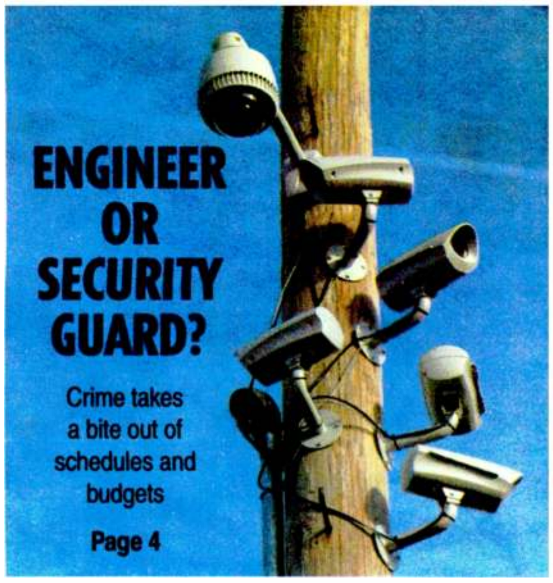


Radio World
ENGINEERING EXTRA
February 18, 2009

WHITE PAPER

The Looming Danger of Digital Host Interference

Operation at –10 dBc Using Separate or Interleaved Analog and Digital Antennas Can Be Dangerous To Your Station's Well-Being

by Doug Vernier

The author is president of V-Soft Communications.

Least considered among the ways that IBOC can affect analog FM broadcast is the issue of host interference.

Ongoing discussions about increasing the IBOC power level have focused on the interference that may be caused to neighboring stations. There has been little or no recent research that effectively explores interference to the hosting station caused by its own IBOC transmissions; nor has there been a thorough study on the vulnerability of analog receivers to higher levels of IBOC injection.

Of the early tests of IBOC host compatibility, the most notable were performed by the ad hoc NAB study group led by engineering consultant Al Rosner. Among their conclusions was one that warned about the use of dual antennas; interference to the host station could result if the antenna vertical field patterns were not well matched. However, the problem areas were identified to be close to the tower and it was surmised that this "self-interference" should not be a problem.

The Federal Communications Commission took this as its lead to allow licensed auxiliary antennas to be used for IBOC as long as the radiation center of the IBOC antenna was at least 70 percent of the height of the analog antenna and no more than 3 seconds of longitude and latitude separated the antennas. (See section 73.404 of the FCC Rules.)

Using dual antennas for hybrid IBOC is relatively inexpensive when compared to other combining methods. Separate antennas are inherently more efficient because there is no power lost in a combiner, where 90 percent of the digital signal can be shunted to a reject load. Typical methods to reach the –10 dBc IBOC power level, such as common amplification and high-level

SEE INTERFERENCE, PAGE 18

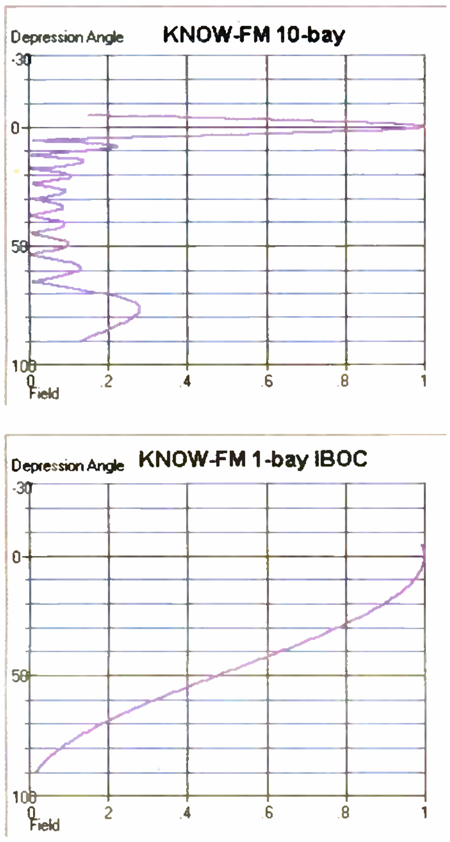


Fig. 1: Vertical elevation field graphs of KNOW(FM)'s analog 10-bay and digital one-bay antennas

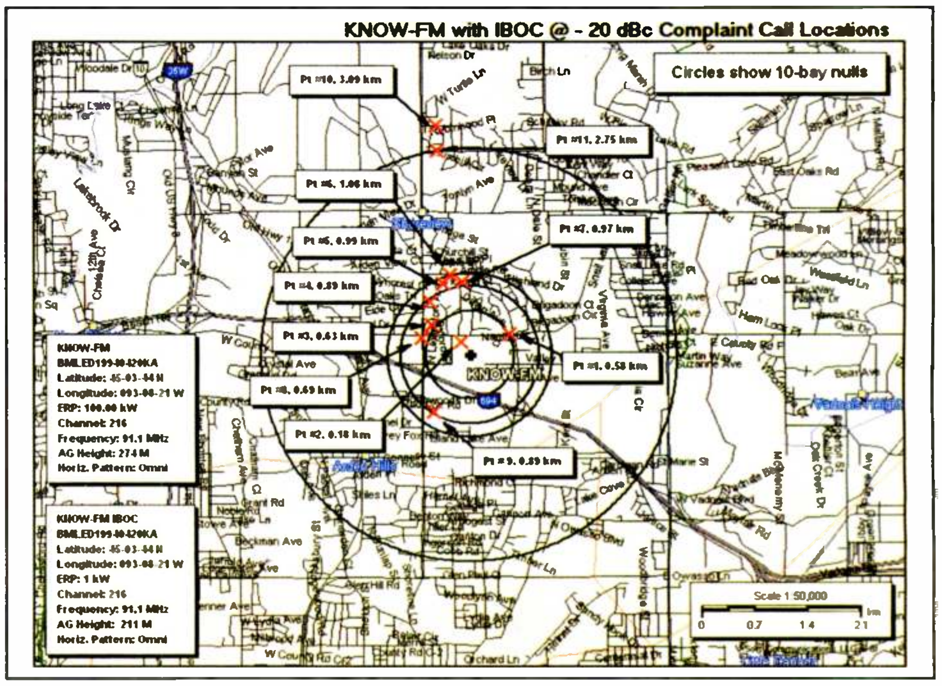
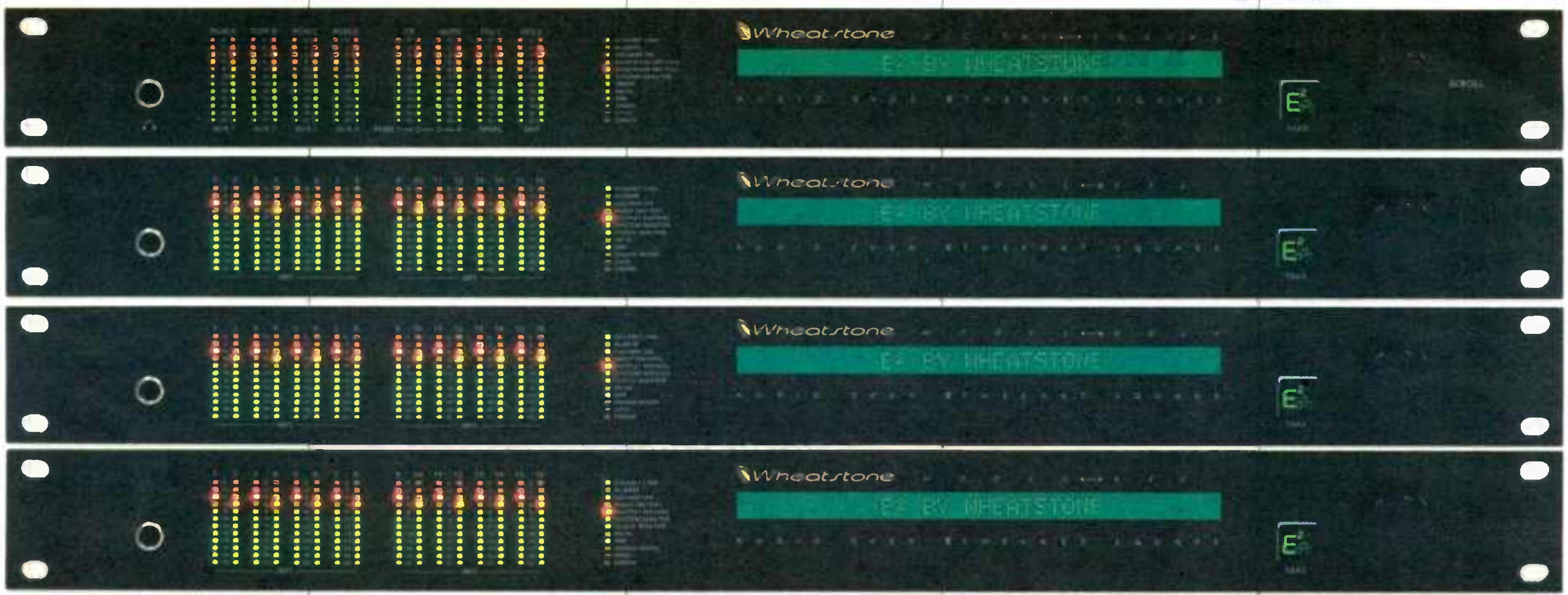


Fig. 2: Map of the locations of the KNOW(FM) documented interference complaints

THE POWER OF THE SQUARE

E² AUDIO-OVER-IP ROUTING. SOME TECHNICAL STUFF.



WHEATSTONE and E²...
Wheatstone is world-famous for consoles and networked audio routing – tried-and-true technology that has become broadcast's de facto standard. With the emergence of Audio-over-IP as a viable transmission medium, and knowing that existing solutions are cumbersome at best, Wheatstone has turned its attention and resources to developing a superior set of tools that are as efficient as they are effective.

Introducing E-SQUARE Audio-over-IP routing and mixing. Wheatstone's goal was to design a system that is extraordinarily easy to implement without the need for super-complicated network engineering, and where the user doesn't need to be concerned about setting network parameters and priorities to assure that those signals that are most critical are available.

Here we give a brief overview of E-SQUARE, and a few considerations that went into Wheatstone's design of a second-generation AoIP system for broadcasters.

GIGABIT ETHERNET
Wheatstone chose Gigabit Ethernet (1000BASE-T) because quite frankly, 100BASE-T just can't simultaneously handle the large number of audio channels prevalent today in large broadcast plants without the very real risk of audio not being available when you need it.

E² SQUARES
Three SQUAREs are access points in and out of the network, the fourth is a digital mix engine.

Each of the I/O SQUAREs handles 16 audio channels in and out, plus logic (GPIO). One model is all analog, one all digital, and one is half of each. The relatively small channel count of each I/O SQUARE allows you to conveniently locate them close to your equipment: in your TOC racks and in the control room or studio furniture.

Each of the SQUAREs and each Wheatstone console control surface connects to the network with a single CAT5E/6 cable.

There's also WHEAT-IP, a software "SQUARE" that you install on a Windows® machine — automation computer, news workstation, or a PD/GM's desk computer — to control, play and record audio on and off the network without a sound card, also with just one CAT5E/6 cable.

EASE OF SETUP
E-SQUARE setup is easy, intuitive, and takes only a few minutes until you're on the air. The front panel setup wizard in each SQUARE gets you up and running in moments. Extensive front panel metering and status indicators provide quick confirmation that all is well. E-SQUARE's web interface and E² Navigator GUI let you further customize your system, locally or remotely, with input and output names, logic associations, routing and much more.

RELIABILITY
Keeping you on the air is foremost in the design of E-SQUARE. It's completely self-contained — no PC is required to perform any of the system functions, including routing, mixing, salvos, and logic control. The PC is needed only for configuration changes.

Each SQUARE carries a complete map of the entire connected network in its onboard CPU flash RAM — this allows SQUAREs to be quickly and easily replaced in a network. Assign an ID # to a SQUARE and connect it to the network — it will query the other connected SQUAREs and import all the necessary configuration settings.

88e E² MIX ENGINE SQUARE
Every nerve center needs a brain. The 88e is it, handling all of the mixes from Wheatstone Evolution Series Console Control Surfaces and the Wheatstone Glass-E Virtual Console Control Surface, a PC-based GUI. The 88e SQUARE houses all DSP power for an individual control surface and distributes the four stereo PGM, four stereo AUX SEND, per-channel MIX-MINUS, monitor outputs and other bus signals to the network. Once on the network, they are available as sources and outputs anywhere. This creates an extremely flexible system, where program outputs from one surface can be a source on any other surface; for example a news mixer's program bus as a source on the air studio surface. While the MIX ENGINE SQUARE doesn't house audio I/O, it does include 12 universal logic ports.

E² I/O SQUARES
Each 88 I/O SQUARE provides connectivity for 16 input channels, 16 output channels (switchable 8 stereo, 16 mono, or any combination), and 12 universal logic (GPIO) ports programmable as inputs or outputs, routable throughout the system.

88a ANALOG I/O SQUARE
16 analog in/out

88d AES DIGITAL I/O SQUARE
8 AES in/out

88ad ANALOG & DIGITAL I/O SQUARE
8 analog in/out, 4 AES in/out

HIGHLIGHTS

- SQUAREs are linkable units that communicate via a single CAT5E/6 over Gigabit/1000BASE-T protocol — Gigabit protocol means all audio everywhere with extremely low latency
- SQUAREs interface seamlessly with Wheatstone's Evolution Series Console Control Surfaces, the Glass-E Virtual Console Control Surface, most of the popular automation systems, and streaming audio
- Install the WHEAT-IP driver on automation system computers to eliminate the expensive sound card and replace tons of audio and control wiring with a single CAT5E/6 cable
- Each SQUARE includes two 8x2 virtual utility mixers that can be used for a wide range of applications
- Front panel headphone jack with source select and level control to monitor any system source
- Silent — no fans — can safely be located in a studio with live mics
- Flexible GPI logic — 12 universal logic ports, programmable as inputs or outputs
- SNMP messaging for alerts
- Silence detection on each output that can trigger alarms or make a routing change

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FROM THE TECH EDITOR

by Michael LeClair

A Look Behind The Editor's Curtain

When Good Technical Studies Come to Different Conclusions, What Do We Do?

Reader Mike Pappas sent us a note last month about our December White Paper from Steve Densmore and Russ Mundschenk of iBiquity Corp., "Study of a 10 dB Power Increase in Digital Carrier Level for HD Radio Ttransmissions in the FM Broadcast Band." The letter is reprinted on page 8.

The gist of his question was, frankly, how this paper could be believed in the face of a contradictory study from NPR Labs. This raises one of the most important issues to be faced by any editor: What is our responsibility to our readers with regards to printing conflicting information of a technical nature?

I would like to take this chance to answer that question and explain a bit about what leads to what you read every other month here at Radio World Engineering Extra.

First off, it is essential to us that this publication be an open forum for any and all ideas and research that concern the radio broadcast industry. We invite anyone with something interesting to say about radio engineering to submit their ideas for publication. We will consider any such submissions equally and without bias.

I like to have a blend of papers for each issue that bring together a mix of technical topics and styles. A lot of the White Papers that we publish are designed to educate engineers on the background technologies behind new products. These papers tend to be the most theoretical work that we publish, and for engineers looking to keep up their technical knowledge these papers are essential.

I also look for papers that are of a practical nature. Project profiles that share how other engineers solved a challenging problem or handled a construction project fall into this category.

Interviews are interesting because they allow our fellow engineers and industry leaders to talk about themselves and broadcasting in a more personal way. Often these conversations reveal the deep and fascinating history that leads to where we stand today in radio.

Some of our best papers come to me without an advance solicitation. I also spend time throughout the year attending conferences and evaluating presentations, looking for interesting ideas and new technologies to bring to your attention.

A SENSE OF BALANCE

It is our goal at Radio World Engineering Extra to weave together a blend of stories and diversity of topics. At the same time we try to capture the full range of ideas and opinions about our industry. In particular, we try to bring to the page a range of different voices and authors to make sure that we address all viewpoints. This is the crucial element of "balance."

The paper is well-reasoned and thoughtfully presented. On the face of it this paper is a good candidate for us to publish on these qualifications alone.

Then there is the crucial matter of balance. NPR Labs released their highly anticipated interference and reception models last spring and summer. They came to a quite different conclusion about potential interference from high-power digital IBOC, based on their extensive coverage data. NPR Labs received full coverage in Radio World for their work, and rightly so. By publishing the iBiquity research in RW Engineering Extra we give you another point of view on this important topic.

Our responsibility when it comes to conflicting viewpoints comes down to this: If both sides are presenting legitimate research and do so in a respectful and thoughtful manner, then we need to print both sides.

And we even invite all of our readers to express their differing opinions as well, by sending us their thoughtful notes as Mike Pappas did. Come on up, take a seat at the table and join the conversation — drop us a line at *rwee@nbmedia.com*.■

It is our goal at Radio World Engineering Extra to weave together a blend of stories and diversity of topics.

Providing a balanced viewpoint to our industry is an essential part of what we do. If we exclude a particular issue, we potentially lose out on an idea or technology that could prove beneficial to all of us. History is filled with examples of scientific ideas that became standard knowledge after an initial period of deep skepticism. If only skepticism had been allowed a voice in print we would not have advanced in our knowledge of the world at the rapid and powerful pace that we have achieved over the last centuries.

On a more pragmatic level, if we exclude a particular voice or point of view then it becomes harder to attract those readers who disagree with our position. It can also have a chilling effect on submissions from writers who feel their ideas will not stand a chance for publication due to an editorial bias. Both of these effects obviously are harmful.

I like to think of Engineering Extra as a conversation amongst a group of intelligent and thoughtful members of an elite group of experts on broadcast engineering. Everyone at the table has something important to contribute and at the same time everyone at the table can learn from the others' experience.

TAKE A SEAT

Let's get back to Mike's question. Here's how I see it. The iBiquity paper was submitted to and accepted by the Broadcast Engineering Symposium of the Institute of Electrical and Electronic Engineers for October 2008. That is a pretty good pedigree for a research paper. The research presented in the paper contains original measurements and tests that have not been done by before on an important topic — increased power for digital transmission.

IN THIS ISSUE

A DAY IN THE LIFE

by Cris Alexander

Am I a Radio Engineer or Just a Security Guard?

Crime Takes a Bite Out of Schedules and Budgets

When I returned from a three-day engineering conference in October, I found my desk piled with the same stuff I'd left, plus a good bit more.

As I began to go through it, it dawned on me how little of the work I do these days actually has something to do with radio engineering. That was a real revelation, and it gave me pause. Has the world in which we ply our trade really changed that much? Evidently it has.

What do I do with so much of my time that is not related to radio engineering? It really comes down to two categories: post-crime recovery/cleanup and crime prevention.

That statement correctly implies that I spend a lot of time dealing with crime. This comes in a lot of forms, but it's basically theft and vandalism. In many cases, both happen at the same time. In others, it's one or the other.

CRIME

In the Dec. 12, 2007 issue of RW Engineering Extra, I told you about a handgun-toting copper thief who repeatedly hit a tower farm on Red Mountain in Birmingham, Ala. I provided you a dramatic photo of the thief pointing his pistol at a security light. This guy came back day after day, taking bus bars, strap, down leads and anything else he could get his hands on.

In one photo sequence from the security camera, a Birmingham police cruiser was seen doing a drive-by of the site just after the thief left.

In cooperation with our friends at Clear Channel, I got the mayor's office involved, reminding them that the city's trunking radio system was on our tower and that if this guy started hacking transmission lines for the copper, the city would be without police, sheriff, fire, ambulance, dog catcher and meter maid radio communications.

Amazingly, the police chief got involved immediately. A trap was set and the thief was caught and arrested. Case closed, or so we thought. More on that later.

THE PRISON YARD

Then in February 2008, copper thieves began hitting one of our 50 kW AM sites in

SEE CRIME PAGE 6

Blacktop was installed to cover the vulnerable ground screen and strap at each tower base.

A real attention-getter: Tower strobes pulsing with several hundred thousand candelas when the tower base alarm trips. Razor wire discourages the over-the-top approach to tower base entry.

Alarm contacts are enclosed in an armored shell at each tower gate, but even if an intruder smashes the box, the alarm goes off.

Crime

CONTINUED FROM PAGE 4

Birmingham. They took or destroyed ground screens and removed strap and radial wire, doing far more damage than the scrap or even replacement cost of the copper alone. We spent a couple of months making repairs and "hardening" the site against future copper theft.

We found out early on that the local sheriff's office was going to be of little help in putting a stop to the theft; we would have to do it ourselves. That site now resembles a prison yard more than an AM transmitter site.

Security measures include:

- Razor-wire topped security fences around the tower bases
- Multiple electric fence conductors around the inside of the base fences
- Blacktop over the ground screens
- Armored alarm contacts on the tower fence gates
- Alarm sirens at each tower base
- High-intensity strobes at each tower base tied into the alarm system
- An array of fixed and steerable security cameras with motion detection

All that may sound excessive, but it's hard to argue with success. We were being hit a couple of times a week before; since we hardened the site, we have had zero theft from the site.

We have had numerous episodes of theft from other sites around the company. In St. Louis, for example, copper thieves stole the telephone trunk lines feeding our site. They ripped hundreds of feet of the stuff right off the utility poles, cutting it and hauling it off.

We could do nothing to prevent that theft; it occurred well off our property, and the local phone company wasn't willing to bury the entire span, so it fell to us to come up with non-telco backups for our T1 and telephone lines to the site.

In Colorado, thieves hit our Ruby Hill AM site on two occasions, taking the strap around the tower base area and pulling up as many radials as they could close to the tower base. At that particular site, we are tenants and responsibility for the repairs falls to the landlord, but the damage still affected our coverage and operations.

At about that same time (early September), the Denver KLZ site was hit. Thieves broke into one of the tower base fences and took some copper strap. They also broke into the concrete block tuning house at that tower and took some radial wire that was stored inside (although it must have been too heavy to carry — they dropped the spool on their way off the property).

At that same site, the security lights were broken at two of the towers. The security light on the back of the transmitter building was shot out, and the top beacon on one of the towers had a bullet hole in it.

THE HITS JUST KEEP COMING

And then … also in September, thieves broke into a storage barn at that same site, trashing the interior. They also took some old copper transmission line pieces and parts (and I mean *old* — it was that four-hole flanged 1-5/8 inch rigid that you occasionally see at really old sites).

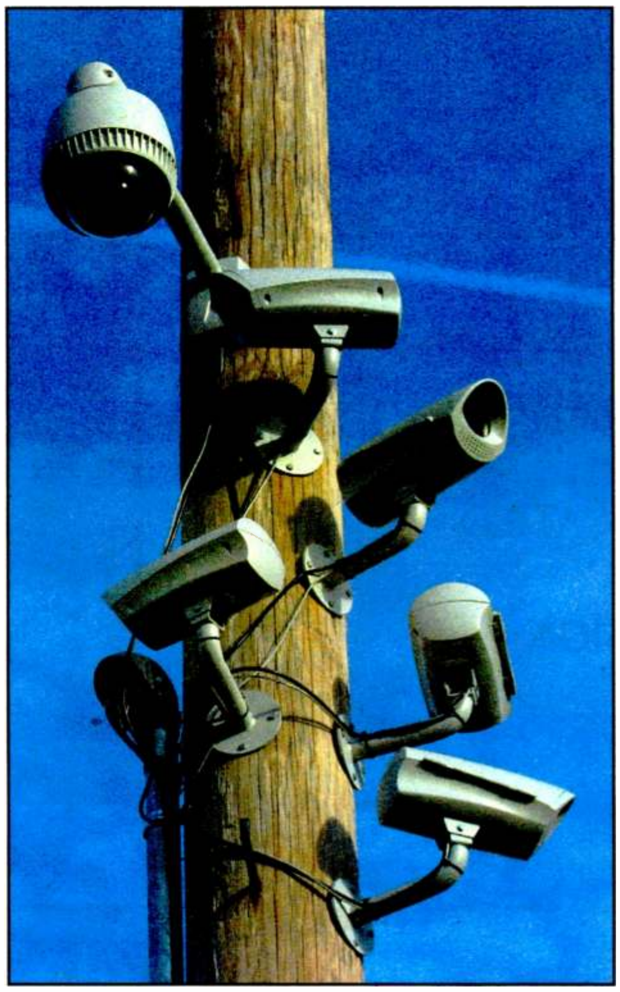
And then … back on Red Mountain in Birmingham, the same copper thief who had been arrested early in the year began hitting the site again. The police got right on it this time and arrested him again. My guess is that we haven't seen the last of him.

And then … in early October, copper thieves took practically the entire ground system at the KLVZ daytime site north of Brighton, Colo.

These scumbags knew what they were doing too. They evidently used a metal detector to find the ends of the radials, dug down to find the wire and then pulled all the way back to the tower base. At the tower bases themselves, they cut the strap and radials, and then pulled out as many of the radial wires as they could out to the fence. So much has been hacked up I couldn't figure out a way to fix this ground system other than replace it.

I haven't mentioned the graffiti problem. The storage barn at the KLZ site has, over the past few years, become a favorite target for graffiti "artists." As fast as we would paint over the graffiti, they would come back and apply more. Eventually, we gave up. Three sides plus the roof of the barn quickly became covered with graffiti.

Radials at this Denver area AM site were ripped out of the dirt from their ends all the way back to the tower bases. These copper thieves knew what they were doing.



An array of cameras covers all the tower bases. A steerable, zoom-capable camera allows folks at the studio (or anywhere via the Internet) to take a close-up look at anything at the site.

A few months ago, I got a citation from the county for failure to remove the graffiti promptly in accordance with some obscure county ordinance. Immediately, I contracted with a painter to wash, prime and paint the whole structure; but knowing that as soon as we provided a clean "canvas," the graffiti artists would be back, I also contracted with a fence contractor to first install an eight-foot security fence around the whole thing. Of course we had to get a county permit for the fence, which took awhile.

I kept the code enforcement people completely informed throughout the process, so it was quite a surprise when a sheriff's deputy showed up at the office with a summons because we evidently weren't moving fast enough. I called

We found out early on that the local sheriff's office was going to be of little help in putting a stop to the theft; we would have to do it ourselves.

the district attorney, who was a reasonable fellow (and who was more than a little miffed at the code enforcement folks for dumping a case on his desk which was well on its way to permanent resolution). The case was dismissed immediately, but it cost the company more than $8,000 to secure and paint the storage barn.

So how did I spend my summer and fall, and how do I and our engineers continue to spend a good bit of our time and efforts? It sure isn't doing radio engineering in any form.

No, we spend our time and efforts fixing the messes criminals make on property owned by our company and taking measures to prevent those messes from recurring. And going forward, instead of budgeting for new transmitters, processors and studio gear that might contribute directly to the bottom line of the company, I will likely be budgeting for fences, cameras, alarm systems, blacktop and other measures to keep the criminals out.

Not one penny of any of this contributes to the bottom line, and the time and labor of our engineering staffs spent implementing these measures takes away from the useful and productive work they would otherwise be doing.

I know with certainty that these thieves and vandals aren't targeting just my company. Copper theft and site vandalism is epidemic, occurring in markets small and large, all across this nation. That means you may well be dealing with the same stuff in a time when we have to do more with less, when companies are watching the bottom line as never before.

Yes indeed. Our world really has changed that much.

Cris Alexander is the director of engineering at Crawford Broadcasting Company and the SBE's Broadcast Engineer of the Year. ■

Photo: Jonathan Tichler/Metropolitan Opera

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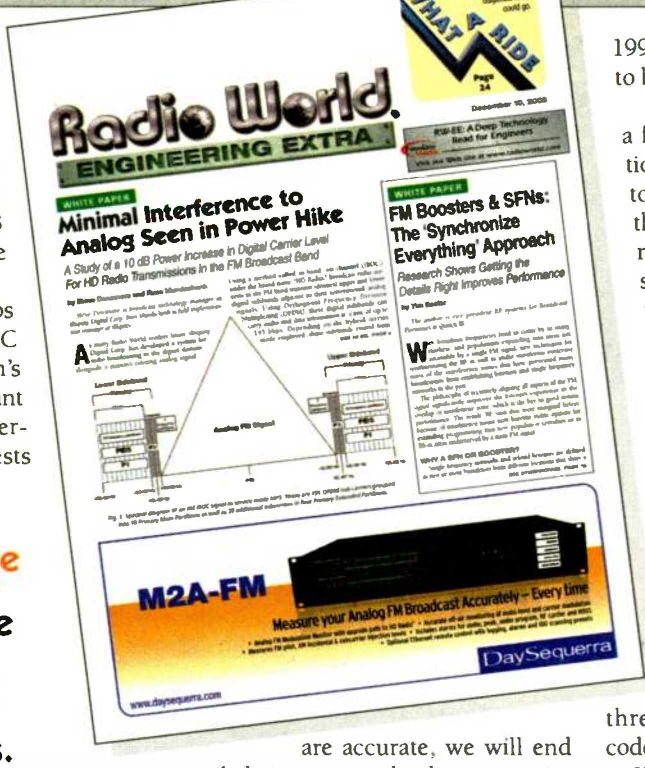
DIAMETRICALLY OPPOSED

I received the Dec. 10, 2008 Radio World Engineering Extra and the front cover has a white paper on how running –10 dB IBOC power isn't going to cause any problems.

I have read all of the NPR Labs papers on the proposed IBOC power increase, and John Kean's work, which included a significant amount of testing on receiver performance along with listening tests



> **I have a hard time reconciling these two completely different studies.**
>
> — Mike Pappas

with in-depth studies on numerous stations, shows that in most all situations there will be a significant loss of analog service to stations if the IBOC power is increased to –10 dB (like 20 percent and in some cases 40 percent).

I have a hard time reconciling these two completely different studies. And I don't understand why –10 dB IBOC power is the "magic" number. If one looks at the "Digital Cliff Effect" swatting coverage issues with a 10 times power increase would seem to be heavy handed and there might be a better choice, like –15 dB.

Additionally, running –10 dB IBOC level is going to be really expensive in terms of equipment and power consumption, and at the end of the day, if the NPR Labs studies are accurate, we will end up cannibalizing our analog listeners.

As the editor of this fine paper I would like to see Michael LeClair step in and explain to the readership how we can have two diametrically opposed results and what it really means ...

Mike Pappas
Chief Engineer
KUVO Jazz 89
Denver

Michael LeClair comments on the above letter on page 3.

FOLLOWING CONVENTION

Michael, I just saw your article posted on *radioworld.com* about your trip to the conventions this year. It brought back a bunch of memories.

I was Engineer in Charge for ABC Radio News' coverage of every convention going back to the GOP convention in Houston in 1992. In '96, '00 and '04 I was lucky enough to be the lead on a team of three engineers.

But then in '00 and '04 we had to set up a facility that included two Dalet workstations and a server in a trailer, a Dalet play-to-air workstation and an air console in the same trailer; essentially a mini-radio news bureau. We also had a Dalet workstation (still on the same server network) in our broadcast booth in the arena, three hardwired floor positions for reporters to go live from and two RF setups for live roving reports from the floor. Each live position could be mixed on the air mixer in the trailer for long-form programming or fed on a T-1 Intraplex channel back to New York for newscast drop-ins.

Of course, each position had routable IFB and/or intercom. I shouldn't forget to mention the 10 positions on Radio Row for affiliates and O&Os, each with a mixer, three mics, three headphones, an ISDN codec and Internet.

We always traveled the Monday the week before the convention and usually had everything 95 percent set up by Thursday. The rest of the time was spent waiting for tables, cables and contractors. You're right about the telco service though. It is top-notch, but then you should see the planning that goes on.

I didn't miss doing conventions this time around, with the three-day interval between the Dems and the GOP. Past conventions were separated by at least two weeks, although in 2000 I had to go from the GOP in Philadelphia to the Democrats in Los Angeles to the Olympics in Sydney without a break. When I finally got home, my youngest son said: "Who are you?"

One funny incident happened at the Houston convention in '92. I was at our workspace doing a facilities check, listening to one of our RF setups. We had an intern walking around the Astrodome floor talking on the wireless mic and listening to IFB on headsets. All of a sudden the signal went down the drain.

I could still hear our intern but she was buried in white noise. My first thought was: "Oh great! We're losing the wireless!" It ran on NiCads, which I knew had been sitting in the charger overnight. It sounded exactly as though the RF power dropped to where it was just strong enough to break squelch but too weak to achieve any kind of quieting. From her description of where she was standing, it couldn't or shouldn't be obstruction interference. I went to where the receiver was located in a locker room that had been designated as the "RF Shop" and saw we had good signal strength and modulation level.

Puzzling. So much for my theory. I decided to go out into the arena and see exactly what was happening. As soon as I opened the door and went out, I had my answer and started laughing: Hundreds of volunteers with scores of compressed air cylinders were filling red, white and blue party balloons for the big balloon drop at the end of the convention, and in doing so they were filling the Astrodome with white noise. Alas for my diagnostic skills, but in this case, I was quite happy to be wrong.

I'm looking forward to the next edition of RW Engineering Extra.

Steve Densmore
Broadcast Technology Manager
iBiquity Digital Corp.
Columbia, Md.

TALK RADIO BEARS SOME BLAME

Dear Guy,

I read with interest your article in the Dec. 10 issue, "Coping With the Meltdown." Your last paragraph, concerning the Fairness Doctrine, got me to thinking about how talk radio was something of a contributor to the current financial meltdown.

I think as engineers it is always useful to pinpoint the events that cause us problems. Talk radio is predominantly "conservative," many would even say extreme, right wing. Those of us who have spent some time in broadcasting know that the political slant of a program makes no difference to broadcasters. They would be just as happy to offer talk programming that is "liberal" or extreme left wing if it would get good ratings. But such is not the case.

For years, talk radio has been a bastion of deregulation, free market principles and no government interference in anything, particularly business. I would suggest to you that these basic ideas are things that, if they are not entirely responsible for the meltdown, certainly played a large part in causing it. And deregulation, the free market and minimal or no government are the main ideas that you hear over and over again on talk radio.

Even Alan Greenspan, a prime force for the deregulation that helped cause the meltdown, was forced to admit before a congressional committee that deregulation had not worked the way he thought it would.

So while talk radio certainly has been a money-maker for broadcasters, it also has been responsible for advancing some of the very same ideas that caused the meltdown.

Kent Tunks
Tehachapi, Calif.

See Guy's reply to this letter and past Guy Wire columns at radioworld.com under Columns/Guy Wire.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by Myron D. Fanton

RF Measurement Techniques For Broadcast Engineers

Vector Network Analyzer Is Versatile Tool for Transmission System Measurements

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Broadcast engineers must be competent in many areas of discipline: IT, DSP, facility and power engineering. In many cases radiofrequency (RF) technology may be a low priority for a station engineer.

This paper will review passive RF measurements of transmission equipment, such as impedance, return-loss, insertion-loss, VSWR, isolation, directivity and coupling. The discussion details the measuring and troubleshooting of filters, combiners, hybrids, transmission lines and antennas. Also, the vector network analyzer equipment used to perform these measurements is described, outlining modern techniques for system measurements.

FROM AC CIRCUITS TO RF

The introduction of RF circuit principals occurs when the physical size of a component becomes a significant fraction of a wavelength. We can compute the wavelength by the formula,

$$v = f\lambda \qquad (1)$$

where v is the velocity of propagation, f is the frequency and λ is the wavelength. The velocity of electromagnetic waves is the speed of light: 2.9979 × 10^8 meters per second in a vacuum. For transmission lines, electromagnetic waves may move more slowly than in a vacuum and the velocity is specified as a factor of the speed of light in a vacuum. For example, AVA5-50, 7/8 inch foam dielectric transmission line has a velocity of propagation of 91 percent of the speed of light.

At the point that systems and components become large with respect to wavelength, the relations of voltages and currents depart from the conventional lumped regime and are described by distributed models. Ohm's law and ohmmeters are replaced by Maxwell's equations and vector network analyzers (VNAs).

With RF circuits it cannot be assumed, for example, that the voltage applied to a circuit is instantaneously applied to a load. Instead, the voltage along a circuit, V(z) is the sum of incident, V_+, and reflected, V_-, voltages propagating as waves in the steady state, according to,

$$V(z) = V_+ e^{-\gamma z} \qquad (2)$$

where the propagation constant, $g = a + jb$, and z is the position. a and b are respectively the attenuation and phase constants. At some positions these interfering waves add constructively and at others, destructively. The ratio of the resulting maxima and minima is the voltage standing wave ratio, VSWR. The ratio of the forward and reflected waves is the reflection coefficient, G. These two values are related using the following equations:

$$\Gamma = \frac{V_-}{V_+} = \frac{Z_L - Z_O}{Z_L + Z_O} \qquad (3)$$

$$VSWR = \frac{1+|\Gamma|}{1-|\Gamma|} \qquad (4)$$

The voltages in Equations (2) – (3) may be complex numbers, meaning both magnitude and phase must be taken into account. Typically the magnitude of the VSWR is noted (the relative position of the standing wave nulls is neglected) or the logarithmic expression of the reflection coefficient, called the Return Loss:

$$RL = -20\log|\Gamma| \qquad (5)$$

Assumed in the above is that the waves are propagating along some uniform media, perhaps coaxial transmission line or free space, that may be described by its constituent material to have a characteristic wave impedance, Z_O, that is the ratio of the voltage and current at a given position. This transmission media is terminated with load impedance Z_L, an antenna or dummy load.

VECTOR NETWORK ANALYZER

The VNA is used to measure the RF network parameters of circuits. Network parameters are generally the scattering parameters, possibly the entire scattering matrix. The reflection coefficient of Equation (3) is one of the scattering parameters. Other scattering parameters are the insertion loss and coupling between ports in a hybrid, filter or antenna inputs. The scattering parameters are converted to other familiar RF parameters, such as VSWR and return loss.

The VNA typically transmits an unmodulated sine wave, slowly swept over a frequency range, and is equipped with phase-locked receivers that measure both amplitude and phase of signal at a return port. At minimum a VNA has one port that delivers the incident wave to the component under test while measuring both the incident and reflected waves with a dual-directional coupler. With multiple ports, the waves passing to and from multiple test points may be measured simultaneously.

The output power of the VNA is much smaller than the typical broadcast system power (approximately 1 W maximum) meaning that devices are characterized at low power. This in no way renders the measurements inaccurate; the VNA receivers are sensitive to very low powers. In fact, care must be taken at broadcast sites to reduce interference from external sources in order to prevent damage to the receiver.

Thus equipped the VNA measures and displays the complex reflection coefficient, the quantity expressed in Equation (3). All of the other relevant parameters are computed from it, such as return loss, VSWR, phase and group delay. The complex quantities can be displayed in polar plots, and the scalar components (magnitude, phase, group delay, etc.) may be displayed as a function of the frequency. Functions vital to modeling or tuning of a component or systems are also available, such as time delay, time domain transforms and gating. Because the input connectors (typically type-N, 7 mm or 3.5 mm) for a VNA are much smaller than typical broadcast transmission lines, adapters from type-N to the transmission line are required.

SLOTTED LINE

The slotted line is a fairly simple and intuitive example of RF measurements.

A narrow slot is cut into a transmission line that does not disturb currents flowing along the line. In a coaxial cable, for example, a narrow slot approximately a wavelength long and less than 5 percent of the diameter can be cut into the outer conductor, along the cable axis. A small voltage probe may be inserted into the slot and moved along the slot to directly measure the amplitude of the standing wave.

Three slotted lines in 7/8 inch, 1-5/8 inch and 3-1/8 inch rigid line sizes.

From the sum of transmitted and reflected voltages on a uniform transmission line the expression for the measured standing wave voltage may be derived:

$$\frac{|V^2|}{|V_o^2|} = 1 + |\Gamma_L|^2 + 2|\Gamma_L|\cos(2\beta x) \qquad (6)$$

where Γ_L is the reflection coefficient of the impedance terminating the line (see Fig. 1), β is the phase constant in the transmission line, and x is the distance from the load reference plane.

The output power of the VNA is much smaller than the typical broadcast system power (approximately 1 W maximum) meaning that devices are characterized at low power. This in no way renders the measurements inaccurate; the VNA receivers are sensitive to very low powers.

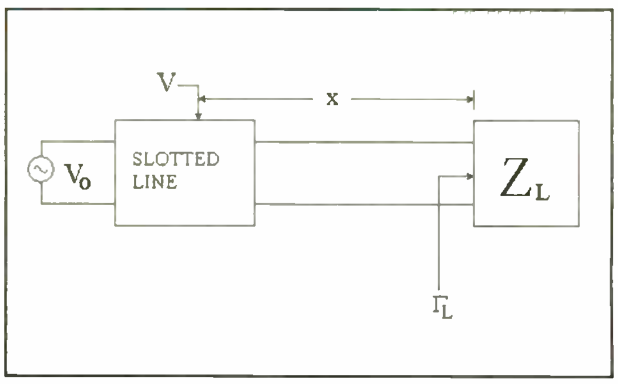

Fig. 1: Slotted Line Circuit

Typically, the probe is moved along the slot while recording the voltage of the standing wave. At some positions the voltage maxima occurs, and the minima occurs at others. The ratio of the maxima to the minima is the VSWR. The magnitude of the reflection coefficient is then computed from the VSWR. In addition, the distance from the desired reference plane to a voltage minimum, x_m, is

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Measurement

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measured, and the phase of the reflection coefficient may then be computed as follows [see Ref. 3]:

$$\theta = 2\beta x_m \pm \pi$$
$$|\Gamma| = \frac{VSWR - 1}{VSWR + 1} \qquad (7)$$
$$\Gamma = |\Gamma| e^{j\theta}$$

This can be done with a vector network analyzer but it is also possible to use a DC voltmeter and diode detector if a constant tone is modulated onto the RF carrier. Another simple slotted line voltage probe may be made with the center conductor of a coax cable routed to a spectrum analyzer or power meter. The measurement of the standing wave is an amplitude-only measurement; the phase information comes from the distance of the null from a reference plane.

In contrast, instrumentation in transmitter and control equipment that monitors VSWR typically computes VSWR using power measurements from a directional coupler. The physical limitation of the transmitter output is the reflected power, and the measurement typically is performed with a scalar, average power detector. In a scheme where average power varies with modulation (NTSC, for example) the VSWR displayed by these instruments will vary. If only reflected power is measured, then the displayed VSWR is only correct for the output power and modulation state at which it was calibrated.

TRANSMISSION SYSTEMS

Because the broadcast engineer typically is faced with measurements of a complete, assembled system, we consider this problem first and turn to each component later. Facilities for the transmission of FM broadcast comprise antennas, coaxial transmission line, connectors, elbows, combiners, diplexers and filters [4]. Coaxial transmission line contains support insulators and bullet interconnections which affect the RF performance as well. Modeling this assembly of components appeals first to two-port network theory.

SYSTEM MODEL

The network description of two components separated by uniform transmission line is shown in Fig. 2. The total reflection, Γ_t, is related to the reflection of component B, Γ_B, and the S-parameters of component S.

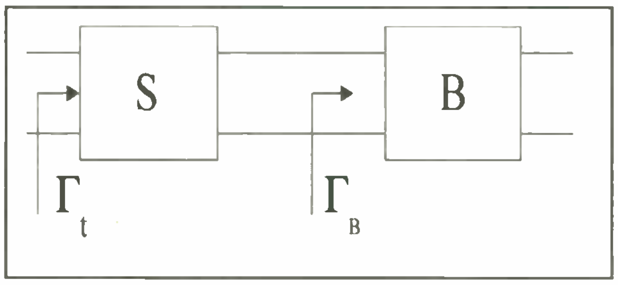


Fig. 2: Network Model

The total reflection is given by

$$\Gamma_t = S_{11} + \frac{S_{12}S_{21}\Gamma_B}{1 - S_{22}\Gamma_B} \qquad (8)$$

Assuming that the through losses and level of reflections are much smaller than unity ($S_{22} << 1$, $S_{12} = 1$, $S_{21} = 1$), a reasonable assumption in the vast majority of system components, the total reflection can be approximated by:

$$\Gamma_t \approx S_{11} + \Gamma_B \qquad (9)$$

which is the addition of two complex numbers. As the two components are separated by a distance, d, the total is

$$\Gamma_t \approx S_{11} + \Gamma_B e^{-2j\beta d} \qquad (10)$$

where the phase constant $\beta = 2\pi/\lambda$.

A depiction of this complex addition in terms of two vectors is shown in Fig. 3. The magnitude of the total reflection varies according to the relative phase of the two component reflections. As Equation (10) indicates, the relative phase of the two reflections depends on the distance between the two components and the frequency. At some frequencies, they add constructively (long red arrow, Fig. 3), and at some frequencies, they add destructively (short, blue arrow).

The total reflection of the entire RF system is the summation of the complex voltage reflection coefficients of each component. With this model the cardinal system design principle has been established: minimizing the individual component reflections reduces the total system reflection.

Considering only the magnitude of each component, the maximum total reflection may be computed. Component values adding to a system VSWR of 1.10 are tabulated in Table 1. The excessive number of decimal places is included to allow the computations to be verified.

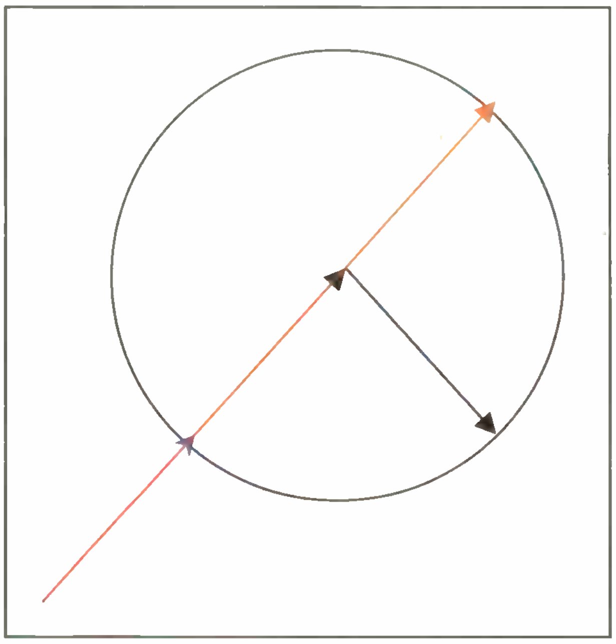


Fig. 3: Vector Addition of Reflections

# Components	Reflection Coef.	VSWR	Return Loss
2	0.0238	1.0488	32.46
5	0.0095	1.0192	40.42
10	0.0048	1.0096	46.44
20	0.0024	1.0048	52.46
30	0.0016	1.0032	55.99
50	0.0010	1.0019	60.42

Table 1: Required Component VSWR for 1.10 System. For example, if there are four elbows and an antenna, the VSWR of each component must be below 1.0192 to make the system VSWR better than 1.10

DISTANCE TO DISTURBANCE

Using Equation (10), many typical measurement scenarios may be analyzed. The input of a transmission line system contributes the first of many reflections, often the large transition from the VNA connector to the large transmission line. Though this may seem undesirable or otherwise annoying, it provides a convenient reference with which to measure the distance to other reflections.

Naturally, an extended run of transmission line precedes the antenna; therefore the reflection due to the antenna occurs a long distance from the system input. An example of the return loss of such an antenna system is shown in Fig. 4. The two reflection coefficients, representing the impedance mismatches at the input to the transmission line and the input to the antenna, were assumed to be 0.01, located 500 inches apart.

This measurement may be generalized and applied to any system composed of two reflections (e.g., mismatched components) separated by a significant distance. The "rippled" characteristic of the return loss may be used to deduce the distance, d, between the contributing reflections with the following relation,

$$d = \frac{(n-1)c v_f}{2(f_2 - f_1)} \qquad (11)$$

where n is the number of nulls across the band, f_1 and f_2 are the respective frequencies at which the first and last null occur, c is the speed of light and v_f is the velocity factor in the transmission line. Equation (11) simply follows from Equations (9) and (10). For convenience, the equation for the velocity factor is given as well:

$$v_f = \sqrt{1 - \left(\frac{f_c}{f}\right)^2} \qquad (12)$$

where f_c and f are the cutoff and operation frequencies respectively. Equation (12) is used in waveguide systems while the specified velocity factor is used in coax systems.

It must be noted that digital sampling at discrete frequencies across the band may produce a "ripple" in the measured data that may be interpreted erroneously as a reflection. Increasing the number of measurement points and decreasing the measured bandwidth will eliminate this

SEE MEASUREMENT, PAGE 14

Who's standing behind our consoles?

(A lot of guys who wish they had chairs.)

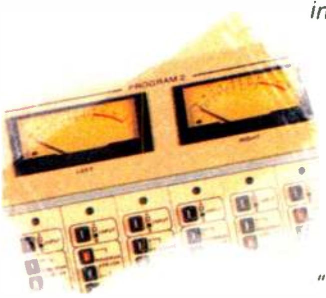
Experience matters

Now and again we're asked "You're a **division of Telos** — you are great at making phone systems and codecs. But what are your qualifications for building radio consoles?"

Fact is, we're uniquely qualified to do so, thanks to a brilliant R&D team whose experience in designing and building successful radio consoles spans decades. A team that's driven to create the most **useful, powerful, hardest-working** consoles in the world.

How It began

"20-odd years ago," says Axia President Michael "Catfish" Dosch, "I was designing custom consoles for recording studios. Somebody at **PR&E** liked what I was doing and invited me to move there. Work with Jack Williams, the guy who practically *invented* the modern radio console? I jumped at the chance; BMX consoles sounded great, and were very nearly indestructible!



"PR&E was a dream job. Jack taught me how to design consoles without compromise — how to **over-engineer** them. It's great to see, 15 or 20 years later, that many of the boards I designed are still on-air.

"By the late 1990s, computers and routing switchers were becoming an essential part of the broadcast studio, and I'd been thinking about how useful it would be to combine console, router, and computer network. I shared some of my ideas with Steve Church, who'd introduced digital phone hybrids and ISDN codecs to radio. He thought the same way I did about using computers in radio studios, and we decided to work together."

First Axia console prototype. Nice test stand, Catfish.

A new kind of console

"In 2003, we launched Axia to make digital consoles, but with a twist: Axia consoles would be integrated with the routing switcher, and **networked** to share resources and capabilities throughout the studio complex. This intelligent network of studio devices lets Axia build consoles that are **more powerful** and easier for talent to use than ever before."

Axia's team of engineers have blended the best ideas from old-school analog consoles with innovative new technology to produce **bullet-proof boards** that can actually make shows run smoother and sound better.

And we invented a way to network studios, consoles and audio equipment using Ethernet. It's called **Livewire**™, and it's now an industry standard. Livewire carries hundreds of channels of real-time, uncompressed audio plus synchronized control logic and program-associated data on one skinny CAT-6 cable. Thanks to this scalable network technology, **integrated router control** is a standard feature of every Element. Any source in any studio can be loaded on any fader with no need for add-on panels.

Feature packed

We designed Element to be user-friendly, yet have all the power of a full-on production board.

For example, Element **Show Profiles** let operators recall their favorite settings with the push of a button — audio sources, fader assignments, and personalized Mic Processing and Voice EQ settings (so the midday guy will stop badgering you for "just a little more low end").

Did we say **"mic processing"**? You bet. Every voice channel has studio-grade compression, de-essing and expansion from the **processing experts at Omnia,** plus three-band parametric EQ to sweeten the deal. Built-in headphone processing means you don't have to build a separate side-chain just for the studio cans.

Making a mix-minus the old-fashioned way is hard to do. So Element **constructs mix-minuses automatically**. And mix-minus settings are saved for each audio source, so sources, backfeed and machine logic all load at once. Plus, every fader has a "Talkback" key to **communicate with phone callers**, remote talent or other studios using the console mic.

Board-ops have enough distractions without having to reach for an outboard phone control panel. Element has **hybrid controls with dedicated faders** for Telos talkshow systems; jocks can dial, pick up, screen and drop calls without ever diverting their attention from the console.

The plastic module overlays used on most consoles crack and chip — especially around switches and fader slots, where fingers can easily get cut on the sharp, splintered edges. Element overlays are **inlaid on the machined aluminum module faces** to keep the edges from cracking and peeling — expensive to make, but worth it. **Custom bezels** around faders, switches and buttons also guard those edges. Element modules will **look great for years.**

Nearly every air talent has accidentally changed a fader's audio source while it was on-the-air. To prevent that error, **Element "queues" source changes**: the operator must turn the fader off before the next assigned source "takes".

More than just products

Catfish learned something else important from his time at PR&E: "Even the best products are nothing without **great support.**" So Axia has become radio's **first console company to offer 24/7 support**, 365 days a year. Chances are you'll never need that assistance, but if you do, we'll be ready for you. Our 'round-the-clock help line is +1-216-622-0247.

Proudly Over-Engineered

If you're looking for a cheap, disposable console, this isn't it. But if you're one who seeks out and appreciates excellence wherever you may find it... Axia consoles are built **just for you.**

AXIA
A TELOS COMPANY

www.AxiaAudio.com

Consoles

Measurement

CONTINUED FROM PAGE 12

error and possibly reveal a contributing reflection from a great distance away.

FAULT LOCATION

Similar measurement techniques may be applied to RF systems to pinpoint reflection problems. Though the plots become more complicated, the location of multiple reflection points can be deduced by noting the nulls and applying Equation (11). The minima with a small separation in frequency correspond to a reflection that is far away while those with a large separation are closer together. Minding the characteristics of the nulls and employing Equations (11) and (12), the locations of the multiple reflections may be computed. The return loss predicted by Equation (10) is shown in Fig. 5 for a three-component system: reflection 1: 0 feet, reflection 2: 194.7 feet, and reflection 3: 1220.8 feet.

The interference of the first and second reflections creates the nulls at 531.3 MHz, 532.9 MHz and 534.7 MHz — the nulls that look like nodes in an AM modulated signal. The interference of the first and third reflection causes the nulls that occur every 0.3 MHz. The frequencies and number of nulls may be used in Equation 11 to determine the locations.

The concepts outlined above aid in the practical location of reflections caused by poor connectors, transmission line obstructions, elbows and damaged components. Improvement of such reflections must be carried out by repair/replacement of the deficient component or compensating individual line components with tuners (e.g., UHF elbows). Extending this technique to its ultimate end leads to the time domain tools in the VNA.

TUNING AND BANDWIDTH

Component reflections are complex quantities. A design criteria relating to the magnitude has been developed above, and one concerning the phase may be developed. Because the magnitude of the total reflection given in Equation (10) depends on the distance between components, the spacing of components may be designed to minimize the total reflection. For a narrow-band application, like a single-channel system, the phase relationship reflections separated by large distances may be exploited to tune the system.

In a transmission line system, this requires that the section lengths be varied along the total length of the line according to the patented method used in ERI WIDELine transmission line [5]. Essentially the spacing of support insulators and bullet interconnects is varied by a half-wavelength along the full transmission line length, making the last stick a half-wavelength shorter than the first.

Many 6 and 12 MHz TV broadcast systems as well as single- or multi-channel FM broadcast systems are successfully designed with the application of a "fine-tuner" section. These sections are a short length of transmission line with a number of capacitive probes spaced along its length. The addition of these tuner sections allows the narrow-band optimization of the total system reflection. Similar narrow-band tuning is accomplished by the addition of capacitive rings or "slugs" at select locations along the line. Neither of these methods will result in a broadband minimization of reflection because the reactance of a shunt capacitor is directly proportional to frequency.

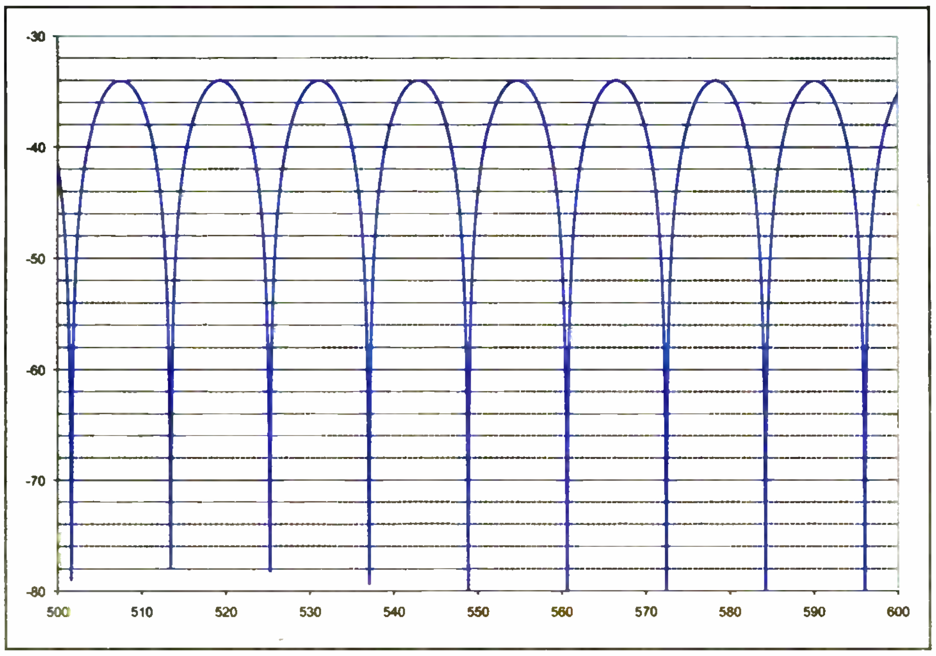


Fig. 4: The Sum of Two Reflections

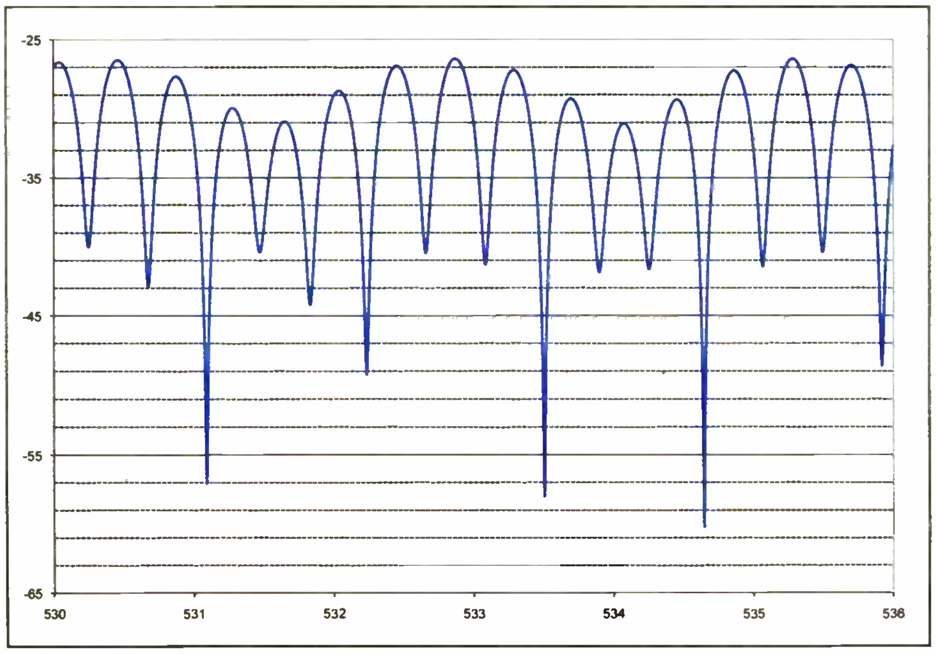


Fig. 5: Predicted Return Loss of the System

TDT TECHNIQUE

The design principles established in the previous sections have highlighted the important contribution of small reflections to the total system reflection. Designing components with return loss performance better than 60 dB presents a challenge to conventional laboratory techniques because this is on the order of the reflections caused by cables and transitions to large broadcast transmission lines. If the reflections from the test transitions add with the device under test, very large errors result. Through the use of a VNA and time domain transform (TDT) analysis, the components may be accurately characterized.

Components in a broadcast transmission system require transitions from large coaxial transmission lines to small standard connectors on the VNA (typically type-N or 7 mm connectors). Such transitions often are narrow-band components tuned by using narrow-band techniques discussed above. As such, the reflections caused by the transitions are typically much higher than the 60 dB reflections demanded from the broadband components. Overcoming this limitation requires the use of TDT analysis.

The reflection measurements of the VNA are performed in the frequency domain. The VNA contains vector voltage detectors and a synthesized, swept frequency source. Frequency domain data are transformed to the time domain using a Chirp-Z transform, a numerically efficient generalization of the discrete time Fourier transform (DTFT). The data may be digitally filtered in the time domain by using "gating" and inverse-transformed back to the frequency domain. Such gates may be positioned in the time domain to remove the troublesome reflections from the test adaptors. Gating may also be applied to filter the TDT data to eliminate all reflections in a system but those of interest, focusing the measurement on a particular component.

The swept bandwidth, or frequency span, affects the range and resolution in the time domain. The range (in seconds) is the largest value of time computed in the transform and is related to the number of data points and the swept bandwidth by the following equation:

$$range = \frac{N_P - 1}{BW} \qquad (13)$$

where BW is the swept bandwidth in Hz, and N_p is the number of points. The time range may be converted to distance by multiplying by the speed of light (approx. 1 ft/ns). This range is the round-trip time of the reflected wave and must be halved to relate to the physical distance.

The resolution, in seconds, of the TDT data is given by

$$resolution = \frac{1.92}{BW} \qquad (14)$$

where the 1.92 constant represents a bandpass transform by using a normal window and ranges from 0.45 to 2.88, depending on the VNA window and transform settings. Note that the resolution is not dependent on the number of points and may be converted to distance in the same manner as the range.

In the laboratory, the range is typically not a problem and the bandwidth is set solely based on the desired resolution. The range may become a factor in field measurements of transmission systems mounted atop tall towers. Measuring the reflections from an antenna atop a 2,000-foot tower needs a range of 4 µs, which requires a bandwidth of 196.7 MHz with 801 points. A measurement that sweeps greater than this bandwidth will reduce the range and not allow TDT data manipulation of items outside the range of the transform. The corresponding resolution at this bandwidth is 4.8 feet, which can only be improved by increasing the bandwidth. By increasing the number of points to 1,601 (at the expense of measurement time), the range may be doubled to 4,000 feet. Alternately, the bandwidth may be doubled, maintaining the 2,000 feet range and improving the resolution to 2.4 feet. Table 2 contains a number of useful range and resolution relations.

BW (MHz)	Npoints	Range (ns)	Range (ft)	Resolution (ns)	Resolution (ft)
6	1601	133333	131136	160	157
6	801	66667	65568	160	157
12	1601	66667	65568	80	79
25	1601	32000	31473	38	38
100	1601	8000	7868	10	9
300	1601	2667	2623	3	3
1000	1601	800	787	1	1

Table 2: TDT Range and Resolution

FILTERS, COMBINERS AND RF COMPONENTS

The RF components in the transmitter room are the most readily available for measurement. The transmitter often requires a mask filter to eliminate off-channel harmonics and spurious emissions, and notch filters are included when a specific modulation product must be eliminated. Filters are specified and measured by their insertion-loss and return-loss over the channel.

Channel combiners also involve filters, and have multiple narrow-band inputs and often a single broadband output. The filters reduce the cross-coupling from one channel to another, and the filter isolation along with the on-channel return-loss is specified. The insertion-loss of each channel input to the output is also a key parameter of the combiner.

Power combiners — used to combine the output of multiple transmitters — are essentially the application of a RF hybrid circuit. The hybrid has at minimum four ports. In the case of power combining, two ports are inputs, one the combined output and one the isolated port containing a dummy load. The transmitters are phased appropriately so that the two are combined in phase at the output of the hybrid circuit. The channel return loss and coupling to the isolated port are key parameters in a hybrid circuit.

Other components that route and switch the RF transmission through the transmitter building are specified by their return loss.

If a high VSWR exists in a section of

SEE MEASUREMENT, PAGE 16

by Charles S. "Buc" Fitch

The Case of the Mysterious Circuit Breaker

Question posed in the last issue
(Exam level: CBRE)

You have installed a new solid-state transmitter in place of your old tube rig using the same power connections. On cold start the supply panel circuit breaker (CB) trips but if you reset the CB fast enough and restart, the rig will run without a trip. What is the most likely cause?

a. When running, solid-state transmitters intrinsically consume more current then comparable tube rigs.
b. You have reversed the phase and neutral wires.
c. The current inrush caused by the highly reactive input of switching power supplies used in most solid-state transmitters exceeds the current "trip curve" of the circuit breaker.
d. You have forgotten to install utility power line surge protection.
e. You cannot start up a solid-state transmitter with modulation applied.

SBE certification is the emblem of professionalism in broadcast engineering. To help you get in the certification exam taking frame of mind Radio World Engineering Extra poses a typical question in every issue. Although similar in style and content to the exam questions, these are not from past exams nor will they be on future exams in this exact form.

The SBE Certification program exams test you on both scholarly knowledge (information gleaned from schooling, text or article sources — essentially secondhand information) and practical personal experience that you are expected to develop as you grow in the industry (firsthand information). The above question falls into both of these categories and is drawn from my own experience.

The answer to the question in the box is **c**.

First, let's eliminate the other four answer choices listed.

Regarding answer **a**, recent solid-state transmitters with their Class D and E amplification schemes make them notably more efficient than older traditional plate-modulated tube rigs. Tube rigs additionally have a need to power filaments and larger blowers, which when added to IR loses in a plethora of transformer cores run up the power requirements. Solid-state transmitters generally are *more* efficient than tube types.

Considering **b**, if you had reversed a phase and neutral wire in a 240-volt single phase or multiphase transmitter, the breaker would trip immediately. If any sort of connection exists between the transmitter's power phase connection points and ground, it will short the AC power. If all of the neutral connections are ground-isolated inside the transmitter, you would notice as soon as power was applied, as the control logic and probably the LED or screen displays were in trouble. It's not likely that you would be able to even move the rig into transmit mode.

The surge suppressors noted in choice **d** are actually *voltage* suppressors. The ubiquitous ordinary circuit breakers that most of us encounter do not trip on a voltage surge as they are designed to sense overcurrent only, so the lack of surge suppression is not the answer. Surge suppressers are invaluable to protect your station's investment in equipment but are not part of the over-current protection picture.

Selection **e** can be eliminated as all professional broadcast transmitters are designed to start up with a program signal input at normal modulation.

POWER UP

So what is happening here? A tube transmitter soft-starts by turning on necessary low-level stages, such as the blowers, filaments, supply voltage to oscillator and drivers, etc. After warm-up, another near equal surge of power is called for to power the final RF and modulation sections. Almost without exception, the high-voltage plate and screen supplies are transformer type using reactor (inductor) filter inputs that limit the current surges. The original circuit breaker could handle these incremental increases easily.

Conversely, a solid-state transmitter requires little control and/or standby current and most of the power is demanded when the transmitter begins to put out its required power output. In this particular instance, the transmitter was populated with switching power supplies that on cold start need a lot of current to "charge up" the input filter capacitors and the switching inductor. This big surge tripped the circuit breaker.

Why was it possible quickly to reset the circuit breaker and keep it running? It takes a finite amount of time for these power supply circuit elements to discharge. With quick action, we were able to reset the breaker, and with the lower "run" current demand were able to sustain operation.

You can see we have a different current demand pattern in these solid-state rigs. The tube rig circuit breaker was a standard model and its "fuse curve" (the graph characteristic of how it responds to current overloads) was flat. When the current reached the rated trip point, it tripped.

As a side note, in this particular instance, we changed the circuit breaker to an HACRS type. This acronym stands for Heating and Air Conditioning Rated Service. This type of circuit breaker is designed to ignore the first surge of current needed by HVAC systems to start motors under load and power up cold resistive heating elements. This new circuit breaker ignored the short current demand precipitated by those reactive components in the solid-state rig, after which it provided appropriate current protection for this new transmitter and the conductors that supplied power to it.

Reactive power loads (equipment that has capacitors and inductors as part of the load) are not unique to transmitters, and the nature of these components is that they have currents charging and discharging from them while they are in normal use. If you remember your AC theory, keep in mind that reactive currents are not consumed, only stored. Once discharged, they are returned to the generator.

So we have two values of power to be concerned with: the real power consumed in the functioning of the equipment, and the apparent power, which is the combination of the real power and those non-consumed charging currents. The real power is

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Measurement

CONTINUED FROM PAGE 14

transmission line at high power it is possible to feel hot spots at points along the component. These hot spots will occur every half-wavelength along the line. It is possible to have a short length of transmission line with high VSWR having low VSWR sections immediately before and after.

A vector network analyzer is also equipped to measure insertion loss. This allows the measurement of power arriving at other ports, much like the return loss is a measure of the power reflected back toward the input port. To measure the insertion loss of a filter, for example, the RF source of the VNA is attached to the broadband input and the output is connected to a second detector on the VNA and displayed. The quantity of power arriving at the output and the amount of power reflected from the input will add up to the amount of power produced by the VNA (minus small conductor losses).

TRANSMISSION LINES

Transmission lines may be rigid coax, coaxial cable or single-conductor waveguide. Transmission lines are, by nature, distributed and broadband devices. However, the periodic insulators in rigid line limit the useable frequencies because the reflections of hundreds of insulators add constructively at some frequencies. This fact gives rise to the various standard lengths of rigid line used for different channels.

The key RF parameter for transmission line is the return loss, and typically the insertion loss is computed from attenuation data. The return loss may be easily measured after installation. TDT techniques may be employed to isolate the transmission line reflections from the other components.

Some components in transmission line systems are not broadband, particularly the elbows, gas barriers and fine matchers. Reflections from these items may be isolated by TDT gating.

Another common measurement that must be performed at the transmitter site is the relative phase length of multiple transmission lines feeding an antenna. For power capacity or system redundancy, an antenna may be fed with two or more transmission lines. The relative phase length of these lines is critical in creating the antenna radiation pattern, and their length must be measured and adjusted upon installation. The electrical length may be measured by placing a terminating short (or open) circuit at the junction with the antenna input. The reflection over a significant bandwidth must be measured, computing the electrical length from the phase of the reflection for each line. The line lengths are adjusted to set the necessary phase difference.

ANTENNAS

The RF parameters of an antenna may be measured, and are often monitored with the transmitter instrumentation in conjunction with the other components in the transmission system. The antenna manufacturer measures the VSWR, patterns and gain of the antenna alone. Once installed, characterization of the antenna VSWR is difficult to separate from the other system components. This may be accomplished using time-domain transform techniques, discussed above.

Measuring the antenna VSWR after installation must be performed with a VNA. The time-domain techniques described above may be used to isolate the antenna from other system components. Antennas terminate the RF system, and care must be taken to set the measurement bandwidth and number of points so that the range and resolution of the time-domain data include the antenna. Often transmission line elbows are positioned very near the antenna and cannot be gated out of the reflection measurement.

RF measurements, in particular the measurement of reflections in a transmission system, are often outside the priorities of a broadcast engineer. The measurements are also a bit mysterious and are confined to the display of VSWR at the transmitter. Knowing how to pinpoint damaged components can be useful in an off-air crisis, and performing annual measurements of system return loss can be part of a proactive maintenance schedule. Affordable VNA equipment is now available covering the broadcast bands, and station engineers can measure and monitor their own transmission facility confidently.

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Interference

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combining require significantly larger transmitters. When (and if) higher IBOC power levels are authorized, we should expect that many stations will choose dual antennas. However, broadcasters who choose to use dual antennas should carefully evaluate the extent of host interference that their primary analog service may receive.

A case study in host interference was presented by Mike Hendrickson of Minnesota Public Radio's KNOW(FM) in the Oct. 17, 2007 issue of Radio World Engineering Extra. KNOW(FM)'s 10-bay antenna is located on a tower in a highly populated urban area of Minneapolis. It was cost-effective for MPR to use its single-bay auxiliary antenna that was already on the tower. This antenna met the FCC's minimum separation standard by having a radiation center that was within 77 percent of the KNOW(FM) analog antenna. The 10-bay and one-bay vertical elevation field graphs for these antennas are shown in Fig. 1.

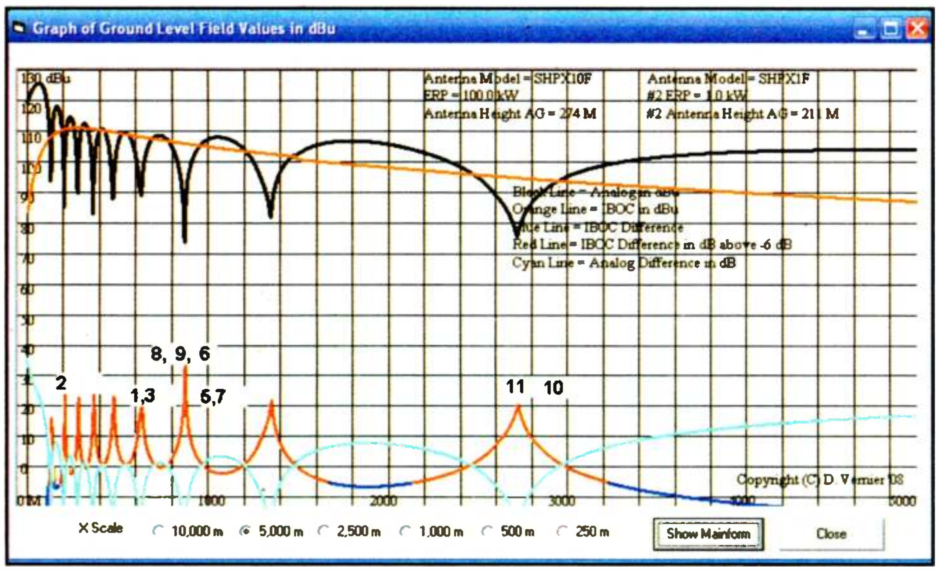

Fig. 3: Graph showing KNOW(FM)'s predicted self-interference zones in red using a separate 10-bay analog antenna with a one-bay digital antenna operating at –20 dBc.

Unfortunately, when MPR turned on IBOC at the authorized –20 dBc power level, they began receiving numerous listener complaints. They carefully documented the location of the complaints, plotted and numbered on the map in Fig. 2. The interference was reported to be quite severe, as listeners in these locations complained about a complete loss of KNOW(FM)'s analog modulation.

The interference locations fell roughly in the nulls of KNOW(FM)'s 10-bay analog antenna. MPR's documentation provides us with the opportunity to calculate the average desired to undesired (D/U) ratio level, which results in interference, and to extrapolate the results to other combinations of antenna bays and radiation centers. After logging the initial listener complaints, MPR engineers shut down the one-bay IBOC antenna system and replaced it with a high-level combined system, thereby solving all the complaints at once.

PREDICTED SELF-INTERFERENCE

To look at why interference occurred at these locations, a computer program was built to plot and compare the KNOW(FM) analog and digital signal strength in dBu from the tower base out to 5,000 meters (3.1 miles).

This program loads the vertical elevation field files for the 10-bay analog and the one-bay IBOC antenna and uses basic trigonometry to determine the distance and angle from the antennas on the tower to various locations on the ground. With this information we can determine the radiated power at the calculated angle (ERP {at angle} = Vertical Elevation Field {at angle} squared times the antenna's maximum ERP). By using the FCC curves we can then determine actual signal strengths at the listener's position.

Fig. 3 shows the interference location points along a horizontal scale of distance and a vertical scale of signal in dBu. The analog signal is plotted in black, while the digital signal is in orange. At the bottom of the graph are difference plots between the black and orange lines. The light blue line shows the difference in dB of the analog signal strength compared to the IBOC signal strength. The other graph line, which starts off as dark blue, is the inversion of the light blue line, however this line turns red when the digital signal fails to be at least 6 dB below the analog signal, a condition which indicates potential interference to the hosting station.

The 6 dB value was chosen because the FCC has established a D/U protection ratio of at least 6 dB for first-adjacent station relationships. This value works well for our predictions, because the numbered interference complaint locations fall nicely on or near the red line peaks where the IBOC exceeds the analog signal by –6 dB or greater. The lighter blue line is the difference in dB between the analog carrier and the digital carrier.

While the 11 listener complaint sampling is small, and certain radios are better than others at rejecting first-adjacent interference, nevertheless there is good agreement between the alignment of the interference complaints and the peaks of the red IBOC difference signal. With this information in hand, we were able to predict the location of the host interference with other configurations.

The Fig. 3 graph was made when KNOW(FM) was transmitting IBOC at –20 dBc. To determine what the interference would be at –10 dBc, we ran the program with 10 kW IBOC vs. 100 kW analog. The antenna heights above ground remained the same at 211 meters for the IBOC antenna and 274 meters for the analog antenna. Fig. 4 shows the results.

Notice that the red graph line shows interference to the host from the IBOC sidebands from 60 meters to 5,000 meters from the tower base. At some points, the IBOC carrier exceeds the analog carrier by more than 30 dB with one point exceeding 40 dB. This would clearly be a bad situation for any station having a transmitter in an urban area.

We investigated whether it would help to move the antenna centers close together by interleaving a two-bay IBOC antenna with the 10-bay analog. The graph in Fig. 5 shows what this would look like at a –10 dBc IBOC power level. Not a pretty picture, but the interference area is reduced by nearly one-half as it travels out to approximately 2,600 meters. Having more IBOC bays to match the 10-bay analog antenna and providing a common center of radiation clearly helps the situation.

However, it appears that even an interleaved antenna will cause substantial host interference when only two IBOC bays are used. Fig. 6 shows the results if we double

SEE INTERFERENCE, PAGE 20

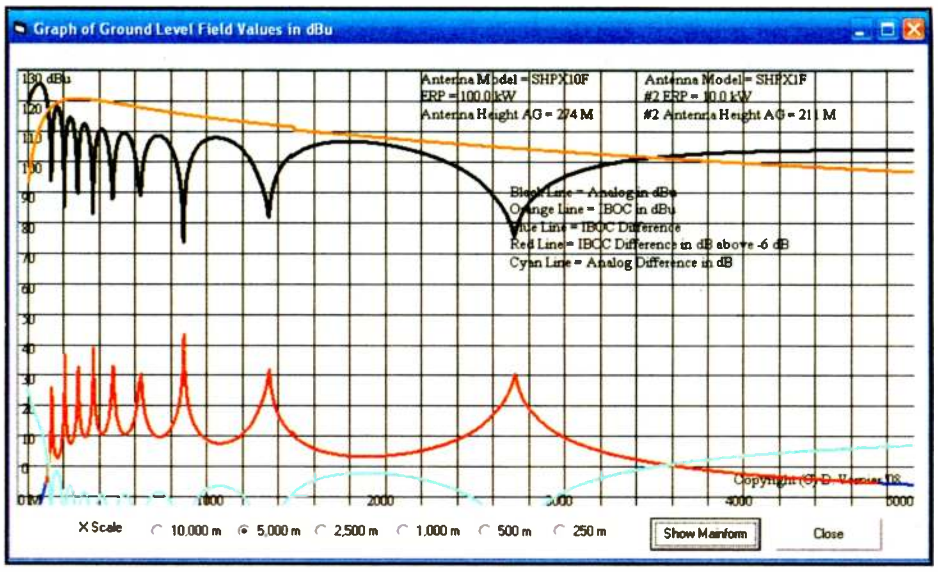

Fig. 4: Graph showing KNOW(FM)'s predicted self-interference zones in red using a separate 10-bay analog antenna with a one-bay digital antenna operating at –10 dBc

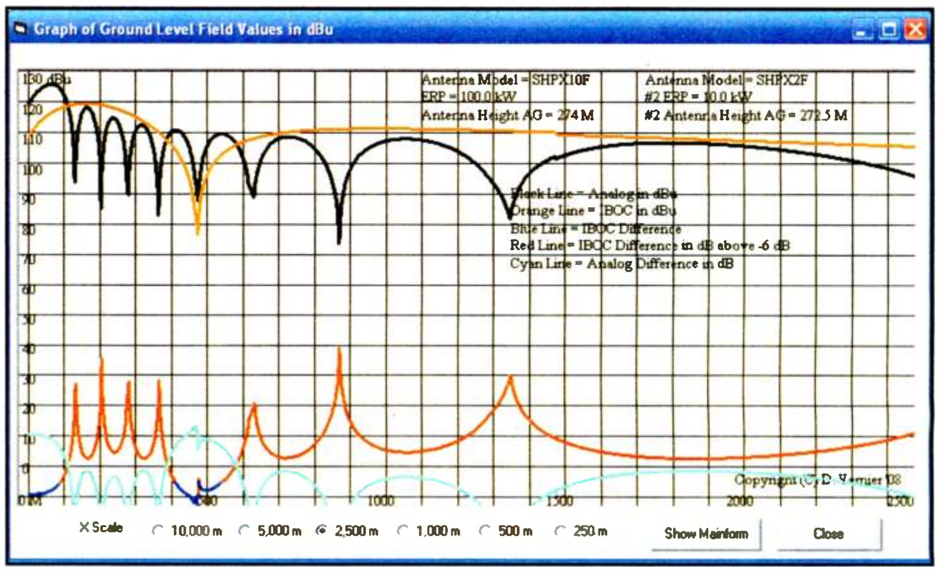

Fig. 5: Graph showing KNOW(FM)'s predicted self-interference zones in red using an 10-bay analog antenna interleaved with a two-bay analog antenna operating at –10 dBc

Circuit

CONTINUED FROM PAGE 16

listed as VA (volt amps) and the reactive as VAR (volt amps reactive).

Power factor is the real power divided by the real power plus reactive charging currents. Most often we see this expressed as a percentage, such that a 97 kW real load divided by a 100 kW real plus reactive demand would have a power factor of 97/100 or 97 percent.

As a final thought, even though the reactive power is not consumed and is returned to the generator, this power must first be generated! So the power company wants to be paid for the extra generation needed for high power factor consumers and the larger lines to deliver that power to the customer. They collect this extra cost from the consumer by having utility meters measure the actual power consumed and the peak demand. Actual consumption is billed as one rate and demand at a penalty rate usually at some dollar figure per kW of peak demand. Part of that demand is the reactive power. American industry has made a major effort to lower demand including mitigation of reactive power to reduce the demand factor.

Don't forget, the deadline for signing up for the next cycle of SBE certification exams is April 1 for testing that will be given on April 21 at the NAB convention in Las Vegas.

★ ★ ★

A CBRE question for April: *Your standard broadcast station is authorized 25 kW non-directional day and 1 kW with a highly directional signal at night. At nighttime pattern changing time, the remote control cannot effect the change or reduce power. How long do you have to correct this problem before you must cease radiating?*

a. 3 days

b. 3 hours

c. 3 minutes

d. The length of time it takes to drive to the transmitter

e. As long as it takes, provided you make notes of the corrective actions you've taken in the station log.

Buc Fitch, P.E., CPBE, AMD, is a frequent contributor to Radio World. ■


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Interference

CONTINUED FROM PAGE 18

the number of bays to four with an interleaved antenna at –10 dBc IBOC injection.

The interference area is from the tower base to approximately 1,950 meters, only a small improvement. Some interference has been removed in several places, including from 590 meters to 1,100 meters from the tower base.

For comparison purposes, let us return to the use of separate antennas with a 10-bay at 274 meters and a four-bay antenna at 211 meters above ground (see Fig. 7). As you would expect, this arrangement does not look very good.

What about adding more bays to the IBOC antenna? In Fig. 8 we look at a dual antenna with a six-bay IBOC and a 10-bay host antenna. This arrangement also looks pretty bad.

RATIOS IN MOTION

We can predict IBOC interference in another way. The map in Fig. 9 was created using the V-Soft Communications' Probe 3 software. The FCC signal prediction method was selected. The KNOW(FM) 10-bay analog vertical elevation field pattern was loaded into the computer with the IBOC one-bay antenna pattern. The antennas were located vertically on the tower using the original KNOW(FM) heights. The digital antenna was within the FCC's 70

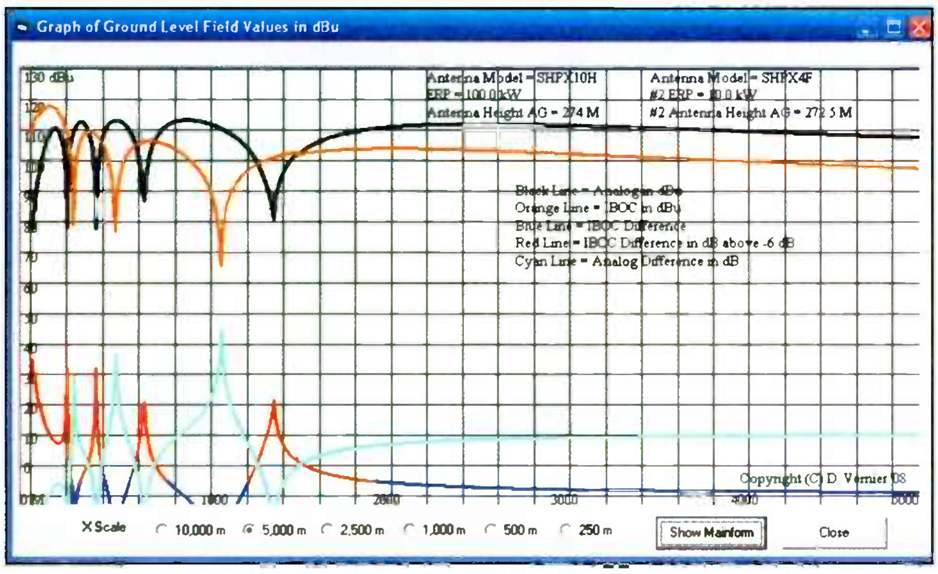

Fig. 6: Graph showing KNOW(FM)'s predicted self-interference zones in red using a 10-bay analog antenna interleaved with a four-bay digital antenna operating at –10 dBc

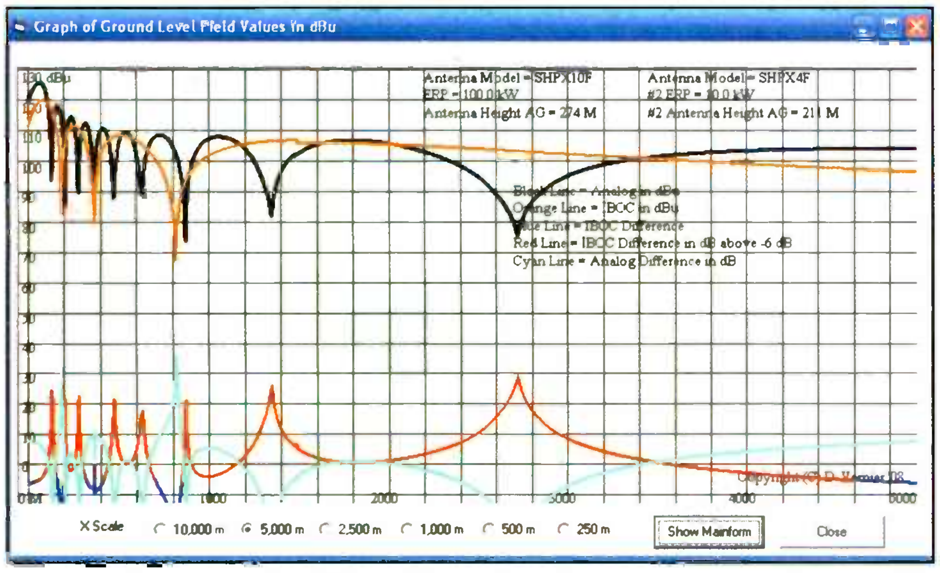

Fig. 7: Graph showing KNOW(FM)'s predicted self-interference zones in red using a separate 10-bay analog antenna with a four-bay digital antenna operating at –10 dBc

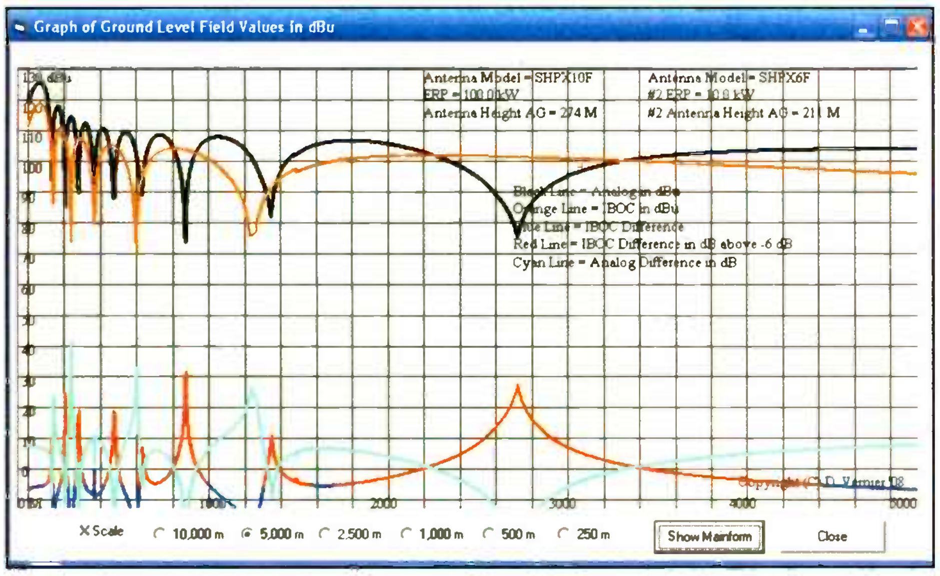

Fig. 8: Graph showing KNOW(FM)'s predicted self-interference zones in red using a separate 10-bay analog antenna with a six-bay digital antenna operating at –10 dBc

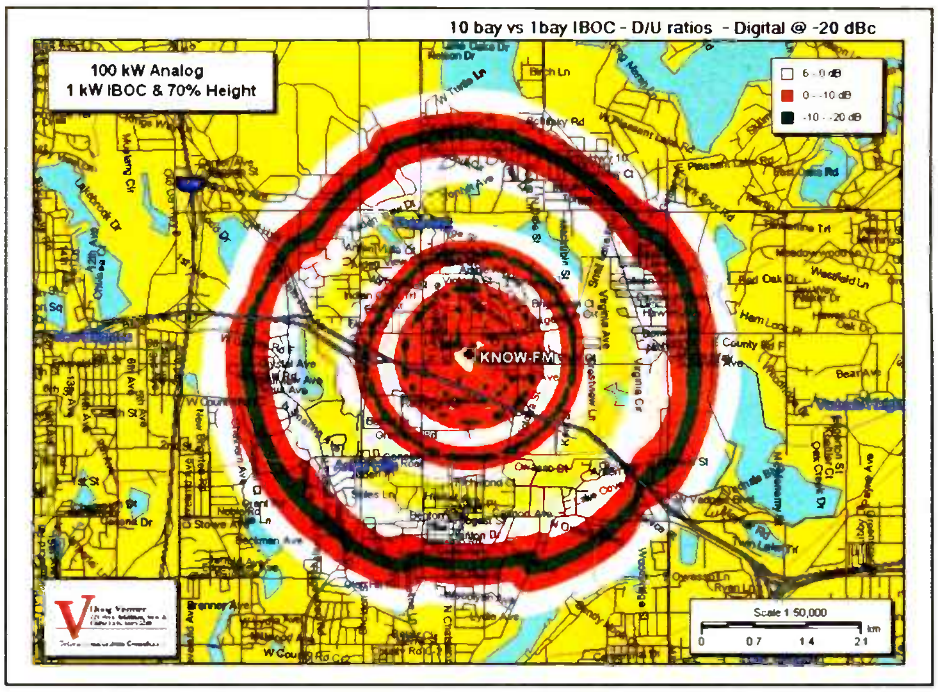

Fig. 9: Map showing KNOW(FM)'s predicted self-interference zones in green, red and white color bands using a separate 10-bay analog antenna with a one-bay digital antenna operating at –20 dBc.

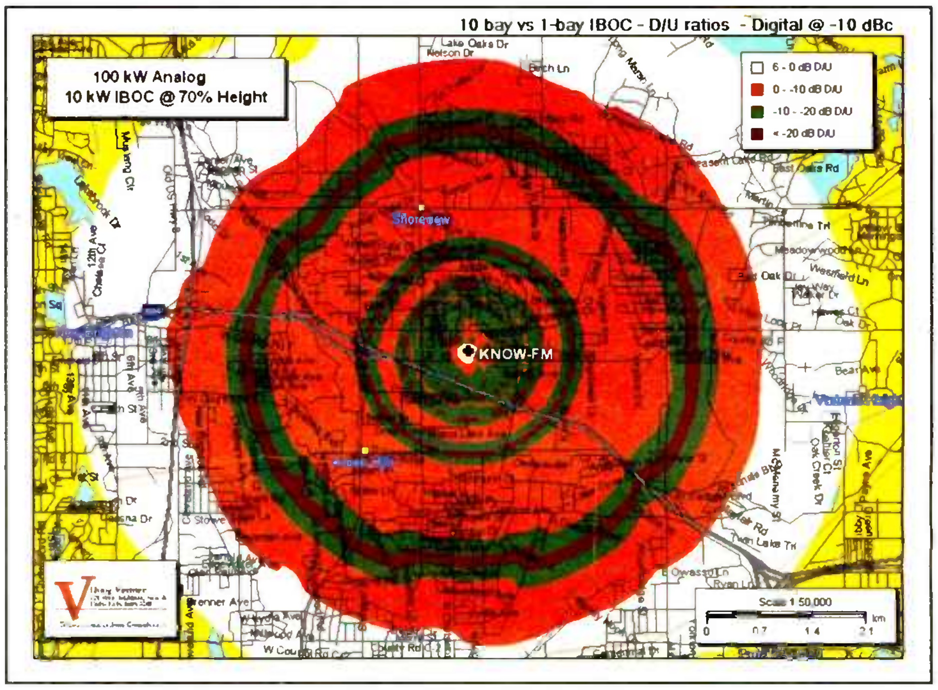

Fig. 10: Map showing KNOW(FM)'s predicted self-interference zones in brown, green, red and white color bands using a separate 10-bay analog antenna with a one-bay digital antenna operating at –10 dBc.

percent requirement. The IBOC injection level was set at –20 dBc.

We told the program to create color bands representing an analog to IBOC D/U ratio which was to be 6 dB or less. The green bands show up when the analog signal level is 20 dB or more below the digital signal, indicating severe interference. The red bands represent locations where the analog signal is between 10 dB below and 20 dB below the digital signal. The white bands represent locations where the analog signal is between 10 dB below and 6 dB above the digital signal. The yellow color is the city boundary background and can be ignored.

As you can see from the Fig. 9 map, the interference bands at the current –20 dBc power level extend out to a radius of approximately 3.5 kilometers from the tower site.

The map in Fig.10 shows the interference area at –10 dBc operation, and it uses the same scale as the –20 dBc map in Fig. 8. Clearly, the host interference at an elevated power level of –10 dBc is unacceptable. The map in Fig. 11 plots the interference area with a 10-bay analog and a four-bay digital antenna for comparison. The antenna heights are the same, offset by 63 meters, but the IBOC power is reduced to –20 dBc.

Finally, the map in Fig. 12 shows the 10-bay antenna with a four-bay IBOC antenna at the KNOW(FM) original height with an IBOC power level of –10 dBc.

OTHER FACTORS

Any time an antenna is side-mounted on a tower, the tower itself causes a distortion of the pattern. Generally, the vertical steel elements absorb the vertically radiated signal in the azimuth going through the tower but reflect it in the opposite direction. The same can occur for the horizontal polarization but to a lesser extent. This is why engineers almost uniformly mount an antenna on the side of the tower favoring the community of service. If dual antennas are used, they should both be mounted in an identical manner and occupy the same side of the tower. Another problem can occur when the IBOC antenna is mounted at a point where the tower face size differs from the analog mounting location, such as in a tapered tower.

In this article, we have not examined the impact of dual antennas having a different horizontal center. While the FCC allows a difference of up to 3 seconds (about 300 feet) if the antennas are installed in this

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Interference

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manner, it changes the angle to and the ground location of the nulls in respect to the analog antenna. This is a further departure from an identical mounting and a common center for the antennas which, as we have observed, helps to prevent interference to the host station. This type of an installation for an IBOC transmitter is perhaps the least attractive of all.

RECEIVER NOISE TO SIGNAL PERFORMANCE

As mentioned, the results of these studies are tempered by the specific interference rejection characteristics of each receiver. There have been few studies of analog receivers to determine exactly how they perform when the host station transmits IBOC. To gain more information about this effect, NPR Labs recently studied the Sony DTR-DE197 component receiver. This receiver should be somewhat representative of the higher-end component receivers available on the market.

The graph in Fig. 13 shows the results of their study. This graph plots the weighted quasi-peak signal-to-noise ratio (WQPSNR) against the IBOC power level. Three receiver signal strengths were plotted as represented by the green, red and blue lines. At an IBOC power level of –20 dBc, with signal strength of –40 dBm at the receiver terminals (green line), the WQPSNR for this receiver is 52 dB. This combination best represents a signal relatively close to the transmitting site. It is approximately the signal strength that would be seen by a radio receiver using an outdoor dipole antenna at field strengths of around 70 dBu.

In its "Digital Radio Coverage and Interference" study, NPR Labs used 40 dB WQPSNR as the point where subject listeners reported that "good" reception was lost. The graph shows that at a digital injection of –14 dBc, the WQPSNR drops to 44 dB. At –10 dBc, the WQPSNR drops to 37 dB, an unacceptable level for this signal strength, indicating the receiver performance is degrading as the digital injection increases to a full 10 percent.

However, at the weaker signal levels of –50 dBm and –60 dBm, represented by the red and blue graph lines, the signal-to-noise ratio at –10 dBc deteriorates by a smaller amount to 42 dB and 45 dB respectively. This indicates that the Sony receiver's ability to reject higher levels of IBOC power is improved as the combined signal strength is reduced in the far field. While the Sony radio is one of the better radios on the market, its signal-to-noise ratio was reduced by 15 dB at the –10 dBc power level. For those FM radios that do not meet Sony's better specifications, the self-interference may degrade the signal even further.

It should be noted that the NPR measurements were performed in the lab and they did not consider Raleigh fading or multipath, which could further deteriorate the signal-to-noise ratio and relative strength between the digital and analog carriers.

These results indicate that increasing the IBOC power level inevitably puts more noise in an analog receiver. While the receiver studied is only one of many, it should be somewhat representative of other higher-end receivers in its class. Such receivers are usually better able to reject interference, unlike less expensive models. NPR Labs Senior Engineering Technologist John Kean reports that NPR plans to study many more receivers in the future.

CONCLUSION

By using existing data from the KNOW(FM) experience, we can predict the location of host interference. Dual antennas with differing centers and numbers of bays will not avoid this interference. For digital operation at –10 dBc, the host interference can be widespread. Interleaved antennas perform better, yet interference cannot be completely avoided without using the same number of bays. NPR's receiver study indicates that a higher-end component receiver will see its signal-to-noise ratio degraded more at higher combined signal strengths than at lower levels. Stations, particularly those in urban areas, need to be critically aware of the looming dangers in the path to elevated IBOC power.

Comment on this or any story. Write to radioworld@nbmedia.com with "Letter to the Editor" in the subject line. ■

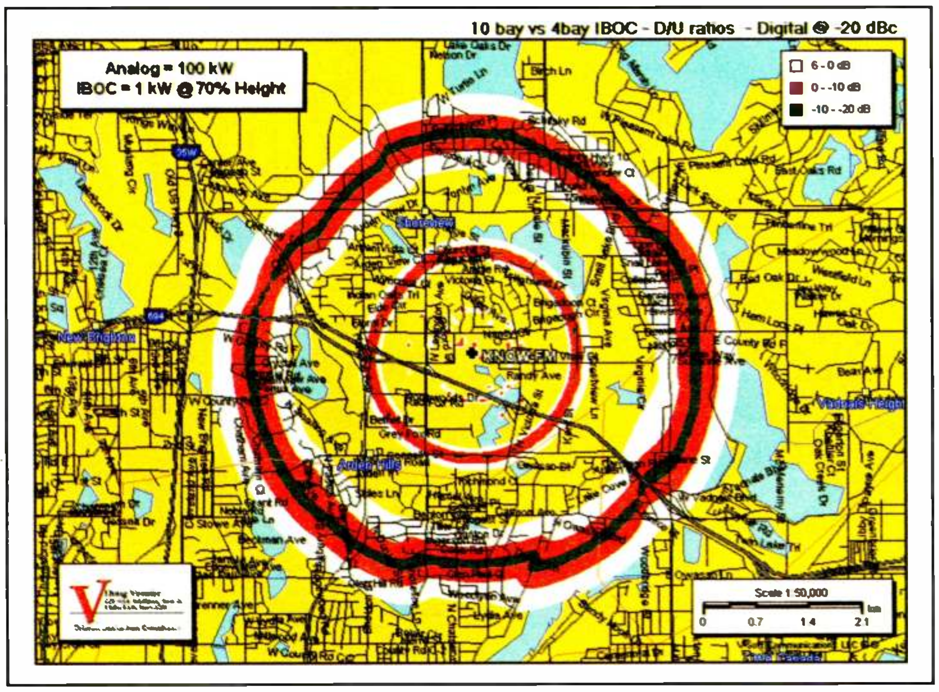

Fig. 11: Map showing KNOW(FM)'s predicted self-interference zones in green, red and white color bands using a separate 10-bay analog antenna with a four-bay digital antenna operating at –20 dBc.

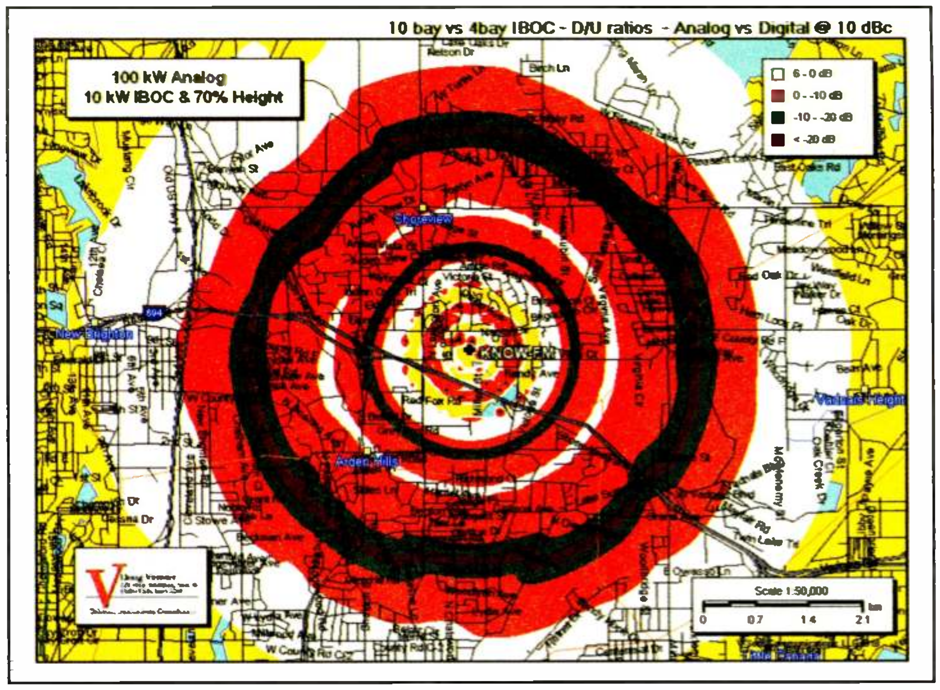

Fig. 12: Map showing KNOW(FM)'s predicted self-interference zones in green, red and white color bands using a separate 10-bay analog antenna with a four-bay digital antenna operating at –10 dBc.

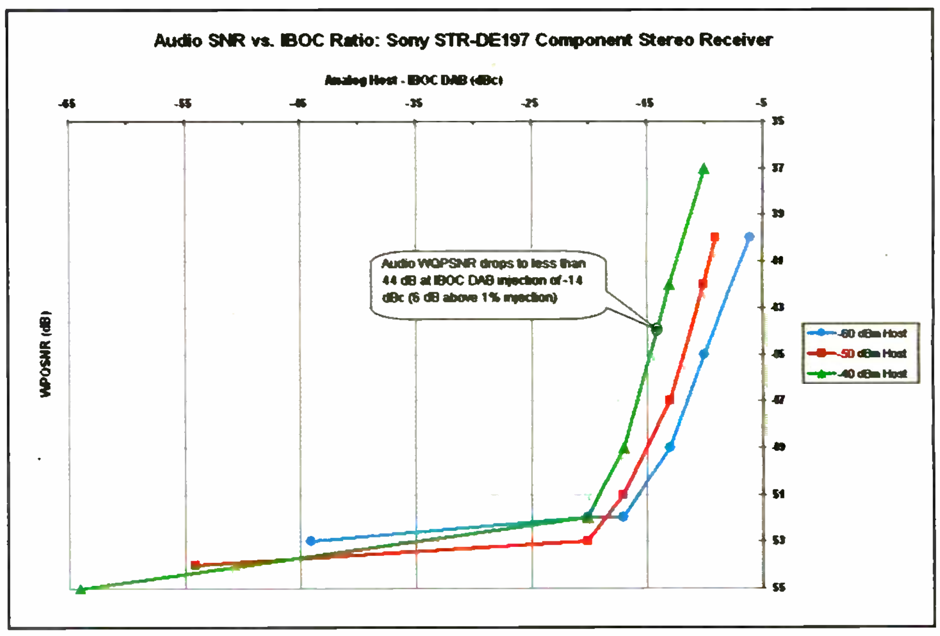

Fig. 13: Audio signal-to-noise deteriorates as the IBOC power level increases.

by Dave Moulton

Thinking About Loudness, JJ's Way

JJ? Who's JJ? JJ is James D. Johnston, one of the major players in codec development and psychoacoustic research, with a distinguished career at Bell Labs, AT&T Labs Research, Microsoft and, currently, at Neural Audio. Naturally, as such a researcher, he has investigated the phenomenon called loudness with a thoroughness, rigor and care that is way, way beyond what us general practitioners settle for in our limited quests for truth and understanding.

As I've repeatedly discussed in these columns, in broadcast we have a real problem managing the level of sound, and in my simplistic journalistic way, I've referred to that problem as a problem with audio levels. My whining finally came to the attention of the good people at Neural Audio, and they put me in touch with JJ for some regrooving. As JJ promptly pointed out to me, loudness is not necessarily the same as audio levels, and this is particularly so in the extremely common case where we use signal processing, particularly, ah, compression.

So, campers, it is time to reboot, and think about this a little more carefully, JJ's way.

THE NATURE OF LOUDNESS

Loudness is a subjective sensation related to, but not the same as, the magnitude of sound pressure level at our ears. We perceive loudness in a way somewhat similar to our

SEE LOUDNESS, PAGE 25

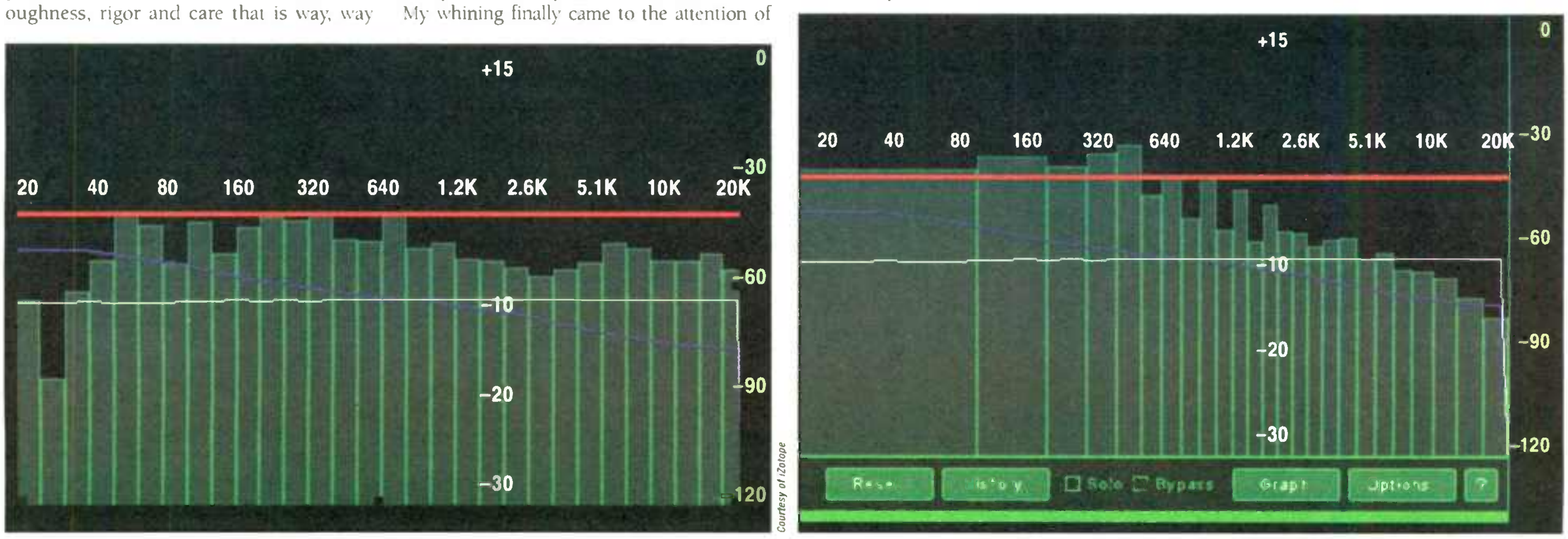

Fig. 1: The audible spectrum seen in 1/3 octave bands (the vertical green bars). Another audible spectrum (R) seen in critical bands (the vertical green bars).

by James E. O'Neal

SolderBuddy Lends You a Hand

Good things do come in small packages, and I'm not speaking today of a box bearing a Tiffany & Co. label and containing some exotic form of carbon.

I recently received a 7-by-9-inch padded envelope containing an even smaller hardwood block which is functional and useful, while at the same time, simple in concept. It's one of those "why didn't I think of that" type of devices.

Those of us who have labored in the broadcast studio/transmitter/production house trenches can appreciate its utility. How many times have you wished that you'd been born with a third arm and hand when it came time to solder audio connectors?

The SolderBuddy from Lee Tingler is that missing appendage. Its price is nowhere near what special custom-made clothing would cost if you were to be somehow equipped with a biological or bionic holding device either.

FEATURES

The SolderBuddy is constructed from a solid (dense) piece of hardwood — mine was supplied in Brazilian cherry, but Tingler offers other woods as options. It comes with 12 holes precision machined into the front (top) surface and an additional four more on the rear. Also included is an alligator clip mounted on a 3-/4-inch piece of stiff tubing (more about which later). Labels are engraved into the wood via laser, and will not likely wear off or become obscured during the life of the device.

(I have a feeling that the SolderBuddy will outlast most of its users and will be passed down to the next generation — if OSHA and the EPA haven't prohibited all soldering operations 30 or so years from now!)

I didn't try all of the supported connector possibilities, but the accompanying documentation says that the SolderBuddy works with 14 types. There are places for male and female XLRs, RCAs, DINs, 1/4-inch and mini phone plugs, to name a few. The alligator clip appendage fits snugly in one of the holes and plays the part of a third hand in securing oddball connectors that aren't directly supported by the collection of machined openings.

Despite its simplicity, the SolderBuddy is a well crafted and precise device, not merely a random block of wood with a bunch of holes drilled in it by unskilled labor operating a 1/4-inch hand drill in the backside of someone's garage. The openings machined into the SolderBuddy are very accurate. (If you're considering bootlegging your own version after reading this review — don't. Unless you're a master craftsman with some amount of time to spend, you won't be satisfied with the results. At the price for which it's offered, the SolderBuddy is a bargain. It's not really worth the time and effort to try and cobble up your own.)

IN USE

I tried out the SolderBuddy in connection with a recent job in my "growing" home studio (actually a recreation of a 1950s/'60s radio station, down to Ampex 350 and Magnecord PT-6 tape decks, along with a Mackenzie repeater, for those of you who were around when these were state-of-the art).

Of course there are a lot of XLR connectors and TRS plugs to be soldered in such an enterprise. Several years ago, I got tired of splashing molten solder on workbench, floor and occasionally myself when I soldered such connectors in an "open air" fashion. This led to the purchase of a fairly expensive (several times the cost of the SolderBuddy) portable bench vise, complete with weighted base and padded jaws.

Over the years, I've used this with some measure of success, but it's far from perfect. As the jaws are padded with a rubber-like material to keep from marring the connector undergoing cable attachment, the grip is not that firm and sometimes connectors can (and do) tilt just as the soldering iron tip is applied.

The SolderBuddy solves this problem handily with its custom-created recesses for audio connectors. The male and female XLR spaces are especially good in this respect, as they include a keyway that precisely fits the locating pin on the connector body and firmly immobilizes the connectors when they are being soldered. Even the relative depths of the male and female XLR species have been compensated for in the creation of holes in the SolderBuddy.

How many times have you wished that you'd been born with a third arm and hand when it came time to solder audio connectors?

My comfort level in attaching cables to XLRs was increased decidedly with the SolderBuddy. The wiring up of 1/4-inch TRS plugs went equally well.

I've never really been a fan of the RCA phono connector (what other audio connector breaks ground before breaking the "hot" conductor?) and only use them when I have to bring a consumer device into the "broadcast" environment. Nevertheless, I gave the SolderBuddy a chance to show me what it could do with RCAs, and the results — while not quite as nice as with XLRs and 1/4-inch phone plugs — were completely satisfactory.

As the RCA is one of the few commonly used connectors (forgetting the old PL-239 "UHF" connectors) that is wired by soldering a conductor within a hollow pin, the SolderBuddy's block, with its series of holes, doesn't support this first phase of RCA connector attachment. (It would have to have a hole drilled all the way through and be turned to an unstable position to do so.) This is one of the reasons that Tingler supplies the alligator clip appliance (it's referred to as the Post and Clip system). It's fitted firmly into the appropriate opening in the SolderBuddy and nicely holds the RCA connector while heat and solder are applied to the long center pin. Once this is done (and the solder sets), the user can then insert the connector's center pin into the machined hole and solder the shield to the rear of the connector.

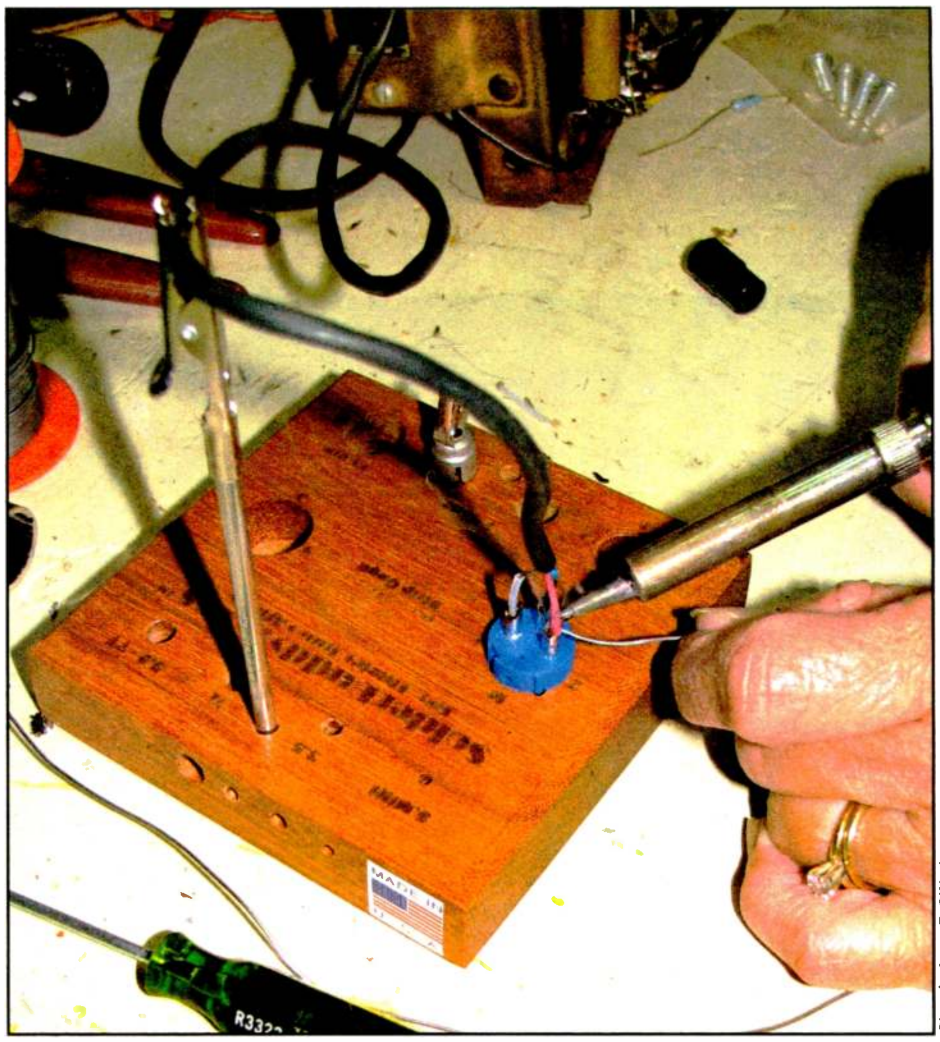

Photo by James E. O'Neal

The SolderBuddy is used to prepare an XLR connector.

The alligator clip "stand" is also useful for wiring up other "oddball" connectors that don't fit into any of the SolderBuddy's holes. Some of my gear uses "Jones type" multipin plugs and sockets, and while the alligator clip device is useful for holding smaller Jones connectors, I have to admit that larger units are probably best handled in a regular bench vice due to their size and weight. But truthfully, how many of us still wire up Jones multipins (unless you've got a stable of Ampex and Magnecord recorders)?

All in all I was well pleased with the performance of the SolderBuddy.

I've soldered on a lot of connectors during the past 50 years or so and have yet to find the perfect tool to replace that fabled third (non-heat conducting) hand. However, the SolderBuddy comes close. It has caused me to give up on my expensive bench vice when it comes to wiring XLRs. I would recommend the SolderBuddy to anyone who regularly wires audio connectors. (It's faster than opening and closing the jaws on a bench vise too.)

Could it be improved upon? Perhaps slightly. Instead of the flat base, I would like to see a model with a mild forward tilt to provide a more natural angle for soldering some connectors. (This wouldn't be hard to do in a later edition.) Also, due to its compact size — not much larger than the palm of your hand — I fear that if you are at all like me, it's going to be an easy tool to misplace, especially when working in a not especially well lighted equipment rack area, or just in the general clutter that finds it way to some workbenches. Until Tingler starts equipping his SolderBuddies with homing devices, I think that I'll dress mine up with some reflective tape or a touch of DayGlo paint just to make it stick out a little more. (By the way, Tingler says that he has perfected a mount for Jones connectors and will be offering it in the future.)

Yes, good things can come in small packages. I wish that the SolderBuddy had been around years ago when I was cutting my teeth in this business.

James E. O'Neal is technology editor at TV Technology and is a retired broadcast engineer. His articles about radio history and other topics appear frequently in Radio World. ■

FAST FACTS

Application

Broadcast studios, transmitter plants, production houses — anywhere electronic soldering operations are performed.

Key Features

Accurately sized openings to firmly hold a variety of connectors when soldering, compact size and permanent lettering.

Price

MSRP $29.99 for "stock" model; units constructed with custom woods start at $45. Handling and shipping charges are extra.

Contact

Lee Tingler, Tingler Innovations
770-476-5337
www.solderbuddy.com

Loudness

CONTINUED FROM PAGE 23

perception of brightness, or intensity of touch, or strength of odor. Clearly, it is a primary tool for survival, and deeply hardwired into our preconscious sensory mechanisms.

Loudness gives us an aural sense of the approximate size, the proximity, and the power of a sound source. Such sensations lead to an emotionally charged sense of relative safety or danger, as well as an unequivocal sense of the probability of our immediate survival. When we are exposed to extremely loud low-frequency sounds, we self-medicate with adrenalin, in anticipation of a struggle and/or an extremely rapid vacation from our current location.

Because of these functions, changes in loudness are an essential emotional ingredient in sound and music, and one of the most powerful energizers for our kinesthetic responses (such as dancing) to sound and music. The effective management of loudness is powerful, powerful medicine in music, movies and audio in general. We ignore it at our peril.

With that said, there are several physical elements that, in combination, affect our sense of how loud a sound is, but first we've got to reconsider the relationship between our beloved audio level fader, decibels and loudness.

"Up is louder," we like to say, as an audio truism. And so long as no other changes happen to a given signal, when we tweak an audio potentiometer we will notice a reasonably consistent and reliable change in our sense of the loudness of the sound that is controlled by that potentiometer, coming from a loudspeaker: as the amplitude of a given signal increases, so will its apparent loudness.

There are some informal rules of thumb for this, such as: +1 dB (100 percent to 112 percent change) is about the smallest change we can usually perceive, while +10 dB (100 percent to 316 percent change) is perceived as about "twice as loud," in a general sort of way.


James D. Johnston, aka JJ

But here's where it gets a little trickier. The above statements are only approximately true for a signal with a given spectrum and crest factor (which can roughly be thought of as the amount of energy occurring over time in a sound).

ENERGY, SPECTRUM AND TIME

There are, in fact, three different acoustical parameters that significantly affect our perception of loudness. We've already mentioned the acoustic energy of sound waves. (As it changes, our sense of loudness changes.) In addition, loudness is related to the bandwidth of the audio spectrum that is present in the sound. (Add some new parts to the spectrum and loudness will increase, even if amplitude remains the same.) Finally, there's the amount of time that energy is present for. Very short impulses don't sound nearly as loud as sustained sounds with the same amplitude. (This is, of course, closely related to crest factor.)

The spectrum part of this is quite interesting. Our hearing spectrum (as detected in our inner ear, the cochlea) is divided up by frequency with filter bandwidths called critical bands (approximately 30 of them). They tend to bunch up in the middle of the spectrum. (See Fig 1.) JJ points out that this is somewhat of an oversimplification, but it will do for our purposes.

What is important about them is that when energy increases in a single band, it follows the rule that "10 dB increase sounds twice as loud." However, if the same amount of energy shows up in two of those critical bands (an increase of only 3 dB), that combined sound will also be perceived as "twice as loud." This is why compression can be so deadly—we increase the levels of all of the softer critical bands while limiting the louder ones. Even though the overall level doesn't go up very much, the perceived loudness sure does, a lot!

Interestingly, this is all quite nonlinear, so that no simple algorithm is going to effectively predict or control the level of a signal in terms of its predicted or perceived loudness. We may be able to squash levels with a compressor, but actual perceived loudness will be a good bit harder to manage, except at the extremes of way too loud and way too soft.

THE NATURE OF OUR POPULATION

Another point needs to be kept in mind when considering these issues. There is considerable variance in the way that individuals hear, and what various individuals actually perceive. This is particularly true for us older dudes and dudettes. Hearing deteriorates with age, and it does so in a variety of ways, with a variety of differing impacts on perception. There is also the possibility that the extreme exposure to music at high levels over headphones (compared with 30 or more years ago) may also be damaging the hearing of younger people as well.

What this all means is that our various engineering simplifications introduce significant and variable loudness errors and irritations for different viewers. Yikes! Background noise makes this even worse, by masking some soft sounds, and giving them zero loudness.

So, there is no bestest. No way we can manage levels sufficiently satisfactorily for all of our listeners all the time, so that none of them are irritated by the loudness or lack thereof in our beloved broadcast signals. What we can do, however, is get it close, and there are a variety of strategies for doing that. We need to more fully understand loudness and its relation to spectrum and time, and more carefully manage it.

Unfortunately, rigor and engineering excellence are called for at a variety of points in the production and transmission paths, and we are not achieving that. We'll talk more about that next month. In the meantime, feel free to check out some tutorials JJ has done about this at *www.aes.org/sections/pnw/ppt.htm*.

Thanks for listening.

Dave Moulton is a frequent contibutor to Radio World's sister publication, TV Technology. Visit his Web site at www.moultonlabs.com. ■

Power Boost or Bust for HD Radio

This year marks the long-awaited shutdown of over-the-air analog TV in this country. It emphatically closes the book on television's first 60 years.

TV's transition to digital has had its own litany of twists and turns. But HDTV enjoyed widespread acceptance and had the blessing of a mandated conversion to digital by FCC rule. Radio, it seems, will not be so blessed.

In the beginning, almost everyone was impressed at how well digital radio performed using only 1 percent of the channel power carried by its analog host. The efficiency of OFDM modulation coupled with clever coding and decoding tricks blew away legacy analog schemes. As with every other electronic-based enterprise, digital technology gifted the broadcasting business a dramatically more powerful and effective set of tools to carry on its mission.

FEW TAKERS

However, the past seven years of the HD Radio rollout has brought us to one painfully obvious conclusion: 1 percent power for the digital signal is not going to make this technology a winner. Impressive though it may be in some markets, it's simply not enough to deliver consistent and reliable performance, particularly for indoor reception. Better receivers cannot get us there by themselves.

No matter how many more features or improvements HD Radio might deliver for the consumer, Joe Public is not going to buy a new HD Radio receiver unless it captures and holds his favorite stations as well as or better than his trusty old analog sets in all the venues he wants to use it. Too many episodes of signal dropouts, blends-to-analog or no HD Radio signal at all leave a horrible impression. Resorting to an external antenna is not an acceptable or realistic solution.

> Receiver manufacturers are not going to keep making HD Radios and introducing new models unless consumers start buying a lot more of them.

The inventors of HD Radio knew going in that the transition from analog to digital was going to be problematic. As early as 2004, Godfather Glynn Walden told many of us that more digital power would be needed to give consumers the same "radio experience" as analog. Blend-to-analog was only a crutch to allow HD Radio to walk. It eventually would have to start running on its own. But iBiquity was constrained to use a conservative approach during the initial rollout to protect the analog host from degrading hiss while trying to keep the primary contour reach roughly equivalent to the analog.

We all knew it would take a while for HD Radio to achieve critical mass on the transmission side in order to convince receiver manufacturers that receivers were worth making and marketing. For the most part, broadcasters have done their part, but even with more than 100 models of HD Radios now available, there is no real consumer demand.

Despite better marketing, receiver sales figures have been … shall we say, rather disappointing. Less than a million receivers have been sold since the technology's introduction, according to iBiquity. That number pales in comparison to that of any other successful electronic innovation targeting a mass audience. Bob Struble can spin all he wants but this one issue has become a real and serious problem that iBiquity and its stakeholders know they have to solve. And they have to solve it sooner than later.

TURN UP THE WICK

The obvious solution, and the only one we can see to turn around the fortunes of HD Radio, is the 10 dB digital power boost. IBiquity's plan all along was to ramp up the power after HD Radio signals became widely available in all significant markets. Radio sales were expected to keep pace and enjoy a corresponding ramp-up so that analog interference issues would be less of a concern. Clearly that hasn't happened.

People on broadcast listservs and in the trade press are reporting a small but growing number of stations that have turned off their HD Radio. Most of them appear to be AM, but it's hardly an auspicious omen. The deepening recession and heavy cost-cutting puts pressure on owners and managers to suspend support for anything that is not producing revenue. Most FM-HD stations are hanging in there, but it appears HD Radio has arrived at that proverbial fork in the road a little sooner than it had planned. Should HD-R power be increased now or later, after it achieves more use and acceptance?

The 10 dB power increase proposal has been under careful review for almost two years. Field testing is being conducted in a number of major markets by several NPR affiliates, CBS Radio, Greater Media and a few other groups. NPR Labs launched a comprehensive HD Radio coverage and interference evaluation effort in late 2006 under the capable leadership of John Kean. With NCE stations tightly packed into their end of the band, using contour protection instead of distance protection, NPR understandably is more concerned about interference issues with such a large power increase on the table.

Kean concludes that a digital power increase from –20 dBc to –10 dBc would significantly enhance digital performance, assuming all stations were operating in digital. NPR prefers to label HD Radio as IBOC DAB. Overall, mobile IBOC DAB coverage would jump from 85 percent to 117 percent of quality analog coverage, as measured by population, for 50 sample stations. Indoor and portable IBOC DAB covered population totals would increase from 38 percent to an average 82 percent of equivalent analog coverage.

This suggests the power boost actually would make digital coverage better than analog for car radios and almost as good for indoor and portable sets; indoor and portable reception more than doubles. These are critical and compelling enhancements.

MEASURING THE DOWNSIDE

There would be an interference penalty of at least some consequence, affecting short-spaced stations especially. Assuming all stations operated with digital and increased power from 1 percent to 10 percent, the mobile analog FM population would be reduced an average of 14 percent to 26 percent for the sample stations due to interference from IBOC DAB. Analog FM indoor covered population would be reduced by IBOC interference an average of 6 percent to 22 percent for the sample stations. Interference to portable analog service was judged minimal at 1 percent digital power but would increase to a coverage loss of 6 percent with a 10 dB digital power boost.

Interference would affect some stations severely in portions of their analog mobile service area. Forty-one percent could lose a third or more of their covered population and 18 percent would lose more than half of their population. These figures assume *all* stations would be operating in HD Radio with the full 10 percent increase in digital power, so they represent the worse-case scenario. Digital-to-digital interference considerations were not evaluated since first adjacencies potentially affected are already significantly degraded by analog interference.

The complete NPR report and summary conclusions can be reviewed at *www.nprlabs.org/research/drcia.php.*

The principle spokesmen for commercial broadcasters Greater Media and CBS Radio are saying that a digital power increase would be beneficial and appropriate for most all HD Radio stations in all markets. They've concluded that the overall service improvements clearly outweigh the modest interference increases and decidedly serve the greater good.

NPR's Mike Starling is supportive about increasing the digital power level but is a bit more guarded and selective on how the full 10 percent increase should be authorized. He feels more study is needed to make sure

An array of HD Radio receivers from iBiquity's booth at NAB2008; photo by Leslie Stimson

those stations likely to receive the most interference are properly protected.

WHAT'S NEXT

Radio World's Dec. 18 webinar, "What to Watch for in 2009 — A Radio World TechCast: 360 Degree Industry Roundtable," gives good insight on how NPR and Greater Media view the power increase proposal and what's likely to happen next. You can watch and listen to the archived podcast at *www.radioworld.com/article/71658*. Register via the form for free access.

Participants Mike Starling and Milford Smith agreed that a 10 dB increase should be afforded to stations with no short-spacing or present interference constraints. A base increase of a lesser amount, probably around 6 dB, should be afforded to all other stations. Some stations may also find that a 6 dB power increase provides an acceptable tradeoff between increased digital coverage and digital self-interference to analog. Increases (or decreases) from that amount could then be granted on a station-by-station basis, pending evaluation of real interference to the protected contours of other stations.

All of the webinar participants agreed that this proposal deserves a fast track at the FCC and hopefully could be adopted later this year.

Considering the evidence produced by the studies and field testing done so far, this proposal is a measured and balanced approach to help save radio's digital future. While many of us may have preferred an open-source and more flexible system design, iBiquity HD Radio is the hand we have been dealt.

Nobody who wants to see radio remain a valuable, competitive and successful service for 235 million Americans who use it every day should want to contemplate what would happen to our enterprise long-term if HD Radio fails. It would take years to resurrect and perfect another effort of implementing the benefits of digital to radio's over-the-air delivery.

Time is beginning to run short. Receiver manufacturers are not going to keep making HD Radios and introducing new models unless consumers start buying a lot more of them. Even if iBiquity were to decide to reduce licensing fees radically it would not fix the performance problem. And all the marketing in the world won't fix it either. For iBiquity and its stake holders, the digital power boost appears to be the last card in the deck they can play to win this game.

Guy Wire is the pseudonym for a veteran broadcast engineer. Read past articles under Columns at radioworld.com. ■

MARKETPLACE

Rycote Adds to Line of Mini Windjammers

Rycote, the windscreen manufacturer, has added to its line of miniature windscreens for digital handheld recorders, the Mini Windjammers.

The new shaving brush-like products now include customized fur-lined screens for the Edirol R-09HR, Marantz PMD620, TASCAM DR-1, Zoom H2 and H4. These join screens for Nagra AresM, Olympus LS-10 and Sony PCMD50 handheld recorders.

Rycote Sales & Marketing Manager Gabby Davis said: "Handheld compact digital recorders are now in such widespread use by broadcasters that we have been getting user requests for bespoke windshields tailored to fit each model for some time. However, the recorders are so different in size and shape that a generic 'one-size-fits-all' design isn't suitable — we had to produce a range."

For information, contact Rycote/Redding Audio at (203) 270-1808 or visit www.reddingaudio.com.

The Audio-Pods Are Here Already

The DM Engineering Audio-Pod is not a mind-consuming threat but rather a multipurpose box designed for use where a portable and independent headphone or mic and headphone station is needed.

The headphone section features a gain control along with front-panel 1/8- and 1/4-inch jacks. The rear has a headphone impedance control (8–400 ohms), a phase switch, a maximum gain switch, 1/8-inch jack and Euro-style screw terminals.

The preamplifier is an option. Large LED-lit buttons control the microphone-on/off and cough.

If more than a single Audio-Pod is needed, up to four can be run from a single power supply. Several mounting options are available.

For information, contact DM Engineering at (800) 249-0487 or visit www.dmengineering.com.

Korg Delivers New Studio Recorder

In these days of DAWs, servers and handheld digital recorders, an honest-to-goodness new rackmountable digital recorder for studio use is an unusual sight.

Korg's MR-2000S is a multipurpose digital hard disk recorder runs the range for 44.1 kHz/16-bit up to high-end 5.6 MHz "1-bit" recording. PCM files can be from 44.1 kHz to 192 kHz. WAV, BWF, WSD, DSF and DSDIFF files are all supported. Included conversion software allows for use of many other file formats.

The onboard hard disk is 80 GB. A USB 2.0 port handles input and output to a computer or other storage.

The MR-2000S has XLR and RCA analog connectors. A S/PDIF connector is also available for digital duty.

For information, contact Korg at (631) 390-6500 or visit www.korg.com.

Skills

CONTINUED FROM PAGE 30

dramatically changed for the better. Everyone was happier, profitability was better and staff turnover was zero. The staff became equally proficient at using hard and soft skills. They were simply enjoying themselves more. Many individuals reported that they also found soft skills extremely useful in their personal life. Unlike hard skills, soft skills are readily transferable from one context to another.

Soft skills are everywhere, and you only need to look for them. Many of my *Last Word* articles in fact have explored specific soft skills, without giving them that label. Some of us actually learned soft skills from our parents if we were lucky enough to have parents who understood the value of "street smarts," which is another label for soft skills. In his book "Emotional Intelligence," Daniel Goleman argued that this kind of intelligence is the best predictor of success, which contrasts to such metrics as receiving high grades in school or having advanced degrees. Emotional illiteracy has a professional and life cost.

Yet for all their value, soft skills are rarely taught in school, even though humanities courses were intended to illustrate them. Such courses simply do a bad job of teaching what the average chimpanzee intuitively understands. Moreover, while there are books that also argue for the value of soft skills, they do not teach them. I have yet to find the book "Soft Skills for Dummies," which I may someday write. In the meantime, I will continue to discuss in these articles those soft skills that are relevant to broadcast engineers. You might want to read Goleman's companion volume "Social Intelligence" as well.

Hard and soft skills are not mutually exclusive but complements. In combination, they are infinitely more productive than either alone. And soft skills never become obsolete because people remain people. ■

Many engineers selected the profession because its focuses on a 'hard' reality. As a consequence, many find themselves at the bottom of the political, social and financial food chain.

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For address changes, send current and new address to Radio World a month in advance at 5285 Shawnee Road, Suite #100, Alexandria, VA 22312. Unsolicited manuscripts are welcomed for review; send to the attention of the appropriate editor.

THE LAST WORD

by Barry Blesser

Soft Skills Predict Professional Success

Engineering Knowledge Is Key, But People Knowledge Is Even More Important

As an engineer working in the broadcast industry, you probably acquired your initial knowledge of the profession in a classroom. And during your first job, you received on-the-job training from senior engineers who were passing along their knowledge and experience.

The skills thus acquired might well have included circuit theory, network communications, computer programming, studio-transmitter links, acoustic equalization of studios, sound editing, equipment calibration and so on. For those of us who have been in the engineering profession for a decade or more, the list of acquired skills is indeed large.

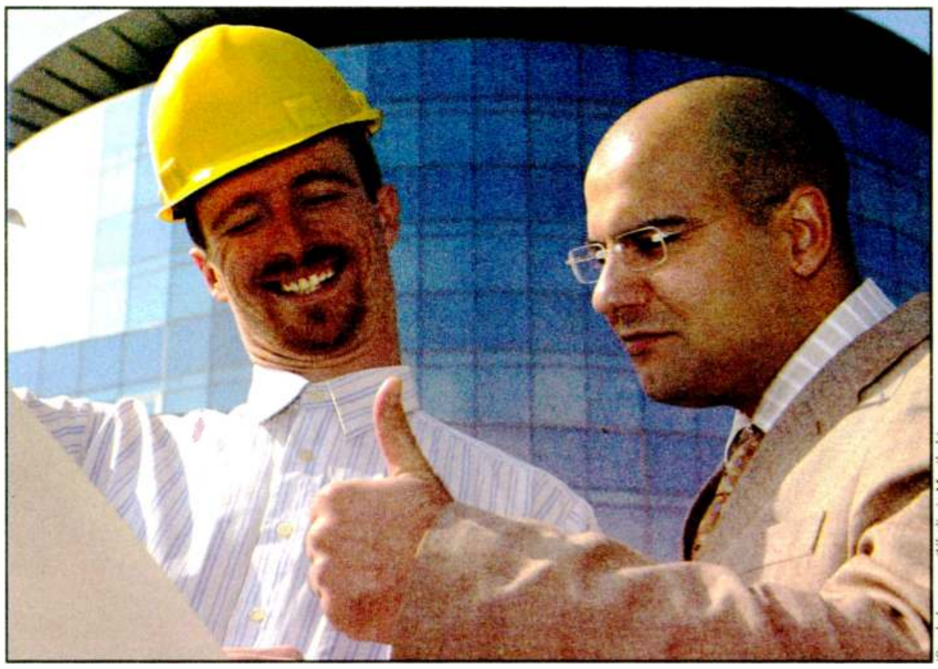
These technical skills are valuable, especially when they are in limited supply and produce results that have value to society. In contrast to a veteran engineer with years of training and experience, beginning engineers have very few hard skills. As they continue in their profession, and if they are wise, they continue to add to their collection of hard skills. Unfortunately for engineers in the 21st century, these hard skills rapidly become obsolete; engineers must acquire new ones continuously if they want to stay relevant and employed.

Analogous skills exist among business executives, such as reading a balance sheet, optimizing profits, managing liquidity, choosing investments, setting policies and optimizing market penetration. Accountants, lawyers, scientists, athletes, actors, teachers, doctors, salesmen and marketers have corresponding collections of skills. Each profession has its own set of "hard" skills unique to that profession.

THE OTHER SET OF SKILLS

From the title of this article, you might suspect that there exists a corresponding set of "soft" skills that are not specific to any one profession.

Soft skills are a collection of methods and techniques by which you can influence the behavior of others in a way that enhance your enlightened self-interest. Soft skills enable the building of alliances with the appropriate amount of trust. Soft skills reveal the degree to which agendas align or conflict.



iStockphoto.com/Vladimir Mucibabic

Perfecting your soft skills can make for more productive, less frustrating meetings.

Negotiation is a soft skill. Conflict resolution is a soft skill. Disambiguating language is a soft skill. Motivating co-workers is a soft skill.

Soft skills enable us to function at the highest level when dealing with people and organizations. Effective leaders have a tool box of soft skills that induce others to want to follow them. Soft skills are the difference between a meeting that is a waste of time and one that is highly productive. Soft skills minimize political sniping in an organization. Soft skills make for good marriages, thriving children and supportive colleagues. Successful politicians have good soft skills even if they might have weak hard skills.

With inadequate soft skills, hard skills rarely are sufficient to produce professional success. Some managers only have soft skills. But the most productive professionals have an equal balance of hard and soft skills.

nless an engineer lives in the northernmost woods of Maine, he will be interacting with many people in complex groups. Nevertheless, many (most?) engineers wish that could they could be left alone to be productive with their technical skills. Because they lack the necessary soft skills to optimize their relationships with others, engineers avoid situations requiring those skills. In fact, many engineers selected that profession just because its focuses on a "hard" reality. As a consequence, many engineers find themselves at the bottom of the political, social and financial food chain.

The lack of soft skill has a real cost. Dilbert cartoons are parodies of degenerate soft skill.

ARE YOU SMARTER THAN A CHIMPANZEE?

As a side note, the modern theory of evolution indicates that survival of a species is based on the gene pool of the group, not that of individuals. Human beings evolved as social animals. In their collection of articles, Richard Byne and Andrew Whiten convincingly show that all primate species possess *Machiavellian Intelligence*, which is also known as political intelligence or social intelligence. Are your soft skills as good as those of the average chimpanzee? If not, maybe it is time to enhance them.

Many years ago, I came across a brilliant mathematician whom I had first met in high school decades earlier. As a teenager, I envied his mathematical ability to see elegant solutions where I was clueless. He had a highly specific type of intelligence that he used to solve tough problems, but only when they were presented in mathematical language.

When we met again years later, he had been sitting at the same desk for decades, having become a grouchy old man in a depressive funk because his isolated life had gone nowhere. Hard skills are necessary, but are not alone sufficient in producing a rewarding life.

Many engineers, including myself during my early engineering years, treated hard skill as king, and correspondingly viewed soft skills as unneeded fluff for those with an interest in the (useless and unproductive) liberal arts. While engineers are forced to take humanities courses in high school and college, most of us considered those courses to be a necessary evil, only serving the function of fulfilling the requirements to graduate. I never could figure out why knowing the history of the Civil War would make me a better engineer. Similarly, I found reading "Moby Dick," speaking French, recognizing a Rembrandt painting, explaining Plato and memorizing a Walt Whitman poem to be a waste of time. Nobody ever convinced me that this kind of education would do anything useful other than allowing me to appear "educated" at a social gathering of snobs.

That was my attitude then. But something happened to me during the last two decades of my 45-year career. I discovered the value of soft skills, not as taught in school, but in real life. Without realizing it, I was beginning to use soft skills to advance my consulting business. And these skills really do make a difference.

More recently, in addition to using them, I have been teaching them to the staff of my clients. In one particular company, after spreading soft skills throughout the company, its culture and economic success

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E²

Usually, the best inventions are those that are the most simple. There's currently a crop of Audio-over-IP studio hardware out there that just doesn't get it. It's complicated, it relies on PCs for mission-critical functionality and is, seemingly, in need of 24/7 support. Hmmm.

Wheatstone, known the world over for the highest quality networked audio and consoles, has a better idea. What about a system that does it all without complicating your life? Interconnect control room, studio and TOC audio seamlessly, all audio available everywhere without having to set network parameters and priorities. The sky's the limit.

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