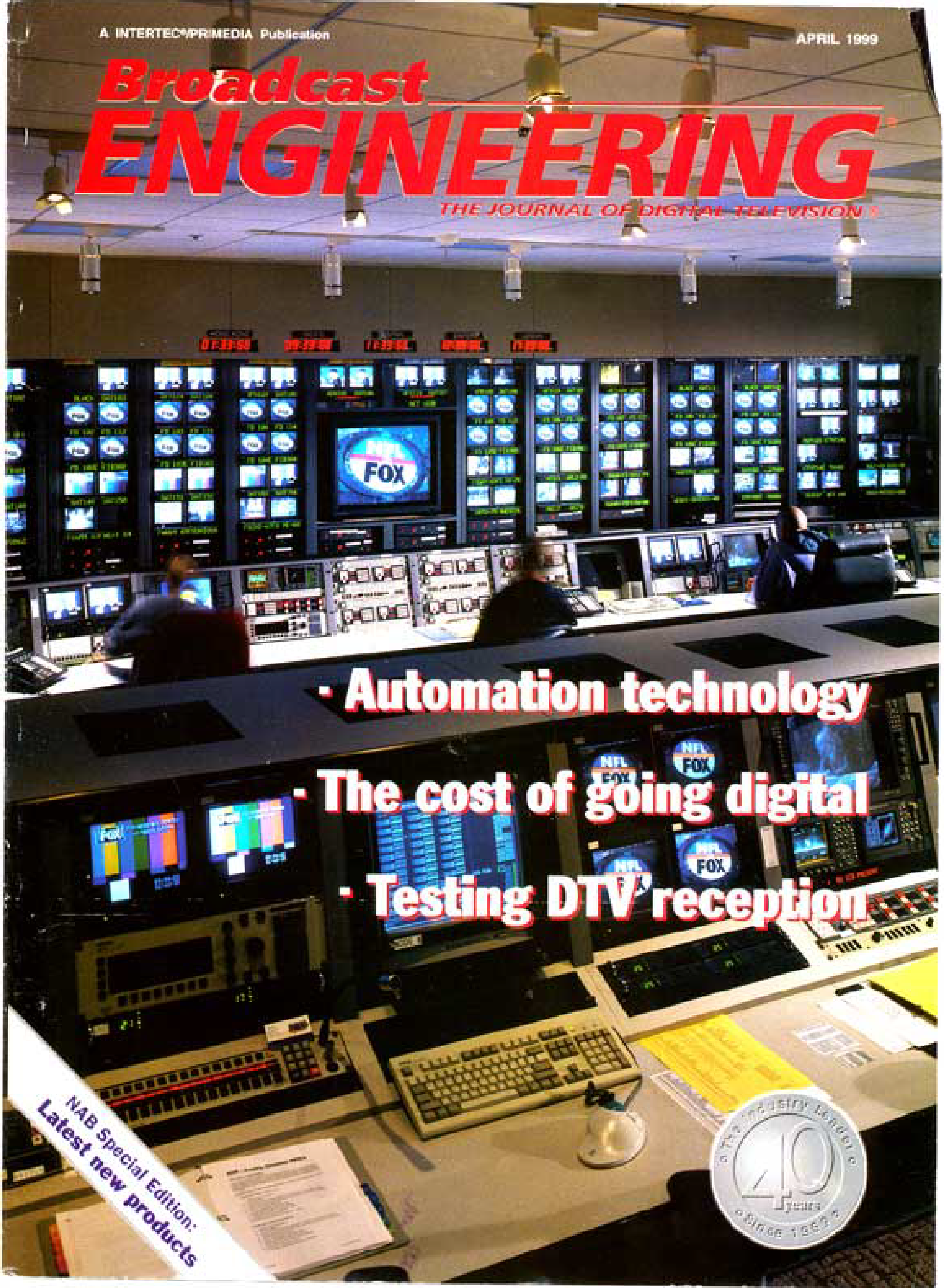
A INTERTEC®/PRIMEDIA Publication

APRIL 1999

Broadcast ENGINEERING

THE JOURNAL OF DIGITAL TELEVISION®



- Automation technology
- The cost of going digital
- Testing DTV reception

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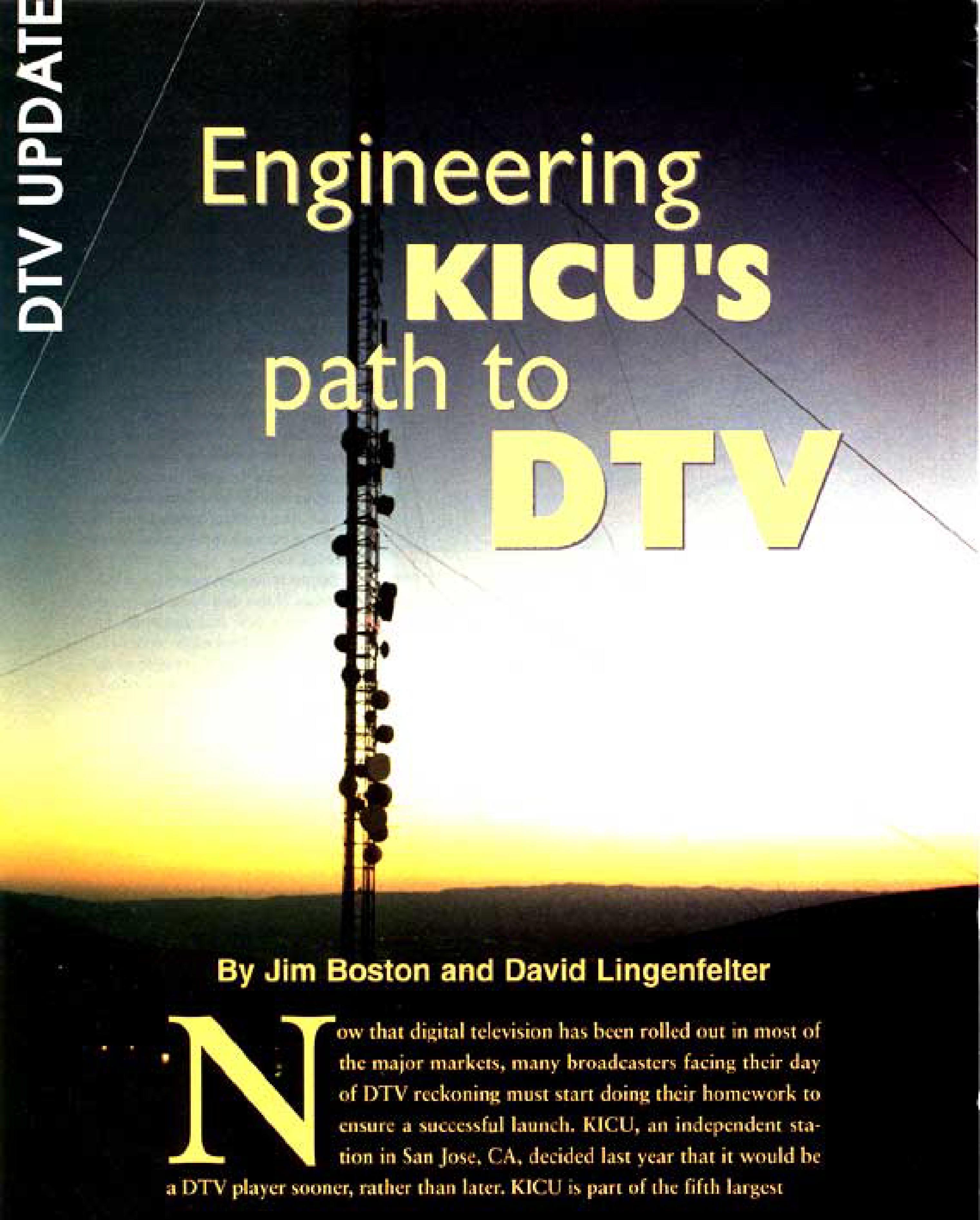

Engineering KICU's path to DTV

By Jim Boston and David Lingenfelter

Now that digital television has been rolled out in most of the major markets, many broadcasters facing their day of DTV reckoning must start doing their homework to ensure a successful launch. KICU, an independent station in San Jose, CA, decided last year that it would be a DTV player sooner, rather than later. KICU is part of the fifth largest

KICU's transmitter site at Monument Peak, CA. The test H and CP antennas were located at 245ft, with the NTSC antenna at 562ft.

State of the art control room in the National Digital Television's Center's Hollywood based all digital production truck. Photo by Bud Shannon.

Second, the expected cash flows are just that: expected. Nobody can forecast what will happen during the next several years, much less the next 10 years. Who, in 1995, could have predicted that Internet ad revenue would be $3 billion in 1999? In the digital era, opportunities develop, mature and disappear at a much quicker pace, adding additional ambiguity to investment evaluation.

Costs

Hidden costs associated with the digital transition appear to be minimal. Once the digital system is operational, early indications show that the power used by the transmitter is the only substantial addition to the operating expense budget. That can vary considerably depending on transmitter type and channel - from $500 to $22,000 per month.

Compared with analog equipment, digital equipment will also provide operating cost benefits. First, digital products are usually easier to operate, enabling existing staff to handle the workload more efficiently. Second, digital equipment tends to be more reliable. Some products have built-in intelligence that is capable of alerting technicians prior to imminent failure, increasing uptime. Finally, if something does go wrong, digital technology offers sophisticated self-diagnostic features and modular repair schemes that can expedite repairs while reducing maintenance expenditures.

Embracing the change

The digital model changes the world for the equipment manufactures as well. It is up to equipment manufacturers to assist with the transition from analog to digital. To be successful, manufacturers need a strategy that offers broadcasters cost-effective ways to manage the transition, ensuring a satisfactory financial return. Manufacturers must offer programs that allow broadcasters to extend implementation costs over several years. Pay-as-you-grow schemes could provide broadcasters with the flexibility to install lower power equipment now and have a financially attractive future upgrade path to higher power equipment. Equipment leasing also could provide another method to defray up-front investment.

This also affords broadcasters the ability to develop alternative services such as data casting. These programs also provide economic incentives for being an early technology adopter.

Broadcasters could reallocate funding from studio equipment to datacasting equipment to enter the data world while simultaneously broadcasting a digital signal. For example, the broadcaster could postpone the studio investment until HD programming becomes widely available. Most people find upconverted pictures acceptable. The broadcaster could use studio funding to purchase a data router, fiber connection and a statistical multiplexer.

What can broadcasters do with the pipeline to earn an acceptable return? First, the broadcaster has access to a new audience: people in their workplaces. A recent Internet study showed that 40 percent of all the Web users gain access from work. Broadcasters, in conjunction with their Web site, could develop new marketing and advertising opportunities.

When combined with streaming technology, any business' network manager could be a new market for broadcasters. In most cases it is cheaper to install a PC converter and build distribution schemes to alleviate network congestion than it is to change network topologies or install network switching.

With the 3G wireless technology, which promises 2Mb/s data rates, the broadcaster has a new business model for Internet access. Data traffic tends to be more intense from the network to the user than from the user to the network. Broadcasters could transmit data-intensive back-haul traffic (network to user) while the wireless connection carries the signal from the user to the network.

The recent CeBIT show has seen a flurry of activity around handheld or net devices. This is another platform that will offer broadcasters new markets. The next wave of net devices will have the ability to surf the Internet, making those media consumers prime targets for broadcasters' new streaming media. Laptops are being introduced that incorporate full telecommunications phone-enabling mobile Internet access.

The Internet Era will bring many challenges and opportunities for broadcasters. Broadcasters can embrace the technology now and begin to develop new, innovative products or postpone the transition until later. With the explosive growth of the Internet and the new media opportunities it world bring, the cost of delaying until tomorrow will be greater than the investment required today. ■

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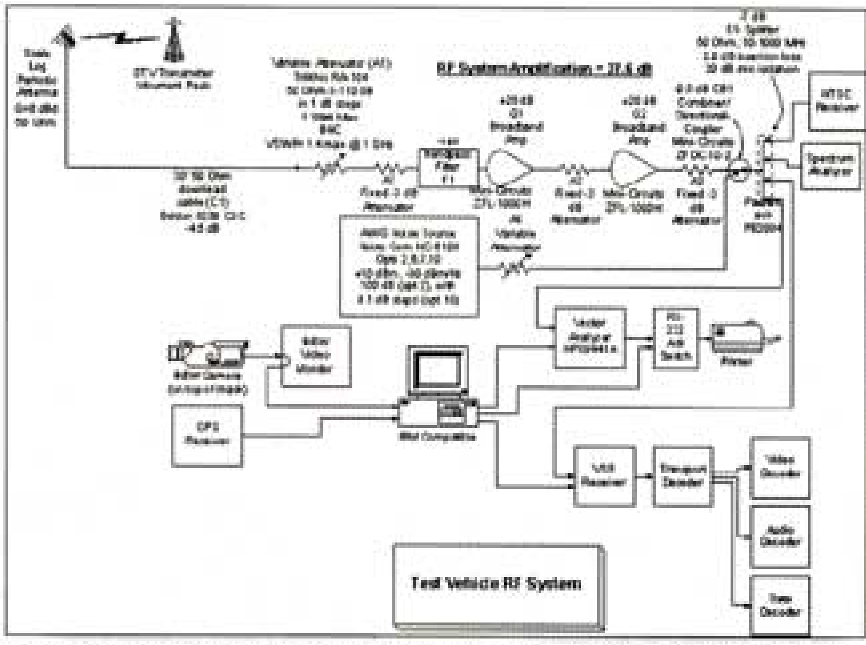
market, but it also straddles the 121st market. KICU is independent, in the fullest sense, in that it is one of the few remaining stations that is not part of group ownership and that it is actually locally owned. From an engineering perspective, this presents opportunities, along with a fair amount of risk. A group-owned station can generally look to its corporate engineering entity for a lot of the answers to the DTV puzzle. KICU was faced with engineering its DTV transition all by itself. The station's chief engineer, David Lingenfelter, and vice president of operations, Bill Beeman, have led this engineering pathfinding. Although both have extensive NTSC baseband and RF experience, a steep DTV learning curve had to be negotiated.

A number of questions would have to be answered before the exact path to DTV could be charted. The assigned channel (52), and the power to replicate the existing NTSC channel (36) was spelled out in the FCC's Sixth Report and Order. This meant that effective radiated power (ERP) was established, or so it would seem. Although Horizontal (H) vs. Circular Polarization (CP) propagation, and reception characteristics had been tested before by the Model Station Group (MSG), the station's staff wondered if the earlier testing, which showed no benefit in using CP, was applicable to KICU's market.



The test vehicle RF system was built by assistant chief engineer, Chuck Pracna. The bandpass filter (in line with the Scala antenna) was used to prevent the NTSC stations on channels 48 and 54 from overloading the analyzers front end. This filter was bypassed when making NTSC measurements on channel 36.

KICU's coverage area is a region of extremely diverse topology. It includes many mountain ranges, with accompanying valleys, large expanses of water and three major metropolitan areas that have expanded to form one megalopolis known as "The Bay Area." This mix of natural and man-made obstacles produces many reflections and casts many shadows for broadcast signals. This situation has caused much degradation of NTSC coverage. As has been widely publicized with the advent of digital television, gradual degradation of the signal should not occur in the digital domain. The baseband, modulated, and transmitted digital signal should be decoded perfectly by a receiver right up to the point where noise, reflections and other factors swamp the error correction system's ability to recover the data, the well known "cliff effect." From testing it has

Transmitter site with the Harris 200W Ultra 1 on the left and rack-mounted Philips encoding equipment just to the right. Philips engineer Ben Sorensen configuring the Philips encoder/multiplexer.

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been determined that error-free DTV reception can plummet to an almost one in two chance for errors with less than a 0.6dB change in S/N.

Signal reflection, or multipath problems, while annoying in NTSC have been rumored to be lethal to ATSC signals. CP propagation has been employed by some broadcasters since the late 70s to minimize ghosting. This is largely attributable to the fact that reflections off buildings and other objects tend to have a different polarization sense relative to what was transmitted. It has also been found that signal components in the H and V fields fade to a great extent, independently of each other. In KICU's experience, H seems to fade or be diffracted off its axis to a greater degree over water than does V. Indeed, diffraction off the H axis has been evident since television's inception. Early CATV systems often mounted receive antennas in vertical orientations rather than horizontal for the strongest receive signal. Horizontally polarized E fields sometimes appear to be diffracted by obstacles along the path and end up with vertical orientation.

There are a number of disadvantages with using CP. Most center on cost. Although true circular polarization is difficult to achieve it also means doubling radiated power, with nearly equal vertical and horizontal E fields. Channel 52's assigned radiated power (251kW), along with the desire to use a fat vertical pattern, low-gain antenna means that CP would need three RF cabinets (one for backup) using IOT or Diacrode technology instead of two cabinets if H polarization was implemented. The power requirements for CP (over 500kW ERP) would preclude any thought of using a Solid State transmitter. A three-cabinet transmitter translates into increased up-front costs, along with increased monthly costs, mainly for power. Some experts have stated that they believe only a 25 percent vertical component might be

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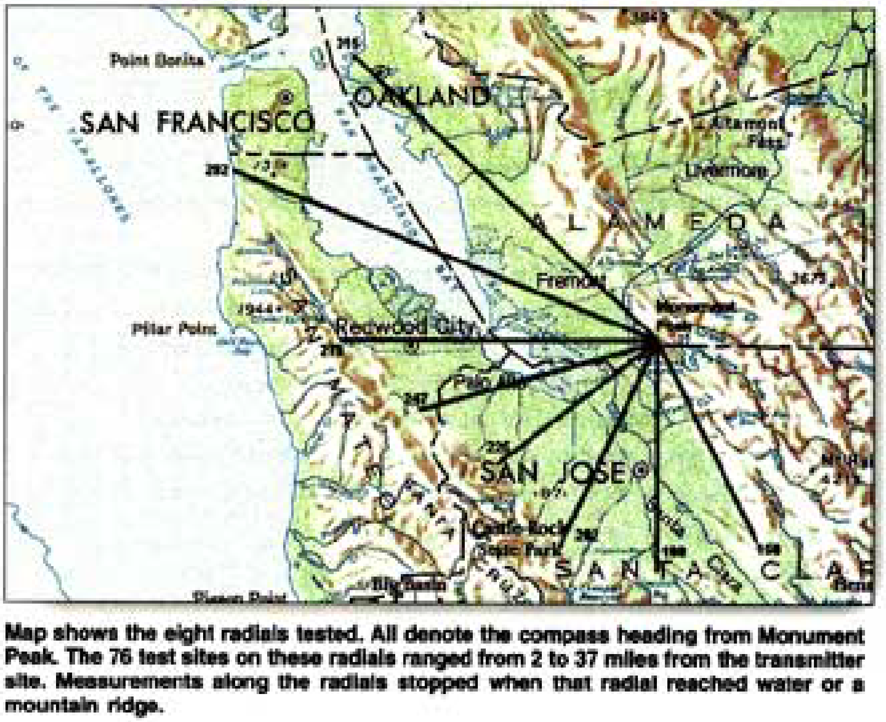

Map shows the eight radials tested. All denote the compass heading from Monument Peak. The 76 test sites on these radials ranged from 2 to 37 miles from the transmitter site. Measurements along the radials stopped when that radial reached water or a mountain ridge.

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necessary. This would obviously lower the power required. Robert J. Plonka, principal engineer for Harris, has said noteworthy diversity improvement can be obtained without doubling the power. A very general rule of thumb for the difference between NTSC and assigned DTV power levels is due to the S/N ratio differences between the two at just acceptable reception. NTSC is generally considered unusable when S/N drops to 28dB. DTV becomes absolutely unusable at a much lower S/N value, which is around 15dB.

After doing a spreadsheet analysis of transmitter capital cost, operating costs, power levels, antenna gains and polarization, it was determined that CP would need to clearly show an advantage over H to justify the increased cost of ownership of the larger transmitters.

It became clear that because CP would impact ERP and antenna selection, which in turn would affect transmitter technology selection, KICU's engineering staff would perform it's own DTV testing to gather information. In order to avoid "reinventing the wheel," the tests were based on the protocol developed by MSG. MSG is an association of equipment vendors and broadcasters that have rallied around a "model station," WHD, to iron out interoperability and testing of DTV. Besides WHD, testing has also been done at WRAL in Raleigh and WGN (using WYCC's final amp) in Chicago under MSG guidance.

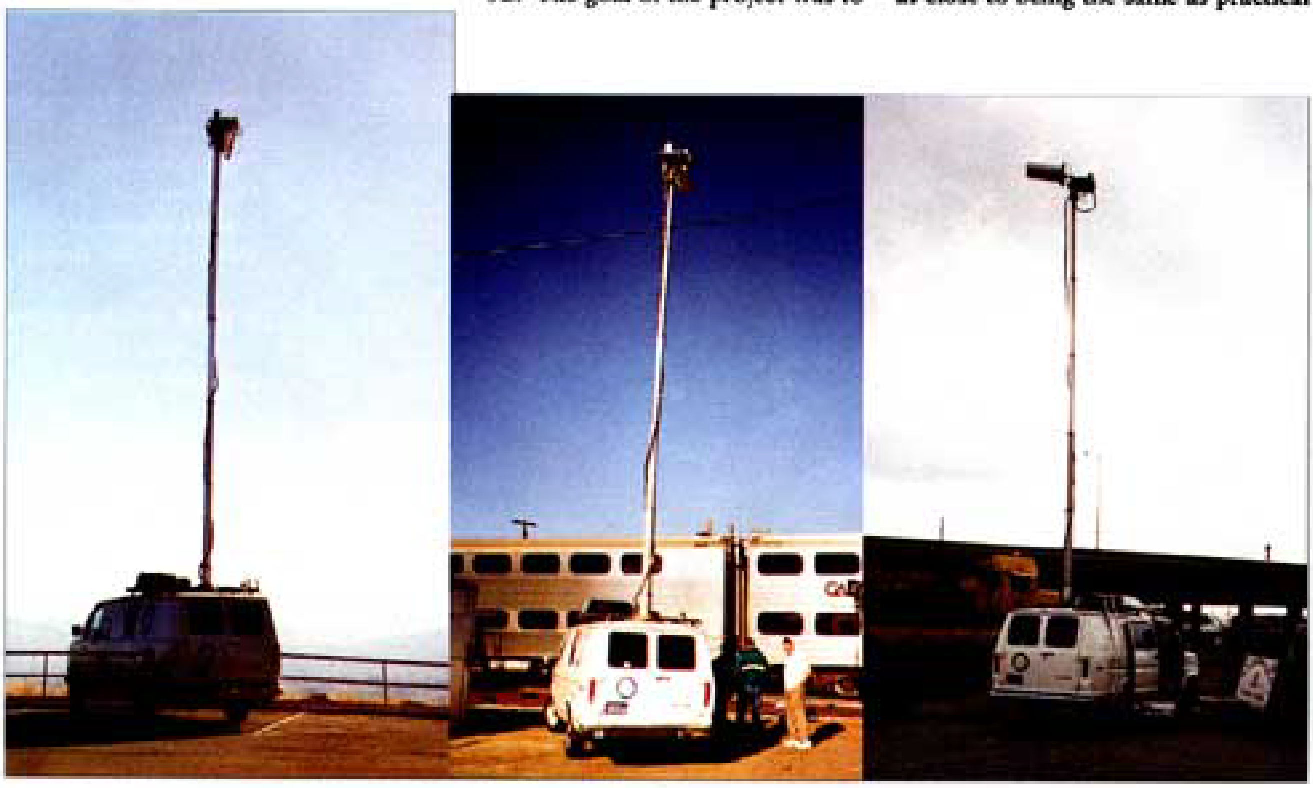
	KICU-TV	KICU-DT
Type	NTSC	DTV
Channel	Ch. 36	Ch. 52
Center Frequency	605MHz	701MHz
ERP	4000kW	1.6kW
Ht. AMSL	3012ft	2695ft

Table comparing key NTSC and DTV parameters. Note the difference in testing power levels between NTSC (4MW and DTV 1.6kW).

The plan

The station's engineering staff set out to design, document, construct, test and place into operation a low-power DTV transmission system for the purpose of conducting tests that would provide answers that can be applied to the design of full power DTV channel 52. The goal of the project was to produce a solid engineering recommendation as to whether KICU-DT should employ horizontal or some form of circular (elliptical) polarization. The fallout from that decision would allow staff members to select a transmitter configuration, transmitter technology and a set of antennas for DTV operation.

After studying the previous tests, a plan was made that would remove as many variables as possible and, hopefully, make the results clear enough that a decision could be made with some confidence. It was decided that an H antenna and a CP antenna would be installed at the same location on the tower with a remotely controlled coax switch selecting which antenna was being fed. The coax switch would be interlocked to the test transmitter, removing drive during switch motion. This would allow easy and safe selection of which antenna was active while the field measurements were being taken. The transmit antennas, built by Antenna Concepts, were such that the H gain of the H and CP antennas was the same. At this point, antenna height, gain and patterns were as close to being the same as practical



Measurements were taken at 81 sites along eight radials. The farthest measurement point was 37 miles from the transmitter.

KICU

thus removing these factors from consideration.

Due to the low power of the available transmitter, the H and CP transmit antennas were mounted on a single pipe which was in turn mounted on a 2000-pound-rated rotator. The top of the antenna-mounting pipe fitted into a strut-supported bearing. It was then possible to align the transmit antennas

Our testing was done with a horizontal receive antenna because that is what consumers have available.

with the radial being measured in the field. Essentially, the rotator created an omni-transmit antenna as far as the measurement van was concerned. This removed the azimuth antenna pattern variable from the equation. A control system was designed so that staff members could change antenna-aiming azimuth, control the coax switch and also turn the transmitter on with a keypad on a two-way radio. This allowed the testing to be conducted without having a person at the transmitter site all day, and, in many cases, late into the night and on weekends.

Our testing was done with a horizontal receive antenna because that is what consumers have available. The measurement van receive antenna was itself on a rotator so that vertical polarity measurements could also be taken as needed for multipath study. At each test site we also performed signal strength and S/N measurements on our Ch. 36 NTSC signal. This was done for two reasons. The first was to compare the DTV signal to the NTSC signal. The second reason was because of the familiarity most of us have with NTSC reception characteristics. The NTSC signal made it easy to confirm several site parameters, such as multipath and signal strength. Our DTV effective radiated power (ERP) for the test was only 1600W (average), while our NTSC ERP is 4MW. Because of the low DTV power a few unique engineering solutions were developed, which we will see shortly.

A generator was installed in the van so the equipment could be warmed up in the morning, calibrated and let run all day. At the end of the day the equipment and generator were shut down. Air conditioning kept the equipment rack temperature reasonably constant so equipment drift was eliminated.

We conducted this study from the viewpoint of getting an answer to CP versus H for KICU. The engineering studies done previously by WHD, and WRAL had already thoroughly documented 8VSB propagation and receive characteristics.

Strategy and objectives

To accomplish the above mission we used as much borrowed equipment as possible in exchange for vendor access to information obtained and the lessons learned.

KICU

• Harris loaned a 200W (average power) Ultra 1 solid state transmitter.

• Leitch loaned an ASC audio/video server to act as a source at the transmitter.

• Phillips provided a DVS3112/2 MPEG-2 encoder, and a TokenMux transport stream multiplexer.

• Hewlett-Packard provided an HP89441A vector signal analyzer.

• Tektronix provided an RFA300 VSB test monitor.

• Antenna Concepts Inc. provided the antennas.

• Zenith provided an ATSC demodulator/decoder and technical advice.

The HP89441A was used to perform a number of the RF measurements. To perform these measurements an IBASIC program written by Zenith for the VSA was used. This unit measured channel passband characteristics, DTV and NTSC channel power, and the truck's RF amplifier gain, and noise floor.

Zenith loaned the latest iteration of what is commonly called "the blue racks," a prototypical DTV demodulation measurement system. Zenith also provided the considerable expertise of Gary Sgrignoli. Sgrignoli has been involved with Zenith's development of the 8VSB modulation scheme since it's inception. His tutoring and guidance on the intricacies of the testing procedure ensured we would be able to accomplish our objectives.

One of the unique aspects of the test is that we applied for and received what is probably the only STA in history for a steerable transmit antenna. Antenna Concepts of Diamond Springs, CA provided panel antennas that were stacked on top of each other. One was a horizontally-polarized emitter, the other a CP. The antennas were designed with the same horizontal gain of 11dB. This was done using a single panel antenna for the H antenna and two CP panels for the CP antenna. The vertical beamwidth is therefore narrower for the CP antenna, 12° vs. 24° for the H antenna. The total CP antenna gain was 14dB.

NTSC CCIR Grade Impairment rating	# of test sites	Satisfactory DTV sites	Med DTV margin (H/CP) (dB)	DTV Tap Energy (H/CP) (dB)
1	7	4/4	25.0/21.7	-12.8/-11.9
2	5	5/3	31.7/27.9	-12.0/-12.4
3	35	34/32	32.2/30.9	-17.3/-17.3
4	30	30/30	37.0/33.9	-17.3/-17.9
5	3	3/3	32.7/34.8	-17.8/-16.4
	80	76/72	33.1/31.8	-17.2/-17.2

Summary results. The bottom line is that CP transmission does not help DTV reception when an H receive antenna is used.

Frank Foge engineered a steering and control system for the antennas. A 1 5/8-inch coax switch directed the RF coming up the tower to either the H or CP antenna. This switch could be controlled from either the base of the tower or via RF control from the test vehicle or at the studio. A camera pointed at the top of transmitter cabinet allowed confirmation of antenna azimuth and coaxial switch position via a TSL back to the studios. Mark Cunningham, president of Antenna Concepts, and his crew mounted the complete antenna(s)/steering system at the 245-foot level of our 600-foot tower in the middle of October. The testing commenced Nov. 2, 1998.

Chuck Pracna, the station's assistant chief engineer, oversaw the transformation of an ENG van into a DTV test vehicle. The truck was built to the MSG test vehicle specifications which

KICU

A 30-foot pneumatic mast with a pan/tilt head, Scala yagi antenna, rotator, compass and B&W camera was used at each measurement point. The camera image provided a picture of what the receive antenna "saw" as it looked toward the transmitter site.

were developed for the initial field tests at WHD for the Model Station Project. Information gathered at each test site allowed the calculation of DTV signal strength and FCC site margin, along with the confirmation that 8VSB signal would always fail when the S/N of the channel dropped to 15dB. We also recorded tap energy using the Zenith demod ("Son of Blue Rack"). Tap energy is an indication of multipath. These measurements were done with both the H, and CP transmit configurations. Since there is a long history of NTSC measurements, we made field strength and CCIR view-ability checks on our Ch. 36 NTSC signal also. The picture on a NTSC receiver will often give hints as to reception problems at a site that are easier to discern to anyone who is new to DTV testing. But it should be stressed that in a very short time we began to be able to detect the symptoms of reception problems by looking only at the DTV measurements. The July issue will explain how to make these measurements and how to interpret them in detail.

General DTV test findings and observations

• Eighty sites were tested over a three-week period during November of 1998. Both DTV (1.6kW ERP) and NTSC (4MW) were evaluated and measured. It should be noted that our DTV test station is 22dB below our authorized ERP of 251kW.

• We found three sites where neither the DTV nor the NTSC signals were useable. In all but one instance, terrain caused low signal levels.

• We found only one site where NTSC was OK but DTV didn't work. This site was two miles out on the 180° radial. We had line of site to the NTSC transmit antenna, but the DTV transmit antenna was below a ridge (the DTV antenna was 317 feet below NTSC antenna). This, combined with the low transmit ERP, caused the signal to fall below the threshold. We found five sites

We found only one site where NTSC was OK but DTV didn't work.

where NTSC was OK but DTV C polarization didn't work. One of these sites is where DTV-H didn't work either (again, two miles out on the 180° radial).

• We found four sites where DTV-H was OK but NTSC was unwatchable due to extreme ghosting, and/or noise.

• One site had noisy NTSC reception while DTV was OK.

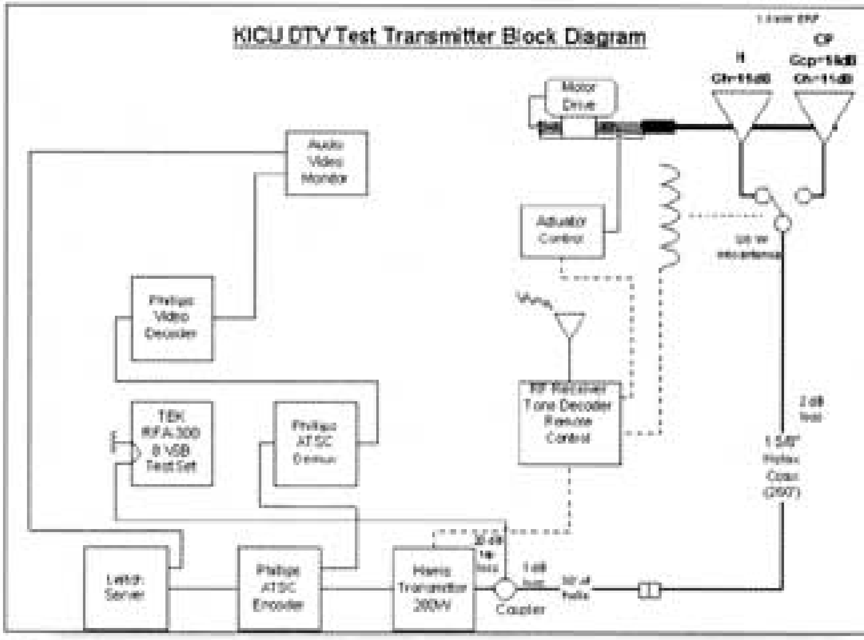
• Ghosting on NTSC was evident at 17 sites, while DTV was OK. Sites with strong and multiple NTSC ghosts didn't always translate into high tap energy values. In many instances, a few pronounced ghosts would not produce enough total coefficient summation to cause poor tap energy readings, but a few high value coefficients seemed to

KICU

track what was seen on NTSC. In 11 instances, tap energy for H was lower (less multipath) than CP and in one instance they were equal. In only five of the 17 instances were the values more than 1dB apart. Also, propagation effects, such as multipath, are not identical at Ch. 36 and Ch. 52 due to the 96MHz frequency separation.

CP does not seem to help DTV outdoor reception when using H-receive antennas, even in high multipath environments.

- At one site we witnessed both NTSC and DTV fades, but there was a ridge line approximately 3/4 miles away that was even in elevation with the test site.
- In two instances at sites close in (large antenna depression angles), NTSC had strong ghosting, while the DTV signals faded. Again we attribute this to the fact that the DTV antenna was 317 feet below the NTSC antenna.
- At two sites near Sutro tower, which is the site for most of San Francisco's VHF/UHF transmitters (292°, 36 & 37 miles), the NTSC signal had high intermod, which was most likely due to receiver direct pickup of NTSC, while the DTV signal was OK.
- At nearly all the sites, the horizontally polarized DTV transmit antenna has a slightly higher site margin than the circular polarized signal. This was due to received field strength generally being slightly hotter for horizontal. This might be attributed to the gains of the H and CP antenna being slightly different. Additionally, because the overall gain of the CP antenna was twice that of H (because of a fixed TPO out of the transmitter), the ERP's for H will be the same for both but the vertical patterns for the H components in both the H and CP antenna were different.



KICU DTV test transmitter block diagram. Key elements were the remotely (H and CP) antennas. This allowed the field test crews to switch between H and CP polarization at each test point.

James Mueller, Chuck Pracna and David Lingenfelter install the transmitter and support equipment. Because the station did not have a digital STL, the ATSC encoder, multiplexer and SDI video source were installed at the transmitter site.

Summary of results

After all this work, what did we learn?

Conclusion: CP does not seem to help DTV outdoor reception when using H-receive antennas, even in high

KICU

multipath environments.

It will most likely be necessary in many cases in the future for DTV stations to conduct these outdoor and, probably as important, indoor tests. The TV manufacturers are very concerned about reception testing. If a customer buys one of these expensive sets, and then takes it home to find that he lives in an area where some, or even all, DTV stations can't be decoded because of reception problems, that DTV set will be coming back to the store where he bought it. This expensive A stock DTV receiver will now become a discounted B stock item. Some manufacturers are concerned enough about this to take pre-emptive action. Panasonic is instructing its dealers to sacrifice a low-end DTV receiver as a test receiver. When a customer buys a set, the dealer sends along with a technician to evaluate reception before the customer's set is taken out of the box.

Sony Electronics is taking a more quantifiable approach. They plan to equip their dealers with a test box that performs a couple of the tests called for by MSG. This box not only measures signal strength of a selected channel, providing an AGC value, but it also has the ability to add noise through a control knob until an LED indicates that errors are occurring. The amount of noise added is displayed on a LCD. This reading gives you a relative indication of the amount of headroom or margin for a given DTV station, at a given location. We tested this box and found it useful.

Digital television does not mean that your analog skills will go away.

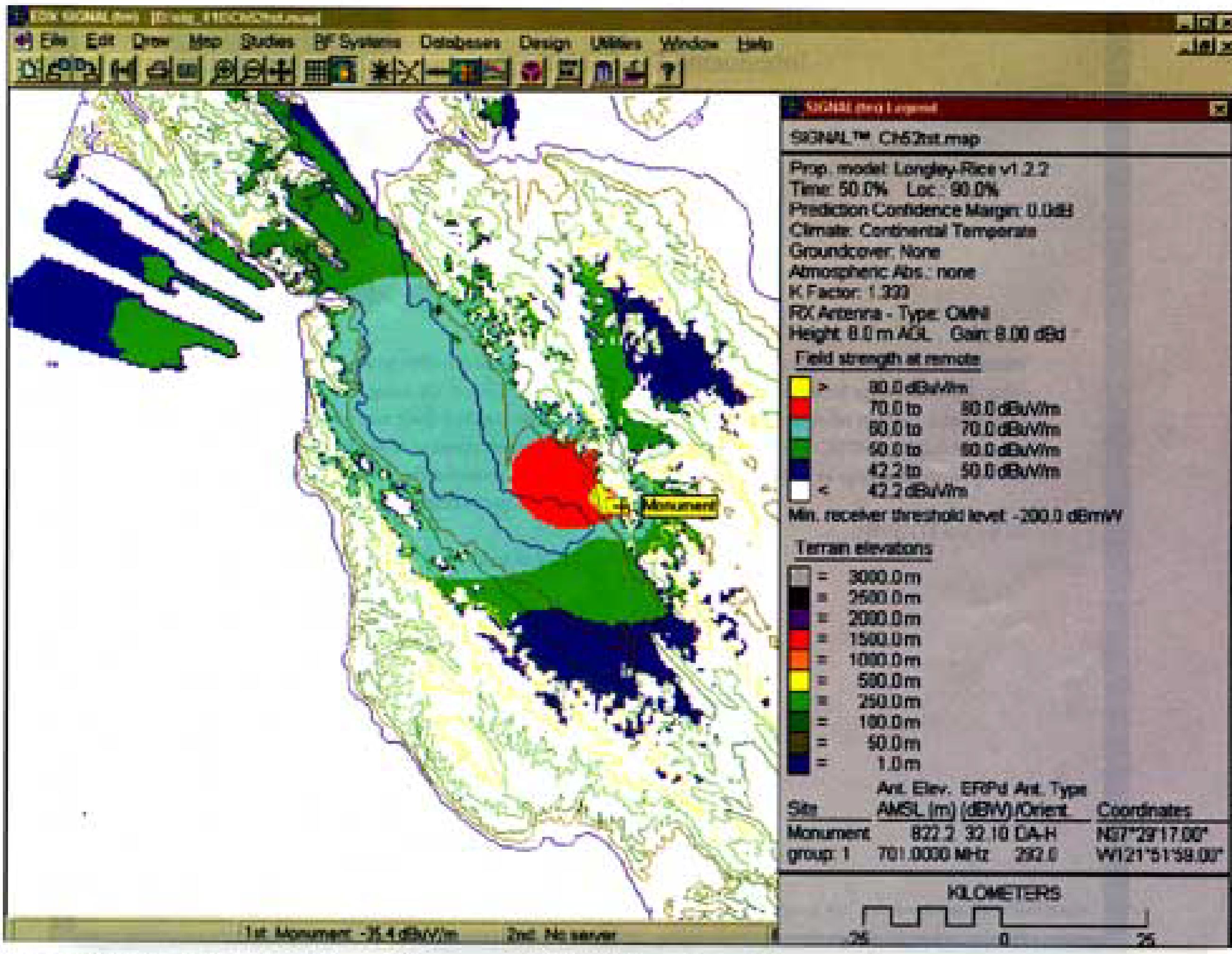
Conclusions

CP versus H

The main reason for our tests were to see if CP would help minimize the effect of multipath with the topology of our market. Tap energy and field strength measurements indicated that CP has no benefit, and in some cases actually performed worse than H for outdoor DTV reception. No indoor tests were performed.

Analog skills remain important

Digital television does not mean that your analog skills will go away. You must stay cognizant of the fact that processing does not end at your ATSC transmitter's encoder. A lot of what



Plot of EDX-Engineering propagation modeling program. This radial predicts a fair amount of coverage toward San Francisco with only 1.6kW ERP. Actual recorded field strength along this radial closely correlates with that predicted coverage. Signal strength was 59.1dBmV/m with H transmit and 57.4 dBmV/m with the CP antenna.

KICU

makes ATSC so robust is the high-powered VSB signal processing that takes place in the consumer's receiver, be it an out-and-out television or just a set-top box.

Once again, it is being driven home to us that just as analog audio and video will be around, your analog skills need to stay intact also. Noise used to be the limiting factor as to how far out your signal could be viewed. With ATSC, it is not only noise, but also transmit linearity. As nonlinearity gets worse, your out-of-band performance gets worse (remember the FCC channel mask) and your in-band signal to noise gets worse. Passband amplitude distortion and group delay affect S/N.

Although transmitter manufacturers are trying to out-compete each other when it comes to S/N out of their boxes, Zenith claims that 27dB is sufficient. Some manufacturers claim values well into the 30s. One has to wonder if this is necessary or just desirable. At 33dB the 8VSB noise threshold is 15.1dB. At 27dB it is 15.25dB, which is a worst case scenario if all the noise is uncorrelated. To keep this value as high as possible, the analog specs remain important. Also, S/N relates directly to EVM. This is the value often reported as an indication of 8VSB's health. Again, manufacturer's specs have values between two percent to five percent. You will see those out of the transmitter but not at most receive sites. Values approaching 15 percent are seen as you approach the cliff. Linearity is extremely important. The coverage area will shrink as the system becomes nonlinear. That's the bad news.

The good news is that the 8VSB system appears to be very robust.

Height is important

The good news is that the 8VSB system appears to be very robust, and the picture quality, even at standard-definition, appears very good. We found comparable NTSC and DTV service availability even though the KICU NTSC is 16 channels below KICU-DT and NTSC is radiated at 34dB higher than our DTV test transmitter. It would appear that having the transmit antennas at high elevations is much more important than power.

A complete discussion of DTV receive parameters will be presented in the July issue of *Broadcast Engineering* magazine. Readers with specific questions on this article or DTV testing can send them to Jim Boston c/o brad_dick@intertec.com. Selected questions may be included in the July feature article. ■

Jim Boston is engineer and David Lingenfelter is chief engineer of KICU-TV, San Jose, CA