ENGINEERING EXTRA

RADIOWORLD

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STATE OF THE STATIONS
Michael LeClair has new projects to keep him busy. Are things picking up? Page 3

Charlie Goodrich, Engineer Extraordinaire

Former DOE of McMartin Industries Still Builds And Repairs Transmitters After All These Years

BY TOM MCGINLEY

ENGINEER INTERVIEW

Charlie Goodrich is truly a Radio Good Guy. As a youngster listening to riverboat radio communications in hometown Omaha, Neb., almost 60 years ago, he got forever hooked on the art and the science of radio. Goodrich is in that rare class of engineers who have always been willing and ready to help those in need of technical assistance, no matter the circumstances or time of night.

As the longtime director of engineering of McMartin Industries, and now the owner of Goodrich Enterprises, he has continued to work full-time doing what he loves best: building and repairing transmitters. Radio World Technical Advisor Tom McGinley interviewed Charlie Goodrich and shares the story of his long and colorful career.

Charlie Goodrich works on a transmitter.

Let's start at the beginning. When did you get involved in radio, later broad-

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Look Before You Leap

If You Plan to Raise FM Digital Power, Be Aware of Unintended Consequences

BY DAVE HERSHBERGER

The author is senior scientist at Continental Electronics.

FM broadcasters may now increase their average digital signal power, in most cases to levels as high as 10 percent of the analog power. Transmitting more digital power will certainly increase the digital coverage area and reduce digital

WHITEPAPER

dropouts. However, there may be some unintended consequences, which every broadcaster will have to evaluate before increasing digital power.

Adjacent-channel interference is one such effect, which has already been investigated. This paper will not discuss the adjacent-channel interference issue.

One negative effect is the way in which increased digital power will mean increased envelope modulation of the linear sum of the FM and OFDM signal components. Peak-to-average ratio reduction algorithms may be called upon to work harder to reduce the envelope modulation.

Although reduction of the positive envelope modulation peaks benefits the transmitter, it is also important to restrain negative modulation peaks for the benefit of the receiver. As envelope modulation approaches pinch-off, receiver noise increases and the analog receiver's FM demodulator may be captured by digital sidebands. Furthermore, reduction of quadrature modulation caused by the presence of increased digital sidebands will also benefit the receiver, by reducing the peak phase modulation component of the self-interference.

Elevated digital power will also aggravate self-interference to the analog signal. The level of self-interference will depend on several factors, including receiver bandwidth, use of extended hybrid modes, analog deviation, crest factor reduction methods and multipath propagation. Self-interference affects primarily SCA subcarriers and stereo L–R reception.

Analog FM deviation dynamically affects HD self-noise. As the instantaneous FM carrier approaches the blocks of OFDM sidebands on modulation peaks, self-noise decreases in frequency, creating more noise in the 53 kHz stereo baseband. This produces some unusual effects. In addition, there are some self-noise components that increase twice as fast (in dB) as the digital power. That is, a 10 dB increase in digital power may produce a 20 dB increase in some self-noise components. At 10 percent digital power, stereo SNR

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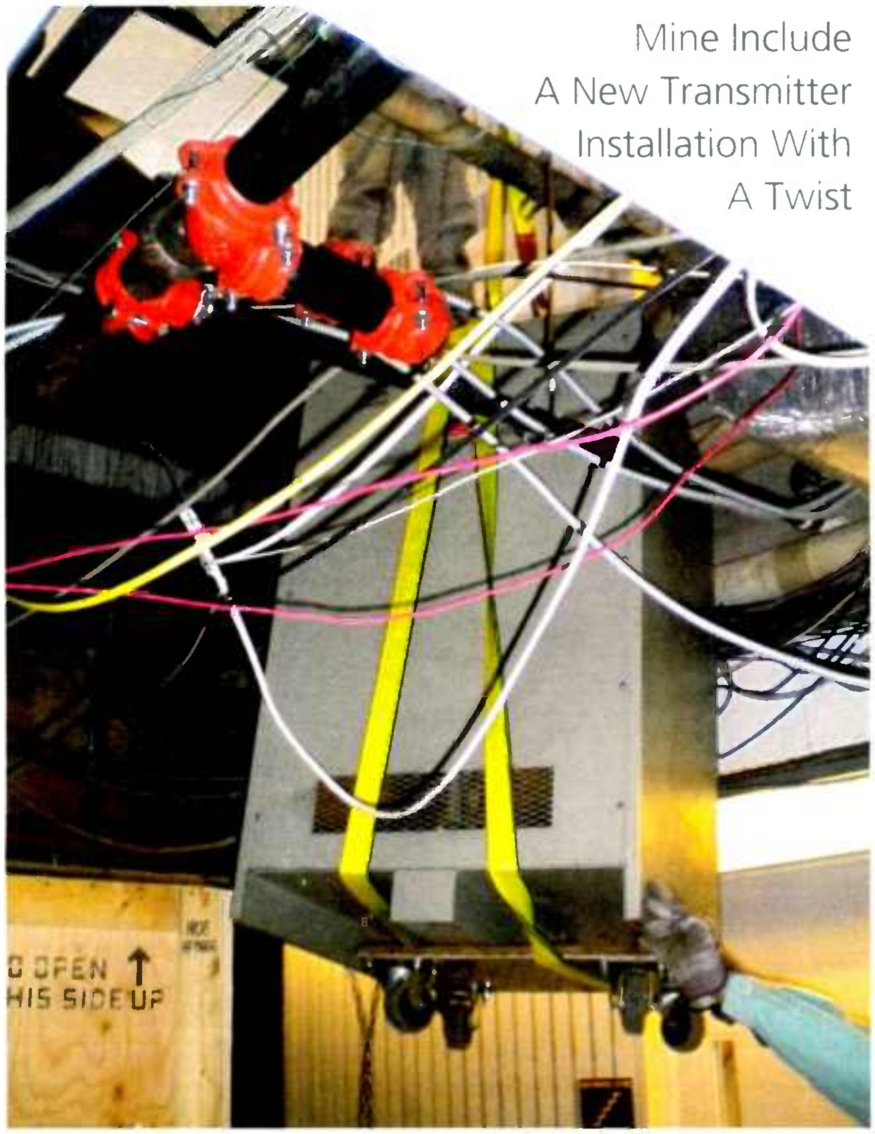
FROM THE TECH EDITOR

Capital Projects Making a Comeback?

Mine Include A New Transmitter Installation With A Twist



Don't try this at home. Professional riggers move heavy gear into place via an access hatch. The day before, an HVAC contractor and a plumber had to move ductwork and building sprinklers out of the way.

BY MICHAEL LECLAIR

So is it finally over?

I mean the radio recession that led to cutbacks in staff and capital projects at stations all over the United States. For many of us, the last 18 months have been marked by careful spending or none at all. Engineers tend to be affected disproportionately in a fiscally conservative environment. Much of what we do is guide investments in equipment and facilities. During lean times, the focus shifts to repairs and extending equipment life.

Personally, I like doing both; but there is no denying that a new studio is a more rewarding project than replacing the power supply in a 12-year-old console. Plus, it can be hard to shift gears.

A few years back I was installing new transmitters and remote controls on a regular basis, so I got pretty good at it. But if I don't install a transmitter for a few years, it takes a while to remember the finer details and become familiar with the latest designs.

I am posing the question at the head of this column because I suddenly have found myself loaded up with capital projects enough to keep me and my assistant chief busy for the next year. And I am hearing from some of my other friends in the engineering business that their workloads are beginning to pick up, even soar.

I'm not complaining. How is it going in your stations?

DOWN THE HATCH

As I write, I am just finishing up the details on the first item on our capital projects list: the installation of a Nautel NV15 FM transmitter. This replaces a 1975 tube model that was ready for the bone yard.

What made this project "interesting" was getting the old equipment out and getting the new equipment in. The transmitter site is on the 18th floor of a building. Unfortunately, the elevators only go to the *17th* floor …

To make matters worse, there are virtually no windows or other exterior openings that might be used to pick equipment into place with a crane.

The sole method of moving heavy gear into this upper floor is an access hatch that was created as part of the original building design to move elevator motors into the mechanical penthouse on the 18th and 19th floors.

Just to make everything as difficult as possible, over the years the hatch opening had been covered up with air conditioning ductwork (three runs!) and a set of retrofit sprinkler pipes and heads. All of this had to be moved to open up access to the hatch before we could move anything. Ducts and sprinklers had to be reinstalled the day after the move was finished.

To do the actual moving, we hired steel riggers. They used a chain lift and an appropriately large piece of steel I-beam to drop the old equipment straight down and lift the new transmitter up through the hatch. To and from the hatch they used rollers because there was no way to get a pallet lifter or other moving device up to the 18th floor.

There were three pieces of gear to get out of the way: a voltage regulator, high-voltage power supply and the tube power amplifier. Each of these weighed around 1,000 pounds. The new transmitter (uncrated) was a mere 850 pounds.

The photo shows one of the equipment pulls through the hatch, the most

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THIS ISSUE

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GOODRICH

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cast engineering, and what was the main attraction for you?

I was a youngster at age 11 years who got attracted to electronics in grade school after listening to boats on the Missouri River on an old Howard 430 shortwave receiver. I also had a friend who had taken Cleveland Radio Institute and National Radio Institute correspondence courses and gave me all of the old books. So I studied them in grade school and wound up getting a ham operator's license in 1954 or 1955.

While attending high school, I got my Amateur Extra License, First Class Radiotelephone License With Radar Endorsement and Second Class Radio Telegraph License. Three days after graduating from high school, I acquired a job at radio station KOIL as summer relief engineer watching over a Gates BC-5P and a Gates 1 kW FM transmitter.

While in high school, I first built a Heathkit AT-1 ham transmitter, and after that many ham transmitters, using TZ40, TZ55, 833s and 4-400 tubes. I built the first carrier-current transmitter for Omaha University. The year after high school, I went to college and continued working for KOIL, advancing to chief engineer.

I always loved building transmitters from scratch, and spent my spare time building rather than operating. The attraction was making higher and higher power with bigger parts and bigger sparks. While at KOIL, they also had me build a news audio console fashioned somewhat like the Gates President line.

After seven years with KOIL under Don Burden's ownership, I left in early 1966.

What is your educational background, Charlie?

I studied electrical engineering and earned a BSEE from the University of Nebraska, Lincoln, while I was working for KOIL. Later, I also completed a few graduate business courses.

What were you doing before meeting and going to work for Ray McMartin?

After leaving KOIL, I took a job at Lockheed Missiles and Space Company in Sunnyvale, Calif., in 1966 and 1967, working on the Agena space vehicle as a project and metrology engineer. At that time, I operated a homebrew transmitter with a pair of 4-400 tubes out of the trunk of my car.

I found the large corporate world a little restraining, decided to move back to Omaha and got a job at McMartin Industries as a design engineer.

Ray McMartin had just secured a contract with Visual Electronics to build 100 solid-state audio consoles. I designed the Visual 8x1 mono and 8x2 stereo audio consoles, which we introduced at the 1968 NAB at the Conrad Hilton in Chicago. These were the first consoles with solid-state interchangeable plug-in cards. We later modified these consoles with the McMartin name as the B-801 mono and B-802 stereo eight-channel consoles.

A lot of us remember the McMartin line of broadcast products, most notably the AM and FM transmitters, exciters, modulation monitors and audio consoles. Could you tell us more about the overall product line?

The McMartin broadcast product line in the early days was known for the modulation monitors. Leonard Hedlund had designed the monitors, and in 1968 introduced the TBM-4500A solid-state 3 meter unit, which became the standard of the industry for many years. There are still many in operation.

Later, McMartin introduced the TBM-3500 mono, TBM-2200 stereo and the TBM-2500 RF amp, a three-unit package. In the early '70s, McMartin went into the exciter business, so they had me design the B-910 fifteen-watt solid-state exciter with plug-in modules. This unit was extremely successful because of the introduction of the new bullet-proof strip line RF transistors made by CTC. McMartin built and sold over 2,000 of these exciters. We built these continuously until the late '70s when we introduced the smaller BFM-8000 unit.

After having an exciter available in the early '70s, McMartin decided to go into the transmitter business. They first contracted a couple of outside engineers who had just left Collins Radio to build a 1 kW AM transmitter, but that project failed, so they asked me if I could build one in late 1971. I said yes and had the BA-1K ready for the NAB show in '72. The transmitter was accepted very well, and I remember we sold 15 units to one customer in Mexico that year at NAB. The following year, I designed the McMartin BF-3.5K FM transmitter, which was the most successful model in the FM line.

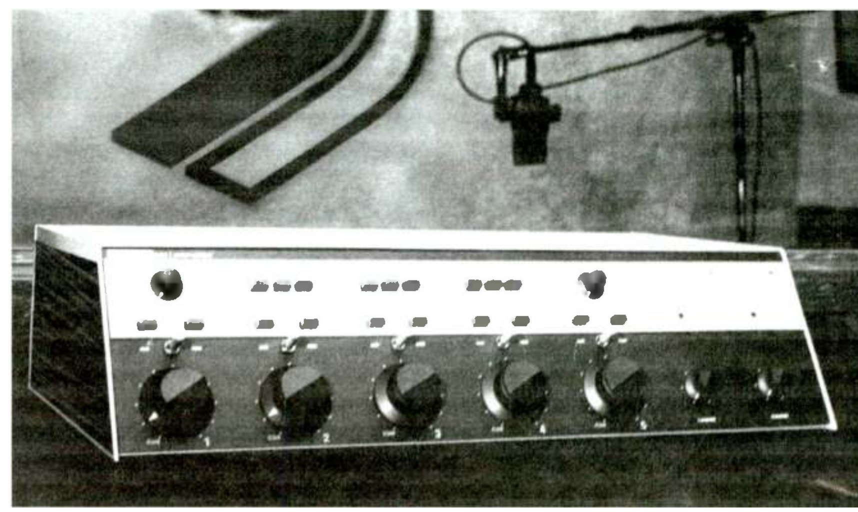
I continued building these at Goodrich Enterprises up until around 2000. Starting around 1990, I also started buying back used McMartin transmitters for refurbishing and reselling to the marketplace. Overall, including all models McMartin manufactured, around 1,000 transmitters were built. I estimate about 100 to 200 are still in operation.

Were you directly involved in the design of most of the McMartin product line? Who were the principal designers?

When I went to McMartin in late 1967, I was the sole audio console, RF exciter and transmitter design engineer. After we got rolling in the mid '70s with the BA-1K AM and BF-3.5K FM transmitters, we hired Juan Gregorio, an engineer from another company to help with the workload. He developed the McMartin BA-2.5K 2,500 watt AM transmitter and then left the company. A few years later, we hired Richard Johnson to develop and build the McMartin BA-50K 50 kW AM. After he left the company, I installed two of the three units built. One of these went to Portugal and one to Brazil. The transmitter that went to Brazil was previously operated by Morris Blum at WANN, Annapolis, Md. One of these units was in actual operation at the NAB Show in Las Vegas in the early '80s before the failure of the company.

I was the principal design engineer for the console and transmitter line. All the first units were hand-built with the assistance of the metal shop and a technician, and then turned over to production to copy. I also oversaw the final test of almost every unit that went out the door. A lot of the simplicity was a result of my self-taught building of transmitters with the resources available at the time in the Omaha area.

McMartin B910 exciter …



… and McMartin B-502 console

I remember installing and/or maintaining a variety of McMartin transmitters in the '70s and '80s. I recall having a few issues from time to time. You were always the guy who was there answering the tech support line.

As McMartin's director of engineering, Ray also had me in charge of customer service, which meant the technical service guys came to me with the tough problems. I would always answer the customer's questions with them listening in on the phone to learn the solution. But as times got tough and staffing suffered, I wound up being the only one available.

During the peak of production including the engineered sound, SCA line, background music line and broadcast transmitters, we had around 125 employees. The transmitter production

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GOODRICH

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and support staff probably accounted for about 30. The peak years in sales were just near $1 million per month. The growth curve showed sales at about $600,000 in 1963, $1 million in 1973 and over $10 million in 1979.

What were some of your most unusual or memorable support calls that come to mind?

My most memorable support call and humorous one was from Tom Andrews at WLKI, Angola, Ind.

He had the very first McMartin FM transmitter, a BF-3.5K. There was an intermittent inside the RF box and he called my home at about 3 a.m., and my wife answered the phone. He asked what she was doing up. With humor she said, "Vacuuming the floors," and then gave me the phone.

With that, Tom wanted to have me listen on the phone as he hit the side of the transmitter with his shoe to see if I could analyze the problem. We later resolved the problem and continued to be friends for many, many years.

Then there was the customer who installed a plate transformer with the primary voltage selecting straps connected in a fashion that shorted all three of the incoming lines together, resulting in huge damage to the contactors and protection circuit breakers and the line pole fuses. Each time we asked him if the incoming lines were connected to the correct terminals, he would check and verify that they were connected correctly.

Another interesting case was when we were putting a pair of McMartin BF-25K transmitters in parallel to produce 55 kW on top of the mountain overlooking Honolulu. The only access was by helicopter. The helicopter dropped one of the power supplies from about 1,000 feet into the wooded hills, never to be recovered.

Left: McMartin manufacturing floor in the early 1960s.

Below: Charlie Goodrich circa 1978

We also had an incident with North American Van Lines trucking our transmitters back from the NAB show in Las Vegas. On the way, the truck had an accident with the transmitters strapped to the side of the laid-over trailer up in the air. The company asked for permission to cut the straps and let the transmitters drop about 8 feet. It was required before the truck could be uprighted. The three transmitters were replaced by the insurance company.

McMartin also manufactured and sold an extensive line of PA and sound equipment as well as SCA receivers. Is a lot of that gear still in operation?

Yes, there are many Engineered Sound amplifiers in commercial applications throughout the country, including rapid transit systems. I remember we built the equipment for BART San Francisco, MARTA Atlanta and WMATA Washington, D.C., to mention a few. Many of the fire support systems, schools, churches and commercial buildings including the Sears Tower all use the amplifiers. We also built background music amplifiers and SCA receivers. Muzak, the Physicians Radio Network and many radio reading services for the blind were large users.

I do not hear much from the SCA line anymore but regularly hear from customers using the commercial amplifiers and Engineered Sound equipment. We built thousands and thousands of amplifiers from 10 watts up to 350 watts. The larger units were used in many of the airports and automobile manufacturing plants. Disneyland and Disney World were also large users for paging and entertainment.

McMartin had quite a long run from the mid-1950s until they had to close their doors in the mid-1980s. Are you able to give us any insight as to why that happened?

McMartin Industries Inc. was founded as Continental Manufacturing Inc. in 1956, initially as a manufacturer of consumer electronics products. Continental Manufacturing made "controla-tone" remote TV volume controls and the "Harmony" line of radio intercom systems. In 1962, the corporate name was changed to McMartin Industries Inc. The first products sold under the McMartin name were FM receivers designed to pick up SCA signals.

Ray operated till the early '80s when a bank took over and liquidated the company. By 1979, things were tightening up as interest rates soared and Ray had a difficult time paying back his loans, so the last 3–4 years were a struggle. The company was caught in what could be described as a perfect storm: the extremely high interest rates, economic changes, SCA market declines with the introduction of satellite delivered radio programming and extremely heavy broadcast sales expenses and outside overhead.

After McMartin Industries Inc. failed, Ray started McMartin International in Gunnison, Colo., which lasted only approximately a year. Jerry Martin and John Miller re-launched the company as McMartin Inc. in 1983, operating in Council Bluffs, Iowa, but that closed in 1985.

Goodrich, right, at McMartin Engineering in 1970, with sales assistant Joe Krier.

After McMartin closed down, you have continued supporting most of their products under the banner Goodrich Enterprises. Tell us when and how you decided to start that venture.

During the early '70s, I had been installing sound systems in bars and restaurants in the evenings after work, using McMartin amplifiers and sound equipment. I designed and installed a few lighted floors for discos, and in no time, this took off as a business. I was

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LECLAIR

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dramatic moment in this phase of the project. But it was also impressive to watch the level of detail and care that was used by the riggers to lift and shift into place these heavy pieces safely. Each item had to be slowly jacked, and then the center of gravity was determined by shifting wedges until a balance point was found. Once in balance, these heavy loads can be rolled safely, minimizing the danger of tipping over and hurting someone or something.

This is a job that took both brains and muscle to do right.

DIY

To make this project work, I had to do a lot of it myself. The move and its associated costs ate up enough project money that we handled installation work, which in the past I used to contract out.

For example, the old transmitter had custom ductwork with a duct fan to exhaust heated air directly outdoors. Consistent with newer transmitter design, we took out all the ductwork and simply mounted a high-capacity (3,500 CFM) exhaust fan into the existing wall opening. Then we sealed and repaired the loose outdoor exhaust hood from 1975 to make it quiet and leak-free.

While exploring my Grainger catalog for the exhaust fan, I found a nifty toy called a "Relay in a Box" (fans of Andy Sandberg and Justin Timberlake can, ahem, chime in their own chorus here) made by Functional Devices.

The relay can control up to 1/2 HP motors and mounts directly to an electrical junction box via a standard knock out, which saves a lot of mounting time and parts. I used this to interlock the exhaust fan to the transmitter remote control, turning the fan on whenever the transmitter is started. The room already had a high-capacity air intake fan and filter system to maintain positive pressure. Between the two fans, there is plenty of air flow.

Unfortunately, the elevators only go to the *17th* floor ...

To dress the room up a bit, we got out the paintbrushes and painted the walls with new white paint. I find that bright white makes everything easier to see, even if the lighting is somewhat limited.

I also had a stash of Dielectric 3-inch rigid interior transmission line in storage with a Dielectric RF switch and a few spare elbows and other parts. With a couple of large pipe cutters we were able to custom cut and mount all the interior transmission line runs to the switch. We also moved and remounted the existing Bird water-cooled dummy load so that we can test this transmitter off line when needed. We were able to keep the pressurized line segments that feed the antenna in position so there was no need to make changes to the exterior line, although we did replace the O-rings on the gas-blocking flange connector.


One project down, many more to go!

I even had a pair of spare Amco equipment racks in the basement that we hand-carried up the stairs and mounted into place next to the new transmitter for all the other site gear.

So with some a combination of new equipment and doing a lot of the systems work ourselves, we were able to carry off the entire project in a cost-effective way.

The second photo shows the completed site.

I hope that this is just the beginning of some new investments in our technical plant and a renewal of investment in radio in general. On to the next project: new automation servers!

Comment on this or any story. Write to rwee@nbmedia.com.

GOODRICH

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building lighted floors and shipping them all over the country. So I decided to create the company Goodrich Enterprises in the late '70s.

Of course, the disco era only lasted a few years, but when McMartin started to fail, I felt for the customers and decided to help them out when the company could not. One thing led to the next as the customers kept calling me for support. I was eventually able to pick up the necessary assets from McMartin liquidation auctions. I specifically bought up the necessary items to build the transmitters and exciters, and I was off and running.

The customers had the trust in me and the trust in the brand name McMartin. Through the help of RF Specialties, I was able to provide systems as well as the tech support. At that time, RF Specialties was comprised of mostly ex-McMartin employees: John Schneider, Don Jones, Bill Hosington, Bill Emery and Bill Turney.

I still manufacture some specialized parts for the transmitters, for example PA tuning line assemblies, plate blockers and metal assembly parts.

Do you sell and support the broadcast products of any other companies that are no longer in business?

I will help customers with just about any transmitter including AEL, Sintronics, Elcom Bauer, CCA, CSI and Gates. We very frequently find ourselves rebuilding plate blockers, high-power tube sockets, tuning line assemblies and blowers, especially the Rotron Centrimax. And of course we supply all the high-power transmitter tubes, either new or rebuilt, and most high-power transmitter parts.

Most all of the McMartin transmitters used the grounded-grid triode design for the FM PA stage as opposed to tetrodes used by the "major" manufacturers. What do you especially like about grounded grid?

The thing I liked about the grounded-grid triode style transmitter was the simplicity of operation. This made it very easy for the station engineer to understand and troubleshoot. With the grounded grid as a shield between the input circuit and the output circuit, there was no need to deal with neutralization. Also, the lack of a screen grid DC supply made the transmitter simpler. We felt the reliability exceeded that of the tetrode transmitters at that time, and if the final stage did suffer a failure we always had the higher-power driver stage available to get back on the air with minimal loss of coverage. Eimac had developed an excellent line of grounded-grid tubes to meet the needs of that growing market.

How has your company fared during the recession? Do you think we are finally coming out of it and that radio will be a good business in the years to come?

My company has fared well during the recession, because I have diversified over the years with the medical and dental industry. What decline I see in the broadcast industry is offset with increases in the med/dental business. I see radio picking up somewhat, but as a mature market, I don't see giant leaps in the future. I think radio will always be a good business for the smart operator who can meet the needs of the local market.

What is your opinion of HD Radio?

I do not have very strong opinions on the subject of HD Radio, but I do believe that AM HD will go by the wayside along with AM stereo. This is more due to the interference caused and in some cases major group stations interfering with their sister stations. I feel the FM HD has a place, but the market is not demanding it. It seems it is driven by the manufacturers, and they have had their first chance to make an impression and missed the mark. It may take many more years, if ever, for this to develop.

Do you foresee AM and FM over-the-air broadcasting ultimately giving way to wireless Internet delivery and if so, how soon?

I do not think that AM and FM will ever give way to wireless Internet. Wireless will make some inroads in the metropolitan areas, but radio will prevail in the less populated and rural areas. Radio has the ability to cover so many more square miles from a single transmitter site with a single investment.

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- Channel Transparency measurement
- I/O Delay Measurement
- Sync to AES3, DARS, word clock & video black burst
- User-generated test signal files

AL1 Acoustilyzer
Acoustics, Audio & Intelligibility Analyzer

The AL1 Acoustilyzer features extensive acoustical measurement capabilities as well as analog audio electrical measurements such as level, frequency and THD+N. With both true RTA and high resolution FFT capability, the AL1 also measures delay and reverberation times.
With the optional STI-PA Speech Intelligibility function, rapid and convenient standardized "one-number" intelligibility measurements may be made on all types of sound systems, from venue sound reinforcement to regulated "life and safety" audio systems.

- Real Time Analyzer
- Reverb Time (RT60)
- Delay measurements
- High resolution FFT with zoom
- Optional STI-PA Speech Intelligibility function
- Automatic Distortion analyzer (THD+N)
- Frequency, RMS Level, Polarity measurements
- Requires optional MiniSPL microphone
- Includes MiniLINK USB interface & Windows PC software for storing tests and PC transfer

ML1 Minilyzer
Analog Audio Analyzer

The ML1 Minilyzer is a full function high performance audio analyzer and signal monitor that fits in the palm of your hand.
The comprehensive feature set includes standard measurements of level, frequency and THD+N, plus VU+PPM meter mode, scope mode, a 1/3 octave analyzer and the ability to acquire, measure and display external response sweeps generated by a Minirator or other external generator.

Add the optional MiniLINK USB computer interface and Windows-based software and you may store all tests on the instrument for download to your PC, as well as send commands and display real time results to and from the analyzer.

MiniLINK

- Measure Level, Frequency, Polarity
- Automatic THD+N and individual harmonic distortion measurements k2 – k5
- VU + PPM meter/monitor
- 1/3 octave analyzer
- Requires optional MiniSPL microphone for SPL & acoustic RTA measurements
- Frequency/time sweeps
- Scope mode
- Measure signal balance error
- Selectable units for level measurements

MR-PRO Minirator
High performance Analog Audio Generator + Impedance/Phantom/Cable measurements

The MR-PRO Minirator is the senior partner to the MR2 below, with added features and higher performance. Both generators feature an ergonomic instrument package & operation, balanced and unbalanced outputs, and a full range of signals.

- High (+18 dBu) output level & <-96 dB residual THD
- Sine waves & programmable swept (chirp) and stepped sweeps
- Pink & white noise
- Polarity & delay test signals
- User-generated custom test signals & generator setups
- Impedance measurement of the connected device
- Phantom power voltage measurement
- Cable tester and signal balance measurement
- Protective shock jacket

MR2 Minirator
Analog Audio Generator

The MR2 pocket-sized analog audio generator is the successor to the legendary MR1 Minirator. It is the behind-the-scenes star of thousands of live performances, recordings and remote feeds.

- Intuitive operation via thumbwheel and "short-cut" buttons
- New higher output level (+8 dBu) & low distortion
- Programmable Swept (chirp) and Stepped sweeps
- Sine waves
- Pink & White noise
- Polarity & Delay test signals
- Illuminated Mute button

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may be in the 40s (of decibels) on a good quality analog receiver.

We will begin our analysis of the effects of HD on FM here and continue with a more detailed analysis of the resultant signal-to-noise ratio in the next issue of Radio World Engineering Extra.

ENGINEERING IS A TRADEOFF

One of Continental's specialties is high power. We build megawatt-level transmitters from VLF to microwaves, so we are not afraid of elevated HD power. Ten percent digital power produces a peak envelope power or PEP of almost three times the analog power, and over three times for the extended hybrid modes. We would love to sell everybody transmitters rated for 10 percent digital power — where 20 kilowatts of analog means almost 60 kilowatts PEP.

But engineering is a tradeoff. Digital power should be enough, but not too much, for reasons we will discuss. Every station should be evaluated individually. Most broadcast revenue derives from the analog signal — for that reason, it should be protected.

Each station must make its own determination and tradeoffs between cost, analog performance and digital performance.

HD POWER INCREASE EFFECTS

If you ask industry people what they think about HD Radio, you usually get one of two rather polarized opinions: "It's the best thing that has happened to FM radio" or "It's the worst thing." Neither is really correct — the truth is somewhere between these extremes.

The reason for the proposed digital power increase is to extend the digital coverage area. More digital power will certainly do this.

Transmitter effects include a lot more envelope modulation, and the peak-to-average ratio is larger. The linearity requirements are more severe because the digital power goes up, but the spectrum mask does not!

The analog power capability for common amplification goes down as the digital power increases for a given transmitter — or the transmitter must be larger to be able to transmit the same analog power with elevated digital power.

Table 1 sets out some of the more interesting numbers associated with 1 percent, 4 percent and 10 percent digital power injection levels. Intuitively, we might not think that 10 percent power would have a very big effect on anything, but it does. It all has to do with peak-to-average ratios, square roots and squares. These little mathematical operations conspire to produce some possibly

Digital Power (%) (MP1 mode)	Hybrid Mode	Actual Digital Power (%)	Digital Voltage (normalized)	Peak Digital Voltage (normalized)	Envelope Modulation (%)	PEP (% of analog)
1	MP1	1	0.1	0.2	20	144.0
4	MP1	4	0.2	0.4	40	196.0
10	MP1	10	0.316	0.632	63.2	266.5
1	MP2	1.099	0.105	0.21	21.0	146.3
4	MP2	4.398	0.210	0.419	41.9	201.5
10	MP2	10.995	0.332	0.663	66.3	276.6
1	MP3	1.199	0.109	0.219	21.9	148.6
4	MP3	4.796	0.219	0.438	43.8	206.8
10	MP3	11.990	0.346	0.693	69.3	286.5
1	MP11	1.398	0.118	0.236	23.6	152.9
4	MP11	5.592	0.236	0.473	47.3	217.0
10	MP11	13.979	0.374	0.748	74.8	305.5

Table 1: PEP and envelope modulation for different levels of digital power; 6 dB peak-to-average ratio is assumed

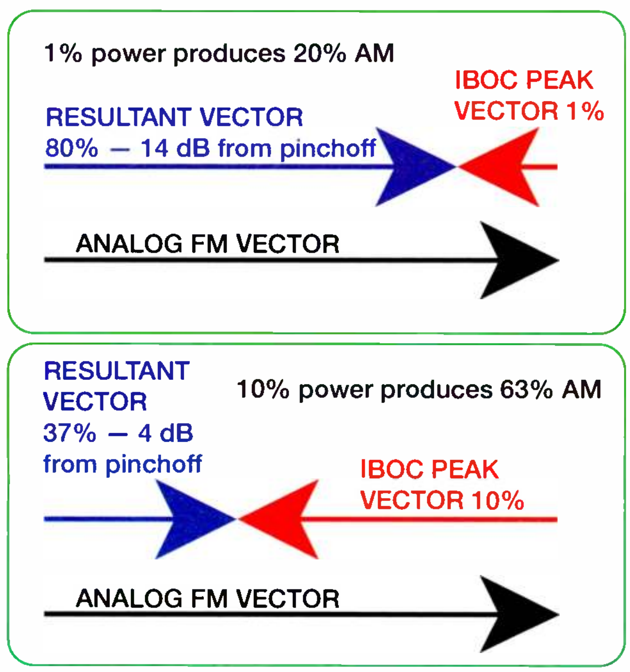

Fig. 1: IBOC vector addition produces negative envelope modulation.

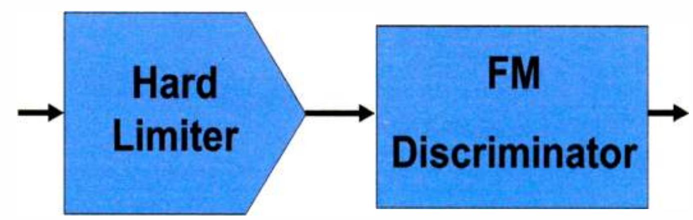

Fig. 2: An FM receiver contains a hard limiter (or its equivalent) whose gain is inversely proportional to the envelope.

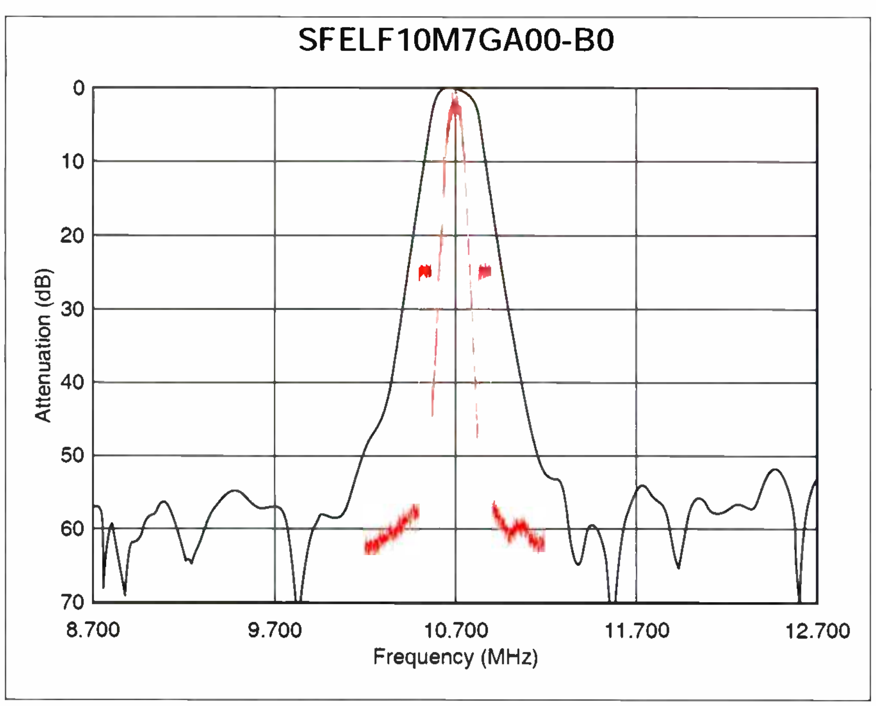

Fig. 3: IBOC in a narrow Murata IF filter

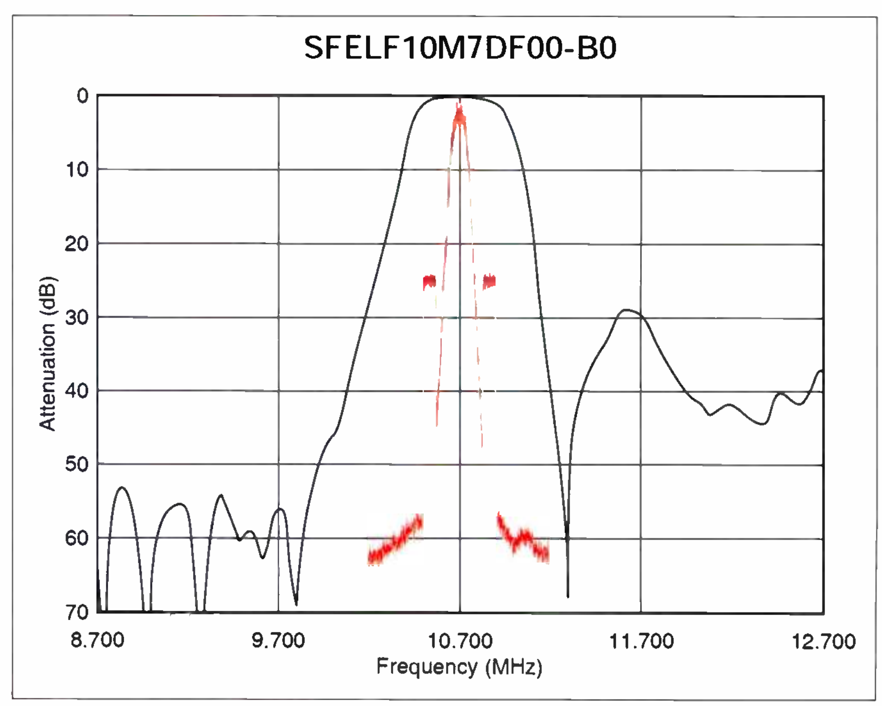

Fig. 4: IBOC in a wide Murata IF filter

surprising results.

Table 1 shows the power increase required for different digital power levels and hybrid and extended hybrid modes. MP1 mode uses 10 subcarrier partitions in each sideband. For extended hybrid modes, MP2 uses 11, MP3 uses 12 and MP11 uses 14. As the number of subcarriers increases, so does the digital power. In the extended hybrid modes, 10 percent digital power may increase to approximately 11 percent, 12 percent or 14 percent. However, power is not exactly proportional to the number of partitions (1.1, 1.2, or 1.4 times the MP1 power) because of the existence of one extra reference carrier per sideband.

Although Table 1 shows the effects of the extended hybrid modes (MP2 through MP11), the calculations, simulations and measurements in this paper are for the basic MP1 hybrid mode.

IBiquity's peak-to-average ratio reduction system reduces the peaks to about 6 dB above the average digital

Each station must make its own determination and tradeoffs between cost, analog performance and digital performance.

power. This is a major improvement over no correction at all. When the vectors for n tones all line up in phase, the peak-to-average power ratio becomes simply n. For the 382 QPSK carriers (tones) this would be a peak-to-average ratio of 25.8 dB — but the probability level would be very low. Still, reducing it to 6 dB is a major improvement.

At 10 percent digital we have 63 percent AM and we need 53.3 kilowatts PEP for a 20 kilowatt analog signal. The ratio becomes even larger for the extended hybrid modes.

Fig. 1 shows what that 63 percent envelope modulation means. If we draw the analog FM signal as the black vector, and the digital signal is the red vector, then the blue vector shown in Fig. 1 is the resultant envelope at the negative modulation peaks. For 1 percent digital power we have about 20 percent AM. At the negative modulation troughs, we still have 80 percent of our signal to work with. The analog signal would have to fade 14 dB relative to the digital sidebands to pinch off the envelope. At 10 percent digital power, the envelope drops to 37 percent of normal on negative envelope peaks. That is only 4 dB of relative fading from pinch-off.

The danger for analog FM reception is that if the vector length goes to zero, the receiver produces noise bursts. Remember that an analog FM receiver contains a hard limiter (see Fig. 2). The hard limiter is a device whose gain is equal to the reciprocal of its input signal's envelope. If the envelope goes to zero, an ideal limiter's gain goes to infinity. A practical limiter will output noise bursts if its input envelope pinches off.

So, if there is a slight amount of multipath, causing only 4 dB of differential fading between the analog and digital components of a signal, the envelope at the receiver may pinch off, causing noise bursts on analog receivers. In other words, the digital signal may capture the analog FM demodulator.

This shows that peak-to-average ratio reduction is a good thing. Reducing positive modulation peaks significantly reduces transmitter PEP requirements. But reducing the negative envelope modulation improves the capture fade margin for the receivers.

It could be argued that the digital sidebands are filtered out before the hard limiter, so there is no problem. This is true, to an extent. Unfortunately, the selectivity of IF filters are highly variable. Fig. 3 shows a plot of a typical FM bandpass filter made by Murata, with an IBOC spectrum superimposed on the same plot to the same scale. Murata makes monolithic ceramic bandpass filters used in many FM radios. They come in a variety of bandwidths. Electronically tuned car radios tend to have narrower bandwidths. Continuously tuned radios tend to have wider IF filters to make tuning less critical.

The filter shown in Fig. 3 has a nominal bandwidth of 230 kHz. It is a narrow

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type that might be used in a synthesized receiver. Careful inspection of the catalog curves show that the IBOC sidebands are reduced about 4 dB where they start and about 17 dB where they end. This is a good thing — if the sidebands can be reduced in amplitude before the hard limiter there is less danger of digital capture.

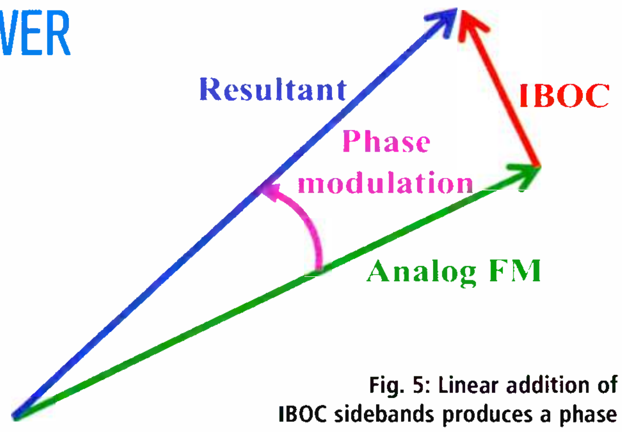

Fig. 5: Linear addition of IBOC sidebands produces a phase modulation component.The derivative of the phase modulation is the frequency modulation self-noise.

Fig. 4 shows one of Murata's wider filters. This filter has a nominal bandwidth of 350 kHz. This one has negligible attenuation at the IBOC sidebands. So receivers with this kind of filter, which would give very good analog FM demodulation, are much more susceptible to differential fading multipath. Receivers with this kind of selectivity curve will get the full effect of the IBOC sidebands.

SELF-NOISE MECHANISMS

When an analog FM signal and IBOC sidebands are both present at a receiver's demodulator, the IBOC sidebands produce a certain amount of phase modulation of the FM carrier. Fig. 5 shows an example at one instant in time. And the derivative of that phase modulation is the FM noise added by the IBOC sidebands.

It helps to look at the frequency domain when analyzing the effects of HD sidebands on the analog signal. We will start by looking at an unmodulated signal. FM demodulation is a highly nonlinear process. In general, we cannot look at an RF spectrum and intuitively predict what will come out of an FM demodulator. However, when the modulation index is low enough, we can look at a spectrum and get an idea of where the first order phase modulation terms will appear. That is the case here — a low modulation index at high frequencies.

Fig. 6 shows the output of the demodulator with no modulation of the FM carrier. This results in a simple analysis. We can expect to see first-order phase modulation components beginning at 129 kHz and going up to 198 kHz. These components are due to the simple beat notes between the FM carrier and each one of the IBOC carriers. The FM stereo composite bandwidth is 53 kHz, so these first-order high-frequency components are out of band and will not be a problem to the demodulated stereo, unless the stereo demodulator responds to harmonics of 38 kHz.

Now imagine what happens if you modulate the analog with a very low frequency. Assume we are modulating 100 percent at 20 Hertz. The modulation is now so slow that we can think of it as a single carrier sweeping back and forth, from minus 75 kHz to plus 75 kHz. Fig. 7 shows what the carrier looks like when it hits a modulation peak. Now the beat notes have changed significantly. The lowest first-order beat is +75 kHz beating with +129 kHz. This produces a beat note of 54 kHz. Stereo L–R ends at 53 kHz. Analog overmodulation will clearly cause a problem with beat note products into the stereo baseband.

If we can imagine what comes out of the FM demodulator in this situation, we have a block of first-order beats that sweep back and forth from 54 up to 273 kHz, driven by the analog FM deviation. If this was all that came out of the FM demodulator, the analog signal with the possible exception of SCAs and RDS would be pristine.

But FM demodulation and the beat note generation process are quite nonlinear. The FM demodulation process takes derivatives of arctangent functions, which can make a real mess in the frequency domain.

SIMULATIONS

What follows are the results of some simulations. The simulations show what happens to the analog FM in the presence of different levels of HD injection, with different kinds of filtering and analog modulation.

First we begin with a FM+HD signal. Then we may filter the signal. The filter may simulate a receiver's bandpass filter, multipath propagation, or both. Next the filtered FM+HD signal is applied to a "perfect" numerical FM demodulator. See Fig. 8.

Finally, we do a spectrum analysis of what comes out of the FM demodulator. This allows us to see noise and distortion in the frequency domain.

Some of the simulations we are about to see were done with full-blast IBOC power, with no bandwidth limiting. This simulates a wideband receiver. Simulations of a narrowband receiver were done with the linear phase FIR filter shown in Fig. 9, which closely approxi-

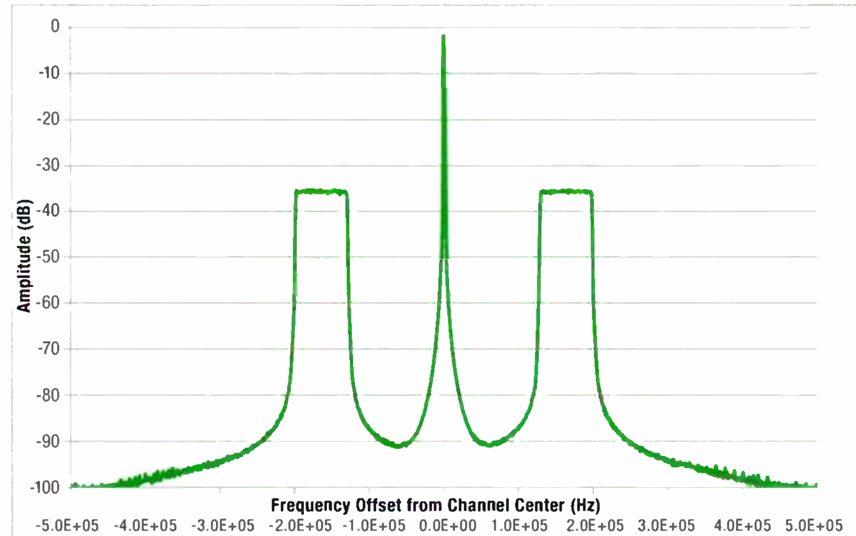

Fig. 6: Unmodulated analog FM with IBOC carriers

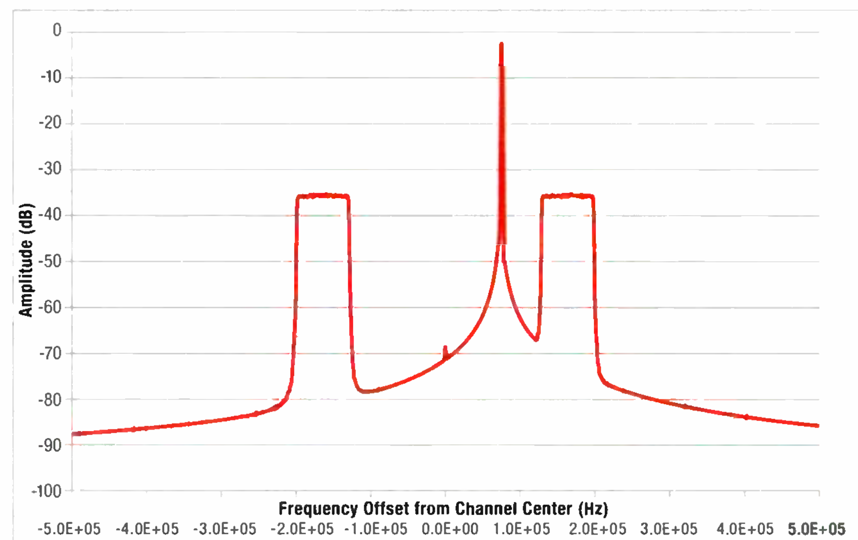

Fig. 7: 'DC' or low-frequency modulation of +75 kHz, producing lower-frequency beat notes

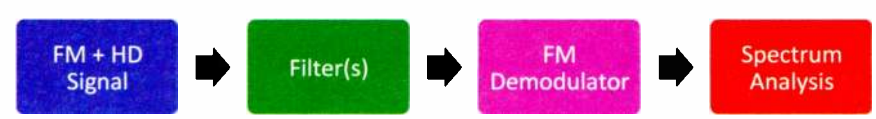

Fig. 8: Complex baseband simulation. The FM demodulator includes a hard limiter and produces $FM(t) = Q(t) \times \frac{dI}{dt} - I(t) \times \frac{dQ}{dt}$ as the demodulated FM.

mates the amplitude response of the narrow Murata filter shown earlier. This filter slopes from –4 to –17 dB across the IBOC sideband blocks. The resulting attenuation of the IBOC sideband energy is 6.7 dB. So 10 percent digital power becomes 2.1 percent after this filter.

In a wide bandwidth, with no de-emphasis, Fig. 10 shows the time domain signal that comes out of the FM demodulator at 10 percent digital power. This is one cycle of 1.9 kHz mono, and the noise riding on it is due to the digital sidebands. This is a very scary picture, but fortunately the situation is not as bad as it looks.

We can insert the sharp IF filter to knock the IBOC sidebands down about 6.7 dB, and a post-detection 53 kHz brick-wall filter to limit the bandwidth to just the stereo composite baseband. These two measures get rid of the great majority of the unwanted FM. The waveform shown in Fig. 11 is not nearly as scary. All we see is a little bit of noise, mostly at the peaks of the sine wave.

The noise appears mainly at the peaks, because those are the points where the carrier has deviated 75 kHz where it is much closer to the IBOC sidebands. So, the first-order beat notes are lower and they start to sneak inside the 53 kHz low-pass filter's passband.

Now we can make a distortion analyzer numerically. Fig. 12 shows the FM detector output with 1 percent digital power with the brick-wall 53 kHz low-pass, but no IF filtering. The green trace is the demodulator output, and the red trace is the output of a notch filter that removes the 1.9 kHz fundamental tone. So the red trace is the demodulated

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noise. It is also shown on an expanded scale with a gain factor of about 10.

Now we can clearly see the beat notes that get bigger as the sine wave reaches its peaks.

Fig. 13 shows what happens when we insert the sharp IF filter. The beat note is

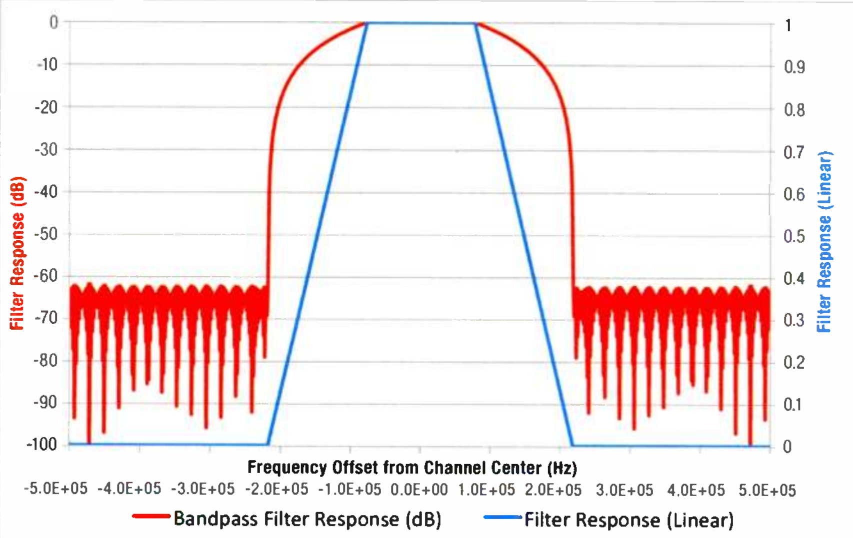


Fig. 9: IF bandpass response used in narrow filter simulations

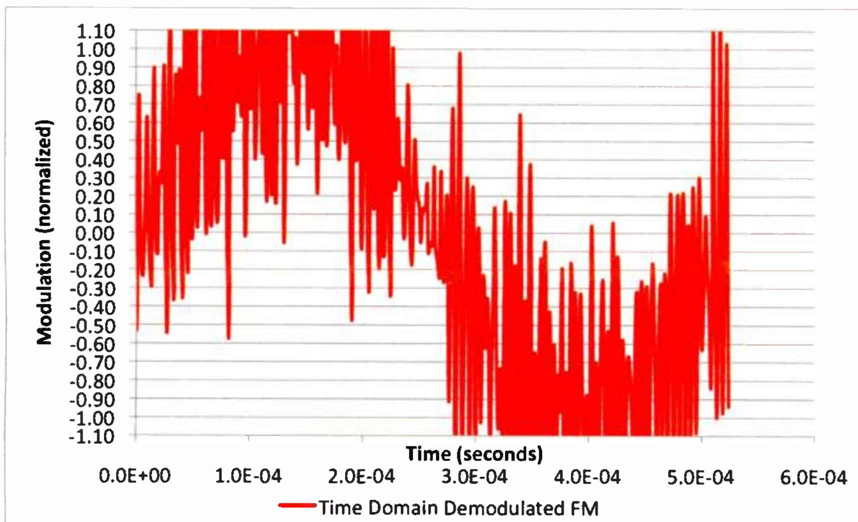


Fig. 10: FM detector output, 1.9 kHz monophonic tone at 75 kHz deviation, 10% digital, no filtering

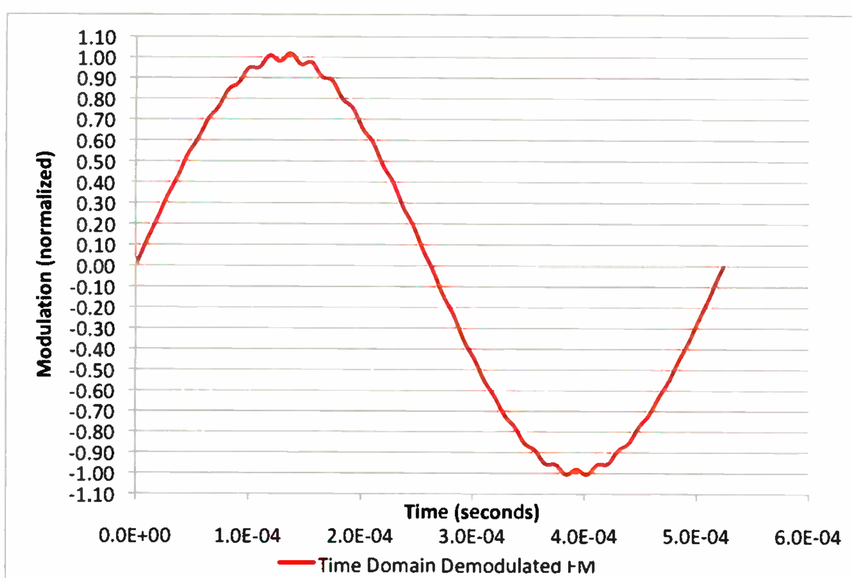


Fig. 11: FM detector output, 1.9 kHz monophonic tone at 75 kHz deviation, 10% digital, narrow IF filter, 53 kHz post-detection low-pass filtering

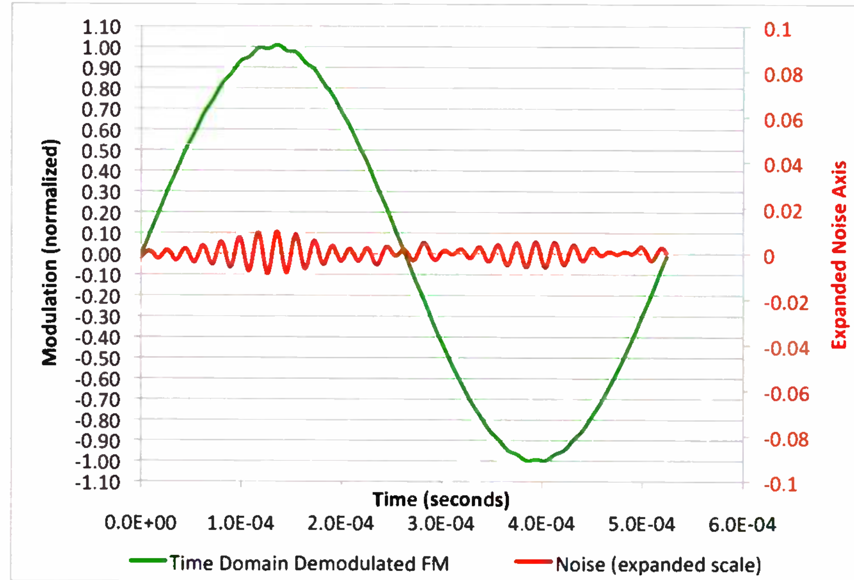


Fig. 12: FM detector output, 1.9 kHz monophonic tone at 75 kHz deviation, 1% digital, wide IF, 53 kHz post-detection low-pass filtering

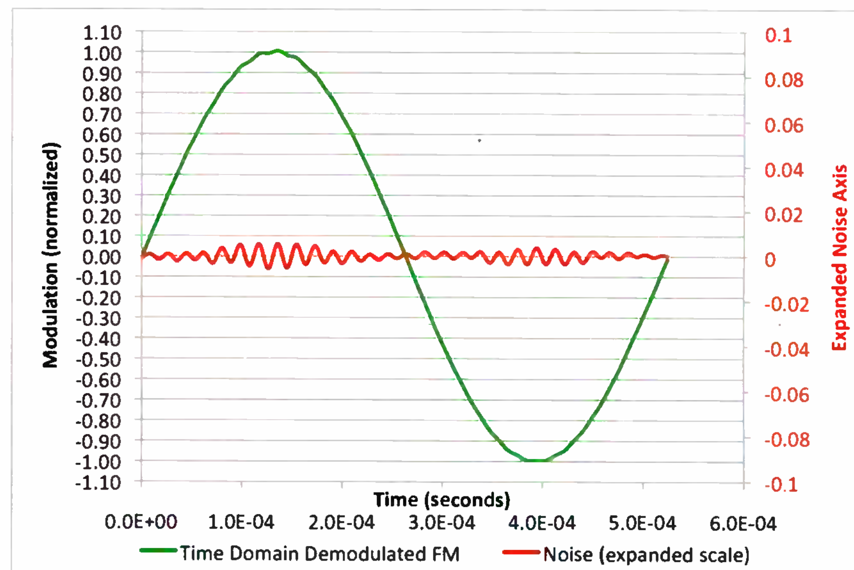


Fig. 13: FM detector output, 1.9 kHz monophonic tone at 75 kHz deviation, 1% digital, narrow IF, 53 kHz post-detection low-pass filtering

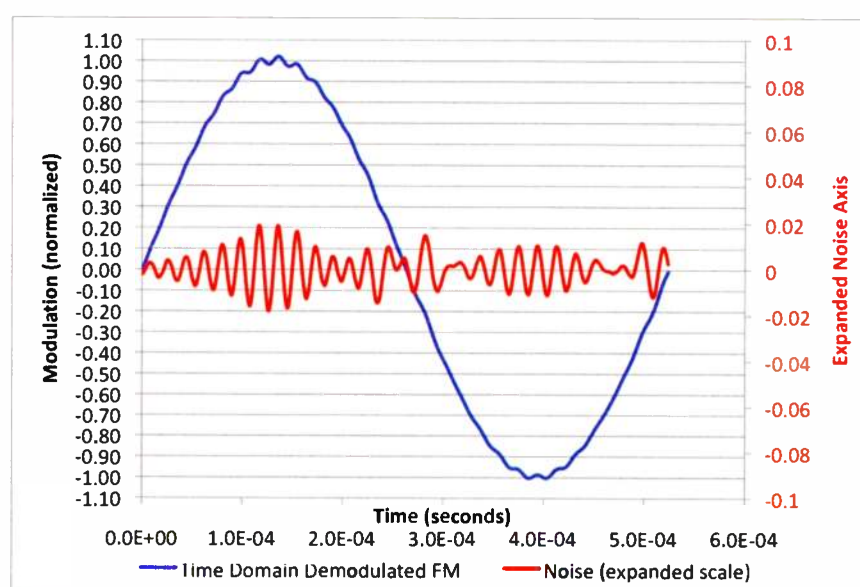


Fig. 14: FM detector output, 1.9 kHz monophonic tone at 75 kHz deviation, 4% digital, wide IF, 53 kHz post-detection low-pass filtering

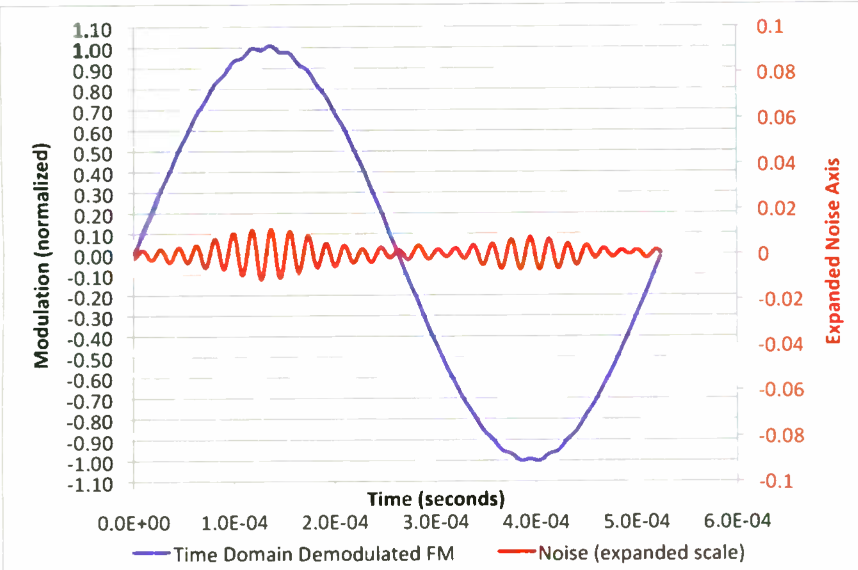


Fig. 15: FM detector output, 1.9 kHz monophonic tone at 75 kHz deviation, 4% digital, narrow IF, 53 kHz post-detection low-pass filtering

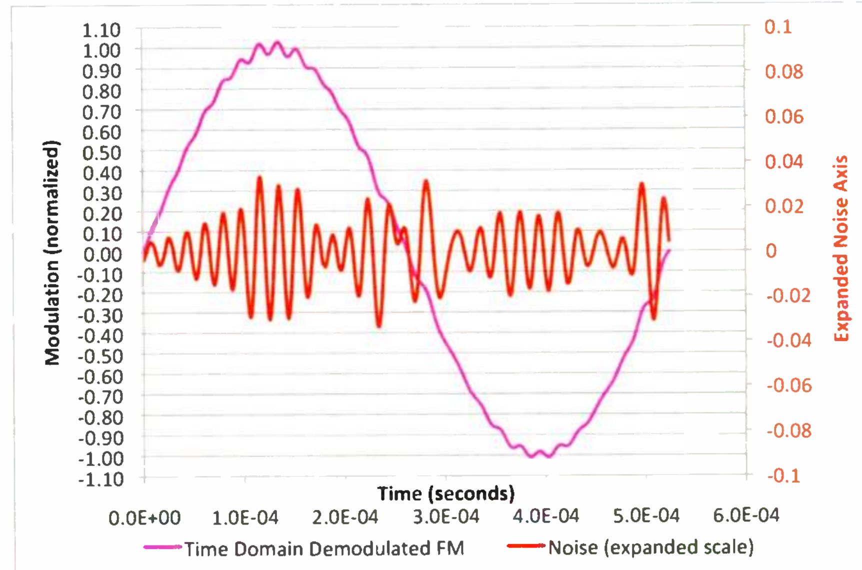


Figure 16: FM detector output, 1.9 kHz monophonic tone at 75 kHz deviation, 10% digital, wide IF, 53 kHz post-detection low-pass filtering

still present, but it is smaller.

In Fig. 14 we have turned up the digital power to 4 percent. This is with no IF filtering, to simulate a wide bandwidth receiver. The noise is bigger.

Fig. 15 shows 4 percent digital power with the sharp IF filter. As expected, the noise amplitude is reduced.

In Fig. 16 we have turned up the digital power to 10 percent. This is with no IF filtering, but the 53 kHz post-detection filter is still present. The noise is still bigger.

CONCLUSION

As has been shown, elevated digital power brings with it various engineering tradeoffs that raise concern. Higher digital power increases the amount of envelope modulation, reducing the amount of signal headroom at the demodulator. This will increase receiver susceptibility to noise bursts during multipath fading or even the possibility of "digital capture" of the receiver.

Additionally, as shown in the simulations, higher digital power results in increased intermodulation between the analog and digital signals, resulting in noise components in the stereo baseband area. This reduces the stereo signal-to-noise ratio on receivers, particularly on higher-quality models with wider IF bandwidths.

In Part II we will analyze the demodulated spectrum of elevated digital FM signals and quantify the signal to noise effects. Real-world tuner measurements will demonstrate the accuracy of the simulations. We will look at peak-to-average ratio reduction algorithms. Finally we will make some recommendations for evaluating elevated HD.

Contact author Dave Hershberger at dhershberger@contelec.com.

The Mysteries of Network Masquerading

All You Ever Need to Know About Nets, NATs and Ports

BY STEPHEN M. POOLE

One indispensable part of the Internet-savvy broadcast engineer's toolkit nowadays is network address translation, or NAT. I introduce it in this article and show you how to use it to enable another great tool, Virtual Network Computing (VNC).

As usual, I'm going to keep this short and sweet. I'll let the True Geeks argue about whether a particular case would more accurately be called "Masquerading" or "Port Forwarding." If you're interested, do a Web search on "network address translation" and "RFC 1631" to get the inside story. You'll see why NAT was developed in the first place (a growing shortage of available IPV4 addresses, which is also why IPV6 has been introduced) and how it has been cleverly adapted to the usage I'll discuss here.

Also as usual, I'll stick to standard IPV4 address (e.g. 192.168.1.100) and my favorite example, a small office network that shares Internet access with a typical DSL modem/router.

NETWORK ADDRESSING

IP addresses can be compared to the delivery location specified for a piece of mail. The "post office" (your network, in this case) sees that address and delivers the "message" (the packet of data) to the requested computer. But there's another number built into that message header that's analogous to the addressee's name, called the *port number*. These are 16-bit values from 0-65535.

It would be inefficient for the mailroom to open each envelope to determine who should get each letter. Likewise, your computer won't examine the contents of each data packet to try to figure out where it should go. Instead, port numbers are used to mark and match each request to a given "recipient."

The analogy ends here, but the cleverness appears: Port numbers are the key to network address translation!

Some port numbers are standardized. For example, suppose you're running a typical Web server at your station. Incoming requests will be destined for your IP address, at the standard HTTP port, number 80. Your PC's network subsystem sees that number and sends the packet to the Web server for handling.

But port numbers are used to mark outgoing data as well. In fact, port numbers routinely are used to mark data packets, as you'll see in a moment.

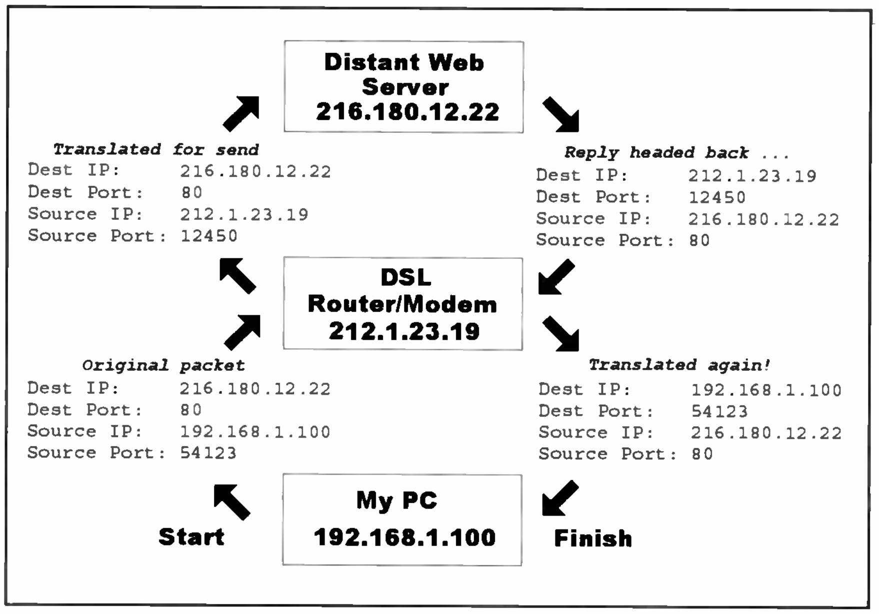


Fig. 1: A simplified diagram of how packets get through a router, onto the Internet and back to the original computer.

For example, your Web server might have several people connected at the same time, all coming from different locations. It might mark each *outgoing* response with a unique port number to keep up with who is doing what.

We can refer to ports and IP addresses as being either for a *destination* (i.e., where the data is going) or a *source* (i.e., who made the request). These designations are always from the *sender's* point of view.

FUNDAMENTALS OF NETWORK ADDRESS TRANSLATION

You almost certainly use NAT every day without even realizing it. If my co-workers and I are all browsing the Web at the same time, the destination addressing is obvious. But how does each reply get back to the correct PC on our internal network?

This is illustrated in Fig. 1. My PC is at 192.168.1.100; our DSL modem has an external ("Internet") address 212.1.23.19.

1. My PC uses DNS (see Radio World Engineering Extra, Dec. 9, 2009) to look up the desired website's actual IP address, which is at 216.180.12.22.
2. My PC crafts a request with that destination IP, port 80. The source is my IP address and a self-generated port number that my PC will use to help keep track of things.
3. The DSL modem now translates this for sending. It stores my original IP and source port number in a table, and then generates its own source port number to index my values.
4. The DSL modem sends the request with its own IP address and "index" source port number to the website.
5. The website gets the request and replies to the DSL modem. The reply destination is my DSL modem's IP address and port number.
6. The DSL modem uses the destination port number as an index to look up my original numbers in its internal table.
7. My IP address and original port number are re-inserted and the packet finally makes it back to my PC.

The key point here is that *it takes more than an IP address to make a conversation*. The port number is part of it too! But if you think about it for a moment, you'll see how we could use this to "masquerade" incoming ports to different machines ourselves. All the modem needs to do is watch for certain port numbers, *which it will then always send to the same internal network address*.

MASQUERADING (PORT FORWARDING)

Since a DSL modem already does NAT routing anyway, most of them toss in the ability to do specifically-targeted port forwarding for free. This allows you to set up a server on the internal network and expose it to the Internet.

DSL modems usually include a built-in Web interface for configuration. Check your modem's manual for details, but there should be a configuration option entitled "NAT," "masquerading" or "port forwarding." This is what you want.

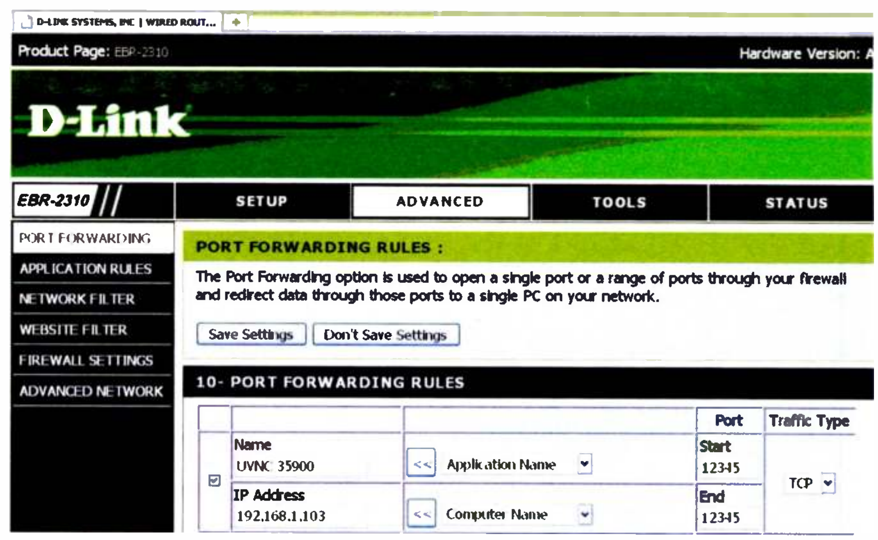


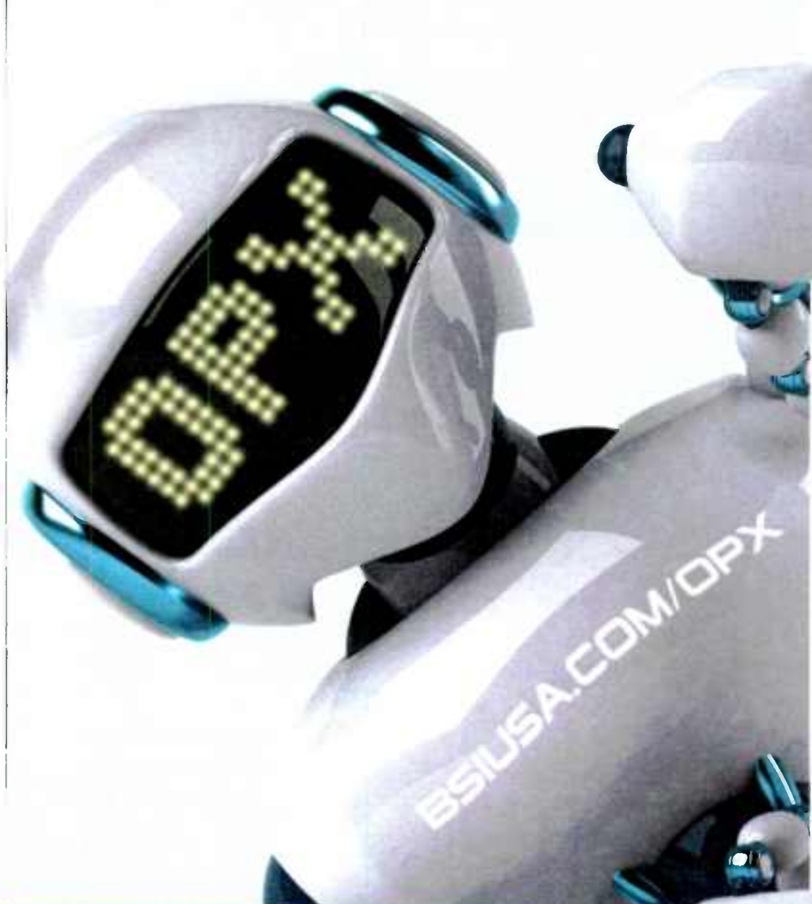
Fig. 2: Port forwarding with a typical modem/router. Port 5900 is routed to a VNC server on the internal network.

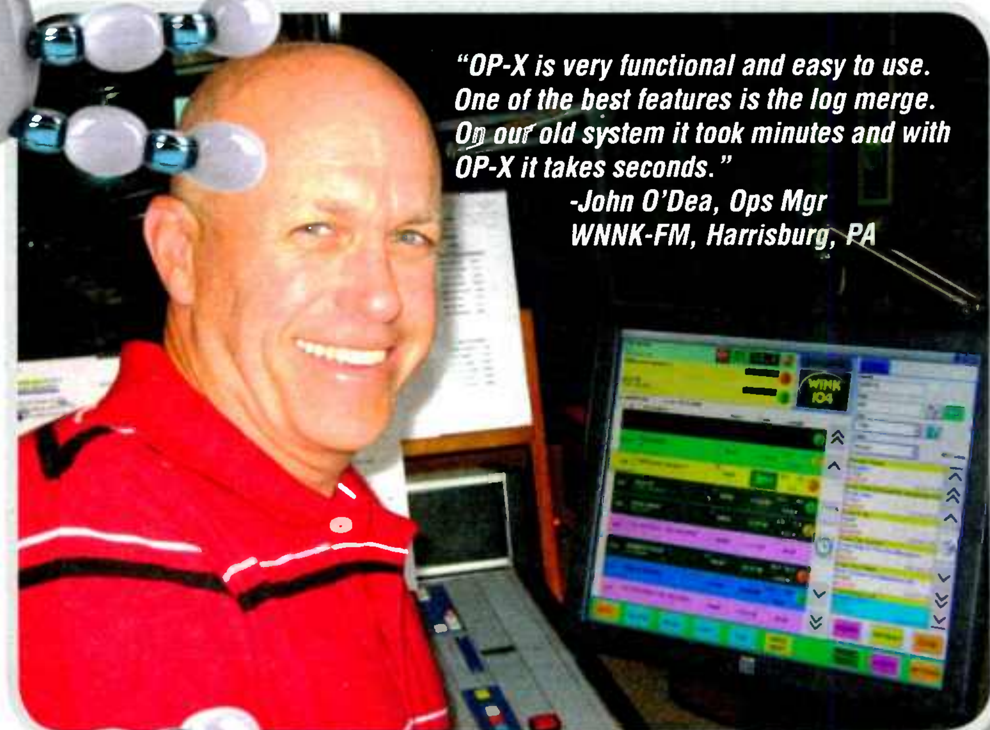
Fig. 2 shows the Port Forwarding for one of our DLink units; I've mapped VNC to one of our internal machines.

Security must get a mention here: Be careful about setting up a Web or mail server like this. High-traffic servers on standard, well-known port numbers not only require a lot of care and feeding, they really ought to be isolated from your internal network. That's for another article.

But I'll close with one ideal use for this: you can give yourself remote access to one of the machines on that local network with VNC (Virtual Network

(continued on page 18)





- Modular Operation in Op-X allows for a tiered system at a fraction of the cost of it's competitors.
- Each studio client is capable of accessing all Audio Server modules on the network.
- Remote voice-tracking allows for creation of content for remote studios also running Op-X.
- The revolutionary design of Op-X's clock builder turns the previous task of scheduling satellite programming into a few simple clicks.
- Share serial devices from any machine using the Op-X Serial Server.
- Importing logs now gets its own module that takes confusion out of the process.
- Engineers will enjoy Op-X because it's easy to install, maintain, and has automatic backup features.

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RADIO AUTOMATION

AUTOMATION

SIMPLE • POWERFUL • REDUNDANT

Not since Axia audio-over-IP *was introduced to the broadcast industry have we at BGS been so excited! It is with great enthusiasm we'd like to invite you to take a look at the new Op-X Radio Automation delivery system for any single or multi-station cluster. Op-X's versatility allows it to operate seamlessly with either Axia IP-Audio networks or legacy audio consoles.*

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READER'SFORUM

WE'VE LOST OUR MINOR LEAGUES

The Guy Wire story about automation assist ("The Advance That Has Led Us Backwards," June 9) misses one very important point: Today we have *very few* young talents coming up.

Radio broadcasting at one time was like professional baseball. Small-market stations were the farm teams where young announcers learned their trade and polished their skills. If they didn't have enough talent, they never made it to the big-league, major-market stations. Then they got honest jobs like selling shoes.

Today, small-market on-air jobs do not exist. Most of the programming comes from satellite or from automation machines. An account executive does what live announcing may be needed during drive-time shows. Name recognition helps give him entrée to businesses. The farm teams are gone.

At one time, a radio announcer was thought to be a glamorous job, right up there with acting in the movies. Children classified "announcer" with "fireman," "policeman" and "railroad locomotive engineer." Today the number of students working on campus radio stations is way down from previous years.

Fred Krock
Walnut Creek, Calif.

GOVERNOR'S 'MUST-CARRY'

Michael, great article ("CAP Implementation Guide Gives Glimpse Into Future System," June 9).

My only quibble would be that the Gubernatorial Must-Carry isn't a feature of the Common Alerting Protocol per se. That was an idea the commission came up with on its own. CAP will be able to accommodate that new provision for states that implement it in their state plans, but the CAP designers can't take credit for that particular aspect of the EAS rule changes.

Art Botterell
Fairfield, Calif.

The author is a consultant and original designer of the Common Alerting Protocol.

WRITE TO RWEE

SEND A LETTER TO THE EDITOR:
E-mail **rwee@nbmedia.com** with "Letter to the Editor" in the subject field. Please include issue date.

NETWORK

(continued from page 16)

Computing). If you do this on your audio network, for example, you can log in remotely to insert programs, move spots and check the logs at nights and on weekends. Very handy!

Here's how you do it:

1. Your DSL modem must have a static IP address on the Internet and it must not block ports. Contact your Internet service provider to ensure this. If you don't currently have a static IP, you may have to pay a bit more each month for that feature.
2. Go to *www.uvnc.com* and download Ultr@vnc. It's a free VNC server and client that work like a champ on Windows machines.
3. Install it on the chosen server machine. NOTE: This PC must have a static IP address on the internal network as well. The modem needs a known, unchanging IP address to forward requests to.
4. You can accept the defaults for most configuration options, but we'll make two changes. Bring up the Server configuration box by right-clicking on the "eyeball" icon in the toolbar. First, give it a strong password, a random mix of numbers and letters. Second, change the "main" port from the default 5900 (see Fig. 3; we can leave the HTTP port to the default 5800 because we won't use it in this example). Hackers love to target these well-known port numbers to try to gain access to your network.
5. Go into Windows' firewall and open your chosen port number.
6. Go into your modem's configuration page and set the forwarding for your chosen port number to go to that VNC machine's IP address.

Now install the VNC client on your PC at home (once again, the defaults will work fine). To connect, enter the IP address of your DSL modem along your special port number. You'll need to enter the password you selected when installing VNC Server so the connection is secure. You can then operate the server remotely, almost as if you were standing at the machine instead of sitting at your PC at home or anywhere else with Internet access.

Here's a tip: If you forget your DSL modem's external address, go to any PC on your internal network and browse to "whatismyip.com."

Once you've used it for a while, you'll wonder how you got along without VNC … and all of this is accomplished through the magic of Network Address Translation!

Stephen M. Poole, CBRE-AMD, CBNT, is market chief engineer at Crawford Broadcasting in Birmingham, Ala.

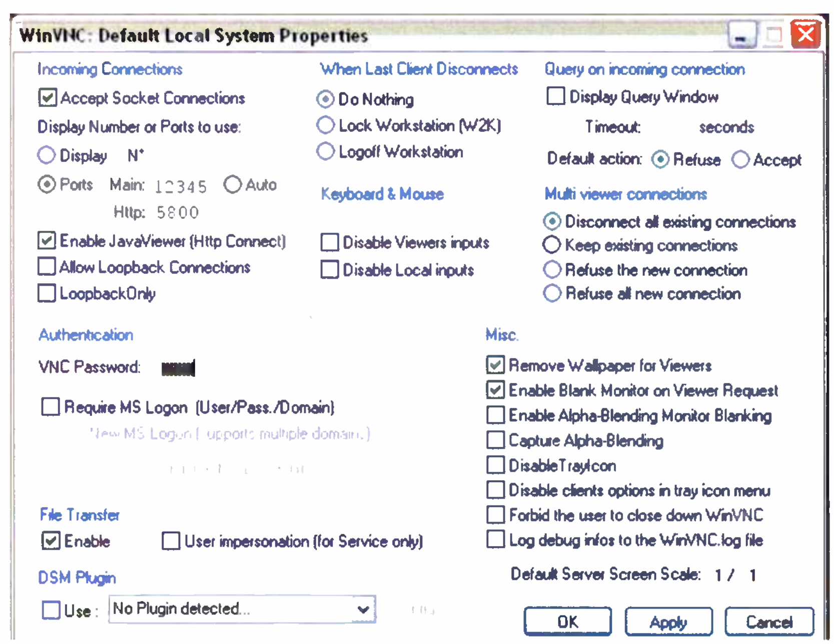


Fig. 3: Changing the default password and port number on a VNC server.

Protect Yourself With the NEC

Compliance Is Smart — and It's the Law

BY CHARLES S. FITCH

Why the National Electrical Code and what is its purpose?

The why and what really are the same: NEC is a standards document intended to *protect personnel* — like you, me and our families — and *material*, such as your station equipment.

The National Electrical Code is an amazing document, one of the oldest, most widely quoted and recognizable standards extant. It is also one of the most misquoted and misunderstood documents *not* read by people who should have done so.

This is unfortunate, as the application of the NEC has a daily, profound effect on us personally and professionally.

Think about it. How many times today have you turned on a light, switched on an appliance or used electric power in some manner? Every electrical function that you initiated was somehow touched by the mandate of the NEC.

The universe of electric power can be divided into three traditional worlds: generation, delivery and consumption. Generation and delivery, in the past, were the realm of utilities; consumption was ours.

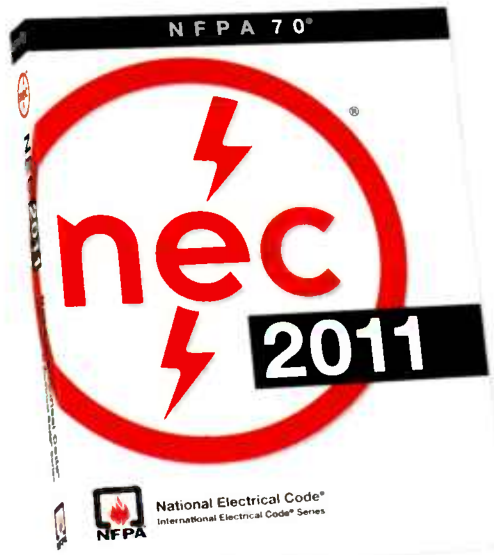
Today this is not necessarily so. New economies bring competition to generation — for instance, electric power is the largest monetary export of Canada — and to delivery, where multiple purveyors compete for customers trying to achieve lowest dollar costs (sounds like broadcasting!).

Things are changing, and you soon may be responsible for delivering your own power or generating some portion of your own.

The NEC primarily involves the world of consumption, defining standards from the place where the utility leaves off to the place where kilowatt-hours are used to do work.

FROM PRIVATE TO PUBLIC

The NEC has an interesting history. It appeared during a transition period, around 1898, when early power technology purveyors and entrepreneurs such as Thomas Edison (DC) and George Westinghouse (AC) started to get out of the "soup to nuts" electric business. The custom had been for a single source to sell into mainly commercial or municipal markets the access to generation, power delivery, switch gear, premise wiring, lighting, utilization equipment, right down to instruction on use, maintenance, even new electric arc light stock. Essentially the customer enjoyed turnkey operation.



The 2011 NEC is due out this fall.

Electricity soon started moving into homes. With that, wiring began to be done by people without technical training.

The insurance industry recognized the need for standards. It would be impossible to insure all the places where power equipment was located unless wiring and devices met minimum standards.

The greatest risk was from fire or personal injury precipitated by improper installation or utilization of electricity. This was a real concern. Materials were not sophisticated (e.g., the covering on wire was often knitted and embroidered cotton over paper), and no universal standards assured uniformity among manufacturers.

The National Fire Protection Code, the fire insurance industry's standards tome,

(continued on page 20)

NEC

(continued from page 19)

got its first electrical section in late 1897. That section blossomed into the NEC.

Progressively, it developed into an independently published document as a more expansive, cohesive, specific text with more than 1 million changes implemented in the last 110 years over subsequent editions, perfecting older details while simultaneously assimilating and covering new materials, technology and techniques.

In paperback the 2008 NEC runs something close to 1,000 pages. An updated NEC comes out every three years or so. The latest copy on my desk is dated 2008; according to the publisher, the 2011 edition begins shipping in November.

One way I can tell if someone has actually ever read the NEC is to ask them how it begins. Essentially, the document starts with definitions but then continues by explaining itself in the first section — what it is and what it is not.

What it is: a set of standards that, if followed, will result in a safe (hence insurable) electric installation. What it is not, we are cautioned by the authors, is a "design manual." For that reason, we also are cautioned that by following the NEC, our installation will be safe, though it will not necessarily be efficient. As long as the installation is minimally compliant, the optimization design for efficiency, suitability and quality are left to the engineer.

WHO KNOWS BETTER?

I frequently encounter two phenomena: an arrogance among station personnel (including management) that they know better than the NEC; and "horror stories" involving broadcast electrical installations.

Most of these disasters, it appears, occurred when there had been no attempt to follow the dictates of the NEC.

The NEC does not and has not appeared wholly formed right out of the head of Jupiter. Over the years, thousands of knowledgeable people like you, from across the industry, have provided input and labored over substance and language to meet the goal of safety. In a typical version update, more than 1,500 people are involved on dozens of subcommittees, trying to optimize a few thousand words of changes. These folks typically bring 30,000 years of experience to the task.

In a typical version update, more than 1,500 people are involved on dozens of subcommittees, trying to optimize a few thousand words of changes.

Do you think that with your meager experience of a single lifetime, you or anyone around you should undercut them on safety factors?

The NEC normally has its greatest impact on us during new construction or retrofit, when engineers and contractors are most involved; the NEC affects both.

I have a leg in both camps; I am not only a registered professional engineer but also a licensed electrical contractor in several states. These are separate yet complementary activities.

An engineer has a strong mastery and knowledge of concepts and a workable knowledge of materials and their use. Conversely, a contractor has a strong knowledge of materials and a workable knowledge of concepts.

An experienced engineer can design for you an installation that is not only safe (NEC-compliant) but also more efficient, flexible, reliable and expandable. But even the best contractors may not be tuned into the specific needs or challenges of your station, although they will supply a workmanlike and compliant (hence, safe) installation.

BUILDING CODES AND INSPECTIONS

The National Electrical Code precisely is Section 70 of the National Fire Protection Code, or NFPC. The latter gathers codified safety standards for many types of installations, where there is a potential for fire danger and personnel injury (for example, range exhaust hoods for food preparation areas are covered in Part 94).

In most jurisdictions, an official body is involved in the permit and inspection process for new and retrofit construction. For most folks and their businesses, such as your station, that is the building office of your local municipality. Most of us interact with this authority in the person of the "building inspector."

To draw together the plethora of codes and standards that affect construction, the Building Officials Code Authority publishes the BOCA code, which, with rare exception, is the umbrella standards document used by most inspection agencies.

For the most part, the NFPC and with it, the NEC, are taken whole form into the BOCA — similar to how the EIA-222 standard is taken in to cover construction and modification of tower structures. However, when you apply

CERTIFIABLY BUC!

Author Charles "Buc" Fitch has been named Educator of the Year by the Society of Broadcast Engineers. Radio World nominated him in recognition of his many contributions to industry knowledge and training, including his Certification Corner series in RW Engineering Extra, which returns next issue.

for your building permit, you should specifically inquire about the codes, the exact version used and what mandatory inspections are required.

Many jurisdictions have additive codes; the NEC is taken in whole body and an additional set of regulations are strapped on. Massachusetts, for instance, has specified exactly the color code for wire that should be used with various voltage systems. The NEC provides some latitude.

You owe it to the next guy at the station to make certain your work is safe and predictable.

Also, many municipalities use a previous version to maintain uniformity among inspectors and to allow all arbitrated decisions to have been finalized regarding new inclusions *before* they implement that version of the NEC. There are many locations still using the 2005 code such as Connecticut (at last check), and not the current, 2008, edition for this reason.

In regard to inspections, most locations require at least two: all rough-in and finished wire systems that will be hidden by walls, *and* a final. Occasionally, that final inspection can require all loads running so that the inspector can do a voltage drop, current and balance check.

In some locations such as Saratoga County, N.Y., inspections are done by a third party such as an independent underwriter, with the results being supplied to the building office and/or utility.

If they are going to be the inspectors, do not connect a wire to a screw before you speak with and arrange for the underwriter. Their involvement varies tremendously from location to location. Many locations that use underwriters require *advance* design approval.

On some projects involving major construction or elaborately designed systems, a peer review is substituted. In Massachusetts, these are known as Section 116 or 127 inspections, wherein the proponent hires an outside engineer (like me) who in turn actually works for the building inspector. As the project evolves, designs are reviewed, inspections are made, reports of these are filed by the outside engineer with the BI and the work proceeds at its own pace as long as the installation is compliant.

Examples of Section 116/127 events that come to mind include a multi-user tower, a complicated data processing center and a huge shopping complex. All were complicated and outside the usual experience of the building office, not to mention their time resources.

THE NEC THING

In summary, the NEC, by itself, is a safety standard that takes on the force of law because of its place in building and safety regulations. No matter the circumstances, your electrical installation *will be* subject to the NEC.

But if you're still not convinced, here are some reasons why *you* should follow the NEC:

- You owe it to the person who follows you — the next guy at the station — to make certain your work is safe and predictable so that he doesn't have the "shock" (pun intended) of discovering something odd, weird or unsafe.
- At minimum the system will continue to be safe, if not as efficient as you might think it could be. A focus on safety will often prevent you from injuring yourself, saving you from your own ineptitude when you're fatigued or careless.
- You will preserve your insurability. Neither life nor business insurance will cover a loss from incompetence without a challenge. If you die of shock precipitated by an electrical hazard that you installed, it could be ruled a suicide.
- Any savings in time or money that you create by cutting safety corners in the electric system will just be squandered by someone else. At the mint, they're printing money three shifts a day, but they're not making another you. No matter how little you might think of yourself, someone will miss you. So think of them before you use Scotch tape instead of a wire nut.
- Make risk management work for you. If you do not feel comfortable doing electric work, the NEC is a great reason to have an outside professional come in to do it. *"Boss, we can't afford to have an unsafe or uninsurable installation, and it moves the liability outside the station. You know, the NEC thing ..."*

Charles "Buc" Fitch, P.E., CPBE, AMD, is a frequent contributor to Radio World. This article is an excerpt of a presentation at the 2010 SBE Chapter 14/ Connecticut Broadcasters Association Engineer's Day.

WIRELESS

(continued from page 22)

minutes of outage would mean to his operations. In the public safety mobile radio world, which is a fairly good model for the emerging "consumer mobile device" environment, the path availability is at best only 95 percent, and reaching even that figure requires some expensive engineering designs.

The public's expectations for electronic communications have been conditioned by almost a century of its use of wired channels or, in the special case of wireless broadcasting, signals that are generally always tens of decibels above the ambient noise level.

Consumers expect 100 percent path availability; they don't know how to deal with lower-quality channels. And if they don't like "dropped" cellular telephone calls now, how well will they do with dropped mobile Web pages, dropped music streams or movies, etc.?

A second advantage of wired channels is their spectral bandwidth availability.

We can see that there isn't a nearly sufficient amount of available RF spectrum to handle the total job of "broadbanding America." (And led by the politicized FCC, the broadbanding job is being pushed onto the RF spectrum largely because doing it in RF is cheap and quick compared to hanging cable. RF capital investments are smaller, and the profits begin rolling in more rapidly.)

But wires always have abundant internal spectrum available, limited only by the ingenuity of engineers to use it. Each copper pair in a cable, each glass fiber in a bundle, has available for use within itself the entire radio frequency domain, or the equivalent capacity in the time domain. And the adjacent wire pair or fiber contains another complete and independent universe that adds to the available resources!

The end uses that the public makes of communications channels are not a legitimate topic for an engineering discussion; ethically, as engineers, "we can't go there." But careful thought should be given before a consumer application that could be satisfied on wires is instead dumped onto the RF spectrum.

Do we really need to do this? Do we really want to burn up our very limited public resources for just a "nice to have" application? Are we about to create the radio spectrum equivalent of a deep-water blowout?

Of course this discussion will have absolutely zero effect on the forthcoming public policy decisions; the Curmudgeon well understood this even as he wrote it. In the marketplace, popular always trumps thoughtful, and the United States is, above everything else, a vast market. We as a country will blithely squander our resources and then, looking back in time, we will wonder why we did it.

But to the Curmudgeon, destroying the RF spectrum solely in the name of chic and a quick profit makes as much sense as slaughtering panda bears for their meat. Wireless is not a toy. It's a very limited resource and a tool. And this fundamental view will never change.

Please consider for a moment, when you reach for your wireless *iTrinket*, that the terms "conservation" and "conservative" derive from the same language root, which root means "to protect from harm or destruction."

What do you think?

"Let's save the universe for RF."

Comment on this or any story to rwee@nbmedia.com.

The Old RF Curmudgeon is broadcast consultant Lawrence Behr. You can follow his blog at www.rfblog.lba.com.

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Must Everything Be Mobile?

A Radioman's Paean to the Wired Telecommunications Circuit

BY THE OLD RF CURMUDGEON

iStockphoto/Brandon Laufenberg

The U.S. economy, juiced by the national popular culture, is about to commit another major telecommunications blunder. The title of this article gives a clue to it. Since there is no way to stop or prevent the developing blunder, it might be of some use at least to understand what we are doing.

American consumers, gleefully aided and abetted by the commercial carriers, have become besotted by the concept of "wireless." Thus the public now demands that its communications and entertainment pastimes must become "untethered!"

They want to take everything they do (voice, text, movies, e-mail, games, television, search, music, navigation, Web browsing, photographs, home video and perhaps even remote control over their kitchen coffee pots) along with them on their persons — everywhere and forever.

They want "permanently connected Web, direct to the belly-button!" They want it 24 hours a day, and even more if they could just fit the time in! They want it all, even though they don't have the background or the interest to understand the future ramifications of this wish.

Would it shock you, Gentle Reader, to discover that the Curmudgeon has a slightly different take on this? That his 50 years as a radioman provides a perspective that a frenetic teenager or a (formerly) upwardly-mobile "Twenty-Something" doesn't have? That all the narcotic-like addictiveness of the latest "Belt Toyz" looks somewhat different when viewed in the context of the history and the engineering realities of telecommunications? (And just to settle a point, yes, the Curmudgeon has used most of the Toyz in his business life, and found them more of a distraction than a benefit.)

CRISIS

Certainly, as a society, we have the technical skill to take every existing telecommunications service and application and to port them all onto wireless platforms. Or, at least we could try to do so.

Whipped up by consumer hysteria and a hype-driven feeding frenzy, we can gloriously burn the radio frequency spectrum and continue to do so until the Nth+1 "must-have" mobile application collides with an empty resource locker.

And that is precisely our looming public policy crisis: There just isn't enough radio spectrum to give every person in America unlimited mobility for every possible application that he or she might ever want.

Let's say it again, just to be sure that everybody gets it: "WE DON'T HAVE ENOUGH RADIO SPECTRUM TO PROVIDE THE PUBLIC WITH EVERY FUNCTION THAT IT THINKS IT WANTS TO USE VIA A MOBILE PLATFORM."

Well, we might possibly have enough spectrum if we zeroed out all the existing licensed radio users: public safety, maritime mobile, business, aeronautical mobile, military, amateur, broadcasting, fixed microwave and satellite, all levels of government and more. Does anyone want to propose doing that to facilitate "universal texting"?

Some rationality, in the guise of humble common sense, is desperately needed to sort matters out here. Which of the myriad telecommunications systems now in use or coming along *absolutely requires* wireless? And which ones can be beneficially entrusted to the humble fixed land line circuit (which includes both metallic and glass transmission media)?

The Curmudgeon spent much of his career working in various aspects of the art and science of what was called "radio" and now is known as "wireless." He has always stood in awe of the wonder of information transmission through free space by electromagnetic waves.

But that doesn't mean that he is in any way ignorant or dismissive of the virtues of the land line telecommunications channel. He would be one of the first to admit that there are many practical circumstances under which the use of a wired telecommunications channel would be preferable to a wireless channel. For, in the final analysis, the limited amount of available wireless capacity should be reserved primarily for those specific applications where *you just can't get it done any other way*.

'JUST' FIVE MINUTES

Fixed land line communications channels have a number of inherent advantages over wireless channels, of which only two of their plusses can be highlighted in the available space.

The first advantage is their very high path availability, which is defined as the percentage of a channel's total operating time during which the channel is fully functional and available for its designated use.

In a properly engineered land line circuit, path availability asymptotically approaches 100 percent. But only in the *very best* wireless circuits — optimized, fixed, point-to-point systems — does path availability approach "five nines," or 99.999 percent. That figure translates into a wireless channel maximum outage time of about five minutes per year.

Do you think that "only five minutes" is a trivial amount of unavailable channel time? Ask a stock broker what five

(continued on page 21)

FIVE MARKETS
OVER 40 STATIONS
ONE NETWORK:
WHEATNET-BRIDGE TDM

For Entravision, with multiple stations in multiple markets, a network with flexible functionality and reliability is key to maintaining the strongest on-air presence with absolutely no downtime. Listeners depend on Entravision for content tailored to each community as well as demographically relevant programming across the grid. Wheatstone's WheatNet-Bridge TDM systems make it possible to keep such a network up and running around the clock.

Entravision currently has Wheatstone TDM systems in 5 of their markets – including Los Angeles where 27 surfaces provide programming for their eight Los Angeles area transmitter sites and seven satellite uplink networks.

Rick Hunt, Vice President and Director of Radio Engineering at Entravision Communications Corporation knows that taking chances with unproven or ad-hoc technology simply isn't feasible – that the ultimate cost of using less than the best can be detrimental not only to day-to-day operations but to their overall success.

"Entravision prides itself on delivering the highest quality content and programming to our loyal base of radio and television audiences, and we rely on the Wheatstone system as an important piece of our broadcast equipment. The system is versatile, easy to manage and one of the most advanced pieces of technology on the market. It also delivers an unmatched level of consistancy, ensuring that our systems operate the same way regardless of size or location."

You do your best to create and maintain a successful business. Wheatstone designs and builds its networking systems, whether TDM or IP based, right here in the USA. Wheatstone knows that your programming, network and content are mission-critical, and that failure is not an option. Don't leave it to chance - choosing Wheatstone can only ensure your efforts are rewarded... continuously.

Give us a call or visit us on the web to learn more - we'd love to hear from you.

TDM WHEATNET BRIDGE W

Rick Hunt, Vice President and Director of Radio Engineering at Entravision Communications Corporation, with one of their Wheatstone G5 consoles.

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ENGINEERING EXTRA

WHAT'S THAT NOISE?
Dave Hershberger continues discussing the effects of elevated HD Power. Page 12

RADIOWORLD

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A Method to Improve Conventional FM Stereo

Use of Single-Sideband Stereo Reduces Multipath And Provides Increased Protection to the Baseband Spectrum

BY FRANK FOTI

The author is president of Omnia Audio in Cleveland.

The FM stereo transmission system employed in worldwide broadcasting has been in place since 1961. The rules governing stereophonic performance

WHITEPAPER

have not been altered since the mid-1980s (in the USA) when they were modified to allow an additional 0.5 percent total modulation (maximum of 110 percent total), for every 1 percent of SCA modulation, if an SCA was being utilized. The rules governing the requirements of the FM stereo baseband signal are quite explicit, and leave little — if any — room for improvement of the stereo transmission system.

This paper will offer, in detail, a method utilizing single-sideband suppressed carrier (SSBSC) modulation of the stereophonic subcarrier in the FM multiplex baseband that is compatible with existing radio receivers.

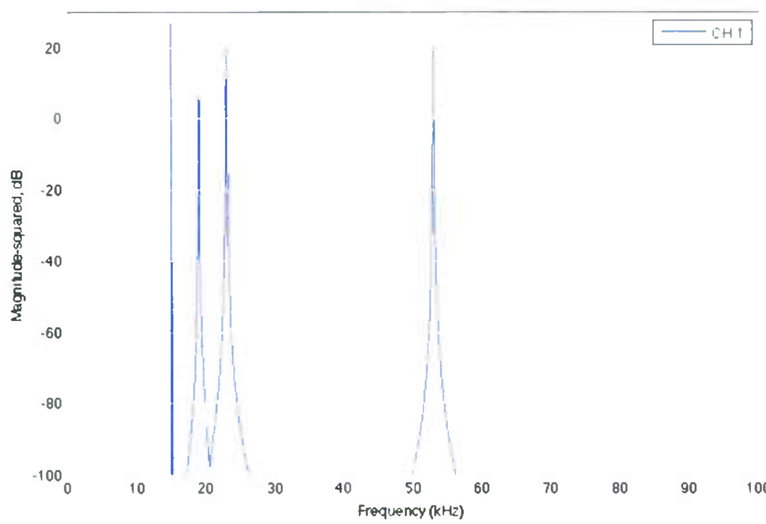

Fig. 1: 15 kHz, Left Channel Only

Additionally, there are multiple overall benefits to the broadcast signal, which are perceivable to the listener. They reduce multipath-induced distortion, and offer additional protection to the spectrum used for RDS, SCA signals and HD Radio content — thereby improving data robustness in the receiver.

(continued on page 6)

Hazardous Duty: Control The Risks

DANGER HIGH VOLTAGE

Recent Accidental Death Reminds Us Of the Importance Of Safety

BY GUY WIRE

It's tragic and sobering when an engineering brother loses his life at the hands of a broken transmitter.

Jerry Campbell, a 73-year-old contract engineer known throughout the Mississippi broadcast community, died while working on the WDMS(FM) transmitter in Greenville, the morning of Aug. 19. Jerry was the founder and long-time supporter of Rebel Radio at the University of Mississippi in Oxford. Our belated sympathies and condolences go out to his family.

Although the incident is being investigated as I write, we'll probably never know exactly what happened that morning; there apparently were no immediate witnesses. It is presumed Jerry came in contact with an energized component while troubleshooting a CCA transmitter with the back door open.

(continued on page 4)

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The Rising Tide of Mobile Data

The Pressure Is on Radio to Maintain Relevance in a Changing World

BY MICHAEL LECLAIR

I was amused by a recent thread on an engineering listserv. While discussing the idea that the music service Pandora was a potential competitor to music-programmed radio, a few of the participants admitted (perhaps with a bit of sheepishness) that they preferred listening to Pandora over their own stations. No names will be mentioned here …

CRYSTAL BALL

This anecdote is a simple reminder that Internet audio streaming as a replacement for broadcast radio has been in the minds of many of us for some time now.

I remember encountering this idea just over 10 years ago when audio streaming was in its early experimental stage. I was not impressed with the sound. But the most passionate of the "webnoscenti" practically pounded their shoes on the table and screamed "We will bury you!" to those of us who worked in broadcasting.

Their predictions, as it turned out, were almost true, but with an unintentional outcome. Those who delved too deeply in audio streaming ended up burying themselves in debt and went out of business in the recession of 2000 rather than officiating at radio's funeral.

Still there clearly was potential.

A lot of time has passed and there can be no question now of the importance of audio streaming. The quality and reliability have increased enormously. More importantly, we are on the threshold of a wave of new mobile Internet services. Popular entertainments that were formerly tethered to desktop computers will soon reach into a wide range of new portable devices.

Apple, which garnered so much success in the music domain with its family of portable iPods, has now transformed the simple cell phone into the powerful iPhone. Ford is beginning to offer mobile Internet service in the dashboard of their cars with the Sync system. These two technological changes are removing the final technical barriers that have protected radio for so many years.

The best protection that radio has is to make sure that we continue to invest in our own streaming services so that we can be a part of these new markets as they open up. Good programming delivered to listeners, no matter the means, is the best way to retain relevance.

THE TIDAL WAVE OF DEMAND

This week I came across an interesting report that speaks about the technical challenges of the mobile internet revolution. Called the "Great Radio Spectrum Famine," it was written by Mitchell Lazarus, a partner in the law firm Fletcher, Heald and Hildreth, which specializes in telecommunications and broadcasting. The report was published in the IEEE Spectrum and can be read at *http://tinyurl.com/2fmyuya*.

It is a thoughtful and well-written consideration of the large and growing demand for radio spectrum. Lazarus discusses the recent decision by the FCC to try to free up another 500 MHz of spectrum for mobile data services. If you aren't aware of this decision, you should be: As far as policy makers are concerned, the demand for wireless is growing fast and we need to move aside existing services, in particular over-the-air TV, to help it expand. While right now it appears the FCC primarily will be looking at UHF frequency bands for wireless data expansion, the need for spectrum efficiency in all services is a high priority.

This demand growth is dramatically shown in a graphic provided by Cisco that estimates mobile broadband data usage. In 2009 worldwide mobile data usage was approximately 100,000 terabytes per month. By 2014 Cisco estimates demand will grow to 3.6 million terabytes per month. At these growth rates, in 10 years demand for mobile broadband will increase by a factor of 100. That is a growth of 10,000 percent. In the face of this demand it is clear that every kilohertz is going to count in the future.

Lazarus gives a few examples to illustrate how past communications services have become more efficient, either by government mandate (such as the forced HDTV conversion) or by the marketplace (the transition from analog to digital cell phones that took place in the 1990s). Lazarus favors policies that provide a marketplace incentive to move to more efficient systems rather than transforming services by regulation.

To provide my own example, HD Radio as a digital service is clearly more efficient than the existing FM analog, as it is able to fit several channels of audio services into essentially the same bandwidth. A possible marketplace incentive to accelerate the complete conversion to digital radio services might be to license FM analog channels at a higher price than digital ones. The trade is that we get more channels to help pay for the costs of conversion, without having to use additional spectrum.

I'm not agreeing or disagreeing with this concept here but trying to point out how the situation might be viewed by the government regulators who oversee our industry.

IS THERE A LIMIT?

In spite of the benefits of a movement toward efficient spectrum usage, there is a flaw in the entire argument.

Lazarus points out the tendency of entertainment providers to increase the amount of data required for their websites as the available bandwidth expands. This creates a self-defeating cycle in which new bandwidth is then consumed in ever-more-complicated streaming. Consider how in the early days of the Internet we looked at text, then at photos, progressing to audio and finally to streaming video.

This situation reminds me of the relationship between automobiles and highways. We have come to accept that no amount of highway construction can improve traffic flow as the number of cars simply adjusts higher when new roads are built. Is this also true of the Internet?

Looked at another way, even if we could improve the efficiency of spectrum usage by 25 percent over the next 10 years, this would simply be a drop in the bucket when compared with growth rates of 10,000 percent in spectrum usage for mobile entertainment.

Something will have to give eventually.

This is where broadcasting can continue to shine. The number of users can expand indefinitely without the need for additional spectrum. And recent auctions and filing windows show that demand for radio stations remains extremely strong.

Streaming is important but we still need to maintain awareness of the benefits of the broadcast model.

THIS ISSUE

OCTOBER 13, 2010

RISKS

(continued from page 1)

Of all the equipment that broadcast engineers maintain, transmitters present the highest risk for shock and electrocution because of the high voltages employed. Solid-state transmitters are not exempt.

This kind of fatal accident remains infrequent in our business. That may be surprising, especially with fewer properly trained engineers working on transmitters in the field. At the same time, it should never really have to happen if proper safety precautions are observed.

CLOSE ENCOUNTERS OF A DANGEROUS KIND

Most engineers can tell memorable stories of their own personal encounters with serious electrical shocks, RF burns and perhaps even a near-miss electrocution. I recall being knocked into brief unconsciousness and falling to the floor after touching 800 Volts inside a ham transmitter while still in high school.

As a young chief engineer working alone on an RCA AM rig, I grabbed onto 4,000 Volts thinking the front door interlock had shut off the transmitter. The switch mechanism had failed. After another knock-down to the floor with no feeling in my entire right arm, I looked up to see the transmitter back on the air. My then-girlfriend DJ was happily reading a local newscast. I recall thinking a few minutes later that the local news might easily have included my own obituary.

Hazardous duty has always been part of the unwritten job description for station and contract engineers working on anything that uses significant electrical power. Since solid-state has now eliminated the higher voltage threats of equipment using vacuum tubes, too many engineers nowadays assume that nothing except the AC primary power side of their operations can be dangerous. Unfortunately, there are other hazards lurking.

HUMANS VS. ELECTRICITY

Any piece of equipment or circuit carrying about 50 Volts or higher with a sufficient current source has the potential to kill a person. Areas we think are "safe" can be dangerous. The 100 Volts of a telco POTS ringer signal has been known to stop hearts. Those who wear pacemakers are especially vulnerable.

The path that electricity decides to take through the body will determine whether one survives contact with a lethal voltage source. Usually it finds the lowest resistance course to a common or ground point to complete the circuit. If that path comes close enough or is strong enough to disrupt the sinus rhythm signaling that commands the heart to beat, it simply stops beating. Quick application of CPR after such an encounter may be the only way to save the victim's life.

In my own close encounters with near-death, I can only conclude that the resistance path to ground in each case was along the surface of the skin where lower resistance was created by perspiration. Whatever the reason, I was lucky. Had the electrons flowed deeper through the central nervous system, I probably would not be here today writing about it.

10-POINT SAFETY SERMON

Since then, I've gained a much more profound respect for high voltage and have modified my approach to troubleshooting.

For anyone who works on any piece of equipment that contains lethal voltages, I offer the following checklist of suggestions and precautions to keep in mind:

1. Treat any piece of failed high-voltage gear you want to troubleshoot like a ticking time bomb that has to be deactivated. Safety is the number one priority.
2. Study the schematics or block diagram and external connections first so you know where high-voltage points, the power sources and disconnects are located. Isolate the unit from all unnecessary external connections if possible.
3. Even with the primary power off and the outside world disconnected, large capacitors and inductors can store lethal energy that must be extinguished with a shorting or Jesus stick.
4. Troubleshooting while power is on with interlocks cheated and doors open is always the riskiest and most dangerous environment you can create. Consider all other methods of finding the problem first without resorting to cheating safety devices.
5. Before you decide to touch anything that had been energized during normal power-up operations, ask yourself twice: Am I certain there is no active or residual energy present? Hit the spot with the Jesus stick again to make sure. I've done that a few times and was surprised but grateful to draw fire and trip breakers. Was this the step Jerry Campbell did not complete?
6. If internal circuit points must be tested with a multi-meter, never attempt to do that holding the test leads on an active circuit near high voltage. Turn off the power and hit your test points with a few strikes of the Jesus stick. Then attach the alligator clip ends of the test leads and place or suspend the leads and the multi-meter in a safe isolated position where you can see it. Then turn on the power and observe the results with hands in pockets.
7. If it's absolutely necessary to work "hot," always work with only one hand. Holding the chassis or cabinet with the idle hand while working with the other provides an easy path for circuit completion through the upper body across the heart.
8. When troubleshooting anything near or containing high voltage, always wear a good pair of shoes with thick rubber or neoprene soles. That gives you more effective insulation above ground.
9. Whenever you encounter an off-air emergency caused by a lightning storm, wait until the storm has passed before getting close to tower bases and transmitting equipment to do troubleshooting. The same applies when you are very tired. Wait until you are fresh before tackling a difficult transmitter repair.
10. When you have to do potentially risky work at a transmitter site, especially one in a remote area, it's prudent to take another engineer along to help; or at least someone who knows CPR and can assist if any kind of accident should occur.

THE BUDDY SYSTEM

Since Jerry's accident, #10 has been the topic of quite a bit of Web chatter on various engineering and SBE listservs. The primary issue of concern is whether employers should require a second engineer or assistant to accompany the primary engineer when doing any risky work at transmitter sites including off-air emergencies.

Power and electrical companies have long required the presence of at least two electricians when troubleshooting or carrying out other risky procedures around high-voltage equipment. OSHA does not address the issue with regard to businesses like broadcasting where a designated employee is charged with maintaining equipment that contains lethal voltages.

A few of the larger group broadcasters understand these risks and have instituted a policy that requires two engineers be engaged in higher-risk transmitter site work including emergencies. Union contracts require it.

That might work for companies that still retain multi-person engineering staffs. But for most stations and sole-proprietor contractors, it's a luxury that is not realistically available. Station managers are reluctant to require the second body since it increases costs and has not been necessary in the past.

iStockphoto/Isaac Koval

Some of the seasoned veteran engineers responsible for transmitter plants have been working alone for so long, they prefer it that way. Having another person present can slow things down and actually cause more distractions, they say.

Such venerable servants are becoming scarce and are not easily replaced.

SHARE THE WEALTH

Unless the knowledgeable vets start sharing their skills and know-how before they retire or move on, even larger stations may have to resort to a local contractor or a transmitter manufacturer's field engineer to provide on-site expertise. Take an assistant along for emergency transmitter site repairs. This is one of the best ways younger replacement engineers can learn the tricks of the trade from the masters.

If you are an aspiring chief engineer who would love to get more training from your soon-to-retire boss, work out an agreement with him and the manager to have you included whenever important transmitter work must be done, especially the emergencies. You may not get management to make it a written policy, but the results will be similar and will certainly benefit everyone.

If you're a solo engineer already being called on to fix dead transmitters and sometimes feel a little uncomfortable dealing with that challenge alone, find a knowledgeable fellow engineer in your area to assist when necessary. Getting your manager to approve this as an occasional outside expense should not be that difficult.

Reread and follow the 10-point approach above and you should be just fine. Think carefully before making any moves inside a misbehaving transmitter plant; and by all means, stay safe.

Guy Wire is the pseudonym for a veteran broadcast engineer.

FM STEREO

(continued from page 1)

COMPETE FOR EVERY POSSIBLE LISTENER

Radio broadcasting has a good fight on its hands. As a media transom to the public, it battles a multitude of additional delivery methods and systems like never before. Until recently, the choices for the listener's ear were television, phonograph records, compact discs or tape. Now, with the advent of good portable audio playback devices and wireless streaming, there are many more franchises available to steal the listener away from radio. What can radio do, technically, to improve its performance so a listener has less reason to abandon it as a media outlet?

HD Radio was introduced to the marketplace within the last 10 years, but has yet to make enough of an impact to keep the casual listener. What's needed is an improvement to the existing infrastructure, one that does not require any change or added expense to the listener. Within present-day radio listening, the FM band is the preferred choice. Recent research and development unveiled a unique means to improve the performance of FM stereo. What follows is the result of that research, along with a recommendation for FM broadcasting.

SILVER ANNIVERSARY OF FM STEREO

April 2011 marks 50 years since the Federal Communications Commission (FCC) approved stereophonic transmission for the United States. The commission, after evaluating 14 proponents, decided upon a method that was of similar design from both Zenith and General Electric.

A quick refresher course how the Zenith/GE system works, courtesy of subpart 73 from the FCC Rules and Regulations:

§ 73.322 FM stereophonic sound transmission standards.

(a) An FM broadcast station shall not use 19 kHz ±20 Hz, except as the stereophonic pilot frequency in a transmission system meeting the following parameters:

(1) The modulating signal for the main channel consists of the sum of the right and left signals.
(2) The pilot subcarrier at 19 kHz ±2 Hz, must frequency modulate the main carrier between the limits of 8 and 10 percent.
(3) One stereophonic subcarrier must be the second harmonic of the pilot subcarrier (*i.e.*, 38 kHz) and must cross the time axis with a positive slope simultaneously with each crossing of the time axis by the pilot subcarrier. Additional stereophonic subcarriers are not precluded.
(4) Double-sideband, suppressed-carrier, amplitude modulation of the stereophonic subcarrier at 38 kHz must be used.
(5) The stereophonic subcarrier at 38 kHz must be suppressed to a level less than 1 percent modulation of the main carrier.
(6) The modulating signal for the required stereophonic subcarrier must be equal to the difference of the left and right signals.
(7) The following modulation levels apply:
  (i) When a signal exists in only one channel of a two-channel (biphonic) sound transmission, modulation of the carrier by audio components within the baseband range of 50 Hz to 15 kHz shall not exceed 45 percent and modulation of the carrier by the sum of the amplitude modulated subcarrier in the baseband range of 23 kHz to 53 kHz shall not exceed 45 percent.
  (ii) When a signal exists in only one channel of a stereophonic sound transmission having more than one stereophonic subcarrier in the baseband, the modulation of the carrier by audio components within the audio baseband range of 23 kHz to 99 kHz shall not exceed 53 percent with total modulation not to exceed 90 percent.

Since the inception of stereophonic broadcasting, there has been no technical change to the infrastructure of the Zenith/GE system at all. The FCC rules are quite specific regarding the multiplex spectrum, and its interoperability as a system. After 50 years of service, the system works fairly well, but it could be better. Considering the alternatives a listener now has, it makes practical as well as good business sense to investigate improvements to the present system. It stands to reason that any means proposed must be backward-compatible with existing stereo receivers. Also, after 50 years, a nice anniversary present is in order!

TECHNICAL CHALLENGES FOR FM STEREO

The FM stereo system, as described above, has worked quite well for 50 years, but not without challenges. Most notable is multipath distortion, especially in areas of hills or mountainous terrain. Also, radio broadcasters have added incremental signals within the multiplexed spectra. Radio Data Services (RDS), as well as a 92 kHz-based SCA can additionally occupy the signal, if desired by the broadcaster. The modulation index of the FM carrier is further reduced with each and every added signal.

Increased multipath is a direct result of low modulation index within the FM carrier. As more of the channel spectrum is utilized within the multiplex signal, the modulation index of the carrier is reduced. The following condition generates the lowest modulation index: a single audio channel of a two-channel system, either Left or Right channel only at 100 percent modulation. For example, a 15 kHz tone in the left channel only will produce multiplex spectra at 15 kHz, 19 kHz (stereo pilot tone), 23 kHz and 53 kHz. Each of these signals will reduce the modulation index to its smallest level, and this increases sensitivity to multipath in the receiver. Fig. 1 on page 1 is an illustration of this.

Note the 30 kHz difference in the L–R subcarrier of the two sidebands located at 23 kHz and 53 kHz. These are generated by the DSBSC process of (38 kHz minus 15 kHz) for the lower sideband, and (38 kHz plus 15 kHz) for the upper sideband. During multipath, as the multiple reflections of the FM carrier arrive at, and then become demodulated in the receiver, the time delay difference created by the carrier reflections will offset the phase of the upper and lower sidebands. During the stereo de-multiplexing process, stereo separation at these frequencies is reduced as the recovered L–R level is negatively altered due to phase shift brought on by multipath.

These findings should be sufficient evidence for the FCC to consider, at least, an STA to enable all broadcasters to implement the SSBSC transmission method.

Bandwidth of the conventional analog FM channel is allocated for 99 kHz of spectrum use. The FM stereo system requires 53 kHz (0 Hz–53 kHz) of this available real estate. The remaining 46 kHz (53 kHz–99 kHz) is used for RDS and SCA services. Common practice requires the use of audio processing to ensure proper peak level and bandwidth control of the various signals present in the multiplex spectrum. Current generation processors are capable of creating near-theoretical multiplex signals. In these cases, there are little, if any, transmission difficulties for the signal.

However, some broadcasters choose to employ a form of processing known as composite clipping. This technique inserts a hard limiter (clipper) at the output of the stereo baseband generator, and will induce up to as much as 3 dB of clipping to the multiplex signal. These devices provide no additional filtering to remove unwanted harmonic content from the clipping process. The additional harmonics will cover the entire 46 kHz, and beyond, used for RDS and SCA services. This creates interference and distortion to those signals. These harmonics may also interfere with the digital carriers generated for HD Radio, as these carriers are set 129 kHz out from the main channel carrier.

Another known challenge for the system is the compromised signal-to-noise (SNR) level when broadcasting stereo. FM transmission noise will rise at 6 dB per octave over the channel's passband range of

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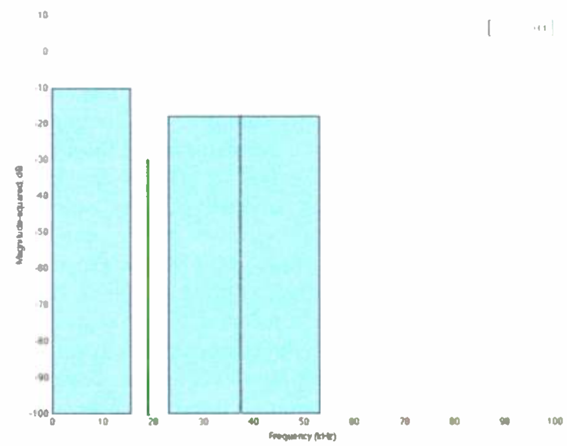


Fig. 2: Baseband Spectra

FM STEREO

(continued from page 7)

99 kHz. It has been generally accepted that FM stereo suffers a 23 dB noise penalty compared to monophonic broadcasting. This is due to the rising noise floor over the subcarrier range of 23 kHz–53 kHz, as compared to the SNR over the range of 0 Hz–15 kHz which is used for mono. Fig. 2 is an illustration of the composite baseband signal. Fig. 3 shows the 6 dB/octave noise floor slope of an FM channel, as it would appear at the output of an IF section in a receiver. Fig. 4 represents the SNR response through the composite baseband signal. This illustration superimposes the noise response across the composite spectrum. It is easy to observe the most severe noise occurs in the upper sideband of the stereo subchannel.

ALTERNATIVE APPROACH

Prior to 1973, when the phase locked loop (PLL) circuit was introduced into the consumer receiver market, FM detectors required the transmitted multiplex signal to employ double-sideband suppressed-carrier (DSBSC) to faithfully recover the stereophonic (L–R) signal. Today, there are very few, if any, pre-1973 stereo radios in use.

An alternative approach for stereo transmission would be the use of single-sideband suppressed carrier (SSBSC) as the mechanism to carry to the L–R payload. The lower sideband is chosen as it reduces the occupied spectrum from 53 kHz down to 38 kHz. In order to support the correct L+R/L–R matrixing in the receiver, the amplitude of the lower sideband is increased by 6 dB. This offers numerous benefits to the receiver:

1. Reduction of occupied bandwidth in the L–R subchannel range increases the FM modulation index by a factor of two. This directly reduces multipath distortion.
2. Narrows the overall FM transmission bandwidth and reduces degradation of stereo performance caused by finite bandwidth of passband filters, cavities, multiplexing systems and antennas. If adopted internationally, this further benefits broadcasters 100 kHz channel spacing used in some countries, as compared to the 200 kHz spacing used here in the USA.
3. Creates additional and significant protection for RDS, SCA and HD Radio signals. **Note:** With a HD Radio power increase looming, reduction of the composite spectrum benefits conventional receivers due to less demodulated overlap of the HD Radio signal.
4. Compatible with all existing modulation monitoring systems.
5. Compatible with detectors in current model (post-1973) receivers.
6. Less harmonic content generated throughout the channel spectrum when composite clipping is employed in the transmission audio processor.

The concept of utilizing SSB modulation for the L–R payload has been written about before. A white paper on this topic, titled "A New Method of Generating FM and Television Stereo Composite Baseband Yields Improved Broadcast Performance," was presented by William Gillman at the 1997 NAB Engineering Conference. Reviewing Mr. Gillman's paper and subsequent testing by this author confirms his findings, and along with technological advances in the transmission firmware, makes this concept much more plausible.

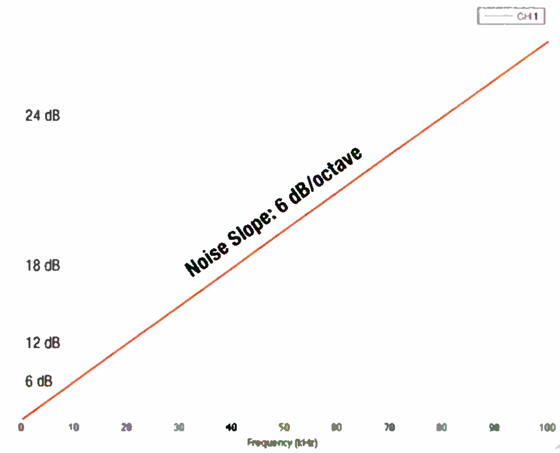


Fig 3: FM Channel Noise Response

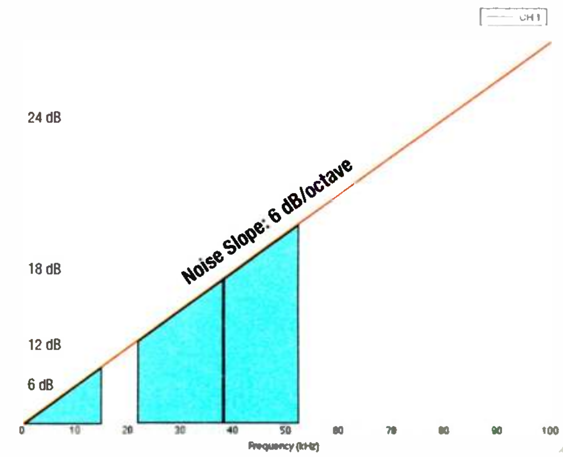


Fig. 4: Receiver IF Output SNR

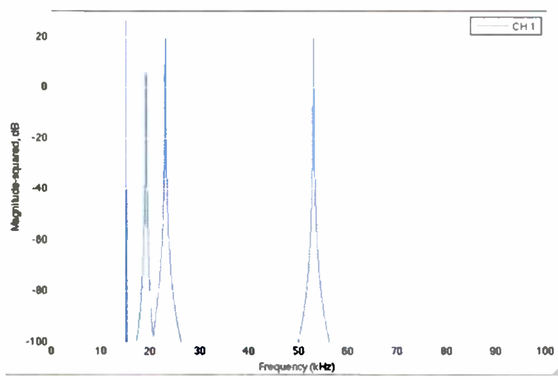


Fig. 5: 15 kHz Tone, Single Channel, DSBSC

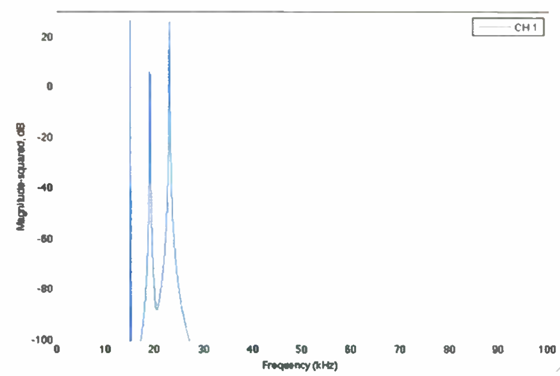


Fig. 6: 15 kHz Tone, Single Channel, SSBSC

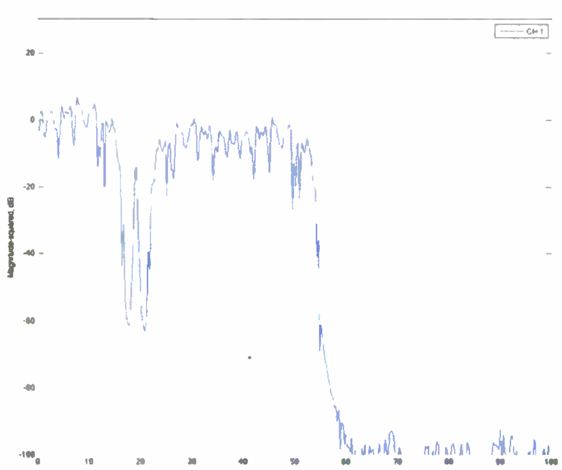


Fig. 7: Noise, Single Channel, DSBSC

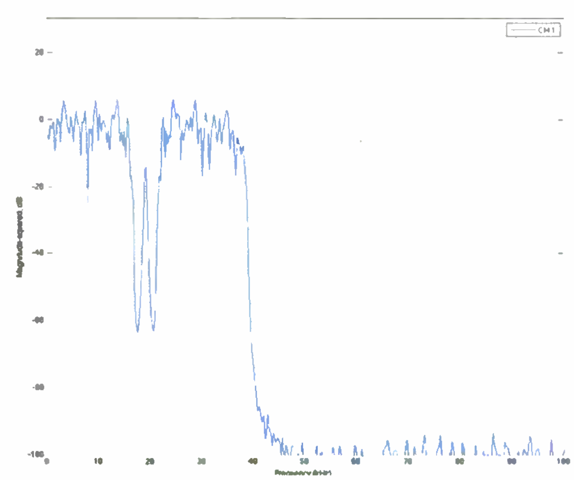


Fig. 8: Noise, Single Channel, SSBSC

TECH FINDINGS

Implementing SSB modulation of the L–R signal is relatively easy to accomplish using DSP. Fig. 5 is a spectral diagram of a 15 kHz single-channel tone using DSBSC system. Fig. 6 is the same condition, except SSBSC modulation is utilized.

Note the 6 dB increase in level of the SSB carrier in Fig. 6. This illustrates the manner in which the L+R/L–R mathematics are upheld in the receiver.

It is easy to observe the significant difference in spectrum used. The DSBSC method forces the single-channel condition of 15 kHz to exist across a broad range. The fundamental is at 15 kHz, and the two sidebands are at 23 kHz and 53 kHz respectively. The DSBSC example illustrates the fragility in faithful reproduction of stereophonic high frequencies during instances of multipath. The group delay at 15 kHz, 23 kHz and 53 kHz becomes non-linear, during multipath, and this is why stereophonic high frequencies are so fragile with respect to multipath.

Compare the spectra of Fig. 5 with that of Fig. 6. The close proximity of the 15 kHz fundamental, and the 23 kHz SSB carrier improves high-frequency robustness during multipath. Due to the closeness of these two frequencies, there is less adverse affect when multipath non-linearities are created, and high-frequency stereophonic performance is audibly improved.

Using a noise source in one channel, the same tests were performed. The results are illustrated in Figs. 7 & 8.

SSB subchannel modulation makes FM channel occupancy more efficient. Fig. 9 demonstrates carrier deviation of the RF signal using DSBSC modulation of a single channel noise source. Fig. 10 is the same test signal, except SSBSC modulation is employed. For the example shown here, the carrier frequency is 400,000 kHz,

(continued on page 10)

MINSTRUMENT MATRIX

Sophisticated Minstruments from NTI give you comprehensive test capability... and these flexible audio instruments fit in the palm of your hand

DL1 Digilyzer
Digital Audio Analyzer

A handheld digital audio analyzer with the measurement power & functions of more expensive instruments, the DL1 Digilyzer analyzes and measures both the digital carrier signal (AES/EBU, SPDIF or ADAT) as well as embedded digital audio. In addition, the DL1 functions as a smart monitor and digital level meter for tracking down signals around the studio. Plugged into either an analog or digital signal line, it automatically detects and measures digital signals or informs if you connect to an analog line. In addition to customary audio, carrier and status bit measurements, the DL1 also includes a comprehensive event logging capability.

- AES/EBU, SPDIF, ADAT signals
- 32k to 96k digital sample rates
- Measure digital carrier level, frequency
- Status/User bits
- Event logging
- Bit statistics
- VU + PPM level meter for the embedded audio
- Monitor DA converter and headphone/speaker amp
- Audio scope mode

DR2 Digirator
Digital Audio Generator

The DR2 Digirator not only generates digital audio in stereo & surround, it is a channel transparency and delay tester as well, all condensed into a handheld package. Delivering performance & functionality challenging any digital audio generator made today, it produces all common audio test signals with sampling frequencies up to 192 kHz and resolution up to 24 bit. The Digirator features a multi-format sync-input allowing the instrument to be synchronized to video and audio signals. In addition to standard two-channel digital audio, the DR2 can source a comprehensive set of surround signals.

- AES3, SPDIF, TOSLink, ADAT outputs
- 24 bit 2 channel digital audio up to 192 kHz SR
- Sine wave with stepped & continuous sweeps; White & Pink Noise; Polarity & Delay test signals
- Dolby D, D+, E, Pro-Logic II, DTS and DTS-HR surround signals
- Channel Transparency measurement
- I/O Delay Measurement
- Sync to AES3, DARS, word clock & video black burst
- User-generated test signal files

AL1 Acoustilyzer
Acoustics, Audio & Intelligibility Analyzer

The AL1 Acoustilyzer features extensive acoustical measurement capabilities as well as analog audio electrical measurements such as level, frequency and THD+N. With both true RTA and high resolution FFT capability, the AL1 also measures delay and reverberation times.
With the optional STI-PA Speech Intelligibility function, rapid and convenient standardized "one-number" intelligibility measurements may be made on all types of sound systems, from venue sound reinforcement to regulated "life and safety" audio systems.

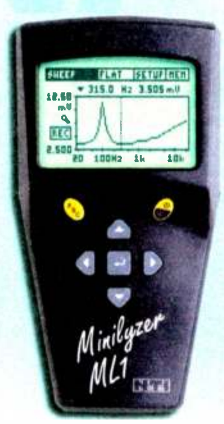
- Real Time Analyzer
- Reverb Time (RT60)
- Delay measurements
- High resolution FFT with zoom
- Optional STI-PA Speech Intelligibility function
- Automatic Distortion analyzer (THD+N)
- Frequency, RMS Level, Polarity measurements
- Requires optional MiniSPL microphone
- Includes MiniLINK USB interface & Windows PC software for storing tests and PC transfer

MR-PRO Minirator
High performance
Analog Audio Generator + Impedance/Phantom/Cable measurements

The MR-PRO Minirator is the senior partner to the MR2 below, with added features and higher performance. Both generators feature an ergonomic instrument package & operation, balanced and unbalanced outputs, and a full range of signals.

- High (+18 dBu) output level & <-96 dB residual THD
- Sine waves & programmable swept (chirp) and stepped sweeps
- Pink & white noise
- Polarity & delay test signals
- User-generated custom test signals & generator setups
- Impedance measurement of the connected device
- Phantom power voltage measurement
- Cable tester and signal balance measurement
- Protective shock jacket

ML1 Minilyzer
Analog Audio Analyzer



The ML1 Minilyzer is a full function high performance audio analyzer and signal monitor that fits in the palm of your hand.
The comprehensive feature set includes standard measurements of level, frequency and THD+N, plus VU+PPM meter mode, scope mode, a 1/3 octave analyzer and the ability to acquire, measure and display external response sweeps generated by a Minirator or other external generator.

Add the optional MiniLINK USB computer interface and Windows-based software and you may store all tests on the instrument for download to your PC, as well as send commands and display real time results to and from the analyzer.

MiniLINK

- Measure Level, Frequency, Polarity
- Automatic THD+N and individual harmonic distortion measurements k2→ k5
- VU + PPM meter/monitor
- 1/3 octave analyzer
- Requires optional MiniSPL microphone for SPL & acoustic RTA measurements
- Frequency/time sweeps
- Scope mode
- Measure signal balance error
- Selectable units for level measurements

MR2 Minirator
Analog Audio Generator

The MR2 pocket-sized analog audio generator is the successor to the legendary MR1 Minirator.
It is the behind-the-scenes star of thousands of live performances, recordings and remote feeds.

- Intuitive operation via thumbwheel and "short-cut" buttons
- New higher output level (+8 dBu) & low distortion
- Programmable Swept (chirp) and Stepped sweeps
- Sine waves
- Pink & White noise
- Polarity & Delay test signals
- Illuminated Mute button

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FM STEREO

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with deviation set to 4 kHz.

Once again, it is easy to observe the reduction in utilized spectrum. The signal shown in Fig. 10 will pass through narrow cavities, combiners and maladjusted antennas with better stereo performance than the broader signal shown in Fig. 9.

Another benefit SSB brings to the transmission method is added spectral protection to RDS, SCA and HD Radio services. Fig. 11 is an example. Single-channel-only pink noise is used to generate the baseband signal with SSBSC modulation. Notice the extremely wide guard band that exists between 38 kHz and where the first SCA carrier would appear at 57 kHz. The reduction in cross-talk to ancillary services is exceptional!

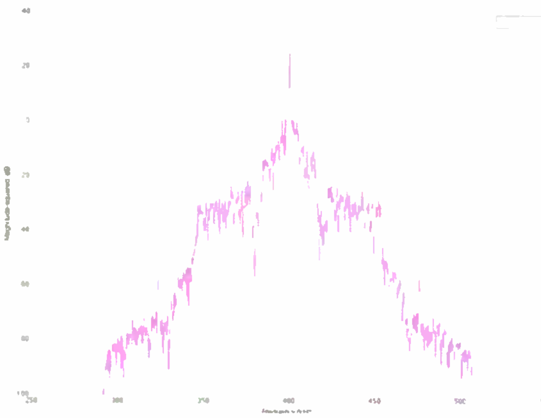

Fig. 9: FM Deviation, DSBSC, Noise, Left

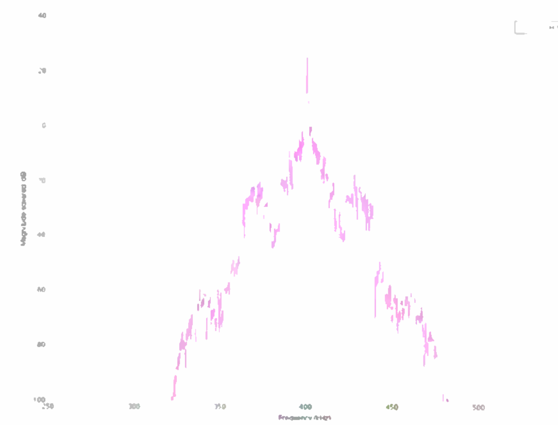

Fig. 10: FM Deviation, SSBSC, Noise, Left

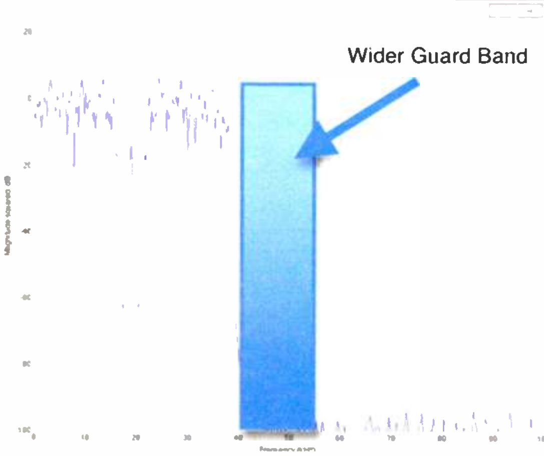

Fig. 11: Single Channel Only Pink Noise, SSBSC

WHAT'S NEXT?

Transmitting SSBSC modulation of the FM stereo signal can be done right now! Software exists to implement this method today. One minor item must be addressed: FCC rule 73.322, section (a), subpart (4) which states "*Double-sideband, suppressed-carrier, amplitude modulation of the stereophonic subcarrier at 38 kHz must be used.*" There was a time, when rule 73.322(a) (4) was required. Times have changed. Both transmission and reception firmware have improved significantly to enable a change in the rules and regulations governing the FM stereo baseband signal.

The theory, testing and findings presented here should be more than enough evidence for the FCC to consider, at the very least, a Special Temporary Authority (STA) to enable all broadcasters to implement the SSBSC transmission method. Benefit will occur immediately to those whom employ this, especially those in areas of rough terrain with significant hills, and mountains.

After 50 years of service, a modification to the rules and regulations governing FM stereo service would be a wonderful anniversary present indeed! Most importantly, the benefactors are the general public as audible annoyances will be suppressed, and in some cases eliminated. At a time when broadcasters are looking to find every possible way to enhance their customers (the listener's) experience, this change in the rules would benefit everyone. This is total upside, with nothing downside for all.

The author would like to thank William Gillman for his exceptional paper written in 1997, which provided a point of reference in this investigation. Additionally, thanks to Steve Church for his support and enthusiasm in our joint audio processing and transmission system efforts.

READER'S FORUM

MUST EVERYTHING BE MOBILE?

As a 41-year veteran broadcast engineer, I much appreciated The Old RF Curmudgeon's outlook on modern-day "wireless everything" (Aug. 18, 2010).

It also reminded me of a paragraph once contained within the FCC Part 73 and Part 74 Rules not all that many years ago, to the effect that "the choice of a radio channel to achieve an auxiliary broadcast link should be considered only when such a circuit cannot be secured through a conventional wire-line provision."

Steve Konopka
Green Bay, Wis.

THANKS, CURMUDGEON

Amen, brother! Hear hear!

Consider this thought: If transmitting via RF is good for all forms of information exchange, then why has pay TV (via RF) not taken off in the 50-plus years that it's been tried and tried and re-tried? And why has pay TV become so profitable when carried via "copper path"?

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(Via comments at radioworld.com)

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Elevated HD Power, Part II

The Effects of Increased Digital Power on FM Signal to Noise

BY DAVE HERSHBERGER

Part 1 of this article, in the Aug. 18 issue of RWEE, introduced some of the potential problems for the analog FM signal when considering elevated HD power. We discussed the increased peak envelope power requirements for elevated HD power and the concurrent higher envelope modulation component. Receivers are particularly sensitive to negative envelope modulation because the FM receiver's limiting function must increase its gain. The receiver gain is proportional to the reciprocal of the received envelope. If the received envelope pinches off, then the receiver will output noise bursts.

Part 1 also discussed the phase modulation mechanisms for self-noise and the mitigating effects of narrow IF filters in receivers. Time domain simulation results were presented for different levels of HD power with wide and narrow bandwidth FM receivers. Self-noise was shown to depend on analog deviation, increasing as the analog carrier deviates toward one of the HD sideband blocks.

Part 1 is available online at *www.rwonline.com/article/105256*, or read it in the Aug. 18 digital edition of RW Engineering Extra via the Resources/ Digital Edition tabs of the website.

Now we can look at the frequency domain. For the simulations shown in Fig. 18 there is no analog modulation, just an unmodulated FM carrier, with 1 percent, 4 percent and 10 percent digital power. The graph stops at 125 kHz, so we do not see any of the first order intermodulation. We only see the higher-order terms, which are the complex beats between multiple IBOC carriers, the IBOC symbol rate and the FM analog carrier.

What is interesting here is that there is a block of noise at low frequencies, reaching highest energy between about 20 and 60 kHz. This will affect stereo reception, RDS and SCA. Another interesting effect is that as the digital power increases by 10 dB, the noise floor increases by 20 dB. This is evidence of a higher-order nonlinearity producing the lower-frequency demodulated FM noise.

The good news is that the monophonic part of the composite spectrum, up to 15 kHz, has the least amount of noise. That is your mono signal. Monophonic FM is quite robust.

Fig. 19 adds sharp filtering of the hybrid signal. That block of low-frequency noise centered around 35 kHz has dropped about 15 dB, and the digital power dropped 6.7 dB because of the filter.

The next spectral plots look at dynamic conditions — with analog deviation.

In Fig. 20 we have added a 1.9 kHz tone at 75 kHz deviation to the analog signal. With no digital signal present, the demodulated signal is perfect. But with digital power present, we can now see more effects of self-noise, with the first-order beats extending down to about 54 kHz. So self-noise increases in the presence of FM deviation.

Fig. 21 shows what happens with our monophonic signal when we add sharp

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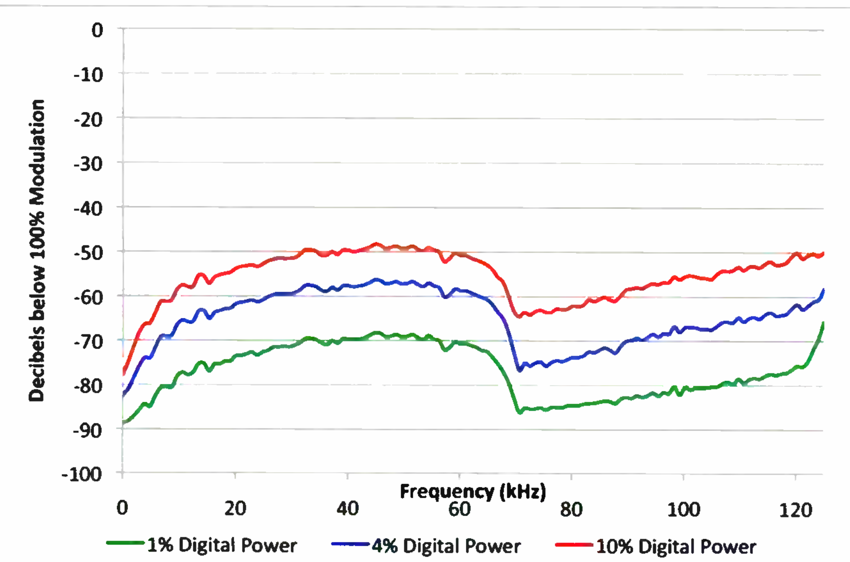

Fig. 18: FM detector frequency domain output, no analog deviation, 1%, 4% and 10% digital, wide IF

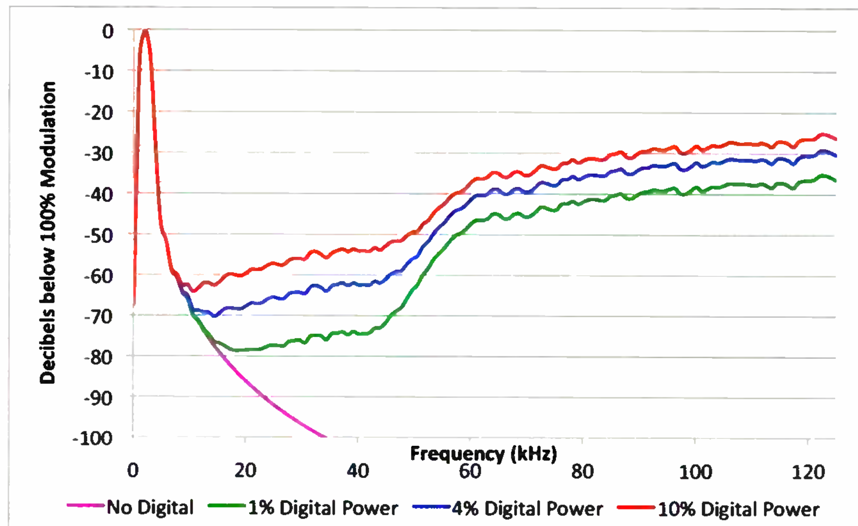

Fig. 20: FM detector frequency domain output, 1.9 kHz analog modulation at 75 kHz deviation, 0%, 1%, 4% and 10% digital, wide IF

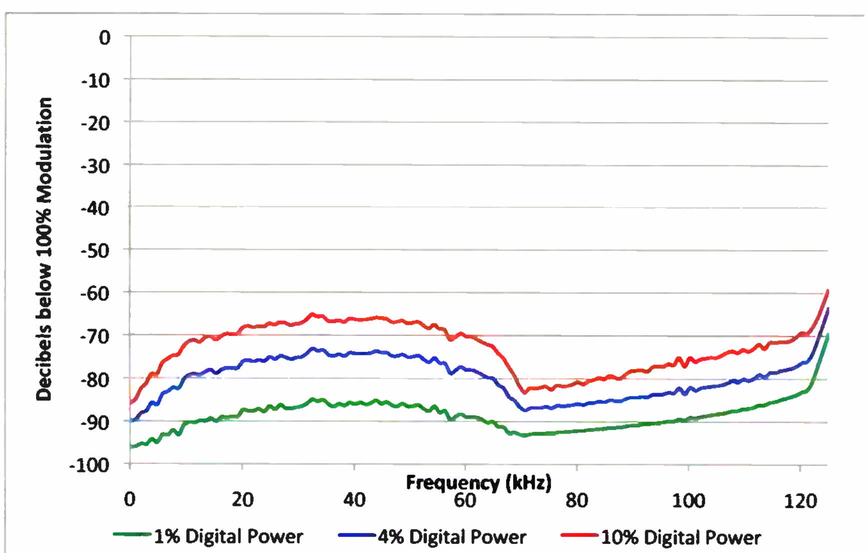

Fig. 19: FM detector frequency domain output, no analog deviation, 1%, 4% and 10% digital, narrow IF

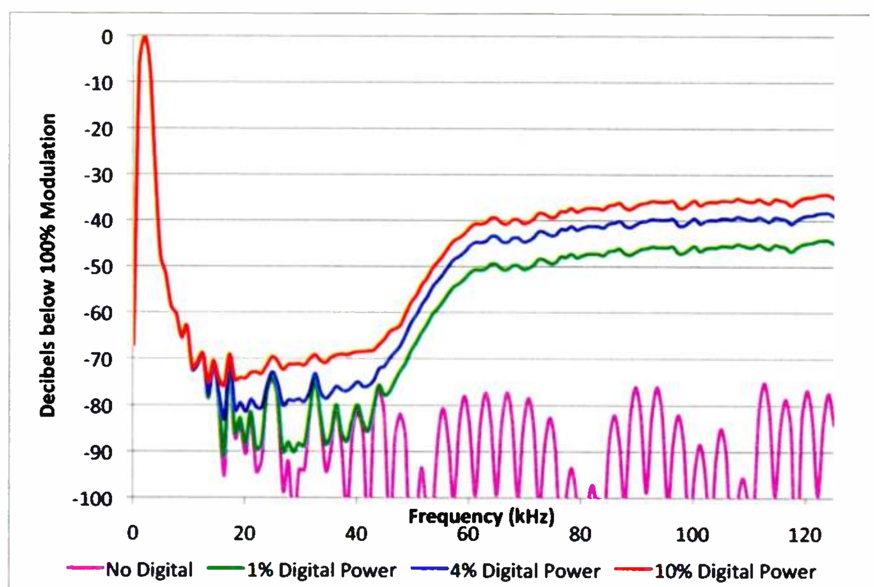

Fig. 21: FM detector frequency domain output, 1.9 kHz analog modulation at 75 kHz deviation, 0%, 1%, 4% and 10% digital, narrow IF

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filtering. First, notice the lowest trace, which shows the signal with no digital power. That spectrum is no longer perfect. The distortion is coming from the band-pass filtering of the FM signal. Otherwise, there is a reduction of the noise level because of the receiver's filtering.

Fig. 22 shows analog FM at 100 percent modulation using a stereo left-channel tone at 1.9 kHz. As before, with no digital the demodulated signal is basically perfect. At high frequencies, above about 60 kHz, a 10 dB increase in digital power results in a 10 dB increase in noise. But down in the stereo composite area below 50 kHz, a 10 dB digital power increase results in an increase in noise of almost 20 dB.

Fig. 23 shows what happens with single-channel stereo modulation with the sharp filter. At 1 percent digital power, the digital noise in the stereo composite region is largely masked by the filtering distortion. But at 10 percent digital power, the self-noise clearly dominates the filter-induced distortion.

HARDWARE-BASED 'SANITY CHECK'

After doing these simulations, we wanted to verify them with hardware as a sanity check. So we got out an old but still very good Sansui tuner with a dual bandwidth IF.

Fig. 24 shows what the tuner's composite output looks like with no HD and 100 percent monophonic modulation. It is simply a clean 400 Hz tone.

In Fig. 25 we have turned on HD at 4 percent digital power, with the tuner set to its narrow bandwidth. The waveform has picked up a little bit of fuzz, and it looks very much like the 4 percent time domain simulations shown earlier.

With HD still at 4 percent digital power, in Fig. 26 the tuner is set to its wide bandwidth. The waveform has picked up substantially more fuzz, in agreement with the simulations.

Fig. 27 shows the Sansui tuner composite output at 10 percent HD with the wide IF. The fuzz is larger near the peaks, as predicted.

Fig. 28 shows a spectrum analysis of the noise, showing a rise near 54 kHz, also in agreement with the simulations.

INTERPRETATIONS AND CONCLUSIONS

The hardware tests show general agreement with the simulations. So what are these simulation results and lab tests telling us?

One of the surprises is that the simple frequency difference terms are not the only significant analog noise components. There are higher-order distortion mechanisms causing noise at lower frequencies in the demodulated analog composite output.

Second, the high-order noise increases twice as fast in dB with increasing digital power. A 10 dB increase in digital power increases the lower-frequency analog noise by 20 dB. Fortunately, the lower-frequency noise is lower in amplitude than the first-order beats.

Sharp filtering in receivers reduces but does not eliminate self-noise. We have no control over receiver filtering, so IF bandwidth variation will affect self-noise.

And finally, the FM monophonic part of the spectrum is largely unaffected. FM mono is robust. This is due to the higher modulation index at the lower frequencies, which is another way of describing the triangular noise spectrum of FM — noise increases with modulating frequency.

The 75 microsecond de-emphasis curve helps reduce the noise in mono and stereo. Table 2 shows calculated composite SNR values with the 53 kHz brick-wall filter for different combinations of digital power and filter bandwidth. Values range from about 37 to 54 dB.

Composite SNR is not a familiar value. So we will relate composite SNR

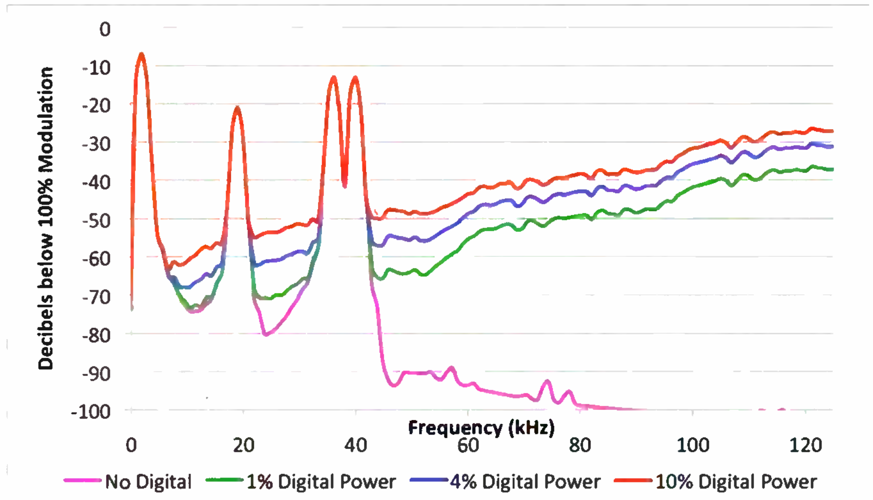

Fig. 22: FM detector frequency domain output, 1.9 kHz stereo left channel analog modulation at 75 kHz deviation, 0%, 1%, 4% and 10% digital, wide IF

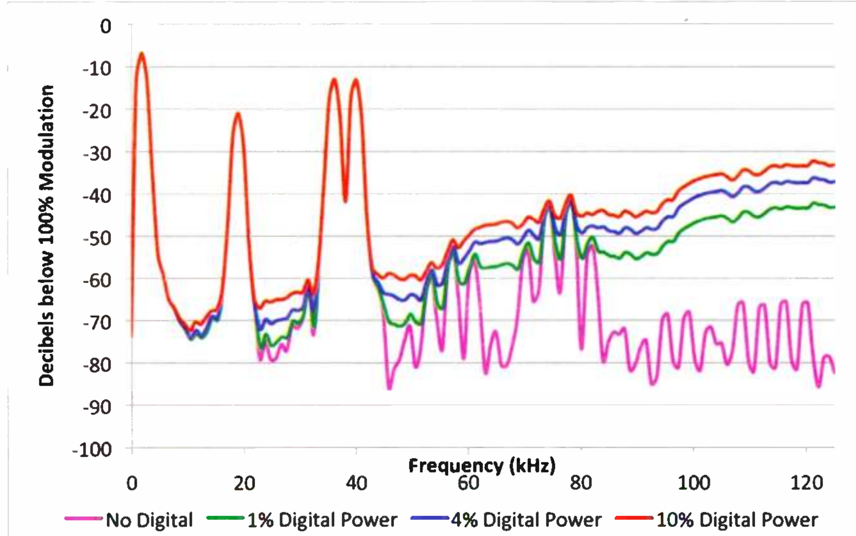

Fig 23: FM detector frequency domain output, 1.9 kHz stereo left channel analog modulation at 75 kHz deviation, 0%, 1%, 4% and 10% digital, narrow IF

Digital power	Composite SNR, no IF filter	Composite SNR, sharp IF filter
1%	50.0 dB	54.1 dB
4%	42.8 dB	48.4 dB
10%	36.9 dB	44.3 dB

Table 2: Composite SNR (53 kHz bandwidth) vs. digital power

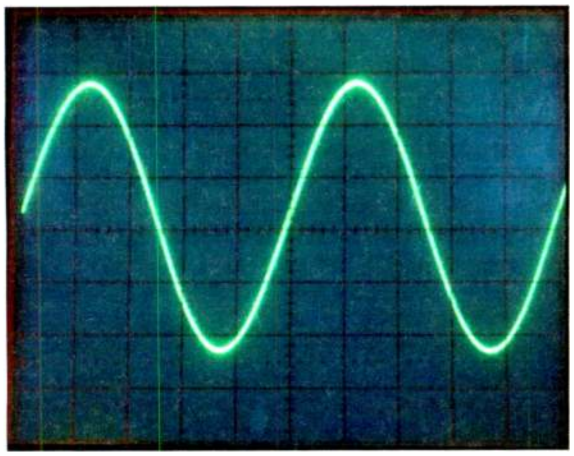

Fig 24: Sansui TU-9900 tuner composite output with no HD and 400 Hz mono tone at 75 kHz deviation

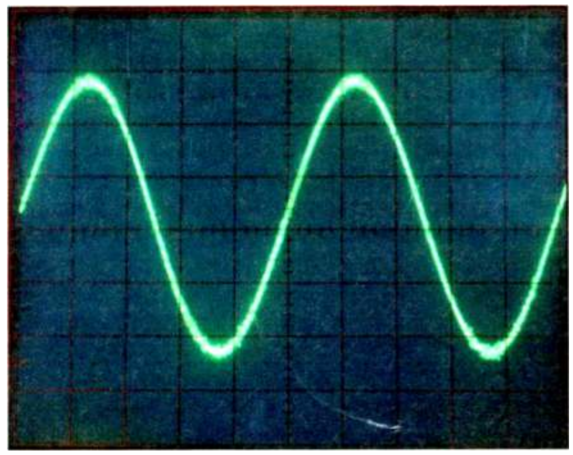

Fig.25: Sansui TU-9900 tuner composite output with 4% HD and 400 Hz mono tone at 75 kHz deviation, narrow IF filter

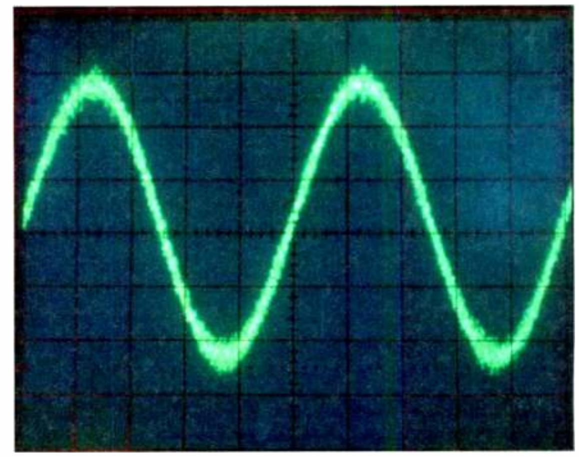

Fig 26: Sansui TU-9900 tuner composite output with 4% HD and 400 Hz mono tone at 75 kHz deviation, wide IF filter

to the more familiar monophonic SNR and stereo SNR measurements. First we have to make some assumptions. Usually we assume that the channel noise is white, which produces a rising noise spectrum after detection. This is not exactly the case with IBOC, but it is a good place to start to get some ballpark SNR values.

Given composite SNR in a 53 kHz bandwidth, and assuming white noise (6 dB/octave increase when demodulated to FM):

Add 29.6 dB to get mono SNR (75 microsecond de-emphasis)

Then subtract 23.0 dB from mono SNR to get stereo SNR

With this assumption, we can take the composite SNR value and add 29.6 dB to it to get the 15 kHz mono SNR with 75 microsecond de-emphasis. Once we have the mono SNR, we can then subtract the familiar 23 dB penalty for FM stereo to get the stereo SNR. Table 3 shows the results.

Mono SNR varies from about 84 to 67 dB, which is great. Mono is robust. Stereo varies from about 61 to 43 dB, so there may be some audible noise. Experimental results confirm that stereo noise goes down with reduced analog modulation.

Our predicted dynamic stereo SNR was 43.5 dB for a wideband receiver. Lab tests with the Sansui tuner produced 41 dB. The conventionally measured stereo SNR, with an unmodulated carrier except for the pilot, was 46.5 dB.

CREST FACTOR REDUCTION AND RECEIVERS

A related topic that affects analog self-noise is peak-to-average ratio (PAR) or crest factor reduction. It is not just for positive peak control anymore. There are three situations where crest factor reduction provides a benefit.

First, when the FM and HD vectors are in phase as shown in Fig. 29, this produces a positive envelope modulation peak. We want to control these peaks so that the transmitter does not have to produce extreme PEP. Controlling these peaks benefits the transmitter. But

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ELEVATED POWER

(continued from page 15)

there are two more situations where there is a benefit from crest factor reduction.

Second, when the FM and HD vectors are out of phase, this produces a negative envelope modulation peak. We want to control these peaks so that the RF envelope does not approach pinchoff where the receiver's limiter gain must increase. Controlling negative envelope modulation peaks benefits receivers by avoiding noise bursts.

That leaves quadrature. When the FM and HD vectors are orthogonal, this is the point where we produce the peak phase modulation self-noise. We also want to control these peaks, to avoid making impulsive self-noise.

Clearly, there are significant benefits to reducing the peaks of the digital signal regardless of what the analog FM carrier is doing.

IBiquity's crest factor reduction controls the digital signal peaks for all phase relationships with the analog FM signal. We believe this is a good thing. If we must transmit somewhat higher positive envelope peaks to reduce negative AM, this is a good tradeoff because it improves analog reception. When evaluating a crest factor reduction system, it is important to consider the entire signal path including the receiver — not just the transmitter. So our conclusion is that iBiquity's peak control system provides the maximum advantage to the entire system, including the analog receivers.

Digital Power	Composite SNR (wide IF)	Mono SNR (wide IF)	Stereo SNR (wide IF)	Composite SNR (sharp IF)	Mono SNR (sharp IF)	Stereo SNR (sharp IF)
1%	50.0 dB	79.6 dB	56.6 dB	54.1 dB	83.7 dB	60.7 dB
4%	42.8 dB	72.4 dB	42.8 dB	48.4 dB	78.0 dB	55.0 dB
10%	36.9 dB	66.5 dB	43.5 dB	44.3 dB	73.9 dB	50.4 dB

Table 3: Composite, monophonic and stereo dynamic SNR (53 kHz bandwidth) vs. digital power and IF bandwidth in the presence of a 1.9 kHz monophonic tone

DECISIONS AND RECOMMENDATIONS

Broadcasters must make the decision about what digital power level to use. Every situation is different. To state the obvious, you want to turn it up enough, but not too much. And hopefully those ranges of "not enough" and "too much" do not overlap.

"Enough" means having a digital signal power that gives you the digital coverage you want. "Too much" means adversely affecting your analog signal.

What is "too much" depends on your format, your terrain, your listeners and other factors.

If your format is classical music, or anything with a wide dynamic range that may include speech, self-noise may be audible, especially on receivers with wider IF bandwidths.

On the other hand, if you run aggressive audio processing, then self-noise may be completely masked by the consistently high analog modulation. When listening in a car, road noise is probably going to dominate any self-noise. And receiver blending will help.

Multipath problems may be aggravated by running a lot of digital power, because of differential fading between analog and digital components, causing envelope pinchoff at the receiver's

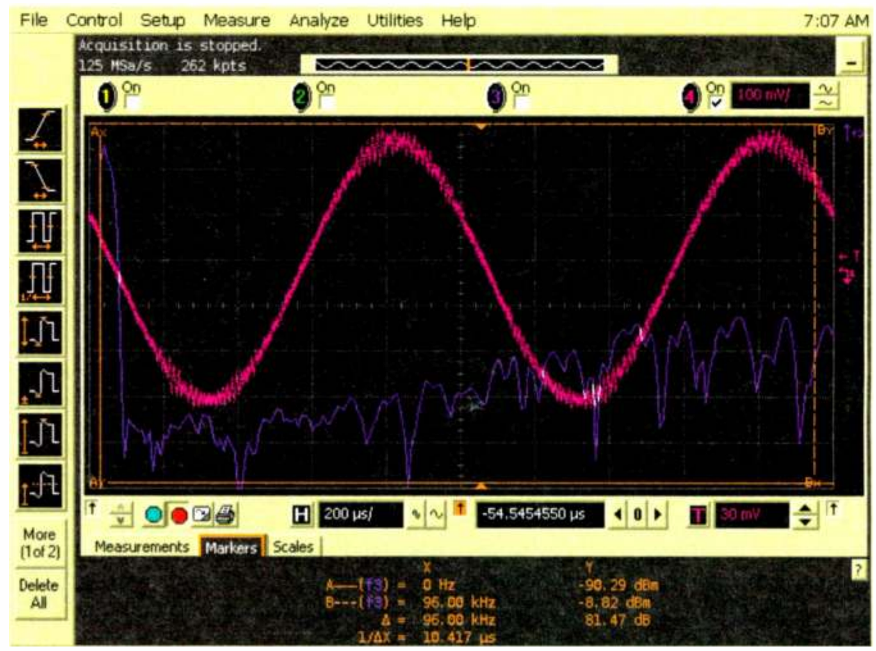

Fig. 27: Sansui TU-9900 tuner composite output with 10% HD and 1 kHz mono tone at 75 kHz deviation, wide IF filter. Red trace is time domain and magenta trace is the computed FFT spectrum of just the two cycles of 1 kHz, 100 kHz span.

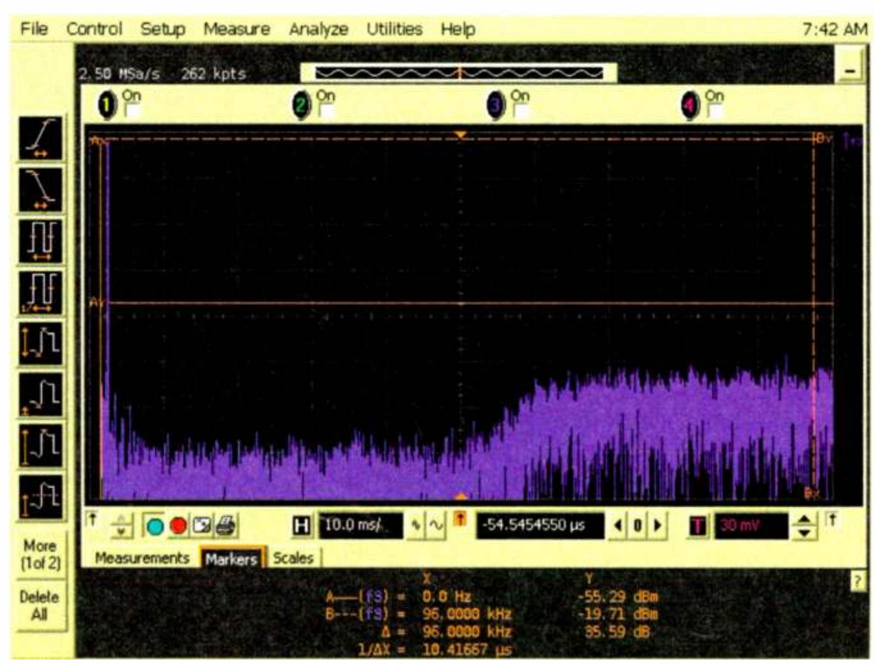

Fig. 28: Sansui TU-9900 tuner composite output spectrum (oscilloscope FFT, 100 kHz span) with 10% HD and 1 kHz mono tone at 75 kHz deviation, wide IF filter. (More samples were used to create a higher resolution spectrum display than what is shown in Fig. 27.)

detector. So your terrain and propagation paths may be a factor.

Although theoretical analysis, simulation and objective lab testing are useful for understanding and quantifying the problem, the ultimate decision criterion will be subjective. Broadcasters should listen to what their on-air signals will sound like before deciding on a power level for elevated HD. This can be done by using just the exciter. With all of your program material types (speech, music, etc.) and with your normal audio processing, try different HD power levels with a variety of receivers. Set the HD power level to a point where you are comfortable with the analog reception. Listen for noise, distortion and stereo blending. Listen carefully on several receivers and then decide before deploying elevated HD power.

Mono reception is robust and mostly unaffected. For mono broadcasters, self noise will be much less of a problem.

Here are a few suggestions.

First, common amplification benefits extend to 4 percent and 10 percent power. It is possible to meet the mask at 10 percent digital power with no high-power mask filtering. Common amplification is simple. Efficiency is reasonable because signal statistics are somewhat better than DTV, meaning lower peak-to-average ratios, even at 10 percent digital power.

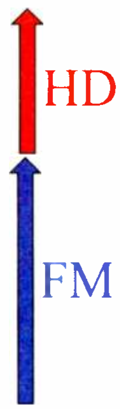

Fig 29: HD and FM are in phase, producing positive envelope modulation. Reduction benefits transmitters.

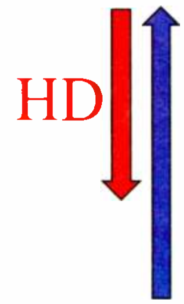

Fig. 30: HD and FM are out of phase, producing negative envelope modulation. Reduction benefits receivers.

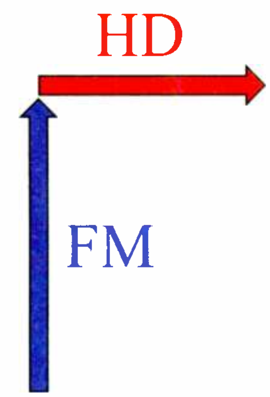

Fig. 31: HD and FM are in quadrature, producing maximum phase modulation. Reduction benefits receivers by reducing self-noise peaks.

Tube technology is still quite economical for producing the increased PEP required for elevated HD. There is the possibility of water cooling if limited space or air conditioning presents a problem.

Although the average power will not be much greater than the analog signal alone, the PEP capability of coax, combiners, filters and the antenna should be checked to make sure that there will not be a PEP problem.

Do not overmodulate the analog! That pushes the instantaneous FM carrier closer to the IBOC sidebands, which produces more noise below 53 kHz.

Finally, crest factor reduction systems should reduce positive envelope peaks for the transmitter, and negative envelope peaks for the benefit of the receiver. Do not pinch off the FM envelope!

CONCLUSION

Good engineering is about making optimum tradeoffs. The tradeoff here is digital coverage vs. analog signal quality. Most of your audience listens to the analog signal. Keep it clean *enough*.

Every station situation is different, so you will have to evaluate each station for the best digital power level.

Good engineering requires good information — and we hope that this information helps you.

Dave Hershberger is senior scientist at Continental Electronics. Contact the author at dhershberger@contelec.com.

Comment on this or any other story to rwee@nbmedia.com.

The Search for STL Bandwidth

Licensed Links in Higher Microwave Bands Provide Attractive Option

BY W.C. "CRIS" ALEXANDER

The author assists the contractor with installation of the 3-foot studio antenna.

Have you tried to get a new frequency in the 944–952 MHz aural STL band lately? How'd that work out for you?

Certainly there are places out in Middle America where frequencies are still available, but get anywhere near a city of any size and you can just about forget it.

By my count, there are 16 500 kHz channels available in that band, and the grid dish antennas we use for those frequencies aren't all that tightly directional. Add to that all the reflections and scatter that you can get at 950 MHz and it's not too easy to reuse frequencies. If a market has an "antenna farm" where many of its stations are located, you've got a single point of convergence and you'll run out of frequencies in a hurry.

Now factor in HD Radio. Ideally you will have an Ethernet path to your transmitter site with enough bandwidth to carry the output of the exporter. Modern transmitter sites also have need of additional Ethernet bandwidth. Many transmitters these days have a built-in GUI/Web interface, remote control units operate over TCP/IP connections and more and more transmitter sites are being equipped with DVR/video surveillance systems that need an Ethernet connection back to the studio. It's hard to do all that on a 500 kHz channel in the 950 MHz aural STL band.

MICROWAVE ALTERNATIVES

Seven or eight years ago, I began looking for alternatives to traditional 950 MHz aural STL links. Because all our stations are in large markets, we have always struggled to find frequencies to operate on and, in many cases, have resorted to landline options such as T1. Those aren't cheap, however, and aging local telco infrastructures plus increasing copper theft combined to reduce reliability. I had to find another way.

Wireless Internet was just getting off the ground in those days, and distribution/backhaul equipment was not hard to come by. I found that we could get a point-to-point Motorola Canopy BH system for about $2,400, including antennas. Such an unlicensed 5.7 GHz system would work well over a 20-mile path. We deployed quite a number of them, using Harris Intraplex multiplexers to transmit audio over the provided Ethernet bandwidth.

We used these systems for years, but as wireless Internet proliferated, so did the number of signals on the air. As that happened, interference levels rose and throughput suffered, eventually to the point that we didn't have enough throughput for the Intraplex to reliably convey audio.

We changed from the Canopy BH systems to the Motorola PTP-400 and got by for a while with that frequency-hopping, dual-polarity system, but the interference eventually caught up with us. The handwriting was on the wall: We had to have an interference-protected, licensed link.

So it was that I began looking hard at licensed 11 and 18 GHz systems last year. We found that Dragonwave and Trango were two manufacturers of this gear, and it was reasonably priced. I was already familiar with the PCN frequency coordination process required by Part 101 of the FCC rules, so finding frequencies and filing applications was no problem. Or so I thought.

WAIT, GIVE IT BACK

In our Denver market, I ran head-on into the Department of Defense and the Table Mountain radio telescope on 18 GHz.

I had done all the coordination and received no objections from these government agencies, but eight months later the FCC called and told me that they were going to have to rescind the 18 GHz license grants I had already received because of late objections. Evidently one of the frequencies I had chosen was too close to or coincident with something the DOD was using in the area (of course they won't tell you what frequencies are in use), and the others might be used by E.T. to phone home. So it was back to the drawing board.

NOT THE LAST LINK

I should have started out on 11 GHz, because I didn't have any trouble finding frequencies and neither the DOD nor the E.T. seekers care a whit about that band. I filed new FCC apps and got grants quickly. It didn't take long to get the equipment in, and soon we had an operating link to one of our transmitter sites.

The tower crew aligns the antenna on the far end of the path.

It should be noted that these links operate under Part 101 as fixed microwave links ("FXO" in FCC terminology). There is a prohibition in Part 101 on using FXOs as "the last RF link" to a broadcast transmitter. When the rules for this section were written, evidently they wanted broadcasters to stick to the BAS bands and not soak up a bunch of fixed microwave frequencies. So we had to find a way around this rule.

One option was to request a waiver. The FCC has, from time to time, granted such waivers upon a showing that (a) there are no Part 74 (BAS) frequen-

White Papers

White papers are technical articles by manufacturers and other developers of new technology; papers are selected by the editorial staff for their relevance to U.S. radio broadcast engineers.

Submit proposals for white papers to radioworld@nbmedia.com with White Papers in the subject line.

cies available for the desired path, and (b) that the bandwidth required for HD Radio operation is not available with a traditional aural STL.

I did not request a waiver, however, because I found another workaround that is actually based in practicality. The Trango Apex microwave radios mount right on the back of the antenna. Power, control and through-data are supplied via a couple of Ethernet (Cat-5) cables. The practical problem is that the antenna is mounted 400 feet up a tower, which is itself 600 feet from the transmitter building. With the Ethernet limit for Cat-5 cable around 300 feet, this wasn't going to work.

So instead of using a couple of boxes of Cat-5e and several switches along the way, I opted to use an unlicensed 5.7 GHz link between the tower and the transmitter building. I chose the Ubiquiti NanoBridge M5, which comes with a 1-foot dish antenna on each end and offers 100+ Mbps of throughput.

The NanoBridge was connected to the Apex up on the tower, and the other end of the NanoBridge was installed on the roof of the transmitter building. The distance between NanoBridge antennas is about 700 feet, meaning that we're not worried about signal strength or interference on that short-hop link.

With this arrangement, the 5.7 GHz NanoBridge and not the 11 GHz Apex is the "last RF link" to the transmitter, thus complying with the Part 101 rule. To keep everything on the up-and-up, I included a statement explaining this in the Form 630 application.

HEAVY METAL

Installation was mechanically challenging — the 3- and 4-foot radome-equipped antennas are *heavy!* — but otherwise straightforward.

Hang the antenna on each end and attach the radio itself to the back of the antenna with the supplied fasteners. The circular waveguide input on the antenna mates right up to the waveguide output of the radio with just an O-ring to install on the connection. Connect the through-data and management Ethernet ports and fire it up.

There is a large red two-digit LED numeric display on the back of each radio that displays the RSSI (receive signal strength indication) in dBm (although a positive number is indicated, the display actually indicates a negative number). Adjust the elevation and azimuth of the antenna for the lowest number and the path is aligned.

On our link, the calculated receive signal was –40 dBm (EIRP + antenna gain – path loss + antenna gain), and that's very close to the "40" that we saw on the display. The link has been in operation for several months now and the signal strength varies between –42 and –39 dBm.

This provides us with about 40 Mbps of throughput using a 10 MHz channel, plenty for our application. We continue to use Harris Intraplex multiplexers to transport audio over the Apex system. In addition to 12 channels of audio, we're also transporting Internet/e-mail, webcam, Amb-OS files, remote control, HD Radio program service data (PSD) and more. The effect is the same as if the transmitter site were connected right into the LAN subnet switch at the studio. I guess in a way it is.

I have filed and received grants for two more 11 GHz links and have one of the systems ordered and on the way. By the time you read this I will likely have both these systems online and operating.

One more thing I should mention: The antennas for these units are heavy and have significant wind loading. A structural analysis is a *must* before hanging one of these things on your tower.

In one of our installations, I am going to have to increase the size of the guy wire at one level to maintain a proper safety factor. Don't assume that the tower can handle it and hoist the thing up. Make certain.

As inadequate bandwidths and scarce frequencies continue to be the rule on the Part 74 aural STL BAS band, radio engineers are going to have to find other ways to get the signals from the studio to the transmitter site and back. Fixed microwave links aren't right for every application, but they do offer an alternative in some cases.

Cris Alexander is the director of engineering at Crawford Broadcasting and a recent recipient of SBE's Broadcast Engineer of the Year award.

Fixed microwave links aren't right for every application, but they do offer an alternative in some cases.

We Got It Wrong Last Time

Just What Is the Relationship Between AM Modulation and Antenna Current?

BY CHARLES S. FITCH

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

I am blessed with an abundance of good, caring friends. No person deserves to have so many people who care about one's feelings and are so supportive.

No sooner did the June 9 issue of RW Engineering Extra hit the mailboxes of my buddies than I started getting calls and e-mails, each telling me gently that the correct answer to the latest question was not among the choices. How could this happen?

The explanation involves a description of how this column is written.

As I come upon an interesting issue or field a question from a client that has a distinct, compact and illustrative answer, I make a note of it for possible use here.

Among many references I use to double-check answers or cite for further reading are such tomes as the ARRL "ARRL Handbook for Radio Communications" and the classic McGraw-Hill tech series, as well as older license exam Q&A prep books. In the latter I have found many "compact questions" to develop into Certification Corner articles.

RWEE editor Michael LeClair and I run through possible choices, attempting to balance the mix of certification grade and subject areas. We also try to identify just plain interesting discussion or theme lines to help you prepare and get pumped up for the exam with an enjoyable and intriguing dissertation. Hopefully this helps the reader, and us, to learn something useful in a fun way.

Among our choices in preparing the June column

What's the Ratio, Kenneth?

Question posed in the June 9 issue
(Exam level: CBRE)

At 100 percent AM modulation, what is the ratio of peak antenna current to unmodulated current?

a. 16 to 1
b. 8 to 1
c. 4 to 1
d. 2 to 1
e. 1 to 1

was a question from an old license prep manual in my father's library, "Radio Operating Q & A" by Arthur R. Nilson and J.L. Hornung. On Page 317 of the second printing of the eighth edition, published in 1946, was the above question on antenna current, with the answer: 2 to 1. That is, Nilson and Hornung tell us the 100 percent modulated current rises to twice the unmodulated current flowing into the antenna. Nilson and Hornung's answer is wrong.

Photo courtesy Kintronic

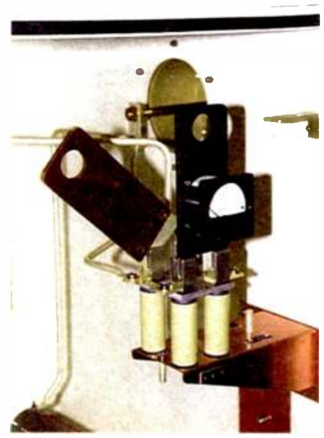

Photo of a thermocouple ammeter on a meter plug shown inserted into the output jack as it would be to make a tower current measurement.

WHY?

But this discussion isn't getting us to the right answer; so back to the question.

Any power transfer calculation has three factors: The resistance of the load (into which the power is sent), the voltage impressed on the load and the current of the supplied power. In this question we're focused mainly on the current.

Consider a typical 1,000 watt AM station with an atypical 50 ohm pure resistance antenna. With just an unmodulated carrier, the current will be 4.47 amps.

$$I = \sqrt{P/R}$$

$$4.47 \text{ amps} = \sqrt{1000 \text{ watts} / 50 \text{ ohms}}$$

If you have a line current meter on the output of your 1,000 watt AM transmitter, you will recognize that number as the line current of 1,000 watts into your 50 ohm transmission line with unmodulated carrier.

The direct formula for antenna current (where "m" is the modulation factor and 1 = 100 percent, 0.5 = 50 percent etc.) is:

$$\text{Modulated current} = \sqrt{1+\left(m^2/2\right)} \times \text{unmodulated current}$$

Thus 100 percent modulation current =

$$\sqrt{1+\left(1^2/2\right)} \times 4.47 \text{ amps}$$

How did we get there? Basic AM theory tells us that at 100 percent modulation, the power in the sidebands created will be 50 percent of the carrier power, or 500 watts in this case. Substituting 1,500 into the original formula we obtain a line current of 5.47 amps.

5.47 amps/ 4.72 amps = 1.225

So the correct answer is really 1.225 to 1 — which was not one of the selections.

Please accept my apology if this has caused you weeks of perplexity.

By the way, don't go running out to the ammeter in your ATU and expect to see the meter peaking 1.225 times higher when your mod monitor is showing peaks at 100 percent. Most of these ammeters are thermocouple types and so have a very high hysteresis and damping factor. A little twitch up is about all you'll see unless you introduce steady tones.

SOMETIMES THERE'S AN ERROR

Incidentally, this question was legendary for the number of times and various forms in which it appeared on the FCC Second (in the context of maritime AM) and First Class examinations — so much so that Robert Shrader addresses the subject area in his industry standard, "Electronic Communication."

Where might the question error have popped up?

Only with everyone's help will the exam quality stay high and improve further.

As my good buddy Cris Alexander notes, the ratio between the sum of the voltages of the carrier plus the sidebands at 100 percent (vis-à-vis modulated to unmodulated) is 2 to 1. The question may have been corrupted by Nilson and Hornung, or two questions fused.

We should mention that with the volume of test material that must be prepared for each SBE exam cycle, sometime and someday there will be some question errors. (Remember that there is no test question list for SBE exams, as there is for FCC exams; pretty much every SBE exam is a new document.)

Answer all SBE exam questions as best you can; but if you feel that a question was written in a confusing or inconclusive manner or that the correct answer wasn't listed, point this out when you submit your exam papers to the proctor. Give that person a written short explanation along with your correct answer. Only with everyone's help will the exam quality stay high and improve further.

If you have been studying for a ham ticket, you will have seen updates that several questions were removed from the FCC amateur question list, for the reasons noted above. A convenient place to check for questions removed from the pool is *www.arrl.org/withdrawn-questions*.

It's tough to write effective exams. Our praise and admiration should be given to all those who work on the SBE certification exams.

The deadline for signing up for the next cycle of SBE certification exams is Dec. 31, 2010 for exams given at the Local Chapters between Feb. 4–14, 2011. If you're a veteran, you may be reimbursed for the Certification Exam fee. Contact Megan Clappe at SBE headquarters for details: *mclappe@sbe.org*.

Missed some Certification Corners or want to review them for your next exam? Find back columns at http://rwonline.com/section/certification-corner.

REFERENCES:

"Schaum's Outline of Electronic Communication," by Lloyd Temes, McGraw-Hill, 1979, pages 1–27

"Radio Engineering," by Frederick Terman, McGraw-Hill, 1937; section on modulation

"Electronic Communication," by Robert Shrader, fourth edition, McGraw-Hill, 1980, page 398

"Radio Engineering Handbook," edited by Keith Henney, fifth edition, McGraw-Hill, 1959, Beverly Dudley section

... And I'm Here to Help

Question for next time

(Exam level: CBRE)

It's a little after 8 p.m. and your five-station cluster has settled into night automation operation. As usual, you are the last in the building.

But now there are two people at the front door, holding up federal FCC IDs to the security camera. They request to inspect your station(s).

Are they entitled to inspect at this late hour?

a. No, it's a constitutional right to have an attorney present when questioned. They can come back when your attorney is present.
b. No, it's after business hours, and meaningful management presence is absent
c. No, you're off the clock
d. No, tours are only given by appointment
e. Yes

METAPHORS

(continued from page 22)

Some words have dual but opposite meanings. Is the word *sophisticated* a positive or negative adjective? The word originally referred to someone who had broad experience in a wide variety of areas but whose experience was at the surface with no depth. The root is the same as sophomoric (also a sophomore in the second year of school), meaning the beginning of knowledge without an awareness of what is not known. Breadth of experience is positive but shallow understanding is negative.

Without realizing the bigger issues, I first experienced word ambiguities when I worked in Germany in the late 1960s. Translating a word, and hence a concept, across languages and cultures forces the hidden issue into consciousness.

How many English speakers recognize that the common word *another* has two meanings? In the sentence, "we should get another tube for the transmitter," *another* could mean a replacement for the existing tube because it is likely to die at any time, or it could mean that we should have an extra tube as a spare even though everything is fine. The two meanings are "additional" and "replacement."

If you want to improve your relationships at work, start to pay attention to the words that you use because they contain metaphors. The metaphor's assumptions are communicated along with the ideas. Similarly, you need to watch for cases in which metaphors either are not shared or have critically important differences among subcultures.

Where does that leave us? Language is flawed and riddled with ambiguous metaphors, but numbers are mostly meaningless quantities even if the details are specified. By proving that language is deficient, one cannot therefore conclude the reverse: that numbers have value in human activities. I can measure the performance of an MP3 encoder but those numbers say nothing about the human experience. We do not hear numbers, we hear music. When one traces numbers and facts to their root, we again find people with human foibles that are simply an artifact of nature's grand experiment in evolution.

Numbers and words are both tools of communications and both can be used to communicate or to mislead.

If you want to improve your relationships at work, start to pay attention to the words that you use because they contain metaphors.

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

Flawed Human Communications

Ambiguous Metaphors and Meaningless Numbers

BY BARRY BLESSER

Engineers have the reputation, probably deserved, for placing a high value on equations, numbers, data and similar forms of information. Engineers believe that these types of information are best for communicating the nature of reality to others.

Lord Kelvin is often quoted: "When you cannot measure it, when you cannot express it in numbers, your knowledge is of a meager and unsatisfactory kind."

Nevertheless, I take exception to his 19th century view for two reasons.

First, even when numbers are accurate and reproducible, there is no intrinsic meaning to them.

You would not buy an automobile on the basis of thousands of numbers about internal construction and observable behavior. If I described your current employer and properties of your professional life in numeric form, you would have learned nothing. Even a simple numeric measure of harmonic distortion tells you very little about quality.

For this reason, I prefer Albert Einstein's 20th century version of the quotation: "Not everything that can be counted counts, and not everything that counts can be counted."

Second, natural language is too central to human existence to be ignored.

Consider trying to do your job without the use of ordinary language, be it written or verbal. Imagine being at work without discussing ideas in meetings or documents. Productivity rapidly would degrade to nothing. We need ordinary language even when discussing highly technical subjects. But this then brings up questions about common language as a way of communicating.

Language has been the subject of study of millennia. In the 20th century, specialists created a framework of linguistic theory based on academic research. From our current perspective, their work described an idealized picture of what researchers thought language should be in some kind of theoretical world.

More recently, a new generation of linguists has begun to look at how real people actually communicate, by using metaphors in a verbal dance.

A metaphor is a figure of speech in which an expression is used to refer to something that it does not literally denote in order to suggest a similarity. For an audio engineer, the most obvious examples are words pertaining to sound, which are often described with such adjectives as bright, muddy, transparent, enveloping, heavy, distant, ponderous, warm, intimate, etc.

All of these words are borrowed from physical objects, visual experiences or other sensory modalities. Literally, a physical *window* can be transparent because one can see through it, but we do not see though sound. Such metaphoric words serve a function because we assume that sound engineers have shared experiences and a common vocabulary. My daughter would not understand these sound adjectives, and neither would the CEO of your station (unless he or she had been a sound engineer in another life).

> **Racial, gender and age discrimination originates in part from basic differences in the metaphors that are used to communicate.**

Analyze the italics words in the following: "Try to *pack* more thoughts *into* a few words." While you can pack a suitcase with physical clothes, words have no emptiness that can be filled. Or consider this: "The idea was *buried* in a *sea* of text." You bury something by digging a hole, putting something in it and then covering it up; text is not water.

Other metaphors are borrowed from physical experiences, such as *up* and *down*. "I am feeling *up*." Why should happy be upwards, which is simply the reverse direction from what gravity does with a ball? The list is large. "Wake *up*; he is in *top* shape; I am *all over* the situation." Conversely, we say "I am feeling down" or "he let me down." Why should upwards really be better than downwards?

If I have *piqued* (which is also a metaphor) your interest from my comments take a look at the book "Metaphors We Live By" by George Lakoff and Mark Johnson.

Our honorable editor Michael LeClair has contributed his understanding of this metaphor: to *pique* comes from the French word *pique*, a sharp blade at the end of a wooden lance. The word pique has dual elements: provocation and curiosity.

VERBAL COMBAT

An important metaphor system influences professional discussions, which have elements of an argument. At least in our culture, metaphors of warfare and combat are used frequently. I was unaware of this until I read Lakoff and Johnson; as a result, I am cleaning up my language.

Take these examples. "Your assertions are *indefensible*; I *demolished* his argument; he *shot down* my conclusions; the criticisms were on *target*." We may have no interest in a discussion becoming combative even though we use a combative language. In another culture, a dance metaphor might be used in a discussion. Many foreign cultures have metaphors that do not translate into English.

We tend to use a mechanized language for thinking and ideas, hence concretizing something that is intrinsically ethereal and abstract. "My mind is not *operating* today; my wheels are now *turning*; I am feeling *rusty* today; we are running out of *steam*; her ego is *fragile*; the experience *shattered* him." Metaphors communicate hidden associations.

Other cultures and subcultures use different types of metaphors, and when crossing metaphor boundaries, communications breaks down. We forget how much of our cultural biases leak into everyday life. Racial, gender and age discrimination originates in part from basic differences in the metaphors that are used to communicate. The subculture of teenagers might say this stuff is way *cool*, or really *hot*.

NOT PRECISE

In my 40 years as a consultant, I have accumulated numerous words and concepts that are believed to be unambiguous but which have no real meaning. To demonstrate the ambiguity of concepts, I often take a group of random people and ask them to define the word "trust." Each person writes down his personal definition and I then read them to the group. For fun, try this experiment with your colleagues.

I have observed a wide range in meaning. At one extreme, the phrase "I can trust him" means that he will take care of me and protect my interests, covering my back whenever possible. At the other extreme, it can mean that he consistently damages my stature and career at every opportunity.

Here is a list of other words whose meanings are at best loose: *learn, manage, should, expect, fair* and *assume*. You may have a clear understanding of each of these words, but it is usually the case that your colleague or manager will have a different definition. Consider this example: "You should check the transmitter." Does that mean that this is a high-priority action item? Or does it mean that in an ideal world, somebody should check it someday if they have nothing better to do?

(continued on page 21)

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IMAGINE THERE'S NO IP HASSLE. IT'S EASY IF YOU TRY.

Preface... Clear your mind. All that anxiety that you've come to associate with the typical AoIP network install is going to leave you now... Think of cool clear water flowing into the coffee maker and the sound of sprinkles hitting fresh, hot donuts... OK. Ready?

1.OPEN

Confront your boxes. You know they're there. They know they're there. But only YOU have the power to change that. Go ahead... open them.

10:03am

2.LOOK

Take a good look at what's in the boxes. You've got a control surface mixer item and rack mount BLADE something or other. They sure look pretty. And they are. Using this stuff you are gonna be a chick magnet. Or a guy magnet. Whatever, you are going to be IN CONTROL. Cool part is, THAT is only moments away!

10:09am

Every BLADE has all the information about your entire network stored in it. Should any part of the network go down, the rest continues to function perfectly. Simply plug in a new BLADE and you'll be where you started in moments!

3.RACK EM UP

Rack mount the rack stuff. OK, we're going to be brutally honest here. THIS SINGLE ONE STEP takes the longest of the entire setup process (unless you have a REALLY dull knife in step 1). Of course you'll need your own rack and screws, but hey, if it's a deal breaker, we'll work it out.

10:20am

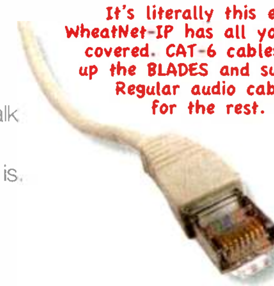
4.PLUG IN

Time to hook them up. You knew it was coming. Your little tummy is wrapped around your throat. I mean, it's gotta be a real hassle, right? Interfacing these things? Setting them up? Getting them to talk to each other? Somebody get me an antacid.

Wait... is that a CAT-6 cable? You know what that is. And that's all it takes? Mmm Hmm. Yep. You bet.

11:02am

It's literally this easy. WheatNet-IP has all your bases covered. CAT-6 cables hook up the BLADES and surfaces. Regular audio cables for the rest.



5.PUSH THE BUTTON

OK. Everything all hooked up (meaning, is the CAT-6 cable plugged in)? Great. Now we're gonna configure the system. We start by turning it on. Then?

Um... that's it. It configures itself. Every piece talks to every other piece and does what it's supposed to do. What? Doesn't EVERY IP Audio system do it that way?

11:05am

WheatNet-IP does ALL the work of configuring your system EVERY BIT OF IT! It knows when you are adding on or when you are taking something out. You concentrate on content. We concentrate on getting it where it needs to be.

6.IT'S WORKING!

You've got a system! From here on out, it's just like the analog stuff you're used to. Except ultimately more flexible. And much more reliable. And better sounding. And completely expand-able. And such a joy to use. Yes – you heard it – I said A JOY TO USE! (Bet you never thought you'd hear an IP system described that way. Certainly not one from the other guys!

11:06am

7.CELEBRATE

Time for that cup of coffee and donut we talked about in the preface. Let's face it...the whole process was painless. AMAZINGLY PAINLESS. So painless, you are already up on Facebook and Twitter talking about what a stud muffin you are with your technical prowess. Don't get cocky, kid. But DO enjoy a delicious coffee and donut. And remember, next time you even think about installing new gear, you've gotta call your Uncle Wheaty...

11:07am

3:40am

8.SLEEP EASY

With a WheatNet-IP system, rather than having to be on the phone to who-knows-where in the middle of the night, you can take your emergency engineers off the clock and let them get a good night's sleep. We ARE here, 24/7, in beautiful New Bern, North Carolina, and if you need us, we'll talk to you all night long. But with Wheatstone's reliability record, chances are much greater that those visions of sugar plums will just keep dancing in your head.

AoIP ADVANCED...

It's great to be able to say you invented something (whether you did or not). Turning that invention into a viable, workable solution for modern applications is what's needed if we are going to take this technology to the next level. The status quo was a pretty good starting point – but taking it out of the vacuum and into the workplace requires a fresh, objective yet passionate approach to advance it. WheatNet-IP certainly advances it, making your workflow everything it should be. We cost the same or less. We can handle 10 times the bandwidth. We are far more reliable. And we're poised for THIS decade as well as the NEXT one. We're Wheatstone! This is what we do! What else would you expect?

WHEATNET IP

Wheatstone

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