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RF transmission systems update

Camera pickups p. 90

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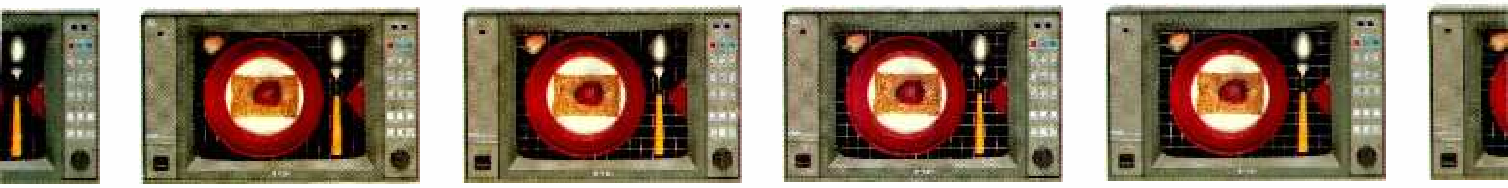

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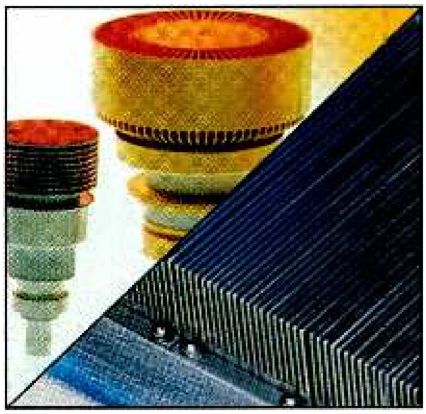

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RF TRANSMISSION SYSTEMS UPDATE:

If there is one thing that separates broadcast engineering from other types of electronic work, it's the use of high-power transmitters. Many of today's older engineers got their start in this business by "babysitting" transmitter sites. Today, things have changed greatly. Modern transmitters are reliable, efficient and much easier to repair. Still, these systems need trained engineers to oversee their operation. This month, we look at some critical elements in the RF system and the latest in TV transmitter technology.

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ON THE COVER

High-power RF requires specialized transmission line. Shown on the cover is an example of modern rigid coaxial line, which is crucial to a reliable and efficient transmission system. (Cover credit: Kim Bracken, *BE* graphic designer. Photo courtesy of **MYAT.** Design by Media/Scan.)

It's time for new directions in television audio.

Television audio has been changing even faster than the rest of the industry. It's time to take a fresh look at the requirements of today's television station—and to find more effective methods of meeting them.

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News

By Dawn Hightower, senior associate editor

NAB asks FCC to retain FM translator reforms

The National Association of Broadcasters (NAB), seeking to preserve reforms that protect against the abusive practices of FM translator operators, has asked the Federal Communications Commission (FCC) to reject all proposals that would "transform FM translators into a for-profit, low-power radio service."

FM translators were originally created to operate as a "fill-in" radio service. They reached sparsely populated areas by rebroadcasting radio programming from full-service stations usually located in larger markets. But in recent years, many translator operators have sought FCC approval to expand their service to "near-primary" status, which would encroach on many well-served radio markets.

In its March 28 filing, NAB said the commission took most of the reform steps needed in a 1990 decision, which corrected years of FM translator abuses. But according to the NAB, many translator operators are seeking to reverse that decision.

NAB has pointed out that translator station requests for increased transmission power, origination of commercials, and entry into established radio markets can erode the competitive footing of many local, full-service radio stations.

"The commission has firmly established that FM translators may provide only a supplementary service to areas in which direct reception of radio broadcast stations is unsatisfactory," NAB told the FCC. Broadcasters said this status must be preserved, in part, to avoid signal interference with full-service stations that serve the same areas as translators.

NAB also asked the commission to reconsider its position on several important issues. For example, NAB advocates granting only a 1-year period, rather than the three years the FCC is giving translator operators, to comply with the commission's 1990 decision. NAB noted some translator operators now advocate an indefinite period, a move that would effectively gut the FCC reforms.

In addition, NAB wants the FCC to reconsider its decision to allow FM translators to sell "advertising messages." Instead of advertising, NAB thinks FM translators should be allowed, at best, to offer "enhanced underwriting" announcements, similar to the type aired by many public broadcasting stations. The association says this remedy would underscore the secondary nature of FM translator services, and at the same time, not undermine full-service, local broadcast stations.

SBE files comments in "congested area" docket

The Society of Broadcast Engineers (SBE) has filed updated maps in the FCC "congested area" docket showing proposed frequency congested areas in the United States and the District of Columbia. The SBE had petitioned the FCC in February 1990 to adopt a clear-cut definition of the term "frequency congested area," which has been in the FCC rules since 1981.

New fixed-microwave stations located in frequency congested areas are required to install Category A antennas, although microwave stations not in areas subject to frequency congestion are allowed to install smaller Category B antennas.

In its February 1990 petition for rulemaking, the SBE proposed using census-defined Standard Metropolitan Statistical Areas (SMSAs) as the first-cut criteria for determining whether a station is located in a frequency congested area. There are 309 SMSAs nationwide, based on the 1980 census. This number will probably be increased when the 1990 census data becomes available.

The SBE filing continues to endorse the premise that any area with sufficient population to be designated as a SMSA is also likely to be frequency congested. In response to input from its 115 affiliated frequency coordinating committees, the SBE fine-tuned its proposal to include a 4-level "safety net" to ensure that no broadcast auxiliary microwave station be required to bear the expense of an antenna upgrade where no need exists.

The SBE also proposed a "structural exemption," to accommodate existing microwave antennas that are installed on towers so heavily loaded that the additional windloading caused by a larger antenna would create a safety problem. However, the SBE proposed that confirmation of the tower loading must be provided by either a registered structural engineer or by the tower manufacturer.

In other news, the SBE office has moved to a new address at 8445 Keystone Crossing, Ste. 140, Indianapolis, IN 46240. BE

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INTERTEC PUBLISHING CORPORATION

Vegas: still our place in the sun

I have received several letters in response to my March editorial in which I suggested that the return of the NAB convention to Las Vegas was, in some ways, reassuring to both attendees and exhibitors.

One reader complained that Las Vegas was little more than "glitz and polyester." He said he once found Las Vegas so oppressive that he had to leave the city and spend a day in Death Valley, just to get away from it.

Another reader chided me for singing the praises of Las Vegas as a stable convention home. He remarked that moving the convention around the country allowed the "lower classes" to attend the show. If the show were within driving distance, he explained, many people who normally couldn't afford to go would be able to spend a day or two at the convention.

He described his staff's determination to attend the Dallas show — the packed cars, long hours on the highways, the overnight stays at the homes' of friends, all of which were enlightening. This was the only way this station's staff could attend. Because the station wouldn't even pay for registration, the staff was forced to beg exhibitor guest passes from suppliers to tour the convention floor.

His point was well taken. Many stations cannot afford to send their staffs long distances to conventions. Airline fares and hotel costs are often too great for many stations' budgets. Of course, Vegas is convenient for those in the lower west portion of the country. But if you happen to be located east of the Rockies, as this writer is, Vegas may be too far away.

I agree with the specific points made by these two readers. However, in fairness to the show's planners, there are many issues related to the convention's production that few readers understand. The most obvious factor is the convention's size. The NAB show requires tens of thousands of hotel rooms and hundreds of thousands of feet of exhibition space. In fact, the NAB convention is so large that few cities can host it. Even with the improved Las Vegas facility, the show is still cramped. Such a large convention cannot be moved to a new city every year because the required facilities aren't readily available.

Organizing a successful convention is a challenge at best. Organizing this show is almost a miracle. This year's show, as in the past, was a well-attended and successful event. The NAB convention will continue to be the yearly focal point for the entire broadcast industry.

I do wish more engineers and other station staff could attend the show. There is so much to learn from it. No where else can a broadcaster examine so many different pieces of equipment in one location. More papers on broadcast industry issues are presented over the five days than in all other broadcast shows combined. For those who can afford it, this is the show to attend.

I'm sorry my friend couldn't attend the NAB convention. He missed a great show. To others of you who couldn't attend, we'll try to provide the next-best-thing to being there. The June issue of *Broadcast Engineering* will provide in-depth coverage of the convention's major issues. From products to technology, the June issue will update you on the latest news about the broadcast industry. Reading about the show won't replace being there, but then it won't cost you anything, either.

By Brad Dick,
editor

More on "time leasing"

By Harry C. Martin

As reported in March, the FCC is permitting radio stations to lease up to 24 hours a day of programming time on competing stations. Although several decisions were issued in December 1990 that set limits on these arrangements, three new rulings were issued in April that further refine the law. The key contract provisions approved in the three cases are summarized as follows:

• *Ruling No. 1.* The first agreement the commission approved provides for a 10-year lease term with a year-to-year renewal option. The time broker will program the second station 24 hours a day, seven days a week, with the exception of two hours on Sunday mornings between midnight and 6 a.m. The licensee will remain responsible for all technical personnel and for the general manager, who will supervise the broker's employees while they are on the station's premises. The licensee also reserves the right to suspend or cancel programs not in compliance with its standards or the public interest, and can pre-empt the broker's programs to broadcast material if it is considered to be of more public interest value. However, preemption of 15 or more hours a week of the broker's programming is grounds for termination of the contract. The licensee will be responsible for broadcasting public service programming and maintaining a public file. Also, the broker has a right of first refusal in the event the station is sold.

• *Ruling No. 2.* This agreement has a duration of seven years and provides for the use of all of the licensee's program time between the hours of 6 a.m. and midnight, seven days a week. The licensee may delete programs it considers not in the public interest, but must provide advance notice, if possible, of the deletions. The broker may simulcast all or part of the programs it supplies to the brokered station. The licensee is to pay all operating expenses and will maintain control over station personnel. Also, the broker can sell a majority of the advertising on either or both stations. The agreement is binding upon any assignee of the brokered station.

• *Ruling No. 3.* In its third ruling, the FCC approved a 2-year program time lease with a year-to-year renewal option. The licensee remains responsible for certifying that all logged advertising is run at the appropriate times, and for maintaining control over programming. The licensee also has authority to pre-empt or reject any advertisements it considers unsuitable. The licensee will maintain the station's public inspection file, cover local issues for its quarterly issues/program lists, air station IDs, and maintain a studio within the principal community area. Furthermore, the licensee will continue to employ a general manager who will oversee day-to-day operations and be responsible for all personnel involved in management or operations. The brokering station will, however, be responsible for all employees involved in the sale of advertising time and the production of commercials. The broker also will have the right of first refusal in the event the station is sold or the commission changes its duopoly rule to permit such a sale.

• *Ruling No. 3 (alternate).* Ruling No. 3 included reference to an alternative agreement that would be substituted for the one previously described if the broker and licensee decide that their two stations will not be simulcast. In that event, the broker would be responsible for program production personnel, but the licensee would be responsible for all personnel used in the actual transmission of the programming. While on the premises, all personnel would still report to the licensee's general manager and/or chief engineer.

Possible problems

In its April rulings on time brokerage, the FCC again emphasized the dangers they could pose. The agency noted that a station that airs brokered programming 24 hours a day must remain responsive to the needs of the community of license or risk losing its license through the denial of a renewal expectancy.

Furthermore, the FCC cautioned brokered stations to take steps to ensure that they comply with political broadcasting laws. All licensees must oversee and take ultimate responsibility for the broker's advertising and program practices with respect to the provision of equal opportunities, the lowest unit rate and reasonable access for candidates running for political office.

As emphasized in March, time-leasing agreements, such as those previously described, pose some additional dangers. FCC licensees must be able to demonstrate that they control and are responsible for their programming and the operation of their facilities. So even in situations in which the licensee retains all of the requisite rights to interrupt and pre-empt the broker-provided programming, problems will arise if those prerogatives are never or seldom exercised.

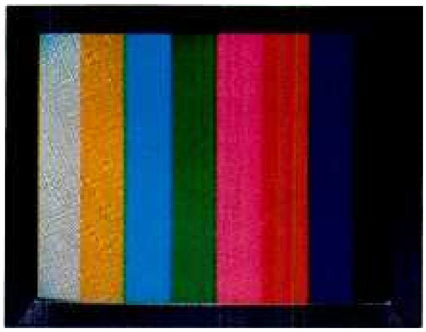
"Pioneer's preference" adopted

The commission has established rules and procedures that will give preferential treatment in its licensing processes to parties requesting spectrum allocation rule changes for the development of new communications services and technologies. A "pioneer's preference" will be awarded to an entity that demonstrates that it has developed an innovative proposal that leads to the establishment of a service not currently provided, or a substantial enhancement of an existing service.

The agency said the new preference procedure will ensure that innovators have an opportunity to participate in new services they develop or in existing services to which they wish to apply new technologies. The pioneer's preference will foster the development of new services and improve existing services by reducing, for innovators, the delays and risks associated with current FCC allocation and licensing processes.

The preference is not available to broadcasters who locate and successfully petition for the allocation of new TV or FM channels for their communities. Although there is growing support for granting such a preference, its fate will be determined separately in the future.

Martin is a partner with the legal firm of Reddy, Begley & Martin, Washington, DC.



SuperNTSC unveiled in San Francisco

By Pete Hammar

The first public demonstration of SuperNTSC, a signal-encoding method reported to noticeably improve the National Television Systems Committee (NTSC) color TV standard, took place in San Francisco in January. The demonstration, which used two TV stations and a cable system, allowed audiences to view live, over-the-air SuperNTSC signals. The signals traveled a variety of paths so that the audience could compare the video from each source.

Proving compatibility

A primary goal of the 4-day demonstration was to show that the new system is compatible with existing NTSC broadcast and cable equipment. To do this, KPIX-TV in San Francisco used its regularly scheduled *People Are Talking* program as a live feed. After encoding at KPIX, the signals went to the transmitter on Mount Sutro via a standard microwave studio-to-transmitter link, with over-the-air reception back at KPIX. The signal was then microwaved from KPIX to KGO, two blocks away. In KGO's studio, the audience watched the video on a SuperNTSC decoder feeding a large-screen television, and a standard NTSC monitor.

The second signal path used the same KPIX transmission chain, but used VHF reception at Viacom Cablevision's Bay Area reception facility, then regular cable plant distribution to KGO and up to the studio.

The audience members, mostly Bay Area broadcasters and video equipment design engineers, agreed that the new system offered some notable improvements. In their opinion, the additional distribution and line amplifiers in the cable system appeared to have no effect on the encoded signal.

Artifact reduction

Current NTSC signal artifacts include cross-luminance, cross-chrominance (cross-color interference or moire), ringing, noise and ghosting. Part of the problem is that NTSC decoders in current TV sets may fail to remove all of the color subcarrier signal burst. Sometimes, residual 3.58MHz color subcarrier beats with the chrominance and luminance information of the signal. When this occurs, close parallel black-and-white lines generate irritating colors — the infamous "Johnny Carson Seersucker Suit Effect." *Cross-luminance*, or dot crawl occurs between sharply defined colors in adjacent frequency bands, such as green and blue. However, the SuperNTSC method overcomes most of NTSC's current cross-luminance and cross-chrominance problems.

The system does not degrade the existing NTSC service. Rather, it enhances it.

The process also improves *ringing*, which most commonly occurs when black lines paralleling white lines echo light-to-dark transitions. The system also reduces noise by using adaptive filtration that adjusts the filtering level according to the changing picture.

Although the system reduces most of these artifacts, it does lack ghost reduction, which requires reference signals in the vertical interval. Currently, all SuperNTSC signals are legal. The promoter says ghost-reducing reference signals could be added, but the move would require FCC approval and the consensus of broadcasters. Also, ghost-reduction circuitry at the station and in the consumer television would be expensive.

But all in all, installing the system does not degrade the existing NTSC service. Rather, it enhances it. SuperNTSC images on standard sets have less cross-color interference and noticeably higher detail rendition, particularly on saturated colors.

Double the fun

The system's intelligent line doubler increases the line count to 1,050 by examining lines above and below the lines to be doubled for luminance and chrominance information, as well as the previous and following frames for changes in motion. The system then uses this information to create the new lines.

Also, the system employs no letterboxing and stays within the current NTSC 1.33 aspect ratio.

Counting the cost

KGO and KPIX engineers estimate the cost of converting a large station to the system at $425,000 (50 encoders at $8,500 each). The figure is high because to work properly, an all-SuperNTSC shop would require new encoders to be installed in place of normal NTSC encoders on every RGB source. STLs and transmitters would require no changes to broadcast the SuperNTSC-encoded signal.

Based on KPIX's installation of encoders for its test broadcast, converting a facility should take about four hours per encoder for installation and setup. By contrast, KGO sources estimate that converting to any of the proposed high-definition TV standards would cost the station at least $40 million and involve the total replacement of most of the equipment and wiring in the station.

But the cost of conversion doesn't stop there. The increased cost of TV sets must also be considered. Proponents estimate that the chip set for the decoder would add from $150 to $400 to the price of a large-screen TV set. Although work to complete the chip set could take up to two years, stations and networks may currently take advantage of the encode-only technology to clean up their signals in anticipation of consumer decoder sales.

HDTV dropout

The SuperNTSC system is produced by Faroudja Research, Sunnyvale, CA. Its development is being underwritten in part by several leading broadcast and cable networks. For several years, SuperNTSC was a contender in the muddled EDTV/HDTV sweepstakes. But last year, Faroudja Research dropped out of the Advanced Television Testing Center program that sponsored the sweepstakes.

Hammar is owner and president of Hammar Communications, San Carlos, CA.

If you've been putting off doing stereo field remotes for fear of risking a fragile, expensive stereo mic, Shure's new VP88 is what you've been waiting for.

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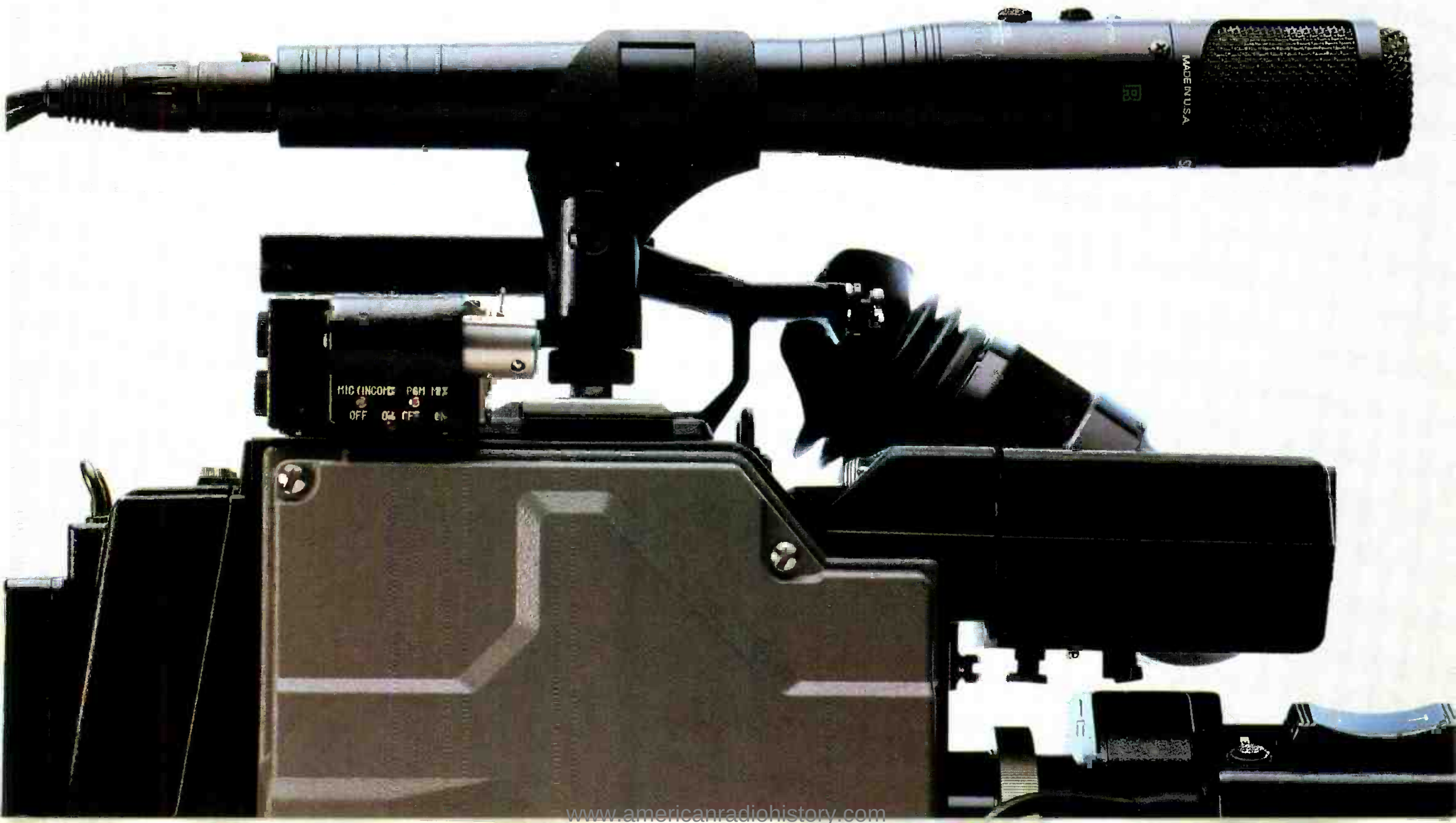


Part 1

re:Radio

Applying vectors

Laying the groundwork

By John Battison, P.E.

During a recent discussion with a group of radio engineers about antenna theory and operation, I referred to "vectors." To my surprise, several of the engineers said they were confounded by the theory of vectors and their applications. Though they seem complex, vectors are actually easy tools to use and an understanding of them can make you more confident when faced with a troublesome directional array or some other electronic equipment problem.

A *vector* is a straight line that possesses magnitude and direction. Straight lines have length, which can express magnitude or amount. These lines are used in graphs and in laying out plans to scale. The lines are not vectors because only the length matters and their direction has no numerical significance.

Conversely, a line that shows the path between two locations is also not a vector because it possesses direction, but no magnitude.

Vectors are easy tools to use and an understanding of them can make you more confident when faced with a troublesome directional array or some other electronic equipment problem.

But when you calculate a course between two locations that considers wind and air speed, the line that you draw possesses magnitude (air speed) and direction (the course to steer). This is a vector.

The vector tells us the speed by its length, and the direction by its *azimuth*, or bearing.

Going in a circle

Most of us think of azimuth in terms of a circle encompassed by the four cardinal points — north, east, south and west. We usually start measuring straight up at 0° or due north and then travel around it clockwise (east is 90° and so on), until we get back to 360° or 000°.

Although this process seems simple and intuitive, mathematics uses a different process.

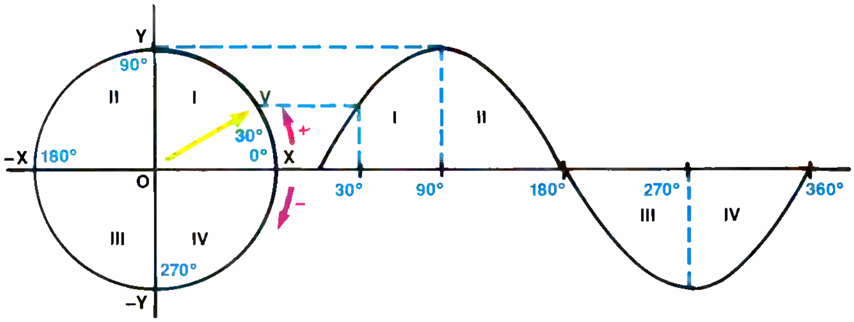


Figure 1. The 4-quadrant phase circle and its relationship to a generated sine wave. The line OX is the reference line, and all positive measurements proceed counterclockwise from it.

In math, 0° is *not* at the top, but at the east, or horizontally to the right. Also, math measures positive azimuth counterclockwise, not clockwise, from that point. This often confuses new radio engineers who think in terms of mathematical bearings.

Many years ago, the company at which I was working hired a young electrical engineer. One of his first projects was to lay out the traditional eight radials on topographical maps to calculate height above average terrain. (Because we hadn't started using the national database to do this, you can guess how long ago this took place.) After laying out the radials, he labeled them 0°, 90°, etc. When he handed his topos to me, the east radial was neatly labeled 0°, and the south radial was marked 270°. He had followed mathematical procedure and started in the east and counted counterclockwise. It was obvious that he hadn't considered compass directions, even though he was working on a map. It took us a while to convince him that we were right, and that he was wrong.

Squaring the circle

The mathematical *phase circle* is divided into four quadrants, as shown in Figure 1. Roman numerals are used to mark them so that they aren't confused with the usual designation. The horizontal reference line from the center O to the 0° point on the circle is the positive X-axis. The line from O to the 90° point on the circle is the positive Y-axis. Normally, all of our vector work is referenced to these axes using (X,Y) coordinate notation. As might be expected, the lower two quadrants, III and IV, are generally known as the negative quadrants and the axes there are designated −Y and −X.

The discussion of this circle naturally leads to the Pythagorean theorem that has had tremendous impact upon electrical engineering work. Starting from the X and Y axes that form a right angle at O, we can use "Pythy's" theorem for guidance.

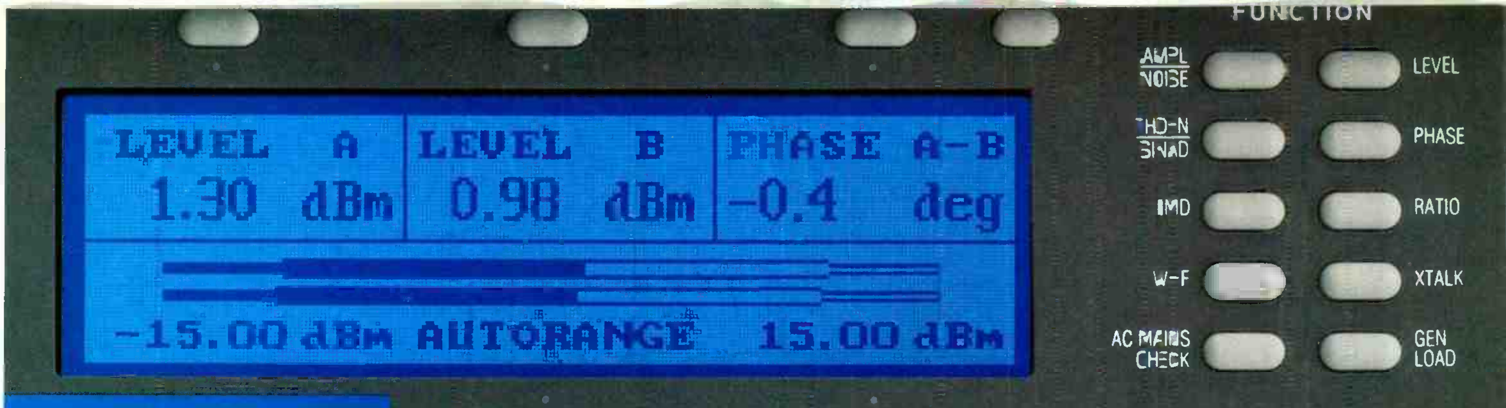
Sine waves

Figure 1 also illustrates a rotating armature generating an AC voltage. In radio work today, voltage is generated by a vacuum tube or a transistor.

As the armature rotates, it generates a voltage whose angle and magnitude change with rotation. The angle, or phase, can be read from the point on the circle, and the magnitude is equivalent to the distance from the origin O to the end of the vector OV. Because the same kind of sine wave is generated in the case of an oscillator, the same rules apply.

Next month, we will apply vectorial techniques to AC and RF oscillations, and show how vector arithmetic can be used for our purposes in radio.

Battison, *BE's* consultant on antennas and radiation, owns John H. Battison and Associates, a consulting engineering company in Loudonville, near Columbus, OH.



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Emergency antennas under new FCC regulations

By Bob Van Buhler

In 1988 the Federal Communications Commission issued a Notice of Proposed Rulemaking regarding RF radiation and environmental factors. This measure, Docket No. 88-387, included extending the FCC environmental rules to include some changes that were permitted without prior authorization from the commission.

Catch-22

Actions enumerated in these "permissive changes" include substituting one type of transmitter for another if it is type-accepted or notified. They also include non-directional antenna substitutions as long as there is no change in height above average terrain or effective radiated power.

Under these permissive changes, it would be possible to substitute a properly designed 10-bay antenna with little downward radiation for a lower-gain 2-bay antenna that has a considerably higher downward radiation. By increasing the transmitter power feeding the antenna, the effective radiated power could remain the same.

In other words, a single-bay antenna's pattern in free space would resemble a donut in cross section, radiating above and below the aperture in a symmetrical fashion. As the gain increases by stacking more bays, the donut flattens out, with more power radiating straight out from the aperture. This decreases the radiation in the area below the aperture, or the downward radiation. In this way, geographic coverage is increased at the expense of the area under the tower.

The change from a high-gain antenna to a low-gain antenna at the same power, the commission reasoned, may be classified as a major environmental action, which would trigger an environmental assessment. In situations such as this, the measure would protect the public from ground-level RF exposures in excess of the ANSI standard C95.1-1982.

Protecting the public health

The accompanying proposal resulting from Docket 88-387, became effective June 16, 1990. Therefore, if the possibility of generating such exposure exists, the station licensee must first obtain commission approval for the change.

Normally, this would not be burdensome for licensees because antenna designs should be studied and planned in advance to assure proper performance in all planes of radiation. However, the wording of the FCC's Report and Order is such that emergency antennas seem to be included.

Emergency antennas are often rigged in a last-ditch effort to return a station to service after a mechanical or structural failure. If this happens, there is usually little or no time for advance planning. Towers can fall, rendering auxiliary antennas useless, and the only way to regain transmission capability is the temporary tower, which is often at a lower elevation, or rigged to the roof of a building in ways that could result in a temporary increase in downward radiation.

Also, though these antennas are usually operated at much lower power, they are mounted closer to the ground, which could create radiation in excess of the 1982 ANSI standard.

Foreseeing this situation, SBE filed a Request for Declaratory Ruling in which it asked the commission to clarify whether emergency or temporary antennas were subject to the new measure. If so, the new rules would conflict with section 73.1680 of the existing rules, which allow a broadcast station that is the victim of an accident, vandalism, natural disaster or other unforeseen event to take the steps necessary to get back on the air as soon as possible. In addition, the temporary antenna rules in section 73.1615 are also intended to give the station the flexibility necessary to accomplish this.

Plan ahead

On Feb. 1, SBE received the commission's answer. It ruled that emergency or temporary antennas are subject to the new environmental rules. SBE members should be aware of their obligation to perform an RFR analysis before rigging an emergency antenna. It would also be prudent to develop a contingency plan that considers all foreseeable consequences of an on-air equipment failure. This contingency plan would involve determining what locations are available to the licensee for emergency antennas in the event a tower comes down, and what amount of RFR will be present at ground level if that location is used. Stations using multisite locations should also consider the effects of radiation from other stations at the proposed contingency site. In all cases, the plan should consider the cost and the availability of the materials and labor that are needed to carry the plan out. Early planning and rehearsal, according to the SBE filings committee, will result in fewer problems when the plan must be implemented.

SBE members should be aware of their obligation to perform an RFR analysis before rigging an emergency antenna.

Further information is available by calling the FCC filings committee chairman and board member Dane E. Ericksen at 415-342-5200. Dr. Robert F. Cleveland of the FCC (202-653-8169) and SBE counsel Christopher D. Imlay, Esq. (202-296-9100) are also good sources of information.

SBE is going to Mexico

AMITRA, Mexico's broadcast engineering organization, has proposed joint meetings with SBE at its annual national seminar in Puerto Vallarta, Mexico. The joint meetings would take place Aug. 7-9, 1991. SBE president Brad Dick, who was a featured speaker at AMITRA's last annual meeting in Acapulco, has been invited to speak again at this year's event.

Van Buhler is manager of engineering at KNIX-FM/KCWW-AM, Phoenix.

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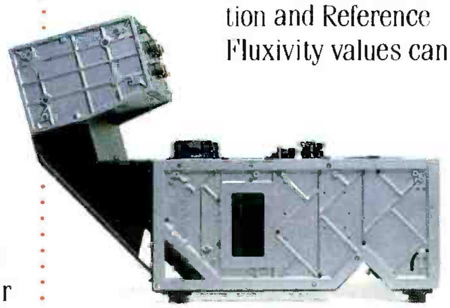

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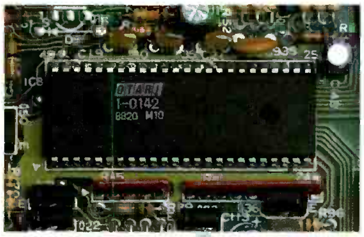

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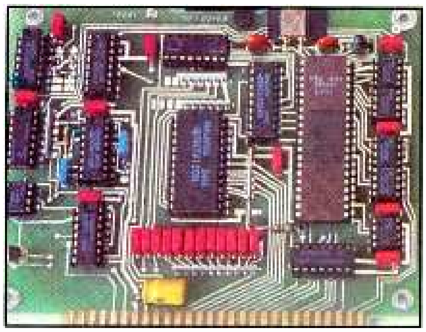
Building with microcontrollers

Inside the UART

By Gerry Kaufhold II



Last month, this column examined a serial communications interface system of a typical microcontroller and described the functions of its four major parts: the crystal and timer T-0, the universal asynchronous receiver/transmitter (UART), the serial I/O section of port 3, and the external electrical interface.

This month, we will take a closer look at the workings of the *UART*, which inputs a parallel byte and shifts it out one bit at a time to create a serial bitstream.

Before the UART

Today's UART (pronounced "you art") has become a de facto standard tool used by the communications and computer industries for controlling serial data communications. However, it was originally used for a different purpose. Years ago, UARTs sent make/break pulses over telephone wires for operating mechanical teletypewriters. Some of the UART's terminology reflects this past. For example, baud rate, in those days, measured the number of make and break transitions per second for teletypes. This is slightly different from the current usage in which baud means the number of digital bits per second.

The UART transmitter

The UART is *universal* because it can connect to any other standard UART. It is also *asynchronous* because it doesn't require a special clock input on its data pins.

The UART on the Z-8 has two independent sections — input and output. These sections can send and receive simultaneously, which makes the Z-8 UART capable of full duplex operation. The output section is easier to describe than the input section, so we will look at it first. (See Figure 1.)

All of the Z-8's input, output and control functions work through the 8-bit registers located in the 256 microcontroller address locations between 00h and 0FFh. Port 3 is set to pass serial datastreams by setting bit 6 of the port 3 mode register (0F7h) to 1. Timer T-0 is programmed to create the correct bit rate. Setting bits 0 and 1 of the timer mode register 0F1h to 1 starts the timing oscillator.

Counting it out

For the Z-8, a logic high voltage is called a *mark*. A logic low voltage is called a *space*. When it is not outputting data, the serial transmit output (port 3, bit 7) is high, or mark.

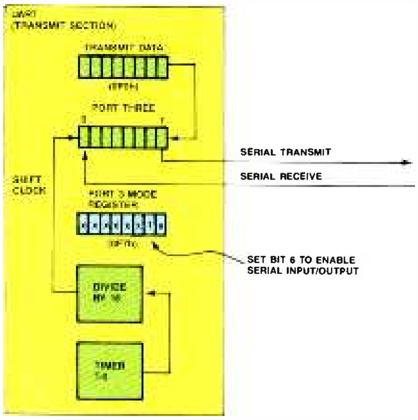


Figure 1. *The UART transmitter converts a parallel byte into a serial word for transmission. Serial operation is enabled by setting bit 6 of port three mode register to 1.*

Data to be transmitted is written to port 0F0h, the serial transmit buffer, using any of the Z-8 instructions that can load data to a register. As soon as the load instruction is complete, the transmitter goes into operation.

Timer T-0 starts by outputting shift clock pulses to the transmit data buffer. Each shift clock has a duration of one *bit-time*. For example, if the bit rate is 300 baud, then one bit-time = 1/300 = 3.3ms.

The continuous mark (high) output on port 3, bit 7 drops down to a space (low) for one bit-time. This initial mark-to-space transition is called a *start bit*. The start bit "wakes up" the receiver at the other end of the line. (See Figure 2.)

A UART is universal because it can connect to any other standard UART. It is asynchronous because it doesn't require a special clock input on its data pins.

One databit appears at port 3, bit 7 for each bit-time, until all eight bits are output. After outputting the last databit, the UART sends two low *stop bits* before the transmit data port returns to the mark condition. The two stop bits permit the receiving circuit to finish reading the current character, reset itself, and get ready to receive the next character.

Counting the start bit, eight databits, and two stop bits, each character transmitted through the UART requires 11 bit-times. There is usually a minimum of one mark between each character sent. This is done for two reasons. First, it gives the receiving circuitry time to prepare to detect the next mark-to-space transition that indicates a new start bit. Second, if a space continues through more than one character time, it registers as a *break*. A break signal is a handy way to generate system reset signals over a serial communications line.

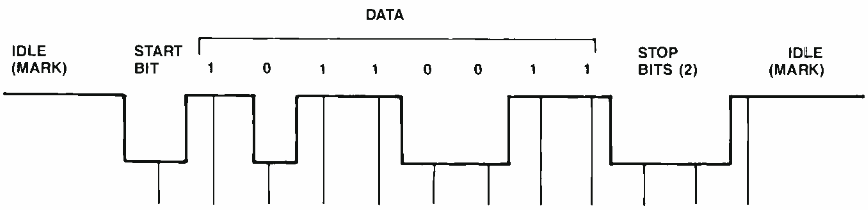


Figure 2. *The serial output from the UART transmitter consists of a start bit, eight databits and two stop bits. During the interval between characters, the line is held high (mark).*

Next month, we will examine the operation of the UART receiver.

Kaufhold is a market development engineer for SGS-Thomson Microelectronics, Phoenix.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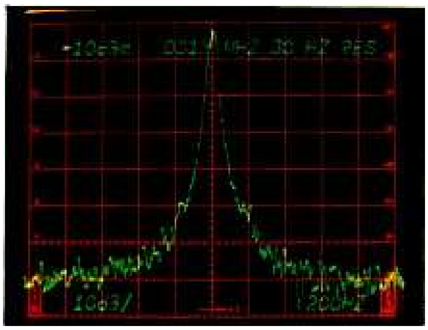


DAT maintenance

Mechanical adjustments

By Richard Maddox

Like VCR transports, DAT transports have several fixed and adjustable tape guides that are used to set the tape's path through the machine. (See Figure 1.)

Four parts—the supply, take-up guide rollers and two slant posts—pull the tape out of the shell and position it against the head drum, capstan and two other guideposts. This process is called *loading*.

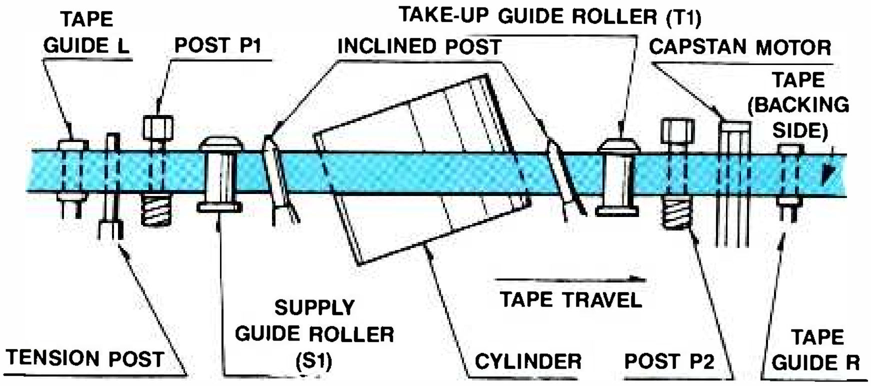


Figure 1. *The DAT tape path. (Courtesy of Fostex.)*

These four parts and the two other guideposts control the tape's path. Two adjustable guides, S1 and T1, control the height of the top of the tape. The remaining fixed guides (tape guide L, post P1, post P2 and tape guide R) are factory set against the bottom edge of the tape. Most manufacturers recommend that you not change the fixed guides in the course of alignment. Typically, S1 and T1, the adjustable guides, are the only transport parts that need alignment as the machine ages, or when the head drum is replaced.

Even a slight misadjustment of these guides can cause the head to improperly trace the tracks. This results in high error-concealment activity, momentary muting and machine-to-machine playback incompatibility.

Figure 2 shows the difference in RF waveforms between properly adjusted tape guides and misadjusted ones. When the track-to-head path doesn't match, the RF envelope level changes as the head scans the track. This distorts the RF envelope and turns the waveform from the correct rectangular shape into a trapezoid, or worse. Each track produces a separate RF envelope that contains PCM audio data in the middle, and subcode data and the automatic track finding (ATF) signal at each end. Because the head drum rotates at a fixed 2,000 rpm rate during record or play, the capstan servo circuit must use the ATF signals to adjust the capstan speed so that the recorded tracks' positions on the tape match the head's rotational path.

The procedure for tweaking the adjustable guides is called *setting the linearity*. A specified test tape (usually called linearity, tracking or ATF test) and an oscilloscope for viewing the RF output are used to set the guides for a rectangular RF envelope. This can be tricky because each track is only one-tenth the width of a human hair (13μm) and it is being traced by a head that is only 1.5 times wider and spinning at 2,000 rpm.

These are the most difficult adjustments in a DAT machine, and it will often take more time to adjust these than it will to make all the electronic adjustments combined. As a rule, never move the guides more than a one-fourth turn from their starting positions. If you turn them more than this, you are either adjusting the wrong guides or you have another problem in the machine.

Because the S1 and T1 guides have set screws that hold their positions, they must be slightly loosened before any adjustments are made. To do this, the elevator assembly must be removed from the machine, which complicates this simple adjustment. Be sure to carefully retighten the set screws, or the adjustment will drift because the S1 and T1 guides move back and forth each time a tape is loaded and unloaded.

Head drum replacement

Because most DAT machines have an integrated head drum, the entire unit can be replaced at one time.

Head life varies greatly between manufacturers. Some models, for example, require head replacement after only 750 to 1,000 hours of use, and others don't need replacement until after 1,500 to 2,000 hours of use. Fortunately, most professional DAT machines have elapsed-time hour meters to keep track of usage.

On units with a separate upper cylinder, the method used to replace the head is virtually identical to that used to replace a VCR head.

Even on a machine in which the upper cylinder can be replaced, you will need to change the entire head drum after 5,000 hours of use.

Next month, we'll look at the most important electronic adjustments found in DAT machines.

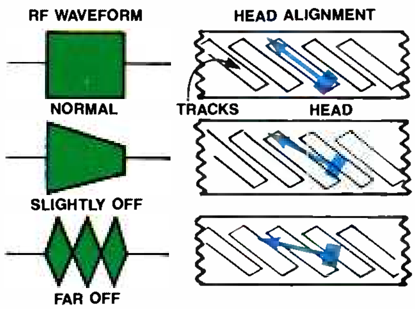
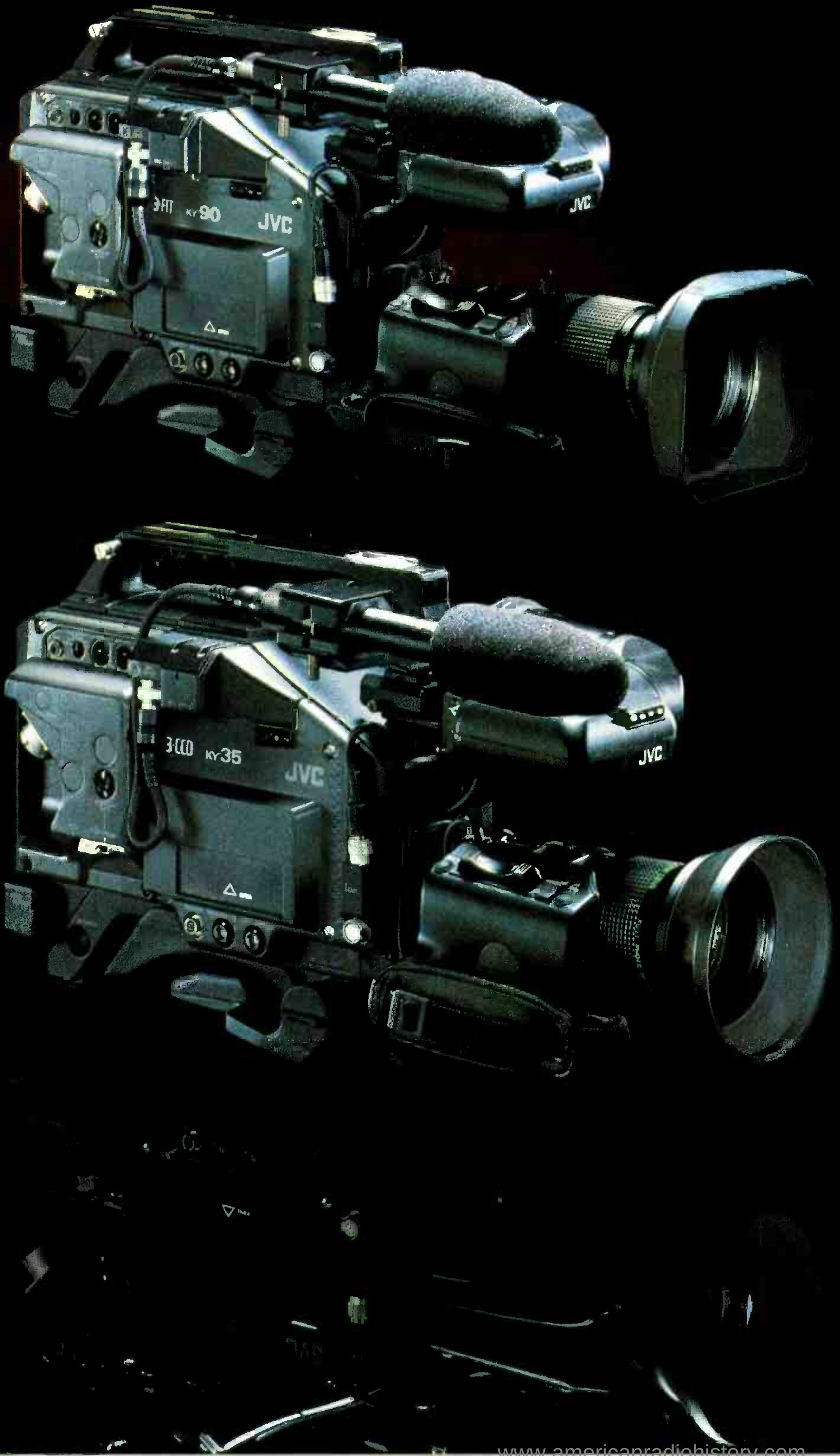


Figure 2. *Head tracking and the resulting RF waveforms. Alignment is viewed from head drum (magnetic) side of tape.*

Maddox is technical manager at Media Management Associates, Lynnwood, WA.

JVC's KY-35U and KY-90U . . .



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Part 1

Management for engineers

Time management

Examine your habits

By Judith E.A. Perkinson

The adage, "Do more, do it faster, with less" certainly applies to today's engineers. As budgets shrink, staff positions are cut, and the workload increases, engineers are being forced to discover new ways to get more out of the time and manpower available to them. Though it isn't easy, there are ways to do more in less time. The solution lies in the use of effective time management skills.

Over the next five months, this column will take a practical look at time management. Easy-to-use tips and suggestions will be included to help you manage your time better. After all, you will never have more time, so you must use what you have effectively.

I clearly remember the first time management seminar I attended. I left it thinking that it would take more time and effort to manage my time than it would to continue my current practices. Something had to be wrong. I immediately decided that I was the problem because I didn't understand time management. For the next several years I carefully avoided all training seminars or discussions of time management.

Then one day I found myself in the middle of a stress management workshop and what was the subject of discussion? Time management. I had been tricked. Before I could get up to leave, I realized that what was being said made sense and seemed to have some relationship to my work, which at times, was filled with unanswered phone messages, piles of paperwork and days that got away from me almost before they began. So I listened, and I learned.

This series of articles on time management is dedicated to all of you who are drowning in a sea of paperwork, falling asleep in senseless meetings, frustrated by constant interruptions, overwhelmed by uncompleted tasks or who simply want to gain more control over your days and nights.

Perkinson is senior member, the Calumet Group Inc., Hammond, IN.

You can't create time

Time management, like so many other organizational tools, is too often viewed as magic. Once you have decided to use one of the suggested techniques, presto, you've solved all of your time and organization problems. Unfortunately, it doesn't work this way. Time management techniques are merely an assortment of tools, some of which will work for you, and some of which will not. You must stop looking for instant solutions and start looking for the right tool for you.

Nothing you do can create more time. Yesterday there were 24 hours in the day, today there are 24 hours, and tomorrow there will still be 24 hours in the day. So far, you have somehow managed to fill up those 24 hours every day of your life.

However, you must understand this key principle: If you are going to make the effort to become organized, you must adjust your time to use the tools. Any time management tool you select should not require more time to use than the time you would save by using it.

Naturally, you must allow for a learning curve. It takes a certain amount of time to learn to use a given tool. Furthermore, if you are currently disorganized, it is unlikely that you can get organized without some investment of time. The key is to find a tool that does the job in a manner that is compatible with your operational style.

Time management tools

Time management tools deal with a multitude of sins. They are often broken into three categories.

1. Paperwork organizers.

Organization strategies can help you control the demonic paperwork in your life. Do any of the following points seem familiar to you? You probably need paperwork organizing tools if:

- You haven't seen the bottom of your "in" basket since it was installed.
- Your office is filled with piles of paper. This applies even if you think you know where everything is in those piles.
- You constantly find that written information given to you gets by you unnoticed. Because of this, you have to take corrective action later.
- You lose papers, have difficulty finding them when you need them or think that your paperwork controls you instead of you controlling your paperwork.
- You feel you can't get ahead of your paperwork without taking it home or working on weekends.

2. Time control techniques.

Everyone faces the problem of "time thieves." These are the people and circumstances that steal precious time from your busy day. Typical examples of everyday time thieves include:

- The dreaded telephone. Some days the phone cuts your schedule so viciously that you can't get anything done.
- "Do you have a minute?"-type interruptions that leave you with no time left to do your own work.
- People who always think that anything they are doing is more important than anything you are doing.
- Meetings that go on and on and seem to accomplish nothing.

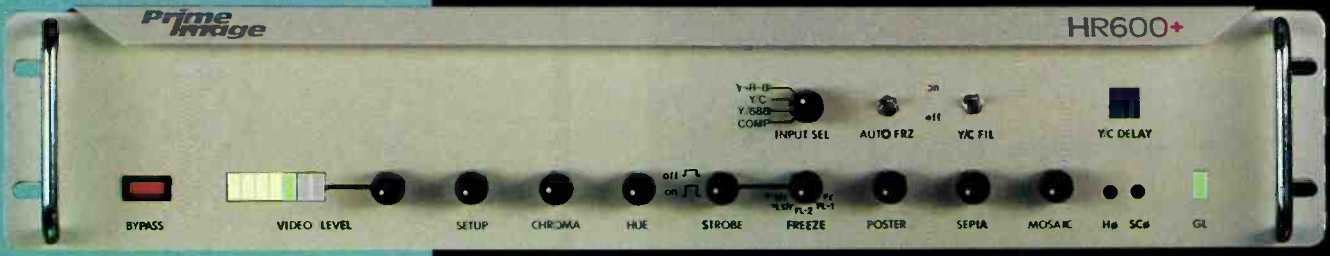
3. Anti-procrastination tools.

Everyone procrastinates doing something. Procrastination within limits is normal. However, excessive procrastination is a sure-fire road to poor work performance, increased stress and stress-related health problems. Do you have trouble:

- Completing small tasks?
- Getting started on a project?
- Finishing a project?
- Keeping promises (even to yourself)?
- Not feeling guilty about what you didn't finish?

If you recognize yourself in any of these examples, then you will benefit from the rest of this series. Even if you are not experiencing some of these problems, the tips that will be provided may help others whose poor time management practices affect you.

Next month, we will look at ways to organize your paperwork. Although you may sometimes feel that a paper shredder is the only answer, developing a logical system is a far better way to do this.



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Annual RF transmission special issue

Maintaining the quality of your RF link could mean the difference between being heard, seen and enjoyed.

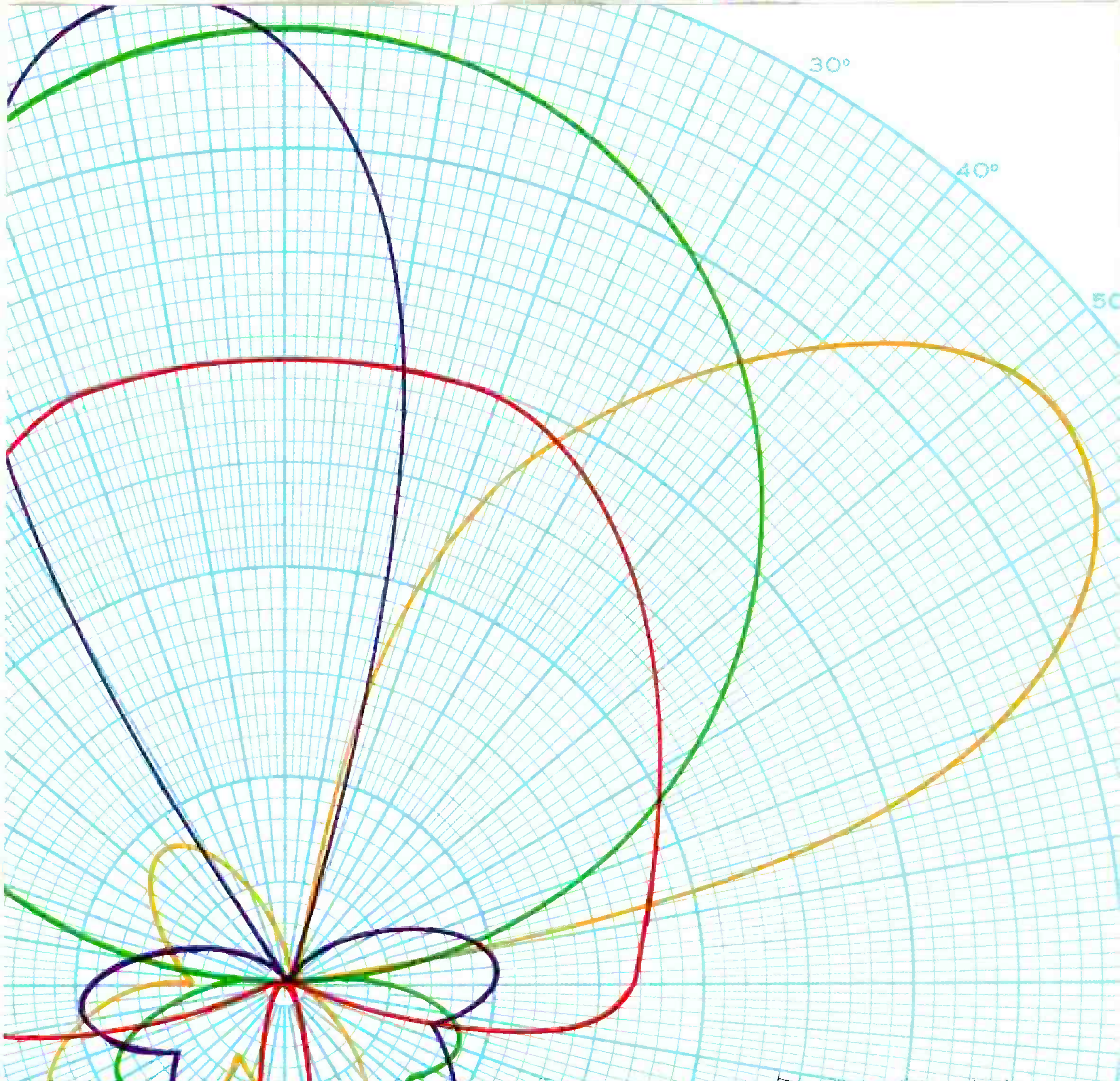
The RF link remains the last critical element in the path to your audience. No matter how good the audio or video, the programming still has to be delivered through an RF system. This is the final area where the broadcaster has any control over the quality of the link.

It is no longer possible to treat the RF link with secondary concern. Even if your signal is being distributed via cable, you have to maintain the best possible quality if you hope to compete effectively with satellite and other signal sources.

In this month's feature lineup, we will look at several important RF-related areas. For AM broadcasters, maintaining adequate signal coverage is a continuing struggle. Engineers are always looking for ways to maintain every possible millivolt of signal. This requires proper design and maintenance of the antenna system.

In the article, "Directional Antenna System Evaluation," the author begins by reviewing the theory behind AM antenna performance. Perhaps you've forgotten some of the math associated with AM antenna design. In this feature, we will review how the math predicts what the AM transmission system is supposed to do. Combined with a knowledge of working RF systems, you may be able to improve the coverage of your station.

Satellite-delivered programming has become the mainstay for most radio and TV stations. As these hardware devices become more common, it's easy to take them for granted. You may think that system design is simple — pick a dish size and it will work properly. That is an erroneous assumption. In the article, "Decibels vs.



Meters: Pricing Antenna Performance," you will learn how design parameters can predict the system's final performance.

A technology battle is waging in TV transmitters. Solid state or tubes — which technology is best for your station? In our unique feature, "Solid-State vs. Tubes in TV Transmitters," proponents of both technologies describe the advantages of each design. Which of the two competing technologies is best for your station is an important consideration when purchasing a new transmitter.

We complete our coverage of RF issues by reviewing an old technology, but new-to-broadcast application. "Using Loran-C in the Field" shows engineers how to obtain precise location information when performing field strength measurements. If you have to measure antenna field strength, learn how to make your job easier and more accurate.

Broadcast engineers have always been the RF experts. Although new equipment can sometimes be operated by untrained personnel without liability, transmitters will continue to be the singular domain of the trained broadcast engineer.

Brad Dick,
editor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SX and Gates transmitters also have a −225° output network (−45° Smith chart phase rotation). Nautel and Continental transmitters have different output networks depending on the transmitter power level. The −225° network provides optimum isolation between plate tuning and plate loading, hence its widespread use. For a −225° network, the transmitter antenna terminals should see either a prefect load (constant 50+j0), or one that has higher resistance at the upper sideband, lower resistance at the lower sideband and capacitive (−j) reactance at each sideband.

A non-directional station can be easily analyzed for proper bandwidth. The transmitter is modulated 50% with a 10kHz sine wave. Choose a suitable monitor point approximately one mile from the antenna. Make sure no power lines or underground pipes affect the reading. Verify this by rotating the field intensity meter (FIM) 360°. There should be at least a 20dB maximum-to-minimum field intensity ratio. Measure and record the carrier frequency field intensity. Next, measure and record each 10kHZ sideband's field intensity. A properly adjusted system will exhibit symmetrical sidebands equal to one-quarter of the carrier field intensity. If, for example, the carrier field intensity measures 10mV/m, each sideband should read 2.5mV/m. If this is not the case, some iteration of the coupling unit design is necessary.

The directional antenna

A DA system is not so readily analyzed. Improper sideband relationships can be caused by shifting of the pattern size and shape, as well as improper loading of the final amplifier. The pattern bandwidth of a DA system can be checked by using an RF oscillator.

Substitute the transmitter's RF oscillator with your variable frequency RF signal source. Run the transmitter with as little power as necessary to obtain a reading of 100% loop current, as displayed on the antenna monitor with the reference tower selected. You may need to increase the day/night sensitivity on the antenna monitor. Record the antenna monitor values at carrier frequency. Next, move the oscillator frequency to ±10kHz, and record the antenna monitor readings for each sideband. Good pattern bandwidth is evidenced by minimal change in ratio/phase angle with change in frequency. If the pattern and/or impedance bandwidth tests do not meet your specifications, it is time to start further analysis so the desired results can be achieved.

For those who are serious about transmitting an optimum signal, a phase redesign may be in order. This is readily accomplished by the use of moment method and Y-matrix computer analysis. When combined with a matrix inversion routine, the moment method computes the current distributions on each tower, and predicts the drive-point (base) impedances, power distribution, base currents and relative phase angles, given the licensed complex field ratios. A phaser can then be designed to feed the system. Careful choice of system phasing and proper selection of matching networks can yield excellent bandwidth.

Even though an infinite number of combinations of system phasing exists, usually only one choice will produce a nearly constant pattern shape and fairly uniform impedance characteristic across the bandpass. A relative phase equal to an odd multiple of 90° for the highest-power tower in the array often yields the best results.[3] In addition, it may be necessary to rede-

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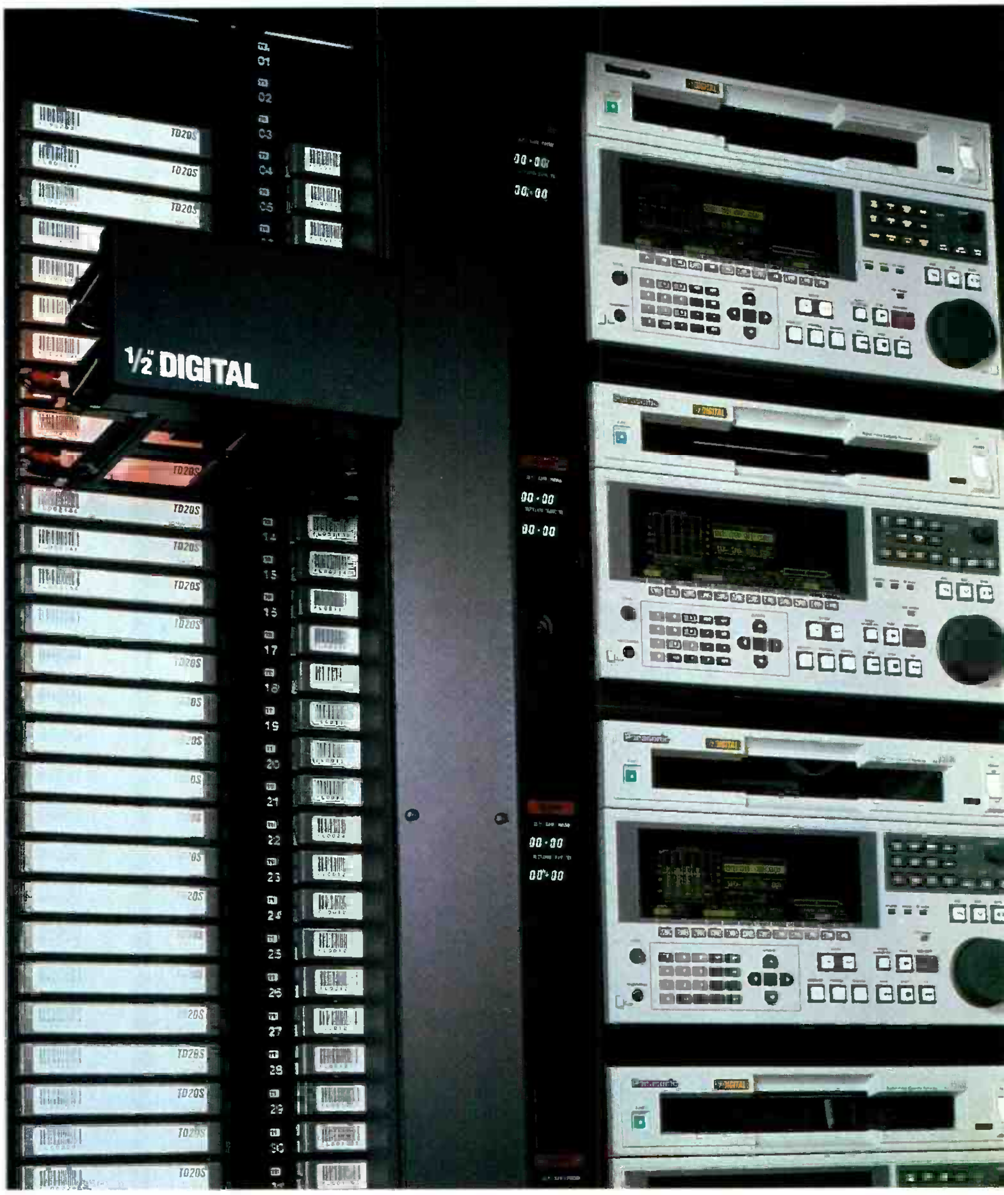

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sign the power divider and alter the ATU design in order to obtain optimum performance.

There is often a temptation to effect a cure for an ailing DA by readjusting the various system arms to produce a value of 50+j0 at the transmission line and phase shifter input terminals. In some instances, an intentional mismatch can produce acceptable results while eliminating some phaser components. Unfortunately, if the system phasing is not of an optimum value, retuning for 50+j0 can yield disappointing results. In one instance, a 3-tower dog-leg array was modeled using −100° of reference phasing as opposed to −90°. The −100° value produced ±10kHz feedline VSWR values for Tower 1 and Tower 3 of 84.1:1 and 14.7:1, respectively. The −90° value produced 1.65:1 and 1.89:1, respectively.

Suggested procedure

For those interested in analyzing a DA system, the following procedure is suggested. First, start in ATU No. 1. Using an RF ammeter of suitable range (preferably a toroidal ammeter), measure the tower feed (base) current, the current in the shunt leg and the input current to the ATU. Do not use extra lead lengths. These will upset the network, and result in useless data. Record these values. Next, use an OIB to measure the base operating impedance and ATU input impedance. Record all values. Repeat the process for all other ATUs and phase shifters. If you use separate day and night DA modes, make sure you repeat the entire process for the night mode of operation, and observe all safety procedures. Do not work alone, and use as little transmitter power as possible. Absolute readings are not necessary, but do not change power during the measurement process. Now record the common point impedance sweep using a bridge.

Don't work alone, and use as little transmitter power as possible.

You will soon observe the correlation between calculated and measured data. Don't be concerned just yet if some of the values don't appear to be optimum. Next, draw a block diagram of your system. First, analyze each ATU and ATU current phase shift given by:

Equation 1: Current phase shift =

$$\arccos\left(\frac{I_{in}^2 + I_{out}^2 - I_{shunt}^2}{2 \times I_{in} \times I_{out}}\right)$$

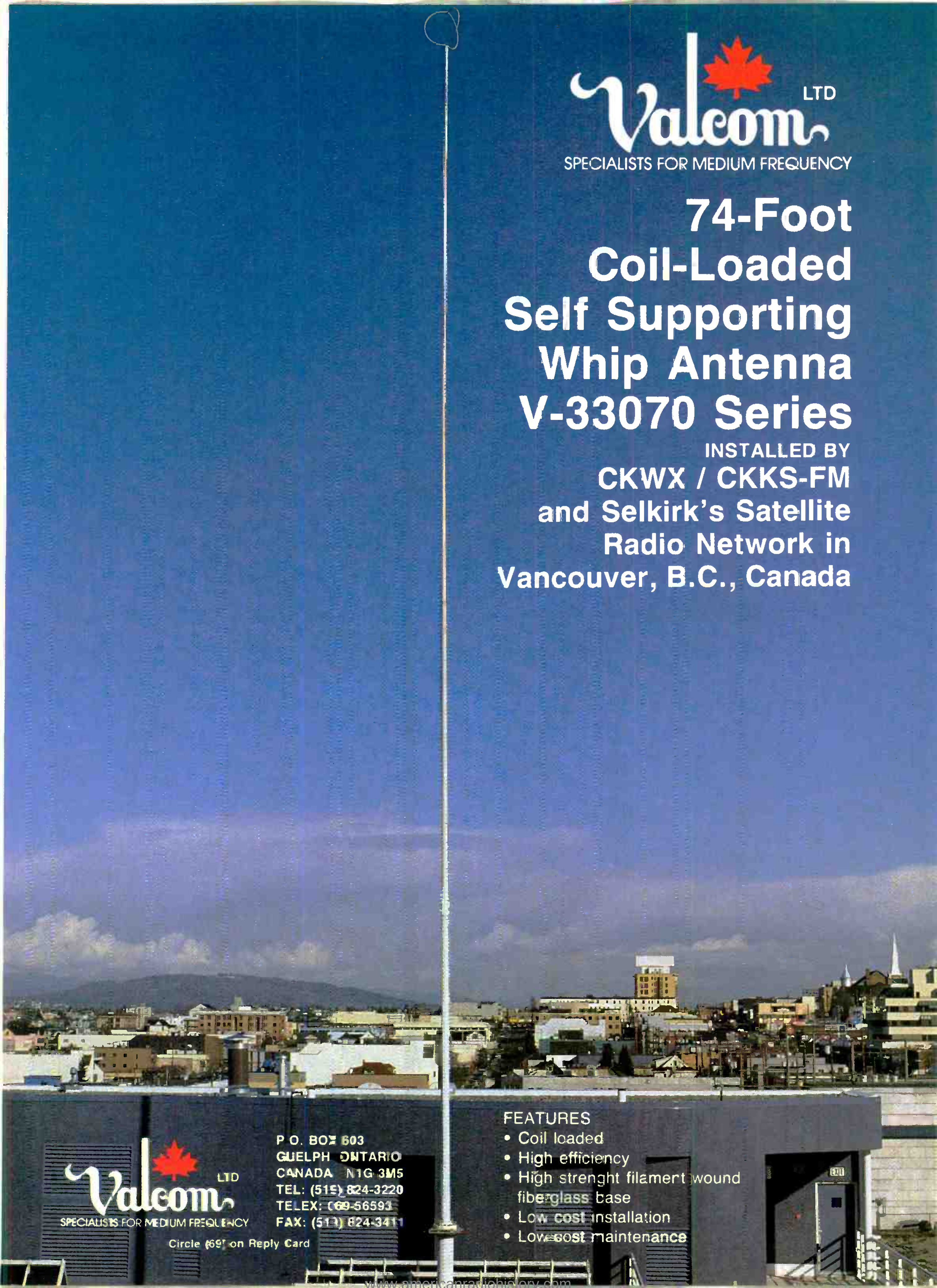
Where:
- I_{in} = input leg current
- I_{out} = output leg current
- I_{shunt} = shunt leg current
- arc cos = arc cosine function

The ATU phase shift can also be directly observed by using the station's antenna monitor and two toroidal samplers. If the transmission line is seeing a mismatched load, its current phase shift is no longer equal to the length in electrical degrees. In this case, calculate the actual phase delay.

Equation 2: Phase delay =

$$\arctan\left(\frac{R_{load}}{X_{load} + (Z_0 \div \tan(\text{Elec. Length}))}\right)$$

If phase delay is >0, subtract 180° from phase delay.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The electrical length is equal to the physical length multiplied by the velocity factor, expressed in decimal form. The electrical length must be expressed in negative degrees. To find the length in electrical degrees, you must know the physical length in feet and the velocity factor.

Equation 3: Electrical length =

$$\frac{\text{Freq. (MHz)} \times \text{Length (Feet)}}{2.734 \times \text{Velocity Factor}}$$

You can determine the exact electrical length of any transmission line by using an RF oscillator and oscilloscope. Open the far end of the line, connecting the RF oscillator to the near end. Place the scope across the RF output terminals. Tune the oscillator to its lowest frequency, and then upward until minimum signal is shown on the scope (the line is shorting out the RF oscillator). Increase frequency until the next null is detected. Then determine the electrical length.

Equation 4: Electrical length =

$$\left(\frac{F_{carrier}}{F_{low\ null}}\right) \times \left[\frac{2}{\left(\left(\frac{F_{high\ null}}{F_{low\ null}}\right) - 1\right) \times 90°}\right]$$

Where:
$F_{carrier}$ = carrier frequency
F_{lower} = lower null
F_{high} = upper null

The purpose of making these measurements and calculations is to construct an accurate block diagram showing the various values of current phase shift, current magnitude and impedances throughout the system. The power divider will have a certain amount of phase shift as will "zero-degree" series L-C shifters. Continue your calculations to determine the power radiated by each tower. You find the power by using Ohm's law.

Equation 5: Power =

$$\text{Base Current}^2 \times \text{Base Resistance}$$

You will easily recognize this as the direct method. For DA operators, this calculation is made at the common point.

The data now consists of the ATU phase shifts and currents, load operating impedances and currents, and line phase shifts, as well as the power distribution of

Continued on page 36

Predicting station coverage on your PC

By Harry R. Anderson, P.E.

The process of studying VHF and UHF signal propagation has advanced remarkably in the past several years, primarily because of the availability of digital terrain databases, propagation analysis software and the widespread use of powerful PCs. Broadcasters now have the opportunity to use their station's computer for propagation studies. Some potential uses are:

- To help choose a new transmitter site.
- To optimize antenna height at an existing site.
- To study STL, RPU and other microwave link paths.
- To prepare accurate coverage maps for advertisers or clients.

With the right analysis software, all of these can be done from your desk in a few minutes rather than through the arduous task of picking points off topographic maps, plotting the points and finally, analyzing the path. Through the use of interactive screen graphics, the PC gives you immediate and substantial design feedback that cannot be provided by a time-share system or consulting service. (See Figure 1.) The interactive design-feedback-redesign sequence is the soul of the engineering process, and software running on your own PC provides this level of control.

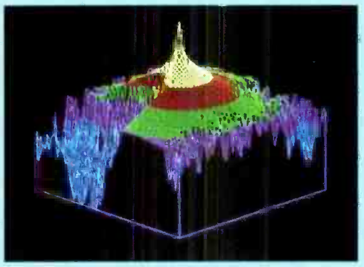

Figure 1. A 3-D screen display of field strengths for a hypothetical FM station near Eugene, OR, provided by a PC running commercially available RF propagation software.

Digital terrain data for your PC

Two terrain elevation databases are commonly used for propagation studies in the United States — the 3 arc-second and 30 arc-second databases. The 3 arc-second database was originally developed by the Defense Mapping Agency (DMA) and is available through the U.S. Geological Survey (USGS). It was derived by digitizing the 1:250,000 scale topographic quadrangle maps covering the United States, and supplementing this data with specific elevation values from benchmarks, streambeds, ridgelines and other known points. This ensemble of data was then used with interpolation algorithms to produce a database with an elevation point every three seconds in latitude and longitude (a point spacing of about 90 meters north-south by about 76 meters east-west at 35° longitude). The vertical resolution of the database is one meter; its accuracy is not quite as good.

The 30 arc-second database was derived from the 3 arc-second database by taking every tenth point. Consequently, the 30 arc-second database lacks much of the finer detail (peaks and valleys) found in the 3 arc-second database. For height above average terrain (HAAT) calculations, the 30 arc-second database still provides perfectly usable results. In fact, at this writing, the 30 arc-second database is the only one used by the FCC for HAAT calculations in the FM, TV and LPTV services.

Because of its finer lateral resolution, the 3 arc-second database is the preferred choice for point-to-point and areawide coverage studies. Although the USGS offers the database on 62 reels of 1/2-inch 9-track tape, it is now available from private companies on 3-1/2-inch and 5-1/4-inch diskettes, and on CD-ROM. To achieve maximum economy of disk space, the data is usually compressed in some binary format and arranged so that each data file covers a 1° by 1° area. The diskettes represent the best media if your area of interest is limited, such as the terrain surrounding your transmitter site, or your state's terrain if you have a statewide network. If your engineering work involves areas throughout the United States, however, using the 3 arc-second data on CD-ROM is the better choice. Advanced data compression techniques have reduced the size of the entire U.S. database (including Puerto Rico and Hawaii) from 9Gbytes to less than 580Mbytes, so that the complete 3 and 30 arc-second databases fit on a single CD-ROM. Having the database on a single disk is a distinct advantage over multiple disk databases, because you never have to switch disks at boundaries, or make sure the correct disk for a given study area is loaded.

Areawide coverage studies

The simplest form of an areawide coverage study is a shadow map. A shadow map gives a quick assessment of coverage by showing areas that are unobstructed from a transmitter site based on the path geometry over terrain obstacles. The receive antenna height is a variable that can be set at 10 meters (or any other value) above the terrain ele-

Continued on page 36

Anderson is president of EDX Engineering, Eugene, OR.

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Continued from page 32

the array. If you were unable to obtain a null on the OIB at one of the tower ATU input and base locations, it may be that the tower is a negative tower. Reverse the bridge in and out leads, and try for a null again. A negative tower returns power rather than radiating it (i.e. it is a receive antenna). A day negative tower may be positive in the night mode and vice versa. Do not confuse the FWD-REV switch on an OIB with reversing the in/out leads. Also, a tower with a negative phase angle (for example, −142°), does not indicate it is operating as a negative tower. You can express −142° as +218° simply by adding 360° to −142°. By using Equation 5, it is obvious that all the base currents added up do not equal the common point current.

A perfect match

The optimum load presented to the final amplifier of a non-d system is usually easy to achieve with a *line stretcher*. Each ATU has a certain value of phase shift. Even though you may have 50+j0 at the ATU input terminals, some experimentation will reveal that numerous combinations of coil taps will produce 50+j0, but only one combination (possibly requiring coil and/or capacitor value changes) will produce the desired sideband relationship previously described. You can use a Smith chart or computer program to calculate the optimum ATU phase shift, which produces the correct sideband relationships. It is possible to empirically derive a more suitable phase shift by moving the output coil one turn in one direction, resetting the input coil and shunt coil for 50+j0, and remeasuring the field. If symmetry gets worse, move the coil the other way and try again.

When considering sideband rotation, you must account for the ATU, transmission line and transmitter output network phase shifts. Care must be taken not to exceed ATU component value ratings. For a Tee network, calculate the voltage and current for each leg as follows:

Equation 6: Input/output Leg I =

$$\sqrt{\frac{\text{Power}}{\text{Terminal Resistance}}}$$

Equation 7: Shunt Leg I =

$$\sqrt{I_{in}^2 + I_{out}^2 - 2\,(I_{in} \times I_{out} \times \cos(p))}$$

Where p = Network Phase Shift

Continued from page 32

vation for the entire coverage area. A study of shadow areas in all directions usually involves evaluating path geometry at every degree in azimuth around the site, with typical terrain elevation point spacings of 0.1km along each radial, and radial lengths out to the maximum distance of interest. For more refined analysis, the 360 radials can be spaced at fractional degree intervals across a selected arc. Another type of areawide study calculates and plots a multilevel, multicolor field strength map for the area surrounding a transmitter site, as shown in Figure 2.

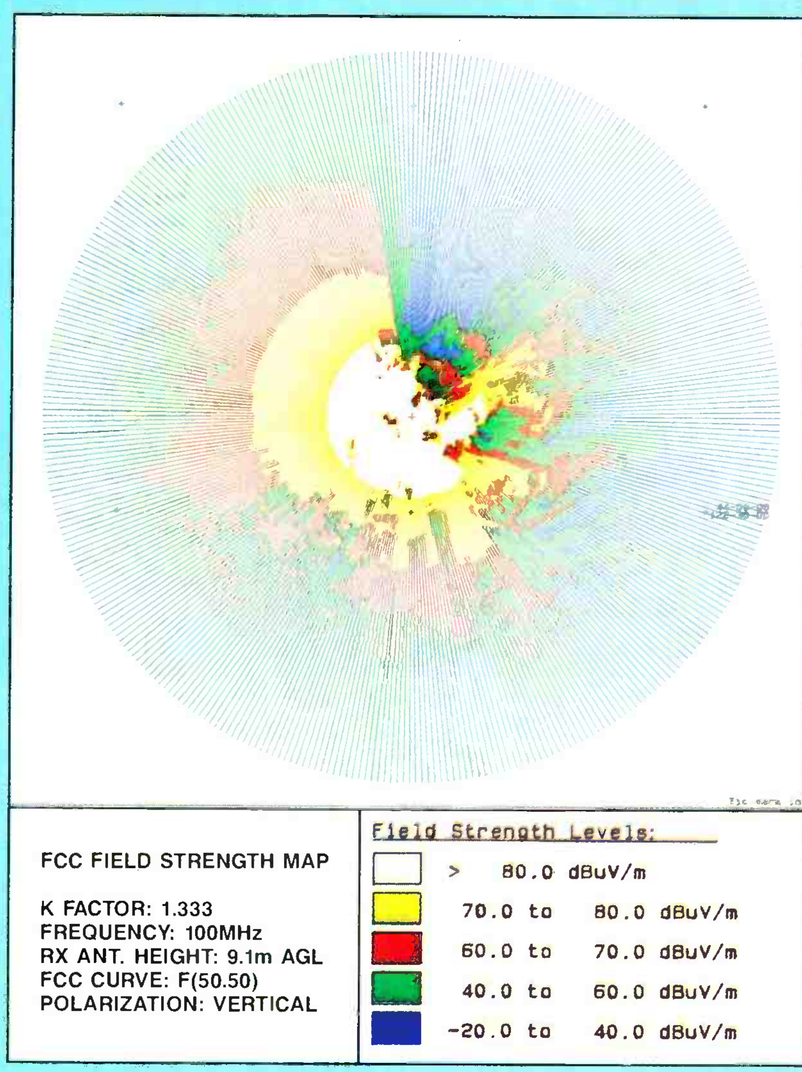

***Figure 2.** A multilevel field strength map for a hypothetical FM station, drawn by a PC-driven 5-pen plotter.*

These kinds of plots provide a much more accurate presentation of field strengths and coverage than standard FCC contours. With PC software, you have complete control over the plot, allowing you to zoom in, change colors, rotate the plot, try different directional antennas, ERPs, or antenna-mounting heights, until you have eliminated or minimized weak areas and achieved the desired coverage.

Path studies on your PC

For an STL, microwave or other point-to-point link, it is almost always necessary to design a path with line-of-sight clearance. Selecting the minimum antenna heights necessary on each end to achieve the required clearance is the challenge. With a PC program, you can interactively adjust the antenna heights and instantly redisplay the path to assess whether the proper clearance has been realized.

Such software also lets you zoom in on an obstacle for a more detailed view of the clearance. The terrain database only contains ground elevations; it has no information on tree or building heights. If you knew an obstruction had 75-foot trees on its top, the PC program lets you edit the display to show their presence, and adjusts its calculations accordingly.

More thorough, accurate and cost-effective site selection and path design on your PC will ultimately contribute to achieving the maximum performance from your broadcast facility.

Courtesy of Stainless

Equation 8: Component voltage =

$$\text{Current} \times \text{Component Reactance}$$

Bear in mind that in AM broadcasting, you must consider modulated conditions. Under 100% sine wave modulation, current increases 22.5% and approximately 59% for 125% positive square wave modulation. Make sure adequate safety margins are observed. Also, mica capacitors are current rated at 1MHz. Derate as shown in Equation 9 for your frequency.

Equation 9: Current rating at carrier frequency =

$$\text{I rating @ 1MHz} \times \sqrt{F_x}$$

Where F_x = Carrier Frequency in MHz

In order to redesign a Tee network, you'll need some equations. The first element to be calculated will be the shunt leg.

Equation 10, 11, 12:

$$\text{Shunt Leg (X3)} = \sqrt{\frac{R_{in} \times R_{load}}{\sin(p)}}$$

Where R_{in} = Line Z_o
p = Phase (±)

$$\text{Input Leg (X1)} = \frac{R_{in}}{\tan(p)} - X3$$

$$\text{Output Leg (X2)} = \frac{R_{load}}{\tan(p)} - X3$$

In the non-d case, rotating the sideband should produce noticeable results. If you are an AM stereo broadcaster, you will have to perform the exciter equalization and delay adjustments again. If you are unsure of your transmitter's output network phase shift, contact the manufacturer.

For the DA and non-d cases, simply tuning a network for 50+j0 may not yield favorable results. Do not be tempted to adjust a DA network for 50+j0, thinking that no further work is needed. Because a DA is a coupled system, all the towers will change operating parameters. You may have matched up one tower, and in doing so, upset the operating parameters of the entire system. Generally speaking, in arrays with one tower having the dominant power (and not necessarily the highest base current), properly matching that tower will produce a satisfactory bandwidth, assuming that it is optimally phased.

In some cases, one tower may not car-

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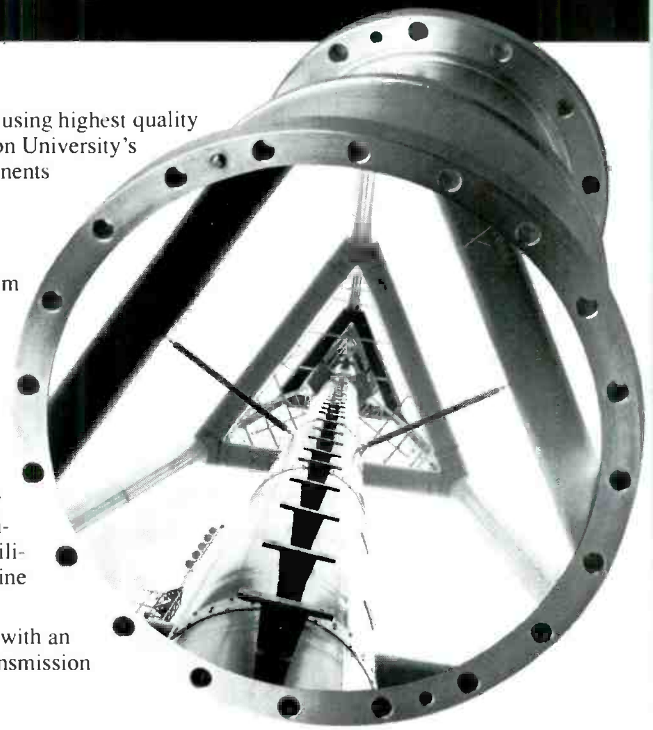

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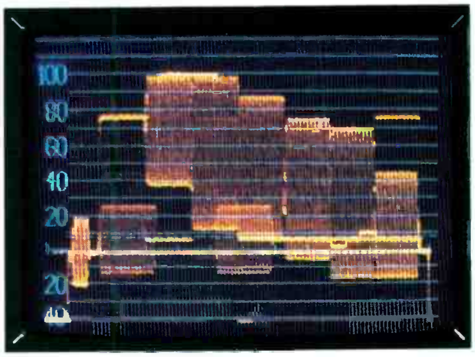

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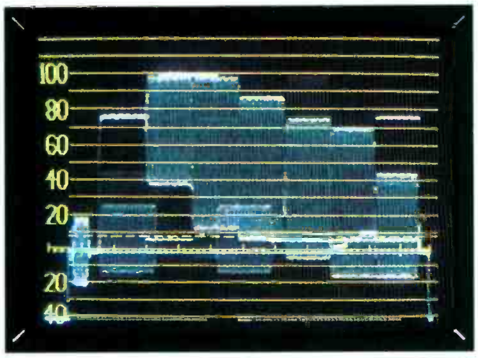

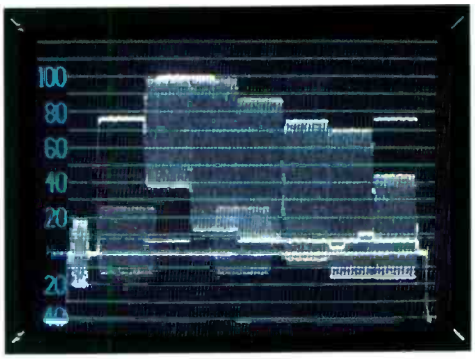

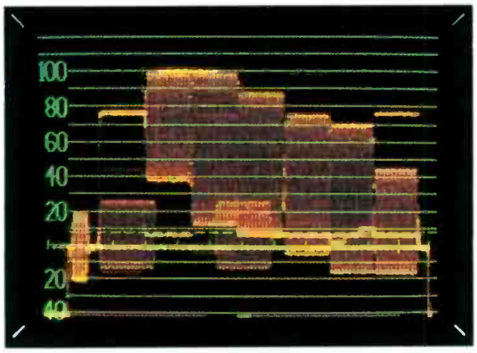

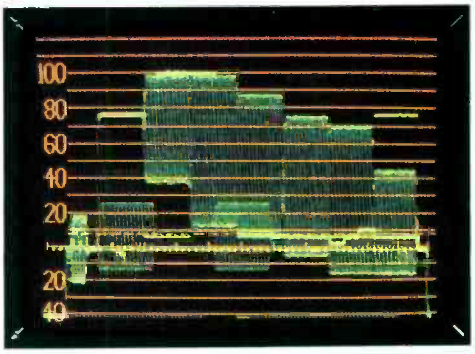

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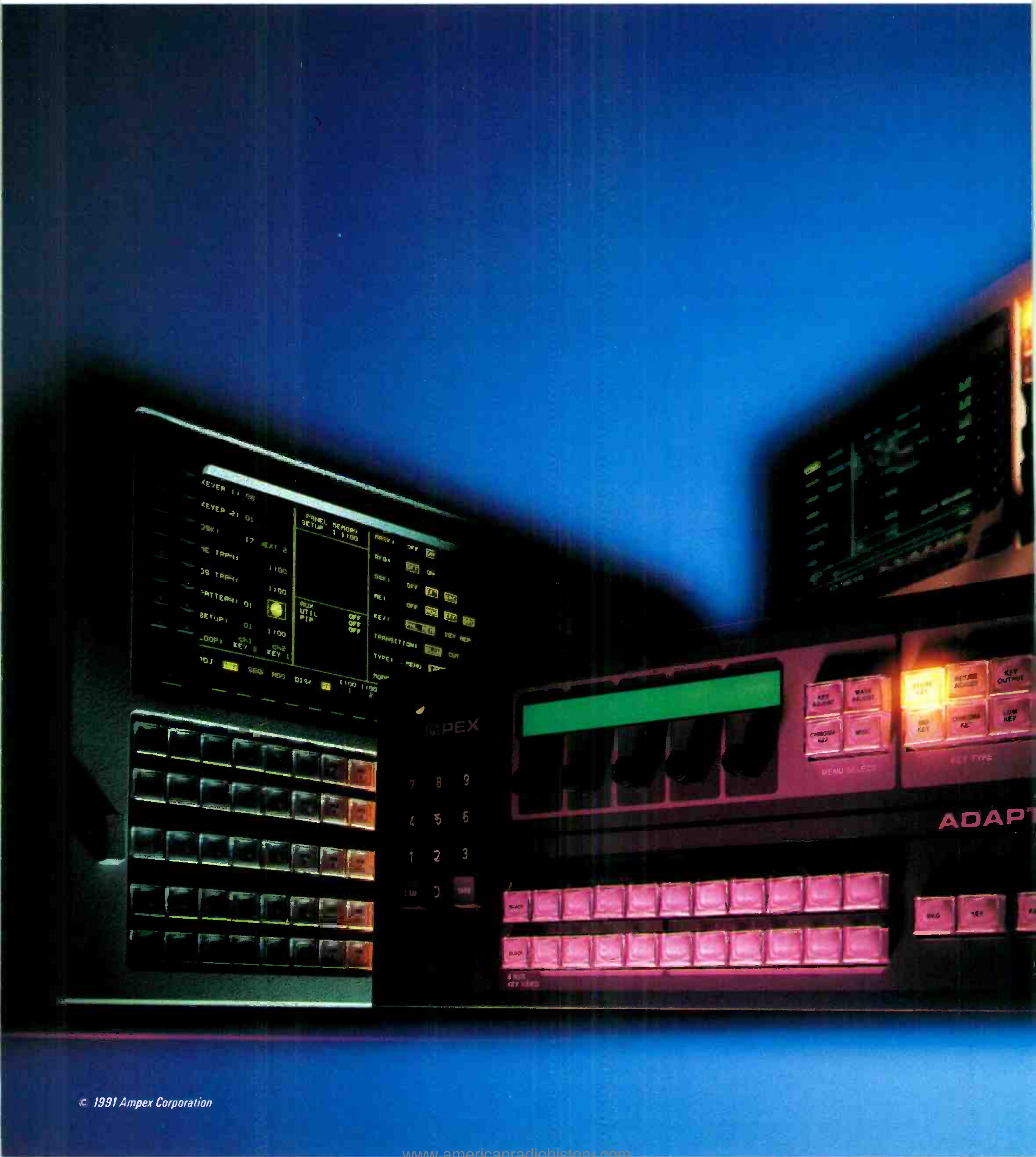

your future, not just ours.

AT AMPEX, we believe that the best way to move into the digital future is by leveraging your current investment in analog.

The fact is, while digital technology may be revolutionary, the market for it will be evolutionary. The economics simply don't support all-digital environments for the vast majority of work being done today. Clients aren't willing to pay more money for a routine effect just because it's done on a flashy new system.

It's also a fact, however, that the digital day is coming. The image clarity and purity, the creative flexibility and opportunities, and the multi-generational capabilities are significant advantages that the market will increasingly demand.

But we think you can move into this future in stages, from composite analog to composite digital to component digital, moving as the market builds and the technologies mature (and become less costly).

The first step is to phase out your analog VTRs as they age, and replace them with D2™ composite digital machines such as our VPR™-300 or -200 Series. The next step is to integrate digital capability into your analog switcher. And to help you do that, we've introduced a revolutionary new system called ADAPT.™

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Continued from page 38

ry the lion's share of the power. Be advised that the antenna monitor reference tower may not be the tower with the most power. In most cases, because current is sampled and fed to an antenna monitor,

Courtesy of Stainless

the highest-current tower is the reference tower. For symmetrical arrays (in-line, 2-tower and certain parallelograms), the option of "moding" is available.[4]

For these symmetrical arrays, there exists 2^{t-1} number of operating parameter combinations (two combinations for two towers, four combinations for three towers and eight combinations for four towers) that produce the identical radiation pattern, but with different operating impedances and power distributions. Through the use of a computer, it is possible to break down the pattern into its original pairs, invert each pair, and then remultiply the new pairs in order to solve for each mode. Asymmetrical arrays have one additional mode, this with physical offsetting of tower(s) by 180°. Arrays having pairs with close to unity field ratios will not have a great deal of difference between modes.

As a practical matter, one of the downfalls I have witnessed in numerous instances is power divider misadjustment. Under normal conditions, the reference tower (highest power) does not require a power control. The exception here is where the next lowest-power tower is close to the reference power. Especially in shunt (Ohm's law) dividers, moving the reference tower down toward the ground can drag the common point resistance down to the single digits. If the reference power is significantly higher than the remaining towers, eliminate the reference tower power control completely. For example, feed the reference tower off the common point bus. A second major problem occurs with the series tank divider. The bus impedance and branch phase shifts will depend on the amount of inductance to ground below the lowest tap on the tank coil. Many early designs used a series divider because placing loads in series yielded the greatest common point impedance. In reality, you can use small (6μH or so) roller "jeep" coils to fine-tune the loads.

A problem check list

In the days when computers and talk-down methods were not widely available, a lot of guess work went into initial pattern tune-ups. Today, it is not uncommon to examine a series divider and find most of the jeep taps piled on top of one another. This results from a lack of range adjustability from the front panel. A schematic representation of the circuit would reveal several 6μH coils in parallel, yielding the exact opposite of what was intended — a large magnitude of common point resistance.

The following is a check list of common problem areas with non-d and DA arrays:

1. A poor or non-existent ground strap between the ATU cabinet, main ground base ring, phaser and transmitter. Do not depend on the transmission line's outer sheath for grounding.
2. An older phaser design may not consider power divider phase shifts with inaccurate driving point impedance predictions.
3. Little attention has been paid to optimizing array phase distribution for best pattern/impedance bandwidth.
4. Symmetrical arrays are not pattern moded to take advantage of optimum power distribution and driving point resistances.
5. Impedance broadbanding attempts may have placed the symmetrical load at the common point or transmitter output, and not at final amplifier.
6. Improper power divider design or adjustment.
7. Mismatched transmission lines because of improper adjustments and unoptimized phasing. Look for 70Ω lines having been replaced with 50Ω lines or RG/6 lines replaced with hard-line (different velocity factors), without network redesign.
8. High L-C ratios used in networks to ease adjustability often result in high Q, which can impair bandwidth and stability.
9. Antenna monitor configured for older 70Ω sample line when 50Ω line is presently being used.
10. On some occasions, toroid transformers have had leads internally reversed, resulting in 180° phase error.
11. Ganged phase shifter arms can be wired out of phase.
12. Reading made with an uncalibrated FIM or with the switch in LOG position.
13. The wrong ATU may have been placed at tower base during initial installation.
14. Look for the use of compensation networks in DA ATUs. This practice results in extremely flat impedance loads, but exceedingly poor pattern bandwidth and unacceptably high IQM for AM stereo.

Follow the steps

After considering the check list, you can design and achieve an optimum transmission system. Begin the process at the generator end, which is typically the phaser cabinet. A phaser cabinet is the easiest part of the system to set up. Start by planning the desired values of required base phase and power, ATU phase shift, transmission line electrical length and phaser phase shifting values. Next, feed the common point with a low-power oscillator set to the carrier frequency. Connect each power divider tap to the respective port on the station's antenna monitor, using equal lengths of RG-213/U or other suitable coax. Begin by adjusting each tower for the required voltage ratio. The voltage ratio is computed by knowing the power delivered to each tower. (See Equation 5.) Divide the lower voltages by the highest voltage.

Equation 13: Voltage ratio =

$$\sqrt{\frac{\text{Power}}{Z_0}}$$

Where Z_0 is usually 50Ω.

Note the value of power divider phase shift. Next, move each coax to the output terminals of the phaser. Now, adjust each phase shifter for the desired phasing. Use the OIB in the "cold" mode to ensure a proper match. The antenna monitor will provide a 50Ω match only if the proper

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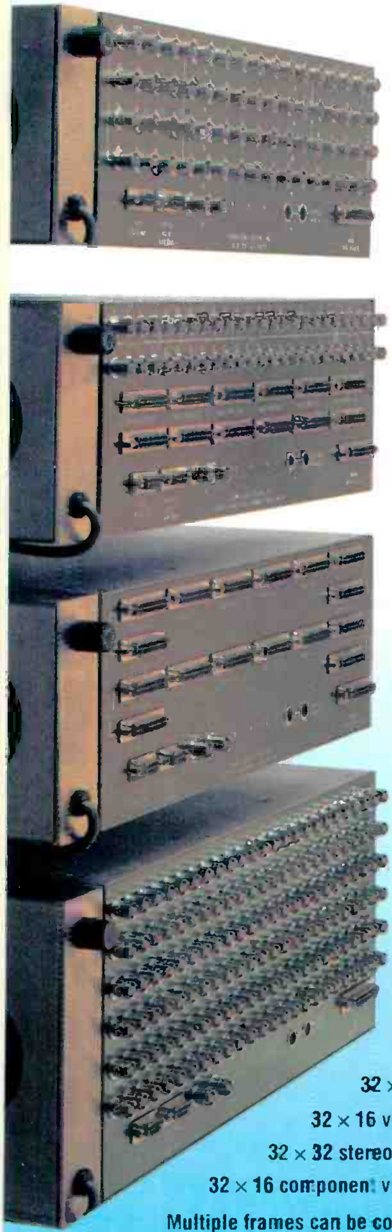

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tower is selected. The cold bridge is used to set the shunt arm for proper match with the input/output arms set for the proper phase value. If a tower has a zero-degree shifter (series L-C), place a short across the L-C network. Note the phase reading. Now, remove the short and adjust the coil for the same phase angle. The L-C is now at resonance. The phaser phase shifts, transmission line phase delays and ATU phase shifts should all add up to the proper base phasing required to produce the licensed pattern. The proper voltage ratio, as indicated on the antenna monitor, should produce the required power at the base of each tower. Any major discrepancies should then be identified and adjusted for at the tower bases. After you have precisely adjusted the phaser, don't be tempted to go cranking the phaser knobs.

An array that uses toroid base sampling solves the need for numerous measurements. An improved phasing system can be designed by knowing the power distribution, required base phase angle and electrical line lengths. The quadrature phasing (odd-multiple of 90°) technique is not always applied to the highest-power tower. In cases of near zero resistance towers or those operating with near zero power, the quadrature technique can be used to stabilize operation. Significant improvements made by upgrading the array feeder system can result in stronger radiated fields synonymous with increasing transmitter power. This may be due to elimination of severe mismatches, raising drive point impedances, and properly returning negative tower power back to the common point. Although few station managers will refuse such benefits, radiation in null or minimal directions may increase beyond FCC limits. In these cases, new operating values will have to be determined in order for the pattern to remain within standard pattern limits.

A variety of solutions

Each array has its own unique "signature," each presenting the designer with a different set of criteria. Techniques, such as compensation circuits, split power division, load shunting, traps, multiplexing, phantom networks and voltage-fed loads have not been addressed because of the limited scope of this article. A variety of networks and feed methods can be used to treat even the most severe arrays. New analysis and design models can be used to enhance existing arrays well beyond what could have been expected as few as five years ago.

There is more to a good antenna system than just matched transmission lines. Every component, from the signal generation point (final amplifier plate) to the radiator(s), plays an important role in how well the signal is demodulated at the receiver. The engineer's role is to ensure that maximum performance is obtained from the station's antenna system. Even with the limitations imposed by location, system age and original design, many of today's AM transmission systems can be improved. Learn what steps you can take to improve the systems — and when to call in an expert.

Footnotes

1. William J. McCarren, "Antenna Q vs. Audio Response," Proceedings of the 30th annual NAB Engineering Conference.
2. Grant Bingeman, "AM RF System Distortion."
3. Jerry M. Westberg, "Sideband Analysis of Medium-Wave Antenna Systems," Proceedings of the 40th annual NAB Broadcast Engineering Conference.
4. George H. Brown, "Design Methods to Improve the Stability of AM Directional Antenna Systems," Technical papers, 12th annual NAB Engineering Conference.

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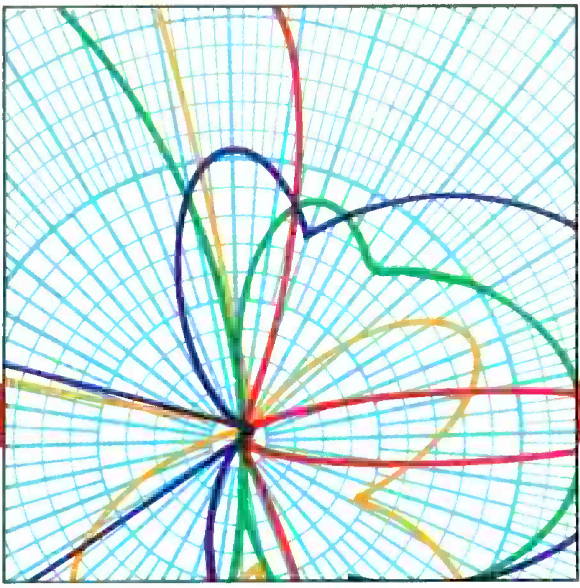


Decibels vs. meters: pricing antenna performance

An investor's view of choosing a satellite dish. Size doesn't matter as much as performance.

By Jack Herbert

If you choose an earth station antenna based on size alone, you may invest more than you need to, and you may not be happy with the results. This article presents some tools for comparing earth station performance, using the satellite antenna figure of merit, *G/T* and an analysis of antenna patterns.

Developing the prospectus

When planning a satellite receive antenna system, the first step is to develop a list of antenna parameters that meet your budget and performance objectives. Identify the satellites that deliver the programming you want, then find their orbital locations. To cover many satellites requires flexibility, and usually a larger dish. Concentrating on just one service allows use of a smaller dish. Defining the station's needs is the first step in buying the antenna. The object is to purchase just enough dish to do the anticipated job, without wasting resources or overspending the budget.

Herbert is broadcast accounts manager for the Andrew Corporation, Orland Park, IL.

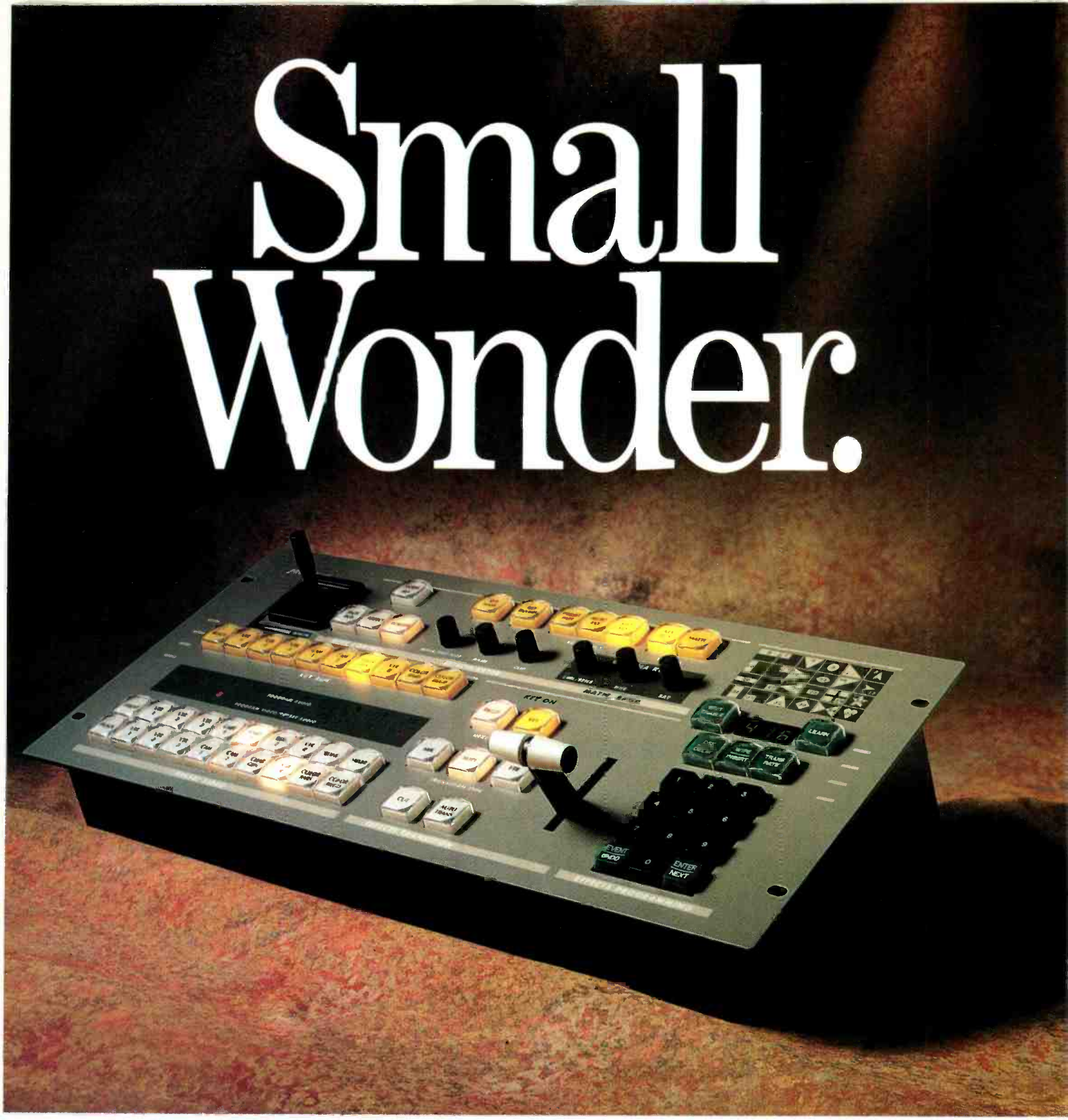
Before shopping, you need a starting point with which to compare products. Traditionally, most broadcast requirements can be fulfilled by the use of 4m to 8m class earth station antennas, depending on the application. Dishes in your area might give clues to the approximate range for your needs. In many cases, the budget provides a limiting factor.

Now that you have gathered some preliminary information, it's time to narrow the search. First, ask the antenna manufacturers for complete specifications and radiation patterns for prospective antennas. The specifications should provide all the electrical, mechanical and environmental data about each antenna.

Remember, although they are a good place to start, the specifications only describe the antenna's design, not its performance. Comparing antenna specifications with financial statements illustrates the problem. Assume antenna size is an asset and gain a revenue — does this yield enough information to justify an investment in the company? Certainly not. Knowing only assets and revenues gives an incomplete picture of a company, just as size and gain tell only part of the story about an antenna. A financial analyst probably would calculate the "acid test" and a battery of other ratios when reviewing a company. Similarly, a series of performance calculations should be completed before making a final decision about investing in an antenna.

Performance measures

When evaluating the performance of an



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earth station antenna system, calculate its G/T (gain over temperature). G/T provides a basis for comparing antennas, and is an integral component of the system performance equation. For video systems, changing G/T changes system performance by the same amount.

Radiation patterns are also important. They provide clues about antenna performance that escape the G/T figure. Patterns affect an antenna's ability to reject noise and interference, as revealed in the carrier-to-noise (C/N) calculation. Analyzing patterns complements the G/T calculation and completes the evaluation of an antenna. As the fixed spectrum becomes more congested, patterns become increasingly important.

Antenna parameters that affect performance include gain (and directivity), noise temperature and cross-polarization discrimination (XPD). External factors include the low-noise amplifier (LNA), low-noise block downconverter (LNB) or low-noise converter (LNC), sky and ground noise and interfering radiation.

When asked how much gain is needed, many engineers answer in meters. Gain isn't measured in meters, no more than accounts receivables are measured in feet. Engineers probably react this way because they assume bigger antennas perform better. Similarly, many engineers assume all microwave antennas are 55% efficient, because this is an industry-adopted rule-of-thumb. Although these perceptions apply to terrestrial microwave antennas, they do not apply to all earth station antennas.

New design and manufacturing techniques have raised the performance levels attainable in earth station antennas. Corrugated feedhorns, dual-reflector optics and shaped reflectors and subreflectors can increase reflector efficiencies to more than 80%. Staying alert to these capabilities may reveal opportunities to cut costs.

Gain vs. directivity

Although diameter and gain are related, earth station antennas with the same diameter do not necessarily have the same gain. Gain is the ratio of an antenna's directivity to the directivity of a standard, less feed losses. Figure 1 shows the directivity of a dual-reflector earth station antenna, measured from the feed phase center.

Feed losses are important, especially in dual-reflector optic antennas. The following are two major issues that are not obvious in the gain definition:

1. The location of the reference point where the feed losses are measured must be clearly identified.

2. Other antenna parameters, most notably noise temperature, must reference this same point.

The greater the distance separating the feed phase center and the reference point, the greater the feed losses. The actual gain reduction can vary significantly, depending on the type of transmission line connecting the feed and the combining network. The antenna in Figure 1 uses highly efficient circular waveguide. Note the loss is only approximately 0.2dB between the feed and combiner.

Because of the weak signals detected by an earth station antenna, transmission line losses between the feed and the combiner must be kept to a minimum. These losses reduce gain, but more importantly, they act as a lever to reduce system perform-

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ance even more. The G/T example later in this article shows how this happens.

Antenna patterns

Radiation patterns define an antenna's gain at each angle from the axis of the main lobe. Patterns can be measured by satellite with the support of a cooperating antenna, or on a test range. Measurements are taken in the azimuth and elevation plane. The azimuth plane is more important because it closely mirrors the arc of the geostationary orbit. Figure 2 presents the receive azimuth co-polarized pattern for a 6m class Ku-band antenna.

Patterns are important. Today, multiple users must coexist while using a common frequency band without interfering with each other. To ensure interference-free operation in today's 2° satellite-spaced environment, the Federal Communications Commission (FCC) has developed regulations describing the minimum pattern characteristics for transmit antennas. (See the related article, "FCC Regulations for 2° Spacing" p. 64.)

For receive antennas, there are no rules, only guidelines. Still, the sidelobes of receive antennas should be as low as possible, because they allow noise and interference to enter the communications system. This shows up in the system's carrier-to-noise ratio (C/N).

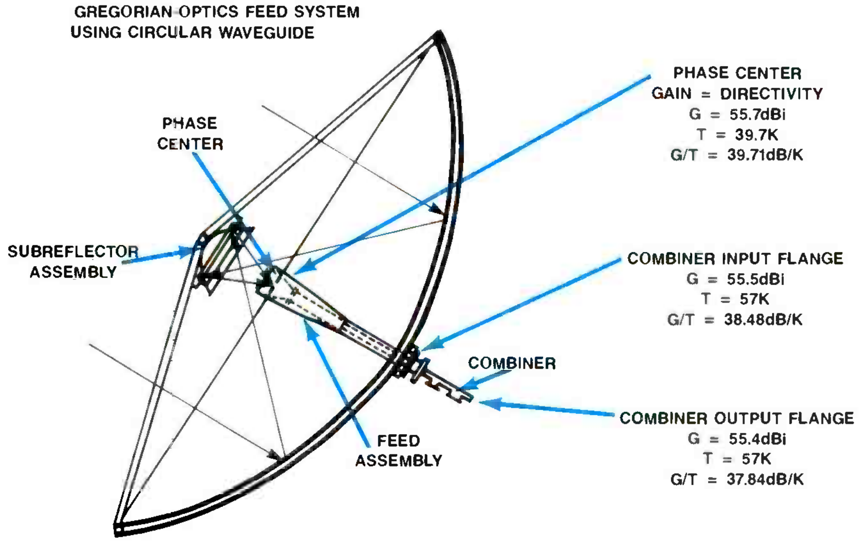

Figure 1. *The asymptomatic G/T shown here measures the gain and noise temperature at a specific location. Note that the gain and the noise temperature increases as the reference point approaches the LNA flange, decreasing the G/T.*

Noise

Noise originates from many sources — some natural and some man-made. The sky, earth, LNA and passive components between the feed and combiner are all sources of noise. Thermal noise is the most

Continued on page 54

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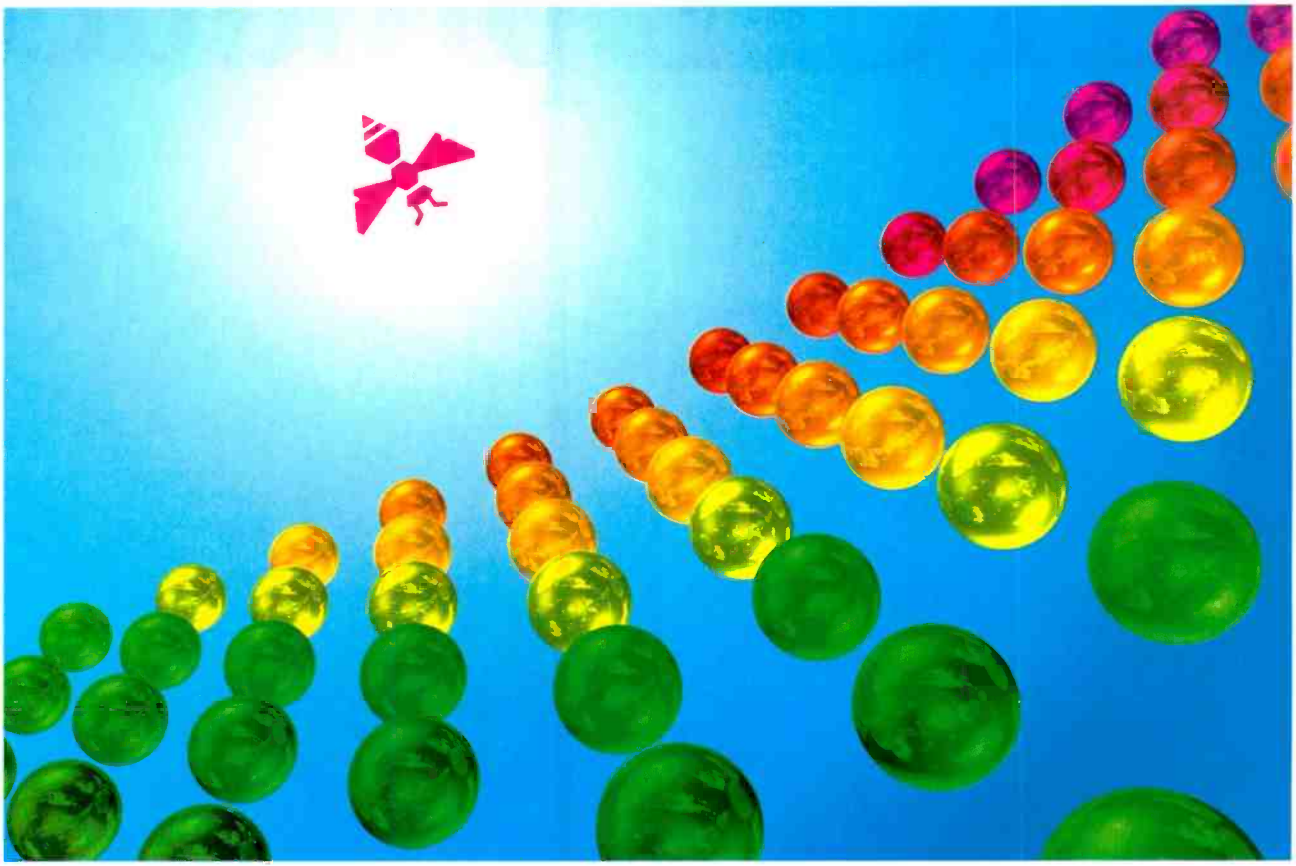

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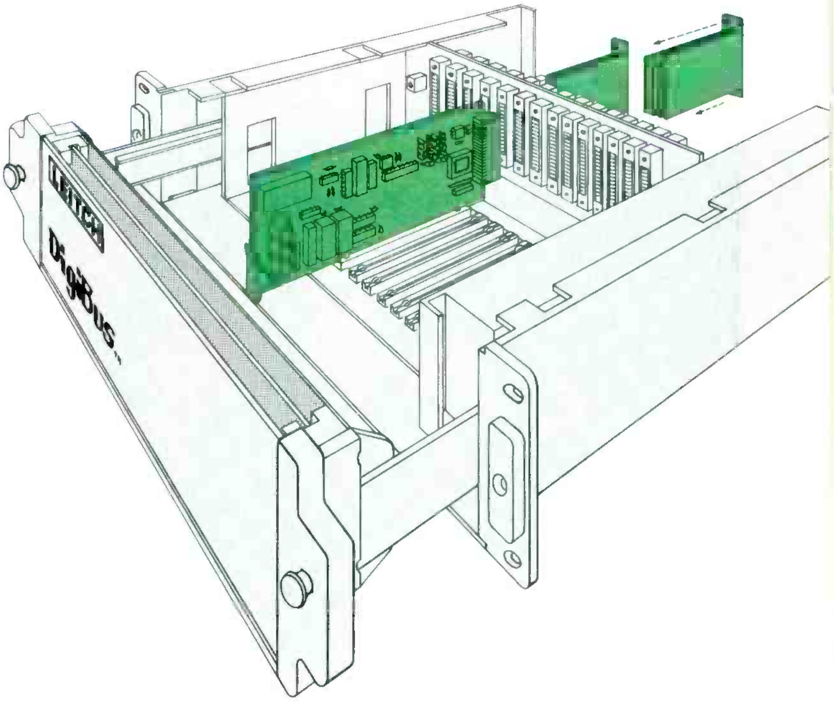

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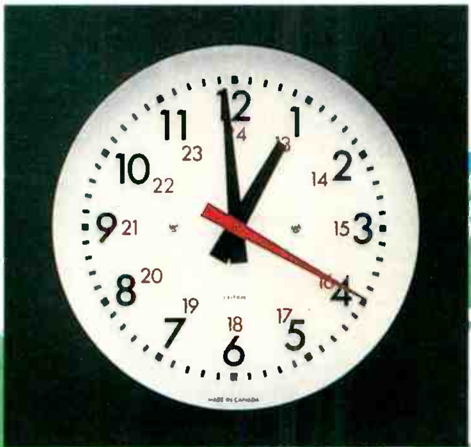

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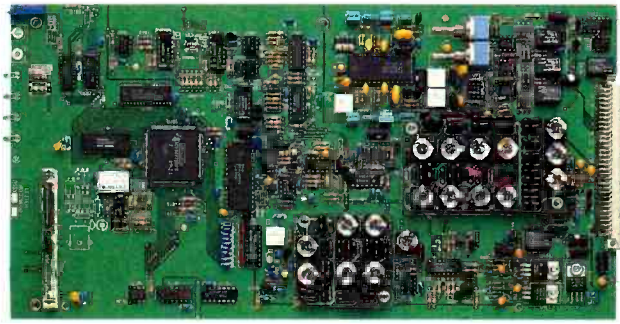

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important type of noise to a receive antenna system. It exists because of the random motion of electrons, and depends on the bandwidth and the absolute temperature, in Kelvins (K), of the component or medium. Thermal noise is also called white noise because it covers the entire frequency spectrum.

Two measures of noise are important to a receive antenna system. One is antenna noise temperature, and the other is system noise temperature.

Antenna noise temperature

Noise from all sources combines and determines antenna noise temperature. Figure 3 shows the major contributors: the sky, the ground and the lossy components between the feed and LNA. Figure 3 also shows noise and interference entering the system through the antenna sidelobes.

Antenna noise temperature is inversely related to elevation. Because the earth is a warm body that radiates energy, the lower the look angle, the higher the noise temperature. This makes it important to compare the noise temperature of different antennas at the same angle.

Antenna specifications present noise temperature in a diagram, such as Figure 4, or in tabular form. It should always include noise contributions from the sky and ground, and it also should include the transmission components between the feed and the reference point.

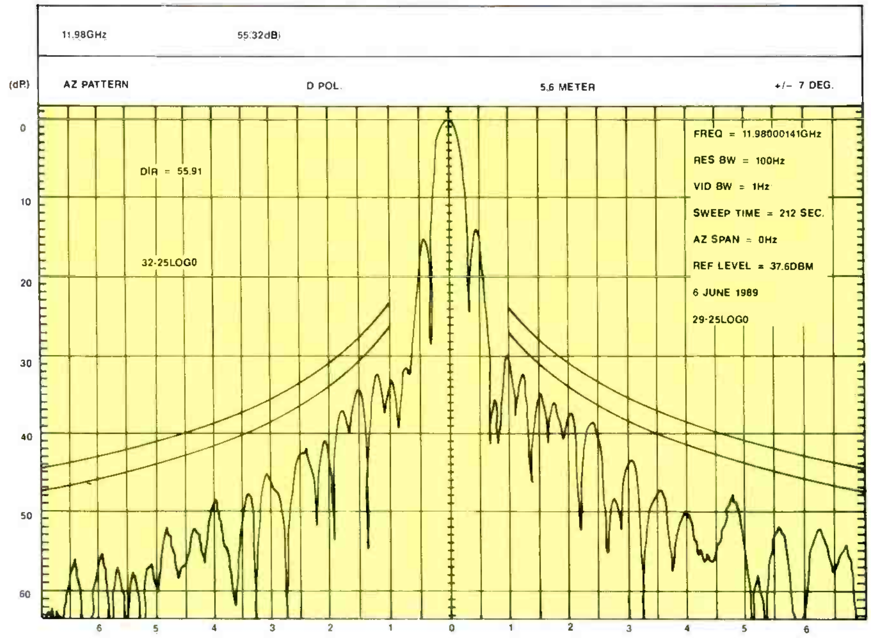

Figure 2. *A plot of the azimuth pattern of a 6m class Ku-band satellite antenna. The peak directivity of the main lobe is the zero reference, and gain of other orientations are described in decibels down from the peak. Log 29 − 25Log*$_{10}$ *reference curve relates to current FCC regulations for 2°-spaced satellites. The 32 − 25 Log*$_{10}$ *curve is the previous FCC standard.*

Antenna noise temperature can be approximated by the following equation:

$$T_{Antenna} \approx (T_{Sky} + T_{Ground}) + \Sigma T_{Components} + T_{VSWR}$$

Note the noise temperature of the passive components add to determine $T_{antenna}$. As with gain, you must clearly identify the reference point where the antenna noise temperature is measured. In Figure 1, the antenna noise temperature is 39.7K at the feed phase center, and 50.4K at the combiner. Again, the greater the distance separating the feed phase center and the reference point, the greater the antenna noise temperature.

System noise temperature

The system noise temperature includes the noise contribution of each component from the antenna to the receiver. T_{system} can be closely estimated by using the following equation:

$$T_{System} \approx T_{Antenna} + T_{LNA}$$

System noise temperature is properly taken at the output of the LNA. Measuring here accounts for the noise contribution from all components in the receiver system, including the LNA. If the gain is high enough, as is often the case today, the LNA effectively masks transmission line losses and receiver noise.

G/T

The G/T, or figure of merit, describes the ability of an antenna to receive a signal from a satellite. It is the logarithmic ratio of the net antenna gain to the system noise temperature, and is expressed in dB/K. Calculate G/T with the following equation:

$$G/T\ (dB/K) = G_{Net} - 10 \times \text{Log}_{10} T_{System}$$

Where:

$$G_{Net} = G_{Antenna} - \Sigma L_{Components}$$
$$T_{System}(K) \approx T_{Antenna} + T_{LNA}$$

The benefit of G/T is that it provides a common basis for evaluating antennas of different size and construction. Because every decibel of change in G/T effects the same change in carrier-to-noise, you can directly see the impact of each antenna on system performance. Also note that G/T is not site-specific, provided the look angles are held constant. It is a computed parameter that depends on the antenna and LNA.

Calculating G/T helps you make decisions. A larger, and probably more expensive, antenna may raise G/T. The same result may be accomplished with a lower-temperature LNA. Obviously, some changes are more cost-effective than others. Calculating G/T shows the impact of any one change on the system, and simplifies the task of evaluating alternative solutions.

G/T example

Before calculating G/T, make sure the antenna gain and noise temperature have the same reference point. Then, determine if there are any components between the reference point and the LNA. If so, find their loss and noise temperature. Table 1 gives the loss and noise temperature for several waveguides.

Figure 1 includes all the information needed for the G/T example. The reference point is the circular waveguide flange of the combiner. Here, the antenna gain is 55.5dBi, and the noise temperature is 50.4K. The combiner separates the reference point from the LNA. Its loss and noise temperature is 0.1dB and 6.6K, respectively. Assume the antenna VSWR is 1.30:1. With a 180K LNA, the G/T for this antenna system is:

$$G_{Net} = G_{Antenna} - \Sigma L_{Components} = 55.5 - 0.1 = 55.4\text{dBi}$$

$$T_{System} \approx (T_{Sky} + T_{Ground}) + \Sigma T_{Components} + T_{VSWR} + T_{LNA}$$
$$\approx 50.4 + 6.6 + 4.9 + 180 = 241.9°K$$

Continued on page 58

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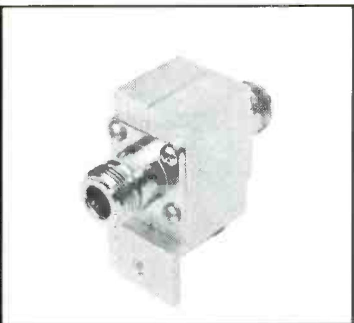
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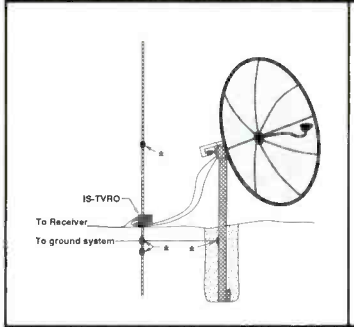

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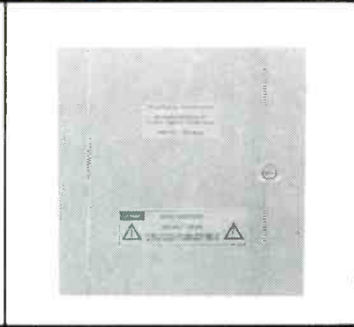
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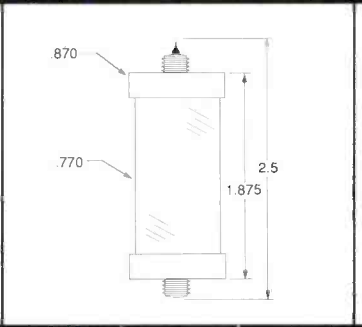

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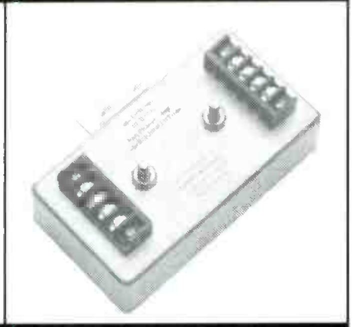
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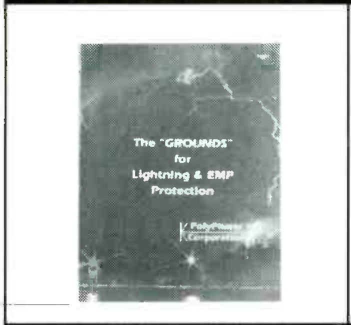

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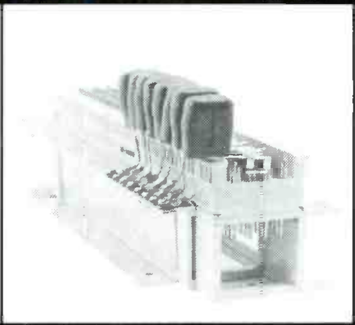
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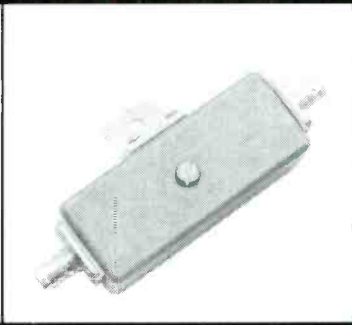
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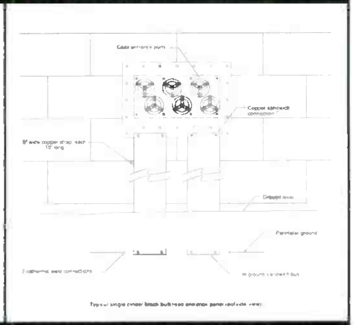
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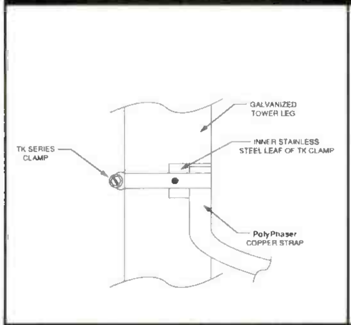

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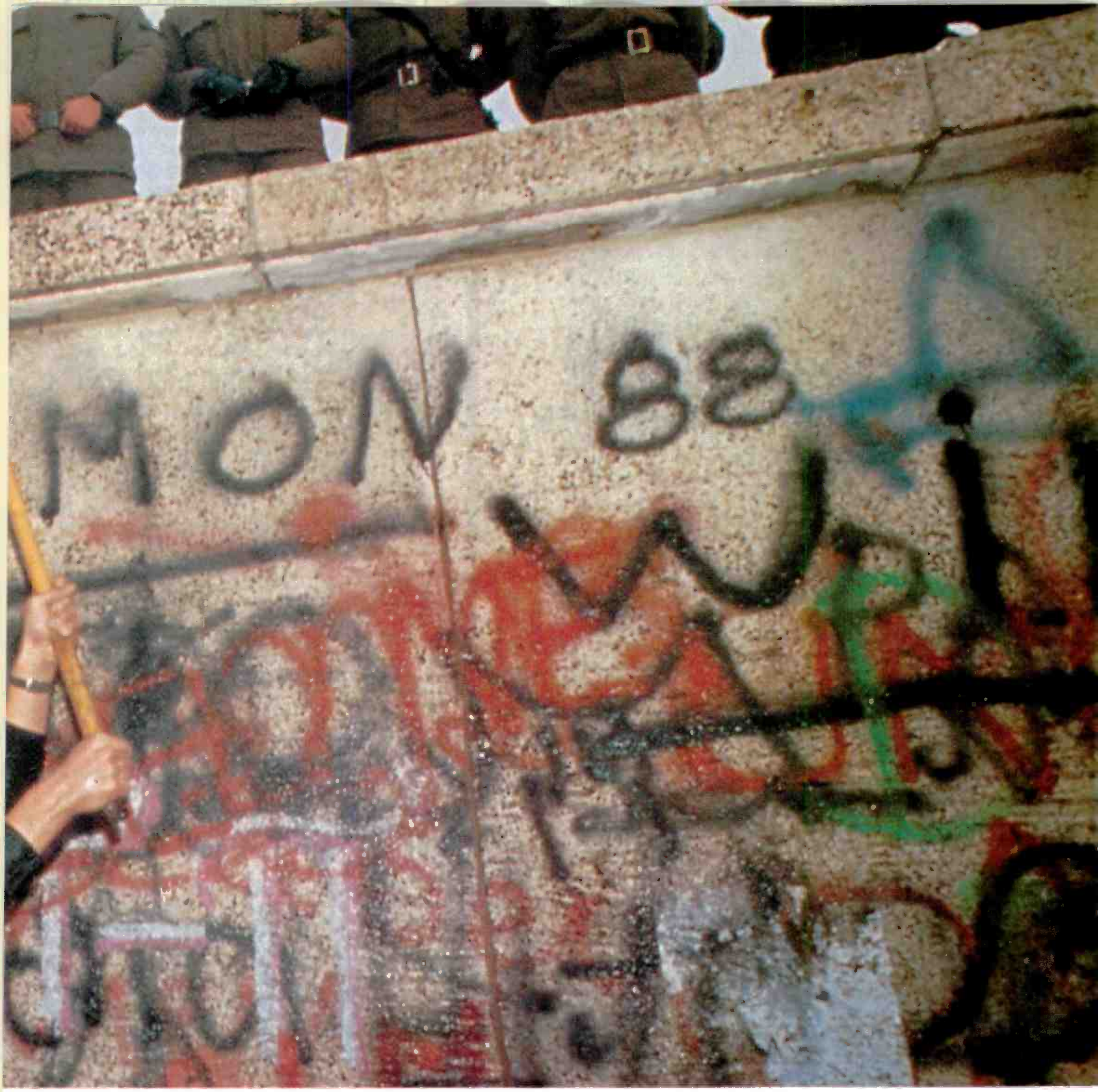

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Continued from page 54

$$G/T \approx G_{Net} - 10 \times Log_{10}T_{System} \approx 55.4 - 23.84 = 31.56dB/°K$$

Now, install four feet of WR75 rigid waveguide between the combiner and LNA. Using the previous example and Tables 1 and 2, the G/T computes to 31.18 dB/K. This illustrates the leverage that transmission line losses have on system performance. The received signal was reduced by 0.176dB, but 0.4dB was lost in G/T. It is important, therefore, to install the LNA as close as possible to the feed phase center, and to interconnect the feed and the LNA with efficient waveguide.

Cross-polarization discrimination

Although not accounted for by G/T, XPD is an important antenna parameter. It measures the ability of an antenna to distinguish between the horizontal and vertical signals of the same frequency, and to reject the unwanted signal. Figure 5 shows the horn collecting reflected energy, and each port of the combiner passing some cross-polarized energy.

The amount of cross-polarized energy exiting the combiner ports depends on the feedhorn, the interconnecting waveguide and combiner, and the matching of these components to the reflector. If these components are mismatched, which can happen when feed systems are mated with reflectors from another manufacturer, XPD can suffer, as can VSWR and patterns. This degrades system performance. The effect of XPD on C/N will be shown later.

If properly made, corrugated feedhorns are well-balanced and can exhibit better XPD than smooth wall and diagonal horns. Being a machined component, corrugated horns can be made with a precision that surpasses other manufacturing techniques.

There are two measures of XPD. One is on the axis of the main beam, and the other is off the axis from 1.8° to 9.2°. The on-axis XPD is the ratio of the antenna's co-polarized and cross-polarized gains, expressed in decibels. Figure 6 shows the results of an on-axis XPD on a 6m class antenna in the Ku-receive band. Note the receive XPD measures 36.5dB.

Antenna specifications should identify the on-axis XPD at the main beam and across the 1dB width of the main beam. Measuring across the 1dB width is the more critical measure, because it recognizes antenna pointing errors that can be caused by wind and satellite drift. Satellite operators, on the other hand, are only concerned with the XPD at the main beam. Below 30dB, there is a risk of interfering with their other users.

The XPD measure across the 1.8° to 9.2° range is an absolute gain term, expressed in dBi, and is an FCC requirement for C-band transmit antennas.

Although there are XPD requirements for transmit applications, it is an important receive antenna parameter. XPD is interference, and it is part of the carrier-to-noise equation.

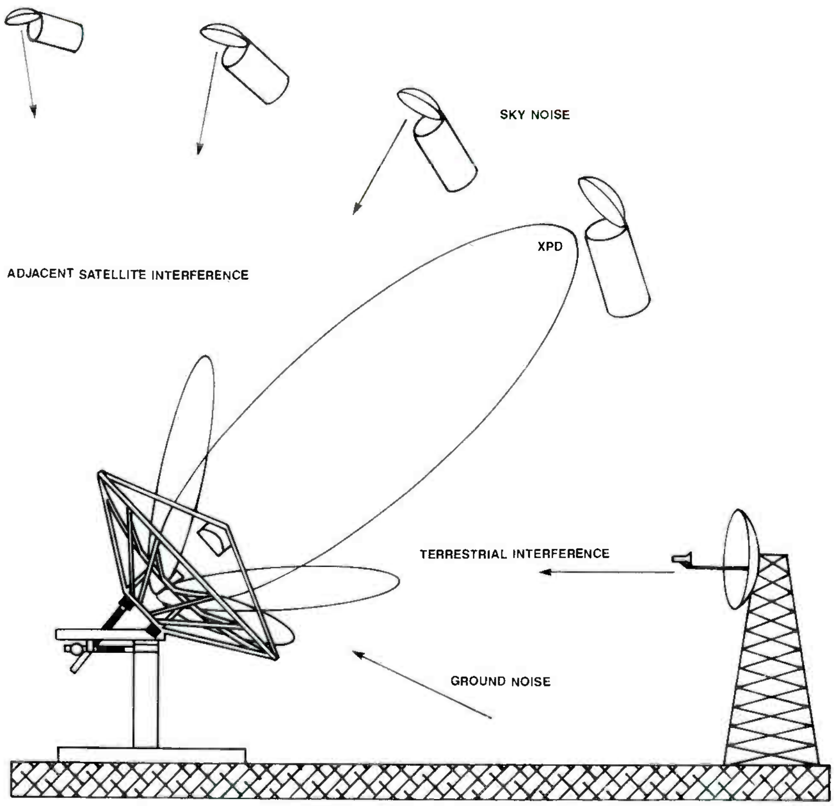


Figure 3. *Satellite antenna noise comes from several sources. Noise sources include interference from adjacent satellites, the background noise of space, terrestrial interference, the "warm body" radiation of the earth, and cross-polarity discrimination (XPD).*

Carrier-to-noise ratio (C/N)

There are several carrier-to-noise terms, so identifying the specific C/N term is im-

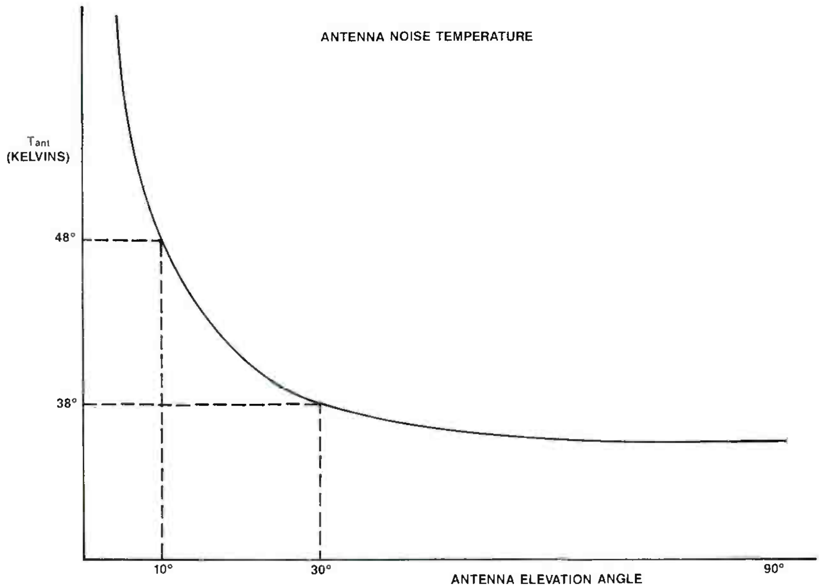
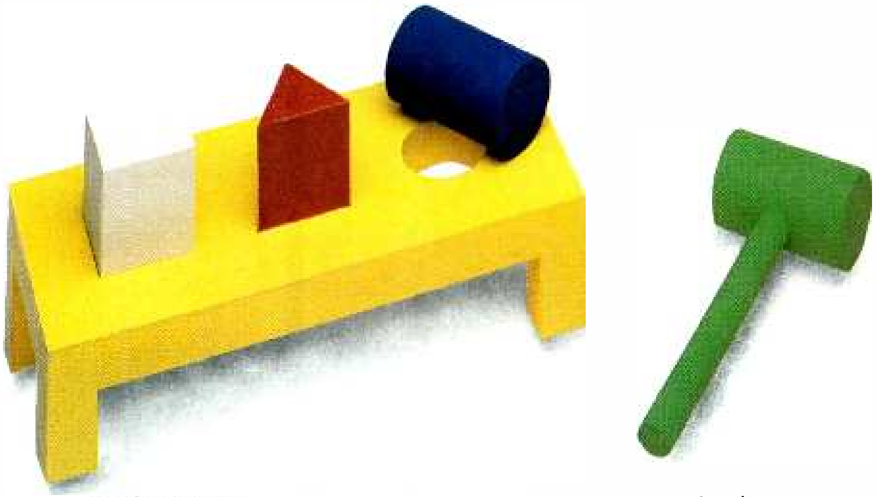


Figure 4. *Because of the "warm body" earth, antenna noise temperature is inversely related to elevation. The lower the look angle, the higher the noise temperature.*



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portant. A satellite path is really two microwave circuits cascaded together. One is from the earth to the satellite, and the other is from the satellite back to earth. C/N_{Final} combines the C/N of both paths and the carrier-to-interference (C/I) terms to determine the C/N for the entire path.

The following equations describe the C/N relationships:

$$C/N_{Final} = C/N_{Uplink} \oplus C/N_{Downlink}$$
$$C/N_{Downlink} = C/N_{Thermal} \oplus C/I_{XPD} \oplus C/I_{AdjSat} \oplus C/I_{Terr}$$

$C/N_{Thermal}$ accounts for thermal noise degradation to the satellite-transmitted signal. It is the maximum performance attainable by the earth station antenna system. C/N_{Uplink} and the C/I terms have the effect of reducing performance, though C/N_{Uplink} is typically negligible.

The on-axis satellite is the primary source of cross-polarized interference, and adjacent satellites contribute both co- and cross-polarized interference. C-band also suffers from terrestrial interference.

The symbol ⊕ in the C/N equations means the summation is performed on a power basis. One method to calculate the power sum of the C/N terms is:

$$C/N_{Downlink}dB = 10 \times Log_{10}\left[\frac{1}{\frac{1}{10^{\frac{C/N_{Thermal}}{10}}} + \ldots + \frac{1}{10^{\frac{C/I_{Terr}}{10}}}}\right]$$

$C/N_{Thermal}$

$C/N_{Thermal}$ is the path calculation for the microwave link between the satellite and earth station antenna. It is similar to the path calculation for a terrestrial microwave hop. Carrier components include the satellite radiated power (EIRP) in dBW, the receive antenna gain (G_{Net}) in dBi, and the path loss (PL) in decibels. Noise components are Boltzman's constant (k= −228.6) in dBW/K/Hz, system noise temperature (T_{System}) in K, and bandwidth (BW) in hertz. By combining the antenna gain and system noise temperature, $C/N_{Thermal}$ displays the now familiar G/T. In equation form, $C/N_{Thermal}$ looks like this:

$$C/N_{Thermal} = EIRP + G/T - PL - 10\times Log_{10}BW - k$$

The EIRP can be read from the footprint published by the satellite operator. The path loss equation includes the geometric terms to account for the distance from the earth station antenna to the satellite in geostationary orbit. Typical values for path loss are 197dB for C-band and 206dB for Ku-band.

LOSS/VSWR AND NOISE TEMPERATURE

Interface Waveguide Degradation

Interface	Typical Loss	Noise Temperature
Waveguide, copper	Per foot (L)	Per foot at 290K **
WR229 rigid (4GHz)	0.008dB	0.5K
Typ. WR229 flex (4GHz)	0.023dB	1.5K
WR75 rigid (12GHz)	0.044dB	2.9K
Typ. WR75 flex (12GHz)	0.150dB	10.1K

** Interface waveguide noise is calculated from the formula:

$$Noise = 290K \times (10^{L_{dB/10}} - 1)$$

Table 1. *The loss and noise temperature contribution per foot of several varieties of feedline.*

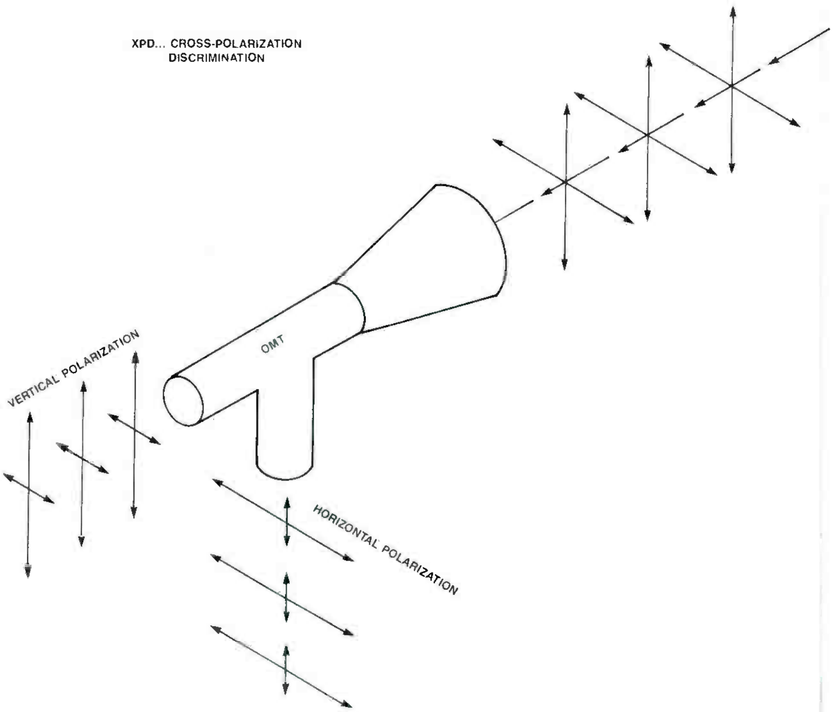

Figure 5. *Cross-polarization discrimination (XPD) measures the residual radiation of the opposite polarity after the signal has left the combiner. The amount of cross-polarized energy depends on the physical characteristics of the feedhorn, interconnecting waveguide and combiner, and how well these components match the reflector.*

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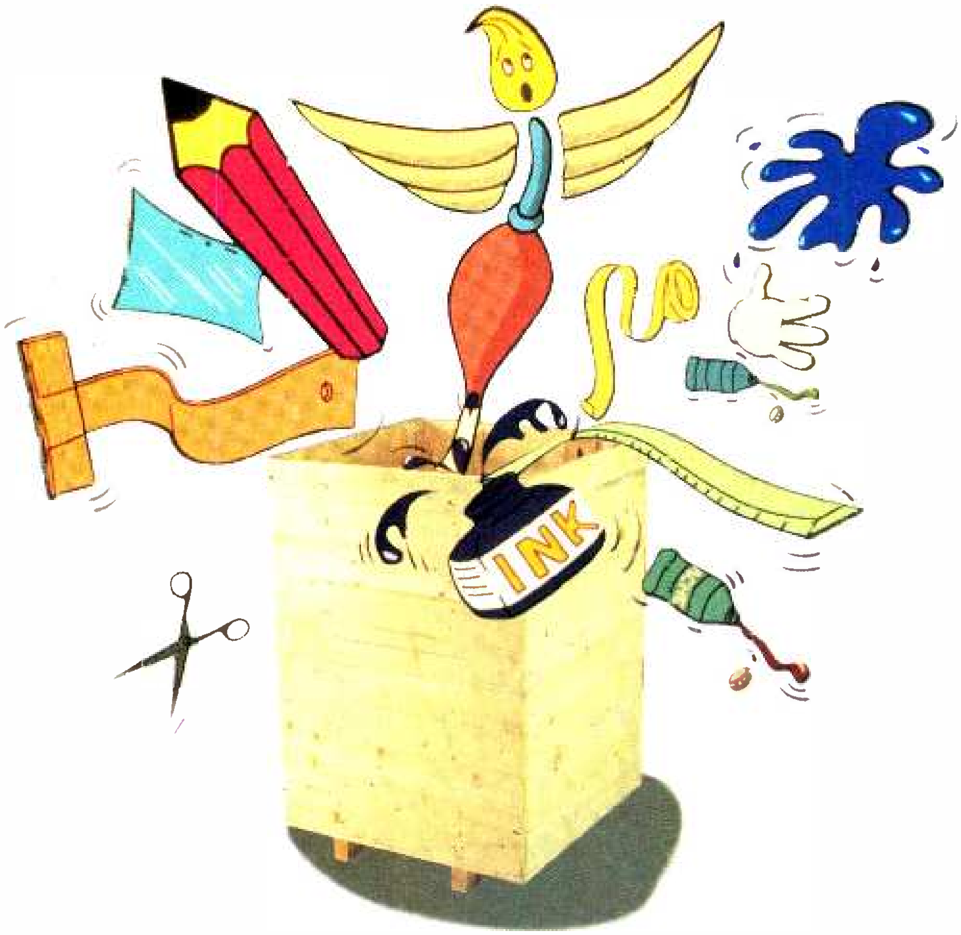

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The bandwidth depends on the receiving equipment. For full transponder operation, the bandwidth is typically 34MHz for broadcast-quality receivers and 30MHz for commercial-quality receivers. At half transponder, which is often the case at Ku-band, the bandwidth may be 18MHz.

On balance, C/N_{Final} is the net measure of performance delivered to the receiver. It represents contributions from the satellite, the antenna, and all noise and interference sources.

How does G/T and C/I affect antenna performance? To find out, calculate C/N_{Final} — it shows the impact each parameter has on performance. The intent of the following examples is to show the importance of good patterns, good XPD and good G/T. (See Table 3).

First, calculate $C/N_{Thermal}$. If the Ku-band satellite EIRP is 43.3dBW, the antenna G/T is 31.56dB/K, and the bandwidth is 30MHz, then $C/N_{Thermal}$ is:

$$EIRP + G/T - 10 \times Log_{10} BW - K = 43.3 + 31.56 - 206 - 74.77 - (-228.6) = 22.69dB$$

Measuring across the 1dB width is the more critical measure, because it recognizes antenna pointing errors that can be caused by wind and satellite drift.

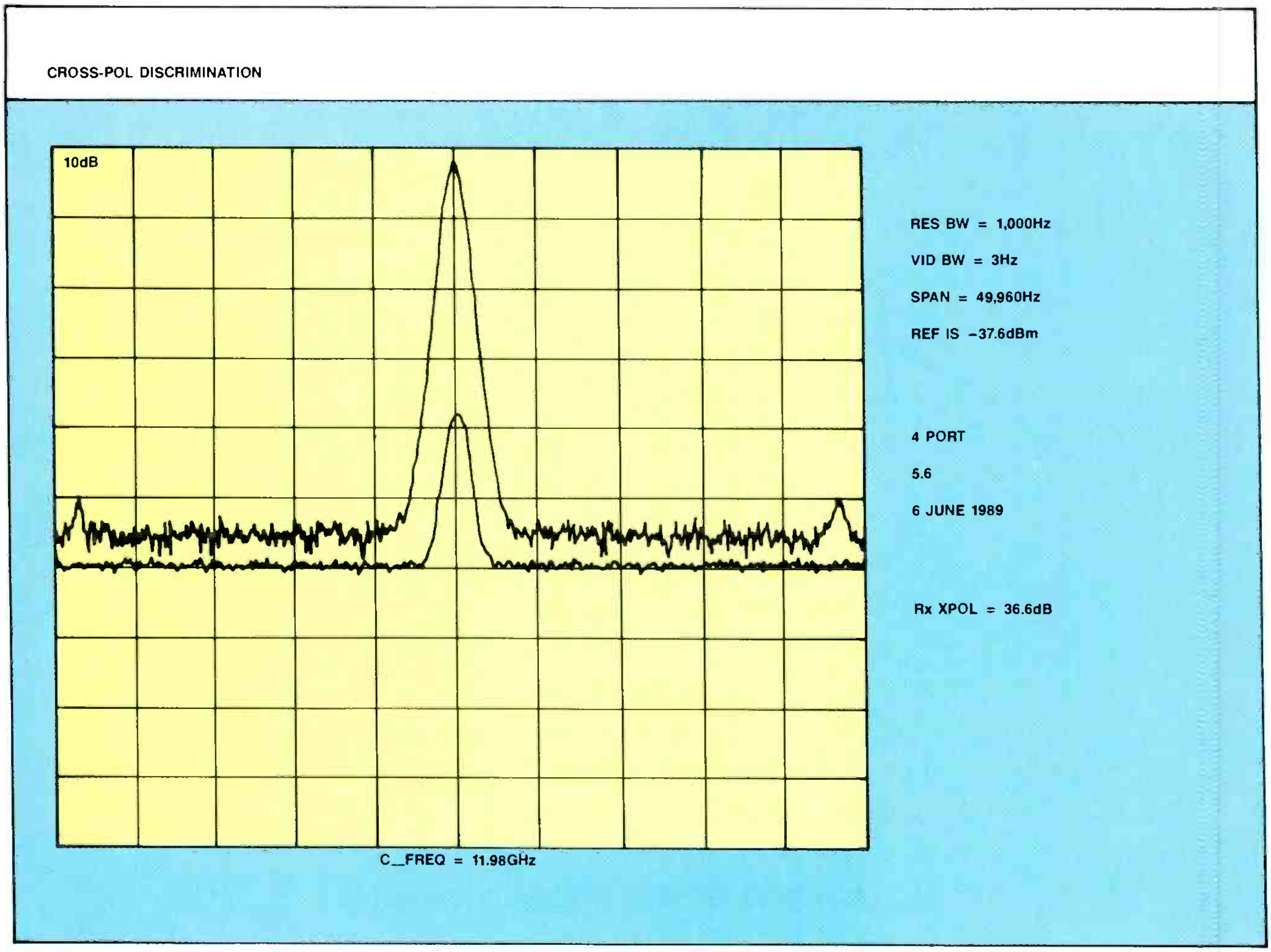

Figure 6. *The on-axis cross-polarization discrimination of an antenna can be determined by plotting the antenna's co-polarized and cross-polarized gains. The difference, XPD, is expressed in decibels.*

If properly made, corrugated feedhorns are well-balanced and can exhibit better XPD than smooth wall and diagonal horns.

VSWR NOISE CONTRIBUTION

VSWR	Noise Contribution
1.35	6.4K
1.30	4.9K
1.25	3.6K
1.20	2.4K

Table 2. *The noise contribution arising from various VSWR conditions.*

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• Case 1 uses the standard antenna parameters with the adjacent satellite interference based on the 29—25 $\log_{10}$ envelope.

• Case 2 shows what happens if the 32—25 $\log_{10}$ envelope represents adjacent satellite interference. C/N can degrade by as much as 0.5dB.

• Case 3 shows that as XPD degrades from 35dB to 30dB, C/N degrades over 0.3dB.

• Combined, cases 2 and 3 reduce C/N almost 1dB. This is no minor change; 1dB represents approximately a 20% reduction in performance.

SAMPLE C/N ANALYSIS

Parameter	Case 1	Case 2	Case 3
$C/N_{Thermal}$ (dB)	22.69	22.69	22.69
C/N_{Uplink} (dB)	30.0	30.0	30.0
C/I_{XPD} (dB)	35.0	35.0	30.0
C/I_{AdjSat} (dB), East	32.3	29.3	29.3
C/I_{AdjSat} (dB), West	32.3	29.3	29.3
C/N_{Final} (dB)	21.04	20.43	20.12
C/N Degradation from Case 1	———	0.61	0.92

Table 3. *A sample carrier-to-noise analysis showing the resultant degradation from various conditions of cross-polarity discrimination and adjacent satellite interference.*

FCC regulations for 2° spacing

To ensure interference-free operation in today's 2° satellite-spaced environment, the FCC has developed regulations describing an antenna's minimum pattern characteristics. Following are sections (A) and (B) from § 25.209.

(A) The gain of any antenna to be employed in transmission from an earth station in the fixed-satellite service shall lie below the envelope defined below:

1. In the plane of the geostationary satellite orbit as it appears at the particular earth station location:

$29 - 25\times\text{Log}_{10}\Theta$ dBi for $1° \leq \Theta \leq 7°$
$+8$ dBi for $7° < V \leq 9.2°$
$32 - 25\times\text{Log}_{10}\Theta$ dBi for $9.2° < \Theta \leq 48°$
-10 dBi for $48° < \Theta \leq 180°$

...the peak gain of an individual sidelobe may not exceed the envelope defined above for between 1° and 7°. For greater than 7°, the envelope may be exceeded by 10% of the sidelobes, but no individual sidelobe may exceed the envelope by more than 3dB.

2. In all other directions:
Outside the main beam, the gain of the antenna shall lie below the envelope defined by:

$32 - 25\times\text{Log}_{10}\Theta$ dBi for $1° \leq \Theta \leq 48°$
-10 dBi for $48° < \Theta \leq 180°$

...the peak gain of an individual sidelobe may be reduced by averaging its peak level with the peaks of the nearest sidelobes on either side, or with the peaks of two nearest sidelobes on either side, provided that the level of no individual sidelobe exceeds the gain envelope given above by more than 6dB.

(B) The off-axis cross-polarization isolation of any antenna to be employed in transmission at frequencies between 5,925MHz and 6,425MHz from an earth station to a space station in the domestic fixed-satellite service shall be defined by:

$19 - 25\times\text{Log}_{10}\Theta$ dBi for $1.8° < \Theta \leq 7°$
-2 dBi for $7° < \Theta \leq 9.2°$

These FCC rules say licensed receive antennas are protected from interference by other satellites to the extent their radiation patterns conform to the envelopes defined in (A) and (B). For terrestrial interference, the envelopes in (A)(2) apply.

Essentially, the rules do not prevent non-compliant antennas from operating. Rather, the rules clearly guarantee protection only to licensed and coordinated antennas with compliant patterns, regardless of whether they are transmitting or receiving.

Conclusion

Decibels are like dollars. You may not think you are losing much when you drop a tenth here and there, but add them up. Do a quick G/T estimate to see what is really happening to the signal. Study the antenna's pattern to see if it is vulnerable to noise and interference. Only then can you select the best antenna for your application.

Acknowledgment: The author wishes to thank Rene Savalle, Dave Neubauer, Tony Campbell and Pat Moore for their assistance with this article. Their contributions were significant, and most appreciated.

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During the past year a significant advance took place in the United States. Following some years of extensive and diverse research and development within major labs directed at the highly challenging task of developing an encoding/modulation system to allow HDTV transmission over a standard 6MHz terrestrial broadcasting channel, dramatic breakthroughs have recently emerged.

The proposal by General Instruments (GI) in the summer of 1990 for an all-digital HDTV transmission system was quickly followed by revelations of similar advances elsewhere. Today, four separate approaches to all-digital HDTV terrestrial transmission are being examined by the FCC Advisory Committee on Advanced Television Services. The United States has stepped forward in dramatic fashion as a world pioneer in digital broadcasting technology.

The relatively sudden heightening of overall interest in a digital transmission system immediately raises the question of a suitable digital HDTV production signal format to feed a possible digital over-the-air encoder/modulator. Accompanying such a question is the attendant scrutiny of the many years of work that might already have been invested in an "analog" HDTV production standard. Is this work suddenly made obsolete?

Happily, the answer is *not at all*. Here in the United States, work has been directed toward developing an HDTV production standard for the past seven years. An enormous amount of progress has been made with extensive contribution from many sectors of the TV and film industries, and from the program production community.

What is especially important was the clear recognition that an HDTV production standard is not an issue of analog *or* digital — it clearly embraces analog *and* digital considerations. Both aspects were part of the first discussions in 1983 within SMPTE (Society of Motion Picture and Television Engineers) and ATSC (Advanced Television Systems Committee).

The first HDTV standard that emerged, SMPTE-240M, at first glance reads like an "analog" document describing an analog set of parameters. Indeed, it does just that. This is necessary, because an HDTV production standard should clearly describe all that is associated with the structuring of an electronic signal parameter set, one that results from capturing the analog real world scene by the fundamentally analog process of an HDTV camera (using tubes or CCD imagers). Any HDTV production standard will always necessitate the inclusion of such a description.

However, behind the scenes in developing SMPTE-240M lies a considerable body of digital thinking. As early as 1985, a proposed genesis of a digital representation of this signal was grappled with to aid in the final selection of key "analog" parameters, such as aspect ratio and camera blanking widths. This was sufficient to allow full documenta-

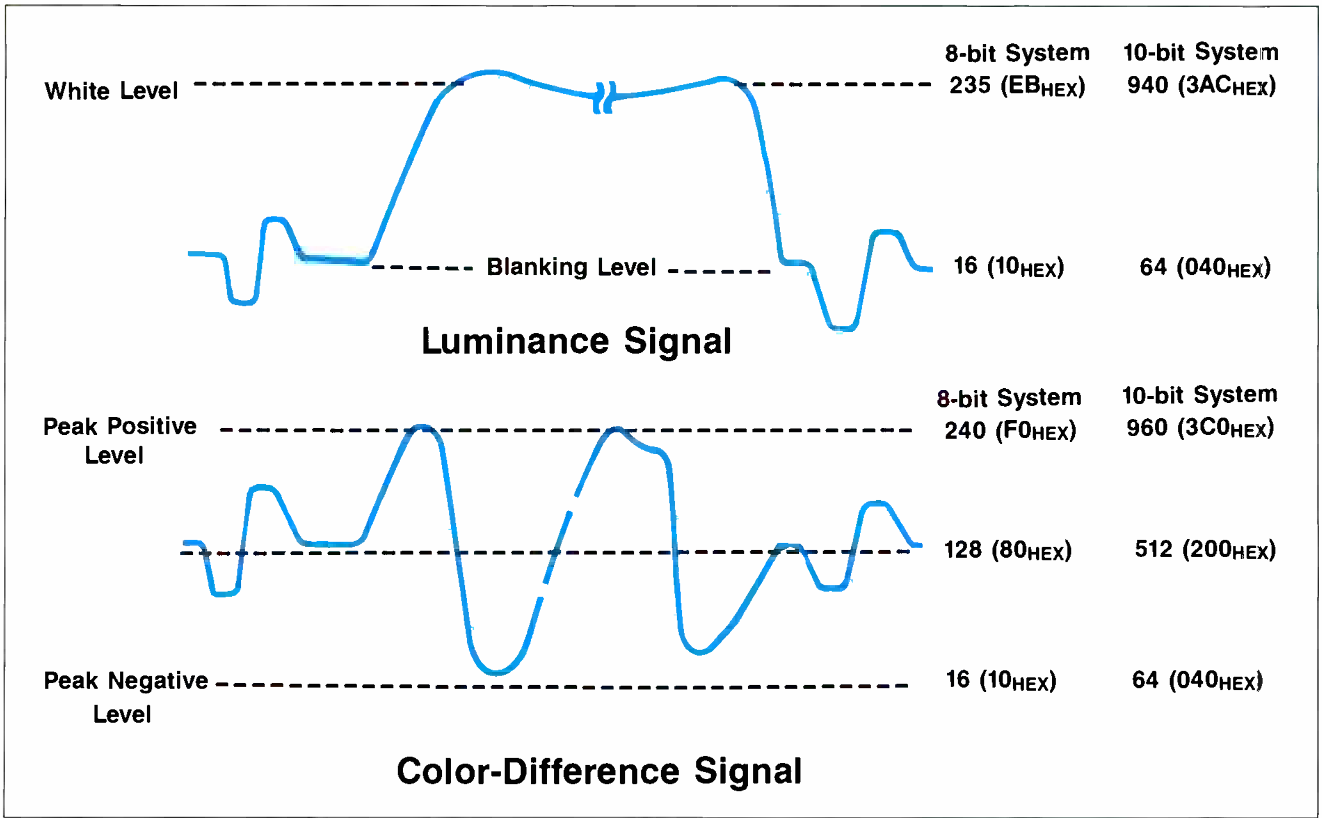


Figure 1. Proposed range of data values for digital 1125/60 HDTV signals.

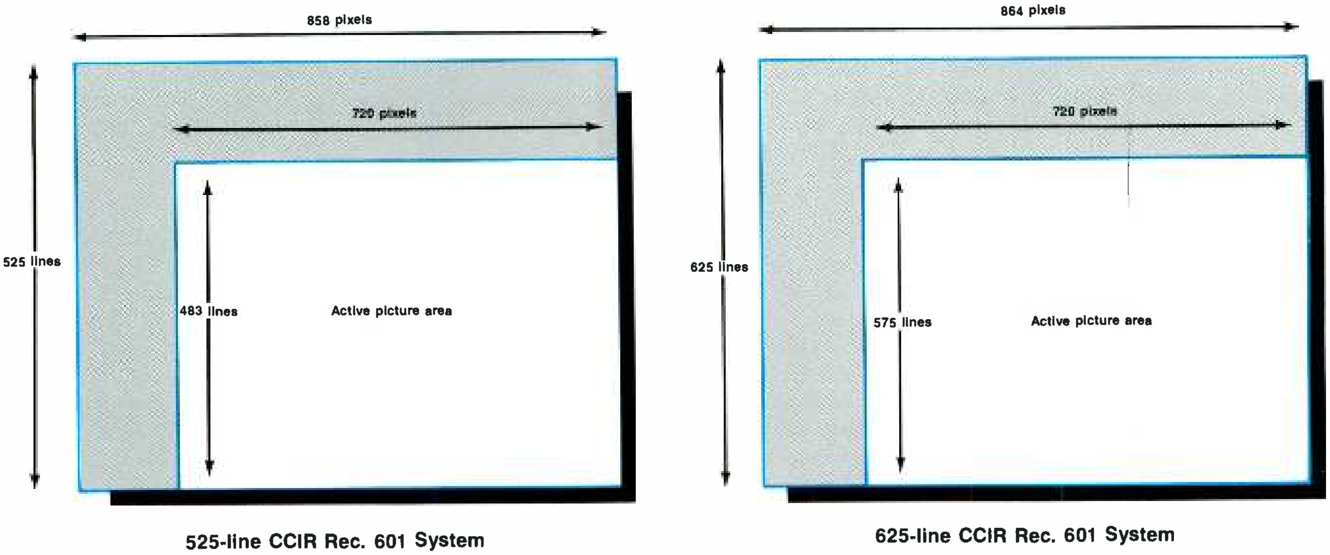


Figure 2a. Pixel count for CCIR Rec. 601 525- and 625 line TV signals.

tion of all basic parameters of the HDTV production signal parameter set — which was standardized by SMPTE in 1988. Work began immediately within a special dedicated SMPTE digital group to build on this standard and study all details for a full digital representation of SMPTE-240M.

THE DIGITAL GAME PLAN

Following the emergence of the SMPTE-240M standard, the rapid and still increasing desire for hardware and software tools for the digital capture, storage, transmission and manipulation of HDTV images in the 1125/60 format created a sense of urgency within the SMPTE Working Group on High Definition Electronic Production (WG-HDEP) toward the completion of the digital characterization of the 1125/60 HDTV signal parameters.

WG-HDEP created an Ad Hoc Group on Digital Representation of 1125/60 in October 1988. The charter of this Ad Hoc Group was to study and document the digital representation of basic 1126/60 HDTV as defined within the body of the SMPTE-240M HDTV production standard. The unified digital description of the 1125/60 HDTV signal was expected to stimulate the development of all-digital equipment and to enhance the development of universal interfaces for the interconnection of digital HDTV equipment from the various manufacturers. Indeed, as SMPTE works moved toward internal consensus, some manufacturers were committing to the recommendations — even before the standardization process was complete.

To fulfill its task, the Ad Hoc Group brought together a large cross-section of industry experts:

- Technical representatives of international manufacturers of HDTV equipment.
- Designers of digital video processing and computer graphics equipment.
- Current users of 4:2:2 digital 525-/625-line equipment.
- Motion picture engineers looking to ensure the highest standards of image quality for motion picture related HDTV imaging.
- Technical members of broadcasting and research organizations.

SPECIFIC AREAS OF DIGITAL STUDIES

The Ad Hoc Group has held about 20 meetings since its creation. The in-depth discussions that took place during these meetings capitalized on the prior decade of experience with 525-/625-line 4:2:2 digital facilities and resulted in new understandings. These translated into multiple requirements for the SMPTE-240M standard as it applied to various high-resolution video and image processing environments.

Numerous studies and recommendations have recently been brought into focus, and a draft document for the digital representation of, and the design of a bit-parallel digital interface for the 1125/60 studio HDTV standard, is now being examined within SMPTE.

It is not easy to read standard documents for the first time and fully grasp the complex technical decisions and implications. It is the intention of this document to help the industry understand some of the important thinking ongoing within this committee. Hopefully, this will prepare many interested parties to better understand this proposal for a standard that may soon emerge from SMPTE. Under normal due process, this proposal will be published to gather wide industry comments before the final standardization process of SMPTE continues.

The following sections describe specific areas of study within the Ad Hoc Group:

- digital encoding parameters of the 1125/60 HDTV signal
- dynamic range considerations
- transient regions
- filtering characteristics
- design of the bit-parallel digital interface

ENCODING PARAMETERS

The process of converting analog signals into their digital counterpart is known as "Encoding of the analog signal," and is characterized mainly by the following parameters:

- Specification of Signal Components Sets
- Number of bits per component sample
- Correspondence between digital and analog video values (assignment of quantization levels)
- Sampling frequency
- Sampling structure

The sections below discuss in more detail the studies surrounding the digital encoding parameters of the 1125/60 HDTV signal.

Signal Component Sets

The specification of the analog characteristics of the 1125/60 HDTV signal, as documented in the SMPTE-240M standard, established two sets of HDTV components:

- A set consisting of three full-bandwidth signals, G′, B′, R′, each characterized by a bandwidth of 30MHz.
- A set of luminance, Y′, and color-difference components ($P_{R'}$ and $P_{B'}$) with bandwidths of 30MHz and 15MHz, respectively.

It should be noted that the primed G′, B′, R′, Y′, $P_{R'}$ and $P_{B'}$ signal components result when linear signals pass through the non-linear opto-electronic transfer characteristic of the HDTV camera.

According to SMPTE-240M, the luminance signal, Y′, is defined by the following linear combination of G′, B′ and R′ signals:

$$Y' = 0.701G' + 0.087B' + 0.212R'$$

The color-difference component, $P_{R'}$, is amplitude-scaled (R′-Y′), according to (R′-Y′)/1.576, or in other terms,

$$P_{R'} = -0.445G' - 0.055B' + 0.500R'$$

In the same manner, the color-difference component, $P_{B'}$, is amplitude-scaled (B′-Y′) according to (B′-Y′)/1.826, or in other terms,

$$P_{B'} = -0.384G' + 0.500B' - 0.116R'$$

It should be noted that these baseband encoding equations differ from those for NTSC (or CCIR Rec. 601) because they relate to a specified SMPTE-240M colorimetry and white point color temperature (i.e., D65).

Bits per Component Sample

The use of 8-bit quantization (CCIR Rec. 601) has become the norm in the digital recording of conventional component and composite TV signals. Today, an 8-bit linear quantization per sample is the practical limit. This limit is determined not only by technical and economic constraints, but also from conclusions reached after objective and subjective testing within SMPTE and EBU in the late '70s and early '80s.

However, increasing demands of the production and post-production community to handle wider dynamic range signals (particularly for very high quality HDTV to 35mm film transfers) and for multiple generations of signal processing have led to the consideration of using 10-bit as well as 8-bit quantization for future generations of digital 1125/60 equipment (see Figure 1). The data below describes the proposed digital encoding characteristics for 8- and 10-bit systems.

Form of Encoding

The process to convert the 1125/60 HDTV signals into their digital form uses Pulse Code Modulation (PCM). An A/D converter uses a linear quantization law with a coding precision of 8 or 10 bits per sample of the luminance signal and for each color-difference signal.

Correspondence Between Video Signal and Quantization Levels

The encoding characteristics of the 1125/60 HDTV signal follow those specified in Rec. 601 of the CCIR (encoding parameters for 525-/625-line digital TV systems) for use with 8-bit and 10-bit systems. The experience gained over the past decade with 4:2:2 systems showed these to be an equally optimal set of numbers for HDTV. This is indeed the case, especially when defining code ranges for "foot room" and "head room," which take into account the effects of signal processing.

8-bit System

Luminance (Y′): 220 quantization levels with the black level corresponding to level 16 and the peak white level corresponding to level 235.

Color-Difference Signals ($P_{R'}$, $P_{B'}$): 225 quantization levels symmetrically distributed about 128, corresponding to the zero signal.

10-bit System

Luminance (Y′): 877 quantization levels with the black level corresponding to level 64 and the peak white level corresponding to level 940.

Color-Difference Signals ($P_{R'}$, $P_{B'}$): 897 quantization levels symmetrically distributed about level 512, corresponding to the zero signal.

Quantization Level Assignment

8-bit system

254 of the 256 levels (quantization levels 1 through 254) of the 8-bit word are used to express quantized values. Data levels 0 and 255 are proposed to indicate timing references.

10-bit System

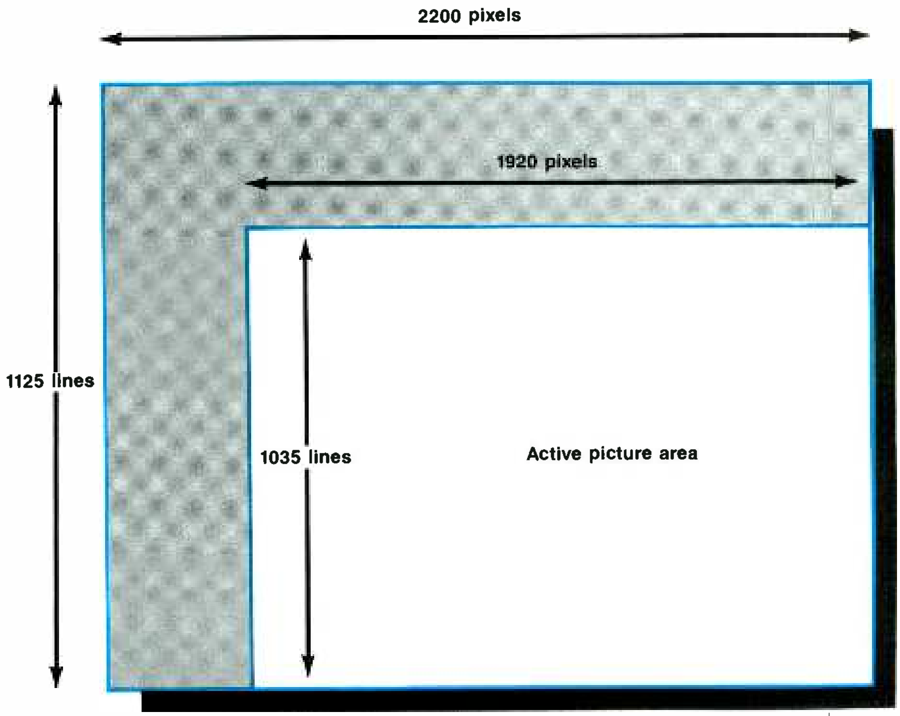
1,016 of the 1,024 levels (digital levels 4 through 1,019) of the 10-bit word are used to express quantized values. Data levels 0 to 3 and 1,020 to 1,023 are proposed for indication of timing references.

Sampling Frequency

In the world of 4:2:2 digital video signals (as established by CCIR Rec. 601 for 525-/625-line TV systems), the frequency values of 13.5MHz and 6.75MHz have been selected for the sampling of the luminance and color-difference components, respectively. It is interesting to note that 13.5MHz is an integer multiple of 2.25MHz, more precisely, 6 × 2.25MHz = 13.5MHz).

The importance of the 2.25MHz frequency lies in the fact that 2.25MHz represents the minimum frequency found to be a common multiple of the scanning frequencies of 525- and 625-line systems. Hence, by establishing sampling based on an integer multiple of 2.25MHz (in this case, 6 × 2.25MHz = 13.5MHz), an integer number of samples is guaranteed for the entire duration of the horizontal line in the digital representation of 525- and 625-line component signals (i.e., 858 for the 525-line system and 864 for the 625-line system). More important, however, is the fact that a common number of 720 pixels can now define the active picture time of both TV systems (see Figure 2a).

Also, the sampling frequencies of 13.5MHz, for the luminance component, and 6.75MHz for each of the color-dif-



1125/60 HDTV raster

Figure 2b. Proposed pixel count for the 1125/60 HDTV production standard.

ference signals, permitted the specification of a "Digital Hierarchy" for various classes of signals used in the now digital TV infrastructure. For example, the studio level video signal was identified by the nomenclature, 4:2:2 (indicating a ratio of the sampling structures for the component signals), while processing of three full-bandwidth signals like G′, B′, and R′ were denoted by 4:4:4, etc.

In the early '80s, numerous international studies were conducted with the purpose of defining basic picture attributes of High Definition TV systems. One of those picture parameters related to the requirement of twice the resolution provided by 4:2:2 studio signals scaled by the difference in picture aspect ratios (that is, between the conventional 4:3 picture aspect ratio and the new 16:9 aspect ratio). The international standards organization CCIR, hence, recommended the number of 1,920 pixels for the active portion of the scanning line. In other words:

$$720 \times 2 \times \frac{(16/9)}{(4/3)} = 1{,}920$$

The desire to maintain as simple a relation as possible between the sampling frequencies of the 1125/60 HDTV signals and the already established digital world of 4:2:2 components led (back in 1985, at technical meetings within the Advanced Television Systems Committee) to the selection of a sampling frequency that was an integer multiple of 2.25MHz.

The proposed sampling frequency value of 74.25MHz is 33 times 2.25MHz. When considering the total horizontal line-time of the 1125/60 HDTV signal of 29.63µs, it gives rise to a total number of 2,200 pixels. This number conveniently accommodated the 1,920 pixels, already agreed by the international TV community as the required number of active pixels for HDTV signals.

Other sampling frequencies are possible. Values of 72MHz and 81MHz have been examined (among others), which are also an integer multiple of 2.25MHz. However, lower values of the sampling frequency result in very narrow horizontal retrace intervals for the 1125/60 HDTV signal, if 1,920 pixels are assigned to the active part of the picture. The sampling frequency of 74.25MHz allows, on the other hand, the practical implementation of a horizontal retrace interval (horizontal blanking time) of 3.77µs. It should be mentioned that this narrow horizontal blanking interval already represents a tremendous challenge in performance for the horizontal deflection circuits of 1125/60 HDTV cameras and displays.

Another important characteristic of this value of 74.25MHz for the sampling frequency is that none of its harmonics interfere with the values of international distress frequencies, i.e., 121.5MHz and 243MHz.

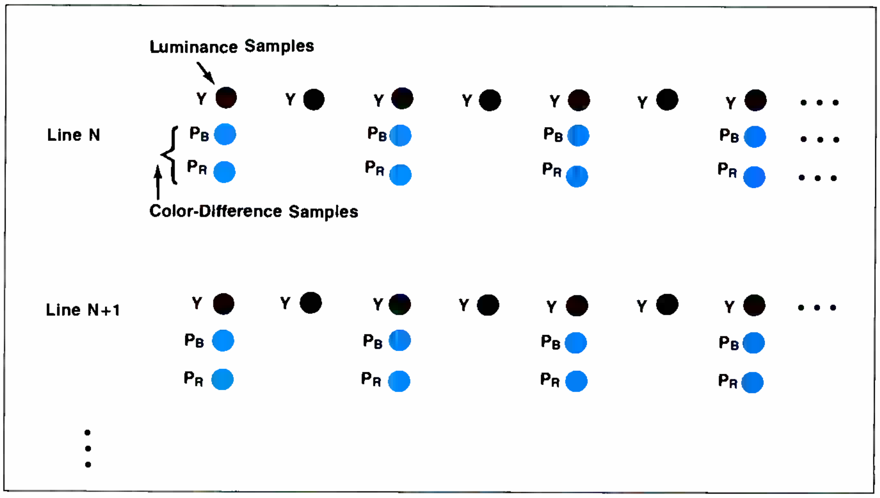


Figure 3. Proposed sampling structure for the 1125/60 HDTV production standard.

For the case of sampling and color-difference components, one-half the value of the sampling frequency for the luminance signal would be used, i.e., 37.125MHz. This gives rise to a number of 960 pixels for each of the color-difference components during the active period of the horizontal line and 1,100 for the entire line.

Overall, 74.25MHz emerged as the sampling frequency of choice in the proposal for the 1125/60 HDTV signal set, because it appears to yield the optimum compromise among many related parameters:

- Practical blanking intervals
- Total data rates for digital HDTV VTRs
- Compatibility with signals of the CCIR Rec. 601 digital hierarchy
- Manageable signal processing speeds

In summary, the current favored set of numbers of the 1125/60 HDTV scanning line exhibits the following number of pixels (see Figure 2b):

Signals\Pixels	Total	Active
G′, B′, R′, Y′ (Luminance)	2,200	1,920
PR′, PB′ Color-Difference	1,100	960

Sampling Structure

The fact that the full-bandwidth components G′, B′, R′, and Y′ are sampled using the same sampling frequency of 74.25MHz results in identical sampling structures (locations of the pixels on the image raster) for these signals. Furthermore, because of the integer number of samples per total line, i.e., 2,200, the sampling pattern aligns itself vertically forming a rectangular grid of samples. This is known as an "orthogonal sampling structure" that is line, field and frame repetitive. This kind of sampling structure facilitates the decomposition of most 2-D and 3-D processing algorithms into simpler operations that can be carried out independently in the horizontal, vertical and temporal directions, and hence, enabling the use of less complex, modular, hardware and software systems.

Also, the relation between the sampling positions of the luminance and color-difference signals is such that PB′ and PR′ samples are cosited with odd (i.e., 1st, 3rd, 5th, 7th) samples of the luminance component in each line (see Figure 3).

The Issue of Square Pixels

The SMPTE committee spent considerable time examining the merits of a proposal quite new to the TV industry — the square pixel.

Originally proposed by representatives from the graphics industry, the existence of square pixels, i.e., an orthogonal sampling grid with equal horizontally and vertically spacing, although a desirable feature for low-end computer graphics systems (because simple software tools can ease hardware demands for still-image manipulation), need not be required for more complex graphics and image processing terminals.

The latter point has been demonstrated universally in post production settings for quite some time with the commercial availability of sophisticated computer graphics and special effects generators for 4:2:2 pictures in the 525-/625-line studio component world (which by definition do not have square pixels), and more recently by similar equipment showing the same versatility in image manipulation utilizing the 1125/60 HDTV format.

The committee was confronted with the following facts:

- The 1,035 active lines of 1125/60

HDTV system were already specified in SMPTE-240M.

- The number of 1,920 active pixels was highly attractive because of the hierarchical relationship with CCIR Rec. 601 (which would facilitate easy down conversion to 525-/625-line systems).
- The new picture aspect ratio for HDTV was internationally agreed to be 16:9.

These parameters give rise to pixels with an aspect ratio of:

$$1920/1035 \times (9/16) = 1.043,$$

4.3% deviation from perfect squareness.

This value should be compared to the 10.4% and 8.4% deviation values of 525- and 625-line 4:2:2 systems respectively. Notice further that even such deviations from perfect square pixels do not materially affect the software and hardware calculations that have to be performed when executing special image manipulations, because the scaling factors, in most cases, are incorporated in the numerical factors used in the 2-D and 3-D rendering algorithms.

DYNAMIC RANGE CONSIDERATIONS

As indicated above, the quantization assignment chosen for CCIR Rec. 601 established video signal black at level 16, and nominal white at level 235. These levels leave a small amount of "foot room" and "head room" to cope with inevitable overexcursions introduced by analog and digital processing (ringing introduced by filtering, image manipulations, etc.) common in any real production/post-production environment. However, to ensure a safe system design quantization levels 16 and 235 (for an 8-bit system) must be viewed to represent the ultimate black and white "clippers." All useful video signals must fit within these two levels. Unfortunately, in practice they do not. In particular, cameras have considerably relaxed the control on video level with the advent of adjustable "Knee Control" circuits.

In tackling the problem all over again within a new HDTV system, the committee felt that the system problem should be squarely addressed: this same rationale must be rigorously employed within the HDTV environment. The most optimum "fit" can only be made when the live HDTV camera or telecine black and white clippers are set to precisely correspond to these two levels. This correspondence is established by the proposed digital HDTV-240M interface standard because it ensures the proper correlation between camera final output clipping settings and digital levels 16 and 235. Figure 4 depicts the process.

In view of this rationale, the Ad Hoc Group has produced a set of guidelines for the operation of HDTV cameras that will ensure proper digital acquisition of large dynamic range camera output signals (resulting from creative exposure beyond nominal white level in the viewed scene). The following relationship between the camera analog signal values and the quantized representation should be observed:

- An upper level of 700mV and a black levels of 0mV should correspond to the absolute maximum (peak-white) and minimum (black level) HDTV signal levels, respectively.
- The effects of camera highlight processing, such as Knee and Slope characteristics, should be included within the aforementioned range.
- Overshoot/undershoot effects caused by video processing circuitry can exceed the above limits.
- The peak-white level of 700mV should correspond to the quantization level 940 in a 10-bit system or to level 235 in an 8-bit system.
- The black level (0mV) should correspond to level 64 in a 10-bit system or to level 16 in an 8-bit system.

Further studies are necessary to continue the work for the precise description of the camera compression curves ("Knee and Slope") in order to achieve the desired extended exposure capabilities within the 700mV range. These studies are being carried out by another SMPTE Ad Hoc Group on HDTV Production Colorimetry.

TRANSIENT REGIONS

The SMPTE-240M HDTV production standard makes use of a picture aspect ratio of 16:9, with 1,920 pixels (proposed) per active line by 1,035 lines. However, the digital processing of the HDTV analog signal sometimes produces various forms of "transient effects" that must be taken into account for the proper use of the HDTV studio digital signal within real-world systems. Based on a considerable body of experience with the 4:2:2 digital system, it is now recognized that among the factors that contribute to these effects, the following are the most important:

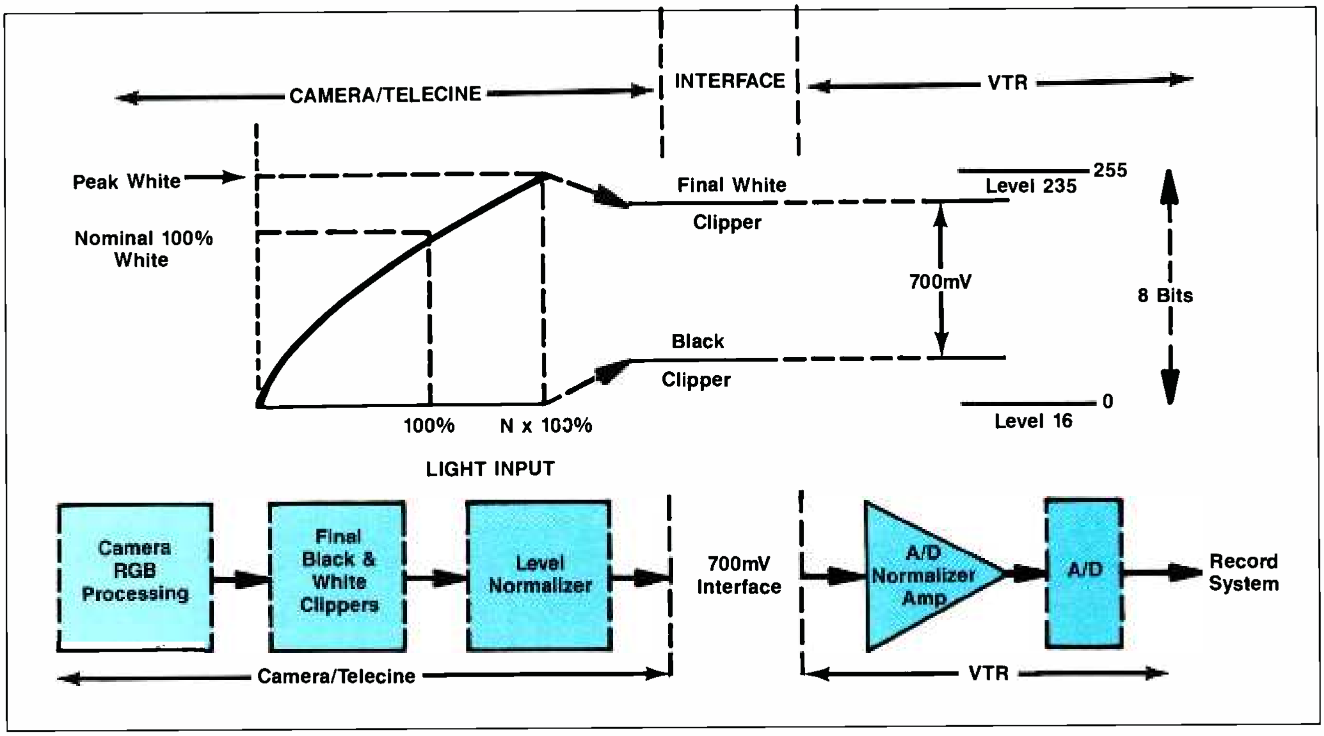


Figure 4. Considerations for HDTV camera-to-VTR (peak video excursion) interface.

- Bandwidth limitation of component analog signals (most noticeably, the ringing of color-difference signals, and the compound effects of filtering in tandem A/D and D/A conversions).
- Amplitude clipping of the HDTV signals due to the finite dynamic range of the quantization process.
- The use of digital blanking in repeated analog-digital-analog conversions.

This was an area of study which benefited immensely from the painful experiences gained by the post-production industry throughout the 8-9 years of work with digital 4:2:2 equipment.

In order to accommodate the needs of spatial filtering during post-production operations (with its possible recurrent reduction of active picture area), as well as to consider the aforementioned limitations, the following technical guidelines have been recommended:

- A Production or Origination Aperture for the HDTV studio digital signal, defining an active area of 1,920 pixels by 1,035 lines of video information, will be produced by HDTV cameras, digital HDTV tape recorders, and computer generated pictures that conform to the 1125/60 standard. This video information should be stored and processed by all HDTV studio equipment.

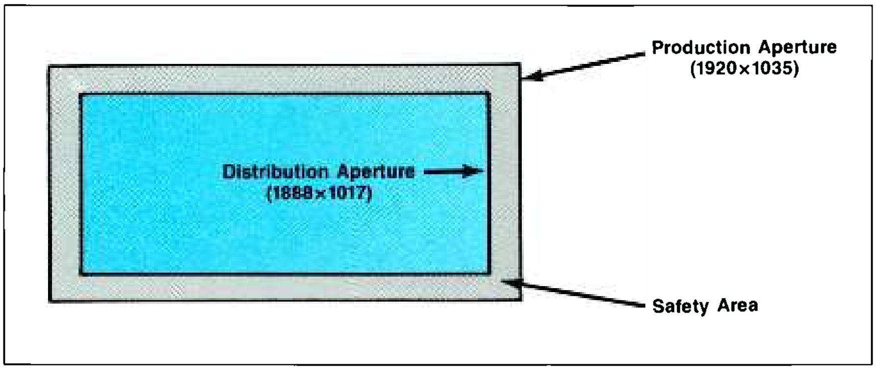


Figure 5. Production and distribution apertures.

- A Distribution Aperture is defined by 1,888 pixels by 1,017 lines (Figure 5). This video area could result from the various degrees of spatial filtering and/or methods for handling the horizontal and vertical edges of the picture under normal post-production processing.
- The definition of this distribution aperture implies the existence of a Safety Area that can accommodate, if required, various amounts of picture transient effects. This area is defined by 16 samples on each side and 9 lines at both the top and bottom of the production aperture. This gives rise to a possible minimum picture area of 1,888 pixels by 1,017 lines, within the production aperture, whose quality is guaranteed for final distribution.

It is proposed that a final edited HDTV master that fits anywhere within this safety area will be in compliance with the proposed standard.

FILTERING CHARACTERISTICS

Spectral characteristics of the component video signals must be restricted to eliminate aliasing. Digitizing Y′, $P_{B'}$ and $P_{R'}$ components (with bandwidths of 30MHz and 15MHz, respectively, as defined in SMPTE-240M), can be achieved by using filters whose insertion loss characteristics are scaled up versions (5.5 times in the frequency axis) of filtering characteristics recommended for 4:2:2 signals. The details of such filters can be found in the recommendations of the SMPTE Ad Hoc Group.

THE BIT-PARALLEL DIGITAL INTERFACE

The transport protocol as well as the mechanical and physical configuration of a bit-parallel digital interface for 1125/60 have been studied both by the members of the SMPTE Ad Hoc Group and by the Broadcast Television Association of Japan.

The present consideration is that the signals on this interface can be transmitted using a multi-core shield-type balanced cable for distances of up to 20 meters. A single connector has been proposed for the interface, which has a total of 93 contacts (three contacts for the shield-type twisted wires; two contacts for the balanced signal pair and one contact assigned to the shield) and is capable of transmitting:

- Y′, $P_{R'}$, $P_{B'}$ at 8 bits (22:11:11 member of Rec. 601 hierarchy)
- Y′, $P_{R'}$, $P_{B'}$ at 10 bits (22:11:11)
- R′, G′, B′ at 8 bits (22:22:22)
- R′, G′, B′ at 10 bits (22:22:22)

(plus a signal pair for clock information at 74.25MHz).

The final standard will include specs for the following interface parameters:

Signal
- Video digital data
- Digital blanking characteristics
- Timing reference codes
- Ancillary data
- Identification codes
- Clock signal (tolerances, jitter, etc.)
- Electrical interface characteristics

Mechanical
- Mechanical characteristics of connector and cable assemblies.
- Drawing diagrams for the connector and cable.

CONCLUSION

Although an all-digital description might be written for a video related data stream used within a computer workstation or all-digital manipulation environment, this cannot be true for HDTV. The HDTV production standard must completely describe the primary attributes of the studio signal origination — the electrical signal parameter set produced by a totally analog optical-electro transformation by the HDTV camera. It must also encompass the electro-optical transformation at the far end of the system — the analog HDTV display.

Elements of these signal parameter sets may indeed be described by a digital representation, but some fundamental analog representations are still central to the standard. SMPTE-240M is an HDTV production standard that describes completely the needed parameters that circumscribe signal origination, interface and display.

Once the signal has been generated by the camera, the signal can be treated exclusively in digital or analog form, or, as is more usual within a total system, in a hybrid digital and analog manner.

The recent major work of SMPTE in detailing a complete digital representation of the 1125/60 SMPTE production signal format, which carefully overlays the existing basic SMPTE-240M standard, will effect a complete description of the production standard. This has been established in a way that will enable manufacturers to design both digital and analog equipments, and will allow users to assemble total systems that are configured as completely digital, analog, or hybrid analog/digital.

The pace of digital implementation of HDTV studio equipment is already vigorous. Digital HD VTRs, digital production switchers, digital video effects, digital frame recorders, digital image enhancement in cameras are already emerging and are almost all in conformance with the proposals currently under study by SMPTE. This confident commitment by many manufacturers is, in itself, a significant testimony to the exemplary work of the SMPTE in forging solid, all-encompassing studio standards for HDTV.

HDTV 1125/60 GROUP MANUFACTURER MEMBERS

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Fujitsu America,Inc.
Grass Valley Group, Inc.
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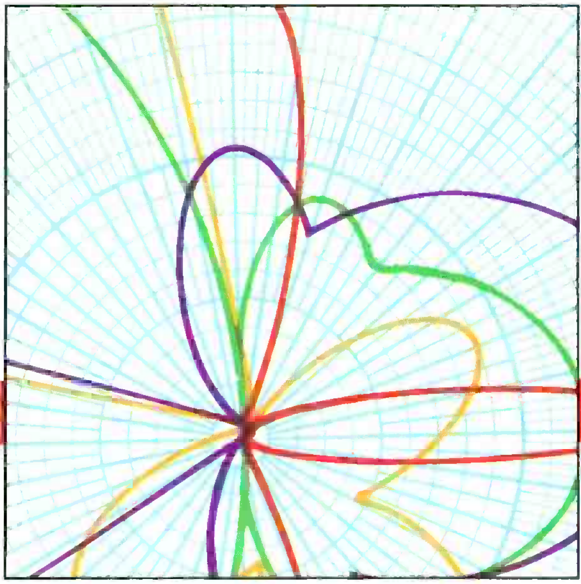

Solid-state vs. tubes in TV transmitters

The last stand of the final tube: showdown or standoff?

By Skip Pizzi, technical editor

Most large-scale technological transitions take place gradually. The new innovation replaces the old standby over a period of time. How quickly the phase-in process occurs is usually due to how improved the new technology is over the old way, especially in terms of cost-effectiveness.

This scenario has unfolded numerous times as electric recording replaced acoustic, magnetic recording superseded mechanical transcription, color supplanted black-and-white, stereo transcended mono and as digital now outpaces analog.

An example of such technological transfiguration is the conversion from tubes to solid-state devices. The transistor is responsible for no less cataclysmic a development than the so-called second industrial revolution. However, just as the steam engine wasn't instantly integrated into our society in the first run of that series, neither was the transistor in the sequel.

Now that the solid-state transition has run its course, a technical world of tubes alone seems almost as bygone an era as those pioneers of steam. You can only ponder how things might be today had that second revolution not taken place. It is hard to believe that it has all happened within our lifetime. (Well, for most of us at least.)

The conversion is so complete that most electronics courses today begin with semiconductors, and make only later or passing reference (if any) to tubes. Nevertheless, there are a few places where vacuum tube technology has not given way to solid-state devices, and the broadcast transmitter is among them. It's in good company, with military and other vital secure-radio links employing tubes for their immunity to the electromagnetic pulse (EMP) predicted in the case of nuclear war, the telecommunications industry sticking with tubes in satellites and their uplinks, and the high-end recording studio and audiophile communities using tubes (often expensive or difficult to find) in their classic microphones and esoteric power amplifiers.

In all of these cases, with the juggernaut of a solid-state invasion to contend with, there must be significant reason for these pockets of tubes' survival. Final tubes in broadcast transmitters have held off the onslaught for a number of good reasons, and it should come as no surprise that the ever-present cost-effectiveness issue is one of them. However, even this high-powered province has now been challenged by solid-state devices, and fully solid-state transmitters are coming on-line in every broadcast band.

Nevertheless, the state-of-the-art is not inactive in the world of vacuum tubes, where new developments continue as applications warrant.

Broadcast Engineering felt that with the battle thus engaged, the two sides should be presented on neutral turf. Two articles dealing with solid-state and tubes are a sort of point-counterpoint by some practitioners within both parties of the fray. Although it is unlikely the dispute will be settled, these two articles may help you understand the relative merits of these divergent approaches. In any event, the broadcaster benefits from the improved hardware that results from such techno-sparring, because there is no better incentive toward excellence than a worthy opponent.

The case for solid-state

By Martha Rapp

Recently, a TV station manager made a sobering observation during a visit to a transmitter factory. "I don't know where our transmitter is," he confessed, "and I'm not so sure I want to know. Frankly, I'm afraid of it."

There were good reasons for his fear.

His station was getting ready to replace a tube transmitter. From the manager's perspective, the aging transmitter had become an essential liability that not only *could* — but too often *had* — gone off the air without warning.

Lost revenues from unscheduled off-air time were only the beginning. The transmitter had become a financial drain in other ways as well. It required a constant supply of spare parts, including aural and visual tubes that seemed to be steadily increasing in price. It required a lot of expert maintenance by highly trained engineers who really had to know what they were doing to work around high-voltage power supplies. Furthermore, despite on-going preventive maintenance, the transmitter often seemed to operate at the whims of the environment.

Although vacuum tubes have operated successfully as final amplifiers since the advent of television, their inherent shortcomings added up to the reasons why this manager had developed a fear and dislike of TV transmitters. On a broader scale, these problems also explain why TV broadcasters would be so quick to embrace solid-state replacements.

Indeed, the application of solid-state to broadcast transmission equipment is not new. The first all-solid-state medium-wave transmitters were introduced in the late 1960s. Gradually, continued advances in semiconductors have made it possible to replace tubes with solid-state devices at progressively higher frequencies. Since the late 1980s, broadcasting has witnessed the steady introduction of solid-state technology in FM, VHF TV and even low- and medium-power UHF TV transmitters.

Understanding on-air availability

Without question, the most important requirement for any broadcast transmitter is on-air availability. On-air availability is the percentage of time a transmitter (or any system) is, or could be, in service. Three variables are used to determine on-air availability.

The first is *mean time between failure* (MTBF) or expected reliability of the transmitter over time. Reliability can be expressed by a simple equation:

$$P(a) = e^{-\lambda t}$$

Where P(a) is the probability of availability, λ is the mean failure rate of a device over time, and t is the amount of operation time in hours.

By summing the individual failure rates of devices in a transmitter, then calculating the overall reliability P(a), it is possible to estimate system reliability.

The following are a few important facts worth noting:

- Overall system reliability will decrease as the number of independent (non-redundant) devices operating in series increases.

Continued on page 68

Rapp is manager of RF marketing communications for Harris Allied Broadcast, Quincy, IL.

The case for tubes

By Guy Clerc and William R. House

Sitting in front of the television, you can easily be excused for thinking that electron tubes (or *thermionic valves*, as they were once called) have virtually disappeared from your life. The transistor radio was the first major solid-state innovation, making wireless even more so. Next, record players and tape recorders succumbed to the transistor, bringing hi-fi into many more homes. Today, even the TV set is almost completely solid-state.

The battle has begun to conquer radio and TV transmitters, and there is a general sense that even if some problems remain, solid-state transmitters are the inevitable future. Some people in the industry believe, however, that electron tubes still have a bright future.

Look at your television. Despite announcements of the impending doom of the cathode-ray tube, flat panel displays have still not replaced the simplicity of CRTs for this particular application. A single electron beam (three for color) addresses all the pixels constituting the entire image, whereas other technologies require each image pixel to be addressed individually. Remember, the electron beam's movement across the screen can be faster than the speed of light, using fairly simple deflection optics.

Electron-in-vacuum systems have numerous advantages. Nevertheless, modern CRT performances would not be possible without the surrounding semiconductor circuitry. Progress is only possible by the correct exploitation of each technology, and this article will specify the applications in which electron tubes benefit broadcast transmitters.

Tubes applications remain

The ground and space segments of the telecommunications industry use microwave tubes. After the signal is uplinked by a traveling-wave tube (TWT) or klystron, the communications satellite beams it back down with a TWT amplifier. The most recent Ku-band (12GHz) space tubes meet stringent specifications with life spans of more than 15 years, efficiencies of 58% (soon to exceed 60%) and good weight-to-power ratios (900g for 130W). Direct broadcast satellites need the power of these devices, and HDTV will benefit from the large bandwidth of TWTs.

In the home, tiny magnetrons power your microwave oven. The medical industry uses image-intensifier tubes, which reduce the X-ray dose that a patient receives. It also uses tubes to help break up kidney or gall stones, and to cure cancer.

Air traffic control uses radar tubes, as does the radar surveillance of national defense systems. Other military applications include electronic countermeasures and night-vision equipment.

For the future, in the search for new sources of electric power, multimegawatt tetrodes are already used for plasma heating in fusion experiments. Research has led to the development of new tube types, including gyrotrons, which are capable of producing high outputs at extremely high frequencies. All of this work results in spin-off improvements in conventional tube types, which can be applied to broadcast hardware to increase efficiencies, lengthen lifetimes and improve associated cost-effectiveness.

Continued on page 76

Clerc is R & D manager for power-grid tubes, and House is technical writer for Thomson Tubes Electroniques, Boulogne-Billancourt, France.

Solid-state

Continued from page 67

• Overall reliability for any system that uses several independent (non-redundant) devices in series will always be less than the reliability of each individual device in the system.

• Overall reliability of a system that uses several independent (non-redundant) devices in series will never exceed the reliability of the weakest device in the series.

The second variable used to determine on-air availability is *mean time to repair* (MTTR) — the average time, in hours, needed for repairs should a failure occur.

The third variable is *mean preventive maintenance time* (MPMT) — the average time, in hours, required to perform routine maintenance.

Given these variables, on-air availability for a specific transmitter can be calculated with the following equation:

$$\text{On-air availability} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR} + \text{MPMT}} \times 100\%$$

It is significant to note that mean time for repairs and preventive maintenance — traditionally presumed to be downtime — will significantly affect transmitter on-air availability. To this end, exceptionally low system MTBF is of little value if system MPMT is inordinately high.

This point can be illustrated by comparing on-air availability for two transmitters. Transmitter A has MTBF of 200 hours, an MTTR of five hours and an MPMT of 15 hours. Transmitter B has an MTBF of 100 hours, an MTTR of 15 minutes and an MPMT of four hours. By using these figures, it is possible to calculate on-air availability for each transmitter:

Transmitter A Availability = 200 ÷ (200 + 5 + 15) × 100% = 90%

Transmitter B Availability = 100 ÷ (100 + 0.25 + 4) × 100% = 95.9%

Although Transmitter A's MTBF is *twice* that of Transmitter B's, its actual on-air availability is *less*, because mean times for repair and maintenance are significantly higher.

How solid-state can improve system on-air availability

Inherently, solid-state devices are more mechanically reliable than vacuum tubes. Today's devices make it practical to develop solid-state transmitters that economically achieve far greater on-air availability than is feasible with vacuum tubes.

Transmitters designed to exploit the characteristics of solid-state devices will increase on-air availability in two ways. First, their highly redundant, modular architecture will dramatically increase mean time between failure. Second, thanks again to their system architecture, they will require significantly less off-air time for maintenance and repair.

The most important requirement for any broadcast transmitter is on-air availability.

Increasing transmitter MTBF

From the beginning, several factors have compromised the on-air availability of even the most reliable tube transmitter. Most significantly, the typical tube transmitter operates many different independent devices in series without backup. Consequently, the failure of a single critical device in the RF chain (for example,

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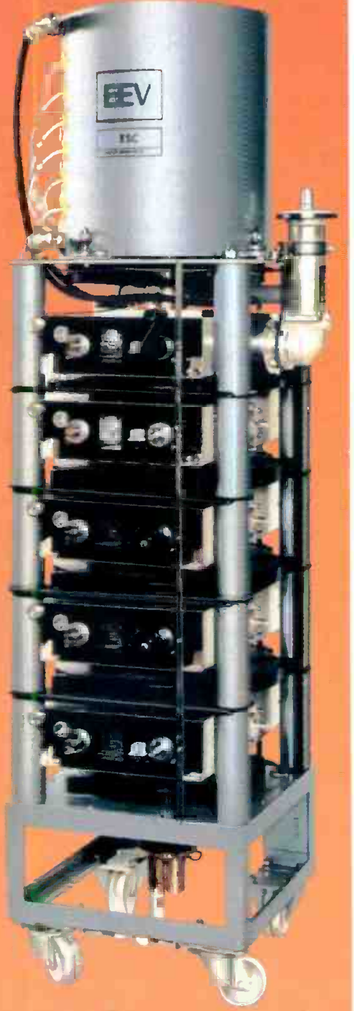

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a tube, a cavity component or the HV plate supply) will result in a total loss of signal. (See Figure 1.)

To overcome this problem, many TV stations have opted for a main/alternate configuration or a backup transmitter. Such options unquestionably increase reliability, but they also increase capital equipment (transmitter, switching system and floor space), maintenance and power costs. Traditionally, however, many stations have absorbed such expense as a hedge against lengthy off-air time.

Perhaps the single biggest advantage of solid-state transmitter technology is that it could possibly eliminate the need for backup transmitters and their associated expenses, without compromising (and most likely improving) overall on-air availability.

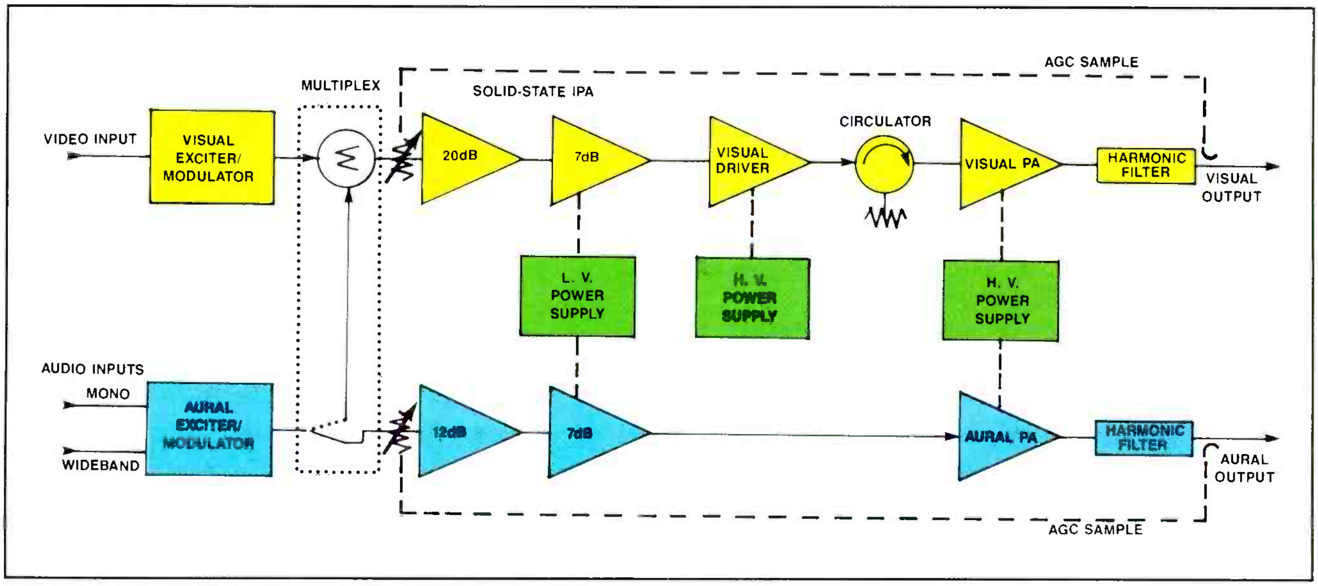

Figure 1. Block diagram of a typical tube VHF TV transmitter.

There is a simple reason why. To a large extent, a well-designed solid-state transmitter will replace the single-point-of-failure components used serially in the RF chain of a tube transmitter with multiple, identical subassemblies that operate in a parallel/redundant configuration. (See Figure 2.)

Called *parallel redundancy*, it is easy to see why this design approach will result in a significant increase in reliability (MTBF). Assume a single vacuum tube is replaced by four identical solid-state power amplifier modules that operate in parallel. When only one module is required for adequate system operation, the probability of overall system failure is greatly reduced. Although the failure of one or more of the redundant modules will cause transmitter output power to drop, it will not take the transmitter off the air.

Beyond parallel redundancy, solid-state devices have other characteristics that can be exploited to increase on-air availability:

- Solid-state amplifiers generally are designed with built-in fault protection. A solid-state power amplifier may protect itself from voltage standing wave ratio (VSWR), overtemperature, over/undervoltage or RF input overdrive conditions. Similarly, a power supply may have built-in overcurrent, overvoltage and overtemperature protection. The result is a transmitter that is highly forgiving to human error, to many ambient extremes, and even to such hardware failures as short and open circuits on the antenna or transmission line.

- Because a solid-state TV transmitter requires only low-voltage (50V) power, regulated power supplies can be used. Regulated power supplies will ensure constant signal quality day after day under virtually any combination of brownout, overvoltage, surge or line voltage variation conditions. Additionally, low-voltage power supplies are not prone to corona, arcing or other problems resulting from the high voltages needed to power beams, grids and screens in a tube transmitter.

- In a solid-state transmitter, energy that is *not* converted to RF power is dissipated by many devices, rather than just by a single tube. As a result, the solid-state transmitter runs cooler. Depending upon operating conditions, a transistor can operate from 50,000 to 1,000,000 hours, whereas a tube can operate from 7,000 to 13,000 hours.

- A solid-state transmitter can cold start in about two seconds; the phase lock loops only need to lock into the exciter before full operation begins. This characteristic enables a solid-state transmitter to return to air quickly after mains power failure, while a tube transmitter may require a few minutes for filament warm-up.

- Modular solid-state transmitters are designed to provide greater transient protection than tube transmitters, because tubes are more forgiving to transients.

Decreasing MTTR and MPMT

In a tube transmitter, the non-repetitive, serial operation of critical components affects on-air availability by increasing mean time for routine maintenance and repair, most of which must be performed when the transmitter is off the air.

Moreover, the inherent complexity of tube transmitters and the presence of high-voltage power requires a highly skilled and RF-experienced engineer for maintenance and repair work.

For optimal operation, a tube transmitter will require constant tuning and interactive adjustments. Extensive technical skill also is needed to properly interpret meter readings to ensure proper adjustments.

Tube operation also demands inventory management. Most stations with tube transmitters stock one of each type of tube used in the transmitter. However, even when sitting on a shelf, vacuum tubes age, becoming gassy and deteriorating in other ways. Consequently, they need to be rotated into the transmitter every several

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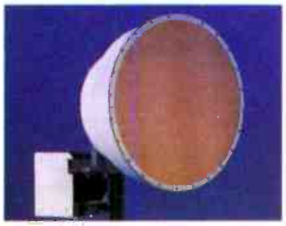

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months. Changing tubes is a complex process involving fingerstock, sliding and moving parts and cavities. Indeed, most maintenance and repair procedures in a tube transmitter require significant RF technical expertise.

In addition to providing far greater transmitter MTBF, solid-state technology can increase on-air availability by overcoming many of the repair and maintenance requirements and complexities typical in tube transmitters.

Commonly, a solid-state transmitter with modularity and parallel redundancy will eliminate the need for most routine maintenance. In fact, a solid-state transmitter can be designed to require up to 90% *less* preventive maintenance than a tube transmitter. (See Table 1.)

In addition, a good solid-state architecture will allow much required maintenance and repair work to be performed while the transmitter is in operation. For example, low-voltage power and high modularity can enable redundant "hot-pluggable" power amplifier modules to be removed, tested and reinserted safely while the transmitter is on the air.

Obviously, it would be impossible to bench test the power amplifier of a tube transmitter during transmitter operation.

Accommodating technology to people

Finally, solid-state technology will outdistance vacuum tubes in the increasingly important area of human interface.

Solid-state

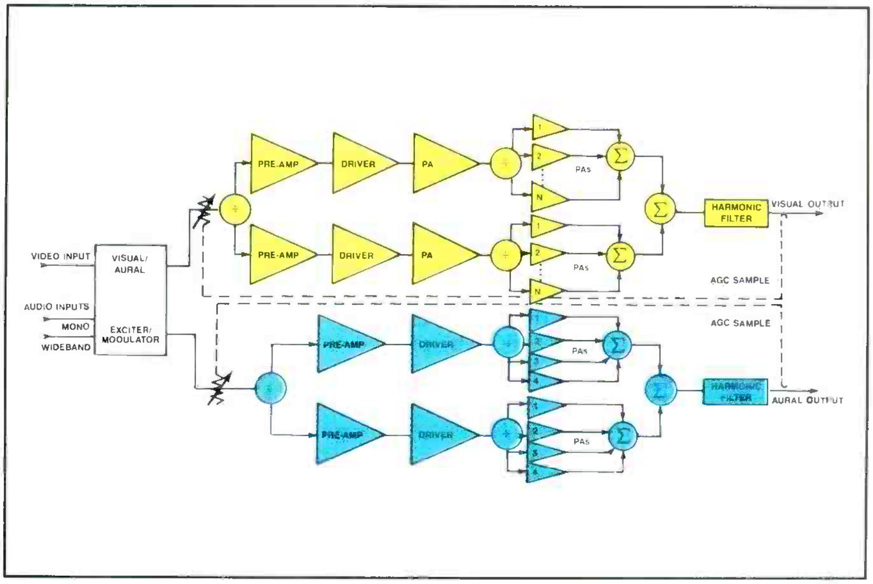

Figure 2. *Block diagram of a typical solid-state VHF TV transmitter, showing multiple low-voltage PA stages. (N will vary with transmitter TPO, but typically ranges 15 to 20 or higher.*

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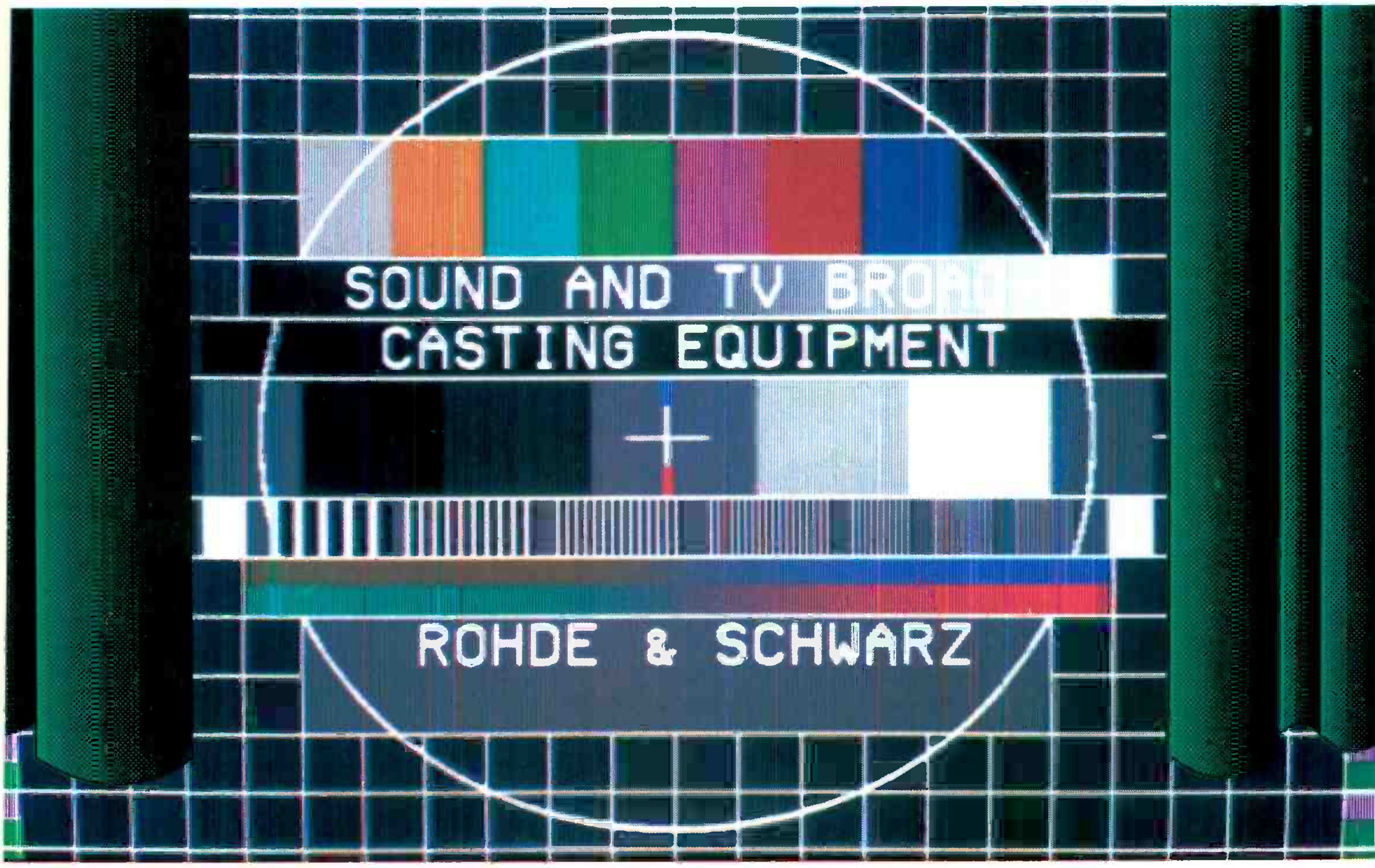

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For years, the number of experienced broadcast RF engineers has been declining at a disturbing rate. Many experienced broadcast engineers who were trained by the military in the 1940s and '50s have

Solid-state

reached or are nearing retirement, making it difficult to find equally skilled replacements. Often, studio engineers who are more comfortable with low-voltage equipment are given RF responsibility. At the same time, the amount of technical equipment in most facilities has increased

This presents a situation in which the personnel charged with operating, maintaining and repairing today's transmitters have, in many cases, inherited RF responsibility by default. Most of these station engineers already are stretched by extensive other demands, and they are not particularly enamored with transmission systems that operate at high-voltage levels.

Solid-state technology is, therefore, the best available approach toward achieving exceptional on-air availability, while effectively responding to the current needs of TV broadcasters.

RECOMMENDED TRANSMITTER MAINTENANCE COMPARISON

Frequency	Tube-Type Transmitter	Solid-State Transmitter
Weekly	Read all meters Calculate tube dissipations	Check display screen
Monthly	IPA input and output tuning, loading and coupling PA input and output tuning, loading and coupling Adjust and replace belts Adjust hum null Adjust all tube bias voltages Adjust group delay Adjust differential gain, differential phase, ICPM and frequency response	Adjust differential gain, differential phase, ICPM and frequency response
Semi-Annual	Clean filters (transmitter off-air) Output power calibration AGC or automatic power control setup Adjust filaments Clean tubes Clean and zero meters	Replace filters (transmitter on-air) Output power calibration Check AGC
Annual	Change tubes, clean cavities, and replace fingerstock Measure three oscillator frequencies Check dashpot fluids Tighten hardware	Measure one oscillator frequency Tighten hardware

Table 1. *Transmitter maintenance comparisons between tubes and solid-state.*

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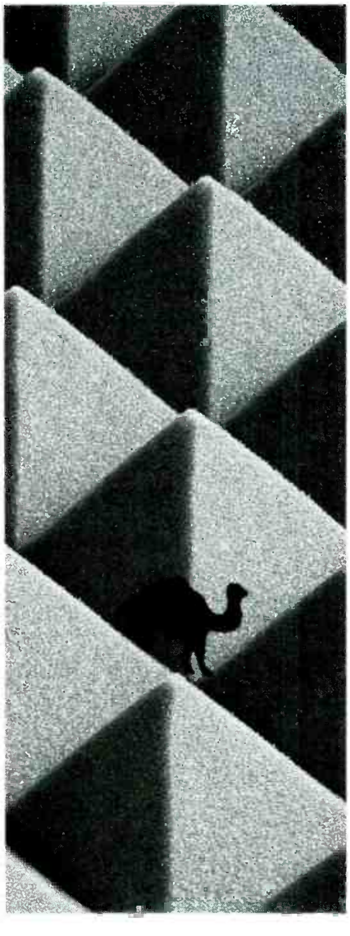

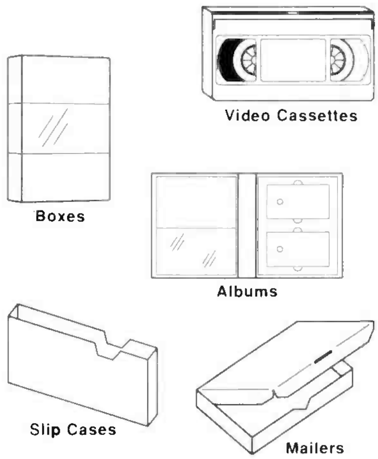

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It is unlikely that so much money and effort would be put into this technology if it were obsolescent, or of diminishing applicational value.

Tubes

If it's power you want...

The first efforts to build high-power amplifiers with gridded valves required many tubes in parallel in the output stages. This multiple redundancy situation was considered cumbersome by the engineers of that time, and much effort was put into R&D to increase the power of each tube.

The results are obvious. A 1MW tetrode has been made for LW/MW radio broadcasting; and for FM radio, power outputs of 100kW are possible with a single tetrode. Most recently, a 42kW tetrode for UHF television has reached the market. Klystrons of 60kW in bands IV and V result in transmitters with TPOs of up to 250kW. These were the same devices that enabled such frequencies to be considered for broadcast use in the 1950s.

This high-power capability comes from the ability of electron/vacuum systems to contain high-power densities. Values run typically at several kW/cm^2 and can exceed $100MW/cm^2$. No known dielectric material can equal these values. For the foreseeable future, if high power is required, electron/vacuum devices will remain the only solution.

Perhaps a review of the operating principles of broadcast tubes is in order, along with a consideration of their relative strengths and weaknesses.

Broadcast electron tubes

Triodes and tetrodes (both power-grid tubes) historically were the first used in broadcasting, and are still widely used today. A grid modulates the current between the electron-emitting cathode and the anode collector. The tetrode uses a second grid that acts as an electrostatic screen, reducing the control-grid/anode interelectrode capacitance, and thereby improving performance.

At higher frequencies, two phenomena complicate tube operation. If the transit time of the electrons between the cathode and the control grid approaches the period of the wave ($T = 1/f$), the electrons are alternately accelerated and slowed, and the amplification effect is minimized, if not completely canceled. The second effect is due to the RF circuits. On one hand, phase differences through the circuit must be taken into account. On the other hand, the high-frequency energy flows through a narrow surface layer (skin effect), increasing losses due to surface resistance. These issues limit the domain of the tetrode to approximately 1GHz.

As TV broadcasting moved into the higher frequencies of UHF, klystrons (microwave tubes) made power levels of 10kW and above possible. Instead of modulating the current, the electrons are confined in a beam along a linear path by a magnetic field, and the RF signal causes the electrons to be accelerated or slowed through interaction with tuned cavities (the so-called *velocity* modulation process). Therefore, the electrons form into bunches, and the amplified RF power is obtained from the final cavity.

Unfortunately, klystrons are not linear devices, so they have to be designed into Class A amplifiers, which are not efficient. Tetrodes are much more linear, and can be designed into Class B circuits, making much higher efficiencies possible. The *inductive output tube* (IOT), which takes the cathode and grid from the tetrode, and the line and collector from the klystron, is an effort to combine the high-power/high-frequency capabilities of the klystron with the Class B operation of the tetrode.

Tube or solid-state?

The advantages of transistors are well-known — small dimensions, low operating voltage (resulting in low impedance and potentially large bandwidth), and no thermionic cathode ("instant on" capability and no inherent wear out mechanism). They are, however, sensitive to voltage overloads and to temperature.

Transistors are also relatively low-power devices. Power is the product of voltage and current, so the current that a 100V transistor would have to support for a 20kW output would be 200A. High-power, solid-state transmitters are, therefore, condemned to be multiple-component systems with all the problems of increased unreliability that this implies.

If high power is required, electron/vacuum devices remain the only solution.

Furthermore, even with parallel configurations, the management of high currents must still be dealt with. A 20kW peak-of-sync solid-state transmitter eats up 90kW on the AC line, which puts the current to be managed at 900A. On the other hand, a similar tetrode requires only 50kW of AC-line power, so the solid-state transmitter must deal with the cooling problem of evacuating an extra 40kW.

It seems more sensible not to push semiconductors into the output stages of high-power transmitters. Using each technology to its best advantage, application of semiconductors in the low-power stages of UHF transmitters paves the way in the final stage for high-power tetrodes and their advantages of low initial cost, high Class B efficiency, linearity and compact design. The tetrode has become a viable contender to the klystron despite its shorter life and lower gain.

This is not to say that low power is exclusively the domain of semiconductors. The efficiency of electron tubes can make them contenders even at 100W UHF. Triodes and tetrodes can have lives of 15,000 to 20,000 hours, and, in this case, their operating costs become extremely competitive.

A lightning strike will short the antenna, causing power to be reflected back to the output stage.

Finally, remember that transmitters have life spans of 15 years or more. Replacement parts must be available over this period. However, the production span of some transistors is much shorter and, although redesigning output modules to accommodate currently available components may be possible, this is an expensive option. Tetrodes (whose main application is in transmitters) and other electron tubes are produced over long periods, so replacement of a particular model is guaranteed.

Plant efficiency

According to the sales pitch, it is only because of recent energy cost increases that station managers have become concerned with transmitter operating costs. In reality, managers have *always* been concerned by the bills, and now, product improvements and the choice of technological solutions available today has given them the means to cut costs. So what is at stake in the decision? The energy costs depend on the transmitter as a whole. In fact, the entire plant's efficiency is what determines the monthly electric bill. The efficiency of the transmitter's power amplifier (PA) is just one part of this. Consider also the driver, the cooling circuits, the filters and every other power-consuming device needed to operate the station. A PA requiring only simple back-up circuits will, other things being equal, help cut electricity costs.

The PA is still, however, the largest sin-

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gle consumer. Although its efficiency is central, it does not depend solely on the device used, but also on its class of operation.

When considering efficiency, the term *figure of merit* (FOM) is often used. This can be a confusing term because it is arbitrary and only has meaning when two systems are compared using the same criteria. The FOM gives an expression of relative efficiency, and according to the conditions taken, can exceed 100%.

The *absolute efficiency* is the ratio of the average power output to the average power consumed, and it can never exceed 100%.

Bearing this in mind, if plant FOM is considered to be the ratio of peak-of-sync power plus aural power to AC-line power consumption at 50% APL, then tetrode-equipped VHF/UHF transmitters have a plant FOM approaching 40%. Unpulsed klystron transmitters at UHF have a val-

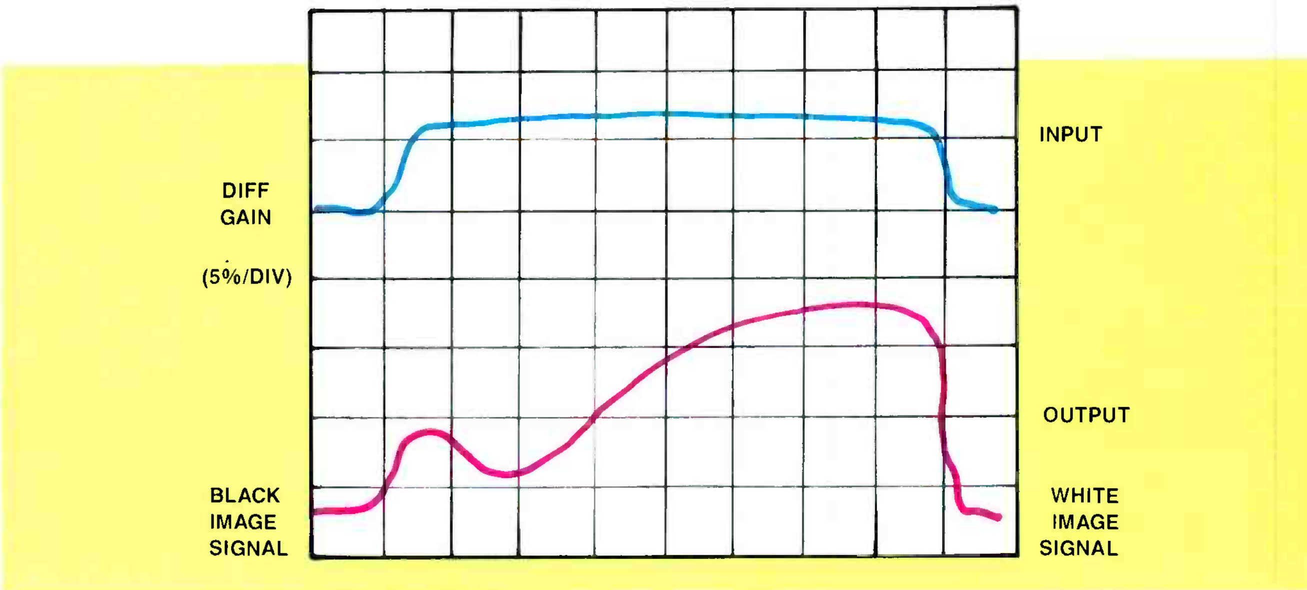

Figure 1. *Differential phase of a UHF tetrode and cavity, operating at 703MHz, with visual power of 26.5kW and aural power of 2.65kW.*

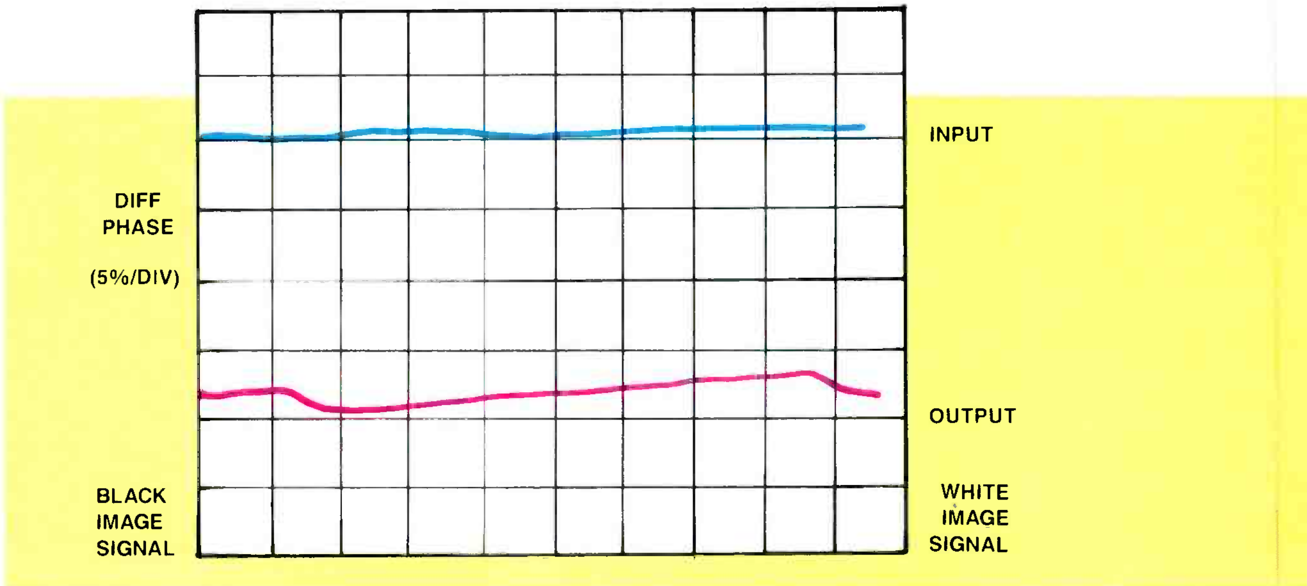

Figure 2. *Differential gain of a UHF tetrode and cavity, operating at 703MHz, with visual power of 26.5kW and aural power of 2.65kW.*

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Tubes

ue of 10% to 15%; pulsed versions reach above 20%.

These figure have convinced some in the industry of the utility of continuing research into tetrode design, with the aim of developing high-power devices in the UHF range. The linearity and efficiencies of the tetrode are further enhanced by their simple circuits and familiarity to many engineers. (See Figures 1-3.)

A UHF tetrode operating at 25kW common amplification has already entered service. Initial study of its performance is promising, with the first unit already at 14,000 hours. Extended lifetime tests have already shown the feasibility of this tube in a 42kW visual-only amplification.

Energy costs will determine which technology is the most cost-effective over a transmitter's lifespan of 15 years or more. In the case of rising energy costs, the tetrode solution holds a decisive edge.

Lightning strikes

Because of the exposed positions required to give maximum area coverage, most transmitter sites experience lightning strikes. According to basic physics, tubes can withstand a strike without a lot of protective devices. They are also able to operate with a relatively high standing-wave ratio (SWR), which has bearing here as well. Besides the high-voltage transients involved, a lightning strike will short the antenna, causing power to be reflected back to the output stage. Although none of these events is desirable, results may be less catastrophic when tubes are involved. Tubes also require less complicated circuitry to protect against such occurrences.

Tubes remain a viable solution to high-power, high-frequency amplification.

Conclusion

Today's technological landscape is being changed beyond recognition. Over time, some innovations of the past will remain and some will disappear.

Solid-state technology has taken over in certain areas, and no one can seriously contest the benefits that semiconductors have brought. Three-inch-high tubes could never have been combined to create some of the wonders of modern studio equipment. The compactness of solid-state devices has made many types of today's common circuits and hardware possible.

Nevertheless, electron tubes remain a viable solution to high-power, high-frequency amplification. This point is proven by their continuing ability to evolve, as demonstrated by the development of completely new devices (such as the IOT or the MSDC klystron), and in the application of the tetrode to high-power UHF applications, which had appeared impossible in the past. It is safe to say that tube transmitters will remain competitive into the 21st century.

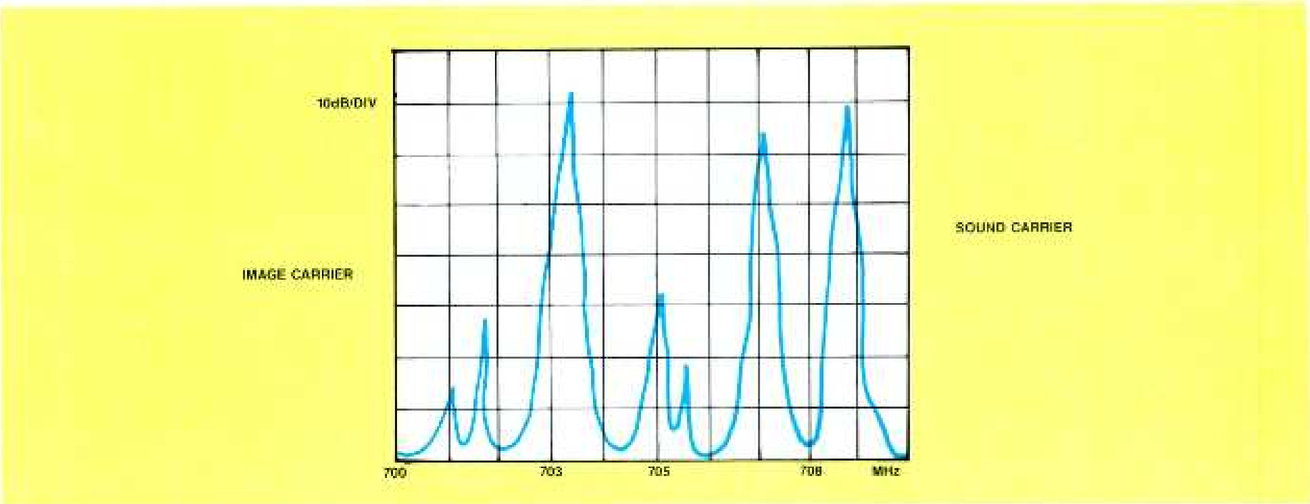

Figure 3. *Output intermodulation product of a UHF tetrode and cavity, operating at 703MHz, with visual power of 26.5kW and aural power of 2.65kW.*

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Growth of Klystrode applications continues

By George M. Badger

In December 1990, the world's most powerful air-cooled UHF TV transmitter went on the air at WSNS-TV in Chicago. The transmitter uses four air-cooled Klystrodes, operating in parallel. In this transmitter design, each Klystrode operates at 30kW, producing a TPO of 120kW on Channel 44. The four tubes also operate in the *common amplification* configuration, in which the visual and aural carriers are amplified simultaneously within each Klystrode tube. (This installation also ranks as the highest-powered transmitter to use the common amplification mode.)

The air-cooling approach provides advantages over water- or vapor-cooling systems in terms of cost, complexity and reliability. Common amplification eliminates the need for high-power diplexers and RF switching systems. The common amplification of visual and aural carriers in each tube also provides a high level of redundancy.

Technical performance is also improved with common amplification techniques, typically reducing third-order intermodulation levels to −60dB or lower.

air-cooling as more advanced tubes became available. The same trend has now reached the UHF TV transmitter.

In an air-cooled transmitter at the 120kW power output level, the acoustical noise level can be a matter of concern. For this reason, Klystrode cooling fins have been designed to be especially efficient, and collectors are optimized for minimum air pressure and flow rate. This allows significant reductions in cooling horsepower. Noise measurements made on these ripple-fin structures in the annoying high-frequency range of 6,000-12,000Hz show a noise reduction of 9-16dB in sound pressure level over earlier cooling fin designs.

Because the Klystrode collector is much larger than the anode of a power grid tube, the Klystrode runs cooler than a VHF tetrode in FM or TV service, and much cooler than a UHF tetrode.

Common amplification

In the Chicago installation mentioned earlier, two 60kW transmitters are multiplexed with phase coherence and are combined in a "Magic Tee" to produce 120kW. Each 60kW section contains a pair of Klystrodes and a modulator. (See Figure 1.) The use of separate modulators for each pair of tubes adds redundancy and improved linearity to the design.

The transmitter is, in fact, two identical separate transmitters combined with a simple, inexpensive and stable Magic Tee. The conventional configuration for a 60kW transmitter consists of two different amplifier chains — one for the visual, and one for the aural carrier, which are then combined in a tuned diplexer. Although it uses the same number of tubes as the common amplification approach, the traditional method offers less redundancy.

Linearity

The well-known high audio and video specs of Klystrode transmitters are, for the most part, due to precorrection techniques. Although the Klystrode is a non-linear amplifier (a characteristic it shares with other high-power amplifiers), its linearity stability is high. Once the precorrection is set, the performance remains consistent, with little or no further adjustment required.

Reliability and efficiency

The Klystrode shares much technology with the external cavity klystron. The Klystrode's grid is the only part of the tube that departs from established external cavity klystron technology. In the nearly three years of field experience with the Klystrode, there has never been a failure attributed to this grid.

The Klystrode has also lived up to its original claim of cutting a broadcaster's power bill in half. This has probably been a factor in its increased popularity. During the last two years, the majority of new UHF TV transmitters installed in the United States have used the Klystrode. Such rapid growth is noteworthy, considering that the first Klystrode was put on the air in June of 1988.

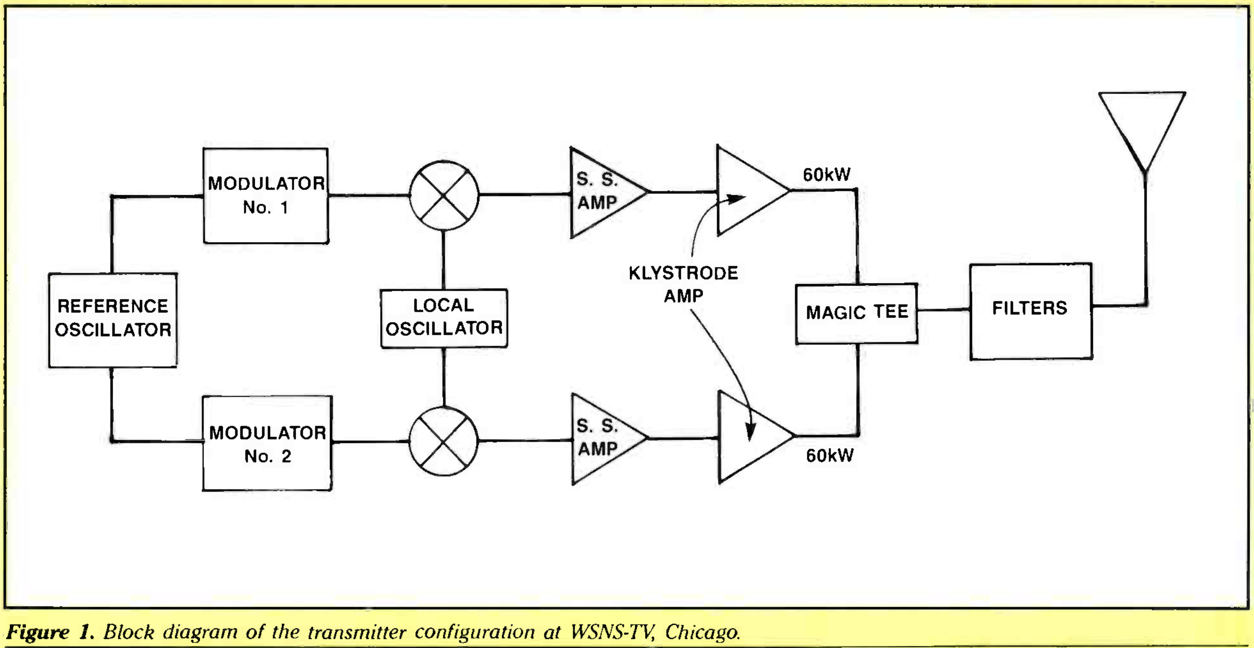

Figure 1. *Block diagram of the transmitter configuration at WSNS-TV, Chicago.*

Air-cooling

Air-cooling is not a new technique. The power grid tube industry has participated in the evolution of high-power AM broadcast transmitters from water- to air-cooling, followed by FM and then by VHF television. Broadcasters have traditionally progressed from water- to

Badger is Klystrode marketing manager for Varian, San Carlos, CA.

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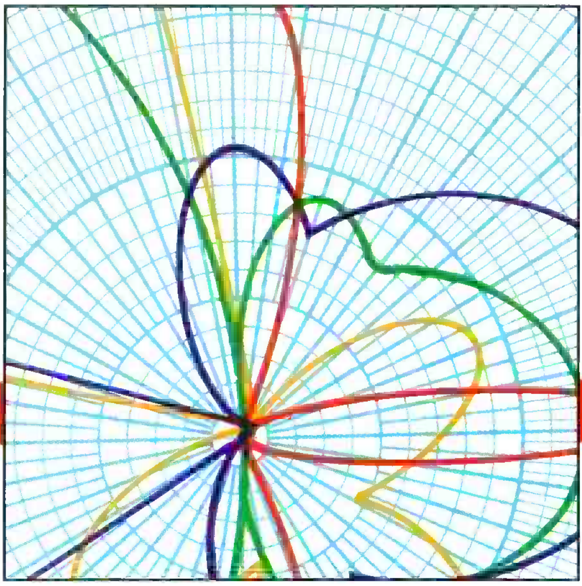

Using Loran-C for field measurements

Determining your exact location in the field can often be a problem.

By Roald Steen

Broadcast engineers must frequently go into the field to conduct field-strength measurements. In some cases, conspicuous buildings or landscape features may help you determine your exact location when making these measurements. However, there are times when such clues do not exist, especially in rural areas. Knowing the precise location of a measurement is critically important when mapping emission patterns.

The Loran-C receiver is an instrument that is now available, which can determine exact location at all times in the field.

Loran is an acronym for LOng RAnge Navigation. It is a radio navigation system that was originally developed primarily for ocean navigation, but has also been widely used in aviation navigation.

Through the modern Loran-C system, it has become a versatile tool for determining your location *on land* across the United States.

The original Loran system was called Loran-A, and was similar to Loran-C in theory, but used radio frequencies around 2MHz. This frequency was not suitable for accurate navigation because of the way radio waves propagate in this band. Radio propagation tends to vary extensively around 2MHz, depending on the season and the time of day. Loran-C uses the more appropriate frequency of 100kHz.

Steen is a certified electronics instructor and free-lance author based in Woodbury, MN.

The Loran systems in the United States are operated by the U.S. Coast Guard. In the United States, the Loran-A system was discontinued by the Coast Guard when the Loran-C system came into widespread use.

Loran is an acronym for LOng RAnge Navigation.

Theory of operation

Loran works through chains of radio transmitting stations. Within each chain there is a master transmitter and several secondary transmitters. Actual location is achieved by triangulation, based on measurement of the varying propagation delays from several of these transmitters to the receive point.

A Loran-C signal is composed of a series of pulses. Each particular chain in the system is identified by a unique delay between some of the pulses in the signal.

Identification through this short time delay is possible, because each Loran receiver contains an oscillator that accurately times the duration of the delay between the pulses.

This delay or interval between the pulses is called *group repetition interval* (GRI). Therefore, the 89,700μs delay that identifies the Great Lakes chain can be called GRI 8970. All Loran-C transmitters use the same frequency, 100kHz, so they cannot be distinguished by frequency alone. The transmitting stations in a Loran chain are equipped with accurate atomic clocks to keep the delay intervals extremely accurate.

Loran stations transmit their pulses in bursts. Atomic clocks also keep the various transmitter chains synchronized so their transmission pulses do not overlap

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in time. Therefore, signals from different chains will not interfere with one another at any receive point.

The signal from a master station is distinguished from its secondary station's signal by detection of a "phase coding" of the pulses. This coding consists of a variation in the individual sine wave elements that make up the pulse in that their leading wave goes either positive or negative. The important information for a receiver to detect is the shape of the leading edge of the pulse, which will vary in relation to the phase (actually "polarity") coding of the individual sine wave elements.

After identifying the pulses by comparing their unique characteristics with its inboard database, the receiver then measures the delay between a master and a secondary signal as received. This is enough information to place the receiving location somewhere along a hyperbolic line drawn in the area around the master and the secondary station. The hyperbolic line is called a *line of position* (LOP).

This is insufficient information to fully determine your position. This situation can be remedied by detecting the signal

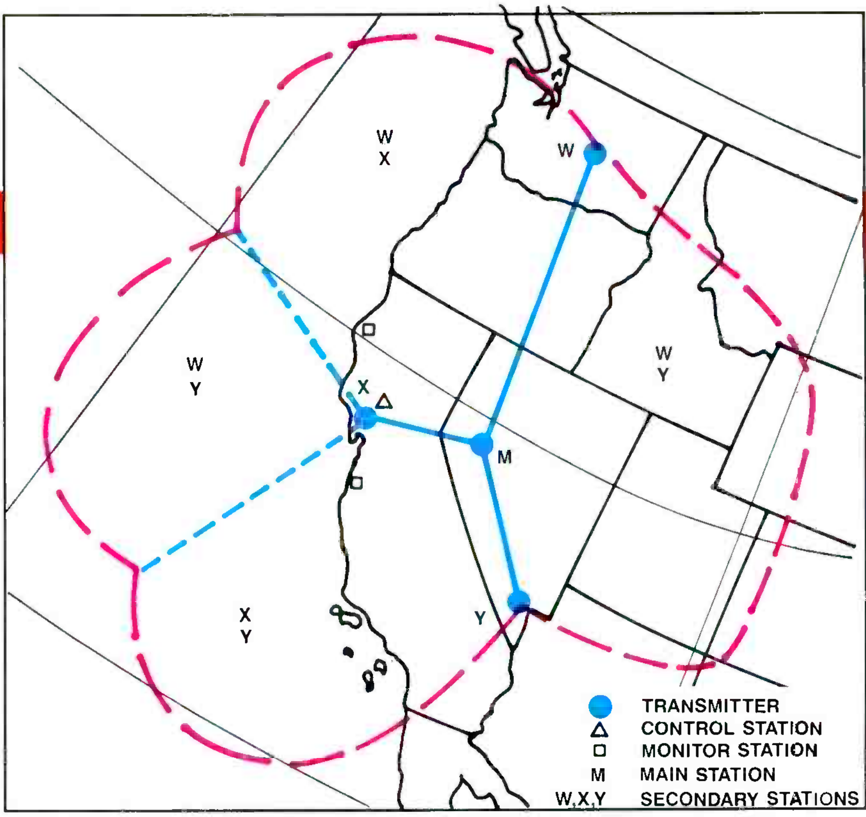

Figure 1. *Coverage map showing approximate range of Loran-C service in U. S. West Coast Chain (GRI 9940). Letter pairs (for example, WX and WY) denote the two secondary stations serving that section. Main station serves all sections shown.*

from the Loran-C master station and *more than one* secondary station. As the receiver detects the interval between the signal from the master station and *another* secondary station, a second LOP is determined. Exact location can then be determined by plotting the point at which the two LOPs intersect.

A Loran receiver may obtain LOPs from more than two secondary stations in a chain in order to more accurately determine location, or to confirm a position. In order to achieve a positive Loran position fix with most receivers, the minimum requirement is a clear signal from at least two secondary stations and the master station. More sophisticated receivers can operate in "master independent" mode, in which they can determine position with only signals from several secondaries after losing the master, or in the "multichain" mode, where signals from two separate Loran-C chains can be compared for location fixing.

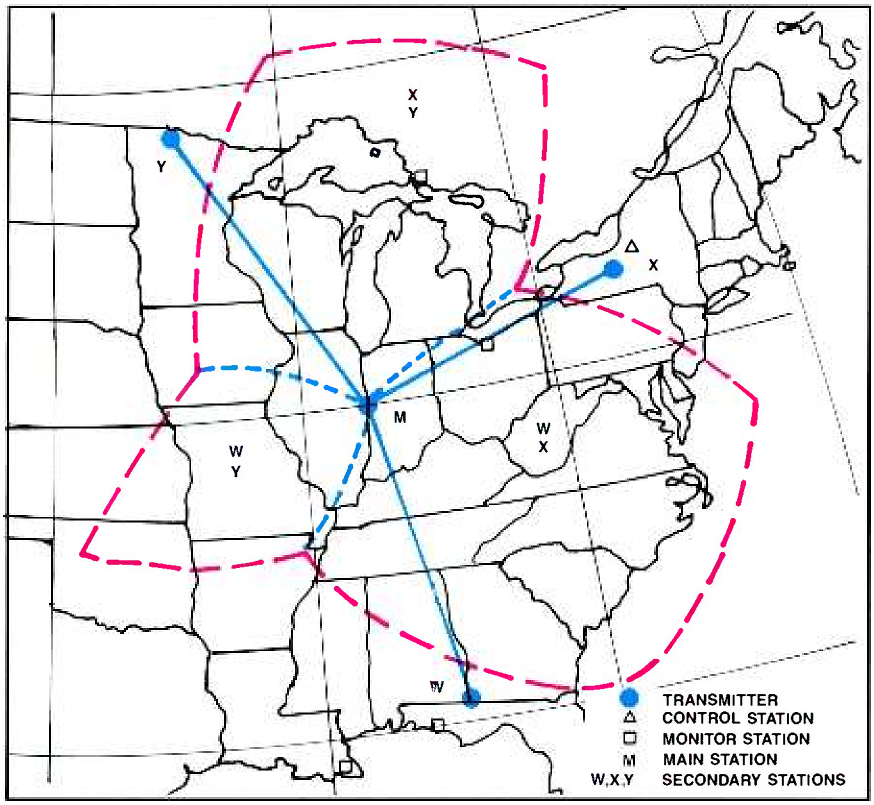

Figure 2. *Coverage map showing approximate range of Loran-C service in U. S. Great Lakes Chain (GRI 8970).*

Grid coordinate location

Navigators at sea who used the original Loran-A system had to use a special map with the LOPs printed grid-like on it to determine location. This method may have been useful for a highly trained navigator aboard a slow moving vessel at sea, but left much to be desired for other users.

The microprocessor inside a modern Loran-C receiver does almost all of this work for you. The microprocessor has information about various Loran chains stored in its memory. It interprets the information received from the Loran transmitting stations, and quickly outputs a position in longitude and latitude coordinates.

Again, navigators aboard vessels at sea are probably used to navigating by longitude and latitude, but broadcast personnel are more used to finding their way through names and features on a map.

Fortunately, many modern Loran-C receivers have the ability to provide a location in the form of landscape names. The name of a particular point of reference may be indicated together with its exact distance and bearing from the current position. For example, some advanced Loran-C receivers used in aviation contain an airport database, or store the location of other important places across the country, and can supply their output information in the form of an airport or place name plus distance and bearing to it.

However, when using Loran-C, broadcast engineers may also find it useful to determine location through latitude and longitude, because most of the topographic maps used during field strength measurements include latitude and longitude information.

Closing the gap

Although the Loran-C system works well most of the time when you're within range of a Loran chain, there are some exceptions. For example, inaccurate information may be caused by abnormal radio propagation or vehicle reflections. Radio frequency noise and interference may also cause problems.

A wide variety of Loran receivers with varying degrees of microprocessor sophistication are on the market. The higher-quality units may overcome some of the difficulties encountered in areas of poor reception. Such enhancements are a primary determinant of price of a Loran receiver. Because of the variety, completely reading each receiver's owner's manual is critical to understanding the unit's operation.

Because Loran-C was developed as a maritime navigation system, it is only natural that its coverage has been best in the United States near the coast and the Great Lakes.

There has been an unserved area in U.S. Loran-C coverage, called the *mid-continent gap*. However, the Federal Aviation Administration (FAA) and the U.S. Coast Guard have recently installed two Loran chains from Congress. These two Loran-C chains are primarily designed to serve aviation and land mobile users, although they will still be operated by the Coast Guard, with the FAA serving as an adviser.

One of the chain's master stations is located in Boise City, OK, (called Southern Continental United States [SOCUS]). The other (NOCUS) master station is located in Liberty, MT.

The chain in Liberty was built in cooperation with Canadian authorities because it includes a secondary station in British Columbia.

These Loran-C facilities eliminate the mid-continent gap, and they are scheduled to be fully operational by the time you read this article.

Therefore, the entire continental United States will be covered by Loran-C. In addition, much of Alaska is already covered by the Gulf of Alaska chain (GRI 7960) and the North Pacific chain (GRI 9990). The Hawaiian Islands are covered by the Hawaiian chain (GRI 4990).

Propagation effects

The Loran-C signal arrives at your receiver through two different routes: the groundwave signal and the skywave signal.

The low frequency of 100kHz was selected mainly because of its groundwave range. Extremely low radio frequencies such as this have the longest groundwave range.

The groundwave is the component of a radio signal that follows the surface of the earth. Groundwave effects are responsible in part for the significant range of the low AM broadcast radio frequencies, whereas their effects at FM broadcast frequencies are negligible. Because the transmitting frequency of Loran-C radio stations is even lower than the AM broadcast band, the groundwave has an even more pronounced effect. The groundwave radio signal is also quite stable, because it is not subject to variations in propagation due to sunspots and magnetic storms. Therefore, it is well-suited for navigational purposes.

Naturally, the groundwave signal is attenuated as it moves out from the radio transmitter, but its attenuation is least over water. Therefore, the groundwave Loran-C signal has the longest range across the highly conductive salt water of the ocean.

The skywave signal may reach even farther out from the Loran-C station, especially at night. The skywave, however, is subject to variations in propagation due to variations in the ionosphere (the charged atmospheric layer that reflects the skywave back to earth). These variations cause the skywave to be an unreliable signal for use in a radio navigation system such as Loran-C.

Most Loran-C receivers have the capability to distinguish between the skywave signal and the accurate groundwave signal. This is possible because the groundwave signal will arrive at the Loran-C receiver a fraction of a second before the skywave signal (assuming any groundwave signal is received).

A new system, called the global positioning system (GPS), is being instituted.

Receiver features

Although some Loran-C receivers come with keyboards for entering information and inquiries, the use of a scrolling system is more common. Unlike a keyboard, a well-designed scrolling system saves space.

A Loran receiver will be programmed with some warning messages that are displayed at appropriate occasions. For example, when the Loran-C receiver loses the reception of a chain, it will flash a loss-of-signal message. Some Loran-C receivers can flash an alert as they approach a preprogrammed location in their memory. This feature may be useful during field strength measurements; a series of fixed locations visited on each measurement trip can be loaded into the device once and recalled uniformly on subsequent occasions.

Most Loran-C receivers are made for use aboard vehicles, boats or airplanes that are equipped with a 12VDC power supply. A Loran-C receiver can also be made portable by attaching a 12V portable battery, such as a gel cell, so the unit can be used for off-road field strength measurements. Such operation can power most Loran-C receivers for approximately three hours.

Eventually, GPS will provide full 3-D data (coordinates plus altitude).

Broadcast engineers may also find Loran-C useful in some other situations, such as in servicing a remote microwave relay station or transmitter facility that may be difficult to find at night or in poor visibility.

Beyond Loran-C

A new system using satellites is being instituted for navigation and location-finding. It is called the *global positioning system* (GPS). Operating in the 1,500MHz band, this system provides even more accurate fixes than Loran-C. However, receiver hardware is more expensive. (Low-end Loran-C receivers start at around $500, while equivalent GPS units cost $1,500 or more.)

Eventually, GPS will provide full 3-D data (coordinates plus altitude), but not all the satellites required for this are in orbit yet. Nevertheless, most U.S. locations are already served with 2-D, and GPS receivers are widely available. This, coupled with the fixed nature of broadcast field strength measurements ("low dynamics" in avionics terminology), makes GPS a viable alternative right now. However, receiver costs will probably drop in the future. The GPS system is also less sensitive to interference and reflections, and will no doubt be the successor to Loran-C for most radio navigation applications of tomorrow.

Acknowledgment: Thanks to Jim Cook at Palm Beach Avionics, Ens. Bob O'Connell and Lt. (JG) Roger Barnett of the U.S. Coast Guard, and George Quinn of the FAA for their help in compiling this article.

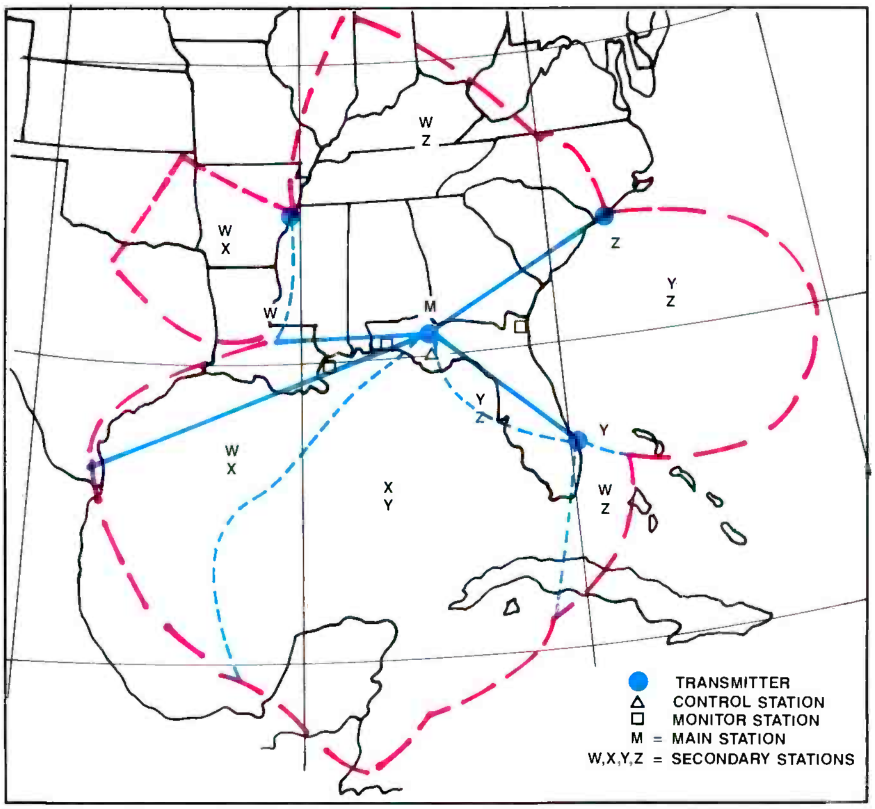

Figure 3. *Coverage map showing approximate range of Loran-C service in Southeast U. S. Chain (GRI 7980).*

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CCDs vs. camera tubes: a comparison

Are camera tubes down for the count or merely moving in new directions?

By Roald Steen

The TV camera is one of the few areas in which vacuum tube technology has remained competitive with solid-state. The camera tube represents a mature technology, which has advanced significantly since the first practical TV camera tubes were developed in the 1930s.

The charge-coupled device (CCD) entered the broadcast market less than 10 years ago. Early CCDs suffered from several problems that delayed their widespread adoption, but many prominent semiconductor and TV camera manufacturers have pushed the young CCD technology forward. The past several years have yielded impressive results, with CCD cameras now capable of producing images that are competitive with the best images from camera tubes.

Although CCD technology continues to progress, there are a few areas in which CCDs are not yet capable of taking over from the camera tube. High-definition television (HDTV) is one of the special niches that CCDs have not been able to satisfy. CCDs cannot yet be manufactured with the resolution that HDTV cameras require. Tubes are capable of resolution that exceeds the requirements of all the proposed HDTV systems. Camera tubes also remain strong in special uses, such as infrared imaging.

Steen is a certified electronics instructor and free-lance author based in Woodbury, MN.

Many broadcast camera manufacturers have replaced camera tubes with CCDs. Most of the broadcast camera tubes manufactured today are destined for the aftermarket. Many consumer and industrial cameras, however, are still being manufactured with camera tubes instead of CCDs. Interestingly, this may be occurring more as a function of the state of lens technology than of CCDs. (See the related article, "Coping with CCDs and Chromatic Aberration," pg. 108.)

Comparing image quality

The following measurements can define the performance of an imaging product:

1. Sensitivity to light.
2. Resolution capability.
3. Lag retention.
4. Durability.
5. Dynamic range.

If you were to compare sets of curves showing the characteristics of CCD chips that have entered the market over the years to similar curves plotted for camera tubes, you would see that in recent years these curves have started to merge. The performance of some CCDs can now equal or exceed that of camera tubes in all five tests. This may explain why CCDs have taken over in most of today's broadcast cameras.

- CCDs are available with a sensitivity surpassing that of the camera tube.
- Lag and resolution at every light level is improving — CCD devices can now equal camera tubes in this test.
- The dynamic range for some CCDs exceeds that of many camera tubes.

HDTV remains one of the strongholds of camera tube technology. The industry has not yet made it clear which HDTV standard it will adopt, but if 1,000- to 1,100-line resolution becomes the HDTV standard, CCD technology may be able to produce devices with enough resolution within a few years. For now, the field seems to be the exclusive province of tubes.

Figure 1 overviews two forms of camera tube technology. Figure 2 shows three versions of CCDs.

Camera tube technology

The vidicon has been the leading broadcast photoconductive TV camera tube since the 1960s. Photoconductive camera

Continued on page 94

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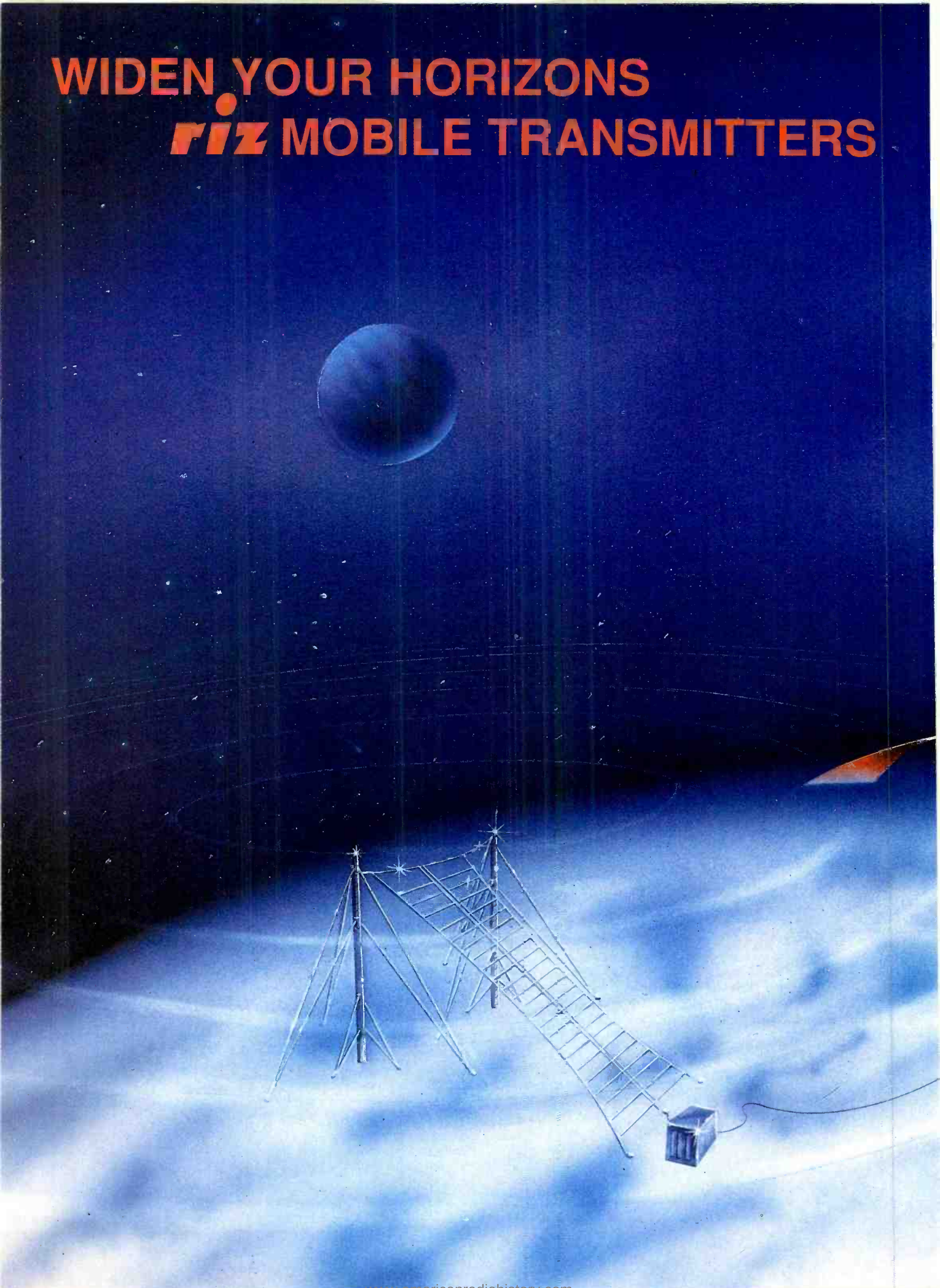
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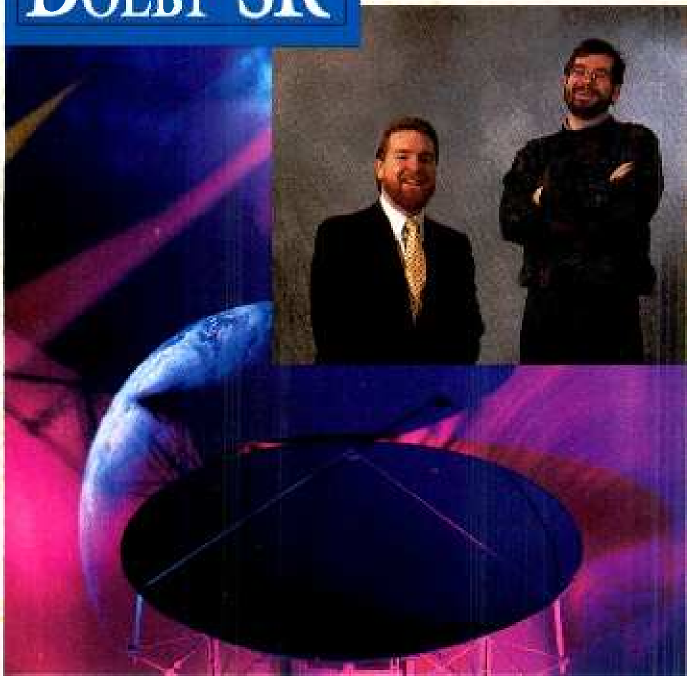
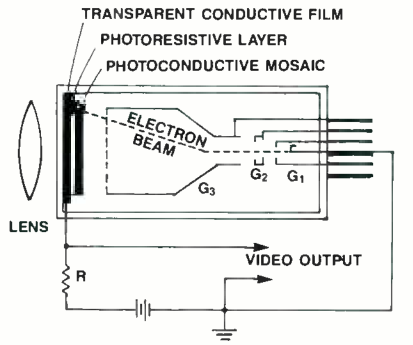


Continued from page 90

tubes have replaced the image orthicon, used in early TV cameras, because of their more compact size. Truly portable TV cameras became possible when 2/3-inch electronic news gathering-sized tubes be- [redacted] came available.

A



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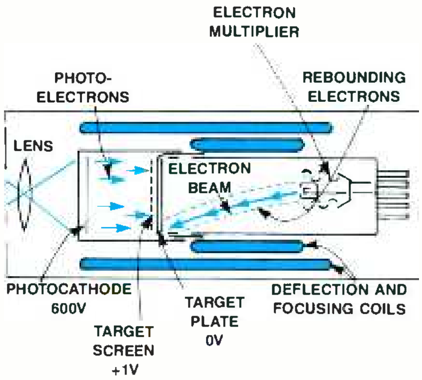

***Figure 1.** The basic principles of the vidicon and the image orthicon. The vidicon has a photoresitive element at the image plane of the tube. The element's resistance varies with light intensity. The scanning beam encounters areas of high and low resistance, depending on the image. This sets up voltage fluctuations corresponding to the video. The image orthicon magnetically projects patterns of electrons, which resemble the image, onto a target. Image electrons impacting the target bounce away target electrons, which are soaked up by the screen. This creates positive and negative zones on the target, corresponding to the scene. The scanning beam is either absorbed or reflected by the targets charges. A multiplier stage amplifies the reflected beam.*

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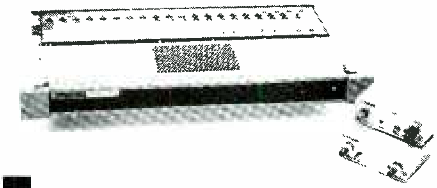

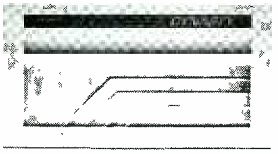

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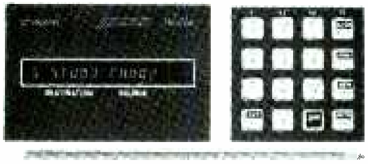

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Photoconductive camera tubes.

Most modern TV camera tubes are the photoconductive lead oxide type. Three varieties have held the bulk of the market. These are the vidicon and its variants, the Plumbicon and Saticon.

Photoconductive tubes employ photoconductors in their image sections. This material changes its conductivity in proportion to the light that it receives. The photoconductive material has high resistance in darkness, and its resistance falls with increasing light intensity.

The scanning beam from the electron gun scans the photoconductive material, producing a current that is proportional to the conductivity of each point. This forms a current that is proportional to the light intensity.

Lead oxide photoconductive tubes could be made smaller than other camera tubes. When 2/3-inch tubes appeared on the market, ENG cameras quickly replaced film in news gathering and remote cam-

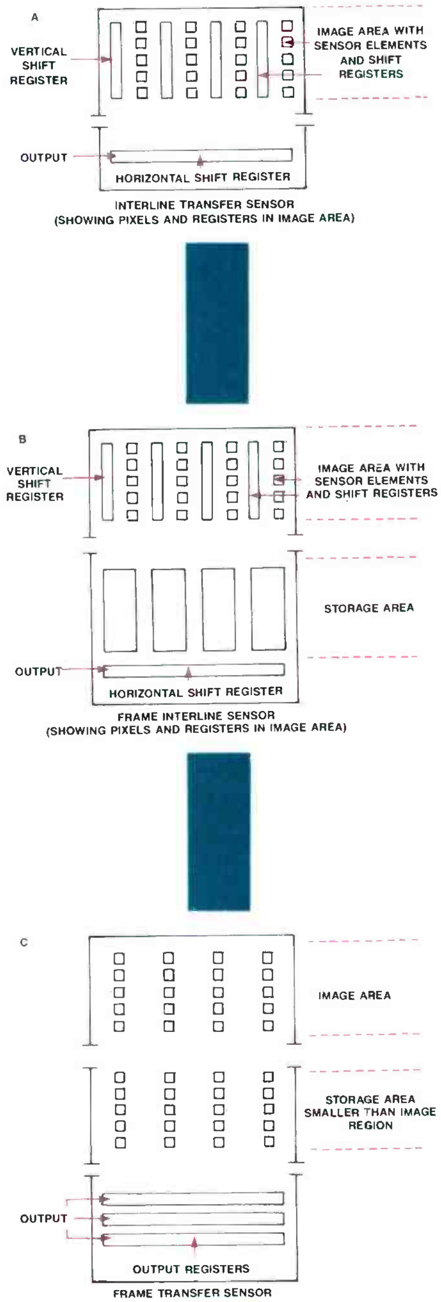

Figure 2. *Three common CCD configurations. A) The interline transfer sensor shifts the charges beneath individual pixels into an adjacent vertical shift register, and from there to the horizontal shift register for output, on a line-to-line basis. B) The frame interline transfer sensor passes charges from the image pixels to the vertical shift register, and from there to storage registers, during the vertical interval. C) The frame transfer sensor moves pixel charges into an optically isolated storage area all at once. Contents of the storage cells then move to output registers to form the video signal.*

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era applications.

Some special-purpose tubes may include a multiplier or amplifier section within the tube envelope. If used, such a tube resembles its forbearer, the image orthicon.

The image orthicon.

The image orthicon tube has nearly faded from memory. The tube consisted of an image section, a scanning system and a multiplier section, all mounted within a single vacuum cavity. The image section had an electron-rich photoemissive layer located on the inside of the tube's faceplate. When the image was focused onto the photoemissive layer, the film issued electrons in proportion to the intensity of the light at each point. A magnetic field focused the electrons onto the target. Each electron that hit the target knocked loose several electrons. These were collected in a positively charged mesh called the target screen. Rounding up the stray electrons kept the target positive in light areas of the scene, and neutral in dark areas. A scanning electron beam swept the target. The beam was partially absorbed when it struck positive areas of the target, mostly reflected with striking neutral zones.

In the electron multiplier section, the current from the scanning beam was multiplied because of secondary emission on the multiplier plates.

Image orthicons began to disappear from broadcast use in the late 1960s. However, a modern special-purpose imager, the *silicon intensifier tube* (SIT), has similar principles of operation. The SIT can use a fiber-optic lens in the image section. Its silicon target consists of many individual photodiodes. Each photon of light can produce thousands of electrons in the silicon diode target, allowing the camera to image extremely low-light scenes.

CCD technology

The CCD is a solid-state device, manufactured as an integrated circuit. Each pixel consists of a metal electrode mounted on silicon. (See Figure 3.)

Figure 3. *The charge-coupled device image sensor is a complicated device built in an integrated circuit configuration. (Courtesy of BTS.)*

The silicon is doped with a small amount of another element to make it photoconductive. There is an insulating layer of silicon oxide between the metal pixel electrodes and the doped silicon.

The metal electrode is given a positive charge, which attracts free electrons. As light shines onto the photoconductive material, it knocks the accumulated electrons loose. This develops a charge under each metal electrode, proportional to the light intensity at that point. By manipulating the voltage on each pixel in a row, it is possible to move the charge from each pixel across the CCD and into a storage device.

CCD chip technology has made strong advances in recent years. Manufacturers have now overcome many of the earlier limitations that prevented its widespread use in broadcast cameras.

Earlier CCDs had restricted resolutions. According to one manufacturer, the resolutions of CCD devices have been growing at a rate of approximately 100 lines per year. The best CCD devices are now capable of about 800 lines of resolution.

Broadcast-quality camera tubes have resolutions of 800 to 1,200 lines, so CCDs are still somewhat behind tubes in this


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field. Camera tubes manufactured for special applications can have even higher resolution. Some industrial camera tubes have resolutions as high as 2,500 lines.

Fixed noise pattern was once a significant limitation. A fixed noise pattern occurs when the pixels in a CCD produce fixed variations in their background noise. This results in definable patterns in the image when viewed on a TV monitor.

Several new CCD configurations have emerged to overcome fixed pattern noise, smear and other problems inherent in the first commercial CCDs. One of these improved CCD technologies is the frame interline transfer (FIT) CCD sensor. The FIT sensor moves the pixels into shift registers adjoining the pixel elements during the vertical blanking interval (VBI). From the registers, the charges next move to a large storage register on the chip, away from the image areas. The FIT CCD has nearly displaced the earlier interline transfer (IT) CCDs.

Another new development is the frame transfer (FT) CCD sensor, which includes an electronic shutter on the CCD chip. The FT CCD sensor uses an advanced transfer technology to move the pixel charge packets quickly from the image region to the storage region during the VBI. The shutter prevents pixels from building up a charge during the VBI, when the charges are transferring. (See Figure 4.)

Another CCD manufacturer has successfully followed a different route in developing a chip with little lag, smear and fixed noise pattern. This technology is called the CCD hole accumulator diode (HAD) sensor. (See "CCD Imagers are New and Improved," November 1990.)

The HAD sensor is a complicated integrated circuit. It uses metal oxide semiconductor (MOS) diodes and small lenses as part of each pixel element. The HAD sensor also uses an electronic shutter mechanism. HAD devices are available in IT and FIT versions. (See Figure 5.)

A problem with the CCD is that it is more sensitive to temperature variations than the camera tube. The temperature sensitivity is one characteristic that the CCD has in common with many other semiconductor devices. The dark current of a CCD device increases with temperature.

Several CCD designs include a dark area. This gives the camera a reference with which it can deduce the intensity of dark current. The camera's microprocessor can then compensate for the dark current value.

Color cameras

Broadcast-quality color cameras use dichromatic mirrors, or prisms, to separate the three primary colors of the image. One color goes to each tube or pickup. Some camera tubes are equipped with a built-in stripe color filter. This filter allows a single tube to produce a color image. The resolution and overall image quality of the single-tube color camera, however, is typically inferior to a 3-tube system.

Stripe color filters can also be embedded into CCDs manufactured for the consumer and VCR market. However, the single-chip CCD color camera is also unable to meet broadcast-quality standards.

Comparing benefits and problems

In recent years, CCDs have risen in quality to meet the tube technology. This has resulted in increased CCD use. One large camera tube manufacturer says that most of its broadcast camera tube sales are now going into the aftermarket. The manufacturer, which also produces CCDs, expects to stay in the camera tube market for a long time. It notes that, although the CCD has taken over most of the broadcast camera applications, the camera tube is still

Continued on page 104

12

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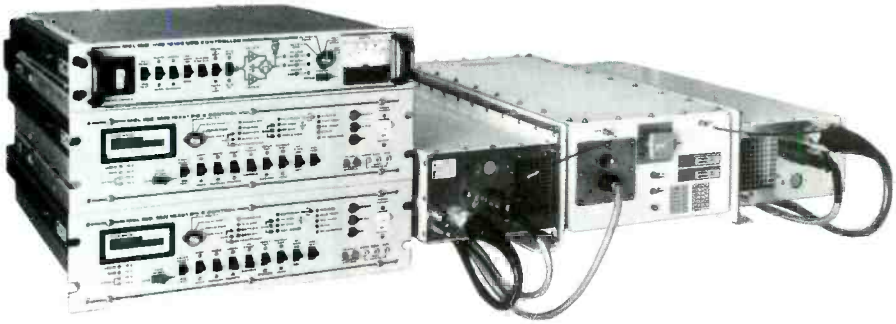

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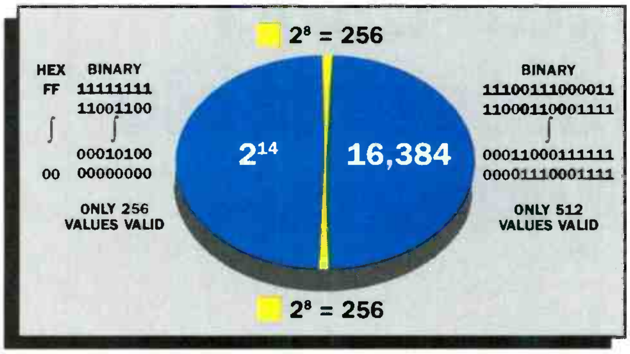

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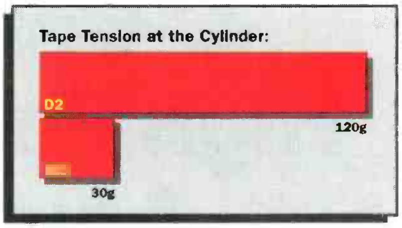

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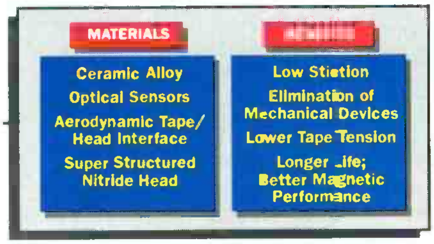

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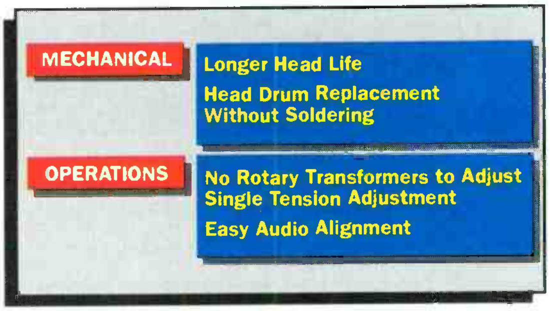

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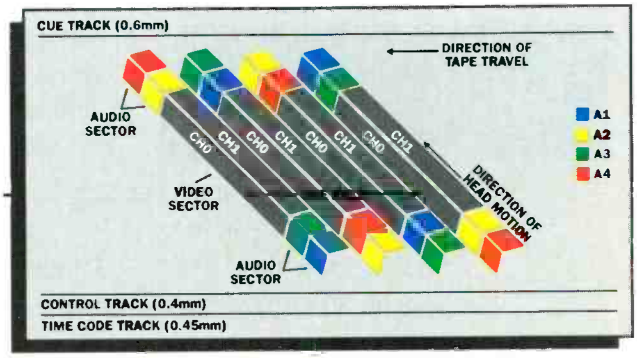

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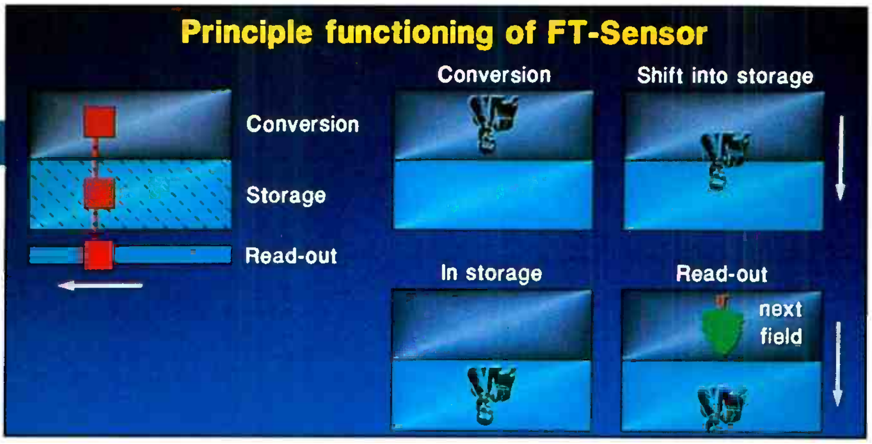

Figure 4. Frame transfer CCDs avoid the use of storage registers in the image area by locating the pixel storage cells beneath the imaging plane. This can increase image performance, because more pixels are available, and reduce pattern noise by not breaking up the image plane with storage registers.

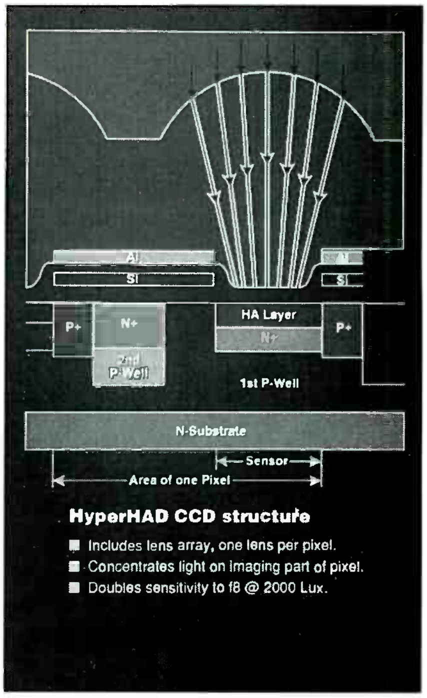

Figure 5. The hole accumulator diode (HAD) CCD sensor uses metal oxide semiconductor (MOS) diodes and small lenses as part of each pixel element. The HAD sensor also uses an electronic shutter mechanism to avoid contaminating pixels with stray light. HAD devices are available in IT and FIT versions.

Cameras for consumer VCRs are primarily single-tube systems, with a stripe filter for color separation. The solid-state VCR camera is also predominately a single-chip, stripe filter design. CCD cameras for broadcast use employ 3-chip technology with color separation through a dichromatic prism. This overcomes the lack of resolution inherent in devices using the stripe filter technology.

One camera manufacturer that purchases all of its CCDs and vacuum tubes from outside vendors reports that CCDs are not yet uniform. CCD performance varies so much across a batch that manufacturers must align each CCD when it is installed. According to the same manufacturer, CCDs that cannot make broadcast specifications often end up in consumer items, such as VCR cameras, instead of being discarded. This is similar to tube technology, where camera tubes that cannot meet the grade end up in the consumer market.

Several intrinsic benefits of CCD technology have contributed to its rapid acceptance into television. CCDs are small. Therefore, the space savings make it possible to produce small, compact cameras. (See Figure 6.)

The CCD is a low-voltage device with low power consumption. This makes it possible to design cameras with smaller and less expensive power supplies than tube cameras. In contrast, the camera tube, with its high operating voltages, requires a bulkier and more expensive power supply.

The CCD camera draws less current. A relatively small battery will be able to power it in the field. This is an obvious advantage in ENG applications, because small size means greater portability.

Although a camera tube has limited durability, modern CCDs appear to degrade only a little over time. The question remains whether CCDs will have to be replaced periodically, or whether the CCD will last as long as the other solid-state components. Because the CCD glues directly to the prism, there is some question as to precisely what is replaceable and what must be discarded or reworked at the factory.

The camera tube represents a mature technology, and there is some doubt as to its further technical progress. On the other hand, the CCD is a developing new technology that will probably progress far beyond its current capabilities.

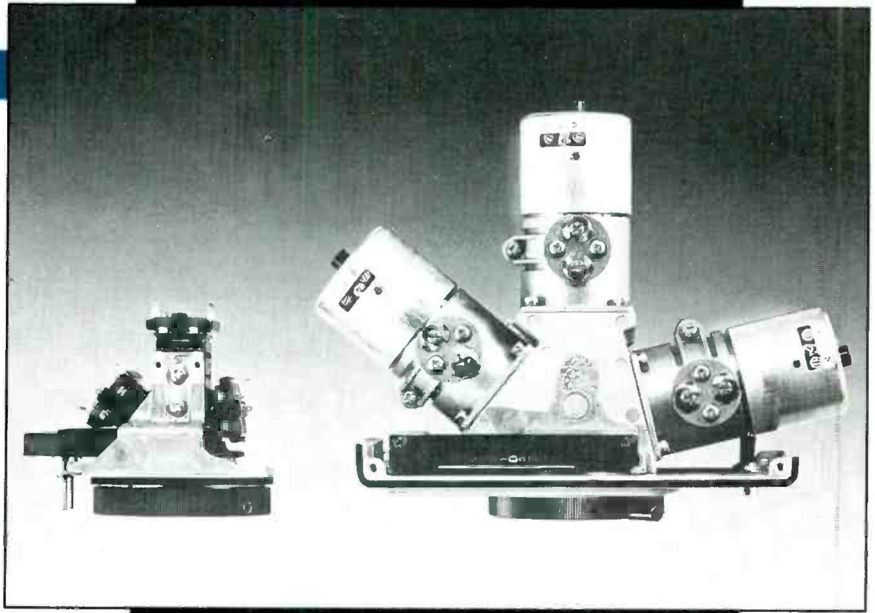

Figure 6. *There can be a great difference in size between a 3-chip color camera pickup device and a 3-tube device. Power supplies can also be simpler. This is one reason why CCD technology has become so important in electronic newsgathering, where size and weight are important.*

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Coping with CCDs and chromatic aberration

By Dave Waddell

The charge-coupled device (CCD) has revolutionized the video camera and rearranged the entire hierarchy of price and performance. Today's low- and mid-priced cameras owe much of their performance — and perhaps their existence — to the CCD. The problem of accommodating the unique demands of these revolutionary devices is left to the lens manufacturer.

The most notorious of these demands is control of longitudinal and lateral chromatic aberration. These characteristics are far less a problem in tube cameras, in which deflection circuitry can help compensate for them.

What is chromatic aberration?

Chromatic aberration is caused by a fundamental characteristic of optical glass — the variance of its refractive index with the wavelength of light. There are many types of chromatic aberration, but two of the most difficult to remedy are the longitudinal and lateral types.

Waddell is marketing manager for Fujinon, Wayne, NJ.

The longitudinal type produces tracking error, and the lateral type produces a phenomenon similar to the registration error encountered in cameras.

Longitudinal chromatic aberration causes light at different wavelengths to focus at different distances from the back of the lens. (See Figure 1.) The problem increases in severity with focal length, and is particularly troubling in zoom lenses. As the lens is zoomed from wide-angle to telephoto, longitudinal aberration changes. The result is a blurring of red and blue. (See Figure 2.)

Lateral chromatic aberration occurs because the magnification of the image projected by the lens on the image plane varies with wavelength, and causes the

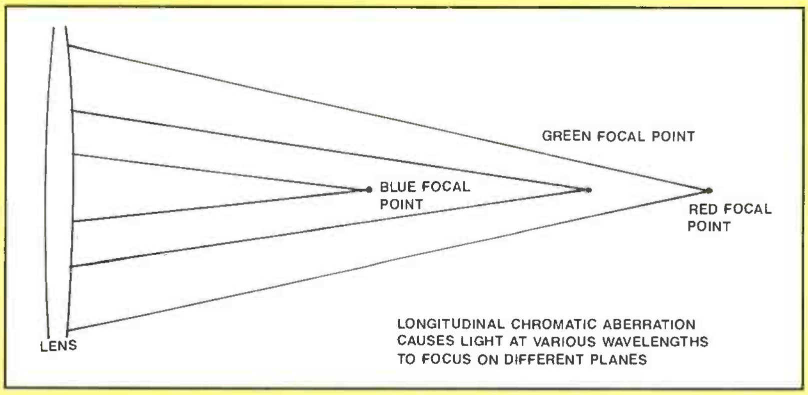


Figure 1. *Longitudinal chromatic aberration causes light at different wavelengths to focus at different distances from the back of the lens.*

image to focus on different points across the face of the focal plane. Lateral chromatic aberration changes as the lens zooms and focuses and the iris opens and closes, causing an effect that resembles registration error. Nearly all types of optical glass produce chromatic aberration, but the higher its index of dispersion, the less the chromatic aberration.

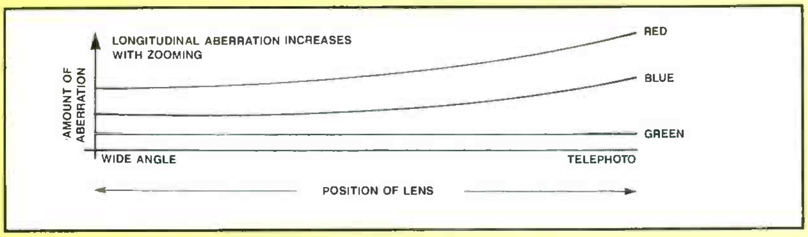


Figure 2. *Longitudinal aberration varies with the amount of the zoom.*

Enter the CCD

The dispersive characteristics of optical glass can be accommodated in tube cameras. Users can adjust the tube and its deflection yoke to correct for error. The CCD is a different type of sensor. Unlike the cathode-ray tube, the CCD is mounted securely in a fixed position that is accurately determined, so there is no way for a CCD camera to correct for dispersion. The CCD also registers an image equally on all parts of its rectangular surface, so edge distortion is more apparent and chromatic aberration is more detectable.

All of this presents a challenge to a lens manufacturer faced with the conflicting goals of manufacturing a high-performance product for lower-priced equipment. The problem must be corrected to some degree in every lens, but is far more a problem in long focal length zooms with high magnifications.

The solution

Longitudinal and lateral chromatic aberration can be minimized effectively by exploiting the properties of a naturally occurring mineral called fluorospar (calcium fluorite), through advanced coatings, and by using optical glass that has a high index of refraction in negative and positive combinations to produce achromatic lenses that refract light without breaking it into its component colors.

The properties of calcium fluorite make it the ideal material with which to combat chromatic aberration. Unfortunately, naturally occurring fluorospar crystals large enough for optical applications are rare, and the material's handling and durability properties are poor. Before researchers found a way to grow fluorospar crystals artificially, it was used only in microscopes and other small optics. Today, however, artificially grown calcium fluorite is a component in the elements of lenses from all manufacturers.

Longitudinal chromatic aberration is generally corrected optically at two wavelengths in the spectrum. Lateral chromatic aberration must be corrected over the entire operational range of the lens.

Technology marches on

Although chromatic aberration is one of the most difficult lens characteristics to control, the superb performance of the latest generation of lenses and CCD cameras visually illustrates the effectiveness of current solutions. New coatings, lens materials and manufacturing techniques will continue to place chromatic aberration in its proper perspective.

New products

PC application

By David Taylor

• **Units and Conversion Factors:** software for PC/compatibles operating with DOS 2.0 or greater; converts values from one system of measurement to another; library of units can be expanded by the user; includes many scientific and engineering constants; supports CGA, EGA displays; 512k memory suggested; available on 5-inch floppy; comprehensive operator's manual.

Circle (360) on Reply Card

Digital multimeter

By Fieldpiece Instruments

• **HS-20 series:** hand-held, stick-type DMM; integrates DMM, voltage checker, current clamp meter in one housing; yellow Valox case withstands contaminants and falls from 10-foot heights; overload protection to 1kVDC and transients to 6kV with metal oxide varistors; jacks accept test leads, special probe tips and current clamp head; "hold" feature captures readings, allowing technicians to watch what they are doing, instead of monitoring the LCD display.

Circle (367) on Reply Card

Digital audio deck

By JVC

• **DS-DT900N:** record/play digital audio system with SMPTE time code, full compliance with draft IEC specifications for DAT synchronization; XLR analog and digital AES/EBU inputs, outputs; 45-pin, 9-pin control ports; 64× oversampling delta sigma modulation.

Circle (378) on Reply Card

Technical publication

By Dranetz

• **Power Line Harmonic Problems:** 12-page booklet outlines causes of and solutions to power line harmonics to reduce problems to computer and other electronic equipment.

Circle (363) on Reply Card

Transfer switch, transmitters

By Harris Allied Broadcast Equipment

• **Motorized switch:** 4-port unit for AM transmitters; accommodates 8kW RF power at 125% modulation; ports included for main and auxiliary transmitters, antenna system and optional test load; remote or local control.

• **HT500FM transmitter:** containerized, solid-state FM system; available for purchase or short-term rental as maintenance or emergency standby unit; 235-525W range with frequency-agile tuning; THE-1 exciter; FlexPatch feature.

Circle (369) on Reply Card

Facility security

By Liebert

• **On-Site/1000:** access security system; complete for complex multi-user requirements and multiple sites; single system operating under UNIX with capacity for 50,000 users, 256 access codes, sensing for 1,024 doors, multiple passwords and 10 alarm priority levels; information-gathering modules (IGMs) link to central control through twisted pairs; user database permits easy change and updating.

Circle (383) on Reply Card

Graphics software

By AIM Graphics

• **AIM-3D package:** for PC-based modeling, animation; originally used in Microtime ImagePlus systems; now available as stand-alone software offering; full-function VTR controller; custom-made versions available for input/output devices not yet supported by the package and for other special applications.

Circle (352) on Reply Card

VCR upgrade kits

By Electronic Technical Services

• **DUB-IT Y/C:** expands a range of Type 5, 7 and 9 U-matic VCRs by adding S-VHS features; Dub-It Y/C Out converts U-matic outputs to S-VHS (Y/3.58) format; Dub-In Y/C kit for recorders accepts S-VHS-type Y/C inputs; both result in improved playback when used with Y/C-type monitor.

• **Sync-In kit:** uses external sync with Type 5, 7 and 9 Betacam SP players; locks VCR to a reference signal; includes 3.58 input, dropout compensator output; SMPTE time-code output and Y/R–Y/B–Y output.

Circle (366) on Reply Card

Product guide

By ARS Electronics

• **1991 product selection guide:** covers many product areas for radio and TV station requirements as well as for the professional music and audio fields; items include rebuilt PA amplifier tubes, HV capacitors, camera tubes, solid-state devices and difficult-to-find tubes for older TVs, radios and other electronic equipment.

Circle (353) on Reply Card

Protective UPS systems

By Computer Power

• **Trimax II smart series:** 3-phase, on-line UPS systems covering power ratings from 10kVA to 300kVA; microprocessor-controlled diagnostic interface to monitor system status; supervised control and data acquisition produces status information for 80-column ASCII printout on local printer or for remote center via integrated modem.

Circle (357) on Reply Card

Controllable amplifiers

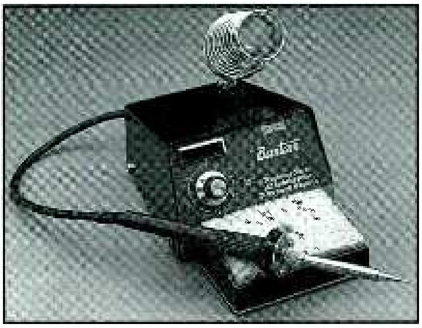
By Dynacord/Mark IV

• **PCA series:** processor-controlled power amplifiers; dynamic signal processing includes integrated processor, limiter; thermal protection; PCA 2250, 2×250W rms 4Ω; PCA 2450, 2×450W rms 4≅; PCA 2544, 4-channel with 2-way stereo, 3-way mono or 4-way switchable Linkwitz-Riley crossover; Neutrik Speak-on output connectors.

Circle (364) on Reply Card

Component transcoder
By Axon Digital Design
• **ACT-100CPTM:** bidirectional transcoding system between RGB/S and YCrCb video component systems; feedback clamping and blanking processor for each channel; DIP switch permits individual sync insertion on outputs.
Circle (354) on Reply Card

Maintenance product
By Hexacon Electric
• **Therm-O-Trac Bantam:** soldering station designed for densely populated circuitry maintenance; slim, short case for easier operator control; 500°F-850°F temperature control range; no magnetic, electrical or electrostatic effects.



Circle (371) on Reply Card

AF signal correction
By BBE Sound
• **BBE 701:** modular unit for TOA Electronics 900 series power amplifier; corrects phase, amplitude distortion inherent in loudspeakers; single-channel version of BBE Sonic Maximizer; front- panel adjustment for definition and low contour; hardwire bypass switch for comparison tests.
Circle (355) on Reply Card

Camera support
By Birns & Sawyer
• **Porta-Jib:** lightweight jib designed to fit 100mm ball or Mitchell top tripod; unit can be assembled easily in five minutes; supports loads to 90 pounds; six feet of boom travel; slip clutches on boom and pan axes, precision ball bearings.
Circle (356) on Reply Card

Surge, spike protection
By Intermatic
• **Electra Guard EG240RC:** circuit-breaker panel protector; nanosecond range response time to power surges, spikes; designed for use with equipment using two parallel 15- or 20-amp circuits by hardwire installation into electrical breaker panel; rated for 120/240VAC, 60Hz; indicators show proper operation.
Circle (373) on Reply Card

DMM test leads
By ITT Pomona Electronics
• **No. 5677 Maxi-Kit:** includes red and black 48-inch test leads; features extendable Slip-tip probes and Pop-Jack connectors for user flexibility; silicone insulation; packaged in sealable pouch.
Circle (376) on Reply Card

Telecine adaptation
By Digi-Grade Systems/DGS
• **70mm transfer system:** retrofit for Rank Cintel Mk III telecines for 70mm and 65mm film while retaining 16mm, 35mm capability; motorized focus; pressure, vacuum integral film cleaner; modes include 5, 8, 10 and 15 perf formats.
Circle (362) on Reply Card

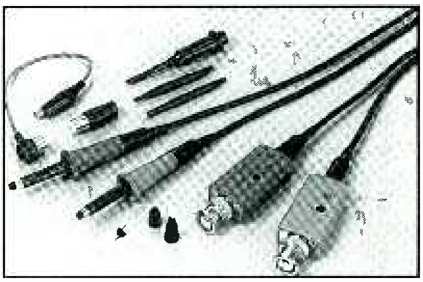
Wiring documentation
By Electro Insulation
• **Logo on heat-shrink tubing:** custom printing service of logos, part numbers, special ID codes on heat-shrink or non-shrink tubing; various sizes, tubings, colors, lengths may be selected.
Circle (365) on Reply Card

Time-code analysis
By A/Z Associates
• **Time-code monitor:** portable or rack-mount package; identifies time-code problems and logs up to 800 errors in memory for review; spot-checks tapes for time-code data discrepancies before on-air, editing use; checks duplicated tapes for quality control prior to shipping; by Summertone Ltd., of England.

Circle (351) on Reply Card

Fiber-optic data
By DiCon Fiberoptics
• **1991 Fiberoptic Switches:** 16-page catalog details technical information on a variety of fiber-optic switches; includes on-off, 1×2, 2×2, 2×4, FDDI, fiber protection, A-B switching, 1×n multi-channel and M×N matrix types.
Circle (361) on Reply Card

O-scope probes
By Test Probes
• **M12DF set:** a pair of 250MHz passive probes; one with fine attenuation adjustment at DC and low frequencies; enables measurements across points of a circuit where one point is not directly referenced to ground.



Circle (402) on Reply Card

Wideband signal control
By Datatek
• **D-2400 system:** 40MHz video bandwidth matrix with associated audio and data routing units; eight addressable levels permit individual control of video, audio, time code, key video, RS-422 data, and more; expandable to 800×800 matrix.
Circle (359) on Reply Card

Studio consultants
By RMS/Modular Studios
• **Studio designs:** capabilities for technical, electronic, acoustic parameters for music studios; specialists on noise leakage, monitor speaker and listening zones; modular studio with complete, acoustically tuned, isolated listening environment; may be disassembled, transported and relocated.
Circle (391) on Reply Card

EMI survey software
By Interference Control Technologies
• **ICT No. 7700:** predicts and diagnoses the effects of the ambient electromagnetic environment on your proposed facility; forecasts electromagnetic interference problems without measurement equipment; enhances other diagnostic instruments.
Circle (372) on Reply Card

High-quality sound
By Intraplex
• **PT/PR-150 codec:** modular approach to digital coding of 15kHz or 7.5kHz audio channels for CD-quality sound; 16-bit coding with compression algorithm for data bandwidths of 128kb/s for 15kHz signals; 4:1 compression without subjective audio quality compromise; for satellite and terrestrial T1 link applications.
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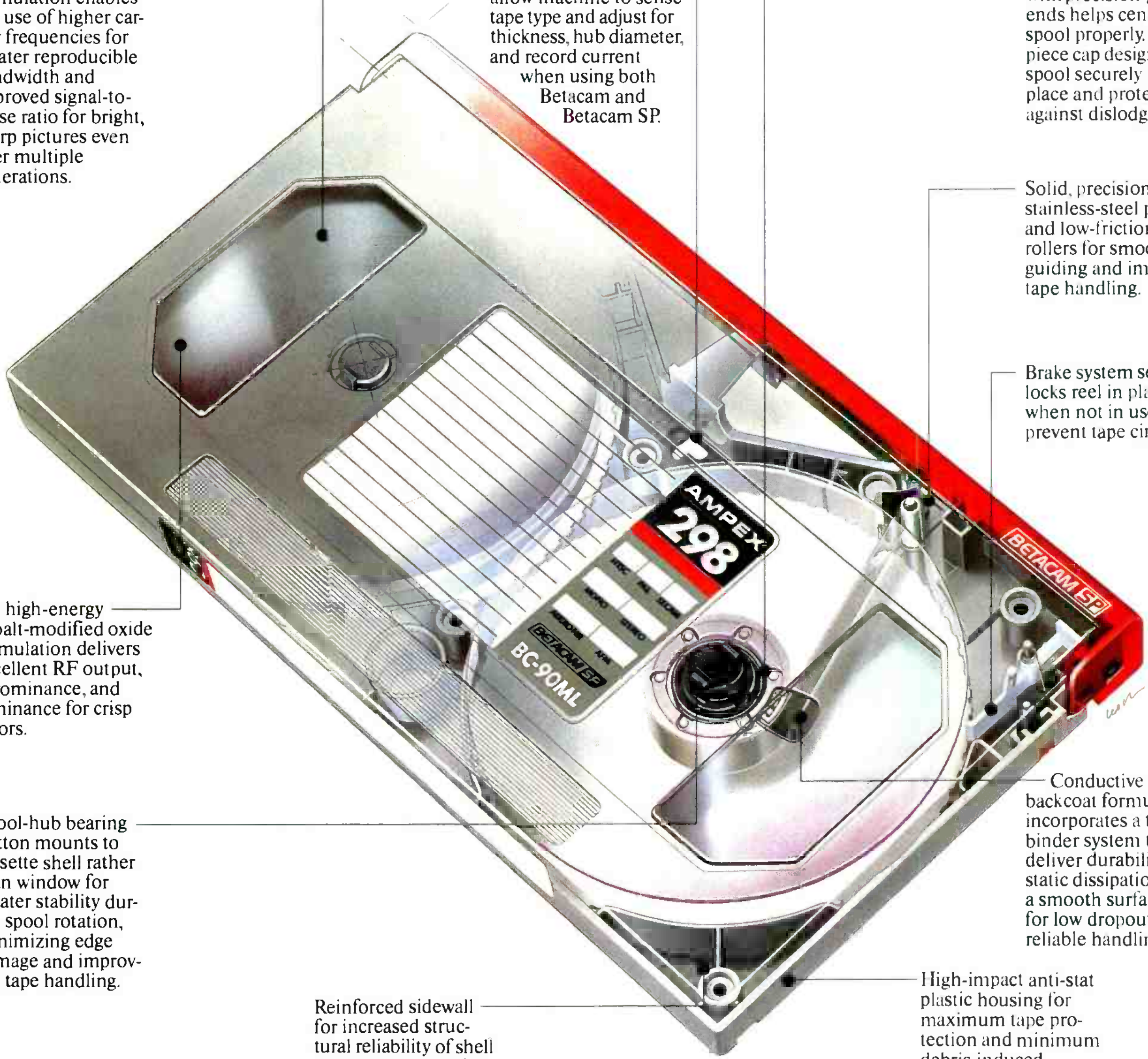

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Circle (85) on Reply Card

Tower lighting

By Crouse-Hinds Airport Lighting

• **TLC controllers:** solid-state universal relay programmable systems in NEMA 3R, 4X and explosion-proof enclosures; for obstruction lighting on broadcast towers and other tall objects that pose possible hazards to aircraft; features lamp failure alarms, standby lamp transfers.

Circle (358) on Reply Card

FO information

By fotec

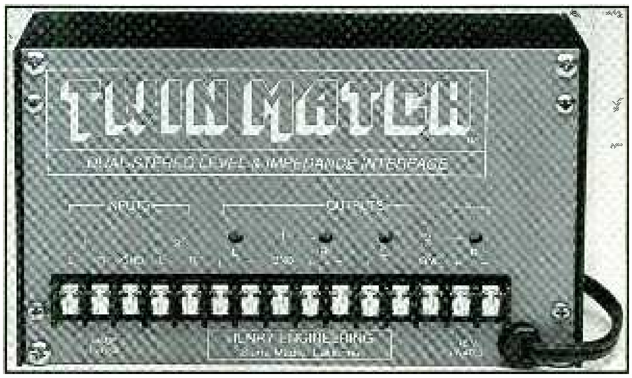
• **FOTN newsletter:** quarterly publication discusses topics related to fiber-optic technology, testing, applications and installations; includes section on fotec products and calendar of seminars.

Circle (368) on Reply Card

Audio utility interface

By Henry Engineering

• **TwinMatch:** permits unbalanced outputs from two CD players to be connected with balanced audio system; converts impedance and level; adjustable gain with DC-coupled circuitry; 115dB dynamic range operates from 115VAC or 230VAC.



Circle (370) on Reply Card

Product information

By LEMO USA

• **Series B, S catalog:** specifications and data for circular quick connect and disconnect connectors; Quick-Lok designs for coaxial, triaxial, high-voltage, fiber-optic applications.

Circle (382) on Reply Card

Subcarrier equipment

By Learning Industries

• **SAP/R demodulator, SAP generator:** equipment to support C-SPAN Audio Schedule Advisory Programming (ASAP) service; permits special audio information service provided by C-SPAN to be modulated on SAP subcarrier of BTSC stereo signal.

Circle (381) on Reply Card

Helicopter ENG system

By Istec

• **Model 12DB300:** integrated system including broadcast camera with gimbal mounting; full remote control, gyrostabilization; pointing direction may be slaved to helicopter heading; environmental seal against weather; weighs less than 55 pounds; 14-inch diameter, 18-inch height.

Circle (375) on Reply Card

MIDI enhancement

By JL Cooper Electronics

• **PPS-2 sychronizer:** reads, generates and converts SMPTE time code to MIDI code or direct time lock; jack sync, regeneration, flywheeling features; SMPTE strip format can be changed to 24, 25, 30 drop-frame and standard 30 fps; also reads, generates JL Cooper Smart FSK sync and converts to MIDI clock with song position pointer.

Circle (377) on Reply Card

Multisystem video

By Panasonic AVSG

• **AG-2600E:** VHS VCR configured to play tapes programmed in NTSC, PAL-D/-B/-G/-I and SECAM D/K (B/G) without the need for standards converter; requires multistandard monitor or monitor compatible with standard being played; permits viewing of NTSC tape on PAL monitors.

Circle (388) on Reply Card

Product reference book

By Motorola Semiconductors

• **DL110/D RF data book:** 2-volume listing of standard products from RF products division; covers power FET, power bipolar, small-signal and modular components.

Circle (384) on Reply Card

Product literature

By OFTI

• **FO catalog:** color presentation includes full line of products including connectors, cable assemblies, terminations, related products; detailed features, diagrams; specialized epoxies, dispensers, installation tools and polishing materials.

Circle (385) on Reply Card

Battery products

By Lamp Technology

• **Replacement guide:** lists specifications, data for a range of lithium batteries for computers; direct replacement for clock and memory backup units for a range of personal computer systems.

Circle (379) on Reply Card

Oscilloscope products

By Leader Instruments

• **Model 3100D:** autoranging analog/digital oscilloscope; 100MHz capability enhanced with memories for display, reference; on-screen cursors; 40ms/s maximum sampling rate; download data to computer or HP-GL plotter for analysis and hard copy.

• **Model 300:** combination digital oscilloscope with digital multimeter; battery-operated portable unit with 30ms/s sampling rate; dual, add, subtract, X–Y display features; auto-setup, autoranging; display uses supertwist LCD panel.

Circle (380) on Reply Card

Circle (86) on Reply Card

Circle (87) on Reply Card

Professional services

Preview

June...

NAB CONVENTION REPLAY

• Perspective on the Convention
The NAB convention remains the primary event for most broadcasters and video production professionals.

• NAB Engineering Conference Report
Many of the technical papers presented at the engineering conference represent tomorrow's technology. Others are designed to help engineers take advantage of today's hardware.

• Pick Hits of the '91 NAB
Our annual Pick Hits panel can help you locate the key products introduced at this year's show. A panel of independent, highly qualified judges scour the floor, looking for those unique and useful items that can help produce a winning signal for your station.

• Show of Shows
The hundreds of new products introduced can never be seen while you are at the show. Carl Bentz, *BE* special projects editor, relieves that burden with his detailed coverage of all the new items shown.

July...

AUDIO TECHNOLOGY UPDATE

• Digital Audio Broadcasting Arrives
One of the newest challenges to the broadcaster is digital transmission. In a surprise move, the Europeans have launched a campaign to implement their proposed digital broadcasting system in the United States. The EBU/Eureka 147 system of digital audio broadcasting represents a challenge and an opportunity for American broadcasters.

• Measurements in the Digital Domain
Because of the increased use of digital audio, testing equipment performance becomes a much more complex task. It is no longer simply a matter of hooking an analog meter to the recorder and measuring distortion. As the equipment stores the data in digital format, different types of texts must be completed to ensure proper equipment performance.

• Disasters: Preparing for the Inevitable
The recent hurricanes and earthquakes have emphasized the importance of being prepared for a natural disaster. Unfortunately, preparing adequately for such phenomena requires special planning and knowledge.

People

William Brock has been appointed sales director of Peerless Sales, Melrose Park, IL. He will manage Peerless' national network of sales reps and direct the company's sales to new national accounts and distributors.

Mike Momosawa has been promoted to senior director and general manager of Canon's broadcasting equipment division, Lake Success, NY. Momosawa was formerly director of the division.

William F. Hammett and **Harrison J. Klein** have been named managing directors of Hammett & Edison, Consulting Engineers, San Francisco. Hammett and Klein will be responsible for the company's management.

Dan Cole, Jim Sandy and **Steven Blum** have been appointed to sales manager positions for the northeast region of Sony Business and Professional Group, Park Ridge, NJ. Cole has been named regional sales manager, broadcast sales. Sandy is regional manager, dealer sales and Blum is sales manager, corporate and government sales.

Pierre Noizat and **Alain Pecot** have been appointed to high-level positions with Thomson Broadcast, Englewood, NJ, the U.S. subsidiary of the Thomson Group. Noizat is president and will have overall management responsibility for the company's administration, sales, support and service. Pecot has been promoted to product manager for the company's digital video products. He will be responsible for the marketing of all Thomson digital video products.

Steve Larson has been appointed vice president of sales and marketing for Current Technology, Richardson, TX. Larson is responsible for the sales and marketing of the company's power supply and power conditioning products.

David Finley and **Daniel Marchetto** have been appointed to positions with Gentner Electronics, Salt Lake City. Finley is director of marketing and sales and will direct the worldwide marketing and sales efforts of the company's broadcast, professional audio and teleconferencing product lines. Marchetto is the company's teleconferencing national sales manager. He is responsible for all domestic sales in the company's teleconferencing group.

Larry L. Seehorn has been appointed director of engineering at Alamar Electronics, Campbell, CA.

Andre Skalina has been named product manager, advanced technologies, of Dielectric Communications, Raymond, ME. Skalina will spearhead the development of the company's HDTV business.

Andreas Koch has been appointed to vice president and general manager of Studer Editech, Menlo Park, CA. He will be responsible for the company's operations.

Nick Balsamo and **Arnold Toshner** have been appointed to positions with Neve, Bethel, CT. Balsamo is senior sales engineer and Toshner is western regional manager.

Bland McCartha has joined Sony Business and Professional Group, Park Ridge, NJ, as vice president/general manager, northwest region. McCartha will be responsible for the general management of the region and for implementing the company's recent structural and operational changes in that area.

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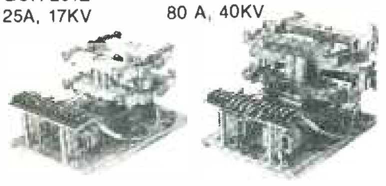
GCR-701
80 A, 40KV



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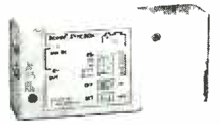

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CHYRON...prices as much as 50% off on CG's.
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