BROADCAST engineering

AN INTERTEC PUBLICATION

May 1992/$4.50

Program transmission systems update

Radio on a budget

Acoustics for engineers
p. 74

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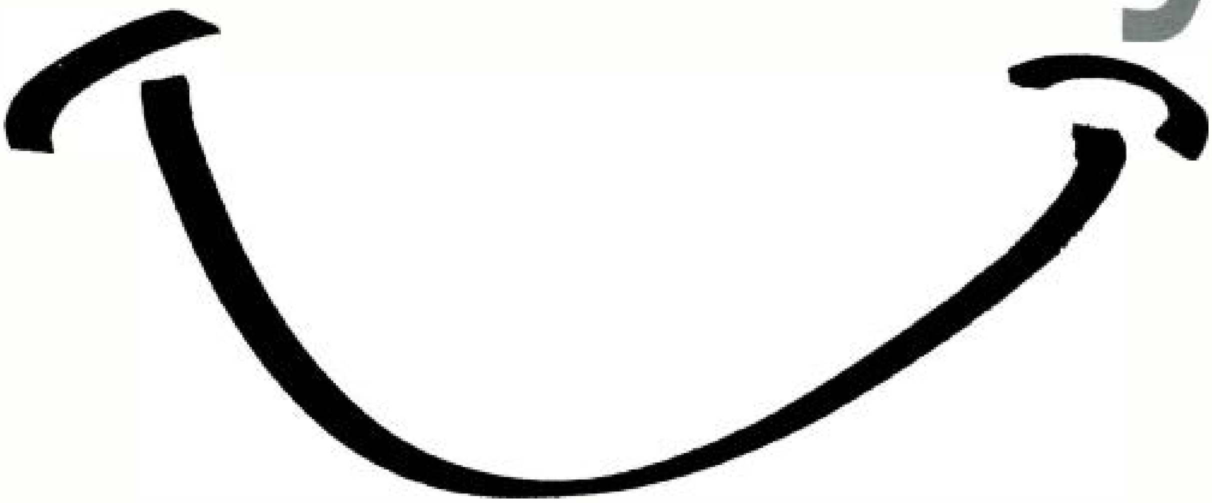

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Contents

BROADCAST ENGINEERING

May 1992 • Volume 34 • Number 5

Page 42

Page 49

Page 74

PROGRAM TRANSMISSION SYSTEMS UPDATE:

Without reliable transmitters and antennas, terrestrial broadcasting would cease to exist. Fortunately, manufacturers have provided engineers and managers with reliable solutions to this dilemma. It is now easier and more cost effective than ever to deliver your station's signal to the audience.

FEATURES:

OTHER FEATURES:

DEPARTMENTS:

ON THE COVER

Two facets of modern transmitter technology are illustrated by this month's cover: solid-state amplification and computer diagnostics and control systems. These developments make today's transmitters not only more reliable, but also easier to troubleshoot and maintain. (Cover design by MediaScan, photography by Harris/Allied.)

News

By Dawn Hightower, senior associate editor

Keynote speaker chosen for SMPTE Technical Conference

A keynote speaker for the SMPTE Technical Conference has been selected. Patrick Watson, chairman of the board of the Canadian Broadcasting Corporation (CBC) will deliver the keynote address at the 134th Technical Conference and Equipment Exhibit Nov. 10-13, at the Metro Toronto Convention Centre, in Toronto.

Watson has been involved in the broadcast industry for 35 years. In Canada, he has distinguished himself as a TV journalist, filmmaker and writer.

Papers are now being accepted for presentation at the conference. The deadline for submission of a 500-word synopsis is June 15. If you are interested in participating, contact Marilyn Waldman, SMPTE editorial/program coordinator at 595 W. Hartsdale Ave., White Plains, NY 10607.

Movie ticket sales down, video sales up

According to *John Naisbitt's Trend Letter*, sales and rentals of videos rose by approximately 9% in 1991, while box office revenues dropped. Consumers are spending more than twice as much for videos than for movie tickets. The newsletter predicts that during the next few years, a number of changes will occur, such as the proliferation of "bargain days" at movies and the option to purchase tickets with credit cards and by phone. In order to remain competitive, the movie industry will have to continue to redefine itself.

Outdated manual not necessary in public file

The National Association of Broadcasters (NAB) has asked federal regulators to suspend all fines on broadcasters who do not keep an outdated government manual in their station's public file. The manual no longer accurately depicts FCC regulations and the ways that the public may participate in the regulatory process.

In letters sent to officials at the FCC, NAB pointed out that the document, *The Public and Broadcasting — A Procedure Manual*, gives misleading information about FCC rules and procedures that no longer exist. These include several references to the Fairness Doctrine, former 3-year broadcast license terms, an outdated political broadcasting primer and several other abandoned FCC regulations.

NAB also said the manual omits any reference to important FCC licensing reforms, which grant broadcasters "abuse of process" protections shielding stations from spurious legal claims.

Many stations have complained recently of being fined heavily by the FCC for not having the 18-year old document available for public inspection, even though inspection of this document would mislead rather than inform the public.

At the request of NAB's regulatory review committee, the NAB letters were sent to the chiefs of the FCC's Mass Media and Field Operations Bureaus, and the agency's general counsel. These letters emphasized that the current manual "fails to convey a realistic, contemporary picture of the commission's regulatory process and the public role in that process."

In the letters, NAB executive vice president and general counsel, Henry L. Baumann, urged the FCC to suspend its enforcement of this public file requirement until the commission could revise the manual or find another way to convey more accurate regulatory information to the public.

SSPI names four to Hall of Fame

The Society of Satellite Professionals International (SSPI) has named four pioneers to its Hall of Fame in a ceremony held in Washington, DC, on March 4.

The inductees included Rene Anselmo, chairman of Alpha Lyracom/Pan American Satellite; Stanley S. Hubbard, president and chief executive officer of Hubbard Broadcasting; Sidney Metzger, retired vice president and chief scientist of COMSAT; and Dr. Tadahiro Sekimoto, president of NEC.

These men were honored as pioneers who opened new doors and continue to shape the satellite industry today. This is the fourth time SSPI has bestowed its highest honor.

■

BROADCAST engineering

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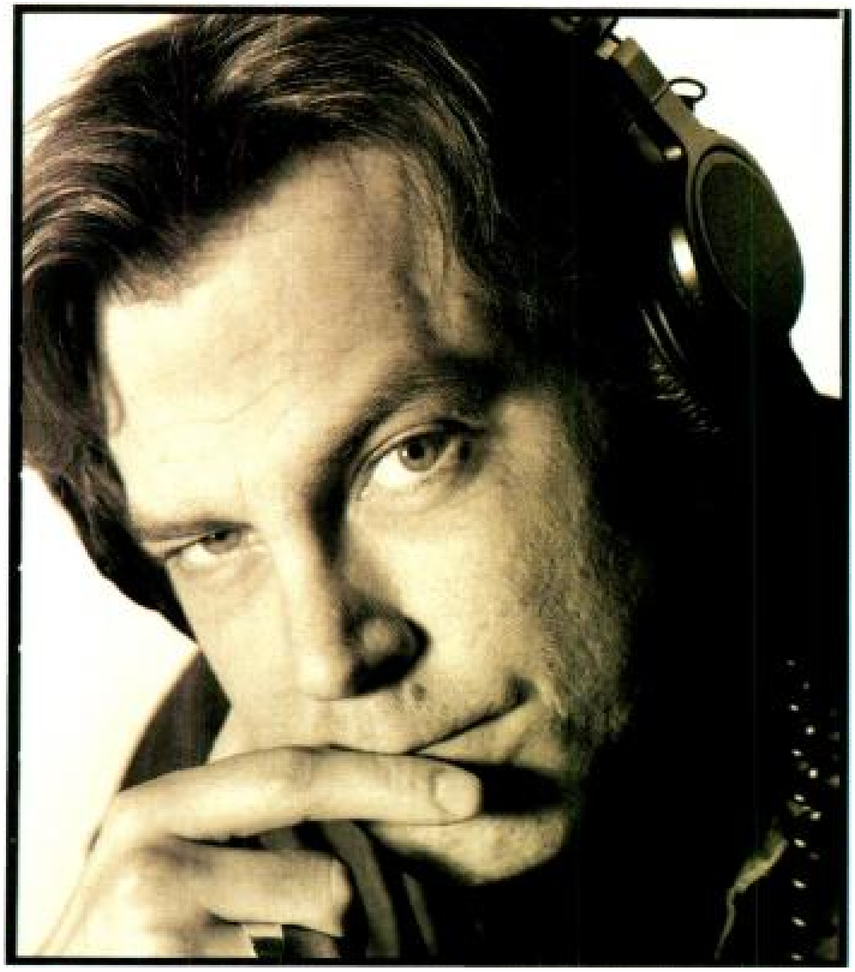

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Circle (6) on Reply Card

A new idea with better results

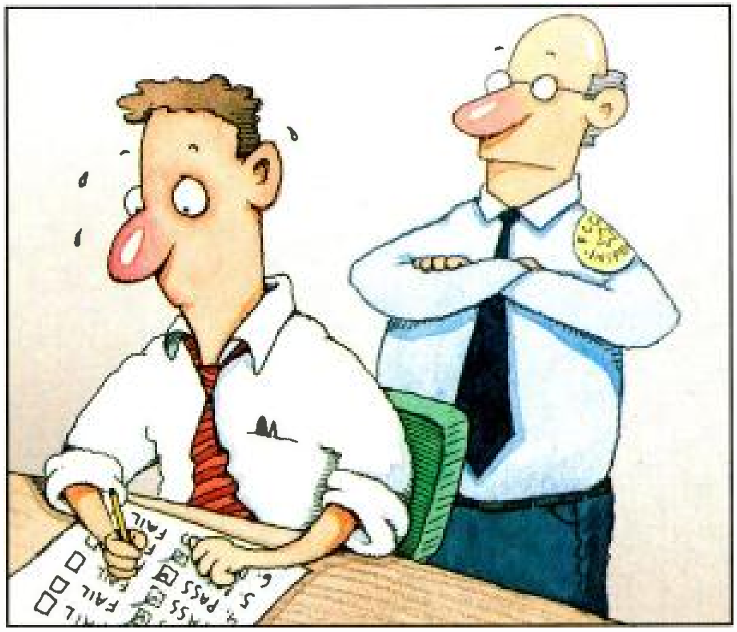
A guest editorial

Misconceptions often arise in response to new ideas or procedures. Apparently, the FCC's broadcast self-inspection program is no exception. Perhaps some clarification of the program's experimental stage and its overall goals will dispel any further anxieties.

This self-help/educational program was developed to meet two goals:

1. To establish and maintain a high rate of rule compliance.
2. To identify those areas where the commission feels strict compliance is necessary.

The commission, faced with the reality of dwindling resources, hopes to accomplish these fundamental goals by methods other than the traditional field inspection.



Nine AM stations were originally approached with the idea of self-inspection. Each of them eagerly volunteered to participate in the program's experimental stage. Although future use of the program may not be on a voluntary basis, the process will not be used to generate "mail-order fines." Forfeitures, commonly known as fines, are not a part of this program. Instead, the program is aimed at educating broadcasters in rule compliance by allowing them to assume the role of the FCC inspector. However, the commission could issue a fine in the future if violations are discovered.

During the experiment, apparent rule violations that would otherwise subject the station to sanctions were reported in the returned documents. The FCC staff reviewed the reports and worked with those stations that reported violations to resolve the matters. In keeping with the cooperative spirit of the educational effort, no sanctions were issued.

Uncertainties raised in the industry press regarding the commission's new fine assessment schedule has increased the awareness of rule compliance. The self-inspection program helps licensees to improve compliance on their own. It is designed to reduce the number of violations and fines that result from the FCC's traditional random-inspection program.

Although nationwide reaction to the experiment was favorable, the length and complexity of the report book generated some concern. It will therefore be scaled down, and areas of ambiguity will be clarified. The final version may soon be approved for expanded use.

Rule compliance can be easy, but the industry is complicated, and even more help may be needed. So far, we've found a high number of violations in a number of crucial areas of broadcast operation. Working through the self-inspection program allows stations to determine easily if they are in compliance with the commission's rules. By doing a little homework, you could prevent your station from being fined by correcting a problem before it becomes officially noticed.

Michael H. Ritter

Michael Ritter
Public Affairs Specialist
FCC Field Operations Bureau
Los Angeles

Editor's note: In response to an earlier editorial regarding the FCC's self-inspection program, Michael Ritter, Public Affairs, provided the following reply. The views expressed here are those of the author and do not necessarily reflect those of the Federal Communications Commission.

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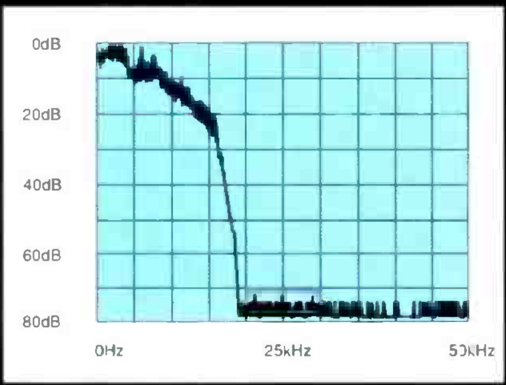

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Circle (7) on Reply Card

FCC Update

Radio ownership rules relaxed

By Harry C. Martin

In a sweeping deregulatory move, the FCC has revised its national and local radio ownership rules. The specific changes, which became effective this month absent a stay or Congressional action, are as follows:

- A single licensee now may own up to 30 AM and 30 FM stations nationwide.
- In markets with fewer than 15 stations, a single licensee may own up to three stations, with no more than two being FM, provided the combination represents less than 50% of the stations in the market.
- In markets with 15 to 29 stations, the licensee may own up to two AM and two FM stations, provided the combined audience share does not exceed 25%.
- In markets with 30 to 39 stations, a licensee may own up to three AM and two FM stations, provided the combined audience share does not exceed 25%.
- In markets with 40 or more stations, a single licensee may own up to three AM and three FM stations, provided the combined audience share does not exceed 25%.
- Same-service simulcasting exceeding 25% of either station's programming is prohibited if the stations' service areas overlap by more than 50%.

For purposes of the new rules, *market* will mean the Arbitron-designated market.

LMAs

The commission has imposed the following restrictions on local marketing agreements (LMAs), where one station *leases* or *brokers* time on another in the same market:

- A station will not be permitted to time broker another local station that it could not own under the revised ownership rules.
- A licensee may not simulcast more than 25% of its programming on another station in the same service (i.e., AM or FM) in the same market.
- LMA agreements must be put in the contracting stations' public files (with confidential information edited if desired).
- LMA agreements will have to be filed with the FCC, along with station ownership reports.
- For purposes of applying the ownership rules, a station brokering time on another serving the same market will be considered to have an attributable ownership interest in the brokered station.

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

Restrictions on broadcast investment examined

In a further effort to improve the economic environment for broadcasters, the FCC is considering removing restrictions on investment in radio and television.

The commission is seeking comment on whether it should allow former licensees and financial institutions to hold security and reversionary interests in broadcast licenses. The commission is also suggesting alteration of its ownership attribution rules by raising the basic attribution benchmark from 5% to 10% and increasing the attribution benchmark for passive investors from 10% to 20%. The agency is also proposing to broaden the class of investors eligible for passive status under the ownership rules to include MESBICs and other equity financiers, such as widely held limited partnerships.

Anti-drug certification required

In February, new FCC rules went into effect implementing the Anti-Drug Abuse Act of 1988. Under the rules, applicants for new, modified or renewed FCC authorizations must certify that no party to the application is subject to a denial of federal benefits because of a drug conviction. The 1988 law mandates the denial of any federal license, grant, contract or loan to people convicted of distribution or possession of controlled substances.

The new certification, which broadcasters must separately prepare and attach to any request for a special temporary authorization, an experimental or field test authorization or a request for a new or modified call sign assignment, must contain the following certification:

- The applicant certifies that no party to this application is subject to a denial of federal benefits pursuant to Section 5301 of the Anti-Drug Abuse Act of 1988, 21 U.S.C. 853(a).

The commission will soon incorporate this certification in its official application forms. In the meantime, parties that have filed such forms will have made the necessary certification by signing the form.

The U.S. Court of Appeals strikes down FCC rule favoring female applicants because it violates the Fifth Amendment.

Female preference policy stricken

In an opinion written by Supreme Court Justice Clarence Thomas, the U.S. Court of Appeals for the D.C. Circuit has determined that the hearing preference the FCC has awarded to female-owned companies violates the U.S. Constitution. The court found insufficient records to demonstrate that the commission's sex preference policy promotes diversity on the airways. Because no compelling governmental interest was shown for retaining the preference, it was found to violate the Fifth Amendment.

Audio IDs are optional for TV political ads

Effective April 1, TV stations are no longer required to give audio identification of sponsors of political ads. However, stations will be required to abide by new standards that specify the size and duration of video identification of the sponsors of such ads. The minimum video ID of the sponsor must be in letters equal to or greater than 4% of the vertical picture height. Such IDs must be aired for at least four seconds.

The FCC emphasized that nothing in its ruling in any way altered prior policies requiring that a political ad contain sufficient information to allow viewers to identify the real sponsor of the ad. ■

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Circle (8) on Reply Card

re: Radio

RDS in action

By Mark D. Humphrey

In preparation for an SBE Chapter 18 meeting on the radio data system (RDS). WRTI-FM recently had the opportunity to install and evaluate some RDS equipment, which was used during the meeting for a live, over-the-air demonstration.

RE America provided an RDS encoder for the demonstration, along with a prototype Delco RDS mobile receiver. The encoder was installed at the WRTI-FM transmitter site in Philadelphia a few days prior to the SBE presentation. This allowed ample time for some field testing of the RDS system by the WRTI staff.

Getting on the air

The encoder's 57kHz output was connected to the SCA input of the FM exciter. The composite FM signal was also fed to the sync input of the encoder, allowing it to sample the 19kHz pilot, which served as its phase reference.

Some spare outputs on the station's dial-up remote-control system were also connected to the encoder. This allowed certain RDS functions to be activated via telephone.

Prior to shipment, the encoder had been programmed with our call letters, program identification, program type and several text messages, and the subcarrier output voltage had been set to the proper level. So once the appropriate connections were made, the system was fully operational.

Watching the radio

Upon activating the encoder, the RDS receiver immediately indicated new information. Its stereo pilot light was joined by an RDS pilot and three other new indicators. The letters TP showed that the station carried periodic traffic reports; MSG indicated that a radiotext message was being sent; and AF meant that our programming was being simulcast by translators on alternate frequencies. (An RDS receiver can track the signal strength of up to 25 other channels specified by a station's AF data, automatically switching to one of them whenever its received level exceeds that of the currently tuned channel. See "Rx for Radio Profits," March 1992, for full explanation of all RDS functions.)

Humphrey is assistant general manager and chief engineer at Temple Public Radio Network, Philadelphia.

The station's call letters (WRTI-FM) and program type (JAZZ) appeared in the alphanumeric display, in place of the usual frequency indication. Switching the receiver to its RDS mode allowed a short radiotext message to be displayed or the format-seeking function to be activated. The receiver's clock display (which had been incorrectly set at first) showed the exact time, which it obtained from the time data in the RDS signal.

Activating the traffic announcement (TA) function on the encoder caused the receiver's volume to be automatically turned up. If a cassette was being played when this function was engaged, the tape was stopped, and the radio switched on. (The system can be programmed to do the same for emergency messages, hence its consideration as a possible replacement for the EBS system.)

Road trip

The receiver was installed in a vehicle to evaluate its ability to switch to an alternate frequency as the main channel's signal strength faded. One of WRTI's translators serves Reading, PA, about 45 miles northwest of Philadelphia. Although the main signal from WRTI became fairly weak before the translator could be received on the typical car radio, the RDS receiver handled the transition smoothly. While tuned to the translator, the RDS features of the radio were again tested. Although the translator (which is fed off-the-air from the main station) is equipped with a special high-selectivity IF strip, the 57kHz RDS subcarrier apparently passed through without difficulty — all the RDS features worked as they had previously, when tuned to the main transmitter's signal.

Finally, the vehicle was driven through some hilly terrain to evaluate the effect of multipath on RDS performance. The large amount of redundancy in the coding scheme allowed the system to work reliably in all but the most severe multipath conditions. Even in spots where the audio was heavily distorted due to multipath, there were no false RDS indications, although the time required to display text messages was several seconds longer under these conditions.

RDS appeared to be a transparent service — it did not audibly affect signal quality.

RDS also appeared to be a transparent service — it did not audibly affect signal quality. With the RDS subcarrier injection at 3%, the increase in total peak modulation was nearly impossible to detect. It wasn't necessary to reduce main channel modulation in order to keep peak-flasher action within the legal limit. Throughout the testing period, WRTI staff listened closely on a variety of receivers, and no one reported hearing any "birdies" or other audible side effects that could be associated with the additional subcarrier.

An RDS future?

The experience with RDS generated substantial interest toward its future applications among this test's observers. For instance, the alternate frequency switching function should be a major convenience for mobile listeners to stations that use translators. The capability to provide forward promotion, enhanced advertising/underwriting service or information about the musical cut and artist currently playing should also be of interest to stations. (The data for such messages could be fed automatically from a program automation system.) Simply having a station's call letters and slogan displayed on receivers is an advantage, especially because it could result in more accurate diary entries during ratings surveys.

This test convinced us that RDS may have a significant impact on radio's future in the United States. ■

Part 3

Management for Engineers

The human network: a management tool

Making the most of a FEN

By Judith E.A. Perkinson

In October 1984, the building that housed PBS headquarters in Washington, DC, suffered a major fire, in which its Technical Center was destroyed mostly because of water damage. The outpouring of assistance and support after that fire still remains one of the industry's legends of cooperation.

PBS received much outside assistance after the disastrous fire. Other stations relayed PBS programs via microwave, or direct uplinked portions of the PBS broadcast schedule. Technical facilities were shared and equipment, such as videotape trucks, VCRs, routing switchers and monitors, was loaned.

Additional support came from public and commercial stations, broadcast groups and corporations. The industry effectively demonstrated the dramatic potential of teamwork.

This cooperation and teamwork does not have to be reserved for emergencies or natural disasters. It can be put to work now.

The last two months have focused on one way to capture that spirit of cooperation and build it into one of your standard professional resources. The Flexible Engineering Network (FEN) can be a vital tool in this process. This month, we are going to learn how to make the network a viable resource.

Primary benefits

Any FEN can offer a variety of benefits to its members. The most obvious is the solution to whatever problem on which the group is working. Therefore, selecting a problem to focus on is important.

The initial effort of a FEN should have a good chance of succeeding in a relatively short period of time; and the resolution of the problem should benefit the entire membership.

Some issues, however, are better left alone in the beginning. Avoid issues that involve proprietary information, that reveal damaging information about members, that have territorial implications or that directly affect a station's competitive position.

Perkinson is a senior member of The Calumet Group, Inc., Hammond, IN.

When the network is established and the members have a history of working together, it can deal with more sensitive areas. The goal is to build trust and a positive experience with one another.

Secondary benefits

Secondary benefits that members can receive may be just as important as the resolution of the primary problem.

- *Reduce isolation.* Engineers can become isolated at their stations because many of their peers are not technical people. They may not understand or care about engineering problems — even engineering terms can be barriers to understanding and communicating. The FEN offers you a chance to reduce your isolation and literally opens a world of contacts.

- *Share ideas and information.* It doesn't take a network project for members to share ideas and information. The informal communication that takes place between FEN members can be invaluable.

- *Learn to give and to get.* Encourage members to communicate what they can give and what they want to get. The FEN provides a structure in which you can ask and you can offer.

- *Make give and get possible.* One way to move your FEN further down the road to success is to structure effective communication relating to give and get. This begins with each participant completing a network member survey.

Completing a network member survey

Each member is asked to list the items they would be willing to give for free and for pay, as well as the items they would like to get for free and for pay. It is amazing how many resources can be generated when possible items on the list are discussed.

Making use of the survey forms

Once the forms are completed, it is important that the members are made aware of the information contained on the forms. A good way to do this is to share the contents of the survey in a meeting. Make sure members have time to speak to one another about the possible uses of the survey responses. Even if you don't have a meeting, it is important that a composite report be made of all of the responses, who said what, and the contact information. This should be distributed to all of the members.

Finding a balance

Using this information is up to each member. In order for this information to be successful, each member must take the responsibility of giving and getting. To give without getting breeds resentment of the process. To take without giving makes a member a liability, not an asset.

Flexible Engineering Networks are a valuable resource when they are properly managed.

Ongoing network activity

The ongoing network activity should center on addressing specific problems or undertaking projects as a group. This will require a structured meeting process. The nature of the problem and the method used to address that problem will dictate the frequency and nature of the meetings. The give and get matrix needs to be updated periodically. Remember, if members do not perceive and receive a benefit from participation in the network, there is no justification for its existence. Flexible Engineering Networks are a valuable resource when they are properly managed.

Next month's column will discuss how to maintain a network, and the kinds of activities necessary to ensure that it remains viable and valuable. ■

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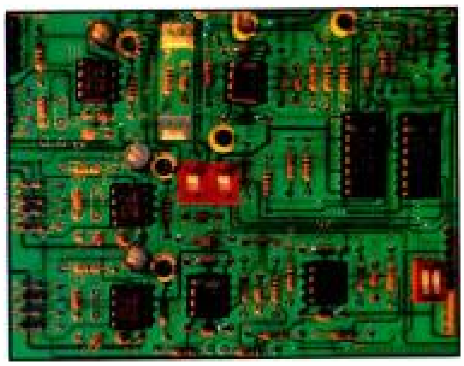
Part 1

Circuits



Looking into CCDs

How a CCD works

By Gerry Kaufhold II

Broadcasters have used charge-coupled devices (CCDs) for ENG cameras since the early 1980s. Their light weight, low cost and high reliability allowed CCDs to gain rapid acceptance. Manufacturers have produced high volumes of these devices for use in professional and consumer video camcorders.

This is part 1 in a 3-part series that will focus on CCDs.

Looking through the glass

The first step in creating a camera image is to gather light. This is the job of the *lens*. Most broadcast cameras use separate channels for green, blue and red. The light must therefore be separated by frequency. This is the task of the *prism*.

Although a lens for a tube camera will work on a CCD camera, there is one important difference: Tubes are adjustable, CCDs are fixed. Camera tubes mount in movable holders. The signals feeding the beam steering coils that surround the tubes are also adjustable. This means that you could adjust tube cameras to compensate for the unique characteristics of each lens.

CCDs, on the other hand, are rigidly and permanently mounted, usually to the prism itself. There is no possibility for adjusting the scanning process. This has required lens manufacturers to greatly standardize their wares. (For more information, see "CCD Lenses — Shooting for Perfection," February 1992.)

How a CCD works

All three CCDs in broadcast cameras operate alike. For this discussion, we will consider the green pickup.

Figure 1 shows a block diagram of a typical CCD. There are three sections. An array of photo diodes is positioned at the green output of the prism. As varying amounts of filtered light strike the diodes, those that are illuminated become forward biased. A current flows that is proportional to the intensity of the light.

A shift gate acts as a switch. This permits the current from each diode to be stored in a solid-state capacitor in the CCD. This circuit is similar to the *flying capacitor* used for analog-to-digital conversion. (See "Circuits," June 1988.)

The CCD analog shift register stores the charges coming from the diodes. Each of these analog registers has an address decoder that allows each portion of the image to be individually addressed. An address encoder cycles through the field of photosensitive registers, and reads out the analog voltages for each pixel. The speed of operation of the address decoder is synchronized to the scan rate of the selected standard (NTSC, PAL or SECAM).

Shifty register

The CCD analog shift register actually performs two functions, because it has a parallel input/serial output capability.

First, it performs a parallel input function, enabling all of the shift gates to provide their light-intensity signals at once. This function is similar to a camera shutter opening for a brief instant to let light pass through, and then closing and staying closed while the film is advanced. Shutter functions on CCD cameras perform high-speed video sampling. This allows creative coverage of high-motion events, such as the upcoming Summer Olympics in Barcelona.

Second, the serial reading of all its individual storage elements provides image scanning. By scanning through the addresses at the correct speed, one CCD circuit can serve for all three major broadcast standards. This feature makes CCDs the obvious choice for future broadcast cameras. It reduces overall costs by increasing unit volume. ■

Kaufhold is an electronics industry analyst based in Tempe, AZ.

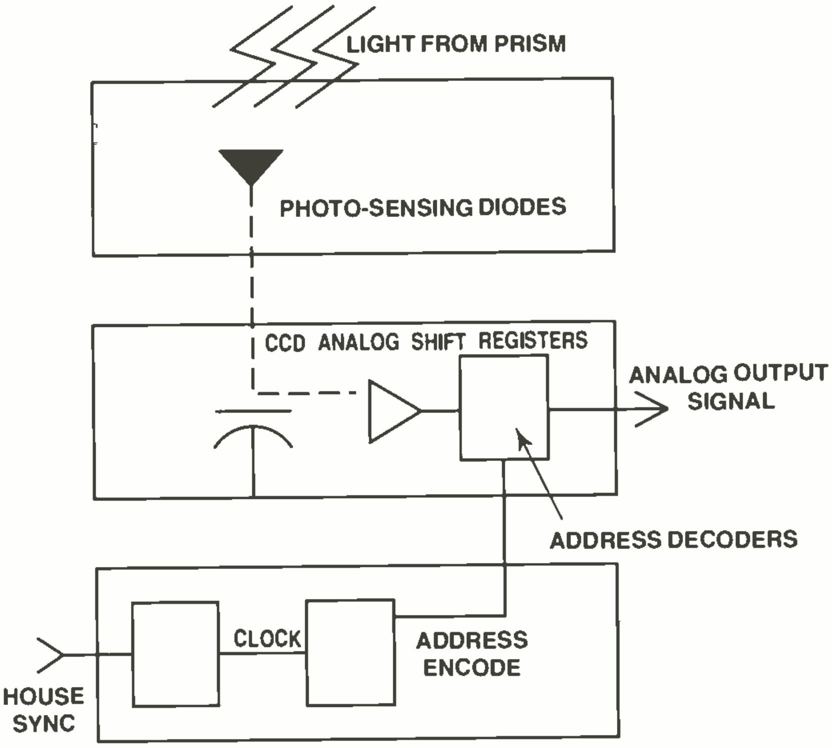


Figure 1. A CCD image sensor has three parts. An array of photo-sensing diodes converts light from the prism into currents. These are stored in the analog shift registers. The address encoder clocks out the image data in sync with the broadcast standard in use.

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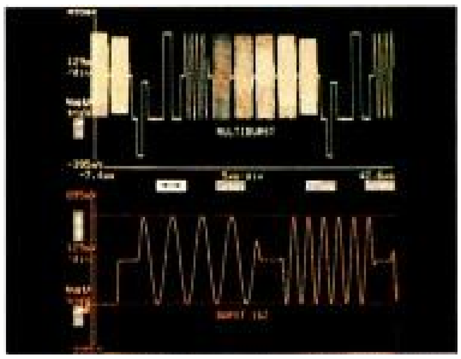
Part 3

Troubleshooting



Maintaining STLs

Antennas and feedlines

By Chris Durso

In addition to the essentially fixed nominal power output of a video or aural STL transmitter, *antenna system gain* and *feedline loss* are the primary factors in determining received signal level in any STL. Increasing antenna size (gain) will increase the reliability of the system in most cases. Windloading of the tower and sensible fade margins necessary for a given path length provide some limits, of course. Overdesign of an antenna system can also cause interference to other users.

Part 74.536(a) of the FCC rules states that aural broadcast STL stations are required to use directional antennas with the minimum beamwidth necessary — consistent with good engineering practice — to establish the link. Proper design should consider adjacent and co-channel users, and strive to maximize service availability within the market.

Antenna maintenance

Antenna maintenance primarily involves annual, semiannual or seasonal visual inspection of all hardware. *Think safety first.* Never work alone on a tower. Always wear protective clothing and boots, and use a safety belt. Hire a qualified climber if you are not confident in your ability to do tower work.

On the tower, check to ensure that all antenna hardware is clean and tight. Only stainless steel or galvanized hardware should be used on the antenna. Visually check that the antenna appears to be properly aligned with the other end (bore sight). Carefully examine the radiating element and radome cover for signs of damage. Verify proper operation of heating elements. Take the time to look around to see if any natural or man-made obstacles have appeared in the path of the antenna. Inspect the mechanical integrity of ice shields if they are used.

At microwave frequencies, even a small alignment error can result in a great loss of received signal strength. If you suspect an alignment problem, first log the existing receiver signal-strength indication as a reference. Next, carefully adjust the receive-antenna's azimuth and then its elevation to obtain the best signal. The same procedure should be repeated at the transmit end while observing the received signal strength. Fine-tune the adjustments on each end until no further improvement is noted.

Durso is chief engineer at KPBS-FM, San Diego.

When using a compass to establish an initial azimuth heading during antenna installation or replacement, remember to factor in your local magnetic variation (aeronautical charts can provide this information).

Connectors

Connectors are probably the single greatest cause of antenna system failure, typically resulting from improper installation, poor solder connections or moisture damage. If a connector is suspect, replace it. RF adapters should also be replaced with proper connectors.

Connectors are probably the single greatest cause of antenna system failure.

Although waveguide connectors are simple to install, extreme care should be taken not to damage the feedline or allow foreign material to enter the line. Always cut the line with the end facing down. Use an abrasive pad to remove accumulated oxidation from the cable walls.

Coaxial connectors require careful attention to feedline preparation. Be sure not to nick the center conductor on flexible cables. When preparing hard line, use a fresh hacksaw blade and an abrasive material to shine the copper before applying solder.

Always follow manufacturers' step-by-step instructions, no matter how many times you have installed connectors in the past. After installation, check for shorts and opens with an ohmmeter. Outdoor connectors should be properly protected with a combination of electrical tape and electrical coating (for example, Scotch Kote).

Feedline components

Feedline components include the feedline, connectors and, in the case of pressurized lines, nitrogen or a dehydration system. Regular maintenance on feedlines should include checks for damage by tower workers. Dents or kinks in cable will result in a distortion of the characteristic impedance of the line. Also, check to ensure that the line is properly attached to the tower.

Often, a section of outer jacket will be removed for the connection of a grounding kit. Verify that the ground connection is mechanically sound and free of moisture damage. The point at which the ground strap attaches to the feedline should be well protected from the environment.

Water can travel downward along a feedline and find its way inside a building or even an equipment rack. To alleviate this potential problem, a drip loop should be formed by the feedline immediately before the building penetration. The moisture will accumulate at the low point in the loop and be kept from entering the building.

After ensuring the transmission line system is in good condition, establish a reference level for *reflected power* on the line at the transmit end and *signal strength* at the receive end. Later, a change in these readings could indicate a problem in the feedline system. Of course, the engineer must eliminate the effects of the "active" components in the STL system, which may influence these readings before suspecting the feedline.

Pressurized feedline systems rely on compressed nitrogen or dried air for the feedline dielectric. The pressurized gas is applied to the feedline via a gas barrier connector at one end of the line. Occasionally, a nitrogen bottle will require replacement. Track the use of nitrogen, because it is a good indicator of the condition of the O-rings and pressure windows in the gas barrier connectors. The drying agent in a dehydrator system will also require maintenance. Follow manufacturers' recommendations for conducting dehydrator maintenance. ■

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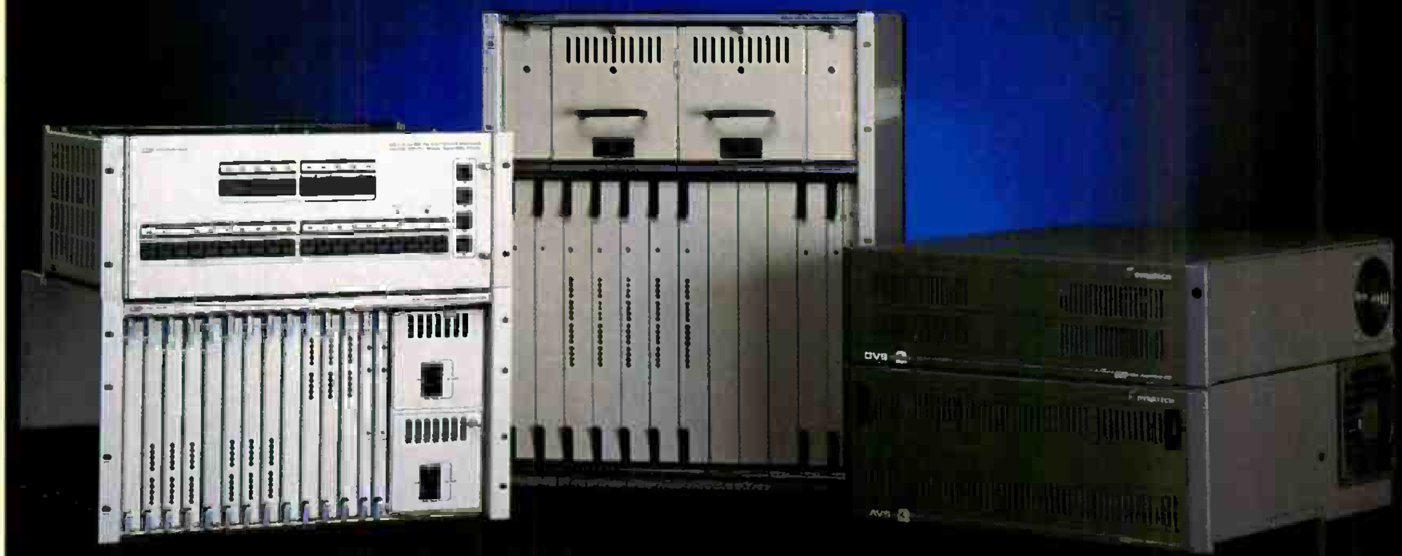

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Technology News

A universal TV system

By Carl Bentz, special projects editor

Picture the family room of tomorrow's modern home or the conference room of a business establishment. The focal point is a large screen display. It will serve as much more than just a television to watch local broadcast, cable and satellite TV channels or VCR and videodisc playbacks. At home, there will be TV games, a home computer, a video phone and perhaps, via modem, a link to a reference library permitting information on almost any subject to be viewed.

The display of the office system will also provide several functions — the teleconferencing system, computer workstations, a link to the stock market and other selections. Unlike today's televisions and monitors, the display will accommodate multiple imaging functions from synchronously unrelated sources on the screen simultaneously.

An open architecture

Today's video display units are based on a strict relationship between pixels, lines, fields and frames, using relatively simplistic methods to sense H/V sync, luminance and chroma information. Some can accommodate the different line and frame rates of different video sources, as long as each is selected one at a time. Some include a picture-in-picture mode from mutually synchronous sources.

Tomorrow's information center display will feature an open-architecture approach. The display module, controlled by a microprocessor, will include framestores fed by several input processor modules. The result will merge sources of varying scan rates into a single display, which may operate at still another rate. Think of it as a truly multimedia display — capable of showing images from film, NTSC, PAL, SECAM, HDTV, computer, teleconferencing and other diverse sources. Add multiple stereo audio channel sound and the whole family could use one display for several projects. Multinational businesses could conduct meetings among their international corporate offices, including drawings from a CAD workstation. Frame rates will no longer be critical issues, depending upon the type of input modules selected for the system. Separate standards and scan conversion equipment won't be needed.

Scaled to fit

Your new information display based on open architecture will operate at its own scan rate. Input modules and interim processing will be responsible for the conversion of source signals into a scalable form, which will subsequently be reproduced on the screen. The processors, using a time base corrector approach, write data into the framestore at rates based on the sources. Data is extracted from the memory at a rate specific to the display.

The term *scalable* goes beyond multiplying or dividing by some factor. Here it suggests that you may elect to decode only part of the input signal to arrive at an image with a resolution lower than that of the source, depending upon your display options.

Scaling produces a multi-image picture-in-picture type of presentation. Technically, the size and position of any image should be fully adjustable. The resolution of each will be automatically adjusted for optimum viewing. Separate stereo audio channels for each image will drive headphone outputs, but may be selected to go through the room sound system.

N-dimensional subband coding

To accomplish such visual presentations means that a multiresolution representation of the input video signals must be developed for transmission. One method uses single dimension high- and low-pass filters to subdivide horizontal and vertical information. This subband sampling of each band by a factor of two produces four new bands, described as low-pass in H and V, low H/high V, high H/low V and high-pass in H and V. The process is carried out recursively or repeated on each of the four bands, producing a number of levels of resolution. (See Figure 1.)

In the receiver, complementary interpolation filters will reconstruct the image from the subbands, using those necessary to achieve the desired resolution. The selections will range over full screen to reduced-size displays from any of the sources, including HDTV and computer systems. Equally challenging for the designers of tomorrow's television will be the development of a user interface that will not alienate non-technical viewers, and that will permit more technical-minded viewers to take advantage of the new system's flexibilities.

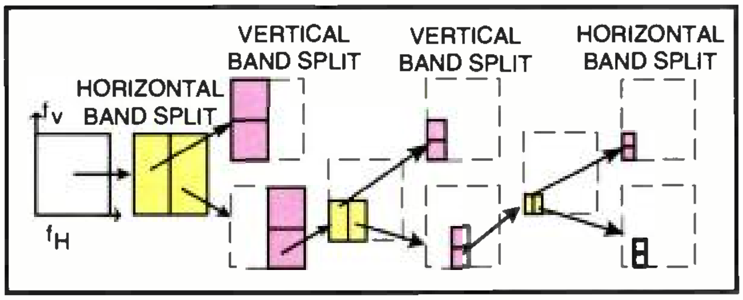

Figure 1. In an open-architecture system, a series of recursive low- and high-pass filters repeatedly split signals into narrower subbands. By selecting a specific set of subbands, you can recreate an image on screen with a specified resolution.

Editor's note: This column is based on the article "Scalable Open-Architecture Television," by V. Michael Bove Jr., and Andrew B. Lippman, SMPTE Journal, January 1992, pp. 2-5.

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- **1988** • AutoCam ACP-8000 touch screen, menu-driven eight camera controller. • AutoCam SP-200 Servo Pedestal for HS-110P and HS-105P. • AutoCam Newsroom Computer Interface for ACP-8000.
- **1989** • AutoCam SP-200/X-Y. The world's first "free-roaming," full-motion X-Y base. • AutoCam SportsFocuser automatic focusing system. • Patent awarded for SP-200/X-Y targeting system. • Copyright for ACP-8000 touch screen software.
- **1990** • AutoCam Full-Motion control editing. • ACP-8000 on-screen air tally. • Real-time CCU control. • MCB-1 local manual control box. • ROP Remote Operating Panel. • Battery Pack option for SP-200/X-Y.
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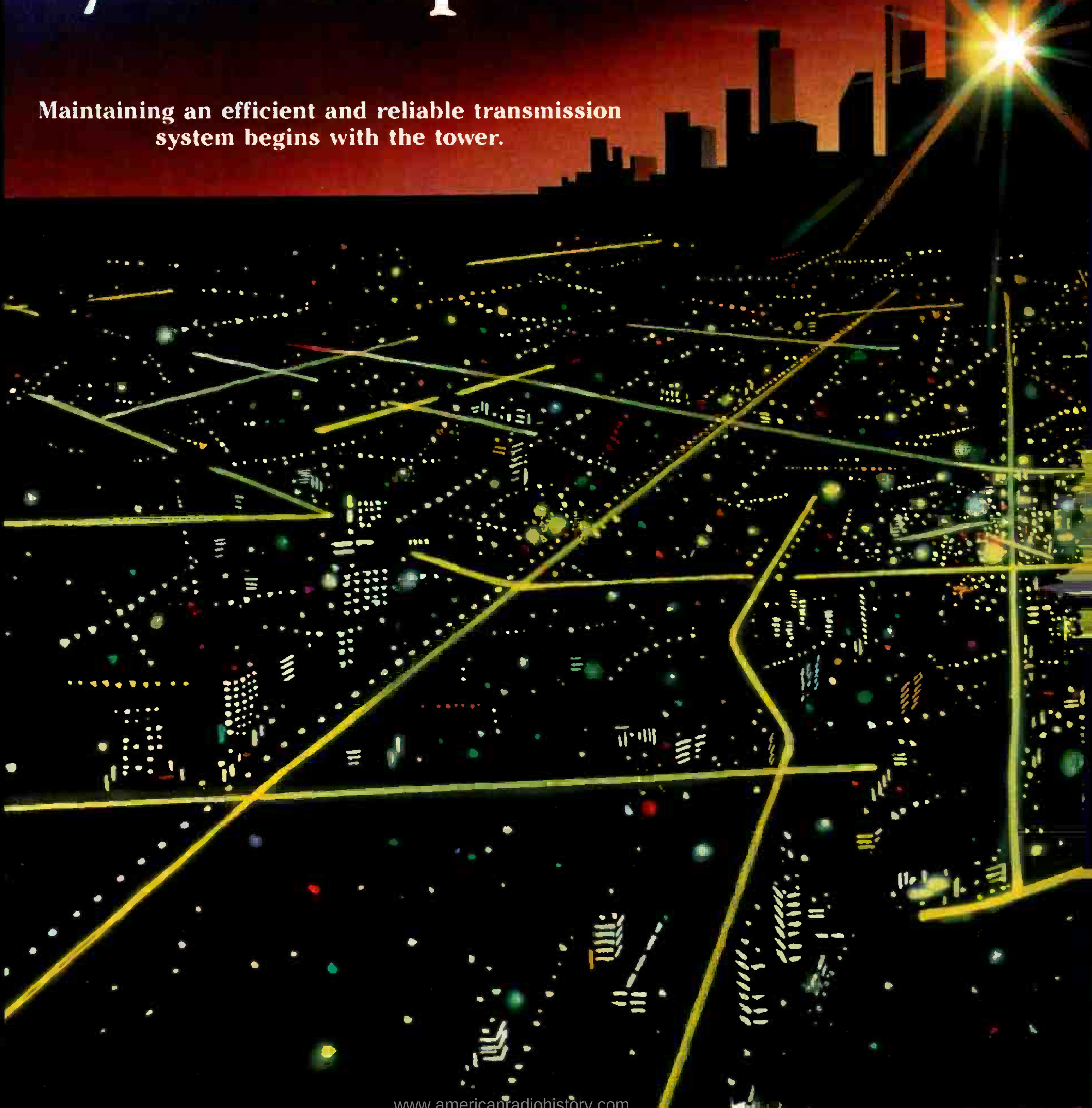
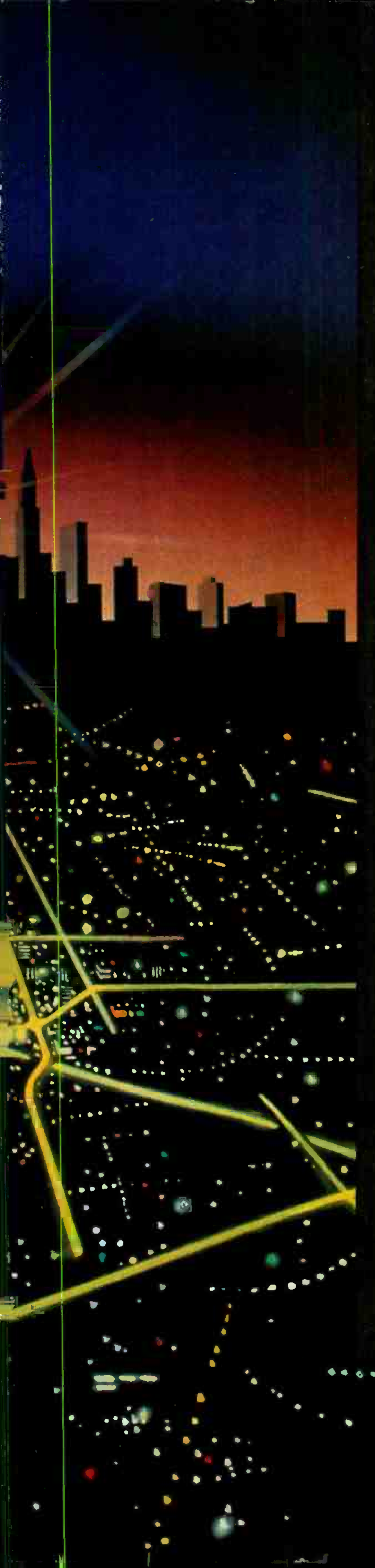
Program transmission systems update

Maintaining an efficient and reliable transmission system begins with the tower.





The most critical link between you and your audience is the RF system. A console or cart machine can be replaced if they quit. A facility may have a backup camera or studio, but most stations have only one transmission system. If it fails, your station is out of business.

This month's issue is devoted to this crucial side of the business. The goal is to build and maintain efficient and reliable systems. We will begin with the tower.

As land becomes more expensive, finding a site to locate a tower can be difficult. In some areas, the cost of land may exceed the price of an entire RF system including transmitter and tower. This phenomena is forcing stations to re-examine the entire tower-building process. One increasingly common approach is to build one large tall tower designed for multiple stations.

The article, "Considerations in Building a 1,000-Foot Tower," provides important guidance in building such a tower. Selecting the site, tower company and contractor, are all decisions that require detailed attention.

The second step to joint tower projects is usually the antenna. Modern designs allow stations to share the same antenna. Such an approach has two important advantages over separate antennas.

First, one antenna system will likely place less windload on the tower.

Second, using a single antenna for multiple stations allows each station to enjoy optimum placement on the tower. It is no longer a case of the guy on top having the best pattern. Now, everyone can enjoy optimum height and signal coverage. "Multichannel TV Antennas" outlines the technology behind these designs.

Protecting transmission systems from lightning strikes is one area that everyone agrees upon. Damage from lightning to transmitters and antennas is a common (and expensive) problem for radio and TV stations. Fortunately, systems are available today that can reduce the likelihood of being struck.

"Lightning Protection Systems" describes the technology behind such devices. Even if your station has yet to be zapped by a bolt from the sky, it could be next. This is one area where an ounce of prevention is worth far more than a pound of cure.

Today, radio stations often find that their success is tied to visibility within the community. One effective way to do this is to get your on-air talent out of the studio and in front of the audience. Stations have discovered that there is money to be made by being visible at the local mall and community events.

In the feature, "Solving RPU Intermod Problems," the author provides practical solutions to the often complex and misunderstood area of remote pickup transmission systems. The article reviews the theory behind intermodulation interference, how it is generated and what you can do to prevent it from ruining your next broadcast.

Fortunately, you don't have to reinvent the wheel when it comes to getting extra performance or value from your facility. In the feature, "Radio On a Budget," the author reveals how easy it can be to improve performance or obtain new features — without going bankrupt.

We conclude our RF coverage by looking at new developments in TV transmitter design. "RF Technology Update" reviews the types of amplifiers used in modern UHF transmitters. If you're involved in the maintenance or purchase of these systems, don't miss this article.

Broadcast transmission systems will always be an important link to our audiences. Fortunately, there are more solutions than ever in maintaining that connection.

Brad Dick

Brad Dick, editor

Introducing multi-cassette software so ahead of

The Electronic Industries Association (EIA) sets specific standards that dictate minimum criteria for the design and construction of antenna-supporting structures. Specifically, a broadcast tower should meet the latest version of the EIA/TIA-222-E standard, which addresses towers.[1]

The tower must also conform to local ordinances, which sometimes are more stringent than federal standards. If a tower should fail for any reason, the broadcast operator will be charged with proving the tower met all required standards. One source of this proof is to have a locally certified structural engineering company approve the design. It can signify its acceptance by affixing the company's seal. When comparing bids for a tower, be sure that the price includes sealed designs. Some vendors charge extra for sealed drawings.

Flexibility in design

Design ahead of time for extra antenna and dish loads. It is hazardous to increase a tower's load without first estimating the effects. It is much safer to ensure the tower has capacity for growth from the outset. Failing to design for growth may mean that the tower cannot be upgraded later without significant additional cost.

A manufacturer's flexibility is important. Portions of the tower may be customized designs, but make sure that custom design doesn't mean custom time or prices. The manufacturer should understand that last-minute changes are par for the industry, and don't necessarily have to mean an increased cost.

Guyed towers are the most common

Towers more than 1,000 feet nearly always stand with the help of guy wires. Guy cables resist the horizontal windload. Ideally, the guy radius should equal 80% of the tower height. Towers with a smaller guy radius will be more expensive. The more vertical the guys, the less effective they are. This requires larger steel members and additional bracing to bear the increased torque and horizontal load.

A critical design facet of a tall guyed tower is selecting the right tower face width. Usually, the smaller the tower face width, the less costly the tower. On the other hand, the wider the face width, the

Although you may save money with an inexpensive site, the cost may rise if you need to build a special foundation.

stiffer the tower. Some tower manufacturers have used too small a face width only to find that excessive tower movement has damaged antennas and rigid transmission lines.

The manufacturer should understand that last-minute changes are par for the industry, and don't necessarily have to mean an increased cost.

Be especially careful if the tower design has a cantilever. The cantilever is the portion of the tower or antenna that extends above the top guy level. An inappropriately thin tower with a large cantilever may exhibit *dynamic motion*, rocking back and forth like a pendulum.

Down to earth

It could be a costly surprise if a tower manufacturer assumes the soil at the site is normal. EIA/TIA-222-E defines normal soil as "a cohesive soil with an allowable net vertical bearing capacity of 4,000lbs/ft^2 and an allowable net horizontal pressure of 400lbs/ft^2 per lineal foot of depth. Rock, non-cohesive solids or saturated or submerged solids are not to be considered normal soil."

This definition is significant when comparing bids. Few places in the country have normal soil conditions as defined by the EIA.

Hire a trained geologist, one familiar with tower and foundation construction requirements, to examine soil samples from the tower site. Soil testing provides information on seismic considerations and susceptibility to frost. It also provides insights as to which type of excavation is appropriate, and what kind of foundation is required.

Unless a detailed soil analysis has been made available to vendors, ignore the foundation cost when comparing bids. A vendor may submit a low bid on the foundation, citing normal soil, then later increase the price to accommodate soil conditions.

Safety first

Safety is a prime consideration for technicians working on or around the tower, and for antennas and equipment. The burden of choosing the correct design wind velocity and ice accumulation lies with the tower purchaser. Be sure all vendors are using the same wind- and iceload in their calculations. The EIA guidelines set forth a uniform design standard for broadcast towers throughout the country. These standards are based on the ANSI A58.1 publication, which serves as a guide for most building codes.

The EIA standard specifies a minimum design wind velocity on a county-by-county basis. Specific areas of the country, such as the coast of the Great Lakes and the top of the Rocky Mountains, are considered special wind regions. For these, the EIA makes no wind velocity recommendations.

The standard also makes no recommendations concerning radial ice accumulation. The EIA standard does caution "very tall towers may experience large thicknesses of in-cloud icing over portions of the mast." Do not allow the tower manufacturer to ignore this critical design consideration.

In most locations, the maximum wind velocity and ice accumulation do not occur simultaneously. For this reason, the EIA standard allows a 25% reduction in windload considering icing. Unless you specify that the maximum wind- and iceloads should be considered to occur simultaneously, the tower manufacturer will often automatically include this windload reduction in the calculations.

I meant a tower light

The Federal Aviation Administration (FAA) dictates tower lighting requirements, and the FCC enforces them. All towers more than 1,000 feet require lighting. Lighting options include red incandescent

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or white strobe lighting. For the convenience of people who live around the tower, operators can install a dual lighting system, using red incandescent lighting at night and the white strobe during the day.

Lighting controls should have alarms to show lamp failures, flash failures or power outages. If a lamp fails, the operator must notify the FAA within 30 minutes. The lighting system must be repaired as soon as possible, and the FAA notified when repairs are completed. (See the related article, "Lighting Rules Update," pg. 32.)

The FCC can impose stiff lines for improper lighting. Furthermore, the FCC can cite all users of a tower for improper lighting. This is the case even if some of the users are merely tenants who are under the impression they have transferred responsibility to the tower operator.

It is especially important to light towers during construction. Unless it is lit during construction, a general aviation pilot may not be aware a tower is going up. This poses a potential hazard, for which the tower operator may be liable.

Be sure to find out if the tower requires painting. Although the use of strobes obviates the requirement in some situations, it may not do so in all cases. Furthermore, the FAA standard of alternating bands of international orange and white may prevent liability if an aircraft accident occurs while the strobes are out of service during the day.

Consider having the factory paint the steel during manufacturing. Because the paint can go on in a controlled environment, factory-painted towers can have a better seal and more even coating.

> ***Unless a tower is lit during construction, a general aviation pilot may not be aware a tower is going up.***

Be secure

An elevator is a safety precaution for technicians working on or around the tower. Some towers more than 1,000 feet will have an open-lift elevator mounted on an inside face. The face width should be at least eight to 10 feet to accommodate an elevator. If there is no elevator, place intermediate rest platforms every 200 to 400 feet. These may or may not include RF-safe enclosures.

Anti-climb devices can prevent unauthorized access to the tower. Owners often supplement these with a barrier or fence around the tower base.

Quality materials

When purchasing a tall tower, make sure the manufacturer intends to use quality steel. Ask for mill certifications. It is common to construct tall towers out of high-strength steel. However, some manufacturers may use an inappropriate (too brittle) steel, or claim that an unlisted steel has unrealistically high strength. Higher-strength steel allows the tower manufacturer to reduce the size of the steel members. This saves money, but reducing member sizes may create more tower movement.

Workmanship is as important to the tower's success as the materials. A reputable vendor should be more than willing to offer a tour of its manufacturing facilities.

Check the references of the manufacturer's independent contractors. Ask how long they have been doing tower work. Examine recently completed projects to ensure they are living up to their reputation.

Apples to apples

Many options need to be considered when purchasing a tower. When bids are compared, be sure the specifications are equivalent. Pay particular attention to such areas as:

- Wind- and iceload
- Antennas, dishes and line loadings (including azimuths)
- Consistency in tower face width
- Quality of steel
- Welded vs. bolt-up construction
- Inclusion of sealed drawings
- EIA-applied standards
- Painting
- Lighting
- The foundation price based on a detailed soil report
- Freight charges (including off-loading)
- FOB location
- Delivery times

Make sure a tower manufacturer's warranty exists for your protection, and is not merely a long-term employment contract for parts, materials and labor.

Request that the manufacturer break out all bid options into line items. This will help you make even comparisons. It will also allow you to more readily add and subtract options without greatly affecting the calculation of the total cost.

Also, thoroughly examine a tower manufacturer's warranty. Make sure it exists for your protection, and is not merely a long-term employment contract for parts, materials and labor. Some warranties may require that the broadcast operator have the manufacturer's personnel perform periodic inspections at a cost of $750 to $1,000 each. Make sure this meets *your* needs.

Be sure a manufacturer's bid has a waiver of subrogation and lists the purchaser as additionally insured. Include this in your request for a quote. It is also wise to request that the manufacturer provide a lien waiver that ensures it has paid all its subcontractors. This assures you that no subcontractor will approach you for payment.

Financial protections

The manufacturer should be financially stable. Examine Dun & Bradstreet reports that apply to the companies you're considering. Also check the manufacturer's insurance coverage. Tower manufacturers should have at least $500,000 basic general liability, plus $1 million in umbrella coverage. The manufacturer's contractor also should carry an all-states-endorsed worker's compensation plan.

An installation floater policy is another form of insurance that tower manufacturers and subcontractors should carry. This covers all materials in the care, custody or control of the manufacturer.

Finally, requiring a performance bond can help ensure that the manufacturer will complete your project as expected.

Final considerations

A tower is a product that has more than a 30-year lifespan. It needs long-term support. Careful planning will ensure the longevity of the investment that is supporting your sensitive antennas, equipment and personnel.

Because constant service and airtime are a priority, you must carefully evaluate vendors, vendors' bids and warranties when it comes time to buy a tower more than 1,000 feet.

Endnote:

1. Copies of the EIA/TIA-222-E "Structural Standards for Steel Antenna Towers and Antenna Supporting Structures" are available from the EIA Standards sales department at 202-457-4966.

Acknowledgment: The author would like to thank Kevin Bauman, Paul J. Ford and Company.

➡ *For more information on towers, circle Reader Service Number 300.*

Lighting rules update

By Bob Mosher

One of the worst scenarios for the owner of a broadcast tower is to have an aircraft collide with it. Tower marking systems are designed to keep the airways safe. Lighting systems, like everything else, break down. When they do, the tower operator is obligated to tell the FAA within 30 minutes, and then fix the problem as soon as possible.

The FAA's rules on tower markings specify standards designed to ensure tower visibility. These standards are published in a series of advisory circulars distributed by the FAA Air Traffic Rules & Procedures Service. The current circular is titled AC 70/7460-1H.[1] Chapter 2, paragraph 23 of the circular states,

Lighting systems break down. When they do, the tower operator is obligated to tell the FAA within 30 minutes, and then fix the problem as soon as possible.

"Conspicuity is achieved only when all recommended lights are working. Any outage should be corrected as soon as possible. Any failure or malfunction that lasts more than 30 minutes and affects a top light or flashing obstruction light regardless of its position should be reported immediately to the nearest automated flight service station (AFSS) or flight service station (FSS) so a Notice for Airmen (NOTAM) can be issued."

Toll free numbers are listed in most telephone directories. Notify the same AFSS/FSS as soon as normal operation is restored.

Non-compliance with notification procedures could subject its licensees to penalties or fines. Avoid complacency. The penalty can be a stiff one. (See, "FCC Update," October 1991.)

Ring around the tower

Recently, the FAA standards have been updated. AC 70/7460-1H effectively supersedes all previous AC circulars. (Suffixes -1G, -1F and -1E).

The new rules could affect tower operators who have added significant new equipment to their structures. Rules for red light and white light systems require that the tower members and feedlines do not obscure the beacons or flash heads.

Chapter 5, paragraph 54, sub 2B states that on a structure exceeding 350 feet (107m) AGL, one beacon (L-864) may be installed either within or outside the structure if the transmission cable (conduit) or the tower legs do not have an effective diameter of more than three inches. If either is more than three inches, two beacons must be installed opposite each other on the outside of the structure. The same holds for medium-intensity (L-865/L-866) white lighting (Chapter 6, paragraph 62, sub 3B).

Existing tower structures lit in accordance with previous FAA standards are not yet required to change. However, any addition to the structure may require relighting to conform to new standards.

Measure first

Changing an antenna on an existing structure may also lead to problems. The standard on white (strobe) lighting (Chapter 6, paragraph 62, sub 3) states, "On appurtenances exceeding 40 feet (12m) above the tip of the main structure, a medium-intensity flashing white light should be placed within 40 feet (12m) from the top of the appurtenance." Furthermore, Chapter 7, paragraph 75 states (in part), "When a structure lit by a high-intensity flashing light system is topped with an antenna or similar appurtenance exceeding 40 feet (12m) in height, a medium-intensity flashing white light (L-865) should be placed within 40 feet (12m) from the tip of the appurtenance. This light should operate 24 hours a day and flash simultaneously with the rest of the lighting system."

Incidentally, the flashing of all obstruction lights (red/white beacons) on a single structure should occur simultaneously. There should be no more flip-flop or asynchronous flashing.

Newspeak

Some terminology has been altered in the updated rules. *Pulse* is replaced with *flash*. There has also been a change in lighting nomenclature. The red flashing 300mm code beacon has been redesignated from L-866 to L-864. The red L-810 side lights, however, remain the same. White light (rectangular) flash heads are L-856 (40 flashes/minute) and L-857 (60 flashes/minute). Conical white light beacons are L-865 (40 flashes/minute) and L-866 (60 flashes/minute).

Longitude and latitude coordinates are now required in reporting the location of towers, for whatever purpose.

Because federal inspectors are paying closer attention to tower lighting, operators may consider updating their flasher systems to include more sensitive lamp failure alarms.

Goodbye, Rube Goldberg

Broadcasters have historically used fairly primitive means to ensure that tower lights are operating. Because federal inspectors are paying closer attention to tower lighting, operators may consider updating their flasher systems to include more sensitive lamp failure alarms. New tower lighting controllers incorporating solid-state relays and alarm control devices are available for new or old towers.

Keep in mind that a properly lit structure not only includes the appropriate light fixtures and controls, but also does not forsake the NEC or local electrical codes to which the lighting system should conform.

Mosher is an electrical engineer and obstruction lighting consultant for Crouse-Hinds Airport Lighting, Chalfont, PA.

Footnote:
1. For copies of the AC 70/7460-1H Standards, contact the Department of Transportation, Utilization & Storage Section (Publications), M443.2, 400 7th Street, Washington, DC. 20590. ■


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Multichannel TV antennas

Broadband radiators make sense for today and tomorrow.

By Dennis M. Heymans

The Bottom Line

Antennas that are tuned to a single channel have long been the norm, but today's fiscal realities are causing some broadcasters to explore alternatives. Improved cost effectiveness at the transmitter site is possible when an antenna is shared by two or more stations. Signal quality and/or coverage may also be improved. Multichannel systems could play an even larger role in the HDTV transition by allowing use of the same antenna for NTSC and HD simulcast channels. $

Heymans is sales manager for Micro Communications, Manchester, NH.

Multichannel antenna systems have been used in FM radio and by international broadcasters in general for many years. But relatively few American TV broadcasters have realized the benefits of these systems until recently. In today's marketplace, it makes good economic sense to co-locate, thereby minimizing initial capital expenditures. This approach can help each station involved in a shared system in several ways:

- Lower start-up costs for tower and transmission line.
- Sharing of the prized "tower top."
- Reduced physical construction at the site (buildings).
- More space available on the tower.
- Reduced intermodulation and ghosting.
- Reduced RF radiation problems at the site.

Because of the ever-increasing pressures and local restrictions on antenna installations, it is important to have a system that is expandable and in compliance with local ordinances. Non-ionizing radiation issues have also become important for site approval. Community antennas for new or existing structures that minimize downward radiation will reduce these approval hurdles.

Antenna element characteristics

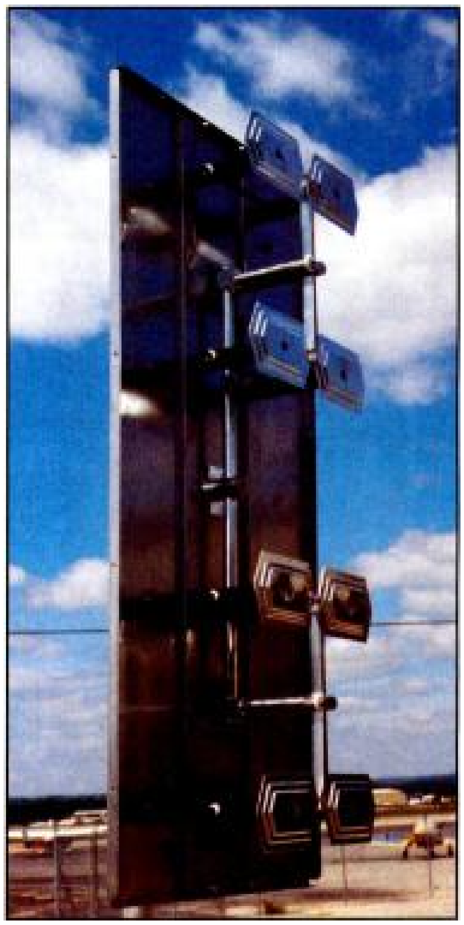
The first items to be examined are the radiating elements. A wideband antenna often uses a modular panel design, which can provide various azimuth and elevation patterns.

Figure 1 shows five standard azimuth patterns. Special patterns can be easily configured using panel elements. Shaping of the pattern with null-fill also provides excellent near-field coverage. A wide range of total system gains is also available, running anywhere from four to more than 130 times the input power.

The VSWR performance of an individual panel is typically 1.10:1 over the entire UHF band (470MHz-800MHz). Construction of the panel consists of a number of dipoles mounted in front of a reflector. Research has shown that a flat dipole is far superior in performance to a tubular dipole.

Dividers, cables and feed systems

The only way to ensure a broadband system is to start with wideband basic components. Panels, power dividers, flex and rigid coax lines are the required building blocks. The antenna panels used in these systems are designed to exhibit wideband response, as previously mentioned. Power dividers are simply multistepped impedance transformers and are broadband devices. Coax cables or rigid



A single panel from a multichannel panel array, with radome removed.

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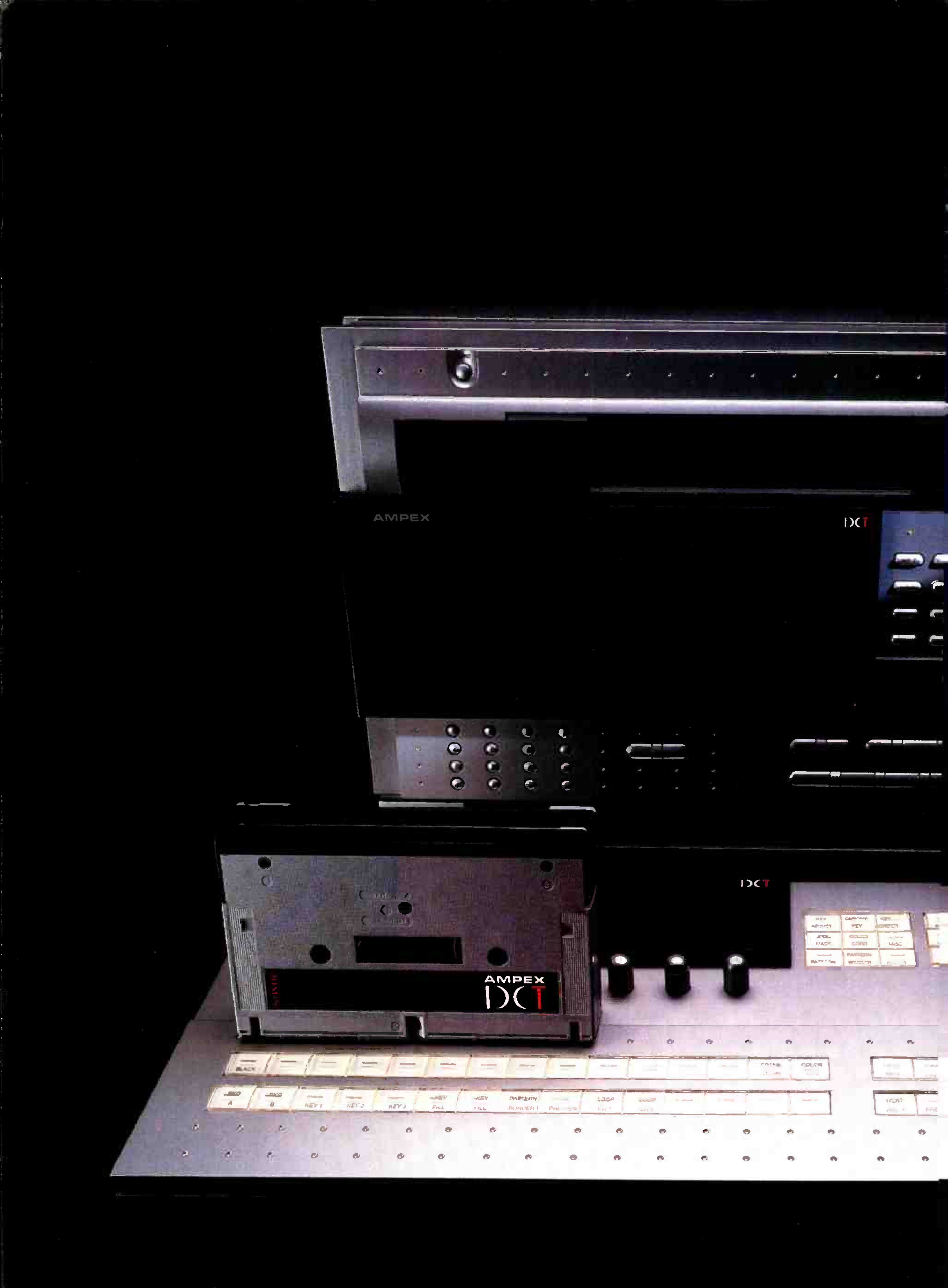
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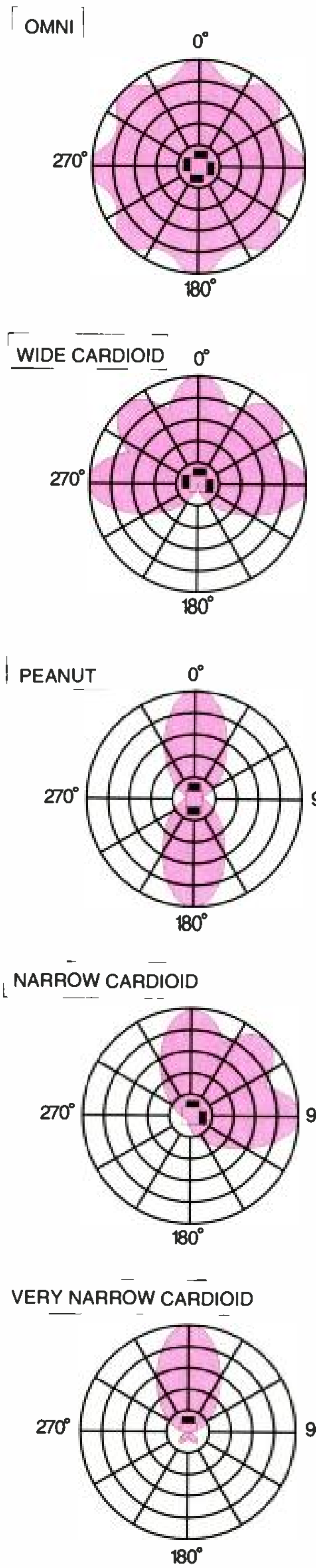

Figure 1. *Polar plots of five standard antenna azimuth patterns.*

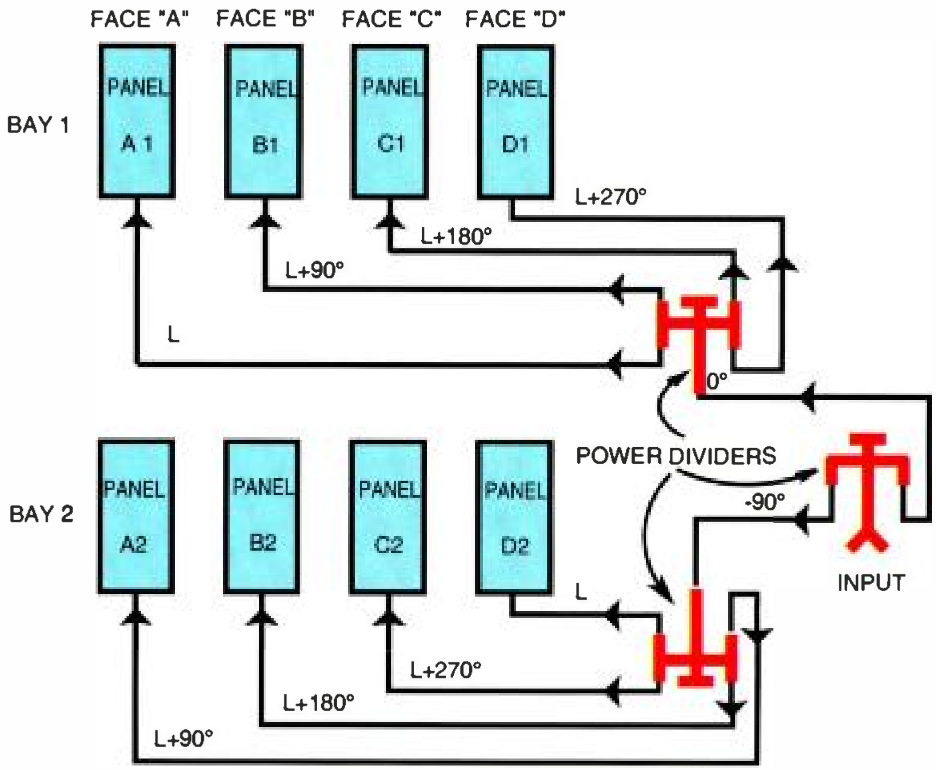

Figure 2. *Quadrature phasing of a 2-bay panel antenna.*

lines are inherently wideband. All that remains is the assembly of these items into a system that retains the individual wideband nature of each of its components. This is the role of the feed harness.

By using a branch (or parallel) feed system, it is possible to have a complete antenna system with good performance over the entire band. The branch feed system allows the use of *quadrature phasing* to perform the required impedance compensations.

Quadrature phasing provides complete cancellation of identical signal reflections through the use of quarter-wave difference cables. Feeding a power-divided RF signal to radiating elements via this so-called cable phasing arrangement allows the required bandwidth to be achieved. Figure 2 illustrates the use of quadrature-phased cables in a 2-bay array.

This principle is based on the physics of phase rotation. If all the radiating elements present an identical load to the transmitter in terms of amplitude and phase, the result will be complete cancellation of reflected power. To accomplish such complete cancellation with four identical dipole panels, they must each be fed with vectors of the same amplitude but quadrature-phased. As Figure 2 shows, the signals feeding the four panels of each bay are phased 0°, 90°, 180° and 270°, respectively. This causes any reflected RF coming back from the panels to cancel at the power divider.

Other methods of reflected-power cancellation using RF hybrids can also be used. These involve mechanical polarity inversion of the panels (i.e., exchanging panels top to bottom), and the use of quadrature phasing with 3dB hybrid couplers.

Panel displacement

Complementing the phasing of the feed cables is the mechanical displacement of the panels around the tower. In displacing each panel by a certain physical offset, the correct phase of the combined radiated field is achieved.

> ***The only way to ensure a broadband system is to start with wideband basic components.***

This allows tight control of coverage patterns, and provides the possibility for easily adjustable, constructive interaction between antenna elements. The actual amount of offset is calculated from the geometry of the panel layout.

Channel combiner techniques

Equally important in a wideband shared antenna system is the method in which multiple RF channels are fed to it. Two approaches are used today to combine the outputs of multiple transmitters into a common RF signal: *constant impedance*

TTC

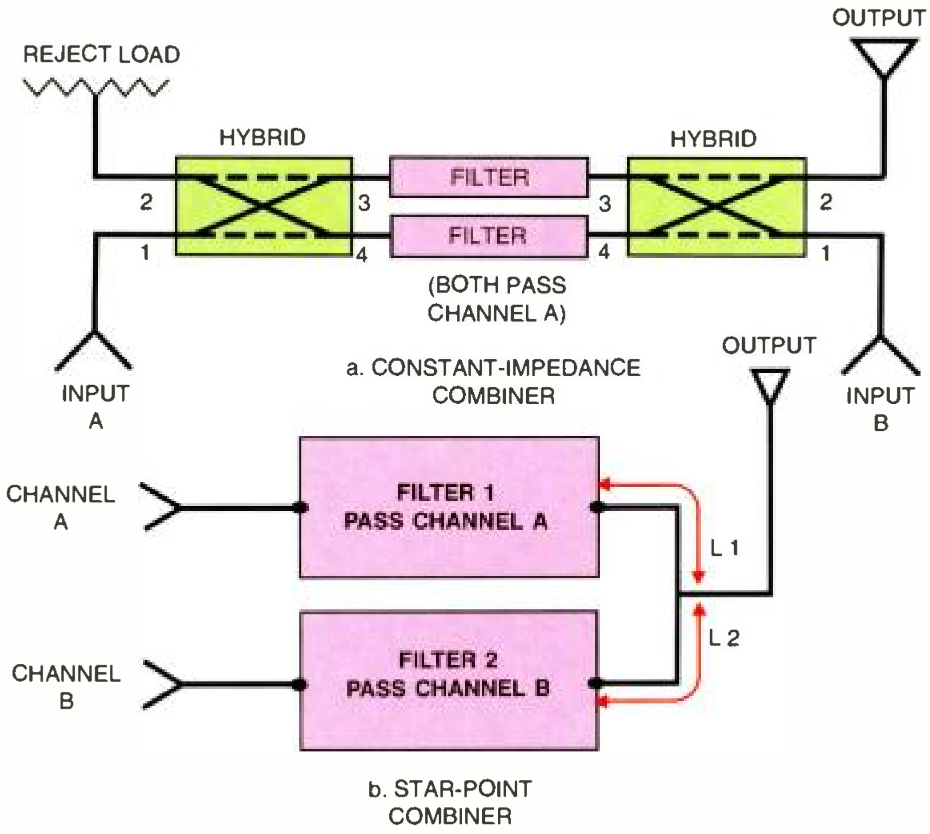

Figure 3. *Two methods of combining transmitters to feed a common wideband antenna.*

and *star-point* combiners.

Constant-impedance types use two identical filters placed between quadrature RF hybrids, while star-point systems feed each signal through a single filter, then combine all filter outputs at a common tee junction. (See Figure 3.)

Constant-impedance combiners

The constant-impedance combiner uses the quadrature phasing relationship of the 3dB hybrid alluded to earlier. As Figure 4 indicates, when a signal is introduced to port 1 of such a hybrid, it is split equally (in terms of power) to ports 3 and 4. Port 2 is isolated from port 1, and therefore sees no power. Now if outputs 3 and 4 are each short circuited, all the power will reflect and appear at port 2 because of the phase relationships in the hybrid.

The constant-impedance channel combiner (Figure 3a) combines two RF signals (channels A and B) as follows: Channel A is split in the first hybrid and passed through two identical bandpass filters tuned to that channel. The split/quadrature signal arrives at the second hybrid and is combined, because of the signals' phase relationship, at the output (port 2 of the second hybrid). If the filters are identical in performance, channel A's output will not appear at channel B's input (port 1 of the second hybrid). This isolation between channels also depends on the performance of the two hybrids in the circuit.

Meanwhile, channel B is split in the second hybrid, and the two outputs each see an effective short circuit, because they are terminated by a filter tuned to another frequency (channel A). These split/quadrature signals then reflect and are combined in-phase at the output (port 2 of the second hybrid). Any small amount of channel B's power that gets through the filters is combined in hybrid No. 1 at its port 2, and absorbed by the reject load terminating this port. Thus, a combination of filtering and hybrid action provides isolation between transmitter outputs, while combining both channels to a single output. This output is then fed via a common transmission line to a single wideband antenna.

Star-point combiners

The star-point combiner (Figure 3b) consists of individual channel filters (each tuned to the frequency of that channel's input), connected to a common tee. The bandpass characteristics of each filter allow that channel to pass, while rejecting all the other channels. If the rejection of the filter is high, it will appear as a short circuit to the other channels' transmitters.

Proper combining of channels requires correct design of the transmission lines between the filters and the output tee. At the reject channel, a perfect open circuit must appear at the tee. When L1 and L2 are the correct length, both channels combine at the output with the loss and VSWR of their respective filters.

An all-band antenna can handle a station's present needs and its future channel assignment for ATV simulcasting.

No additional VSWR or loss is added from the other channels' operation. Isolation between inputs is purely a function of filter rolloff. Therefore, the star-point combiner's performance relies solely on the performance of its filters.

Multichannel installation

Each of the combiner designs that has been described has its strengths and weaknesses. For instance, to combine more than two channels, constant-impedance combiners must be linked together in series, while star-point combiners can accommodate many channels in a single assembly. Although this would seem to be an advantage for the star-point design, most multichannel installations have traditionally chosen the constant-impedance approach because it allows easy incremental expansion in the future. Table 1 (below) summarizes the advantages and disadvantages to both combiner types.

Continued on page 93

CONSTANT IMPEDANCE		STAR-POINT	
Pro	Con	Pro	Con
Expandable	Hybrids have effect on performance	Less costly	Not expandable
		Filter determines performance	All isolation comes from filters
Each channel has separate modules	Many connections		
		All inputs similar in performance	Frequency-selective only
Lower power modules are used at input	Losses add up as modules are added		
		Smaller size	Not expandable
Various power levels can be used	Powers to be used must be predetermined	Constant power inputs	Tee junction is power limited

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Lightning protection systems

Static dissipation techniques avoid lightning strikes by dissipating the charges that lead to them.

By Bruce A. Kaiser

The Bottom Line

Lightning strikes can do more than damage equipment. They can also destroy profitability by robbing your station of revenue and market share during the time you are off the air. Most lightning protection systems wait for lightning to strike. When it does, they provide a safe path that (hopefully) leads it away from your equipment. Static dissipation systems, on the other hand, attempt to prevent lightning by intervening in its creation. This approach can protect against direct lightning hits and secondary damages caused by near misses.

$

Kaiser is president, Lightning Master, Brooksville, FL.

Axiom:

The probability of a given structure or system being struck by lightning is directly proportional to its value.

Corollary:

If two structures or systems of equal value sit next to each other, the one that will be struck by lightning is the one in which replacement parts are no longer available.

Why is one structure more likely to be struck by lightning than another? More important, what can be done to make a structure less susceptible to lightning strikes?

To answer these questions, we need to examine the cause and propagation of a lightning strike. This article will attempt to explain lightning by exploring its mechanisms. It will then suggest practical methods for coping with this hazard.

Rub two clouds together

Various mechanisms within an electrical storm produce stratified charges in a storm cloud. (See Figure 1.) This results in a strong electrical charge at the cloud's underside, known as the *cloud base charge*. This charge induces a shadow of opposite charge on the surface of the earth beneath it. This is known as the *ground charge*.

As the charged cloud moves through the atmosphere, it drags the ground charge along beneath it. If the charged cloud passes over a structure, it pulls the ground charge up onto it. This concentrates the ground charge on and around the structure.

If enough ground charge accumulates, the difference in potential between the cloud base charge and the ground charge overcomes the dielectric of the intervening air. This leads to an arc, or lightning strike.

A lightning strike begins with stepped

leaders that branch down from the cloud. These stepped leaders move downward in jumps of approximately 150 feet. Each set propagates down through the set before it, leapfrog fashion. Stepped leaders form tendril-like branches from the cloud down. These are often visible in a photograph of a lightning strike.

When the stepped leaders are approximately 500 feet off the ground, the electric field intensity becomes so strong that structures on the ground begin to break down electrically. They respond by shooting streamers up toward the stepped leaders. When a streamer connects with a stepped leader, the ionized path becomes the channel for the main lightning discharge. The other streamers and stepped leaders never mature.

For this discussion, it doesn't matter whether the cloud base charge is positive or negative, because it can vary. The entire process can occur in the opposite direction.

Lightning solutions

Given our current technology, nothing can be done to affect the cloud charge or affect the propagation of stepped leaders. To protect a structure from lightning, something must be done about the ground charge and the formation of streamers from the structure to be protected.

One of the primary tools for lightning control is the *air terminal* (a lightning rod). In most cases, this is mounted at the topmost point of a structure.

One of the primary tools for lightning control is the air terminal. All air terminals are not created equal, nor do they function alike.

All air terminals are not created equal, nor do they function alike. Three schools of thought include:

1. A structure can be protected by installing air terminals that attract lightning. The energy of the strike can then be conveyed through a low-resistance path to ground. This is generically referred to as *early streamer-emitting* air terminal technology.

2. *Conventional* air terminal technology can be used that is designed to intercept nearby strikes and convey the energy to ground.

3. *Static dissipation* technology can be used to attempt to reduce the likelihood of a strike.

A static dissipation array consists of many air terminals with small point radii. These discharge ground charge, and build up the corona to discourage streamers.

The first two approaches assume that strikes are inevitable. They attempt to handle them with minimum damage. Static dissipation technology attempts to reduce the incidence of strikes. However, a well-designed static dissipation system can also handle direct strikes in the same manner as conventional systems.

Spare the rod?

Conventional air terminal technology is well understood. It is described in detail in Underwriter's Laboratories UL 96A and in National Fire Protection Association NFPA 78. For this article, we will focus on static dissipation techniques.

This method of lightning prevention has two thrusts. First, the buildup of the ground charge can be reduced to keep it from reaching the critical flash point. Next, the points on the structure from which streamers are most likely to originate can be identified, then their formation or their height can be delayed. Doing this would make these streamers less likely to be the first to reach a stepped leader. This means the arc would form elsewhere, effectively diverting the lightning strike.

Static dissipation devices function because of the *point-discharge principle*. Point-discharge theory holds that electrical discharge from the point of an electrode (such as a broadcast tower) into a surrounding medium (such as the atmosphere) will follow predictable rules of behavior. The smaller the radius of a static dissipation electrode (actually, the smaller the radius of the point at the end of the electrode), the greater the resulting

When the sparks fly

By Timothy R. Wolf

Electrical surges come from many sources. They can be caused by atmospheric discharges, such as lightning, or they can originate at electric utility companies. Surges can be transients from the cycling of HVAC equipment, or inductive hash generated by SCR light dimmers. Even the switching of the heater in a laser printer can generate transients strong enough to adversely affect nearby equipment.

Protecting electronic equipment against damage is becoming increasingly more important. Sensitivity to surges seems to increase in proportion to the price tags and complexity of the equipment.

The ideal circuit-protection component would be a switch with high current capacity that would momentarily close, shorting the surge to ground. It would then re-open immediately, leaving the power essentially uninterrupted.

No device today can fulfill this requirement. However, a combination of existing devices can give a high level of protection. Let's examine some of these components.

- *Protecting AC power lines:*

A protection device at the service entrance or main panel would clamp large environmentally or utility-generated transients to ground. This requires a good ground system. In clay or shale-based soil, this usually means using a ground rod. In sandy or rocky soil, obtaining satisfactory results may require using an array of ground rods, or enriching the ground with chemical supplements. (See "Fundamentals of Studio Grounding," April 1992.)

This application requires devices with a medium response rate and high current capacity (surges of 20,000A or more). A *surface discharge arrestor* can carry up to 100,000A for a few microseconds. Because it only limits the voltage to two or three kilovolts, it is often teamed with a *metal oxide varistor* (MOV). These are typically constructed

Wolf is an engineer at Phoenix Contact, Harrisburg, PA.

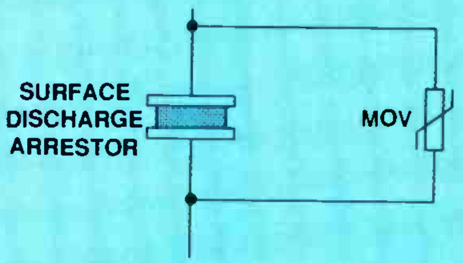

Figure 1. *A surface discharge arrestor and an MOV can be paired to protect devices on their AC inputs.*

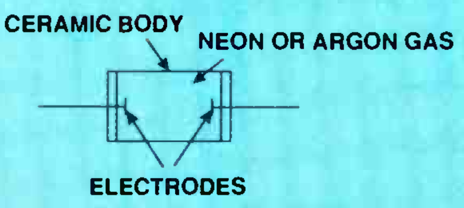

Figure 2. *A gas-filled surge arrestor resembles a neon bulb in its construction.*

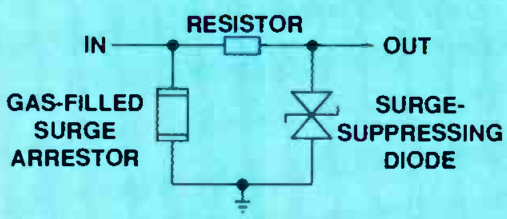

Figure 3. *A network of a gas-filled surge arrestor and a surge-suppressing diode provides superior protection for data lines. The gas-filled arrestor absorbs the bulk of the surge. The diode handles the remnant.*

of zinc oxide, and have a response time as low as 1ns, with capacities up to 40kA. (See Figure 1.)

- *Data lines and coaxial cables:* Signal and control lines between pieces of equipment are subject to inductive coupling if located near power lines. They are subject to atmospheric discharge if located outside. The *gas-filled surge arrestor* is similar in construction to a neon lamp. (See Figure 2.) It can pass up to 10kA in its conductive state.

A combination of existing devices can give a high level of protection.

Typical capacitance is 1pF at 1MHz. This makes operation feasible to more than 100MHz.

Surge-suppressing diodes are a type of Zener diode. They are capable of conducting higher peak currents, and are available in a bipolar construction. They feature response times of less than 1ns, and can handle peak power dissipations of more than 1,500W without degradation. When used in a low-capacitance diode bridge, they are suitable for use in circuits to more than 100MHz.

Tying it together

Facilities can obtain the maximum protection by combining surge-suppressing components. One major TV network is investigating protecting its earth station data and control lines with a combination of surge-suppressing diodes and gas-filled surge arrestors. (See Figure 3.)

When a surge occurs, the diode begins to conduct. The increased current is limited by a low value resistor connected between the diode and the gas tube. The gas tube clamps at a high level, but absorbs most of the surge. The diode then clamps the residual voltage to a safe level.

Help available

Several reputable manufacturers offer surge-suppression equipment. Many will offer assistance in setting up an effective system. Ask detailed technical questions. If the company is worthwhile, it should be willing to explain how and why the products work.

Remember, surge suppression is like a seat belt — to be protected, you've got to use it.

A well-designed static dissipation system can handle direct strikes in the same manner as conventional systems.

electric field intensity and flux density.

As the dissipation electrode radius approaches zero, the electric field intensity approaches infinity. These strong fields bleed off some of the ground charge into the atmosphere surrounding the air terminal. This reduces ground charge accumulation. This high electric field intensity and flux density also retards the formation of streamers. It is difficult for the cloud charge or stepped leaders to pull a streamer through the intense corona.

This is illustrated by comparing a sharp lightning rod with a blunt one. Assume a sharp rod and a blunt rod sit side-by-side. As the ground charge reaches the two rods, the potential rises on both. The sharp rod will tend to break down into corona under a relatively low potential. The blunt rod will hold its charge, with ions accumulating on the blunt end.

As the ground potential builds, the corona builds around the sharp rod, while the blunt rod tends to hold its charge. When the ground potential becomes extremely high, such as when the stepped leaders are on their way down from the cloud, the sharp rod's corona will build in density and elevation. On the other hand, when the blunt rod finally breaks down, it does so catastrophically. The accumulated charge jumps off of the blunt rod in a streamer extending well upward toward the stepped leaders. Because the object that throws off the best streamer is the one most likely to be struck, the blunt rod is more likely to trigger a strike than a sharp rod.

All objects on the ground dissipate naturally to some extent. How they dissipate is also related to the point-discharge principle. The ground charge is first drawn to the top of the object (the ultimate point), and then to the corners or other points

All objects on the ground dissipate naturally to some extent. How they dissipate is related to the point-discharge principle.

from which it bleeds off into the atmosphere.

These natural charge accumulation points also tend to be the points from which streamers originate. How are these points identified? Perhaps an oversimplified method is to imagine turning the structure upside down and dipping it into syrup. When it is lifted out, the points from which the syrup drips will be the charge accumulation and streamer formation points. Applying static dissipating air terminals or arrays to these points will reduce the accumulation of charge and retard the formation of streamers. An array of dissipation elements is merely a series of air terminals on which the points' radii are reduced as close to zero as possible, without harming the structural integrity.

Although a satellite dish is not likely to be struck because of its rounded shape, it may still be vulnerable due to secondary effects of the ground charge rushing to a nearby strike. The dissipation array helps bleed off the accumulated ground charge.

Broadcast facilities

Towers are a prime target of lightning. As the ground charge is pulled up the tower by the cloud base charge, it accumulates according to the point-discharge principle.

In spite of bonding and grounding wires provided for the purpose, the ground charge will flow, even over insulators, and accumulate on a structure according to point-discharge principles.

The ground charge flows to the top of the tower on the tower structure and the guys. Therefore, a dissipation device, or sets of dissipation devices, should be installed on the tower above the top guy cable of each set. If the tower uses a candelabra, a dissipation device should also be installed at the tower top. One should also be mounted at the top of any top-mounted, DC-grounded antennas. It can be mounted to the lightning rod cage if one exists.

Different ground rules

Sometimes it is helpful to remember that the ground charge is not a free-electron charge that moves around the structure on wires. It is an ion charge that flows over a structure in a fluid (the atmosphere). In spite of bonding and grounding wires provided for the purpose, the ground charge will flow, even over insulators, and accumulate on a structure according to point-discharge principles.

This concept of ground charge motion helps address the question of the need for a bonding wire from the dissipator to the grounding system. Obviously, the ground charge gets to the top of the structure all by itself (or else the structure would not have a lightning problem). Therefore, the structure of the tower is sufficient to convey the ground charge to the dissipator.

If the dissipator acts as a lightning rod and takes a hit (all static dissipation systems should be designed to withstand this possibility), lightning will follow the path of least impedance to ground. The tower structure will usually offer a path of sufficiently low impedance so that a separate ground wire is not necessary. Therefore, in either case it is unnecessary.

Other structures

This approach to arranging dissipation devices works for all towers except AM towers. On a series fed AM tower, the dissipator should mount horizontally and symmetrically, slightly below the top, but above the top guy cables. This way, it will not change the length of the tower. On a folded unipole, the dissipator should mount horizontally and symmetrically at the tower top. A properly designed and installed dissipator should not change the impedance or the tower's radiating properties.

Satellite dishes present unusual problems in a lightning environment. Their shape tends to retain ground charge. However, because the top of a dish is usually a large, smooth arc, it tends not to emit good streamers. Dishes, therefore, rarely suffer direct lightning strikes. However, they are prone to secondary effect damage. When a strike occurs within the area

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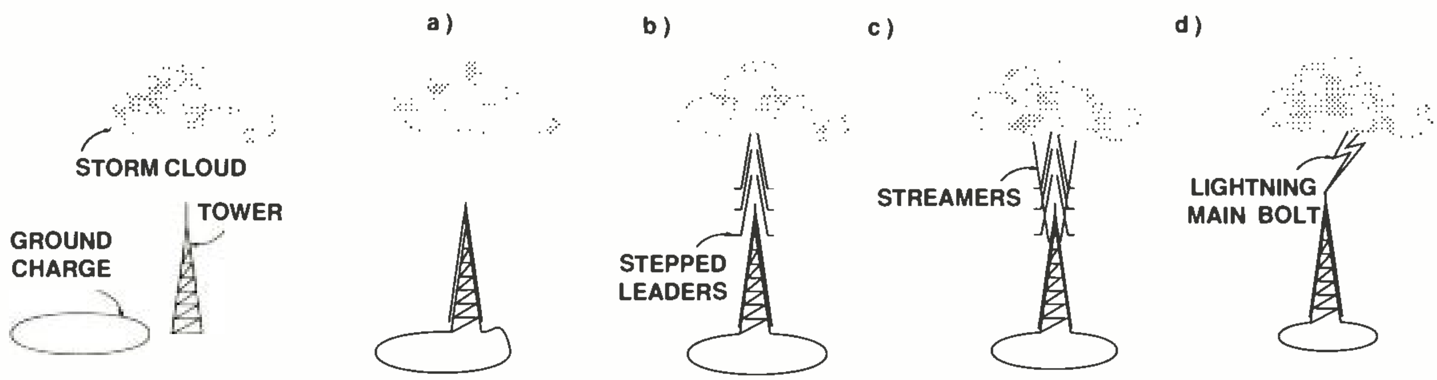

Figure 1. The charged storm cloud pulls a ground charge along beneath it a) when the ground charge encounters a tower or other structure, the cloud charge draws it up, concentrating the charge; b) as the dielectric of the air breaks down, the cloud sends down stepped leaders; c) when they are about 500 feet off the ground, the tower emits streamers; d) when a stepped leader meets a streamer, the ionized path becomes the course of an arc, or lightning bolt.

of ground charge occupied by the dish, charge may rush off the dish toward the point of the strike. This often adversely affects the dish's aiming mechanism. Installing dissipation equipment along the top of the dish allows some of the accumulated charge to leak into the atmosphere. This reduces the amount of charge available to cause harm due to secondary effects from a nearby strike.

No bolts from the blue

Lightning rods on a conventional system do offer a limited amount of protection if a lightning strike occurs. Static dissipation systems offer this same level of protection, but they also work to avoid strikes. This is done by dissipating the ground charges that accumulate on structures. They also delay the formation of streamers by promoting a strong corona. Therefore, such systems offer protection by decreasing the likelihood of a strike and by duplicating the action of a traditional lightning rod.

Lightning rods on a conventional system offer a limited amount of protection if there is a lightning strike. However, static dissipation systems do their work by avoiding strikes.

➡ For more information on static dissipation technology, circle Reader Service Number 302. ■

Solving RPU intermod problems

As the RF spectrum becomes more congested, extracting your remote broadcast from the sea of intermod is an ongoing challenge.

By John Collinson

The Bottom Line

The investment your facility makes in remote pickup equipment can be nullified by interference. A big problem is intermodulation products (intermod). This can be caused by the interaction of two or more transmitters, or by problems in a receiver. Either way, this article discusses several cures for intermod. Implementing these aids can help facilities keep their remote operations and newsgathering capabilities intact.

$

These days it is the rare but fortunate facility that can enjoy a noise-free receive site for remote pickups. Most sites are afflicted to varying degrees with chattering receivers, intermodulation products or occasional outright interference. Wideband radio remote pickup systems are more prone to these problems than narrower band 2-way type systems, but nothing is immune.

At the least, these disturbances are a nuisance. At worst, they cost money, depriving the facility of revenue because of ruined opportunities for remote production and newsgathering.

This article discusses how a facility can prevent or overcome many RPU intermod problems. Although radio remotes are the primary focus, many of these principals apply to STLs or TV remotes as well.

Beware of transmitter trash

Designers of 2-way systems have long been aware of the problems caused by transmitter-induced *intermodulation products*. These can also impact the RPU user. Locating multiple transmitting antennas close together can create transmitter-induced intermod products. This occurs when a transmitting antenna inadvertently functions as a receive antenna. The afflicted transmitter's antenna captures an interfering signal or signals and feeds it back into the transmitter's PA stage. (See Figure 1.)

Once in the output stage, the interfering signals can wreak havoc. The amplifier often functions as a highly non-linear mixer, creating a variety of phase- and amplitude-modulated products. These are unpredictable and may vary, depending on relative frequencies, signal strengths, the deviation of either the desired or interfering signals, and the instantaneous modulating frequencies. Once these spurious signals form, they can be amplified and reradiated by the same output stage. This can result in signals that interfere with your RPU equipment.

The closer in frequency the interfering signals are, the more likely the problem. This is because closer frequencies may pass more easily through the tuned PA output circuits and into the amplifier.

One of the toughest things about this problem is its transient nature. The received signal will be cleanly absent when the interfering transmitter is off. Even when it is on, the intermod may be transient or varying.

Often, multiple stations may operate remotes from the same event. This increases the likelihood of developing an intermod problem. Land mobile and other 2-way services are also close in frequency to many RPU channels, especially in the 450MHz band. Considering the abundance of signals in most metropolitan areas, it behooves anyone planning a broadcast to keep proximity to other transmitters in mind.

Signs of trouble

Most intermod problems show up directly at the receiver. The most blatant effects are distortions, squeals or other audio mixed in with the desired signal.

Intermod can occur whether the desired signal is present or not. When this happens, receivers will show varying levels of received signal even with no transmitters operating on that frequency. Squelch relays may appear to switch randomly.

It can often be difficult to figure out whether the problem is a signal coming in corrupted or if intermod is occurring inside the receiver. A spur from a land mobile unit, someone else on your frequen-

Collinson is chief engineer, WDAF/KYYS radio, Kansas City, MO.

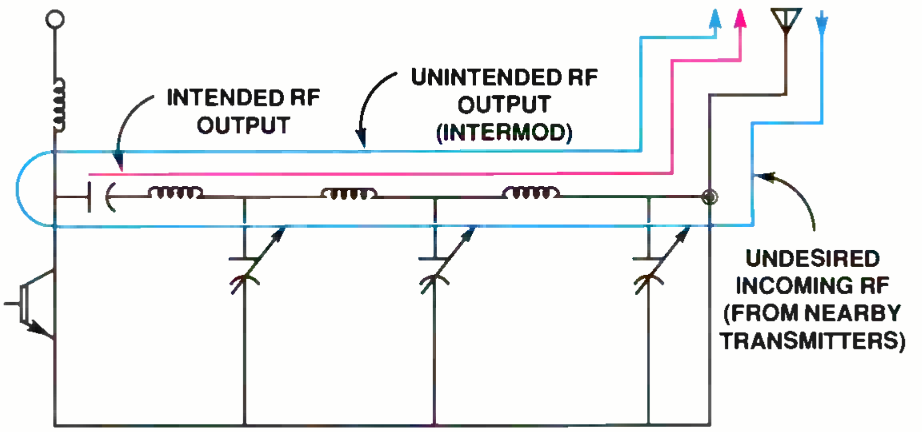

Figure 1. Intermod products can form when a transmitter antenna unintentionally acts as a receive antenna. The undesired signals feed back into the PA, where they can form spurious products. These can be amplified and re-radiated, potentially causing interference.

cy or a 2-way on a nearby channel overloading the front end of the receiver may all sound alike. Without the right equipment, it may be impossible to tell.

The right tools

Perhaps the most useful tool for tracking intermod or other interference is a communications service monitor. These monitors can be found in most 2-way and avionics shops. In addition to chasing signals, service monitors are perfect for checking the frequency and tuning of RPU transmitters, alignment and testing of receivers, adjusting cavities and troubleshooting 2-ways. Most communications monitors have spectrum analyzers built in.

Any major market station that does many remotes should find a service monitor to be a worthwhile investment, even though the several thousand dollar price tag may be difficult to sell to management. Time and cost savings in out-of-house maintenance and lost remotes will help offset the expense. If purchasing one is impossible, make friends with a local 2-way shop or another station engineer who has one. Some outlets offer used units at reduced cost.

Another useful tool is a computer program that can predict likely intermod frequencies from a set of specified primary frequencies. These are readily available as shareware.

Trouble spots

After determining that an intermod problem exists at your facility, what should you do about it? Several avenues can be explored.

- *Antenna systems*

Naturally, most stations mount their RPU receive antennas on the highest structure available. Unfortunately, they mount all manner of transmit antennas in these spots as well. These can be trouble if they are too close either physically or in frequency. In most cases, a vertical spacing of half a dozen wavelengths provide adequate physical separation.

Many stations mount their RPU antennas on the same tower as their primary transmitter antenna. This is a reasonable practice, because few harmonic combinations of FM or TV transmissions fall in the RPU bands. However, loose hardware in high RF fields on a tower can pick up RF and cause arcs. This can generate spurious emissions over a wide spectrum. These situations can be challenging to pinpoint, especially if they are intermittent.

- *Receiver splitters*

Many stations feed multiple receivers from a single receive antenna by use of

Naturally, most stations mount their RPU receive antennas on the highest structure available. Unfortunately, they mount all manner of transmit antennas in these spots as well.

a receiver multicoupler. In this arrangement, an amplifier feeds a passive splitter, which then drives the receiver inputs. (See Figure 2.)

Study gain carefully in these arrangements. More amplifier gain (with low noise) generally means better reception. This amplifier can be a trouble spot if unwanted signals within its bandpass overload it, even if the desired signals don't. Bipolar transistor amplifiers are especially prone to intermod of this type. CMOS or, better yet, GASFET (gallium arsenide

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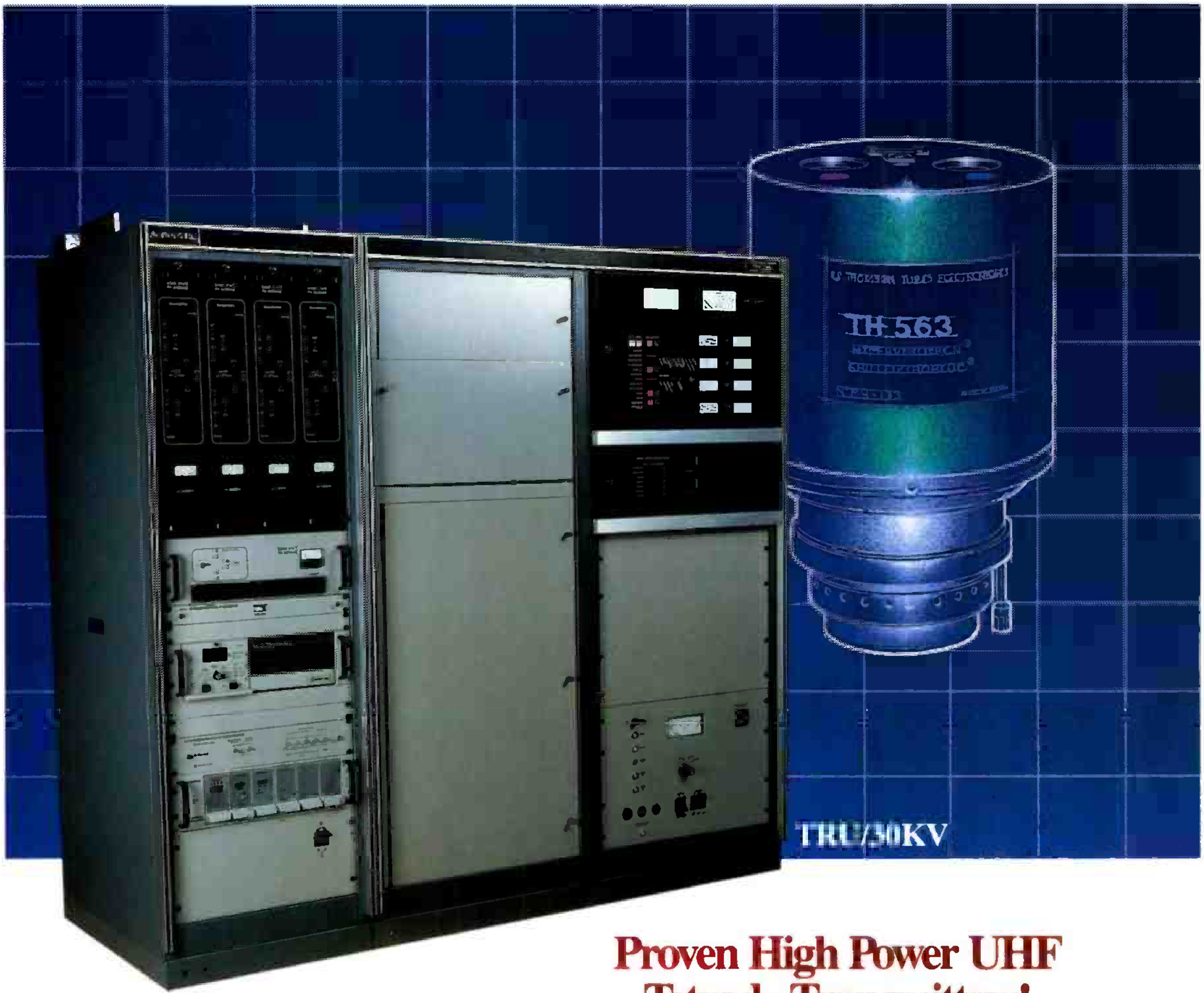

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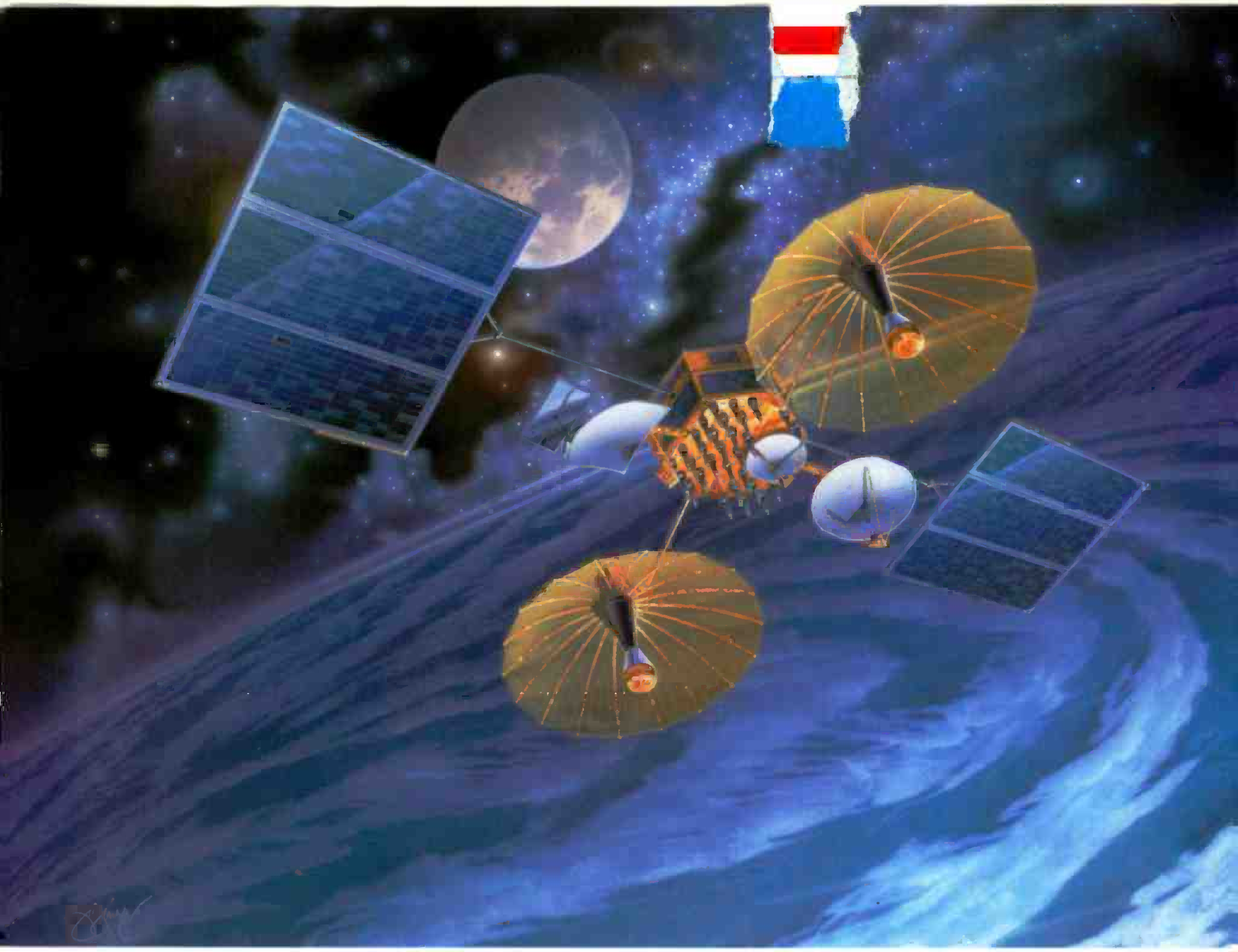

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ly, receivers required several tuned RF stages, which required more gain in the front end. Balanced mixers eliminate this need.

Finally, updating a receiver may eliminate a maze of filters, cavities and headaches. This may save money. Borrow a demonstration receiver from an equipment supplier. If it solves your problem, you will have concrete evidence of the wisdom of the purchase.

- *Tuned-up transmitters*

A mistuned receiver or a transmitter that is badly off frequency can degrade reception. This can show up as an impairment, ranging from a slight distortion to a complete loss of signal. Older units especially tend to drift.

Use a spectrum analyzer, or preferably a communications service monitor, when tuning older RPU transmitters. Many of them generate spurious emissions easily if improperly tuned.

- *A circulating cure*

By installing a *circulator* on their RPU transmitters, facilities can borrow a technique often used by co-located FM or TV stations to help eliminate intermod. (See Figure 3.) A circulator may be thought of as a 1-way valve for RF. It is a form of hybrid coupler in which forward power passes through unimpeded. Any signal coming back down the line from the antenna, including reflected power, is rejected. Combined with a reject load, a circulator becomes an isolator. Any signal entering the output port dissipates in the reject load.

Regardless of how high quality your receiver is, it will not be able to clean a signal that has been trashed before it even leaves the antenna.

Isolators are available from companies that manufacture antennas, cavities and associated equipment. Pay attention to tuning and impedance matching of your transmit antenna. Reflected power will serve only to heat the reject load in the isolator.

Regardless of how high quality your receiver is, it will not be able to clean a signal that has been trashed before it even leaves the antenna. Spending a few hundred dollars for an isolator may seem extravagant, but it may be the price for keeping clients and program directors pleased with their remotes.

A communications service monitor is an ideal tool for troubleshooting intermod problems, as well as aligning RPU equipment. They are frequency agile for fast setup and ease of use. Many units include a spectrum analyzer.

2-way RPU systems

Even with their narrower bandwidths, many RPU systems based on 2-way radios can suffer from intermod problems. Because most 2-ways (and all repeaters) use low-frequency CTCSS tones or digital-coded squelch systems, they generally won't break squelch from intermod products. However, once they are keyed up by a desired transmitter, they may still suffer interference. Beware of strong signals on nearby frequencies that may be using the same CTCSS tone. This can seemingly randomly key a receiver or repeater, sometimes giving the appearance of unauthorized users on the frequency.

Earlier *burst and latch* tone systems sent only a few seconds of CTCSS tone when the transmitter was first keyed. The receiver latched open at this short burst, then waited for the carrier to drop before squelching. These systems are prone to some unique problems. An intermod product may be covered during an active signal, but then appear after the transmitter unkeys, holding the receiver open. Certain interference or intermod conditions could squelch the receiver, possibly cutting off a reporter in mid-sentence. Because the CTCSS tone isn't retransmitted until the transmitter is released and rekeyed, the live report could suddenly be dead.

The burst and latch system made it possible to eliminate the notch filter in the receiver audio passband (required to remove the low-frequency CTCSS tone). Modern parametric equalizers can form a narrow notch, and can also provide other audio shaping at low cost.

2-way diplomacy

If another legitimate signal is causing an intermod problem, diplomacy is of supreme importance. A newcomer on a nearby channel who inadvertently chooses the same CTCSS frequency as yours should be convinced of the benefits of changing to another, because interfer-

Combining analog and digital for cost savings

By Allan Lamberti

A little-explored option in short-haul video transmission is to mix analog and digital systems. This gives the facility the simplicity and low cost of analog today, yet preserves the advantages of digital where it is appropriate for the present and future.

Lamberti is vice president, sales and marketing, Microwave Networks, Houston.

Cost advantage

The principle advantage of mixing analog and digital technologies is lower equipment cost. By integrating an analog video radio and a digital DS3 radio into one 23GHz system, users may be able to eliminate the codecs used on either end of a short-haul digital link. This can save more than 30% of the cost. (Of course, the radios chosen must have RF heads that are capable of carrying either analog or digital signals.)

For example, one customer recently requested a proposal for two channels of simplex video plus a DS3 duplex link over a single path. The customer ordered four 23GHz radios (two for data, two for video) and four video codecs. The requested proposal was generated, but an alternate plan using a mixed analog/digital solution was also presented. The potential cost savings was almost $150,000 on $500,000, with the probability of improved video quality.

Combining digital and analog transmitters in the same unit also saves money in installation, because it uses a single antenna and mounting structure, as well as minimizes waveguide and cabling needs.

Short-haul analog video transmission can also edge out digital in linking a remote site to a digital central office. To avoid the cost of on-site digital codecs, digital phone services or negotiating right-of-ways for fiber, many companies set up a short-haul analog video microwave link that connects them directly to the central office.

The principle advantage of mixing analog and digital technologies is lower equipment cost.

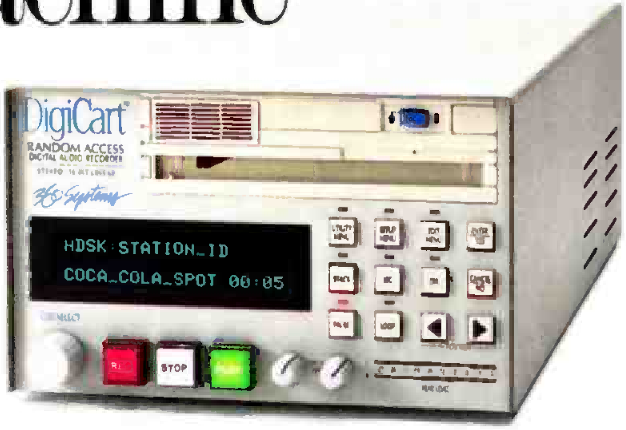
Another analog advantage is not technical, but regulatory. Despite an increase in the number of local digital circuits offered by the telephone companies and others in the last several years, local digital network tariffs are often much higher. Installation time for digital may also be longer.

Digital quality?

Generally, digital codecs work best in long-haul applications, or when the signal is manipulated many times and must be switched to different locations. For shorter links — two to three microwave hops — microwave-based analog/digital video combinations may be more cost-effective.

Digital systems are able to carry traffic indefinite distances without degrading quality. However, quantization errors often extract a penalty on the way into and out of the digital domain. Few of today's codecs are truly RS-250 quality.

Furthermore, the data-compression systems used to cram the video signal into the digital pipeline may take a toll



QUALITY CONSIDERATIONS
(for video through codecs at various data rates)

Compression Ratio	High 1,200:1 56Kbps—112Kbps (DSO)	Medium 60:1 1.544Mbps (T1)	Low 3:1 45Mbps (T3)	None 1:1 100+Mbps
Picture Degradation	• Significant loss of resolution • Jerkiness • Significant motion deterioration • Chroma smearing	• Loss of resolution • Blocking • Edge crawl	Close to RS-250B/C	Imperceptible
Audio Quality Provided	Voice grade 3kHz	Voice grade 3kHz (7kHz optional)	• Broadcast quality • Multiple audio channels	CD-quality available
Price (1 Codec)	$30,000—$50,000	$25,000—$45,000	$15,000—$40,000	$5,000—$15,000

Table 1. *The price of digital transmission hardware, such as codecs, generally increases with the amount of compression used. However, as compression increases, quality tends to suffer.*

on quality. High digital compression ratios can result in significant loss of resolution, blocking and motion deterioration (jerkiness). Usually, the picture and sound quality are unacceptable at the high end of the compression spectrum, and the bit rate bandwidth requirements are unacceptable at the low end. (See Table 1.)

Analog pluses

Frequency-modulated (FM) analog systems can provide a high-quality video signal. In commercial use, high-quality FM analog microwave radios can provide a signal-to-noise ratio of 70dB or better, with minimal differential gain and phase degradation.

Another plus for analog is that it is well understood. The broadcast TV industry possesses more than 50 years of experience in dealing with analog TV signals. Although the migration toward digital remains steady, the standardization of digital video transmission systems is far from complete.

Standardization emerging

Throughout the 1980s, codec manufacturers developed their technology and equipment independent of standardization. Each relied on its own exclusive algorithm for compression, transmission and display of digitized video. Because no widely accepted standard existed, various brands of codecs could not communicate (or interoperate) with one another. Most of the focus was on low bit-rate codecs, because business conferencing seemed to be the most viable marketplace.

Today, however, a standard has emerged: CCITT H.261. The standard contains a definition of the algorithm that describes the process by which video is compressed and coded.

Manufacturers have come to realize that equipment interchangeability is a selling point. But until there is full compliance with standards and equipment prices tumble with volume, analog transmission systems will likely continue to remain a cost-effective choice.

In times of economic uncertainty, the safest route may be to use a less expensive, expandable analog system that will support a digital future.

ence of this type may go both directions. Sometimes, a swap of frequencies between two users may benefit both.

Itinerant users in town to cover a certain event can cause real problems. Most reputable organizations have started checking with the SBE frequency coordinator in the area they plan to visit. The coordinators perform an invaluable service in preventing spectrum collisions. The National Association of Business and Educational Radio (NABER) coordinates most land mobile radio systems. Although these do not operate in the RPU bands, they operate near them, and present an intermod potential.

Two urgent points arise here. Even though many stations may not require licensing under the 720 hours-per-year rule, it is false economy not to license your RPU. If someone pops up on your frequen-

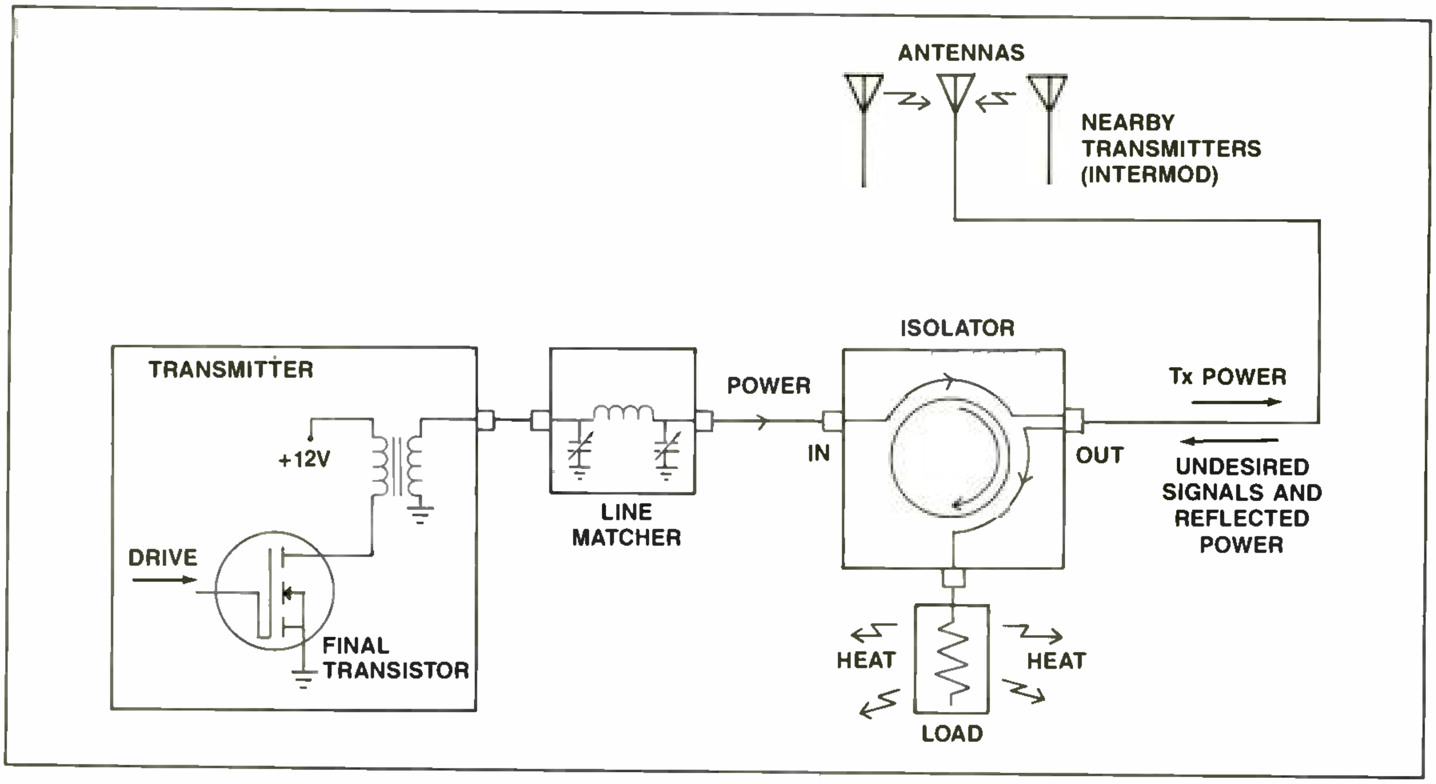


Figure 3. A circulator and reject load together form an isolator. This acts as a 1-way RF gate. Undesired incoming signals and transmitter reflections dissipate in the reject load.

Stations take advantage of any high spot to mount RPU and 2-way antennas. This can set the stage for intermod problems.

cy, you hardly have a case if you are unlicensed. Furthermore, check with your frequency coordinator to make certain the information on file about your operation is accurate. The Society of Broadcast Engineers (SBE) has created this free volunteer service, but it is only as good as the data available.

Happy neighbors

The timing of intermod problems give some clues about their source. If it happens for three straight hours on a Saturday, odds are it's another station's remote. An intermittent 9-to-5 problem may indicate it comes from a business or municipal 2-way system.

Detected audio may also provide clues. If you can catch the morse code identifier or voice clues, you can usually track down the offender.

One frequent source is spurious emissions from 2-way systems. A spur will pop up and waltz up or down the band, possibly right across your frequency. Without a service monitor, this is virtually impossible to trace.

Some 2-ways are capable of generating spurs that drift in frequency while the main carrier stays on frequency. Because the radio still works, the user may never suspect it is causing a problem. Don't be surprised if your first call is greeted with suspicious hostility. Remember, that person's radio is still working. Help him understand you are keeping him out of trouble with the FCC. This point usually eases tensions. Offer to cooperate with the 2-way shop to help everybody.

If you get no satisfaction, enlist the FCC's help. Again, the importance of a license for your RPU is evident. You'll receive much more support if someone is interfering with a licensed station. The more precise details you can provide the FCC, the more readily it can help.

No one simple answer will cure all intermodulation or interference problems on RPU bands. Careful attention to details and the proper tools will help keep the neighbors happy on frequency bands with no elbow room to spare.

Acknowledgments: The author acknowledges the help of the following people in preparation of this article: George Marti, Marti Electronics; Vince Mercadanti, Moseley Electronics; Allstair MacCabe, Lunar Industries; Dr. M. K. Stone, Lunar Industries.

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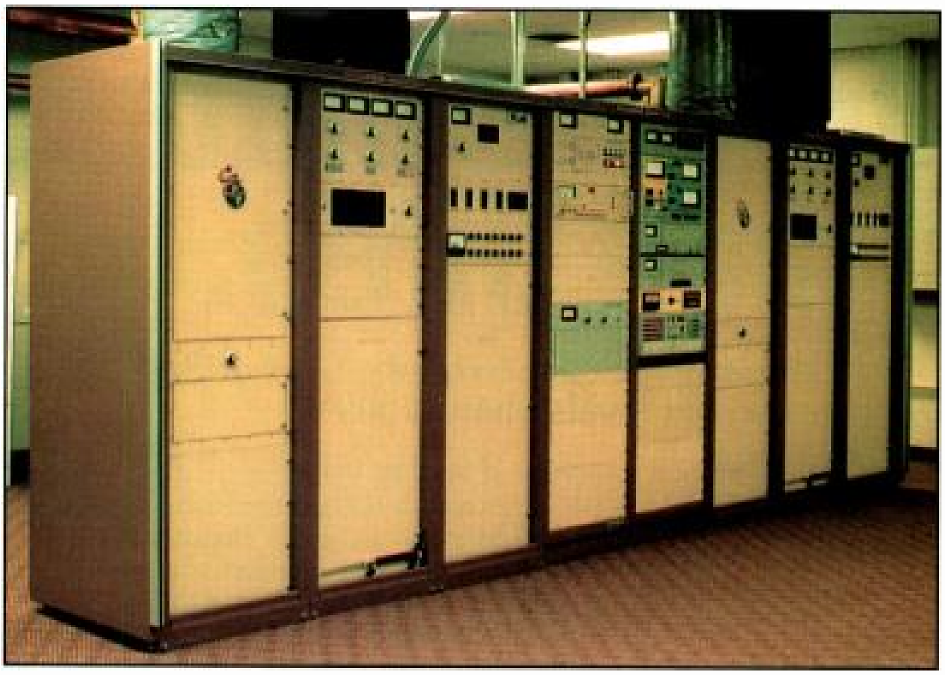

Photograph by Ben Weiss

The transmitter system is the largest power consumer at a radio station. Maintaining its operation in a clean and efficient manner can result in significant monetary savings over time. (Courtesy of KLSI-FM, Kansas City, MO.)

wait until the filter is shrouded in dust. If you can see accumulation of dirt on the filter, then the filter's efficiency is restricted. You might increase airflow and filtering by replacing your original air filters with pleated disposable ones. Pleated air filters offer more passage area (and catch smaller particles) than metal or household fiber-type air filters.

4. Transmitter tuning for maximum efficiency should be checked often. More importantly, the maximum-efficiency goal must be understood by the person doing the tuning. FM transmitters should generally be tuned for best efficiency first, then tweaked for lowest incidental AM noise. FM transmitters using tetrode tubes must be tuned with the proper relationships of PA tuning, PA loading, screen grid voltage and bias voltage. Experimenting with different levels of screen grid voltage and PA loading should reveal a best-efficiency operating range. Proper PA tuning is often most accurate when peaking the PA screen grid current while adjusting PA tuning.

AM transmitters vary widely in their tuning procedures for best efficiency. One area of common deficiency, however, is a poor match to the transmission line at the station's antenna tuning unit (ATU). If 50Ω transmission line of any appreciable length is being used, a reasonable impedance match at the ATU's input should exist. Otherwise, reflected power will reduce your base current and increase transmitter power consumption in making up for the loss.

5. Proper filament voltage management will yield short-term and long-term savings. If a typical large power tube rated at 7.0 filament volts can be operated at 6.4 filament volts, you're saving more than 200W of power, or more than $10 per month in electricity costs. You can also increase the life of a typical power tube from 200% to 300% by such filament-voltage management.

Another area of energy savings may come from your air conditioner. Some stations keep their transmitter building considerably air-cooled during the summer months, using copious amounts of electricity in the process. If you're accustomed to keeping your air-conditioned building at 80°F, you may consider setting the thermostat at 85°F or 90°F. Most electronic equipment will still work well in an ambient temperature of 105°F. If proper airflow and exhaust handling is in place for your transmitter, then these somewhat higher intake temperatures can be tolerated. Running other (convection-cooled) hardware at higher ambient air temperatures during hot weather is only possible if adequate airflow exists around equipment. If possible, leave one or two rack spaces open between rack-mounted devices.

In many parts of the United States, adequate ventilation at the transmitter site may be possible by using forced airflow *without* air conditioning. An adequate forced-air system will use a squirrel-cage blower inside the filter housing to push filtered air into the transmitter building faster than exhaust air is being released. For example, if your transmitter exhausts 1,000 cubic feet per minute (cfm) out of the building, your blower should put 1,200cfm to 1,500cfm of filtered air into the building. This difference will create positive pressure and keep dust from entering through cracks and holes.

A squirrel-cage blower that is capable of maintaining positive static pressure is required here — a fan-style blower won't work well. Place the intake blower/filter housing on the north side of the building to draw in the coolest air. A well-designed system such as this will result in lower electric bills than an air-conditioned system. If maintained, it will reduce the dust and dirt accumulation that results from a negatively pressurized building, and thereby reduce long-term maintenance costs.

When inspecting your transmitter site during the day, check that the photocell controls for the tower and security lights are working properly. If your tower has two levels of red beacons and two levels of obstruction lights, and the lights are burning 24 hours per day instead of 12 hours, you'll be spending approximately $70 extra per month (on average) for electricity.

Some other preventive maintenance can also render savings from damage that it may circumvent. Keep undesirable insects, rodents and reptiles out by careful use of pesticides and traps. Moth balls are an inexpensive and relatively effective deterrent to most pests. Scatter a few moth balls in building corners, in equipment racks and on shelves. Ultrasonic pest eliminators may also prove worthwhile.

Telephone service

Check with your station's bookkeeper to see what types of phone service you're paying for at the transmitter site. You may find old circuits that are no longer needed, but still being paid for.

If you have a dial-up line at the transmitter site, look into having it changed to measured service. Many phone companies offer this service for low-usage installations to commercial and residential customers. If you rarely use your transmitter phone for outbound calls, measured service will save you several dollars per month.

> ***If your request lines are used only for inbound calls, you may save money by switching to measured service.***

Some transmitter sites have more than one dial-up remote-controlled device. Traditionally, these each required a separate phone line at the site for individual access. But now, telephone companies in many areas offer so-called *distinctive ringing* service (marketed as RingMaster, Custom Ringing, IdentaRing, or under other

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names), which can be adapted to allow a single physical line at the site to access multiple dial-up devices. Typically, up to four different ring patterns can be accommodated on a single incoming line, each activated by dialing a different number from the calling site. A box installed at the transmitter site detects which ring pattern is coming in and directs a call to the appropriate device. For example, 555-2000 could be your dial-up remote-control unit; 555-2001 could be your phone-accessed modulation monitor; and 555-2002 could ring a real telephone, and so on. Distinctive ringing service is usually less than $4 per month per additional phone number. A ring-pattern detector/switcher is less than $150.

For transmitter sites with difficult or expensive telephone service installations, some other options exist. A fixed cellular phone will often work from a hard-to-access site, especially when the phone is outfitted with a yagi antenna aimed at the nearest cell site. Adapters are available for interfacing a cellular phone to any remote-controllable device designed for regular wired telephone hookup. The interface will produce a ring voltage when called and will produce a dial tone for placing automated outbound calls.

Another option for remote control and staff communications involves the installation of a UHF-band repeater at the transmitter site. Most dial-up remote-control systems can be interfaced to such a repeater and, with password access, meter readings and transmitter control functions can be acquired from a walkie-talkie or a base station. This type of system is currently in use at stations where neither wired nor cellular service is available at any price.

If your remote control uses dedicated control loops or circuits, check to see if a less costly burglar alarm circuit might be available. Many stations are still paying for broadcast or conditioned circuits when a simple, unconditioned DC pair will suffice for remote-control operation. Long-term savings may also be obtained by replacing your old remote control with a dial-up unit that doesn't require a dedicated circuit. Often, the expenditure for the new dial-up remote-control hardware can be quickly amortized by telco cost reductions.

Another area primed for cost savings is the phone service at your studios. If your request lines are used only for inbound calls, you may save money by switching to measured service. With most telephone operating companies, measured service is only billed on local outbound calls. Therefore, any phone lines used exclusively for incoming requests should be the minimum bill each month with measured service.

Also, look into which local phone service options might work best for your size and type of business operation. Stations with many lines may end up paying less per month by using Centrex or a similar PBX-like service provided by your local phone company. Small stations may save money by removing hunting lines and opting for call waiting or similar services. However, before doing so, consider the possible adverse effects on others' perceptions of your operation. You may also consider distinctive ringing service to obtain virtual distinct numbers on a single incoming line for various phone-interfaced devices at your station (fax machine, computer modem, ENG/frequency-extender line, and so forth). Remember that this technique works only for low-use items. A listener-response fax machine and a call-in weather line would not coexist well on such a service.

More preventive maintenance cost savings

Just as they are at the transmitter site, dirt and dust are also the enemies of electronic equipment at the studio. Changing the filters in your studio HVAC system on a regular basis will result in better long-term equipment performance and lower maintenance costs. If operators are still smoking in control rooms, consider banning this practice. Cigarette smoke near cart machines, CD players, computers and tape decks is notoriously destructive, and could require thousands of dollars in equipment replacement.

> ***Engineers shouldn't try to perform tasks that they are not trained to do, and for which they don't have the proper tools.***

Some stations are using consumer-grade equipment as on-air or production room sources. The most common are CD players and cassette decks intended for home use. Purchasing and using such devices instead of their professional or broadcast-quality counterparts can indeed result in cost savings. In terms of servicing, however, it is often cheaper and more prudent to purchase a new unit rather than to repair the old one. Keep this in mind when budgeting for such items. For most consumer electronic items, service manuals and parts are troublesome and time consuming to obtain. It is possible to spend two hours in labor obtaining a $10 service manual and a $2 plastic part — hardly efficient use of engineering time.

Do it right the first time

When new equipment is purchased and installed, verifying that it is installed and used correctly will maximize its value and thereby minimize its overall cost. Using inept or inexperienced technical personnel rarely results in any cost savings. Stations that employ the services of a local 2-way radio, TV or CB repair shop to install or repair broadcast equipment must often pay again to have the work done correctly by a qualified broadcast engineer.

Correspondingly, chief and contract engineers shouldn't try to perform tasks that they are not trained to do, and for which they don't have the proper tools. It is often less expensive to hire a qualified professional to get a certain job done than to attempt it yourself and fail. Tasks, such as tower work, transmitter moving, plumbing and even repair of certain hardware, can sometimes be best (and most cost-effectively) done by professionals in their respective fields.

The practices mentioned here, and others that you develop yourself along these lines, will invariably show up in improvements to the station's bottom line. This kind of partnership between management and engineering will forge the proper relations that every radio station (and its staff) requires for survival in the 1990s and beyond. ■

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RF technology update

Selecting the best transmitter design for your station is not an easy process.

By Don Massa

The Bottom Line

Next to personnel costs, the electric bill for your transmitter (especially if it's UHF) can be one of the biggest factors that affects your station's profitability. Because these costs can be accurately determined, you have the opportunity to know in advance what effect a particular transmitter will have on your monthly cash flow. The difficulty is usually taking into careful consideration each of the technical factors involved. This article will help the nontechnical manager understand which parameters to identify and where trade-offs in types of technology can be made without affecting the quality of your product.

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Massa is director of marketing for TTC, Denver.

The sophisticated technology used by broadcasters to deliver their programs, whether directly to the home or to cable head-ends or satellite uplinks, has increased considerably over the past three years. Even so, broadcasters still rely on RF transmission to relay their programming to the audience. Because the cost of electricity continues to escalate, the use of efficient and cost-effective transmitters can be critical to a station's cash flow.

Let's look more closely at some of the types of RF technology used in today's TV transmitter. Multiple choices are available, each with its own advantages. Often, the issue that the engineer and manager face when purchasing a new transmitter isn't what brand to buy, but what RF technology is best suited for the station. We'll look first at solid-state technology.

Solid-state technology

Transistor manufacturers continue to improve the power-handling capabilities of their products and reduce their costs. Because the 80W to 150W power-handling capability of a single RF device cannot begin to approach that of a single tube, high power outputs are achieved by paralleling multiple devices. Cost and efficiency are directly related to the number of RF devices in the transmitter. Cost is a fairly linear function: the more devices, the more it costs.

Efficiency is a more complex relationship. It is a function of the total number of devices, the number of cascaded devices and/or stages, and the amplification class used by the transmitter. If the efficiency of a single device is some number x, the overall efficiency of a transmitter in which those devices are in *parallel* will also be x. This assumes that as devices are added and power requirements increase, power supply efficiency remains constant. This may or may not always be a valid assumption.

However, when devices are *cascaded*, overall efficiency becomes x^n, where n is the number of cascaded stages. Because the efficiency of a single device is less than 1, overall efficiency decreases exponentially. Thus, the challenge is to improve power-handling capability and device efficiency. As amplification capability is improved, fewer amplification stages will be required for a given output. The improvement in overall efficiency, therefore, would be exponential. And as efficiency of individual devices improves, this can have a magnified effect as the value of n decreases and the value of x approaches (but never reaches) unity. Efficiency is also affected, usually to a lesser degree, by device cooling requirements and the power necessary to run fans and blowers.

Class of operation has a distinct affect on transmitter efficiency. The price for the linearity of Class A amplification is fairly high in terms of efficiency. Because most VHF transmitters use metal oxide semiconductor, field-effect transistor (MOSFET) power amplifiers, Class A or AB is generally used.

UHF options

For the most part, the attention given to UHF transmitters has focused on increasing its efficiency. As electricity costs approach — and in many areas exceed — $0.07 per kilowatt hour, transmitter efficiency becomes an increasingly important topic.

In UHF, the choice of transmitter technologies has been expanded from conventional klystrons to tetrodes, multistage-depressed collector (depressed collector) klystrons, inductive output tubes (IOT) and solid-state. Often, the choice of which technology is right for a particular facili-

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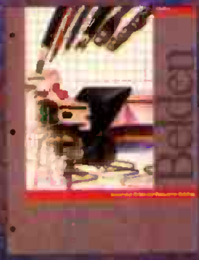

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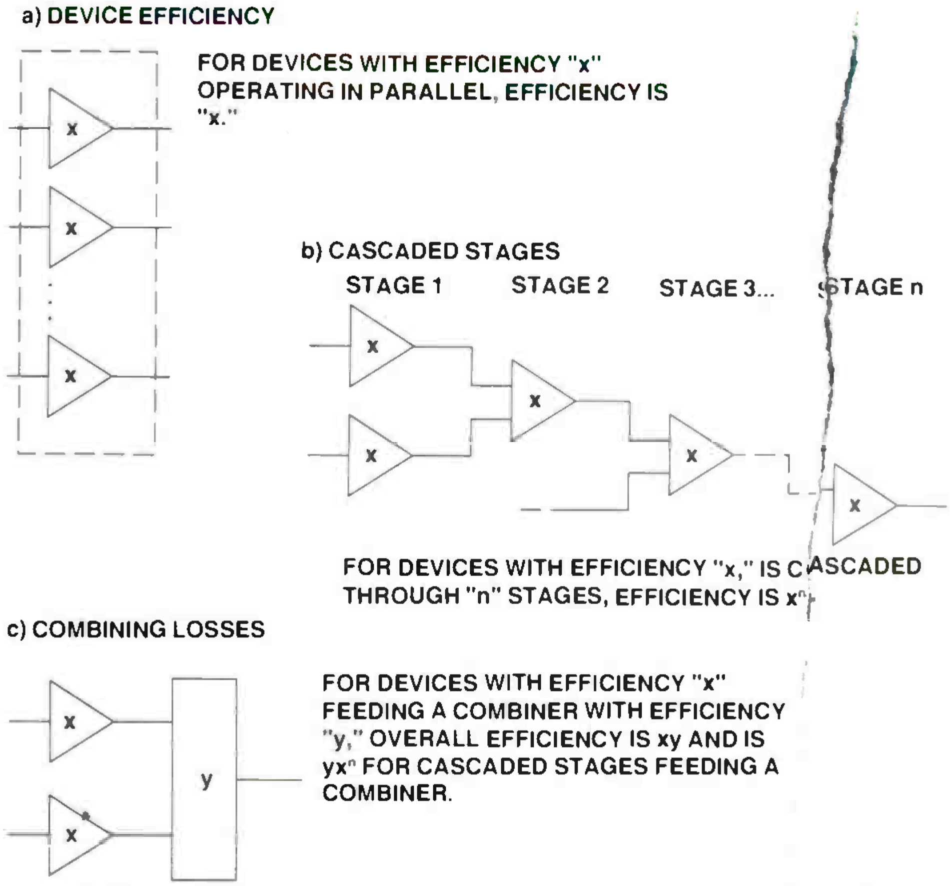

***Figure 1.** The overall efficiency of a solid-state amplifier is based in part on the number of devices and how they are interconnected.*

ty is not always easy or simple. Let's examine the state of the art in UHF amplification technologies, the advantages each technology has to offer and some possible drawbacks.

Klystrons

Today, when klystrons are discussed, it is generally understood to mean pulsed klystrons. Pulsing is a way to reduce the beam power in the klystron during blanking and active picture times and increase it during sync pulses. By reducing power consumption during the blanking and video, efficiency is greatly increased over nonpulsed klystrons. Pulsed klystrons have been used for UHF power amplification for many years.

Klystrons offer broadcasters several advantages. First, they are familiar to UHF engineers. Second, they provide high gain with good tube life. Unfortunately, klystrons are not highly efficient devices.

Efficiency ratings for UHF transmitters are often expressed as *figure of merit* (FOM). If you spend time researching the literature on TV transmitters, you will discover that several different methods are used to derive FOM. Whichever method you choose, be sure you use the same one in your transmitter comparisons.

For our purposes, FOM will be defined as:

$$FOM_T = \frac{\text{visual output power} + \text{aural power}}{\text{total average input power}}$$

Where:

- FOM_T = figure of merit for total output in percent
- Visual output power = power in watts at peak sync
- Aural power = CW aural power
- Total average input power = average main AC line input to the transmitter.

Using this method, the FOM for a typical klystron transmitter will have a range of 35% to 50%, depending on whether the klystrons are used in a combined or separate visual/aural configuration.

Klystrons are high-gain devices, and output power levels of up to 60kW from a single tube are available. Klystrons are usually used in diplexed (separate visual/aural) operation because their non-linear transfer characteristic makes it difficult to adapt them to combined operation. The presence of a continuous audio signal effectively eliminates the ability to pulse the tube, which further reduces efficiency. However, an important advantage of conventional klystrons is that they can be expected to last approximately 30,000 hours with reasonable care.

Depressed collector klystrons

In an effort to improve klystron efficiency, the multistage-depressed collector klystron was developed. Unlike electrons in a conventional tube, which vary the tube's output as they arrive on the plate of the tube, electrons in a klystron do their work on their way to the collector or plate. Many of them arrive at the collector with excess energy. High potential energy differences between electrons and the collector indicate that energy has been expended by the transmitter to raise the energy level of the electrons. Because the electrons delivered what energy they could to the RF collector, what remains is essentially kinetic energy. This energy is converted (and wasted) as heat when the electrons strike the collector. By providing multiple collectors at different negative potentials (depressed potentials relative to the anode which is at ground), the depressed collector klystron reduces the difference in energy potential between remaining electrons in the beam and the multiple collectors. More of the electrons return to the beam supply, making the tube more efficient. Using the formula shown earlier for FOM, you can expect the figure of merit for a depressed collector klystron transmitter to be 75% to 83%, with 80% being typical.

Furthermore, because there is less heat to dissipate from the collector, air cooling becomes a realistic possibility for power levels as high as 30kW. This can mean significant savings in acquisition costs, because liquid cooling requirements for depressed collector klystrons are quite stringent and add greatly to the transmitter's complexity and cost.

Klystrodes™ and IOTs

The Klystrode™ and IOT are similar devices whose heritage is based on the best characteristics of the klystron and tetrode tube. The klystron is known for providing good reliability and power-handling capability, while the tetrode provides an efficient design scheme with modulation taking place at the grid. This reduces the problems caused by the long drift space required to produce dense modulation in other designs.

Unlike a pure klystron, which modulates the *velocity* of an electron beam, the Klystrode™ and IOT modulate the *density* of the electron beam much the way a tetrode does. The tube uses a high beam voltage potential, approximately 32kV. This high beam voltage allows beam current to be reduced. This, coupled with the reduced *grid transit time losses*, results in a highly efficient amplifier. Figures of merit for IOT transmitter facilities approach 72% in the separate amplification mode and 80% in combined amplification.

These tubes can be air cooled up to approximately 40kW. Above 40kW, water cooling is generally required. However, with these tubes, direct glycol cooling can be used because the collector is at ground potential. This avoids the complexity and maintenance considerations associated with depressed collector klystrons. Because of the high efficiencies available in combined operation and the relative simplicity of the transmitter system required, use of these tubes can result in an exceptionally cost-effective transmitter at most power levels.

Problems with early designs included grid contamination, but these have been largely resolved. Currently, 58 Klystrode™ tubes are in service and 38 IOT tubes are in or scheduled to be in service.

Tetrodes

For many years, tetrodes have been an accepted form of amplification of VHF signals. However, problems were encountered in attempting to adapt the tetrode to use at UHF frequencies. Those same laws of physics that were encountered before dictated that all of the elements in the tube had to be reduced in size, corresponding to the smaller wavelengths of UHF. But, as surfaces decrease in size, power handling and heat dissipation become more difficult. Also, as the size of the tube shrinks, the delicate control grid is moved closer to the hot cathode. This can cause additional problems, such as warping of the grid, secondary emissions from the grid and mechanical fragility. The development of control grids made of pyrolytic graphite and new cooling methods have given tetrodes a second wind. Today, UHF tetrodes capable of 30kW operation are available.

One less desirable characteristic of the tetrode, compared to other technologies, is its relatively short life, low gain and more delicate nature. Although klystrons, depressed collector klystrons and IOT tubes can be expected to last from 20,000 to 30,000 hours with reasonable care, experience has shown that with reasonable care, tetrodes can be expected to last approximately 15,000 hours. Tetrodes also require careful attention to their operation. Inattention, improper adjustment and carelessness can result in greatly reduced tube life.

Using the previous formula, the tetrode transmitter's FOM ranges from approximately 25% to 30%. Typical figures of merit are 28% in combined amplification and 27% in separate amplification service. These efficiencies are low compared to other tube technologies. However, you will soon see that they are higher than solid-state designs.

Solid-state

Solid-state devices for UHF operation have many of the same advantages and disadvantages as when used in VHF. However, some differences do exist. At UHF frequencies, junction capacitance becomes a significant factor and tends to limit power-handling capability. UHF transistors are limited to approximately 80W to 150W per device. The relatively high cost of solid-state transmitters and their comparatively low efficiencies, especially at power levels above 5kW to 10kW, have inhibited their market acceptance.

Nevertheless, solid-state does have some redeeming qualities. One important advantage of solid-state transmitters is their *soft failure mode*. This is the ability of the transmitter to remain on the air if one device fails. Because a solid-state transmitter relies on many small amplifiers, failure of a single (or even several) device should not take the station off the air. Unlike in a single-tube transmitter, where device failure is catastrophic.

Compared to a tube-type transmitter with a single output device, a solid-state transmitter has *n* output devices, where *n* is the number of transistors that are paralleled to develop the output power. Failure of the single output device in a tube transmitter reduces output power by 1/1 or 100%. Failure of a single output de-

Continued on page 86

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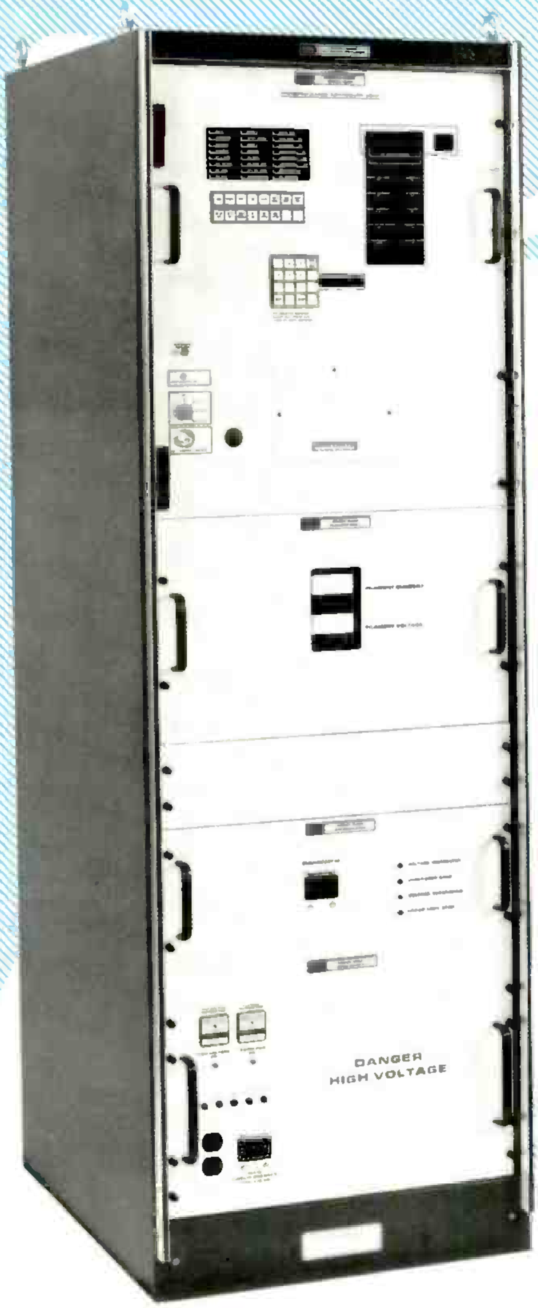

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Acoustics for broadcast engineers

There's still no substitute for good acoustical performance.

By Eric Neil Angevine, P.E.

The Bottom Line

The limiting factor to most facilities' audio performance is their acoustical design. Studio acoustics affect the sound of locally originated programs, while control room acoustics determine how well operators will hear program audio. Weakness in either area is tantamount to money thrown away: It prevents the full value of a facility's audio equipment from being fully realized. Avoid such costly mistakes by calling in acoustical experts when designing or rebuilding facilities. Meanwhile, some basic knowledge of acoustical matters may come in handy.

Angevine, *BE*'s technical consultant on broadcast acoustics, is associate professor of architecture at Oklahoma State University, Stillwater, OK.

A broadcaster's finished product has only one property that the consumer can rate objectively — *signal quality.* Each member of the broadcast audience will have an opinion about programming quality, broadcasters' personalities and so on, but deterioration of audio or video signals is painfully and nearly universally obvious.

Video difficulties are usually caused electronically, but the primary determinant of audio quality is often *acoustical* in nature. Even the best state-of-the-art production electronics cannot compensate for poor acoustics. Therefore, proper acoustical conditions — and an understanding of the physical properties of acoustics as they relate to microphone usage in such spaces — are indispensable initial steps to good audio program quality.

Good broadcast studio acoustics have developed only recently. In the past, most architects and contractors learned about the special needs of studio acoustics and noise control only through experience. More often than not, the studio owners were lucky if the resulting acoustics were merely acceptable.

Much was learned in the intervening years, often leading to audible improvements, although in many cases architects and builders didn't know precisely why. Common beliefs about architectural acoustics were frequently erroneous, and occasionally created problems. (See "Exposing Acoustical Myths," March 1992.)

Architectural acoustics is a science and an art, and good facilities result from a proper blending of those components. A knowledge of the basic principles of architectural acoustics will help the broadcaster to set realistic goals in facility planning, and assess the competence of prospective architects and contractors.

Two separate areas of architectural acoustics must be addressed in the design of any building: *isolation* from exterior sound, and *control* of interior sound. The techniques used to achieve these two goals can differ dramatically. The latter area, commonly referred to as *room acoustics,* will be considered here. (For more on isolation issues, see "Facility Design Special Report," March 1992.)

Properties of sound

An understanding of the behavior of sound is a prerequisite for any acoustical study. Sound is best described as a physical disturbance in the air pressure that can be detected by the ear. Vibrating objects create a series of pressure waves (compressions and rarefactions) in the air. In general, sound waves spread out from the source in three dimensions, with the energy decreasing according to the inverse-square law (i.e., sound pressure level drops 6dB with every *doubling* of distance from the source).

Even the best state-of-the-art production electronics cannot compensate for poor acoustics.

Sound waves travel through any medium at a speed that is a function of the density, elasticity and temperature of the medium, among other factors. For common purposes, the speed of sound in air is primarily a function of temperature. At normal room temperatures, the speed of sound in air is approximately constant at 1,130ft/s (770mph). A handy approximation for this speed is 1ft/ms.


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The distance between any two successive compressions or rarefactions is called *wavelength*. The number of vibrations that will pass a given point in one second is called *frequency*. Most natural sounds consist of complex waveforms that can be broken down into many component pure tones (periodic sine waves). The lowest and typically loudest of these frequencies

Diffusive rear wall in control room at Red Bus Recording Studio, London, features quadratic residue diffuser panels. (Courtesy of RPG Diffusor Systems.)

is called the *fundamental*, and it controls what we perceive as the *pitch* of the sound. All the other frequency components, which are often numerically related to the fundamental, are called *harmonics*, and these affect the perceived *timbre* (or tonality) of the sound.

The human ear generally detects frequencies of sound between 20Hz and 20,000Hz. (One hertz [Hz] is simply one vibration per second.) In terms of musical sounds, fundamentals only extend to approximately 4,000Hz (the highest note on today's piano keyboards is tuned to 4,186.009Hz). Above this frequency, most musical sound energy is only of the harmonic variety.

The velocity, frequency and wavelength of sound are related by the following equation:

$$c = \lambda f$$

Where c is the velocity of sound, λ is the wavelength and f is the frequency.

This relationship shows that frequencies below 100Hz have wavelengths of more than 10 feet, while sound at frequencies nearing 20,000Hz have wavelengths of less than one inch.

Because we do not see sound waves, we often forget the significance of these dimensions. The relatively wide (10 octave) range of audible sound dictates that the physical behavior of sound waves at one end of this spectrum will differ greatly from that of the other end. Among other things, these varying physical properties of sound will determine the optimum size and shape of rooms, and the thickness and mass of materials used for controlling sound.

Sound energy

Energy cannot be created or destroyed, but it can be converted from one form to another. Sound energy is created by the conversion of mechanical energy in a vibrating object to analogous vibration of air molecules. Conversely, sound waves that impact upon a solid surface may be converted to mechanical energy in the surface. In either case, the total energy is always preserved. (Any sound energy that is seemingly lost in the conversion process has typically been converted to *heat* energy.)

Sound that strikes a surface must either be reflected back into space, transmitted through the surface or absorbed by the material, as shown in Figure 1. It is important to remember that sound actually travels not in lines (as the figure uses for clarity), but in *waves*. This applies to all of its functions: Sound is generated, reflected, transmitted and absorbed as waves.

These waves have a physical dimension in wavelength and amplitude. For this reason, the physical size of objects determines their ability to reflect, absorb or transmit sound energy.

Sound reflection

Most sound that strikes a hard surface will be reflected back into the space. Sound reflection is much like the reflection of light, in that the angle of reflection from a flat surface is equal to the angle of incidence. A small surface that appears smooth and flat to high-frequency sound with short wavelengths may appear to be irregular to long-wavelength sounds of low frequency. But a large surface with dimensional irregularities of only about an inch will appear flat to the long wavelengths and appear irregular to short wavelengths.

Surface irregularities in a reflecting surface will break up the sound wave and disperse it randomly throughout the space. This phenomenon is known as *diffusion*.

Most room surfaces are hard and relatively planar. As such, they may be useful in reflecting wideband sound energy to other locations in the room (a so-called *specular* reflection), in order to increase the sound level at those locations. This approach is commonly used in the design of performing spaces, but reflecting surfaces can also be useful in studio applications. Reflecting surfaces can be equally harm-

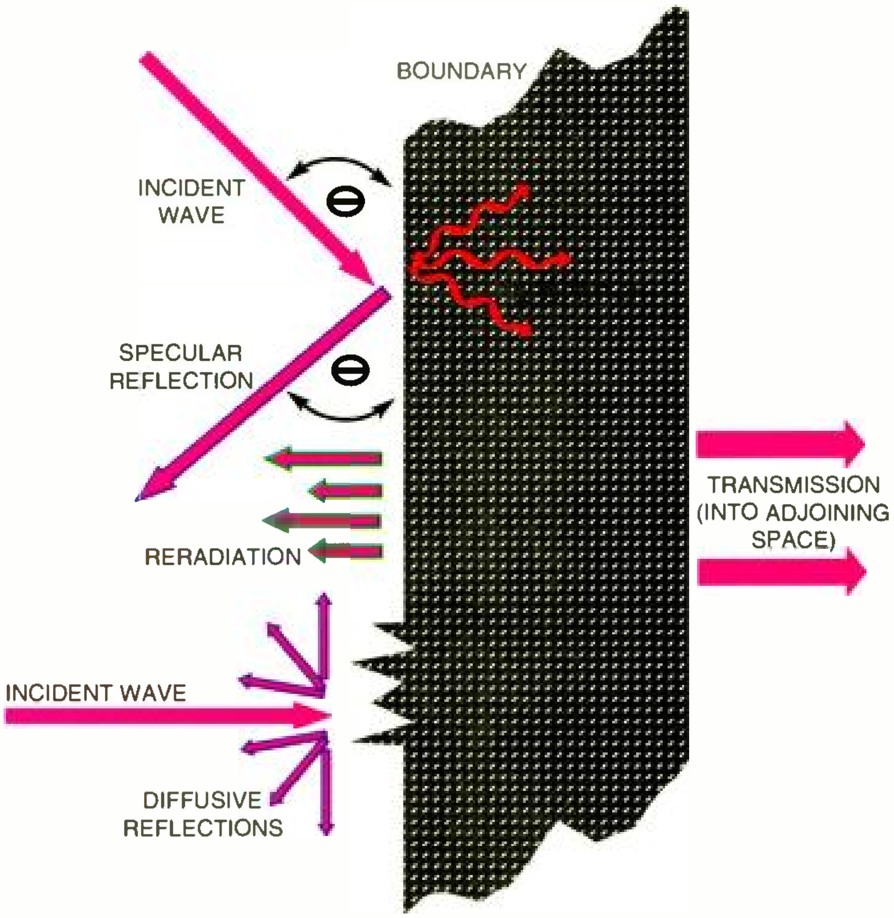

***Figure 1.** Sound that encounters a boundary surface is either reflected (in specular or diffusive forms), absorbed at the boundary, or penetrates into an adjoining room (transmission). Sympathetic vibration induced in the boundary by the incident wave causes re-radiation.*

MATERIAL	SOUND ABSORPTION COEFFICIENTS						NRC
	125Hz	250Hz	500Hz	1kHz	2kHz	4kHz	
3/4" mineral fiber acoustical tile:							
hard backing	0.03	0.27	0.83	0.99	0.82	0.71	0.75
suspended	0.68	0.67	0.65	0.84	0.87	0.74	0.75
1" fiber glass tile:							
hard backing	0.06	0.25	0.68	0.97	0.99	0.91	0.70
suspended	0.69	0.95	0.74	0.98	0.99	0.99	0.90
Brick:							
unglazed	0.03	0.03	0.03	0.04	0.05	0.07	0.05
painted	0.01	0.01	0.02	0.02	0.02	0.03	0.00
Carpet, heavy:							
on concrete	0.02	0.06	0.14	0.37	0.60	0.65	0.30
on foam pad	0.08	0.24	0.57	0.69	0.71	0.73	0.55
Concrete block:							
coarse, unpainted	0.36	0.44	0.31	0.29	0.39	0.25	0.35
painted, sealed	0.10	0.05	0.06	0.07	0.09	0.08	0.05
Fabric:							
10 oz. medium velour hung flat to wall	0.03	0.04	0.11	0.17	0.24	0.35	0.15
14 oz. medium velour draped to half area	0.07	0.31	0.49	0.75	0.70	0.60	0.55
18 oz. heavy velour draped to half area	0.14	0.35	0.55	0.72	0.70	0.65	0.60
Floor materials:							
concrete or terrazzo	0.01	0.01	0.01	0.02	0.02	0.02	0.00
tile on concrete	0.02	0.03	0.03	0.03	0.03	0.02	0.05
wood parquet on concrete	0.04	0.04	0.07	0.06	0.06	0.07	0.05
wood on wood joists	0.15	0.11	0.10	0.07	0.06	0.07	0.10
Glass:							
std. window glass	0.35	0.25	0.18	0.12	0.07	0.04	0.15
heavy plate glass	0.18	0.06	0.04	0.03	0.02	0.02	0.05
Gypsum wall board nailed to 2x4 studs	0.29	0.10	0.05	0.04	0.07	0.09	0.05
Plaster:							
smooth, on brick	0.01	0.02	0.02	0.03	0.04	0.05	0.05
rough, on lath	0.14	0.10	0.06	0.05	0.04	0.03	0.05
3/4" plywood paneling	0.28	0.22	0.17	0.09	0.10	0.11	0.15

Table 1. *Absorption coefficients of some common building materials, listed at the six standard frequencies of measurement. A value of 0.00 denotes a totally reflective surface, while 1.00 indicates total absorption. The column on the far right shows noise-reduction coefficient (NRC). This single-number rating can be misleading when compared to low-frequency performance of most materials.*

ful if improperly applied, however, and this has been a common problem in studio and control room designs of the past.

Room faults

If sound propagation paths are sufficiently long, reflections can also create annoying echoes. Human hearing cannot perceive reiterations of sounds as distinct echoes unless they are separated from the direct sound by more than about 50ms (0.05s). Because sound travels at approximately 1,130 feet per second, surfaces closer than approximately 25 feet will not produce audible echoes. (See "Live-end/dead-end" subhead.)

The repeated reflection of sound between two parallel walls is known as *flutter echo*. It is heard as a repeated echo or buzz after a single percussive sound, such as a hand clap.

Sounds reflected from hard surfaces closer than 25 feet will still be delayed in their arrival relative to direct sound's incidence at the listener's location, but not enough to be distinguished as an echo. These *early reflections* reinforce the direct sound, generally increasing the sound pressure level. But once again, the wide frequency range of audible sound comes into play. Not all frequencies will be reinforced to the same proportion, and some frequencies may be *reduced* in level, depending on the wavelengths and reflecting-path lengths involved. The delay times involved can place certain wavelengths of the reflected signal out-of-phase with respect to those same frequency components in the direct signal (or in other reflected signals). The resulting *comb filtering* can cause a change in the timbre (or tonality) of the sound, often referred to as a sonic *coloration*.

A special case exists for concave reflecting surfaces, such as those in circular rooms, barrel vaults or domes. These boundaries tend to focus all their sound reflections at a single point, creating a *hot spot* relative to all other locations in the room. (See Figure 2.) This focal effect can exaggerate level and frequency anomalies of the room's reflection characteristics, and should be avoided when designing an acoustical space.

Too many hard surfaces in a room can produce excessive *reverberation*. Reverberation is defined as the persistence of sound in a space after the source has stopped producing sound. Reflections of the original energy continue to bounce from surface to surface of the room until their full energy is dissipated. (See Figure 3.) Excessive reverberation can interfere with the comprehension of speech and the enjoyment of music. Generally, reverberation also has a different spectral quality than the original sound. Because typical room boundaries' sound absorption increases with frequency (see Table 1), lower frequencies predominate in reverberant sound.

Sound absorption

One way to avoid room faults due to echo, focusing, flutter echo or reverberation is to apply sound-absorptive materials to potential reflecting surfaces. Most materials that absorb sound are either fibrous or porous, and are called *dissipative absorbers*. They absorb sound by converting the energy to other forms, usually to mechanical vibration first and ultimately to heat. Because the magnitude of the sound energy is comparatively small, the build-up of heat in sound absorption is negligible.

All materials absorb sound to some extent. Their effectiveness in doing so is measured by the absorption coefficient of the material, which is simply the proportion of incident sound that is absorbed. Absorption coefficients can vary from 0.00 (totally reflective) to 1.00 (totally absorbent). Table 1 lists the absorption coefficients of some common building materials at the six frequencies at which sound absorption is normally measured.

Comparing dissimilar materials at each of these six frequencies can be confusing even to an experienced acoustician. Many people desire a single-figure rating with which two materials can be compared. The *noise-reduction coefficient* (NRC) is the arithmetic average of the absorption coefficients at 250Hz, 500Hz, 1,000Hz and 2,000Hz, rounded off to the closest multiple of 0.05. Observe in Table 1 how this method can produce the same single number value from widely differing measured data.

As with reflection, the physical size of absorptive materials is important. Thin materials will not be effective at absorbing low-frequency sounds with long wavelengths. Suspending or otherwise in-

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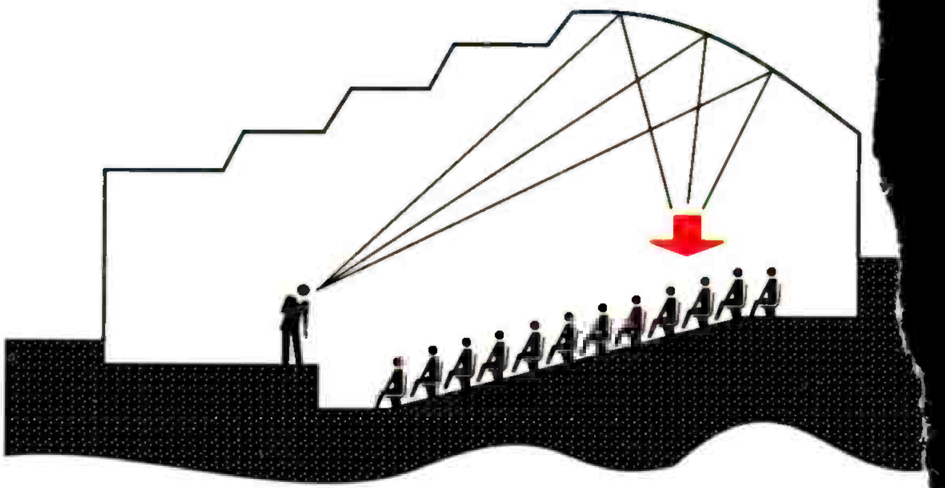

Figure 2. Focusing of reflections by a concave interior surface.

stalling materials over an airspace can increase the effective thickness of their construction, thereby improving their low-frequency sound absorption.

Room modes

Any room may be thought of as a musical instrument. Like a guitar string or an organ pipe, it can be tuned to resonate at specific frequencies or *room modes*. These modes depend primarily on room shape and size, and to a lesser extent, on surface finishes. The dimensions of a room determine the sonic wavelengths that are reinforced by multiple reflections from opposing boundary surfaces. The distribution of these frequencies imparts a tonal character to sound propagated within the room.

The ideal shape of an acoustically critical room is a subject of debate. The author recommends room proportions of 1:1.25:1.6 or, for larger rooms, 1:1.6:2.5 or 1:2.5:3.2. However, other authorities suggest different ratios of proportions. In practice, such accuracy is not essential, although square rooms and rooms whose dimensions are nearly equal multiples of

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exists in a room that possesses a *critical distance*, the point in the room at which direct sound level is equivalent to that produced by reflections in the room. Most studios and control rooms are not constructed with the size or reflectiveness required to produce such an effect, and therefore such facilities do not possess true *reverberation* (although they may still create plenty of *reflections*). On the other hand, *performance* spaces generally do have the size and reflectiveness to produce a critical distance. Any point in the room further from the sound source than the critical distance is said to be in the reverberant field of such a room.

Desirable vs. undesirable reflections

The quest for sound absorption and minimal early reflections does not mean that *all* sound reflections are undesirable. In large studios, a few hard surfaces will reflect sound to more remote locations where it may be desired to monitor the unamplified program. This is particularly true for situations that include a live audience, or acoustic ensembles whose performers are accustomed to playing (and hearing each other) without headphones.

These relatively distant reflecting surfaces in the studio can also enhance loudness and add a pleasant character or apparent enlargement to natural sound sources.

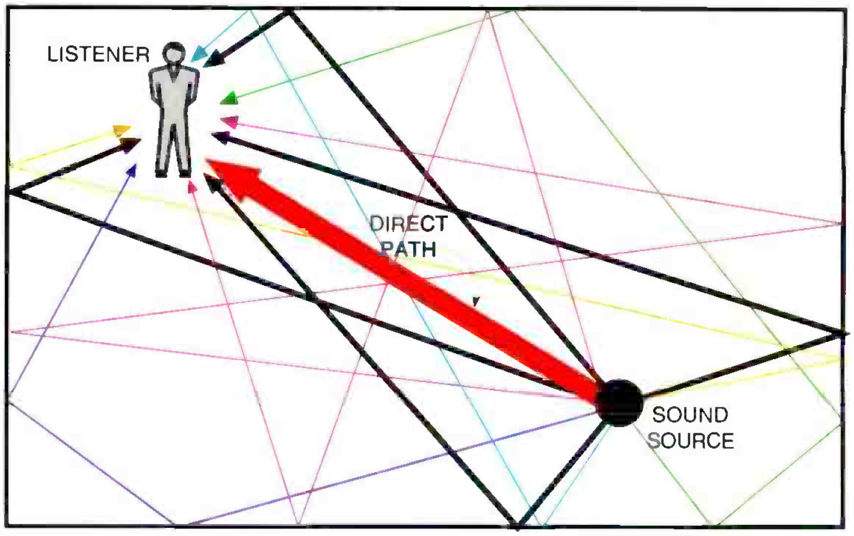
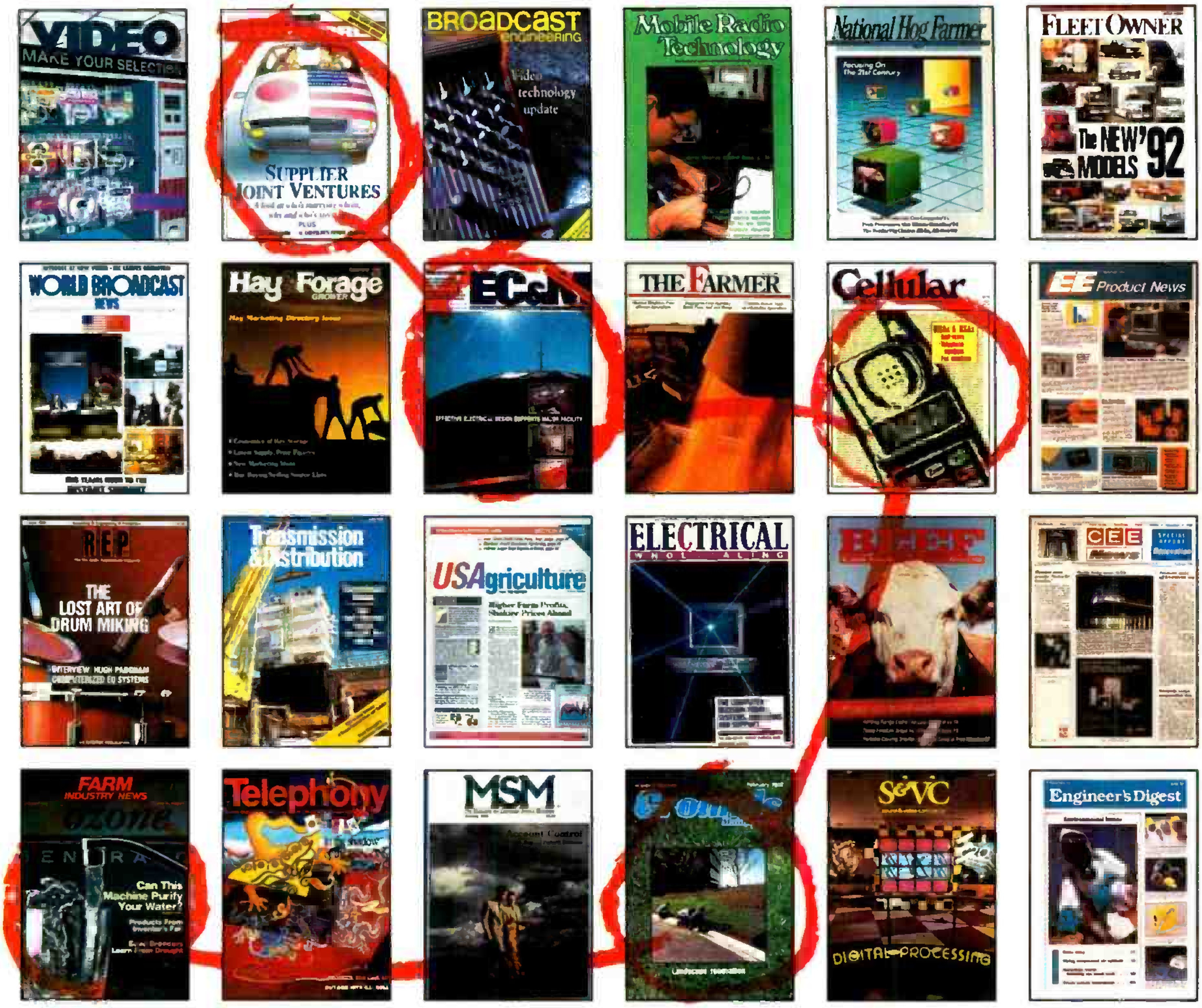


Figure 3. *Reverberation of sound can include components that have been reflected multiple times before reaching the listener (high-order reflections).*

Locating equipment

Production equipment in a broadcast facility may create large reflective surfaces. From mixers and equipment racks in an audio control room to interview tables or cycloramas in the studio, nearly all furnishings are acoustically reflective in some measure.

These hard surfaces can sometimes create problems for the studio engineer. They are commonly located close to the source of sound or to the microphone (or close to the listener in the control room). Therefore, they can create early reflections at relatively high levels relative to the direct sound. Close reflecting surfaces (within a few inches of sound source, microphone



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or loudspeaker) can audibly alter the timbre of the natural sound in the studio or the reproduced sound in the control room. More distant reflecting surfaces (one to 20 feet or so away from the sound source) can affect the frequency response and stereo imaging characteristics of audio monitoring systems. The timbral effects of close reflecting surfaces can become especially bothersome if the sound source (or microphone) is moving, in which case the tonal alterations audibly vary as reflecting paths change.

In TV studios there is also a frequent conflict between appearance and acoustics. Appearance commonly receives priority over acoustics in the selection of surface materials. But in many cases, there is really no need for such conflict. Visual surfaces in a TV studio are typically just facades that can cover absorbent, diffusive or reflective acoustical materials.

Live-end, dead-end

To avoid the significant frequency-response and stereo-imaging anomalies that early reflections can cause in an audio monitoring environment, many recent control room designs have incorporated the so-called *live-end, dead-end* (LEDE)[1] approach. (See Figure 4.)

Here, the front end of the control room is made essentially dead to prevent early reflections from arriving at the listening position. Meanwhile, the rear of the room is made diffusively reflective. The overall effect is to create a period just after the arrival of the direct sound during which no reflections arrive. Reflected sound only arrives at the listening position from the rear of the room, meaning that the sound wave has to pass the listener, hit the back wall and return. The extra time required for the reflected sound wave to make this round trip creates the time window that is free of reflection.

This design takes into account the *Haas effect*, a phenomenon of human hearing that defines how the ear responds to early reflections. Within the first 1ms to 30ms (approximately) after arrival of direct sound, the ear cannot differentiate most reflections from the direct sound, and all iterations are perceived as part of the direct sound. The comb filtering caused by this mix of a sound wave with a slightly delayed duplicate of itself creates frequency and phase anomalies in the received sound at the listening position. Undesirable alterations in the timbre and localization of the perceived sound field will often result. Such effects have also been shown to cause listening fatigue from the blurring of the direct sound (similar to the eye strain caused by reading with improper corrective lenses), especially when heard via reproduction in non-reverberant spaces. Beyond 30ms or so, however, the ear is more easily able to distinguish reflections from direct sound, and essentially ignores them — the direct sound is all that is perceived. Finally, reflections that arrive after 60ms or so begin to be perceived again, but as separate iterations of the direct sound (echoes).

Conclusion

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➡ *For more information on acoustical design, circle Reader Service Number 305.*

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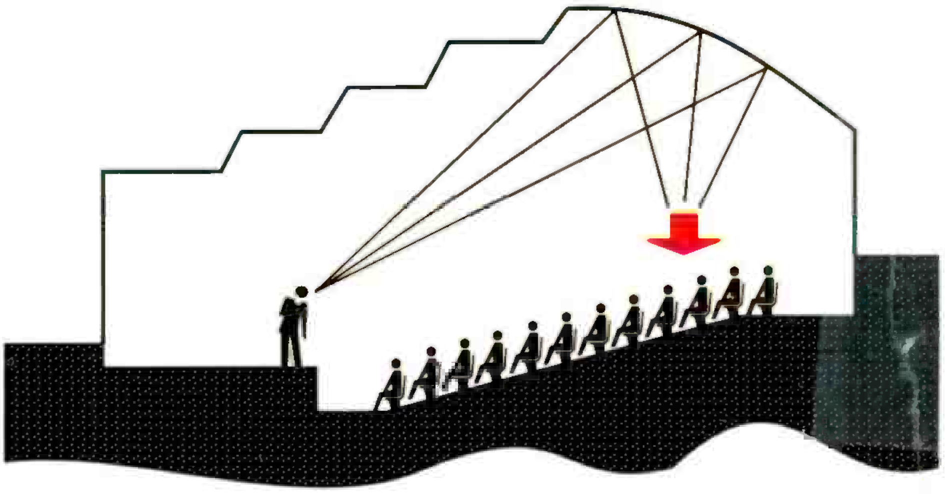

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Non-rectangular rooms and rooms with more than four walls work particularly well because the room dimensions are not constant throughout. When designing rooms with more than four walls, avoid regular polygons, however. Walls may be made non-parallel by tilting them *vertically* instead of horizontally (although load bearing can become difficult in such installations). Parallel surfaces in the floor/ceiling dimension should also be considered. Tilted or diffusive ceiling designs can help.

Reverberation time

The common measure of reverberation is the reverberation time, which is the length of time (in seconds) it takes for sound level in the room to decay 60dB after the source has stopped producing sound. Rooms that have long reverberation times are referred to as *live*; those with little reverberation are called *dead*.

The reverberation time (RT) of any room is a function of the room volume (V) and total sound absorption (A) in the space. It can be approximated by the following equation:

$RT = 0.049\ V/A$

But this really only applies to larger rooms. A truly reverberant condition only

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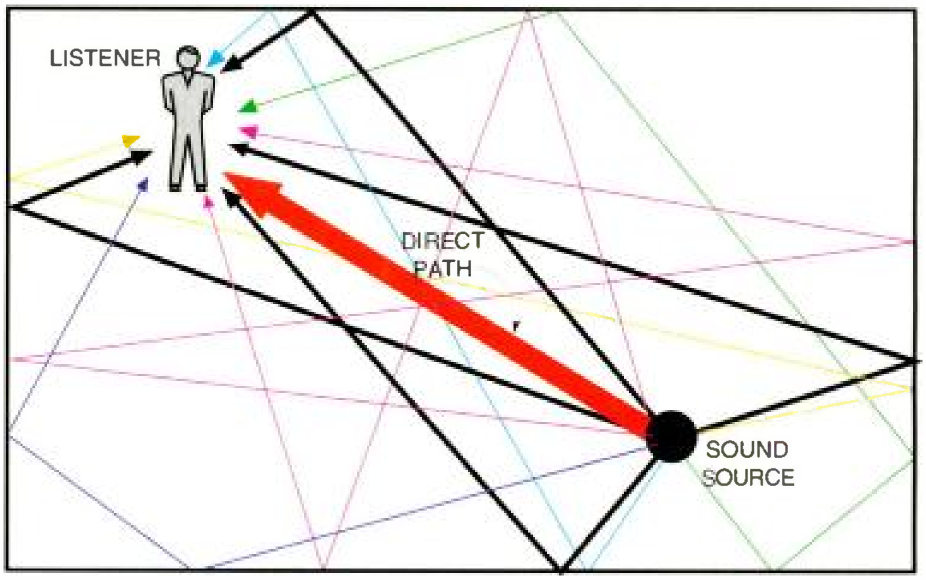
exists in a room that possesses a *critical distance*, the point in the room at which direct sound level is equivalent to that produced by reflections in the room. Most studios and control rooms are not constructed with the size or reflectiveness required to produce such an effect, and therefore such facilities do not possess true *reverberation* (although they may still create plenty of *reflections*). On the other hand, *performance* spaces generally do have the size and reflectiveness to produce a critical distance. Any point in the room further from the sound source than the critical distance is said to be in the reverberant field of such a room.



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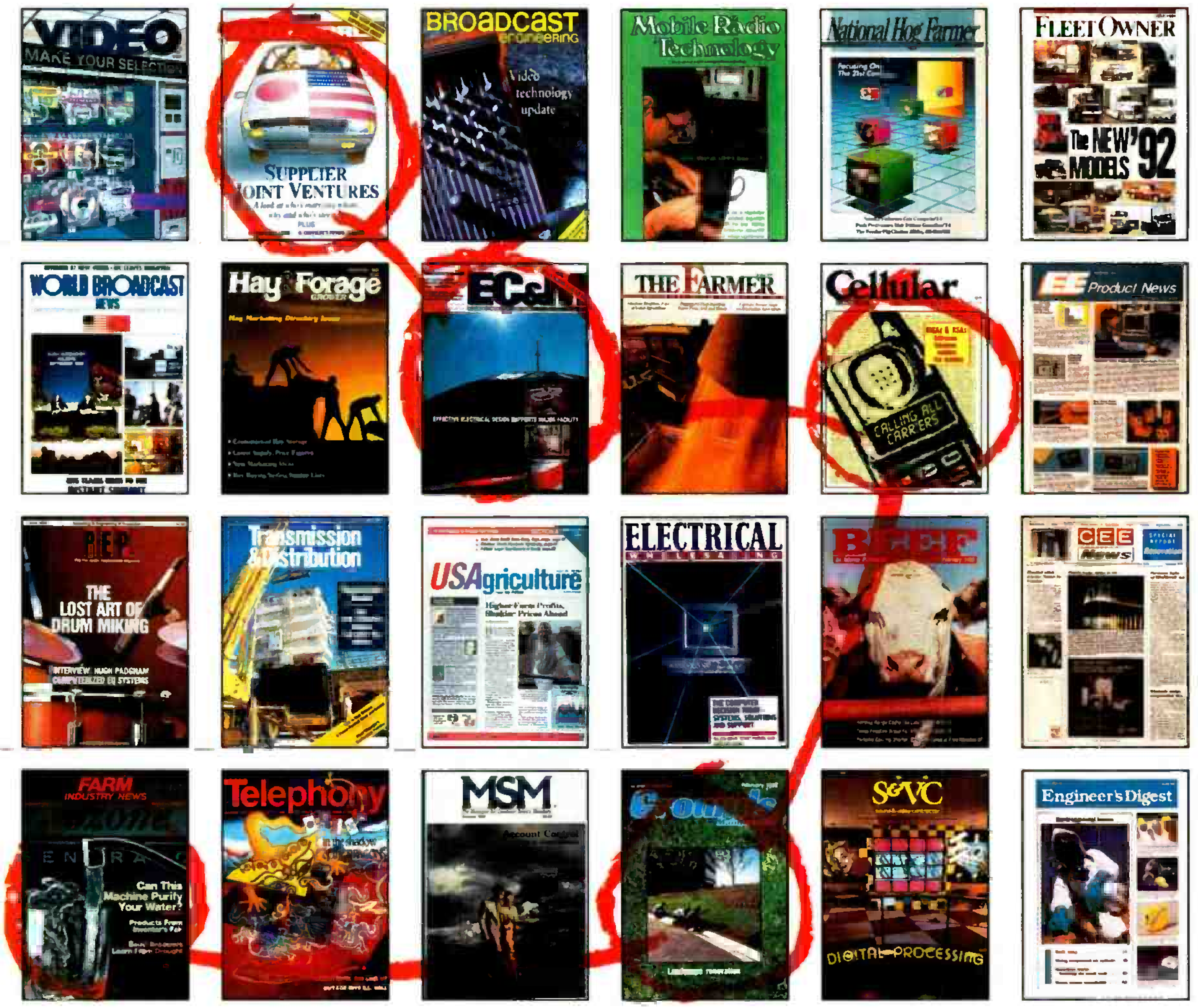

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➡ *For more information on acoustical design, circle Reader Service Number 305.*

Preview

June...

NAB CONVENTION REPLAY

- **From the Convention Floor: A Perspective**

A look at what technical and station managers saw on the convention floor and in the meetings. Professionals from the broadcast, production and cable industries offer their views on the industry's health and future.

- **Pick Hits of '92**

BE's panel of experts will tour the exhibit floor looking for those special devices and equipment for this year's winning roundup.

- **Engineering Conference Report**

A review of the major technical themes presented at the 1992 engineering conference.

- **Show of Shows**

No one does a better job of highlighting the products shown at NAB.

July...

AUDIO TECHNOLOGY UPDATE

- **DAB Update**

The latest news on DAB technology. The emphasis will be on the technical considerations for implementing DAB. Political and economic considerations will also be explored.

- **Digital Audio Processing**

New digital audio processing equipment has opened doors to techniques and higher quality than ever before. The article will look at the advantages provided by digital processing. Emphasis will be on digital audio processors.

- **Hard Disk Recording Systems**

A review of how hard disk technology has influenced today's audio and video recording hardware. The article will look at audio and video editing systems.

- **Using DAT in Broadcast**

DAT audio recorders are making their way into the production rooms of many broadcast stations. The combination of features and digital quality make them the perfect solution to production issues. The article will focus on the features most helpful in field recording and production applications. The compatibility between machines and other user issues will also be discussed.

- **Multitone Audio Testing**

It is now possible to use automated equipment to automatically measure multiple parameters of equipment performance in as little as one second. The article will examine the technology behind this new type of testing.

Digital HDTV and TV transmitters

By Nat S. Ostroff

The predominant RF encoding method for digital HDTV is multiple state quadrature amplitude modulation (QAM). Several of the proponents use 16QAM. This modulation places information on the RF waveform in the form of amplitude and phase. In other words, the correct amplitude of the RF sine wave at a specific sample time will result in the recognition of a digital one or zero.

The 16 states represent 16 distinct amplitude and phase levels of the RF signal.

Thus, digital HDTV transmitters will have to be quite linear in phase and amplitude over the entire 6MHz TV channel bandwidth. The power levels referenced by digital HDTV are average power because the RF spectrum of the multistage QAM looks like a modified noise spectrum.

Higher peak power needed

Although the average power levels are lower than NTSC, the peak power required for digital HDTV will be between 8dB and 15dB above the average. This large peak to average ratio will require TV transmitters to have a large linear dynamic range.

Furthermore, the lower gain of the transmitting antenna caused by its broader vertical beamwidth will require that the digital HDTV transmitter have peak power capabilities in the same order of magnitude as today's NTSC equipment.

The large peak to average ratios of the digital TV signal and the demand for linearity point strongly toward the adoption of Class AB or B type amplifiers. Such systems will use solid-state for lower power applications, tetrodes and Klystrode™/IOT for medium power and Klystrode™/IOT for high power.

Klystrons running in Class A will be unacceptably inefficient. Given the random nature of the peaks in the digital TV signal, it will not be possible to pulse a klystron amplifier to improve efficiency. The MSDC/ESC-type klystron will be more efficient than its less sophisticated brother, but will still require three to five times more energy to amplify the digital TV signal than a Klystrode™/IOT-based system. Furthermore, we still don't know if today's klystrons, including MSDC/ESC klystrons, will have the power bandwidth to deliver the required peak power at any frequency in the 6MHz TV channel.

Ostroff is president and CEO of Comark, Colmar, PA.

Continued from page 72

vice in a solid-state transmitter reduces the output power by a factor of only $1/n$. Even if a complete solid-state output module fails, the transmitter will generally have other modules that continue to operate and keep the transmitter on the air. This gradual reduction in output power as devices fail is known as soft failure. It is a major advantage of solid-state transmitters.

Efficiency is not an asset of solid-state UHF transmitters or their VHF counterparts. However, as with all other transmitters, efficiency is only a part of the total cost equation used to determine which type of transmitter is correct for your operation.

Selecting a transmitter

Choosing which transmitter technology is best for your application is not simple. The following are some factors that should be considered:

• *Acquisition cost.* As a rule, the costs of transmitter technologies in ascending order are:

1. Tetrodes
2. Klystrons
3. Klystrodes™ and IOTs
5. Depressed collector klystrons
6. Solid-state

Remember that the fairly dramatic difference in acquisition cost between solid-state and other technologies is mitigated somewhat by solid-state's inherent redundancy. Tube transmitters lose at least some of their initial cost advantage as redundancy is added. Acquisition cost is one of the main factors you will have to trade off against operating costs and efficiency.

• *Power level.* The power level required for your application is the first decision in determining which technology is best for you. At power levels below approximately 15kW, tetrodes or solid-state may have the largest advantages. You can weigh the various factors, as later noted, to arrive at a rational decision.

At power levels above 90kW, the choice will likely be between klystron and depressed collector klystrons and IOTs or Klystrodes™. Between these two power levels, the analysis gets more complicated and will involve the following factors.

• *Maintenance cost.* These costs include the personnel necessary to operate the transmitter, monitor its performance, perform routine maintenance and service, and repair it when it fails. Also included are the cost of replacement parts and consumable items, such as blowers, air and water filters, liquid-cooling system items (de-ionizing chemicals, distilled water, glycol), tubes and transistors. Assigning quantitative values to these items is daunting, but a few generalizations can be made.

Air cooling is less expensive than glycol/water cooling, and glycol/water cooling is less expensive than 2-stage, pure water glycol/water cooling — unless you need two air-cooled tubes to match the power output of a single water-cooled tube. However, then you would have redundancy, which the single tube could not provide. Tube replacement costs and personnel requirements can be closely estimated. Transistor replacement costs also can be determined from MTBF figures available from the device manufacturers.

• *Operating efficiency.* The affect of operating efficiency on power costs is a function of power output from the transmitter and transmitter configuration (parallel or alternate mains, cooling systems and type of amplification [combined] or separate). With figures of merit above 80%, the depressed collector klystron and IOT stand head and shoulders above the other amplification technologies. In terms of efficiency for transmitters under 10kW, the most efficient are tetrodes and solid-state transmitters, followed by conventional klystrons. From 10kW to 30kW, the order is tetrodes, IOT or Klystrode™, and then solid-state designs. Above 30kW, the order from most to least efficient is IOT or Klystrode™, depressed collector klystrons then conventional klystrons

Balance the trade-offs

If you are a VHF broadcaster, your transmitter choices are fairly clear: tetrodes or solid-state. The choice is not so obvious for UHF broadcasters. Because several competing technologies are available to chose from, you must prioritize the various factors affecting your decision. Then, weigh them appropriately for your facility, and balance the trade-offs to find the technology that best meets your needs.

Will a clear economical and technological winner emerge in the next several years, which will allow you to postpone your decision? Probably not. New technologies, solid-state, IOT and depressed collectors are all likely to improve in the future while maintaining their relative advantages and disadvantages with respect to each other. Therefore, careful consideration of the technical choices today will result in a long-term, satisfactory solution to your transmitter needs.

➡ *For more information on RF products, circle Reader Service Number 304.* ■

Industry Briefs

BUSINESS SCENE

Vistek Electronics' Vector V4401 standards converters were chosen by CBS to handle its PAL-to-NTSC standards conversion during the Winter Olympics in Albertville, France. The V4401 converters were also used by NBC for coverage at the World Indoor Track and Field Championships in Seville, Spain, and the World Figure Skating Championships in Munich, Germany.

Also, a Vector VMC standards converter was used to convert production of the Nobel Prize Awards ceremony from NTSC to PAL. Vistek has also sold an Array V2100 digital routing system to Modern Videofilm, Hollywood.

Harris, Melbourne, FL, has signed an agreement with Fox Television Stations to provide advanced TV (ATV) equipment to the network. Fox is the first station group in the United States to commit to using America's high-definition TV (HDTV) technology.

Ampex, Redwood City, CA, has sold three mobile TV production vehicles to Kuwait Television and Danmarks Radio. The Ampex Systems Group has also completed a 16.5-meter mobile TV production vehicle for Studio Hamburg, Hamburg, Germany.

Intraplex, Littleton, MA, has delivered a variable rate multiplexer 3800 VRM to Westwood One, Arlington, VA.

BTS, Salt Lake City, has supplied a TVS 2000 switching system, a BCS 3000 control system and two MCS 2000 master control switchers to Utah Public Broadcasting stations KUED-TV and KULC-TV. Also, eight BTS VTRs were purchased by the Country Music Television Network.

Nesbit Systems Inc. (NSi), Princeton, NJ, was chosen as the general contractor/systems integrator for data processing for CBS Sports' coverage of the 1992 Winter Olympics in Albertville, France.

Talia, Melbourne, Australia, has delivered its first E.O.S. series of routing switchers to Seven Network's studios, Sydney, Australia. The company has also supplied Seven Networks with 50 Spinknob intelligent control panels and 30 "under monitor displays."

The National Supervisory Network, Avon, CO, and **Gardiner Broadcast Partners**, Avon, have activated the United States' first Musicam-based digital VSAT audio radio network system. The system will be used by Gardiner's Rocky Mountain Radio Network.

Canon, Englewood Cliffs, NJ, has outfitted the SAS Institute, Dallas, with J20X type C lenses. The company's five field units are also equipped with Canon lenses. Canon has also sold two internal focus J14aX8.5B IRS lenses to WCPX-TV, Orlando, FL.

Neve, Herts, England, has sold a 36-channel 66 series console and a 12-channel 44 series console to Anglia Television.

Getris Images, Cedex, France, has sold a Venice paint graphics and animation system to the Seven Network Studios for use in its coverage of the Summer Olympics in Barcelona, Spain.

Louth Automation, Menlo Park, CA, in cooperation with Generation Technologies, has completed an integrated automation system for CBS Newsnet.

Paltex, Middlesex, England, has received more than $1 million in orders for its EDDi desktop video production system.

ColorGraphics, Madison, WI, has sold a LiveLine 5 weather presentation system to WXIN-TV, Indianapolis.

Circuit Research Laboratories (CRL), Tempe, AZ, has sold a record number of MBL-100 short-wave/medium-wave processors to Radio Free Europe/Radio Liberty.

Plateau Digital Technology, Grass Valley, CA, has named Technical Systems and Services, San Dimas, CA, as its exclusive distributor for the PVM-1073 and associated products.

Gentner Communications, Salt Lake City, has completed the acquisition of all products, product rights and technology of MacroMedia.

Analog Devices, Norwood, MA, is offering a full-day linear applications seminar in 34 cities throughout the United States and Canada from May 5 to June 5. The seminar will discuss all aspects of linear design. The admission fee is $20, and includes lunch, a 700-page design and applications handbook, free product samples and a set of SPICE disk models. For more information or to make a reservation, call 800-262-5643 or 617-937-1430.

Dielectric Communications, Voorhees, NJ, has been selected by the Advanced Television Field Test Project of the Public Broadcasting Service (PBS) to provide a UHF transmitting antenna for HDTV field tests. The special HDTV antenna will be a center-fed, top-mount design with a non-directional gain of 20 and input power rating of 60kW. In addition, the antenna will be fully range tested before shipment.

HM Electronics, San Diego, has named Portland Instrument Corporation, Glendale, CA, as the exclusive manufacturer and distributor of its 700 series professional cabled intercom products.

Leader Instruments, Hauppauge, NY, has expanded its line of video test equipment to meet the needs of D-2/D-3 facilities with a digital test-sync generator and a waveform monitor. Both units handle digital signals in parallel and serial form, as well as analog.

Hipotronics has changed its address to P.O. Box 414, Brewster, NY 10509.

Schmid Telecommunication has changed its address to Schmid Telecommunication Binzstrasse 35, 8045 Zurich. The telephone number is 01-456-11-11, fax 01-461-48-88.

Thomson Broadcast, Englewood, NJ, has opened a West Coast sales office and designated six companies as sales/service representatives for territories in the United States and Canada.

Fuji Photo Film, Elmsford, NY, has started operations at its new videotape factory in Greenwood, SC.

Sony Professional Tape Division, Park Ridge, NJ, has donated $1,500 to the Harold E. Ennes Scholarship Fund.

PEOPLE

My Chung has been promoted to FIREBERD division president for Telecommunications Techniques Corporation (TTC), Germantown, MD.

Quentin R. Nelson has been appointed Western regional sales manager of professional video and audio products for FOR.A Corporation of America, Natick, MA.

Darius Bossinas, Jacquelynn Hebrock and **Kenneth Satz** have been promoted to positions with Audio-Technica, Stow, OH. Bossinas is manager of graphic services. Hebrock is director of product development for the company's professional and consumer divisions. Satz is product manager.

Robert Matthew Straeb has been appointed executive vice president, international marketing and business development, for Axcess USA Corporation, Metairie, LA.

Clint Hoffman, Robert Degerstrom and **Robert Freedman** have been appointed to positions with Mitsubishi, Somerset, NJ. Hoffman is business operations manager. Degerstrom is national accounts manager for the company's Imaging Group. Freedman is divisional vice president of sales.

Shawn Briggs has been named executive news director for KAKE-TV, Wichita, KS.

Trish Walsh has been promoted to vice president of broadcast services for IDB Broadcast, Los Angeles.

Rüttger Keienburg, Dick Crippa and **M. Michael D'Amore** have been appointed to positions with BTS, Salt Lake City. Keienburg is president of BTS in North and South America (BTUS). Crippa is senior vice president in charge of BTUS. D'Amore is vice president of marketing and business development for BTUS.

Dean Long has been named RF product design engineer for Television Technology Corporation (TTC), Louisville, CO.

Ronald F. Carness and **Allan R. Lamberti** have been appointed to positions with Microwave Networks Incorporated (MNI), Houston. Carness is director of technical services. Lamberti is vice president of sales and marketing.

Harold L. Glassberg and **Joseph Ponce Jr.** have been appointed to positions with Nikon, Melville, NY. Glassberg is national service operations manager. Ponce is Southwestern regional sales specialist.

Michael Zablocki has been named vice president of sales and marketing for Nesbit Systems Inc. (NSi), Princeton, NJ.

H. Frederick Koehler has been appointed vice president and general manager of power grid and X-ray tube products for Varian Associates, Palo Alto, CA.

Mel Williams has been named Eastern regional manager for The Great American Market, Hollywood, CA. ■

New Products

Battery, lighting equipment

By Anton Bauer

• **Logic series digital battery:** NiCad battery; circuitry monitors and stores state-of-charge and capacity history; data is displayed in camera viewfinder; while on-board, LCD shows percentage available battery capacity, end of discharge and calibrate indications.

• **UL2 with Automatique:** light fixture in quick-change module attaches to on-camera base unit; shares accessories of previous Ultralight units; Automatique control circuit senses camera or camcorder record signal to turn light on and off, conserving power.

Circle (355) on Reply Card

Digital audio board

By Antex Electronics

• **Series 2/SX-15:** digital audio processor as PC add-in board; for simultaneous direct-to-disk record and playback of two audio channels with 18-bit resolution; programmable sampling rates 6.25-50kHz.

Circle (354) on Reply Card

Titler enhancements

By Abekas Video

• **A72 generator features:** character rotation; circular or elliptical text paths; horizontal, vertical mirror reflections with adjustable angle, transparency, focus; graduated colors and shading; line draw, brush size adjustments; trackball and mouse user interface.

Circle (351) on Reply Card

A/D, D/A converters

By Accom

• **ADC, DAC:** bridge units between digital 601 parallel and serial signal formats; 10-bit operation with 525- or 625-line standards; remote control via RS-422 protocol serial digital port.

Circle (352) on Reply Card

Digital mastering tape

By Ampex Recording Media

• **Ampex 329:** D-2 mastering videotape with improved bit error rate, dropout performance, higher RF output; redesigned shell increases stability and protects tape during tape motion; 22 to 208 minute lengths and all three standard cassette sizes; replaces No. 319.

Circle (353) on Reply Card

Special power supply

By Apogee Electronics

• **PS-1000:** dual 12VDC output supply for use with AD-500, DA-1000E reference A/D and D/A converters; 100-120VAC, 220-240VAC input facilities; package complements that of the A/D and D/A units.

Circle (356) on Reply Card

Flexible editing system

By Grass Valley Group

• **Sabre 4100:** linear or non-linear editing system determined by attached devices; edit display combines pictures, graphics, text under Dynamic Editing Software control; point/clock/drag interface controls 36 devices in various configurations; edit points and scenes represented by captured video images.

Circle (371) on Reply Card

Camcorder wireless

By Audio-Technica

• **PRO 88W:** wireless receiver attaches to light shoe of camcorder or back of camera; eight VHF channels; headphone monitor output, mic level output to camera; body pack transmitter and MT830MW subminiature condenser mic or AT829MW unidirectional condenser mic; 9VDC operation.

Circle (359) on Reply Card

Circle (51) on Reply Card

Enhanced amplifier

By Audio Dynamics

• **AD-302 program card:** enhances amplifier of ITC Delta cart machine; provides 14dB dynamic noise reduction with non-encoded approach for near CD-quality audio; EQ trim controls independent of NAB EQ pre-amp; 32Hz-16kHz response; 3-tone cue detector.

Circle (357) on Reply Card

Audio-for-video

By Graham-Patten

• **D/ESAM 400:** audio mixer for digital editing suite; 32-input system accepts analog and digital signals with virtual matrix router to four analog and four digital program outputs, in addition to four monitor outputs.

Circle (370) on Reply Card

Video production

By Grass Valley Group

• **Model 3000:** advanced production switcher; analog and digital inputs with all processing in digital domain; architecture allows nine layers of video to be combined in one pass with negligible noise.

• **DDR-4400:** digital disk recorder; 10-bit component digital recording for full compatibility with GVG Kaleidoscope and Graphics Factory, including depth information for 3-D compositing; does not use compression.

Circle (372) on Reply Card

Automated playback

By MATCO

• **MA-204A switcher:** 22×3 stereo audio-follow-video router; loss-of-video sensing on each output; random or sequential event operation with parallel, serial or IR control VTRs; 24 control outputs for VTRs and peripherals; battery protection of clock/calendar and event list memory.

Circle (388) on Reply Card

Composite digital products

By Leader Instruments

• **Model 411D:** combined sync and test signal generator for composite D-2/D-3 systems; parallel, serial and analog video with serial digital audio AES/EBU format audio outputs; 20-character source ID, calendar/clock; complies with RS-170A; 0% and 7.5% setup selections.

• **Model 5860D:** waveform monitor for D-2/D-3 installations; parallel, serial inputs; parallel/serial decoder, D/A drive analog display and video monitor output; all standard waveform monitor modes, line select functions.

Circle (384) on Reply Card

Video test system

By Plateau Digital Technology

• **PVM-1073 upgrade:** file storage for hand-held combined waveform, vector monitor and color frame timing multimeter; permits measurement information to be saved, recalled, edited and used in reference matching.

Circle (410) on Reply Card

CD sampler

By Roland Pro Audio Video

• **RSS demo CD:** shows effects and capabilities of Roland Sound Space localization processor; 360° H/V position control; effects apparent during playback of material on any conventional stereo playback system; pricing policy for RSS equipment purchasing has been revised downward, in addition to various leasing, rental programs. For more information, contact Roland Pro Audio/Video Group; 7200 Dominion Circle, Los Angeles, CA 90040; Attention: RSS CD; phone 213-685-5141 ext. 337.

Circle (54) on Reply Card

Power conditioning

By Current Technology

• **CT900R series:** power supply rack system; integrated AC/DC conversion, inverter and AC/DC distribution for custom requirements; 24VDC, 48VDC, 125VDC systems to 25kW power levels; controlled charging current, discharge cutoff threshold prolongs battery life.

Circle (363) on Reply Card

Video mic system

By Nady Systems

• **Nady 551 VR:** 2-channel wireless receiver; compact unit with belt clip also mounts on camcorder; 120dB dynamic range and companding noise reduction; SMT device circuitry; HT-10 hand-held, tapered-body microphone or SX/LT-30 body pack with mini XLR connector for any electret lavalier mic.

Circle (390) on Reply Card

Distribution switcher

By Di-Tech

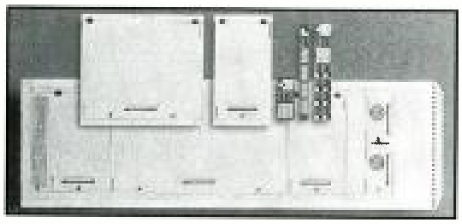
• **Model 5880:** compact router for large systems; basic 32×1 matrix expands to 128×160 stereo AFV; requires 40RU space; video combiners permit larger matrices.

Circle (364) on Reply Card

Multiformat routing

By Grass Valley Group

• **Series 7000:** signal management system with digital matrix routes current and proposed serial digital standards; 32×32 to 128×128 frames with various control panels; accommodated data rates include proposed 16×9 EDTV and compressed HDTV; cable EQ, reclocking; digital and analog modules acceptable in common frames; interface to existing Horizon matrices.



Circle (373) on Reply Card

Ops management, compliance

By Wind River Broadcast Center

• **Bigbook project:** 3-volume guideline to radio station operations management and FCC compliance focuses on technical aspects as well as management of station public inspection file; prepared by consulting firm in response to an expanded FCC inspection program and increases in noncompliance fines.

Circle (408) on Reply Card

Multi-user digital recorder

By Digital Audio Research

• **SoundStation Network:** upgrade to digital audio recording system permits multiple workstations to be interconnected; share resources, recorded material through access under touchscreen user interface; usable with SoundStation II and Sigma systems.

Circle (365) on Reply Card

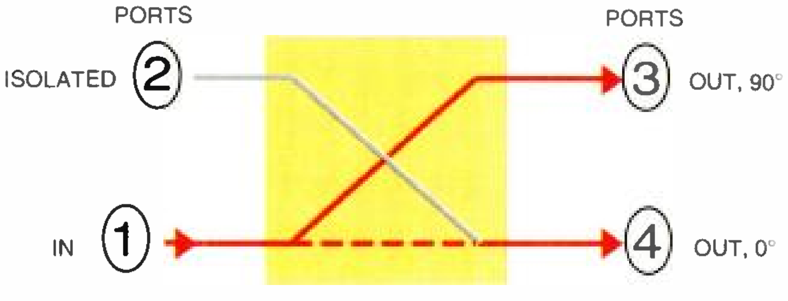
Audio cart replacement

By Studer Digitec

• **NUMISYS:** digital audio automation unit; front-panel slots accept digital cartridges of any length; 2-channel version alternates, sends each step of a playlist between two channels of the mixing console; full manual control facility; commercial insertion option; playlist displayed on integrated monitor screen.

Circle (402) on Reply Card ■

PORT	RELATIONSHIP		
	IN-PHASE	QUADRATURE	NO CONN.
1	4	3	2
2	3	4	1
3	2	1	4
4	1	2	3



QUADRATURE HYBRID

Figure 4. *The quadrature hybrid and a matrix of its ports' relationships to one another. In the application shown, power coming into hybrid at port 1 exits hybrid through ports 3 and 4 with phase relationships as noted.*

Continued from page 40

HDTV applications

The systems just described are capable of covering the full VHF or UHF broadcast TV bands. In this respect, they may have significant application in the upcoming transition to HDTV broadcasting. Broadband antennas can provide the following advantages during this transition:

- An all-band antenna means the system is capable of handling a station's present needs and its future channel assignment for any advanced TV (ATV) simulcasting.
- During the simulcast period, NTSC and ATV signals will be transmitted with the same coverage.
- A single transmission line can be used for NTSC and ATV signals.
- Broadband panel antenna systems with non-dispersive transmission lines will provide a linear phase shift across the band and reduce group delay contribution.
- These antennas typically use half-wavelength element spacing, thereby greatly reducing downward radiation.
- Panel-type radiators can be mounted on the faces of existing towers. Their wrap-around installation can provide less pattern-ripple than a side-mounted pylon antenna.
- Quadrature phasing provides a system that is insensitive to impedance changes due to antenna icing.

All of these advantages are available today, using current multichannel antenna technology. These systems' immediate benefits in shared transmission facilities are enhanced by their potential future utility in ATV applications. Such an analysis presents some compelling reasons to consider multichannel designs at your facility.

For more information on multichannel TV antennas, circle Reader Service Number 301. ■

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TEK 528, 1720, 1730, 1780R

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GVG 100, 200-2AN, 1600-7K, 1680-16AN, AMPEX VISTA 18N

Monitors
SONY BVM & PVM
IKEGAMI PM 930A, 9-5A

Lighting Fixtures
Mole Richardson — All models
STRAND — All models

312-334-4300

Character Generators
Super Scribe, Scribe & Infinit
Chyron VP 2, 4200, RGU-2.

Routing Switchers
BTS 30×30, 20×20, 10×10

Special Effects
ADO 1000
ABEKAS A42, A52, A53
HARRIS Iris still store
AURORA 220, 240, 280.

Terminal Equipment
BTS, GVG, LEITCH

Editing
SONY BVE - 600, 900, 910

Classified

HELP WANTED

TAFT BROADCASTING/NASA DIVISION is recruiting qualified applicants for the position of TELEVISION SYSTEMS DESIGN ENGINEER, to assist in support of video systems and services at NASA Johnson Space Center in Houston, Texas. Candidates should possess the following qualifications: BSEE or equivalent technical degree preferred. MSEE or post graduate work in a technical discipline is desirable. At least 2 years of experience in facilities planning and construction of television systems and subsystems. Other desirable attributes include component and systems level troubleshooting experience in a quality oriented broadcast or post production environment. Prior management experience is a plus. Technical disciplines involved include production, post production, telecine, video tape recording techniques, satellite, teleconferencing, analog and digital signal processsing, computer graphics, microwave, baseband, fiber optic and RF distribution. Excellent organizational, communication, and writing skills required. Please send your resume and four professional references to: Taft Broadcasting, 16441 Space Center Blvd., Houston, Texas 77058, Attn: Debbie Burks. We are an Equal Opportunity Employer. No Phone Calls. Principals Only Please. 5-92-1t

SOUTH TEXAS educational station has an opening for a Chief Engineer. Previous experience desired in maintenance of UHF transmitters and studio systems as well as personnel supervision. SBE certification a plus. Send resumes to Community Educational TV, Inc., Attention Ben Miller, P.O. Box C-11949, Santa Ana, CA 92711. EOE.5-92-1t

RF ENGINEERS

General Atomics, a diversified high technology research company, has openings for qualified RF engineers to work on nuclear fusion programs including the design, building and operation of power supplies and components for pulsed and CW RF systems with a frequency range of 30 to 120 MHz.

Qualifications include an EE degree (advanced degree desirable) and experience in operation and maintenance of high voltage power systems and broadcast equipment. Must be capable of troubleshooting down to component level.

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Ad Index

	Page Number	Reader Service Number	Advertiser Hotline
Acrodyne Industries, Inc.	51	32	800-523-2596
Ampex (AVSD)	36-37	20	800-25-AMPEX
Ampex Recording Media	15	11	415-367-3809
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Belar Electronics Laboratory	89	58	215-687-5550
Belden Wire & Cable	69	41	800-BELDEN4
Broadcast Video Systems Ltd.	90	51	416-764-1584
Cablewave Systems	81	62	203-239-3311
Canare Cable, Inc.	48	30	818-365-2446
Clear-com Intercom Systems	77	47	510-527-6666
Comark Communications, Inc.	63	39	800-688-3669
Computer Assisted Technology	3	5	212-687-BCAM
Continental Electronics	92	50	214-381-7161
Crouse-Hinds Airport Lighting	33	14	203-683-4300
DPS	41	23	416-754-8090
Dynair Electronics, Inc.	72	43	800-854-2831
EEV, Inc.	70-71	42	800-DIALEEV
Fujinon Inc.	43-47	25-29	201-633-5600
Graham-Patten Systems Inc.	60-61	38	800-422-6662
Hall Electronics	94	80	804-974-6466
Harris Allied Systems	29	16	217-222-8290
Harris Allied	27	15	800-622-0022
illbruck	82	55	800-662-0032
Jampro Antennas, Inc.	50	31	916-383-1177
Laird Telemedia	84,87	60,56	801-972-5900
Leader Instruments Corporation	59	45,46	800-645-5104
Leitch Video International	BC	2	800-231-9673
Logitek	82	52	713-782-4592
Macrovision	30-31	17	415-691-2909
Maxell Corporation of America	57	35	800-533-2836
MCL Inc.	73	44	708-759-9500
Microsonics	88	57	617-337-4200
Miller Fluid Heads	75	37	201-473-9592
Nautel Electronics	52	63	902-823-2233
Odetics, Inc.	9	8	800-243-2001
Opamp Labs, Inc.	87	65	213-934-3566
Orban, Div. of AKG Acoustics	7,17	7,12	510-351-3500
Panasonic	48A-H		800-524-0864
Pesa America	IFC	1	205-880-0795
Polyphaser Corporation	79	48	800-325-7170
Radiation Systems	84	61	708-298-9420
Russco Electronics	91	54	209-291-5591
Schmid Telecommunication	35	18	800-955-9570
Shure Brothers, Inc.	1	4	800-25SHURE
Sony Business & Professional Group	24-25		800-635-SONY
Systems Development Group	89	59	800-221-8975
Tascam	85	53	213-726-0303
Thomson Broadcast	80	49	800-882-1824
Thomson Tubes Electroniques	53	33	201-812-9000
Television Technology Corporation	39	21	303-665-8000
Total Spectrum Manufacturing Incorporated	21	13	914-268-0100
Utah Scientific	19	19	800-453-8782
Videotek, Inc.	67		800-800-5719
Vinten Broadcast Inc.	IBC	3	201-263-4000
The Winsted Corporation	54,55	34	800-447-2257
Yamaha International Corporation	65	40	800-395-1313
3M Pro Audio/Video Products	5	6	612-733-1959
360 Systems	56	22	818-342-3127

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