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Radio World

ENGINEERING EXTRA

October 15, 2008

DESIGNER INTERVIEW

Peter Bloomfield

Architect Says Well-Planned Stations Bring Out the Best In Communities

by Michael LeClair

Bloomfield & Associates, Architects has designed and helped construct numerous broadcast facilities for companies as diverse as CBS, Cox, Sandusky, Entercom and National Public Radio. Its work has received

SEE BLOOMFIELD, PAGE 4

WHITE PAPER

A New Approach to Peak-to-Average Power Reduction for Hybrid FM IBOC Transmission

Benefits Are Seen in Reduced Transmitter Size, Lower Cost of Increased Digital Power

by Philipp Schmid

The author is research engineer with Nautel Inc.

The recent move to increase the signal power allocated to the digital subcarriers for HD Radio has prompted Nautel to take a closer look at the peak-to-average power ratio (PAPR) reduction of the standard IBOC solution and its applicability within this new reality.

While the standard PAPR reduction effectively reduces signal peaks from over 12 dB to less than 8 dB, Nautel introduces a novel approach to PAPR reduction specifically for the hybrid FM plus IBOC waveform.

Many of the principles apply to all digital transmission, but significant gains are realizable only in hybrid transmission. Research conducted at Nautel to date indicates that a savings of 30 percent or more in required transmitter power can be obtained.

To take full advantage of the new subcarrier power levels, additional transmitter overhead will be required. However, even existing hybrid transmitter installations can benefit from this innovation and effectively boost the power in their digital subcarriers.

IBOC SIGNAL CHARACTERISTICS

As HD Radio gains more and more momentum, many radio stations are already transmitting the in-band, on-channel signal. However, many stations cite high HD conversion costs with (as of yet)

SEE PAPR, PAGE 20

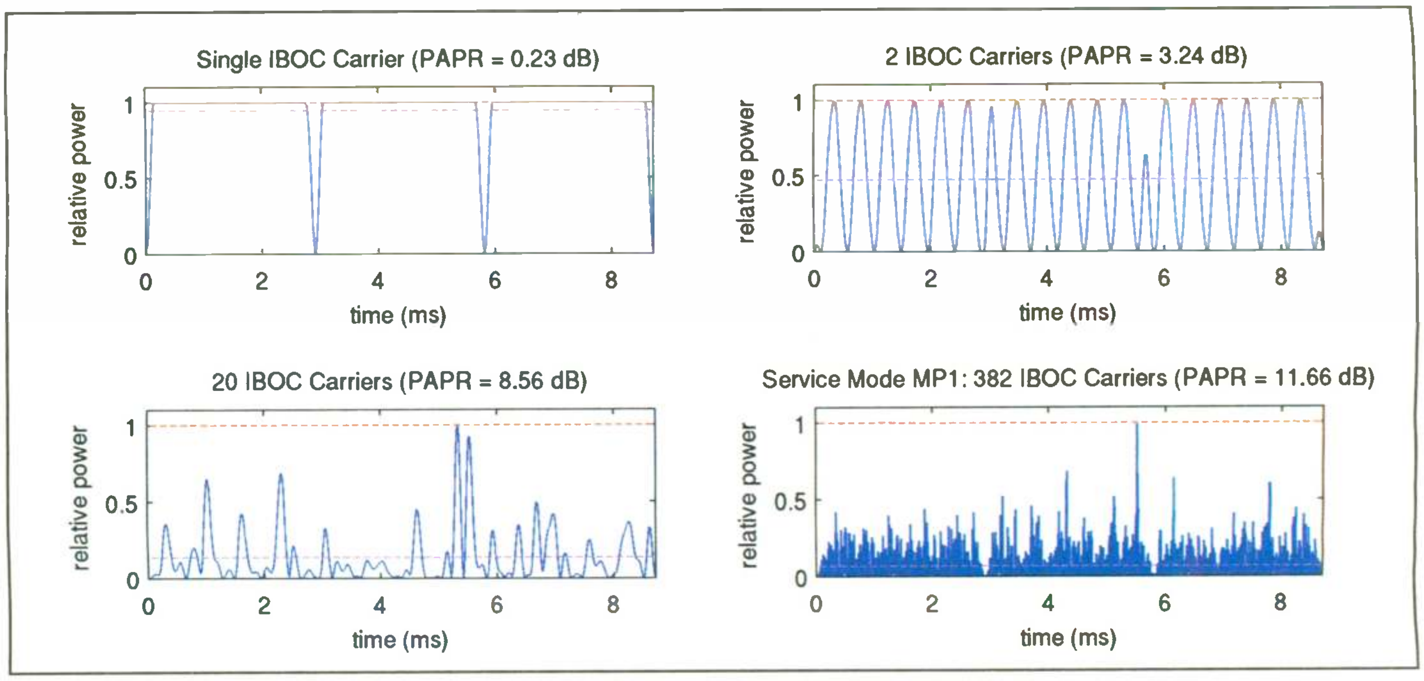
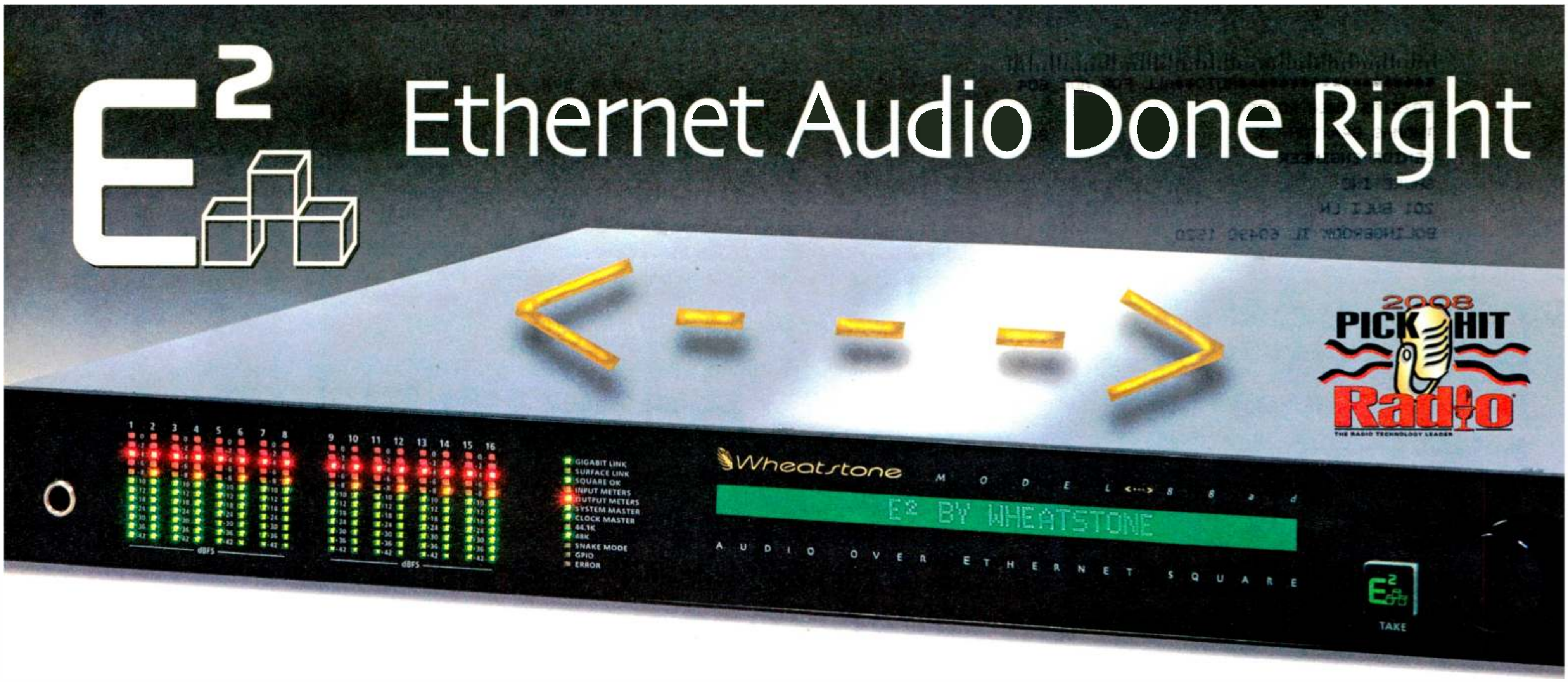


Fig. 1: Instantaneous Power Requirements Over 3 IBOC Symbols



MEET THE SQUARE

The Wheatstone E² (E SQUARE) gives you the convenience of Ethernet audio without all the IP hassle. It just *knows*. The built-in Setup Wizard lets you configure an entire system with just your browser and a laptop. Unplug it when you're done and there's no PC between you and system reliability.

SQUAREs are totally scalable: use one as a standalone 8x8 studio or transmitter site router, with browser access from anywhere. Plug two together and have a standalone digital snake. Add a fanfree mix engine and build yourself a studio using analog and digital I/O SQUAREs.

All the power is *in* the SQUARE. Distributed intelligence replicates all configuration data to every unit. Profanity delay and silence detection are done *in* the SQUARE. Even virtual mixing (w/automation protocol) —it's *in* there; all with real front panel meters, 32 character status indicators and SNMP capability.

88D I/O: 8 digital inputs and outputs. You can headphone monitor and meter any of the SQUARE's inputs or outputs in real time. The 32 character display gives you all the information you need about your audio and system configuration. And because you can operate in either 8-channel stereo or 16-channel mono mode, 16 channels of metering are provided.

88E DIGITAL ENGINE: Just plug an E-SERIES control surface or GLASS E computer interface into this engine and get all the mixes, mic and signal processing you need. Fanfree, so it can stay in the studio where it belongs.

88A I/O: 8 analog inputs and outputs. You can bring a new SQUARE up in seconds and of course use the front panel encoder for your X-Y control. Front panel status LEDs give you continuous link, status, and bit rate information as well as confirmation of any GPIO activation.

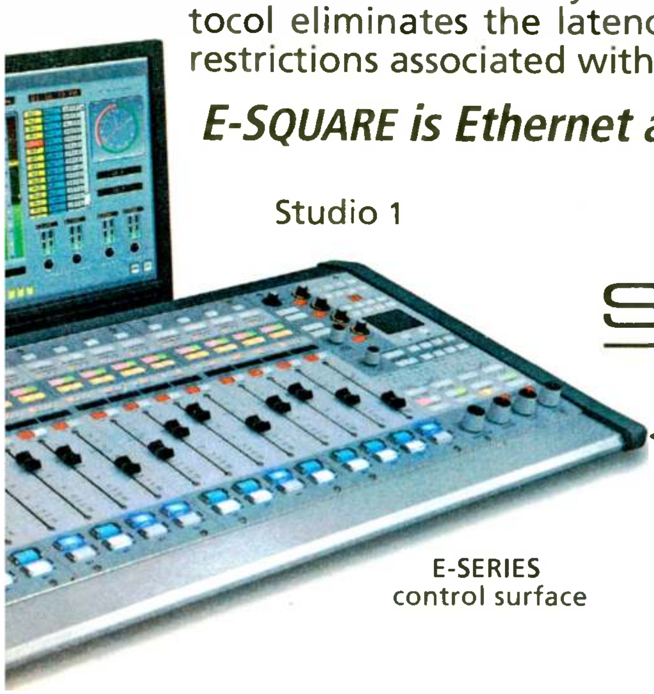
Because the E² system doesn't rely on a third party GUI, tech support is straightforward (and 24/7). Likewise, system operation doesn't require external PCs for continued full functionality. Best of all, 1 Gigabyte protocol eliminates the latency and channel capacity restrictions associated with older technology.

E-SQUARE is Ethernet audio done RIGHT!

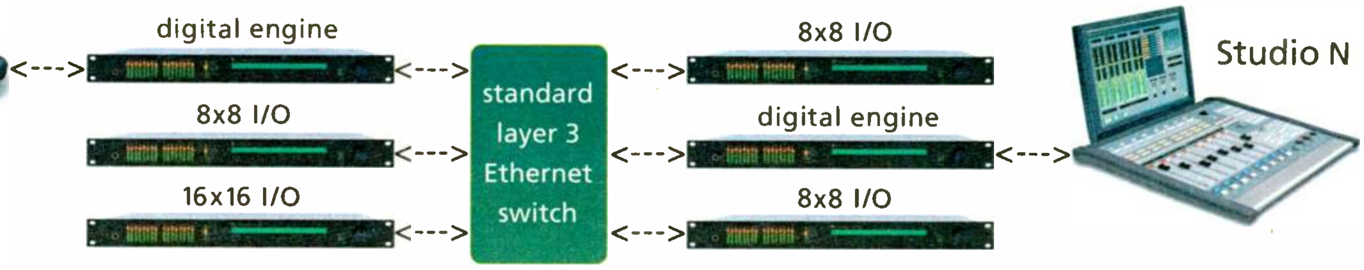
88AD I/O: 4 analog plus 4 digital inputs and outputs—perfect for small studios or standalone routing.

88 I/O CONNECTIONS: E² has both DB-25s for punchblock interface and RJ-45s for point-to-point interface. All SQUAREs have 12 individually configurable opto-isolated logic ports that can be either inputs or outputs.

Studio 1



STUDIOS DONE EASY!



E-SERIES control surface

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FROM THE TECH EDITOR

by Michael LeClair

Live from the National Political Conventions

Helpful Lessons From Denver and St. Paul

In this turbulent political year I had the "privilege" to plan and execute support for two weeks of live radio coverage covering the national political conventions.

While this was a long and relatively hard project to complete it was of great interest to be on-site where these events took place.

The Democrats held their event in Denver first. Immediately after, the Republicans celebrated in St. Paul, Minn. My mission was to assist our crew of 13 reporters, producers and audio engineers to make sure their live broadcasts and news reports would happen on time and with the necessary infrastructure.

The purpose of national political conventions today is vestigial; no presidential candidates have been selected as part of the convention process for many decades. The formal announcement of the primary votes and acceptance by the selected candidate is still done at the convention, but this is mostly a formality.

Instead, the conventions are held largely as media events. The goal is to allow each party to speak to the populace and state their campaign themes and messages at length. This still serves a useful purpose in introducing the end stages of the political campaign season. After the conventions are over, the presidential campaigns begin in earnest.

PLAN, PLAN, PLAN

At WBUR we produce two daily live shows which are distributed nationally. Both of these shows were committed to broadcasting live from both conventions. Our call-in talk show, "On Point," is normally scheduled to run live from 10 a.m. to noon Eastern Time; our daily news magazine show, "Here and Now," airs from noon to 1 p.m. In addition, our news department in Boston was eager to send a host, a reporter and a producer to put together interviews and features that addressed local issues to supplement our local coverage.

Each show had somewhat different requirements. The most complex was "On Point," which required an on-site producer, IFB in both directions and remote computer access to scripts and call screen information from Boston during the show. Somewhat simpler were the requirements for the news reporters. Much of what they filed was done live over ISDN, straight into a digital audio workstation for mixing and editing. However, it was also possible for them to record much of their material on Marantz flash recorders and upload these elements and even interviews via FTP.

I began planning the equipment, furniture and telecommunications requirements for these events in March. Although it wasn't possible at that early date to know for certain the exact needs of all three programs, the general outlines of the events and their background were available for discussion and we could begin to develop budgets and gather information.

One of the most important requirements for planning an operation this large is to retain as much flexibility as possible. I find that the worlds of engineering and news operate so differently that it is essential to communicate regularly and frequently between these two groups so that each is aware of the other's needs.

For example, it is necessary to make payments for all the telecommunications circuits required at least 6 weeks before any event, or risk not having any circuits at all — this is a feature of the world of engineering. On the other hand, news organizations must respond to the latest breaking developments and often must change plans 24 hours before a scheduled event. Both sides need to keep calm and work together to succeed.

On the air with Director Hilary Mcquilken and 'On Point' host Tom Ashbrook.

Meetings between me and various members of the news department took place on about a weekly basis as we refined coverage plans and figured out just what we needed. It helps to have one person tasked on the news side with authority to approve the budget and resolve internal news questions when they arrive.

FREQUENT FLYER

To assist the media in their logistics planning, each party holds a couple of media walk-through events where the site can be inspected. I find these walkthroughs to be immensely helpful in many ways.

First, if your radio station cares enough to send someone across the country to participate in these events, it is noted and respected by the people who organize them. It makes sense to use these events as much for their social networking possibilities as for information gathering about logistics. The names you get, and hopefully phone numbers, often are the ones you go to in an emergency when something isn't working right. Just knowing who to call can often save hours of precious time when a broadcast is on the line.

I also know a few other engineers in the public radio world who broadcast live from the conventions, and generally I can meet up with them and share our plans. Often this results in cooperation that can save money and time during the actual event.

For example, we shared pool audio feeds at both sites in Denver with WNYC, saving us from both having to run separate pool audio lines about 200 feet away to the mult box.

I attended walkthroughs in both St. Paul and Denver. For each I brought with me a digital camera and took as many notes and pictures as I could. When I returned, I prepared a short PowerPoint presentation for the staff that would be going to each site so they could get a glimpse of what to expect before they arrived.

Even such basic things as maps to show the airport and hotel locations are very helpful to travelers on a strict timeline.

I also used each trip as a chance to visit and speak directly to local stations in each city, as we planned to use a local studio for a final live broadcast on the day after the convention ended.

The Democratic convention was a good example of how media events like this can be quite fluid.

One week before I was supposed to fly to Denver for the walkthrough in June, the event was cancelled and rescheduled for about four weeks later (yes, this cost a lot of us in the media to lose money on our airline tickets).

Pepsi Center hallway designated for Radio Row as seen during the media walk-through in July. Site photos help staff prepare for what to expect when they arrive at an event.

To make things more interesting, during the actual walkthrough in July it was announced that Barack Obama would make his acceptance speech at the Invesco Field football stadium rather than at the convention center.

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IN THIS ISSUE

Bloomfield

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multiple awards.

Peter Bloomfield founded the architectural firm Bloomfield & Associates, Architects in 1982 and is the president. The firm's initial focus was on small-scale, community-based projects. The business has grown to serve private and public sector clients on both small and large-scale projects. Bloomfield & Associates is based in Philadelphia, and has 12 employees.

A few years ago the National Association of Broadcasters approached Bloomfield and asked him to write a book on the design of broadcast facilities. "A Face for Radio: Radio Station Planning and Design" was published in 2007. "A Place for Television" is in the works.

Other senior members of the firm include Senior Principal Mark Motl, Principal Mary Ellen Strain, and Senior Designer David Kinnaird.

In this month's interview we spoke via e-mail with Bloomfield and explored his ideas on radio broadcast facility design.

What type of services does Bloomfield & Associates provide?

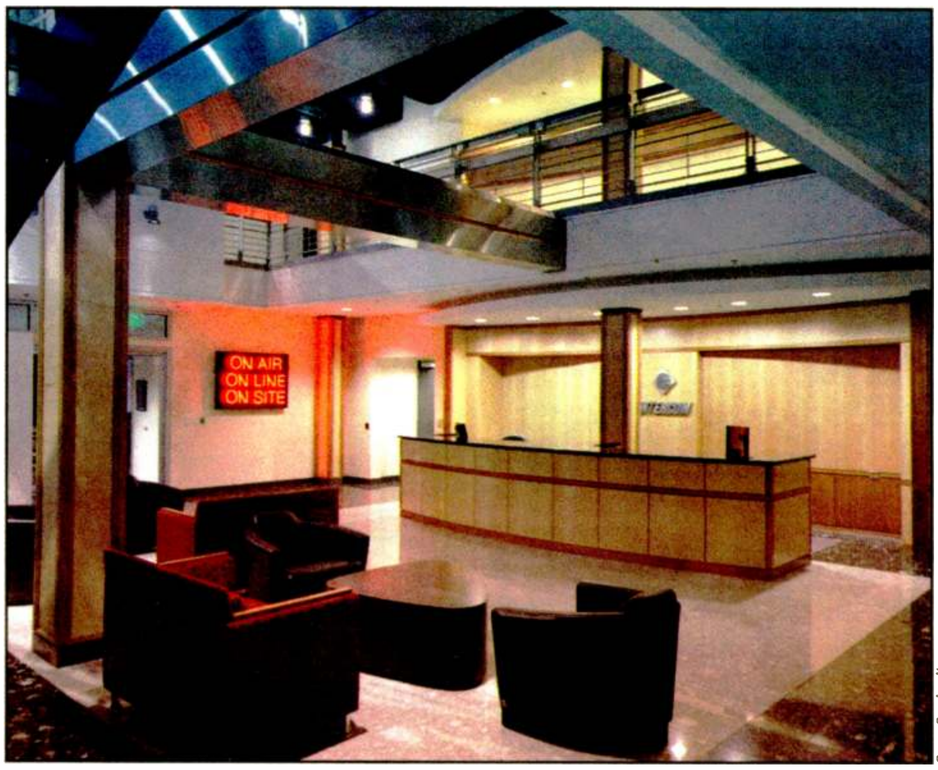
We can — and will — provide whatever a project requires, from helping conceptualize and initial budget development through construction. Actually, we try and monitor our projects for a year or two after completion, but that's more for our education and industry information.

Many projects start small and grow. There have been a number of times when we have told clients that they are better off holding off for a while. Occasionally we will join a team that includes a local architect or we will help clients interview a design firm to help out but mostly we are hired for full design and construction services.

That being said, I think that we are at our finest, and provide the greatest value to our clients, if we are involved very early on.

To us, that means being part of the team that defines the project and considers various site options. Often that means working to define both needs and wants. That can mean helping to define everything from specific equipment and furniture needs to general discussions about organization and how the renovated or new facility will function in the community.

If we are doing our job right, there will be some amount of "Hmmmm, I never thought of that," and a fair amount of, "Yeah, that's pretty much what we thought." In the end of this initial effort, we should have a pretty clear idea as to just how much space we will be looking for or need to build. It should also allow for some expansion (and even contraction) should the need arise. Clearly budget will be part of these early discussions as will schedule.



Steve Swalwell

Lobby of Entercom Kansas City

'Many of our clients in both the private and public broadcast sector are looking to build spaces that do more than just facilitate the making of content.'

At that point, we often help our clients "go into the market" and consider various real estate options. Potential image in community and ease of access by staff and the public are often part of this initial look but, by and large, they give way to engineering and, of course, budget.

We encourage our clients to compare sites based on budget but have also learned that long-term costs can easily trump initial expenditures. We've found that looking 10 years out — what the total cost of occupying a particular locale will be — is a pretty good means when comparing sites.

During the selection process, we will often do some fairly quick plans to test how the "finalists" fare when considered with programmatic needs. Often spaces that look to be more expensive in the long run are a "better deal" because of space efficiencies and costs of operations.

Now the fun begins. With defined space needs and a likely site, we continue the design process with greater attention to detail. Continued discussions regarding general needs and organization slowly give way to detailed room sizes, equipment demands and furniture needs.

As needed, consultants are brought on and the drawings and specifications are honed and refined. All finishes are selected and systems documented in drawing and specifications that are then sent out for pricing.

Once the contractor is procured and a final cost confirmed, we work with our clients to assure that construction matches both the intent and detail of the design drawings.

Let's face it, everybody has horror stories about construction; but a combination of thorough investigation prior to design, complete design documentation, careful contracts and vigilant site supervision can keep surprises down to the very minimum.

Most of our clients rely on us to select, specify and coordinate furniture, which we see as part of the total design. Sometimes the move and even help with disposition of a former facility is part of our service.

In the end, we basically provide design and construction services in a manner that satisfies a vision and need while allowing our clients to do what they do best: sell, produce and broadcast.

One other service we provide but typically don't charge for: We make a concerted effort to revisit our past projects after six months and then again after a year of occupancy. The lessons for future projects are invaluable.

Usually it's a great time and an opportunity to get together with the people we have spent a lot of time with during the site selection, design and construction efforts.

While your work as architects and designers is largely known as serving the communications industry, do you also do work beyond radio and television?

We value our reputation within "the industry" but also readily admit that our work beyond traditional broadcast facility design is vital to providing a well-rounded perspective when we serve our radio and television clients.

Our diversity is a huge asset to our clients. There are lessons to be learned in a broad variety of places and our classroom, library and other facility design work serves to inform our work for the broadcast industry and vice-versa.

This is becoming more and more the case as spaces across the board become more utilitarian and multi-functional.

For example, our background in the making of a broad variety of acoustically sensitive spaces has been developed through years of working with smart and demanding clients in the broadcast industry. That knowledge was invaluable when we worked on the design of the new Wisconsin State Library. While a traditional library in many ways, it also serves as the continuing education hub for the legal industry.

Libraries and classrooms today need to look beyond their walls, and the spaces we design to support that aspect need to be acoustically, visually and technically sophisticated.

From the other side, the last 10 years or

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Bloomfield

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so has seen a huge change in the way we make broadcast facilities. Many of our clients in both the private and public broadcast sector are looking to build spaces that do more than just facilitate the making of content. We look to design facilities that are more accessible and open to the community at large and serve as marketing tools. Image is important in attracting the best in staff and can be a terrific sales tool.

Our institutional and non-broadcast experience — where we are often called upon to help create public forum spaces — gives us an additional insight when working with radio and television clients looking to enhance their image as being truly local.

Can you discuss a project or two that you are particularly proud of and why?

All humility aside, I can say that there are none, so far, that embarrass us or — I'm pretty sure — our clients. Accordingly, there are few projects where we, years after completion, are not in touch with the people at those facilities. We take pride in the fact that, by and large, our past projects have been embraced by the people that use them on a daily basis. It is visible in the way they are cared for and maintained. Many still look new and fresh after eight or ten years of hard use

But to answer your question, the first one that comes to mind is not the largest, the most visible or even the one with the biggest budget. The Entercom facility in Greeneville, S.C., saw us take a cheap and dumpy office building on the edge of town and rework it from the inside out to create a new facility that looks like a broadcast facility. The "re-skinning" of most of the building was more than just a pretty face, as it allowed us to look at how this effort might significantly reduce utility costs.

The existing footprint required a clever and thoughtful plan to satisfy program needs and still feel open and successful; it was accomplished by working closely with management and their chief engineer, Gerry Massey.

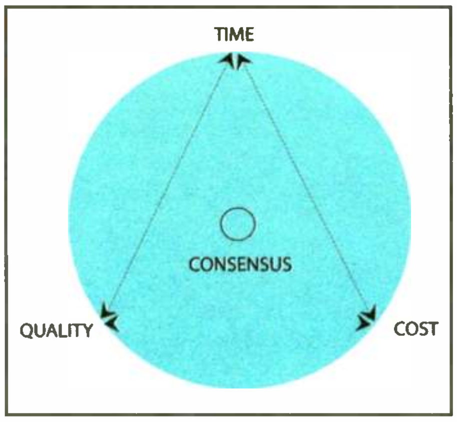
Working with Gerry — truly a gifted engineer — was terrific. Early on, we worked closely with him on the large-scale engineering issues but as integration efforts proceeded, he clearly took the lead in the making of the Technical Operations Center.

His solution to the interconnection of equipment was to use lightweight cable trays that are configured to arch over the spaces between the racks. One can't help but look at it and think of it as some sort of cathedral of communications.

The second project that comes to mind is KYW, the all-news CBS facility in Philadelphia. We had a terrific working relationship with local General Manager David Yadgaroff as well as Regional Engineer Erich Steinnagel, and Wes Spencer who watched over the project at the national level for CBS from the beginning. The result shows it.

We all quickly agreed that even though space was at a premium, the lobby should be seen as a public forum space for the city even if it was on the 10th floor of a relatively nondescript office building. It worked well as an idiom — especially given their well-placed image in the community as the epicenter of news gathering.

We looked to create a space where the public might meet the newsmakers as they proceed to studios or conference areas. From the carefully placed views of the city to the map of Philadelphia made of terrazzo tile on the lobby floor, this facility is everything about the town — short of a cheesesteak vendor.



Do you want it fast, cheap or done well? Pick two.

Steve Swalwell

Lobby of CBS Philadelphia [KYW]

Name the three most important aspects of the design of a radio facility in your opinion.

Only three? OK, how about time, design and money.

Clearly there are other very important aspects but these three are probably not a bad beginning to the discussion.

Let's start with the time issue. Of course there is never enough time!

While it may sound way off in the distance, for many efforts, two to three years out is not a bad view shed when getting started. No matter what the project, the more likely you are able to meet your budget and satisfy your other goals if you have allocated enough time. Page 84 in our book "A Face for Radio" includes this diagram (see illustration). Essentially, if you want quality and have a tight budget, give it plenty of time. The inverse of this, of course, explains that if you are short on time, maintaining quality will likely be more expensive.

Entercom Greenville — Before ...

... And After

With time comes the opportunity to consider a variety of options. That seems like a good segue into the next item on my list of three: design.

Any architect designing a broadcast, or any, facility worth his or her salt must first listen. Architect Louis Kahn is often quoted as saying "Let the site speak to you before you speak to the site." In these types of projects, we think that the users often constitute the site and that good ideas come from a broad variety of places.

The design professionals and team leaders need to listen carefully and incorporate the best ideas whenever possible. Not only does it make for a better product, it encourages an "ownership" of the facility that sets a stage for success that goes well beyond bricks and mortar.

Yes, knowledge of the industry is important and experience with regards to technical components, acoustics and working methodologies is often invaluable. However, good design and successful spaces are made by thoughtful interaction between client and architect. We look at it as "visioning" what our clients "envision."

That good team of user and designer works best if the budget is developed early on and seen as something of a "living" document. If the final dollars are set but the allocation open to adjustment, there are often savings to be had by adjusting budget figures between disciplines.

For example, it may be as simple as looking at how the technology components are bought. In some cases it makes sense for the general contractor to install some of it as part of his or her electrical package; in other cases it does not. Clearly the technology parts and their budget development must be integral to the architectural at all times. The same is true for the furniture and millwork budget. Often a contractor can provide work surfaces cheaper than system furniture suppliers; in other cases the inverse is true.

With careful thought, there are opportunities to save along the way and stay on budget as long as the big picture is kept in mind.

Thoughts about where the design of facilities is heading?

Believe it or not, I think that we may see some simplification and, with that, some reduction in costs. I say that cautiously but it is based on my observing things like the development of market-driven audio equipment such as highly specific microphones and electronic methods of acoustic controls.

That being said, I also believe that broadcast facilities — and our task to create the best possible — are essentially places for people to meet, work and do their best. I will always believe that well-designed work places attract and encourage the best. It takes little extra effort — and often less or no more money — to create a thoughtful, energy-efficient, fun, sophisticated and flexible work environment.

The ho-hum is sometimes the most expedient, but why bother? If you are going to jump into a project, do it right: Understand the budget early on, get a handle on the schedule and make sure you are working with a great team. The rest will fall into place and you can be assured of the correct solution for the long and short term. ■

No Matter What Your Politics...
ACCESS is YOUR Winning Strategy!




Conventions' Journalists are Real-World Super Heroes

Once every four years, the two major US political parties roll out the red carpet and prepare to officially nominate their party's candidates for the Presidency of the United States. Journalists from all over the world are in attendance, grabbing interviews as well as offering coverage and commentary. It's exceptionally fast paced, dense with opportunities to grab passing dignitaries or pundits and put them on the air. The best possible way to be ready is to have ACCESS and a huge number of them did.

ACCESS delivers mono or stereo over DSL, Cable, Wi-Fi, 3G cellular, satellite, POTS (yep, ACCESS is a full featured POTS codec and works seamlessly with Matrix, Vector and Bluebox)—plus some services you may not have even heard of. Given the challenges of the public Internet, it's no small boast to say that ACCESS will perform in real time over most available IP connections.

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Can a radio console be over-engineered?

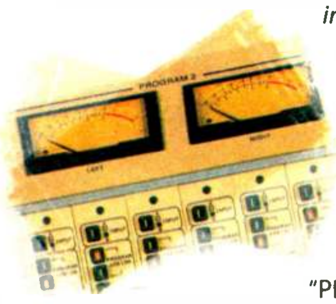
(Only if you think "good enough" really is good enough.)

"OCD" redefined

Building great consoles is more than punching holes in sheet metal and stuffing a few switches in them. Building a great console takes time, brain-power and determination. That's why we've hired brilliant engineers who are certified "OCD": **Obsessive Console Designers,** 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** – it was still called **Pacific Recorders** then – 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 were ultra-reliable, sounded great, and 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 the 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 computers in radio studios, and we decided to work together."

A new kind of console

In 2003, Axia was launched 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 to use than ever.

Our team of engineers 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.

There's a reason these board-ops are smiling. Axia consoles are in more than 1000 studios worldwide.

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 just one skinny CAT-6 cable.

Lots of well-known broadcast software and hardware companies (over two dozen already) now make products that work directly with Livewire. 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.

And Livewire lets you bring computer audio into the air chain without going through multiple A/D/A conversions. Our **IP-Audio Driver** lets you connect computers directly to the network without any intermediate I/O — all that's needed is a CAT-5 cable and your computer's Ethernet port.

Feature packed

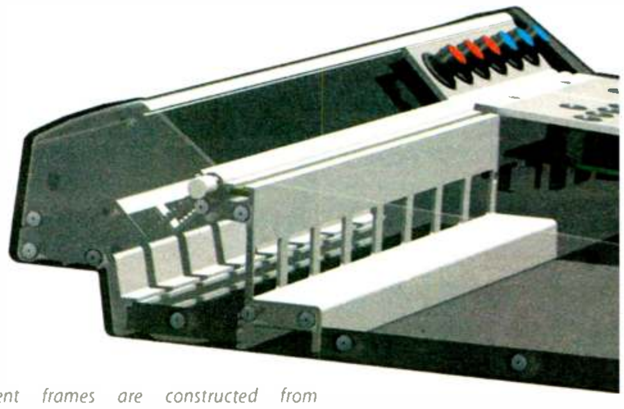
Board-ops told us they wanted a console that's **powerful, yet easy to use.** So we designed Element to be user-friendly, yet still have all the power of a full-on production board.

For example, Element Show Profiles can **recall each operator's favorite settings** with the push of a button — audio sources, fader assignments, monitor settings and more. And each jock's Show Profile contains personalized **Mic Processing** and **Voice EQ** settings that load every time they're on the air (so the midday guy will stop badgering you for "just a little more low end"). There's even a "panic button": one key-press returns a Show Profile to its default state instantly. (No more 3 A.M. "Help!" calls.)

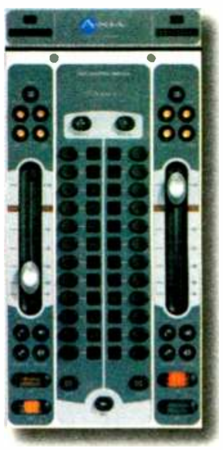
First Axia console prototype. Nice test stand, Catfish.

Did we say "mic processing"? You bet. Every voice channel gets **studio-grade compression, de-essing and expansion** from the processing experts at Omnia, plus three-band parametric EQ to sweeten the deal. There's even built-in **headphone processing** so you don't have to waste money building a separate side-chain just for the studio cans.

Jocks have complained for years that making a mix-minus is too hard — so Element **constructs mix-minuses automatically**. Plus, mix-minus settings are saved for each audio source, so that sources, backfeed and machine logic all load at once. And every fader has a "Talkback" key to **communicate with phone callers**, remote talent or other studios using the console mic.



Element frames are constructed from custom aluminum extrusions for maximum rigidity. Module face plates and console side panels are machined from thick plate aluminum. Even the hand rest is a beefy extrusion. With all this heavy metal, even that ham-handed overnight jock won't be able to dent it.

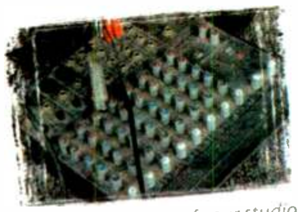


Speaking of phones, board-ops have enough distractions without having to reach for an outboard phone control panel. Element has **hybrid controls with dedicated faders** for Telos talkshow systems; there's even a **dial pad** so jocks can dial, pick up, screen and drop calls without ever diverting their attention from the console.

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".

The radio console, redefined.

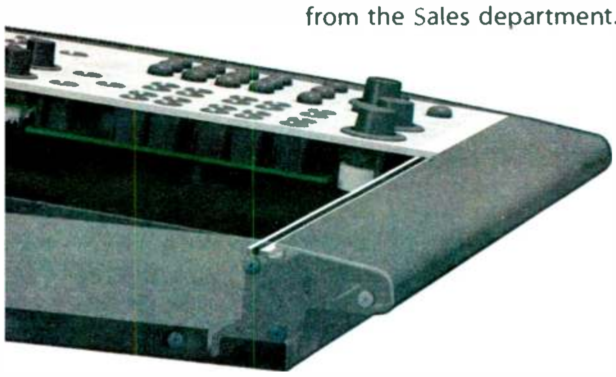
Element was designed to fulfill either a **production or on-air** role, with amazingly powerful features waiting just beneath the intuitive surface. For instance, Element can mix in 5.1 Surround as well as stereo. That's standard; **nothing extra to buy** (except more speakers). There are four stereo Aux Sends and two Aux Returns, so production guys can use their favorite outboard FX boxes. Great for **custom IFB feeds**, too.



Clear the junk out of your studio. Element has 8 submixers built in.

Got a PA mixer tucked away in a studio corner to mix mics for live performers, talk shows and such? Element has **8 Virtual Mixers** — no outboard gear needed. And the Virtual Mixers emulate ACU-1s, allowing tight integration with automation and satellite systems.

You can **administer Element remotely**, from home, the airport — wherever there's network access. A password-protected web server lets you examine the state of the console, see what's on the air and even fix operator mistakes, without ever leaving the comfort of that new Aeron™ desk chair you (ahem) "requisitioned" from the Sales department.



Small VU meters mounted at desk level are hard to read, so we re-invented the traditional meter bridge. Element's **big meters** are presented on an easy-to-read computer monitor along with large analog and digital clocks, event and countdown timers, and tallies that light when mics are open, delay is active, or during phone calls. You can even customize the display by adding your station's logo.

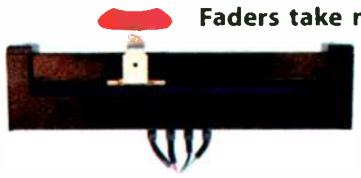
Beneath the surface

There's more to building a great board than just features. **Consoles have to be rugged,** to perform flawlessly 24/7, 365 days-a-year, for years at a time. So when it came time to choose the components that would go into Element, we literally scoured the globe for the absolute best parts — parts that would take the torture that jocks dish out on a daily basis.

First, Element is fabricated from thick, **machined aluminum extrusions** for rigidity and RF immunity. The result: a board that will stand up to nearly anything.

With so many devices in the studio these days, the last thing anyone needs is gear with a noisy cooling fan. That's why Element's **power-supply is fanless**, for perfectly silent in-studio operation.

Element modules are **hot-swappable**, of course, and quickly removable. They connect to the frame via CAT-5, so pulling one is as simple as removing two screws and unplugging an RJ — no motherboard or edge connectors here.



Faders take massive abuse. The ones used in other consoles have a big slot on top that sucks in dirt, crumbs and liquid like the government sucks in taxes. By contrast, our silky-smooth conductive-plastic faders actuate from the side, so **grunge can't get in**. And our rotary controls are high-end optical encoders, rated for more than **five million rotations**. No wipers to clean or wear out — they'll last so long, they'll outlive your mother-in-law (and that's saying something).

Element's **avionics-grade switches** are cut from the same cloth. Our design team was so obsessed with finding the perfect long-life components that they actually built a mechanical "finger" to test switches! Some supposedly "long life" switches failed after just 100,000 activations; when they found the switches used in Element, they shut off the machine after **2 million operations** and declared a winner. (The losers got all-expense-paid vacations to the landfill.)

Individual components are **easy to service**, too. Faders come out after removing just two screws. Switches and rotary volume controls are likewise easy to access. And all lamps are LEDs, so you'll likely never need to replace them.

Engineers have said for years that console finishes don't stand up to day-to-day use. Silk-screened graphics wear off; plastic overlays last longer, but they crack and chip — especially around switches and fader slots, where fingers can easily get cut on the sharp, splintered edges. We decided that we could do better.

Element uses high-impact Lexan overlays with color and printing on the back, where it **can't rub off.** And instead of just sticking the Lexan to the top of the module like some folks do, our overlays are **inlaid on the milled aluminum module faces** to keep the edges from cracking and peeling — expensive to make, but worth it. For extra protection, there are **custom bezels** around faders, switches and buttons to guard those edges, too. Element modules will **look great for years.**

By the way, those on/off keys, fader knobs and bezels are our own design, custom-molded to give **positive tactile feedback**. The switch is flush with the bezel, so it's easy to find by touch. But if something gets dropped on it, the bezel keeps the switch from being accidentally activated.

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 employs an amazing network of people to provide the best support possible: Application Engineers with years of experience mapping out radio studios... the most **knowledgeable, friendly** sales people in the biz... Support Engineers who were formerly broadcast engineers. Plus a genius design team, software authors who dream code... one of the **largest R&D teams** in broadcast.

And now 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

Are Axia consoles over-engineered? **You bet.** If you're looking for a cheap, disposable console, there are plenty out there — but this ain't it. Not everyone appreciates this kind of attention to detail, but if you're one who seeks out and appreciates excellence wherever you may find it... Axia consoles are built **just for you.**

AXIA
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www.AxiaAudio.com

A DAY IN THE LIFE

by Cris Alexander

A Potent One-Two Punch

Lightning and High-Power RF Together Often Do a Lot of Damage

It wasn't too far into my radio engineering career that I learned about the destructive power of lightning — and RF. I found out early on that these two forces often go hand in hand, with one taking over where the other leaves off.

In the first instance a field service technician from the transmitter manufacturer came to the station to go through the 20 kW FM rig and get it working right. This particular transmitter was in apparently good condition. It had been purchased on the used market and the frequency had been changed by an unknown person. While the transmitter worked, it wouldn't make power no matter what I tried.

The field service tech went through the transmitter from AC input to antenna, finding and fixing a lot of little things, getting all the parameters in balance including filament, screen and PA voltage, then tuning up the exciter, driver, PA grid, neutralization and output. In the process, he checked the tube socket for broken fingerstock and overheating. At the end of the all-night session, the very sleepy tech pronounced the transmitter fit. I took him back to the airport to catch a flight home.

NOT TIGHT ENOUGH

It wasn't long after that, maybe three or four days, when disaster struck. An RF arc developed in the PA cavity, damaging the plate blocking capacitor and chimney. The station which had no auxiliary transmitter was dead in the water, off the air.

As I began to assess the damage and take things apart, the cause of the arc became apparent. The big hose clamps that held the plate blocking cap to the tube and chimney had not been tightened; they were just snug, not cranked down hard like they were supposed to be. An arc developed in the tiny gap between the fingerstock and the chimney and migrated around the cavity, creating spot-welds in some places and producing pitting in others.

I got the transmitter back on the air within a few hours. The chimney itself sustained the most damage. To get things going, I pulled it out, flipped it upside down, drilled new holes for the mounting brackets and hardware and reinstalled it. This resulted in a few extra holes here and there, but they were small enough not to matter.

The end result put smooth metal where it was needed, at the bottom closest to the plate blocking capacitor. I had to file and polish the large fingerstock on that blocking capacitor to get it smooth enough to create a solid connection.

As far as I know, that transmitter ran with the upside-down chimney for the rest of its service life. I doubt anyone ever noticed.

You can bet that from that point forward, with that transmitter and every other one that I worked on, when replacing the tube I honked down on those hose clamps as hard as I could. I had gained a healthy respect for the destructive power of RF.

Fig. 1: Lightning hit this top FM bay, pitting the surface and causing an arc within — note the discoloration due to heat.

NO SENSE

It was at that same station in the mid-1970s that I learned how lightning and RF could work in concert to do some real damage.

The station used a 12-bay Phelps-Dodge antenna side-mounted on an 800-foot tower. One day during a thunderstorm, lightning hit the tower and evidently some of the energy jumped from the tower itself to a point on the top bay of the antenna, creating a pit and starting an arc in the antenna.

Now you'd think the VSWR protection circuit in the transmitter would sense such a thing and shut the transmitter off, but I learned then (and have been reminded many times since) that "it ain't necessarily so!"

Those bays — in fact, all the interbay line, power divider and bays — were electrically behind a matching section that did some pretty hefty transformation to produce a match at the transmission line output. And there's no telling how close to an odd number of quarter-wavelengths the total length of the transmission line between transmitter output and antenna was. Add to that the line loss and things start to stack up against the VSWR sensing circuit.

An RF arc started in the top bay and was sustained by the excitation from the transmitter. As the arc melted copper, brass and Teflon, soot and bits of molten metal fell down the interbay line and accumulated on Teflon insulators below, starting additional arcs at each point. That evidently continued for some time before the reflected power detected by the transmitter increased enough to trip the overload. By then, the damage was extensive.

Fig. 2: The real damage occurred some 70 feet below the top bay. This inter-bay line was melted by the sustained RF arc.

A tower crew was called in and the first thing they did was pull the bottom elbow on the 3-1/8-inch rigid line. A pile of soot quickly accumulated on the ground, and it got bigger when they shook the line in its hangers.

The station was off the air for weeks. The entire run of transmission line was removed along with the antenna. It took a lot of parts, including top bay and power divider, to fix the antenna, and a bunch of new inners were needed to fix the line. Every 20-foot stick was disassembled, cleaned thoroughly (with a chemical that it's not lawful to use or even possess today — how did we ever survive?) and reassembled. It was a day of celebration when the signal returned to the air.

IT'S GOT TO END UP SOMEWHERE

Since those days I've seen the same scenario play out time and again, both in FM and AM installations. We have better monitoring equipment and protective circuits these days so the damage isn't usually as extensive, but it still happens.

In recent years, we had a situation with one of our 50 kW AM arrays where lightning would hit the high-power tower in the array and the static discharge across the ball gap

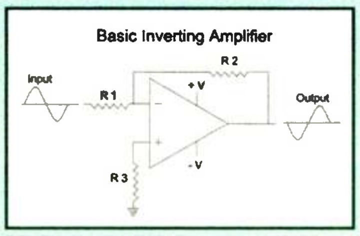
SEE LIGHTNING, PAGE 12

by Charles S. "Buc" Fitch

Gain Insight Into Op-Amp Circuits

Question Posed in the Last Issue
(Exam Level: CBT)

In the schematic, what component or components sets the amplifier stage gain?



a. The gain is set by the chip itself and can be obtained from the IC flysheet

b. The gain is set by V_{CC} as the higher the supply voltage, the higher the gain.

c. By the value of R_3 as this resistor to ground sets the offset bias seen by the op-amp hence the gain.

d. By the value of R_2 as this resistor sets up a voltage divider with the very small input resistance of the op-amp and thus the feedback level.

e. R_1 and R_2 as they create a voltage divider setting the feedback level and thus the gain.

Society of Broadcast Engineers 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 edition. 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 correct answer to the question above is **e**.

The operational amplifier (op-amp) is a high performance gain device with essentially linear qualities. Theoretically the gain of a bare op-amp is infinite, limited only by the voltage of the power supply rails.

In a practical setting, the gain needed is set by the amount of feedback as set by the feedback network. In this very simple case, that feedback network is just a resistive divider that determines the proportion of output signal that is returned to the negative input terminal. Gain in this basic inverting amplifier is equal to R2 over R1 (G=R2/R1) so the last option is the correct one.

Since the example circuit is direct coupled for amplification of a small AC signal, we would want the quiescent output to be at or near zero (midway between the plus and minus supply rails) to provide the best headroom before clipping. R_3, which controls the offset but not the gain, can be calculated to "zero" the output by the formula $R_3 = (R_1{*}R_2)/(R1+R_2)$.

There are cases where DC offset would be useful. R_3 can be used to adjust for the desired offset voltage with no effect on gain.

The answer b is incorrect as the gain is independent of the supply voltage. As op-amps are high impedance input devices, answer d is wrong on its face.

Op-amps are useful and flexible devices in electronic design, with a nearly unique combination of qualities such as:

- High impedance input such that they take little power from the source so the input does not load the source;
- Low impedance output such that they can produce a voltage (hence power) into very low impedance loads;
- Electrically quiet so they can amplify very low signals with little compromise, e.g. the output of capacitor microphone elements;
- As mentioned, the gain is independent of the supply voltage.

Since op-amps are so extraordinarily useful and flexible and because nearly every grade of certification exam reportedly has an op-amp question on it somewhere, a more comprehensive article covering the op-amp for your review follows.

Note: The deadline to sign up for the next SBE certificate exams at the local chapter level in February is Dec. 31, 2008. Details at *www.sbe.org*.

A CBRE question for the next issue: *"At a minimum, what documents should your station engineering records include for the 400-foot-AGL, company-owned FM antenna tower in the studio parking lot?"*

a. Only the FAA "Determination of No Hazard"

b. The FAA "Determination of No Hazard" and the FCC "Antenna Structure Registration"

c. The FAA "Determination of No Hazard," the FCC "Antenna Structure Registration" and the latest (last) license on the tower with lighting/marking directives

d. The FAA "Determination of No Hazard," the FCC "Antenna Structure Registration," the latest (last) license on the tower with lighting/marking directives and at least the last two years of quarterly inspections of the tower lighting, marking and structural integrity.

e. No documentation is required

Buc Fitch, P.E., CPBE, AMD, is a frequent contributor to Radio World. Miss one of his SBE Certification Columns? Visit radioworld.com. ■

Lightning

CONTINUED FROM PAGE 10

would momentarily short the tower out. In the few RF cycles that it took the solid-state transmitter's VSWR trip circuit to kill the excitation, the power distribution in the array would be totally wrecked.

The 30+ kW in that arc-shorted high-power tower had to go somewhere, and momentarily at least some of it went into the transmission line for the low-power tower. Big power and small transmission lines don't mix, and the 7/8-inch line would arc over. The transmitter would then shut off and the arc would extinguish, but the soot would remain. Then, when the transmitter restarted itself a couple of seconds later, that soot would provide a perfect arc path, and arc it would. And that 50 kW transmitter wouldn't even know an arc in the low-power branch of the circuit was happening.

You get the picture. It was ugly. And expensive. And it smelled really bad.

We tried a lot of stuff to remedy this problem (this same sequence occurred at least once a year for several years) with varying degrees of success.

First we put adjustable ball gaps at the J-plugs on each end of the line and cranked them down to the point where they would almost arc on modulation peaks. Then we put fuses in series. That cut down on most of the problem, but we still sustained damage every couple of years.

The trick that finally solved the problem — and we're almost four years into this now — was constructing an outboard circuit that puts the transmitter in "Low-2" (10 kW) when the first VSWR trip occurs.

The theory is that there are usually several VSWR events, caused by static discharges across the ball gaps, before the big strike that starts the damage sequence. By knocking the transmitter down to 10 kW before the big one happens, even when the power distribution is momentarily wrecked, the power handling capability of the 7/8-inch line is not exceeded. So far, so good.

Last summer, I dealt with a situation very similar to that first experience with lightning hitting a top bay. In this case, that top bay was part of an ERI SHPX-8AC some 1,330 feet up in the air. There was considerable pitting on the surface of the bay where the lightning danced around, and there was discoloration where the arc occurred internally (see Fig. 1).

But interestingly, it was some 70 feet below that top bay where the worst of the damage occurred (Fig. 2). Fortunately, the transmission line was not affected. But even so, the price tag for fixing the damage was almost $60,000, most of that labor. It costs a lot to rig a tower that tall.

So often it's a combination of lightning *and* RF that does the damage. Sometimes it's RF alone, and that's usually a function of something loose, as it was with the FM transmitter way back when. And sometimes it's lightning alone that does direct or indirect damage.

But it's the situations where the two work together to conspire against us that we have to really watch out for. Looking at the damage on that ERI antenna, I can't help but think that if the station had been off the air when the lightning hit, there would have been little or no damage from the strike. It's the one-two punch of lightning and RF that is so devastating.

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

Conventions

CONTINUED FROM PAGE 3

This meant planning a second live broadcast site from Denver and replicating all of our telecommunications orders for this one day of live broadcasting.

Our difficulties paled in comparison to what would be required from Qwest Communications, the telecommunications provider for the event. Essentially, Qwest would need to set up the equivalent of a medium-sized city's worth of telephone circuits for one day's use and tear it all down again for an exhibition football game the following week.

SITE DESCRIPTIONS

As time and planning continued, our requirements became clear and I was able to place orders for on-site services.

As a radio station, we wanted our live broadcasts to come from what is called Radio Row in the convention centers. Radio Row clusters the majority of radio stations in one area. It creates a buzz of broadcast activity that is a good background for live programs as well as opportunities to interview interesting party delegates and political figures, many of whom will pass through the area to indicate their availability.

At Radio Row we planned to build a kind of remote studio — Mackie 16-channel mixer with a home-made IFB box, Musicam ISDN codec, Telos phone hybrid and four Sennheiser headsets for the guests and hosts. I find the headsets to be a very good solution for such a dynamic environment where it is difficult to keep people speaking into their microphones and the background noise level threatens to overwhelm everything. They are also easy to set up and take down compared to separate microphone and headphone arrangements.

One other neat piece of equipment was a Mackie headphone mixer that allowed us to build a custom monitoring environment for each headset. This permitted us to use different IFB for each headset if desired and saved us the weight and complexity of individual headphone amps for each feed.

Before I left Boston, I set up the entire remote studio in our event room so that we could test everything and make sure we had all the right cables. I took the opportunity at this time to label both mixers with pre-printed labels. I also invited the producers and audio engineers to have a look so they would know what to expect when they arrived.

The entire equipment complement was diagrammed and stored as an AutoCAD file for the next time we plan a live remote. Re-inventing wheels has a tendency to produce errors.

In addition to this remote "studio" we also needed some place for journalists to work while they were not on the air. We requested and received from the convention planners a work space allocation for each city. While these allocations come at no cost, it is necessary to provide furniture such as tables and chairs, as well as services like electrical power and telecommunications circuits. We planned a workspace that would accommodate six to eight people.

That's about all the room I have for this month. Next time, I'll talk more about the final schedule of events and my mid-western "road trip." ■

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SINCE 1963

by Charles S. "Buc" Fitch

Op-Amps Are Used Widely in Broadcast Circuits

A Primer Into the Ubiquitous Operational Amplifier

My hands-on introduction to operational amplifiers was in 1969 while in the army as a junior scientist in the Atmospheric Science Laboratory at the White Sands Proving Grounds.

We had taken a tremendous amount of data on cloud formations, wind, temperature, barometric pressure and other climate conditions. All these independent and separate data items were synchronized, quantized and then converted to magnitudes of voltage levels. Finally all this information in voltage form was run simultaneously through an analog computer to establish "trends of change" and critical event points associated with that data.

Among other tasks, my job was to build the beast of this specialized computational device (I guess it qualified as a computer.)

These machinations required us to integrate, differentiate, scale, signal process and generally "munch" the data. This data manipulation was done in operational amplifiers, or to be precise their earlier cousins, instrumentation amplifiers. These devices are really only different because they separate the functions of creating a high input impedance and amplifier gain in independent sections of laboratory precision circuitry. The op-amp integrates the two activities with the added bonus of always providing two differential inputs with opposite polarity (positive and negative).

Hundreds of tubes in the multitude of independent amp chassis meant we were never cold in our computer room even with the most frigid desert night outside.

Today's operational amplifiers in a few ICs can replace a rack of those tube units and are far more electrically quiet, not to mention being more power efficient by several orders of magnitude.

Op-amps were an invaluable basic technology in 1969. What today's op-amps can accomplish has expanded dramatically. At present an op-amp is defined as a general-purpose, DC-coupled, high-gain, (normally) inverting external feedback amplifier.

With the invention of the transistor in 1947 (for our related *Milestone* article about the transistor radio, visit *radioworld.com* and type "The Transistor Portable Radio" into the Search field), a parallel development program of tube and discrete transistor op-amp devices competed until integrated circuit technology emerged in 1959, with the first of the IC op-amps appearing in 1961. The 741 op-amp IC, priced under $1, came to market in 1968, moving the device from novelty to the mainstream of design. See Fig. 1 for the functional diagram of the 741.

Focusing on just linear designs let's look

SEE OP-AMPS, PAGE 15

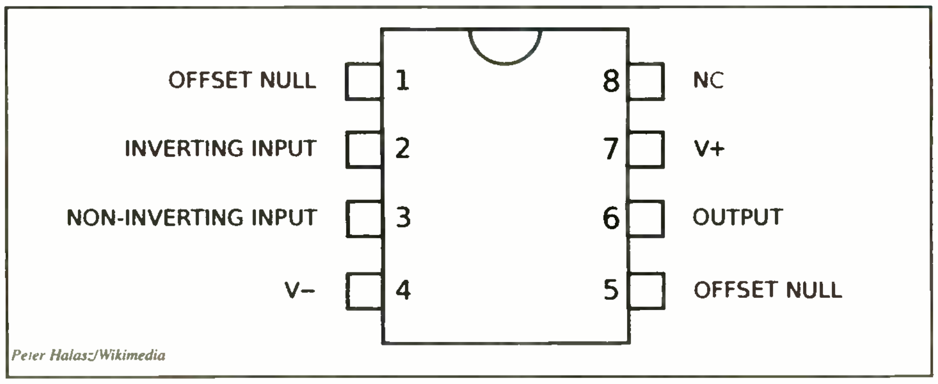


Fig. 1: Pin-out of the LM-741

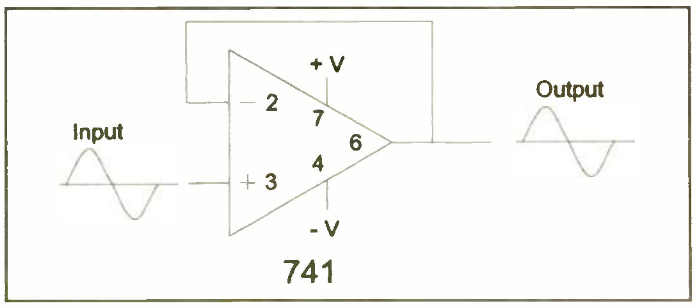


Fig. 2: Unity-Gain Follower (Non-Inverting)

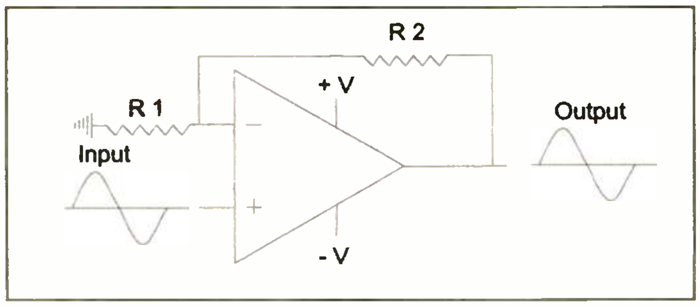


Fig. 3: Basic Non-Inverting Amplifier

Op-Amps

CONTINUED FROM PAGE 14

at some applications of the 741 as a typical op-amp.

USES

Fig. 2 shows a 741 in its most fundamental state, a unity gain configuration normally used as an isolation buffer between stages.

Fig. 3 is the same non-inverting configuration but set up to achieve some value of gain as set by the addition of resistors R_1 and R_2.

This arrangement provides gain set by R_1 and R_2 with the associated formula, $G = 1 + (R_2/R_1)$.

In this issue's *SBE Certification Corner* (page 12) we showed an op-amp in the classic inverting configuration. In comparing the formulas for inverting and non-inverting format, one can see that a non-inverting op-amp can never have gain of less then one.

Of the many valuable features of the op-amp, its very high input impedance is probably the most valuable. The input impedance of the inverting op-amp is set by the series input resistor (R_1). This allows a very useful flexibility in impedance matching. In the non-inverting configuration, with direct input, the op-amp itself sets the impedance, which is usually in the range of millions of ohms.

Because gain in both the inverting and non-inverting configurations is set by the feedback, it should be intuitive that if we can "tailor" the feedback as a function of frequency, we can influence the response of the amplifier.

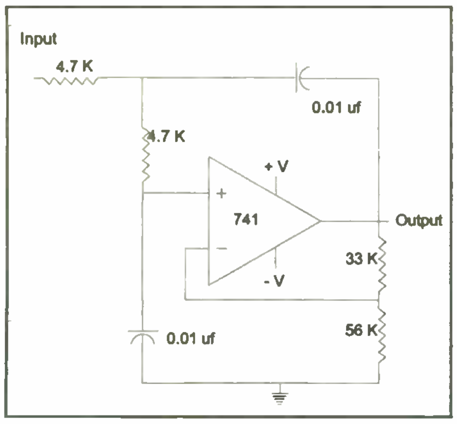


Fig. 4: Low-Pass Filter

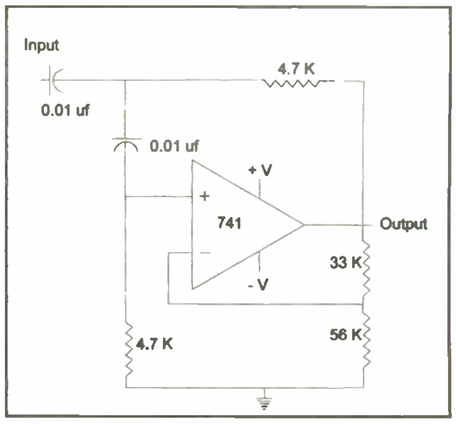


Fig. 5: High-Pass Filter

The circuit in Fig. 4 is a low-pass filter in a non-inverting arrangement that allows frequencies up to about 2 kHz to pass flat (the amp's stage gain figure) with the practical values shown. At this point the response of the filter begins to roll off in correlation to the decreasing X_c of the feedback capacitors. Generally speaking the "cutoff frequency" is the point where the output voltage falls to 0.707 of the peak output.

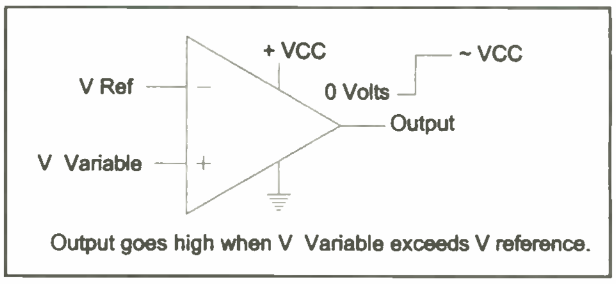


Fig. 6: Basic Non-Inverting Comparator

Theoretically, inductors could replace these capacitors and with the same values of reactance we would then have a high-pass filter with an inverse frequency response curve. However inductors are not usually used as they will pass DC, which can complicate some applications, and they also have a finite amount of resistance from the wire in the inductor, which again can complicate high frequency performance.

Rearranging the capacitors so that the feedback curve is reversed creates a high-pass filter as shown in Fig. 5.

A downside of these circuits is the progressive shifting in phase of the signals going through the op-amp due to the action of the reactive feedback elements. In many cases this is critical when the system has to be phase linear. If it is not critical, such as using the low-pass circuit to remove the hiss on an incoming audio line from a sports remote, the results are amazing for the circuit simplicity.

This is a good place to mention that besides determining gain, negative feedback is almost always needed to stabilize the op-amp. Many high-performance ICs that have exceptional frequency and gain numbers can and will go into self-oscillation without feedback stability. The frequency of oscillation will usually be set by either the stray reactances the op-amp output signal encounters on its way to the input on the PCB (quite often through the power supply system) or by its alpha (voltage gain) cutoff where the IC runs up to the highest frequency at which its gain is unity.

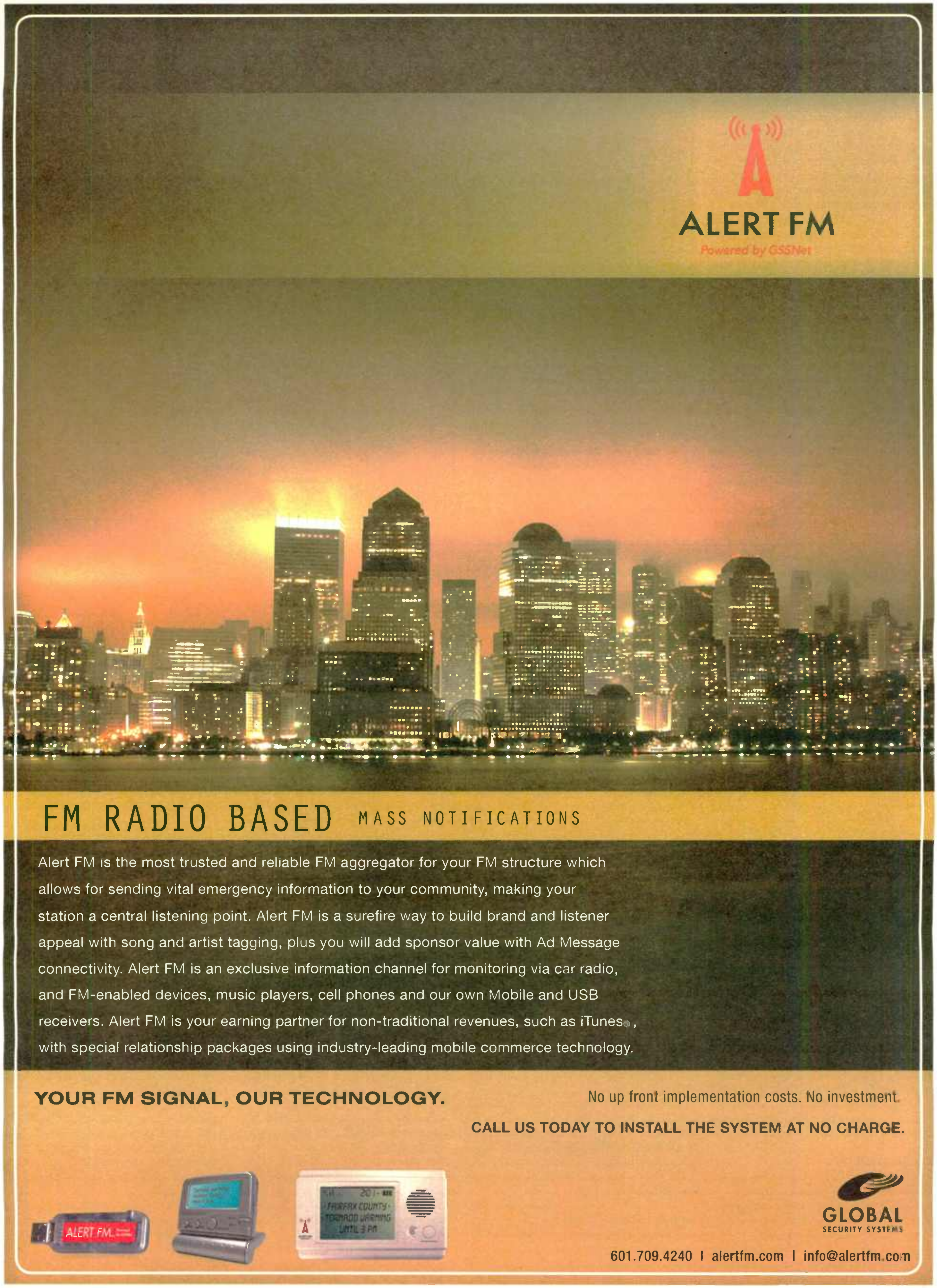
The op-amp responds well to mathematical analysis for design but they are not perfect black boxes. As in all transistor devices frequency response has finite limits and the ultra linear range for most cost-effective op-amp IC devices, such as the vanilla 741, does not extend much above the audio range. With a maximum gain factor of unity at about 1 MHz, the 741 is unsuitable for video.

COMPARATOR

At the other end of the response curve, DC signals, the op-amp has many interesting applications.

One of these is the comparator. The op-amp is a differential amplifier, sensitive to the difference in potential between the + and – inputs. A comparator IC (e.g; LM.339) is really just a specialized op-amp that has been pre-compensated with an internal feedback loop such that when the differential between these two inputs occurs that the output changes state. Setting the gain below infinite with internal compensation makes the

SEE OP-AMPS, PAGE 18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Op-Amps

CONTINUED FROM PAGE 15

op-amp more stable and reduces state jittering at the decision point.

Fig. 6 is the schematic of a typical multi-section comparator op-amp that we could make using one section of a LM.339. The output will go high when the voltage on the positive input goes above the value at the negative input (and vice-versa).

Notice two special features: First, you'll observe that the op-amp is in a single supply arrangement with just a positive voltage; second, that the amp, as mentioned, is actually in high-gain configuration so when the "tipping point" value is exceeded the output goes to essentially the rail voltage.

Fig. 7 is a typical use of this arrangement creating a high ambient temperature alarm signal for your remote control system. When the DC analog of room temperature on the positive input goes above the fixed reference on the negative input (in this case an adjusted DC value corresponding to 85° F), the output of the comparator goes high giving you a voltage for the status/alarm input.

A calmer arrangement of this comparator concept with a much lower gain figure can be used as the control section of a regulated series power supply.

In Fig. 8, actually an inverting comparator, a sample of the supply output is introduced as the variable input on the negative input and the positive input has a fixed reference voltage provided by a zener diode. If the output of the supply goes above the reference, the op-amp voltage output is reduced, adjusting the supply output to the desired value. Conversely if the supply output sags, the op-amp output rises once again, bringing the supply output back to nominal.

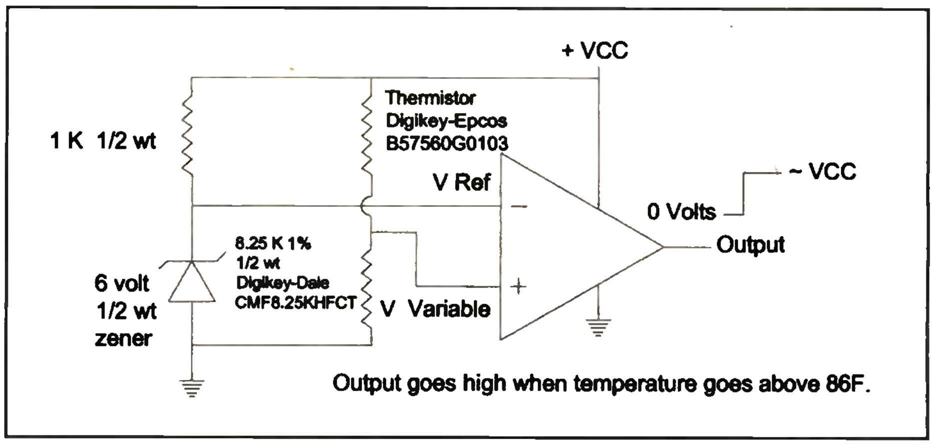

Fig. 7: Basic Non-Inverting Comparator Application

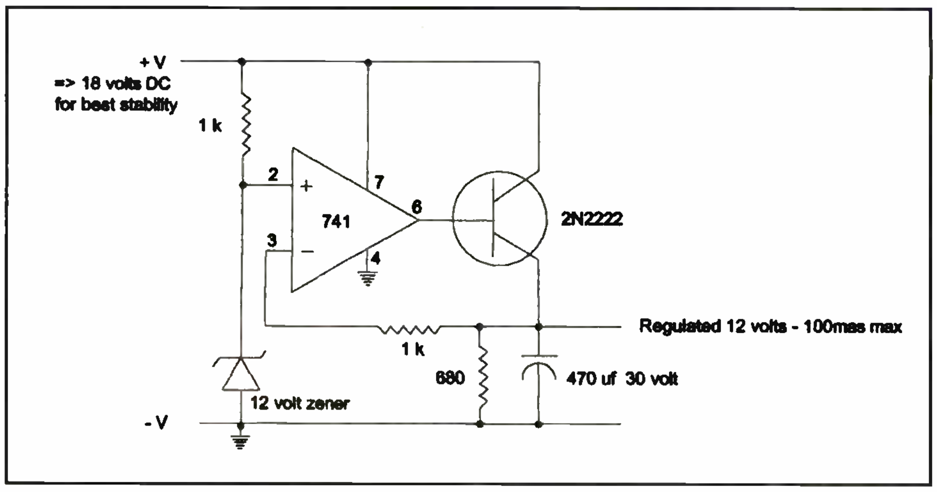

Fig. 8: 12 Volt Voltage Regulator

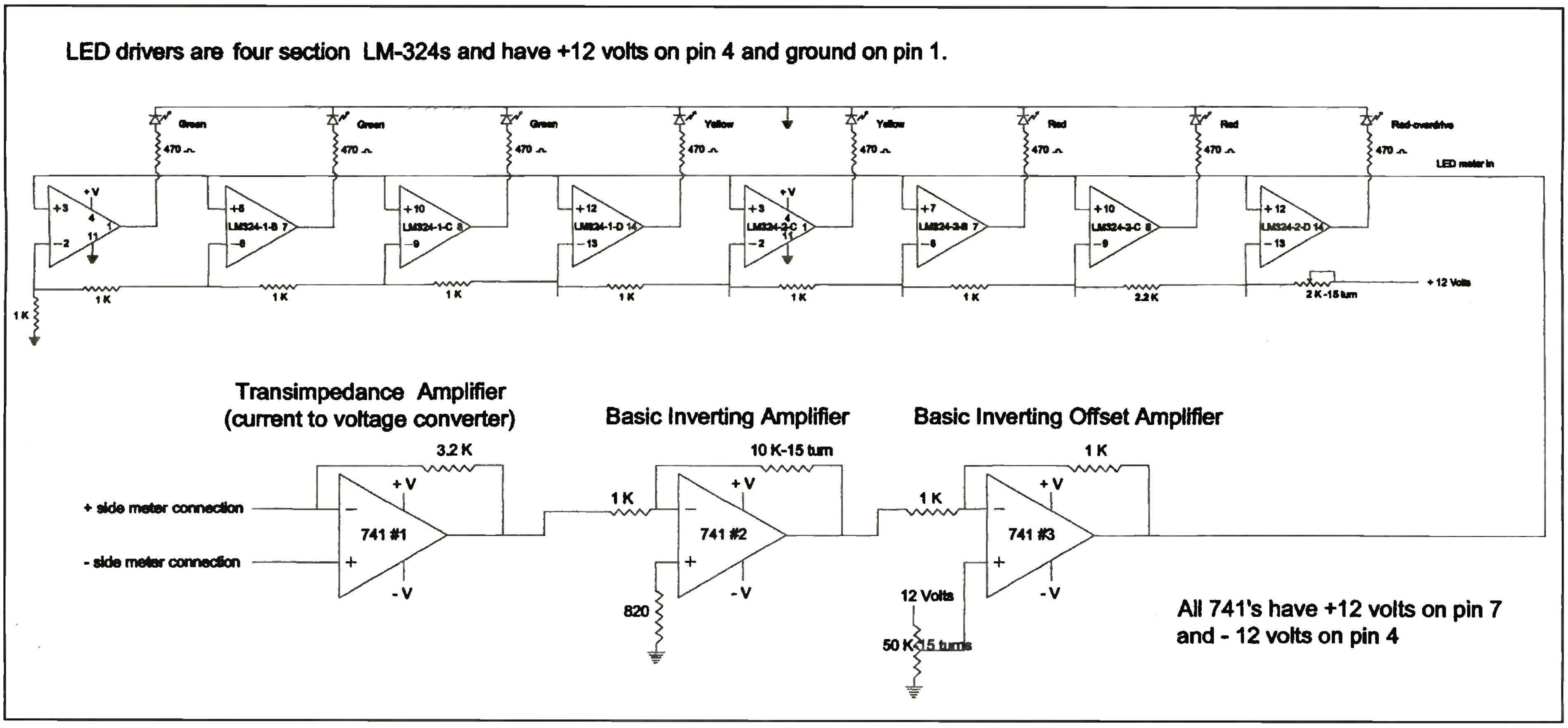

Fig. 9: CBS LED Meter

CASE STUDY

Now let's put some of these op-amp circuits together and consider a case study.

We'll look at an LED meter replacement for the analog meter on the 400 series CBS Audimax and Volumax (see Fig. 9).

The usual casualty in the long life of the classic 400 series CBS Audimax or Volumax is the DC 1 mA "compression meter." The meter actually reads an inverse current flow that drops when it indicates limiting. The resting point of no compression is actually the full scale indication and about 1 mA is flowing through the meter with no compression.

This upside-down arrangement to display compression was a conscious decision of the CBS engineers, who wanted no confusion between an ordinary VU meter (peaks up) and the compression operation of the CBS units … compression deflects down.

As mentioned, the analog meter is really showing the reduction in current flow through it. We then need to convert that representative current flow to a voltage level to drive our LED meter.

Our circuit uses three discrete 741 op-amps for this conversion and subsequent adjustment. The –12 volts needed for the 741s is taken directly from the Volumax supply and the +12 is provided by a three-pin 12 volt regulator downstream of the CBS +20 volt output.

The first 741 is a transimpedance amplifier (a current to voltage converter) where the output voltage is a function of the feedback resistor divided by the current flow. Our approximately 3 k resistor was chosen to provide a nominal –3 volt output when the current flow is 1 ma.

The second 741 is a standard inverting amplifier where we adjust the gain by varying the feedback resistance using the 50k ohm variable resistor. It increases the gain of our voltage signal but inverts the polarity to a negative range.

We need to keep the voltage swing (greatest voltage with most compression) but move it into a positive range. For this we have a third 741 which is an inverting amp with DC offset … adjusting the offset voltage pot moves the output into the positive region.

Set up your CBS unit following the instructions with a 1 mA analog meter (such as your trusty Simpson 260) in the circuit.

After wiring up your LED replacement meter, use the DC reference trimmer to set a resting place of about 1 volt output with 1 ma input from the CBS. The gain pot associated with 741 #2 is set when maximum compression is present to obtain about 10 volts out for the LED display.

The LED display uses comparators in the LED driver circuits with progressively higher trip voltages to create the LED compression display. The rest point (no compression) is fine adjusted with the pot on 741 #3. Zero current (max compression) flow precipitates 10 volts. The display steps are about 1.2 volts apart and quite effectively show the operation of the unit.

Op-amps are ubiquitous in the broadcast engineering world and for this reason a sure and certain knowledge of their uses, limitations, idiosyncrasies and design features is a valuable asset. We have only scratched the surface in this article of the immense universe of op-amps and their applications.

If readers would like to move into RF and other applications or would like some specific circuit suggestions for their station projects, let our editor know and we'll attempt to include them in future RWEE issues. Write to *radioworld@nbmedia.com.* ■

More on Op-Amps

For more adventure and further exploration of op-amps, you might start with a review of the copious material on the Web including the extensive 1978 National Semiconductor compendium of circuits; see the PDF download at *http://tinyurl.com/4tgy6h.*

Also try the main op-amp page at Analog Devices, which has some nifty design tools: *http://tinyurl.com/3tnkff.*

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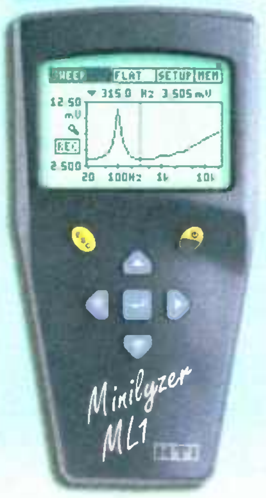

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PAPR

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little realizable gains as the major factor for not adopting IBOC at this time. While IBOC broadcast equipment cost is partly to blame, the chief reason for high conversion costs is the fact that the IBOC signal provides significant challenges to broadcast transmitter designs that often require new IBOC capable transmitters to be installed.

IBOC employs orthogonal frequency division multiplexing to broadcast the digital HD Radio signal. OFDM provides frequency diversity through the use of multiple simultaneously transmitted data carriers that combat frequency dependent fades in multipath environments. FM IBOC further leverages frequency diversity by placing upper and lower sidebands on either side of the FM modulated signal with more than 200 kHz of frequency separation. IBOC also employs time diversity through the use of data interleaving in order to deliver a more robust signal. For more information on the organization of the FM IBOC signal refer to Ref. 1 at the end of this article.

While multiple carriers in an OFDM signal provide for a robust signal, they require highly linear signal amplification in order to minimize carrier intermodulation and ensure spectral compliance. Secondly, the amplifier requires a significant amount of input backoff (IBO) in order to handle large power peaks inherent in the IBOC signal.

Fig. 1 on page 1 shows how multiple carriers constructively and destructively add due to varying phase information in the quadrature phase modulated (QPSK) data carriers.

Presented are three consecutive FM IBOC symbols. The first plot is the power envelope of a single IBOC carrier, which has a constant power envelope at baseband prior to channel modulation, similar to FM modulation. In this case, the IBOC pulse shaping function to smooth out the spectral impact of symbol transitions is apparent. The addition of a second carrier drops the average power of the signal by 3 dB, while maintaining the same power peaks, which can be expressed as the peak-to-average power ratio (PAPR).

With 20 carriers, the random nature of extreme peaks is already visible and the PAPR increases to more than 9 dB. However, FM IBOC uses a minimum of 382 carriers, further increasing the PAPR to over 12 dB. While in theory all carriers could add constructively, in practice peaks of much greater than 12 dB are rarely encountered.

While the IBOC signal power is considerably less than the FM signal power in a hybrid FM plus IBOC signal, requiring broadcasters to install a significant amount of additional transmitter power to handle these temporary peaks in power would present a significant hurdle to the adoption of HD Radio. Therefore, iBiquity Digital Corp. has provided an optional PAPR reduction algorithm as part of the standard IBOC modulator, effectively reducing IBOC signal peaks.

Note: Some literature refers to the signal's PAPR at the RF level after channel modulation. So for example, an FM modulated signal with a constant power envelope at baseband would then have a PAPR of 3 dB at the RF level due to the fact that a sine wave has a crest factor of $\sqrt{2}$ [See Ref. 2]. The same principle applies to IBOC. Provided we understand this relationship, we will continue to express the PAPR at baseband, which directly translates into the required IBO.

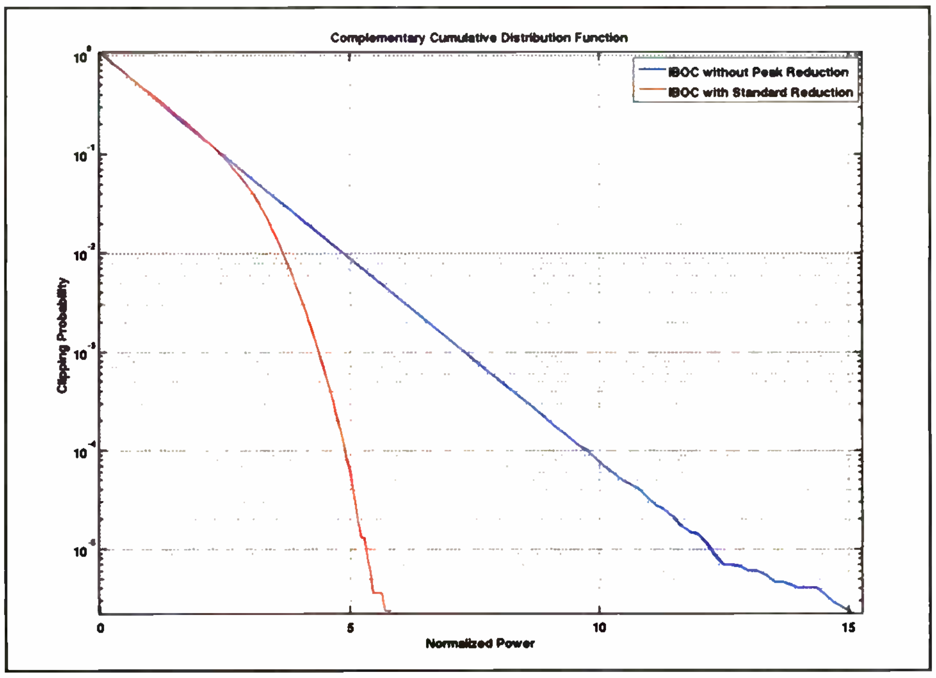

Fig. 2: Standard IBOC Peak Reduction

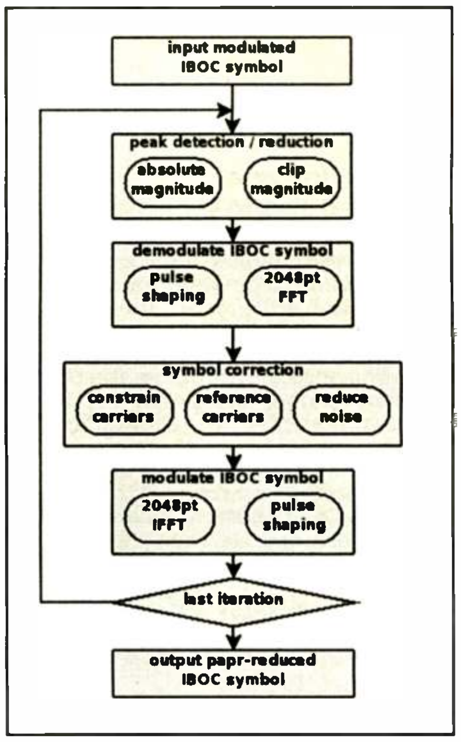

Fig. 3: Standard PAPR Reduction

A more meaningful way of quantifying peak performance compared to the PAPR, is the complementary cumulative distribution function (CCDF), which describes the signal in a statistical way. The CCDF is defined as follows:

$$CCDF(x) = P(X \geq x) = 1 - \int_{-\infty}^{x} f(t)\,dt$$

where F(x) is the probability distribution function of the signal x.

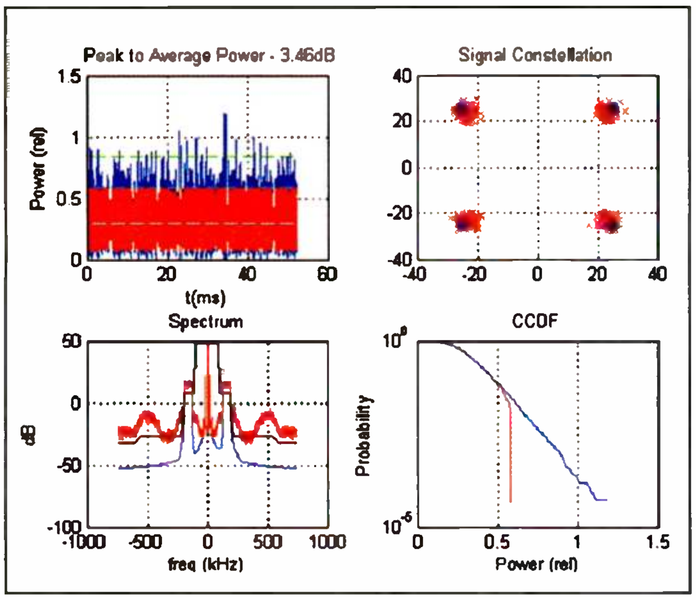

Fig. 4: Effects of Clipping the IBOC Signal

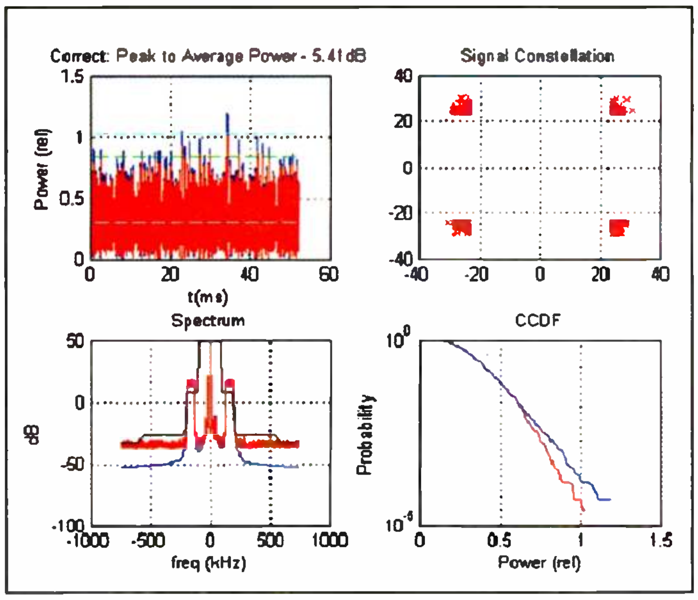

Fig. 5: Effects of Correction on a Hybrid Signal

If we take the random variable X to be the signal's power fluctuation, then the CCDF gives us the practical interpretation of the probability of clipping the signal at a given maximum power level.

Fig. 2 contrasts the CCDF of an IBOC signal to the CCDF of a peak reduced version of the signal at 1 W average power. Note that the X axis in this illustration represents a linear power scale. With a peak duration of around 1 µs, achieving a clipping probability of at least 10^{-6} (around 1 clip per second) would require an IBO of 8 dB (6 times above average power), while without peak reduction an IBO of 12 dB (15 times above average power) would be needed.

The CCDF not only provides a comparative measure, but it also provides us with an idea of how far a transmitter can be driven into saturation. It does not, however, detail the spectral effects introduced by this clipping operation, which greatly depend on the transmitter characteristics in the saturation region. Fig. 4 shows the effects of hard clipping on the spectrum and signal constellation.

While standard PAPR reduces signal peaks from 12 dB to 8 dB, in practice it has been found that peaks can be reduced further by driving the signal into compression. Depending on the transmitter, the signal can often be driven into compression to yield a final PAPR of 5.5 dB.

What this means to the broadcaster is that in order to achieve a 3 kW digital transmitter power output, a transmitter capable of delivering 10.6 kW of instantaneous power must be installed. Without standard PAPR reduction a much larger transmitter would need to be installed depending on how much that signal could be compressed in the transmitter.

As it provides significant gains we will take a closer look at the operation of the standard PAPR reduction algorithm as implemented by iBiquity.

STANDARD PAPR REDUCTION ALGORITHM

The following is a basic description of the standard PAPR reduction algorithm included by iBiquity as part of the HD Radio system as described in the patent held by Brian William Kroeger [see Ref. 3], which should be considered the authoritative source. Fig. 3 reproduces a basic version of the algorithm's flow chart presented in Ref. 3.

Peak Detection and Reduction

The standard PAPR reduction algorithm inputs a single modulated IBOC symbol at a time. Peaks are detected by computing the absolute value of each sample point and comparing it against a predefined threshold value.

Once a peak is identified, the standard PAPR reduction algorithm clips the magnitude of a sample point associated with this peak to a given threshold while maintaining the sample point's instantaneous phase value. Regardless if hard or soft clipping is applied, the act of clipping effectively introduces a delta function δ(t) to the digital signal. The nonlinear effect of adding a delta function to the signal is to add frequency content across the entire discrete frequency spectrum that is related to the magnitude of the peak reduction, which may violate the spectral emission mask. It also introduces error in the signal constellation, which degrades the noise performance of the IBOC signal.

Fig. 4 depicts the effects of clipping the IBOC signal, where the blue plots represent the original input symbol, and the red plot represents the clipped signal. A scattering of constellation points is observed that tends to move to the origin, as peak reduction tends to reduce the signal's power. This is not an issue, as the signal can easily be scaled back up in order to maintain the same output power. However, the impact on the noise floor is clearly visible and often is the limiting factor compared to the impact on the signal constellation.

Symbol Correction

Because of the signal distortion introduced in the previous step, the signal must be cleaned up. To do so, the standard PAPR reduction algorithm performs an IBOC

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PAPR

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demodulation of the distorted signal down to the individual carrier level.

This involves removing the IBOC pulse shaping from the OFDM symbol and a consequent FFT operation at a sampling rate directly related to the original symbol creation, such that each frequency bin at the output of the FFT perfectly describes the information in a single carrier.

The first part of the correction process limits the amount of error that is allowed in a single carrier by pushing the constellation point of the carrier back toward its ideal constellation point. As all carriers are QPSK modulated, this is accomplished by simply pushing all points away from the XY axes to a desired threshold but not all the way back to the ideal QPSK point. Pushing back the constellation points toward the ideal QPSK point brings back the same peaks we eliminated in the previous step. By only going part way, we increase the carrier's bit energy, but the peaks are only partially restored. Fig. 5 provides a clear example of this effect.

Particular attention must be paid to reference carriers that allow a receiver to lock on to the IBOC signal. While the amplitude is not significant, it is important that the phase of the reference carrier is preserved. Therefore, the reference carrier's phase is restored to its original value while the corrected amplitude is maintained.

As a third part of the correction process, the error in the non-carrier frequency bins must be suppressed. The same principle applies here; as we correct the signal back

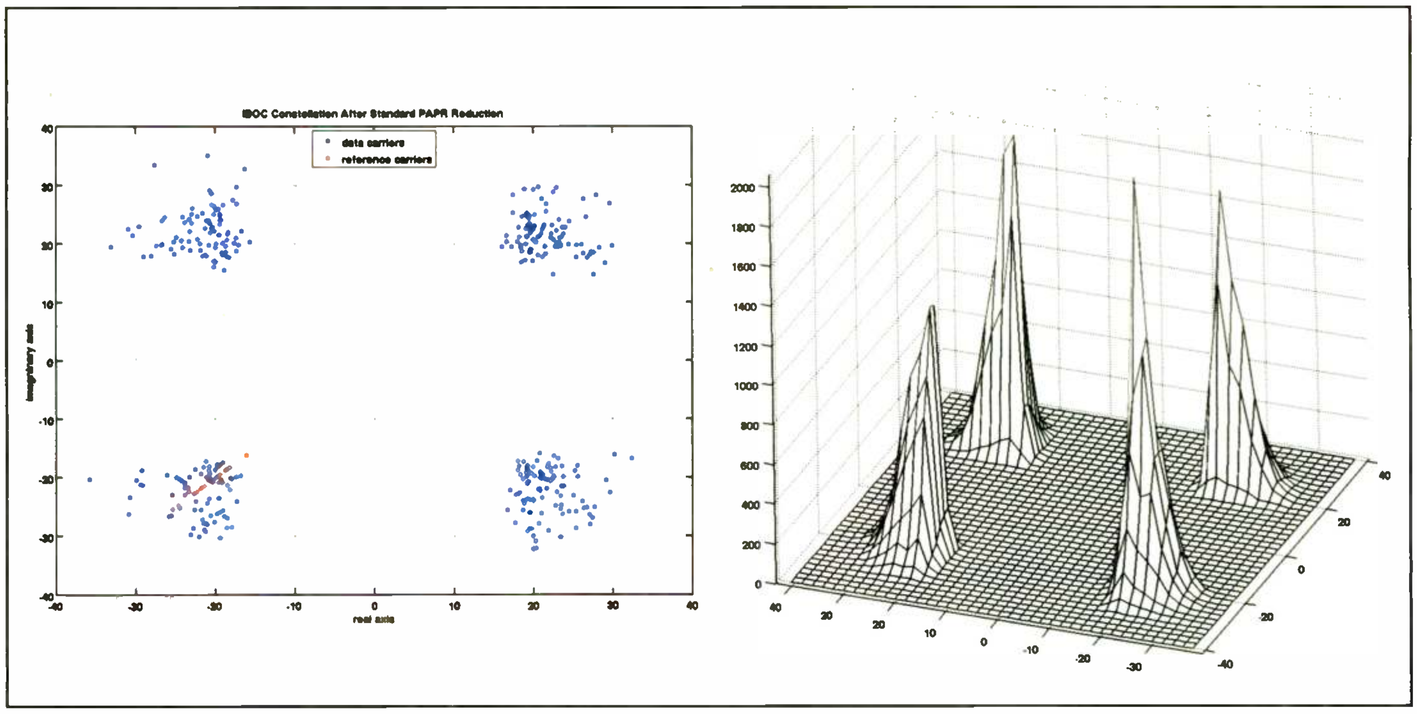

Fig. 6: IBOC Constellation and Histogram of Standard PAPR Reduced IBOC

to its original spectrum more of the peaks are starting to come back. A mask is applied in correcting this signal content, allowing varying amounts of noise to subsist in the IBOC signal without violating the spectral emission mask.

Because of the opposing effect of these steps, the PAPR reduction is an iterative process; each transition through the loop yields an improved solution. However, this is computationally expensive due to the iterative computation of a 2048 point Fast Fourier Transform (FFT) and its inverse (IFFT). Each additional iteration yields diminishing returns approaching a final limit that is mainly a function of our correction parameters, as well as the frequency and magnitude of peak reductions.

Standard PAPR Reduction Performance

With the understanding of how the standard PAPR reduction operates, we will take a closer look at the output provided by the standard exgine IBOC modulator.

The sample stream is directly captured at the exgine output and demodulated to determine the PAPR and signal constellation. It has already been determined that the standard PAPR reduction reduces the PAPR from 12 dB to under 8 dB. This represents a significant improvement, but we need to ensure that this process has not degraded the IBOC symbol's noise performance.

Fig. 6 provides a plot of the demodulated signal constellation as captured from the exgine IBOC modulator in service mode MP1. It also highlights the reference carriers in the symbol. We observe a significant spread in the signal constellation points that indeed affects the signal's noise performance. However, looking at a traditional constellation plot may lead one to incorrect conclusions. Fig. 6 also provides a

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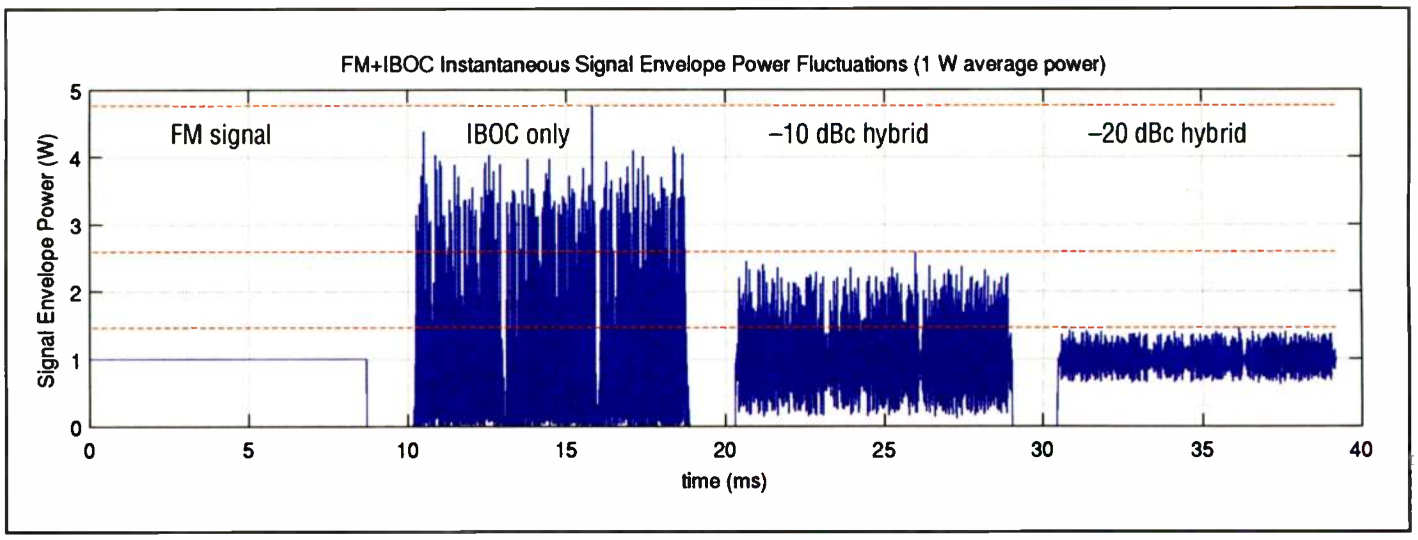

Fig. 7: Comparative Instantaneous Envelope Power Fluctuation

3D histogram that simply tallies the number of constellation points per unit area. Looking at the histogram reveals that the spread in the constellation is truly not so bad. The majority of data points are concentrated in defined clusters and only infrequent data points fall outside this region and no point approaches the bit decision boundary along the X and Y axes.

A true measure of the impact of standard PAPR reduction is to look at its noise performance in an Average White Gaussian Noise Channel (AWGN). Therefore, the output of the exgine modulator is added to AWGN, the result is demodulated and the bit errors in the carriers are tallied compared to the original symbol. Depending on the tolerable bit error rate, we can quantify the power increase required to restore noise performance back to the noise performance of an ideal QPSK modulated IBOC symbol.

Given a certain bit error rate, Table 1 lists the power ratio between the ideal symbol and its PAPR reduced version. This provides a figure of merit in comparing the error introduced into the constellation by different PAPR reduction schemes. Because of the substantial amount of forward error correction (FEC) inherent in the IBOC signal, IBOC can indeed operate in channel conditions with very high bit error rates.

Carrier Bit Error Rate	Reduction in Noise Performance (Reduced/Ideal)
$5x10^{-2}$	0.29 dB (1.07)
10^{-2}	0.49 dB (1.12)
10^{-3}	0.57 dB (1.14)
10^{-4}	0.72 dB (1.18)
10^{-5}	0.83 dB (1.21)

Table 1: Comparative Noise Performance

We are not really interested in the region of low bit errors, since FEC will provide us with great performance in that region regardless. We want to choose a bit error rate at the edge of our coverage area, but which still does provide acceptable service. For the remainder of this discussion, we take this point to be at 10^{-2} but this number may be qualified further in the future. All noise performance is to be taken with respect to the ideal IBOC symbol.

Therefore, while it is computationally expensive, standard IBOC PAPR reduction is a very effective means of peak reduction that only introduces a small to moderate degradation in noise performance.

However, the argument could be made that the algorithm's parameters should be under a broadcaster's control, as it is conceptually conceivable to relax correction parameters to achieve greater gains in peak reduction and only incur a further small degradation in noise performance. We will look at the performance and applicability of this PAPR reduction in a hybrid system next.

10 dB CARRIER INCREASES: THE NEW REALITY

When discussing the effectiveness of the standard PAPR reduction in the context of low-level combined IBOC, we must touch on recent developments that aim to increase digital carrier power levels by 10 dB in a hybrid waveform. The proposed increase is an effort to match more closely the coverage area of the IBOC signal to the comparable coverage area of the simulcast FM signal and to improve building penetration and general IBOC signal robustness.

While it is outside of the scope of this paper to discuss this development in detail, we have to look at the applicability and effectiveness of the standard PAPR reduction in the context of this new development.

Increasing digital carriers by 10 dB only increases the average IBOC signal power from 1 percent to 10 percent of the transmitted FM signal. However, it would be a grave mistake to think that this change would have only minor implications to a low-level combined hybrid transmitter.

By now, it is apparent that broadcast transmitters are limited by their peak power capability and not their average power capability. So we must look at the signal peaks as shown in Fig. 7, which depicts the baseband power envelope of an analog modulated FM signal, a digital only signal, and a hybrid signal at –10 dBc and –20 dBc injection levels all at the same average power of 1 W.

While at –20 dBc about 40 percent of transmitter overhead was sufficient, going to –10 dBc carriers we now require more than 160 percent of transmitter power. Assuming that the spectral emission mask stays at current levels, this means that this hybrid waveform cannot be driven into amplifier compression to the same degree as in the –10 dBc case. Therefore, almost all of the signal must fall into a linear amplification region. This now means that in order to achieve a hybrid TPO of 8 kW one must install a transmitter capable of handling 22 kW, while a 11 kW transmitter suffices at –20 dBc.

Fig. 8 depicts the power distribution of hybrid signals at different injection levels all scaled to the same average power. The absolute maximum point is indicated via the red dashed line and the corresponding PAPR ratios are given in the legend. This leads us to a significant observation:

As the analog component of the signal increases, the peak distribution of the resulting hybrid signal changes shape. The peaks in the digital waveform are not necessarily the same as in the hybrid waveform.

While it is true that a peak reduction in the IBOC signal is beneficial to the hybrid waveform, a peak in the IBOC signal may in fact not turn out to be a peak in the hybrid signal, if the addition of the FM signal to the IBOC signal happens to add destructively. On the flip side, a lower IBOC signal peak may entirely add constructively to the FM signal creating a notable peak in the hybrid signal.

While this fact has received little attention at –20 dBc carriers, for the –10 dBc carrier case, this observation makes a significant difference. In short, peak reduction must simply be performed on the final signal that is to be passed through the power amplifier of the transmitter. However, the standard PAPR reduction scheme cannot simply be applied to a hybrid signal without significant changes to both the algorithm operation as well as the implemented radio systems broadcast architecture, as defined by iBiquity Digital Radio. The remainder of this paper will detail Nautel's innovative approach to peak reduction in a hybrid signal.

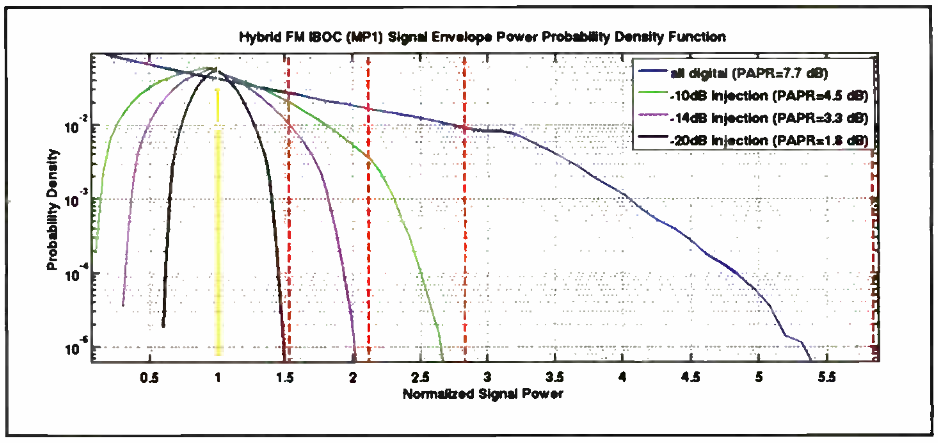

Fig. 8: Hybrid FM+IBOC Signal Distribution

PROPOSED PAPR REDUCTION

This section outlines the operation and innovation in the proposed PAPR reduction method.

Peak Detection

The major difference between the standard PAPR reduction and our proposed PAPR reduction is a difference in peak detection. Fig. 9 contrasts the difference of peak detection in the standard PAPR reduction vs. the proposed reduction method at a single instance in time.

Fig. 9 depicts a complex plane, where the X axis reflects the baseband signal's real (or in phase – I) component and the Y axis represents the signal's imaginary (or quadrature – Q) component. As the analog component of the signal increases, the peak distribution of the resulting hybrid signal changes shape. The peaks in the digital waveform are not necessarily the same peaks in the hybrid waveform.

The first graphic illustrates the case of standard PAPR reduction that only operates on the digital signal and then adds the result to the analog signal. The second graphic, on the other hand, shows how the analog signal is taken into account in detecting a peak.

The output of the FM modulation process produces a constant envelope signal with varying phase. At baseband, this signal is represented as a vector in the complex plane with constant amplitude, which is represented by the white circle in our illustration.

For the sake of comparison, let us assume that both methods could achieve the same level of peak reduction. Since the standard PAPR reduction method is agnostic of the analog modulation, it can only detect a peak based on the digital signal alone and it does not know whether this peak adds constructively or destructively to the analog signal.

Should the peak add constructively, then the standard reduction method performs the correct operation by introducing a large peak correction. However, if the peak adds destructively to the analog, the standard PAPR reduction unnecessarily performs a potentially large peak reduction.

For demonstration purposes, if we choose an analog signal point at one point in time and perform a vector addition of all possible digital signal points, then a peak in the digital signal creates a large circle around the analog signal point. The standard PAPR reduction method reduces the peaks in the digital signal down to the radius of the inner circle, which borders the circle representing the maximum desired peak of the combined signal. This leaves a large area in the complex plane where peak reduction is performed as indicated by the red shaded area in the illustration. Hence, the standard PAPR reduction scheme causes many samples to be unnecessarily corrected when they do not in fact form an actual signal peak after combining with the FM signal.

The proposed innovation suggests a different approach for determining the correction vector C, which is used as the input to the peak correction process. When determining a peak, the analog vector A is first added to the digital vector D. The resultant hybrid vector H is then compared to the maximum desired peak threshold. Only if the digital signal adds constructively to the analog signal, is a large correction required. A smaller correction is needed if the vector addition falls close to the maximum desired peak and no correction is required if the

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result is below the maximum desired peak.

Our illustration comparatively shows a red shaded region where a relatively large correction is required in the same way as is performed in standard PAPR reduction and a yellow shaded region where only a smaller degree of correction is required.

Using the proposed PAPR reduction method yields a much smaller region that requires a large correction. By introducing a lower amount of correction, the proposed algorithm can achieve the same maximum desired peak value with a lower degree of distortion in the original signal. This allows us to reduce the signal's peaks further compared to the standard PAPR reduction method.

In order to realize this difference in peak detection, the standard PAPR reduction algorithm, and consequently the broadcast architecture for IBOC, must be somewhat modified. Fig. 10 highlights the differences in red to the standard PAPR reduction method shown previously.

Fundamentally, the biggest difference is the fact that the digital IBOC modulator must now know about the FM modulated MPX signal, while the standard PAPR method does not require this input. The FM signal, as well as the non-PAPR reduced symbol, are both interpolated to a higher sample rate. While digital sampling theory faithfully preserves a signal's frequency content, there is no guarantee that the signal's peaks fall on discrete sample points. An interpolation process allows us to captures peaks more reliably. Performing PAPR reduction at the standard IBOC sample rate of 744 k samples/second may miss actual signal peaks by 30–40 percent. By interpolating by a factor of 2, this error is reduced to around 5 percent for the IBOC signal, but it significantly increases computational requirements.

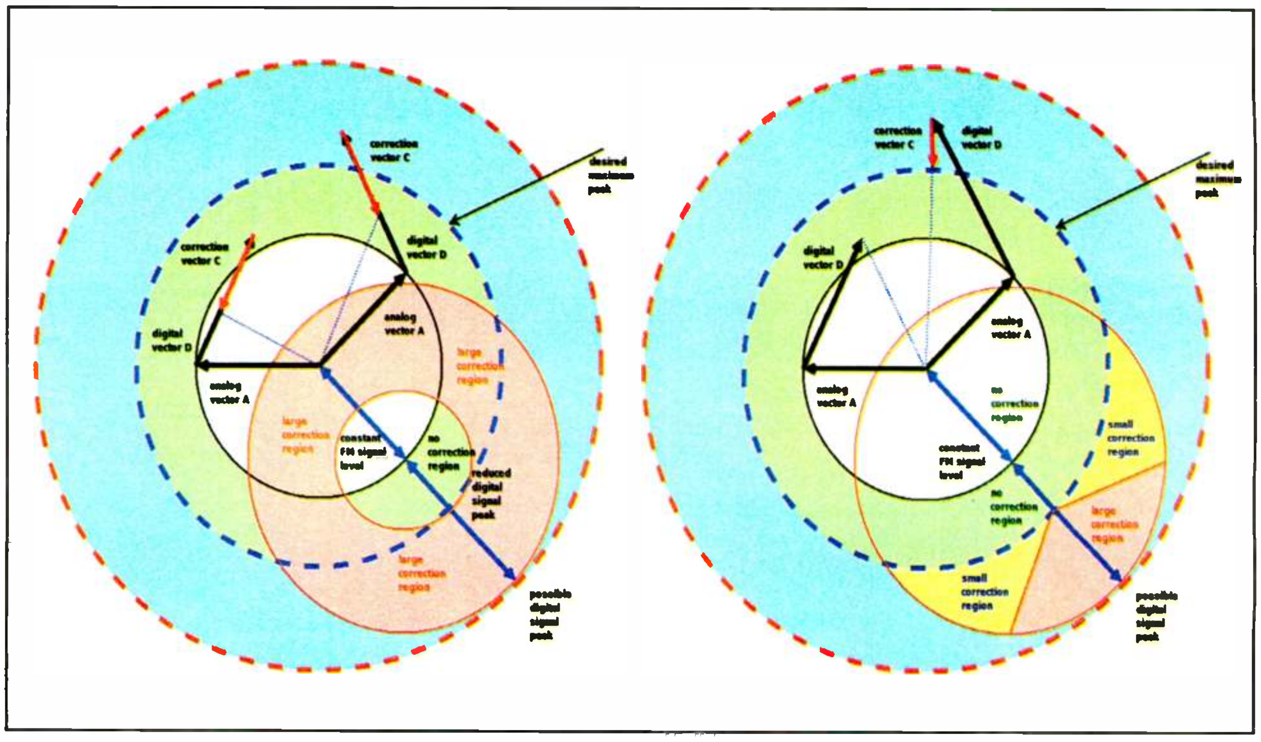

Fig. 9: Standard Peak Clipping (left) Contrasted to Hybrid Optimized Peak Clipping (right)

Peak Reduction

With the standard PAPR reduction algorithm it was found that hard clipping provides an efficient and effective means of peak reduction. In our discussion thus far, this simply means that the correction vector C is added to the digital vector D on a sample per sample basis. A similar approach can be employed for our case. By not simply clipping the hybrid signal, but keeping the correction vector C separate and only applying it to the digital component, it allows us to use the established correction techniques described with the standard PAPR reduction. It also uses the FM signal only during the clipping decision process and, thereby, faithfully maintains the FM portion of this signal until it is finally added to the digital component to form the hybrid signal stream. Therefore, the FM transmission is not impacted by the proposed PAPR reduction technique.

Applying the correction vector directly to the digital symbol essentially clips peaks. However, based on the correction vector we could also create an error signal as follows:

$$E[n] = \sum_{k=0}^{length-1} \text{correction function}[n-k]C[k]$$

This allows us to shape the spectral impact of the reduction via the correction function to concentrate the introduced noise in more convenient frequency bins rather than the wide impact of the delta function introduced through clipping. Tone or pulse injection techniques may be applicable here. Depending on the choice of the correction function,

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the error signal can be small enough that one can even safely bypass the constellation and spectrum correction step altogether.

Constellation and Spectrum Correction

Just as for standard PAPR reduction, the modification of the digital signal in the time domain can negatively impact the signal constellation as well as increase out of band noise requiring correction. Unlike the standard PAPR reduction, different correction functions in the proposed method will have varying impacts on the constellation and injected noise level.

While other implementations of this step are conceivable, the standard implementation can work very well on our modified signal at this point. However, key parameters, such as the number of iterations and correction thresholds can be adjusted to achieve various levels of PAPR reduction performance.

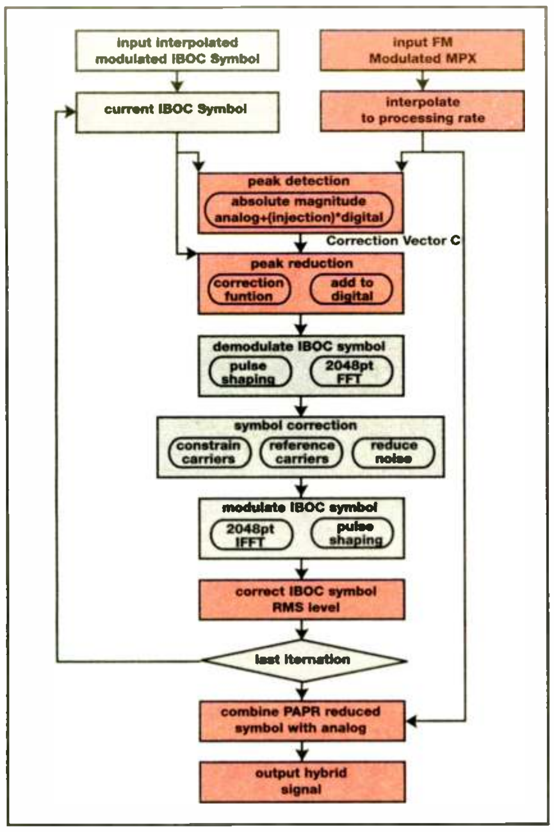

Fig. 10: Proposed PAPR Reduction

PROPOSED PAPR REDUCTION PERFORMANCE

While intuitively the proposed PAPR reduction method should provide superior results in comparison, the theory must be put to the test, first using simulations and second using real hardware. Nautel is assembling an IBOC modulator proof-of-concept prototype system able to perform rigorous hardware tests. In the meantime, this paper reports on the simulation results obtained thus far.

Since –10 dBc carrier levels are of interest to the broadcast industry at this time, our first simulation case is aimed at obtaining a comparable IBOC constellation to the standard PAPR reduction with comparable noise performance. Basic clipping and no other advanced options, such as using the extended carrier spectrum, are used to compile these results in order to provide a fair head-to-head comparison of the two reduction methods.

For comparative purposes, a standard PAPR reduced symbol stream is captured from the exgine modulator and the PAPR reduction is removed by moving all constellation points back to their ideal location. A symbol stream comprising a particularly bad power spike is selected in order to ensure the proposed PAPR reduction can effectively deal with a worst-case scenario.

The resultant proposed PAPR reduced symbol stream is subjected to a noise performance test to ensure similar noise performance to the standard PAPR reduced symbol. The standard and proposed symbols are compared to ensure no bit errors are introduced in the PAPR reduction process. Fig. 11 graphically reports the results of this test.

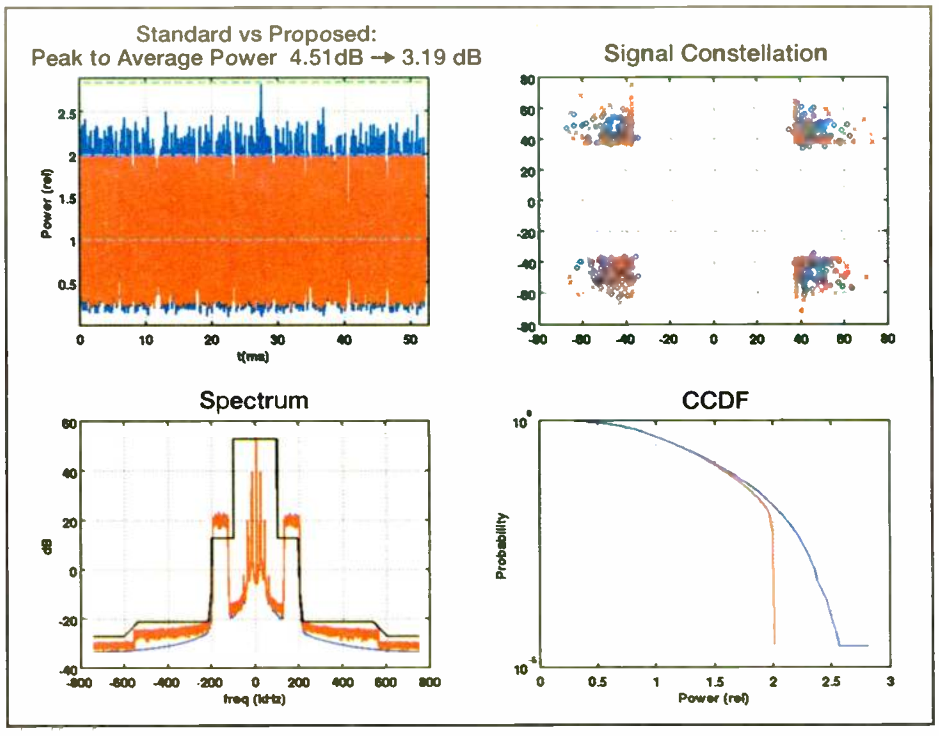

Fig. 11: Performance Comparison of Standard (Blue) vs. Proposed (Red) PAPR Reduction

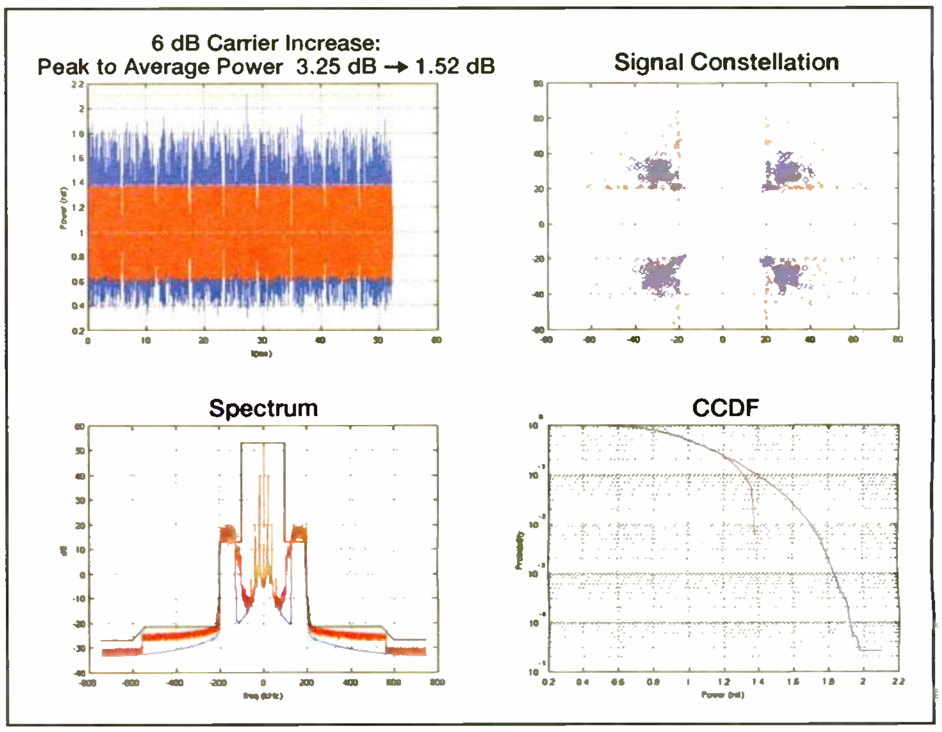

Fig. 12: Aggressive PAPR Reduction Utilizing Extended Frequency Partitions

The blue plots pertain to the standard PAPR reduced IBOC symbol, the red plots pertain to the proposed PAPR reduced IBOC symbol. The spectrum plot reveals that carriers are indeed increased by 10 dB with respect to the more stringent IBOC emission mask and both methods maintain this level throughout. Noise performance tests reveal that the standard PAPR reduced symbol performs 12 percent below the ideal IBOC symbol, while the proposed PAPR reduced symbol performs 14.8 percent below the ideal IBOC symbol, well within comparable levels.

While this does not represent the best maximum gain possible with the proposed PAPR reduction, it does show a very substantial reduction in the PAPR from 4.51 dB down to 3.19 dB.

Graphically the presented time domain plot shows how the required transmitter overhead is reduced. The CCDF, however, presents a better picture of the situation. The discontinuity in the blue curve is explained by the fact that we have specifically selected the input signal based on a maximum peak, but this should not be disregarded as the frequency of this peak in an actual symbol stream is still significant. However, the proposed PAPR reduction has been able to effectively remove this singular peak.

One caveat of the proposed PAPR reduc-

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PAPR

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tion method is the fact that the proposed reduction has a much sharper dropoff in the CCDF compared to the standard PAPR reduced symbol. This means that this method won't be able to be driven into amplifier compression as much, but at –10 dBc carriers the amplifier simply may not be driven into amplifier compression by any significant amount and maintain spectral compliance.

PAPR Reduction Method	Injection Level	Modulator PAPR	Compressed PAPR	Noise Performance	Signal Improvement	Peak Power for 8kW
Standard PAPR Reduction	**-20dBc**	**1.85**	**1.50**	**0.49 dB**	**0.0 dB**	**11.3 kW**
Standard PAPR Reduction	-14dBc	3.25	3.25*	0.49 dB	6.0 dB	16.9 kW
Aggressive Reduction using Extended Partitions	-14dBc	1.52	1.52*	2.22 dB	4.3 dB	11.4 kW
Standard PAPR Reduction	**-10dBc**	**4.51**	**4.51***	**0.49 dB**	**10.0 dB**	**22.6 kW**
Proposed Reduction	-10dBc	3.19	3.19*	0.60 dB	9.9 dB	16.7 kW
Proposed Reduction using Extended Partitions	-10dBc	2.53	2.53*	1.34 dB	9.2 dB	14.3 kW
Aggressive Reduction using Extended Partitions	-10dBc	2.19	2.19*	2.14 dB	8.3 dB	13.2 kW

Table 2: Comparative PAPR Reduction Options

EXISTING HYBRID INSTALLATIONS

A regulatory move to allow the transmission of higher IBOC carriers may place low-level combined broadcasters that have already converted to IBOC at a disadvantage. Therefore it is an interesting exercise to see how the gains achieved using our proposed PAPR reduction can be applied to existing low-level combined stations. At this point in the discussion it should be clear that power levels can be very easily be increased, if no attention is paid to the underlying signal constellation. So we must consider the impact of constellation degradation.

While our proposed reduction provides significant gains, a 10 dB carrier increase is too large to be absorbed by these gains without seriously deteriorating the signal constellation. However, a 6 dB carrier increase is possible with some impact on noise performance using backoff figures for current low-level combined transmitters. Fig. 12 provides the results for this case. The resultant PAPR of 1.52 is very close to the compressed PAPR used to specify current low-level combined transmitters. For this case various advanced techniques had to be employed, such as using the extended carrier space, pulse injection and scaling individual symbols to maintain constant symbol-to-symbol peaks.

The noise performance impact in this case is significant and requires 67 percent additional power to achieve the same bit error rate as an ideal IBOC symbol. Considering that a standard IBOC symbol requires 12 percent additional power, we have effectively improved our noise performance by 6 dB – 2.22 dB (degradation from ideal) + 0.49 dB (with reference to standard constellation) = 4.3 dB at a BER of 10^{-2}.

Our objective is to increase the signal's noise performance, not the signal's output power. A power increase may not translate into an identical noise performance improvement if the underlying signal constellation is modified. We have achieved not quite the 6 dB corresponding to the power increase, but considering it requires no additional transmitter hardware, this represents a significant improvement in IBOC transmission.

If the station has some initial head room available, and we don't have to compress quite as heavily, it will allow us to first improve the signal constellation and recover some losses. We can then either free up the extended carrier space, or further increase carrier power. The optimal operating point will have to be determined on a station-by-station basis depending on the available headroom, transmitter type and station preference. Table 2 presents a number of simulation cases at varying injection levels. These results should be taken for reference only and don't represent any official transmitter performance specifications. The compressed PAPR for most of these cases has yet to be determined and are marked with an asterisk(*). Assuming a TPO of 8 kW, the table also lists the comparative required FM transmitter size required to handle the signal's peak power.

It is apparent that a wide variety of choice exists and broadcasters will likely have to make choice such as is it worth installing additional 2.4 kW of transmitter power in order to marginally improve our signal and free up our extended carrier space. These choices should neither be dictated by manufacturers, nor iBiquity Digital Corp., but should be a broadcaster's choice.

CONCLUSION

This paper has demonstrated the potential gains to be obtained using this novel PAPR reduction approach. It is understood that this paper only scratches the surface of an extensive topic. Simulation results must be verified in real hardware, both in the laboratory and through field trials. The purpose of this paper is to detail Nautel's novel PAPR reduction approach with the hope of setting the framework for more extensive testing and experimentation involving the broadcast community at large.

Providing a stronger HD Radio signal and increased coverage area for a lower additional investment may prompt additional broadcasters to adopt HD Radio delivering more HD content choice to the listener.

This paper was adapted from one presented at the 2008 NAB Show.

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Decisions

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Another colleague, who possessed vast marketing experience and wisdom accumulated over 20 years, could only communicate by responding to questions. His psychology was entirely reactive, not proactive. Without adequate questions, critical information remained unavailable.

Did you ever hear someone say that he *feels* that a decision is wrong but could not explain his intuition in a logical fashion? Should one respect a conclusion that does not fit a rational linear model of language?

In his book "Blink," Malcolm Gladwell explains the power of intuition, which exists entirely independently of logical thinking. On one hand, intuition can reveal the essential truth buried in a deep fog; on the other, intuition can be misleading or simply wrong. It is not easy to know which is which.

And finally, many of us are actually engaging in an internal dialog with imaginary managers, parents, siblings and friends while we are participating in a professional context with colleagues. Both conversations exist at the same time and they can fuse with each other without us being aware of that duality. Such internal dialogs with imaginary people exist without our necessarily being aware of this fact. One can compensate for this duality by recognizing that there is an inner world that only partially aligns with the external world.

Do these "extraneous factors" invalidate my early model of decision-making? The answer is no if the decision-maker expands his model to include this additional texture. Working at so many levels simultaneously (rational, irrational, fantasy, linguistic and cognitive) is an art form that can only be acquired from experience. To become proficient, one must accept that life is messier than a simple model of people as being like elements in an engineering system.

Acquiring the skills of being multilingual dramatically enhances one's utility to the organization, the family and career. If you can become multilingual, you can become a good decision-maker and great manager; if you are monolingual, stay as an engineer making technical contributions to well-defined problems.

How did I acquire these skills? It was not from classroom teachers, trade journals or academic books. Rather, these insights arose from what I call "hyper-listening," which includes the humility to abandon the preconceived belief that facts dominate the decision-making process.

Dr. Barry Blesser is the director of engineering for 25-Seven Systems. ■

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by Barry Blesser

What Does It Mean to Be Multilingual?

Thoughts on the Role of Language and Psychology in Decision-Making

Having discussed the formalism of decision-making in the previous Last Word articles [June 11 and Aug 20], I would like to expand the discussion still further.

Conventional wisdom would have us believe that engineers do not make good managers and decision-makers. Is this viewpoint valid or an unfair bias?

Before attempting to answer this question, I will examine how irrationality, skewed psychology and language difficulties influence or even dominate the process of decision-making. At the end of the article, you can then answer the question for yourself.

As engineers, we are trained to believe in rationality and causality. Moreover, those of us who have a personality with a bias toward thinking of reality as being concrete and tangible are more likely to have become engineers rather than psychologists.

Engineers tend to say that something is either true or false, which is a clean polarization in a binary rational world. Engineers are not unique in their love for rational clarity. Classical econometrics also assumes that all behavior can be explained by rational and predictable self-interest. Their conclusions are often wrong because they assume that there is a rational basis for decisions.

In contrast, a lawyer believes there is no truth, only varying degrees of possible truths emanating from the available evidence; hence, we have juries to make a best guess about truth. The legal system has at least three definitions of truth and none of them relate to an engineering definition of there being a knowable reality.

Similarly, psychologists accept that there can be multiple simultaneous truths that can be inconsistent with each other.

Cognitive psychologists have recently demonstrated that different brain substrates each have their own reality. These substrates talk to each other through neural networks that are limited. Neurological activities controlling our behavior are usually not present in consciousness (analogous to the dashboard of an automobile, which only reveals a few details about the state of the engine).

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Previously I described decision-making as an algorithm with sequential steps. This approach has the invalid hidden assumption that people are similar to engineering systems: rational and predictable.

What happens to our nice clean model of decision-making when we introduce emotion, narcissism, greed and psychological distortions?

In the engineering world these factors would be the equivalent of impulse noise, temporal instability, scrambled interrupt stacks that do not recover and a collection of unpredictable inputs from unknown sources. This alternative view of human behavior is not a critique, but rather a commentary on how our brain has evolved over millions of years. A good decision-maker incorporates this messy reality rather than starting with silly assumptions.

I remember a story that I heard at MIT about a biologist who explained the basis of milk production using a model of a spherical cow with one input and one output. While the model produced a clear conclusion, it had no utility because the model's assumptions were inconsistent with real cows.

LANGUAGE AND COMMUNICATION

Another major problem with data collection is that we use language to get information from colleagues.

Language may be the best form of communicating for humans but it is still highly flawed. For example, when writing my book on aural architecture I remember being surprised by the ill-defined meaning of the simple word "acoustics," from the Greek word *akoustikos*, meaning that which pertains to hearing. That same word now also means any form of vibration in solids, liquids and gases without necessarily being audible.

On the other hand, in the context of the phrase *an acoustic guitar*, the adjective "acoustic" means without electronics. Acoustics can refer to the way in which a concert hall changes the experience of music. In fact, there is no clear definition of the word. Sometimes acoustics is used to mean any sonic process.

As a general rule, language skews communications. And to compensate for this fact, I try to build a unique dictionary for each person with whom I am communicating.

At the extreme, think of a group of people where one individual speaks French and others speak German, Russian, Greek, Swahili, Dutch, Portuguese and so on, without anyone serving the function of a multilingual translator.

Linguists know that language is overflowing with ambiguities and ill-defined concepts. Try the experiment of having your colleagues write down a definition of "trust," "ethics," or "responsible." The definitions will span a wide range.

Even such words as "sophisticated" and "manipulation" have complex and contradictory meanings. Sophisticated means both worldly wise and educated, but also means surface knowledge without depth, as in sophomoric. Manipulation means to influence a situation in order to change the outcome, but may also carry the *optional* meaning of using power for personal rewards, perhaps to the detriment of the target person.

If you have a recreational interest in language, I strongly recommend the book "The Unfolding of Language: An Evolutionary Tour of Mankind's Greatest Invention" by Guy Deutscher.

Among other insights, he describes that a word begins as a reference to a single concrete object, and then over a period of time, the word becomes generalized and more abstract. An abstraction becomes notoriously ambiguous and dependent on context.

I am sure that all of us have had the experience of saying something very clearly and only later discovering that there were ambiguities that resulted in a completely different message being received.

One of my clients recently got into trouble on the design of a new power supply. Marketing, sales, engineering and customer support all agreed that the new supply should be equivalent to the old one. But nobody realized that the word "equivalent" meant something different to each discipline.

Rather than recognizing the flaws in language, for which we are all responsible, there were arguments about which group was incompetent. When everyone realized that linguistic ambiguity was the basis for the disagreement, the discussion shifted from personal hostility to clarifying examples.

Everyone owned the problem of language, which is like the third law of thermodynamics. You cannot win, you cannot break even and you cannot get out of the game.

In some sense, each of us has a private and unique language based on our particular personality and psychology. The vast richness of human diversity is nature's way of creating a robust gene pool to ensure survival of the species. Evolution values differences among people.

The idea that each of us has a unique language leads us to the uniqueness of each individual's personality and psychology.

For example, one of my colleagues is extremely creative because he can consistently think "outside of the box," but this ability arises from an associative mind that jumps randomly from image to image without any sequential logic.

His unique skill comes with a corresponding inability to put ideas into language, which is intrinsically linear. The rest of us are faced with the choice of either ignoring his engineering brilliance or compensating for his lack of language skills.

SEE DECISIONS, PAGE 29

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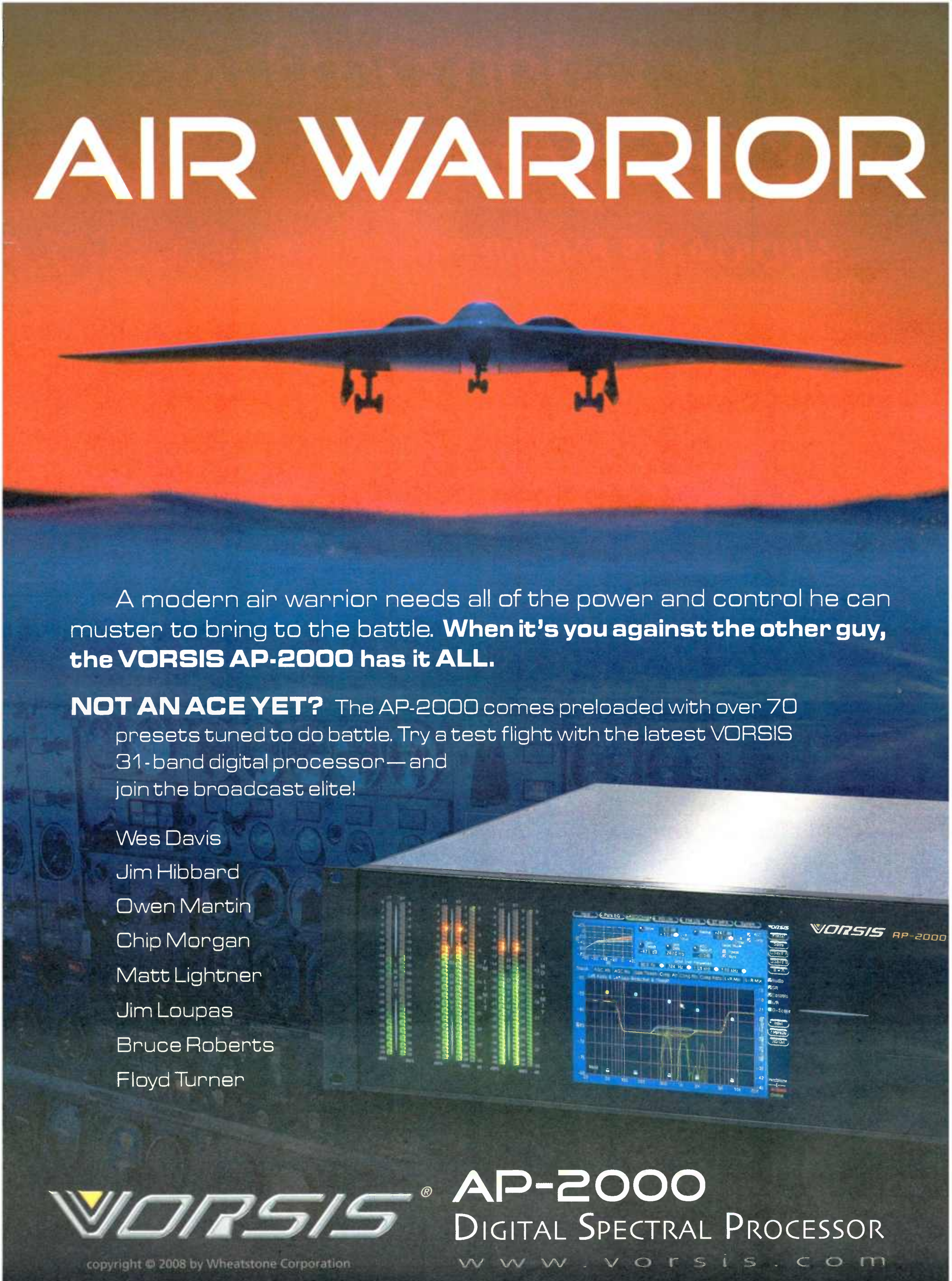
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