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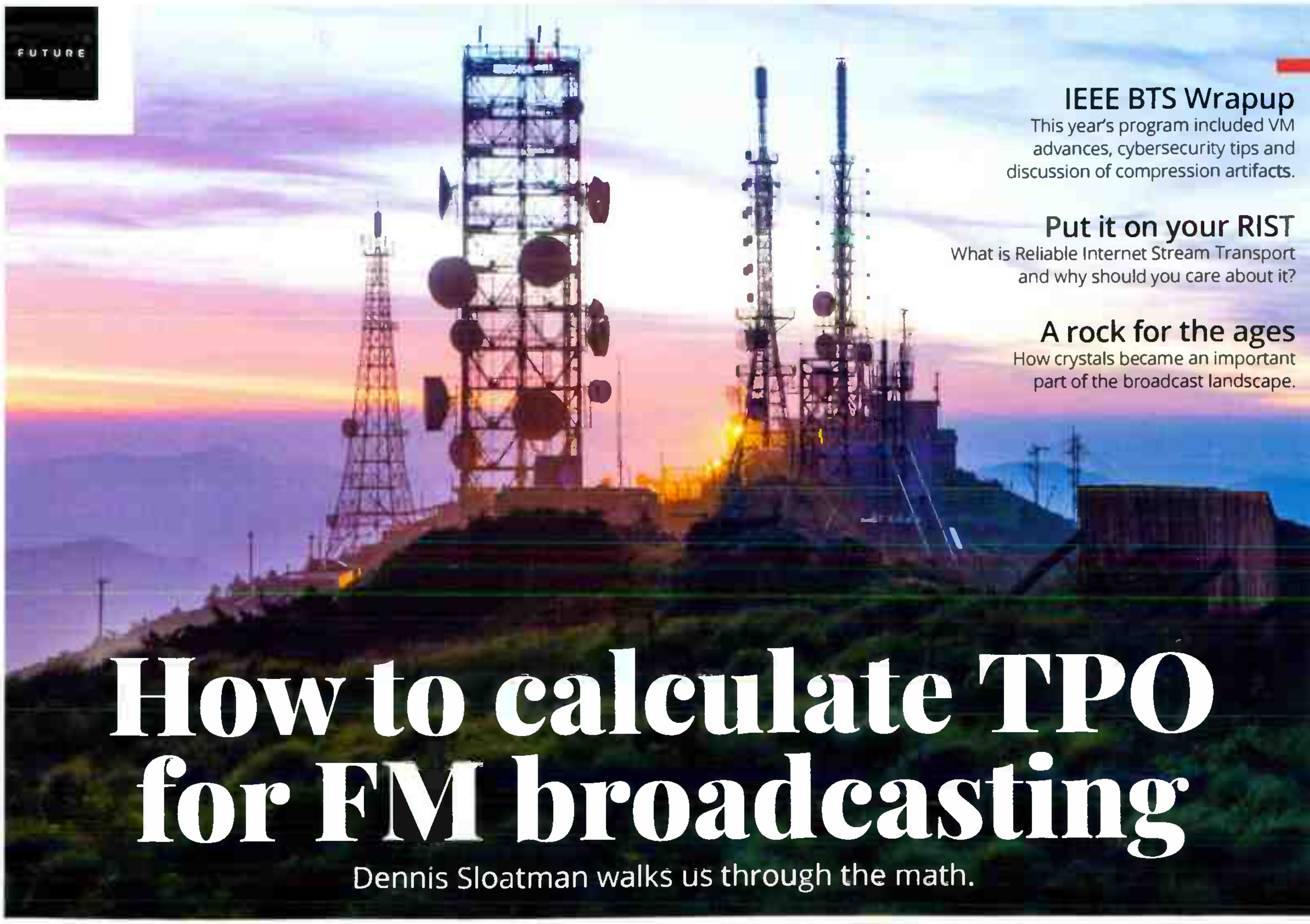

IEEE BTS Wrapup
This year's program included VM advances, cybersecurity tips and discussion of compression artifacts.

Put it on your RIST
What is Reliable Internet Stream Transport and why should you care about it?

A rock for the ages
How crystals became an important part of the broadcast landscape.

How to calculate TPO for FM broadcasting

Dennis Sloatman walks us through the math.

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CONTENT
Managing Director, Content & Editor in Chief Paul J. McLane, paul.mclane@futurenet.com, 845-414-6105
Content Producer & SmartBrief Editor Elle Kehres, elle.kehres@futurenet.com
Technical Editor, RW Engineering Extra W.C. "Cris" Alexander
Technical Advisors Thomas R. McGinley, Doug Irwin

Contributors: Susan Ashworth, David Bialik, John Bisset, Edwin Bukont, James Careless, Ken Deutsch, Mark Durenberger, Charles Fitch, Donna Halper, Alan Jurison, Paul Kaminski, John Kean, Nick Langan, Larry Langford, Mark Lapidus, Michael LeClair, Frank McCoy, Jim Peck, Mark Persons, Stephen M. Poole, James O'Neal, T. Carter Ross, John Schneider, Gregg Skall, Dan Slentz, Dennis Sloatman, Randy Stine, Tom Vernon, Jennifer Waits, Steve Walker, Chris Wygal

Production Manager Nicole Schilling
Group Art Director Nicole Cobban
Senior Design Director Lisa McIntosh
Senior Art Editor Will Shum **Art Editor** Cliff Newman

ADVERTISING SALES
Senior Business Director & Publisher, Radio World
John Casey, john.casey@futurenet.com, 845-678-3839
Publisher, Radio World International
Raffaella Calabrese, raffaella.calabrese@futurenet.com, +39-320-891-1938

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Solving the variables in the FM equation

Design of an optimized FM transmission system requires careful analysis

Cris Alexander
CPBE, AMD, DRB
Technical Editor

It was late 1984, some 39 years ago this month, and I was new to the company where I still work today. Right out of the chute, the president of the company handed his new D of E an assignment: Fix our Detroit FM station.

We had in those days two "superpower" Class B FMs in our company, one in Buffalo and one in Detroit. Our Detroit station was 115 kW ERP at 300 feet above average terrain, impressive by any measure, at least on paper. The problem: The Detroit FM had severe multipath throughout the market and was unlistenable in many locations.

The site was right in the geographic center of the Detroit metropolitan area, near the intersection of I-96 and the Southfield Expressway. The station had an RCA 10-bay antenna, pole-mounted on a 360-foot free-standing tower.

The antenna looked fine and the transmitter was operating at full power. There was no indicated reflected power. What could the problem be?

Some sleuthing and scrutiny of the geography and topography of the Detroit area gave me some clues.

The downtown area, with its buildings some 600 feet tall, was about 10 miles to the east, and there were other high-rise buildings scattered around the area, some not far away. Could those buildings be producing strong reflections to cause the severe multipath that the station was experiencing?

At that point in my career, I didn't have much experience with FM except at the operational level; I had been a TV guy until just months prior. I had done some FM allocations work in addition to building and maintaining a few FMs, but what I had not done was any kind of systems engineering. All my experience on the ground was building or maintaining what other people had designed, so I was out of my element with this project.

THIS ISSUE

RWEE's Final Issue

Hi, just a note to let you know that this is the final issue of Radio World Engineering Extra. Preferences among our advertisers and readers for how to consume this content have led us to prioritize the twice-monthly Radio World Engineering Extra SmartBrief e-newsletter. (If you don't already receive it, you can sign up for free via the Subscribe button at *http://radioworld.com*.) My thanks to the editors who have led RWEE's print edition over its 19 years including Michael LeClair, Rich Rarey and Cris Alexander; they remain part of the Radio World family. Also expect us to continue to explore technical trends and issues in the regular issues of Radio World; on the Radio World website; and in our monthly ebooks.

— Paul McLane

Still, I had it to do, and while not expressly stated, I figured that this was a test and that my job was on the line. I had to get it right.

And so I took a self-administered crash course in FM antennas, vertical plane patterns, multipath and FM propagation. I learned about vertical nulls, Brewster angle and how direct and reflected signals could constructively or destructively combine in a receive antenna. I also learned how subcarriers could sometimes produce multipath-like effects in an imperfect transmission system or where there were already signal issues.

At the end of that study and my analysis of the situation with our Detroit station, I concluded that we had too much antenna gain, too little signal in close-in areas below the main vertical lobe and reflections off the downtown and other high-rise structures that were destructively combining with the direct signal to produce the multipath.

Was I certain of all that? No. But it was my best, somewhat educated, guess.

Superpower FMs had been grandfathered, but if you made a change to the HAAT or ERP, the facility would have to come into compliance with the later rules. Clearly we needed more height, and to get that, we would have to become a compliant Class B station with maximum facilities of 50 kW and 150 meters (492 feet) AAT.

It was with great anxiety that I took that proposal to the president of our company, telling him that the way to fix his FM signal was to *reduce power* from 115 kW to 50 kW. How would he respond? Should I just go ahead and clean out my desk?

To my great surprise, he gave his full approval to the project.

It included a new 500-foot free-standing tower (not cheap!), a four-bay antenna, new rigid line and a new 27.5 kW transmitter. That tower height got us 142 meters AAT, not 150 meters, but 500 feet AGL was all I could get the FAA to approve.

I filed the CP application and got a quick grant.

The project was built in record time by today's standards, just a few months. There was no ASR, NEPA, NPA and all that back then ... we just pulled a building permit, drilled the piers into the ground and stacked the steel.

With the new tower up and the new transmitter building in place and fully equipped, with great trepidation I threw the switch to put the new facility on the air. Would this huge expenditure fix our problems, or had I just thrown several hundred thousand dollars down those pier holes?

It didn't take long to figure out that *YES! IT WORKED!* The new facility had none of the multipath issues that the old one did. Coverage in the city was solid, with just a few identifiable and very localized areas with any discernible multipath at all.

Above
The "new" 500-foot tower is shown next to the older 360-foot structure. Note the identical four-bay main and aux antennas.

But what about distant coverage? The station manager and others drove the outlying areas and found that the coverage was equal to or better than what it had been with the higher ERP. I was greatly relieved, and it was with great pleasure and pride that I reported all this to the boss.

I learned a lot from that project, and the knowledge has served me well over the years. I'm very grateful to my boss for his faith in me when I didn't have a lot of faith in myself, and I thank God it all worked out.

I mentioned that our company had two superpower Class B FM stations, with the other one being in Buffalo. That one was 110 kW ERP at 195 meters (640 feet) above average terrain. It used a 10-bay antenna on a 400-foot tower. Buffalo had a lot of tall buildings like Detroit. If a high-gain antenna creates multipath issues in urban areas, why didn't it do the same thing in Buffalo?

The answer is really simple: location-location-location. The Buffalo site was some distance south of the city. That tight vertical pattern had little impact on the urbanized area some distance from the antenna. That station continues to perform well for us, as does our no-longer-superpower Detroit FM.

In this month's issue, Dennis Sloatman deals with some of these issues and teaches us about all the variables that go into an FM transmission system. He shows us how to arrive at a transmitter power output (TPO) figure given all those variables.

We also hear from Dominic Giambo of Wheatstone about RIST, a new, open-source protocol for audio transmission over IP and in particular the public internet. This is exciting and may well represent the next big thing in audio transport.

Does anything use quartz crystals anymore? Modern transmitters and their exciters are often frequency agile and can go to any frequency in the band with a menu selection, so surely not; why would you need a crystal?

Not so fast! Even modern, frequency-agile transmitters, receivers and other equipment have a quartz crystal at their heart, often a highly accurate, highly stable reference oscillator running at some low frequency. It's true that it's rare to find a crystal cut for the carrier frequency in a modern transmitter, but there's some quartz in there somewhere.

In this issue, Buc Fitch takes a look at quartz crystals, including their history and how they are made and work. I think you'll enjoy it.

I hope you'll learn (or relearn) something from this group of really smart writers. I know I did.

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Hamback Mountain, South Korea, Getty Images/sigint/Imazins

Writer

Dennis Sloatman

CSRE, AMD, CBNT, BSEET

Calculation of TPO for FM broadcasting

A number of factors enter into this question

FM stations are rated by ERP, effective radiated power. This value is found on the FCC license or construction permit. The question for the engineer is to figure out what transmitter power output or TPO is required.

When tasked with building an FM broadcast transmitter plant, the engineer must consider tradeoffs consistent with the capital budget and long-term expenses of the new facility. Factors include the ERP as a starting point. Then there are antenna gain, transmission line losses, combiner losses (if applicable), filter losses, isocoupler losses (if using an AM tower) and other concerns that we'll examine.

The equation for ERP can be given as follows:

$$ERP = \sum GAINS - \sum LOSSES$$

where the Greek letter sigma ∑ means "summation" or "sum of."

This may be expanded as:

$$ERP = (TPO + G_{ANT}) - (T_L + F_L + C_L + M_L)$$

Where:

TPO = transmitter output power in dBk or in watts

G_{ANT} = RMS antenna gain in dB or in power gain
T_L = Transmission line loss
F_L = Filter loss
C_L = Combiner loss
M_L = Misc. losses (connectors, switches, etc.)

Written another way, to solve for TPO, the equation becomes:

$$TPO = (ERP - G_{ANT}) + (T_L + F_L + C_L + M_L)$$

But before we go further, we need to examine the options for selection of antenna gain vs. transmitter power rating.

Age-old question

Higher antenna gain implies more elements and higher weight/tower wind loading, which is a constraint imposed by the tower site available. Also, higher antenna gain means a significant reduction in monthly utility bills (by virtue of lower transmitter RF output power required meet ERP requirements).

Some engineers believe a "high-bay count" antenna with lower TPO is "not as good" as a high-power transmitter and low-bay count/low-gain antenna. I believe this to be nonsense.

Except in cases in which the antenna is in the center of an urban area, antennas appear to be a point source in the far field. Consider a super bright light source observed from a kilometer away. Now, consider eight light sources of the same directivity of the single light source placed 3 meters apart, which when combined equal the lumens output of the single light source. From your point of view, it still appears to be a single point of light.

In my opinion, 48 kW of transmitter power and a four-bay antenna will cover the metro no better than a 12-bay antenna and 20 kW of transmitter power, as long as the antenna is a kilometer or more outside the metro area, as most are. All you accomplish with the 48 kW/four-bay antenna is a larger utility bill. Of course, as I mentioned, tower loading may significantly affect this tradeoff.

Safety first

There are other factors that may affect your decision. If the antenna is to be located by necessity at a low elevation on a tower or a building rooftop, consideration must be given to controlled and uncontrolled RF power densities on the ground per OET Bulletin No.65, which is available in PDF form on the FCC website (just Google "oet65").

In such cases, you may be faced with low-bay count, half-wavelength-spaced antennas with very low gain and a corresponding high TPO to reduce radiation and yet meet FCC RF power density requirements.

So far I've described just some of the considerations for a new FM transmitter site. This can be a confusing process, and you may find it helpful to seek the advice of a consulting engineer or knowledgeable colleagues.

Above
Fig. 1: A map of central Florida

Transmission line selection is a significant factor. Larger transmission line means less loss but also more expense and more tower loading. Manufacturers provide both power rating (average and peak) as well as loss figures for different frequencies in their specifications, and this is the place to start when considering which transmission line to use.

Other losses to consider are filters (band-pass or band-stop "notch"), combiner losses for multi-station installations and "miscellaneous losses" such as for connectors, antenna switches and transmitter room connections. You'll need to consult manufacturer-supplied test data for filter and combiner losses while using manufacturer "book" data on transmission line sections.

In general, I find it useful to "work backwards" to calculate the transmitter power output requirements given an ERP. Some examples may prove beneficial.

"In general, I find it useful to 'work backwards' to calculate the transmitter power output requirements given an ERP."

Say we have a full Class C FM station with a licensed ERP of 100 kW at 1,500 feet (457 meters) above average terrain. [Note that per 47 CFR §73.211, the minimum Class C parameters are 100 kW ERP and 1,479 feet (451 meters) center of radiation above average terrain (HAAT).]

Further, let us suppose we have a tower of unlimited loading capability so that we are not constrained as to antenna type or transmission line size. Also, we have unlimited power available from the utility and unlimited floor space. (These sorts of assumptions are useful in problem-solving and are similar to the methods used in science and engineering when considering multiple variant parameters: Simplify the problem and then make the real-world adjustments.)

For this example consider that our hypothetical tower is between two major population centers such as Orlando and Daytona in Florida (see the map on the previous page).

After a year of real estate searches, FAA and FCC studies, local zoning and permits secured as well as determination of utility availability, we have a tower with space available near Deltona, midway between Orlando and Daytona.

We seek to deliver a 60 dBu (1 mV/m) or greater signal fully encompassing Orlando and Daytona. Further, we seek to be a full Class C facility. What next?

Inasmuch as the tower is infinitely strong and we have whatever utility power available at the site we require, we have flexibility to explore a few scenarios. We also observe that this Deltona facility is midway between two metropolitan centers in which we are eager to sell our brand.

For this hypothetical facility, we consider a "wrap-around" panel antenna so that the resultant coverage is essentially uniform and is of a broadband design such that we may accommodate several stations. We will select an eight-bay wrap-around panel design ("wrap-around" implies three elements per bay — one element per side of a three-sided tower). The RMS gain of a typical eight-bay panel antenna is approximately 6 dB or a power gain of 4.

We also assume we have three FM stations sharing this same antenna, each of which are Class C FM stations licensed for 100 kW ERP. This means we will require a constant-impedance combiner to combine the three transmitters to share the transmission line and antenna. The manufacturer's declared combiner loss is 1 dB.

We will require about 1,600 feet of 6-1/8-inch rigid transmission line with an average power rating at 98.1 MHz of 178 kW. For this example, all other losses, such as internal connecting line and connectors, will be considered negligible. All three FM stations are, for simplicity, identical except for frequency.

“For this hypothetical facility, we consider a ‘wrap-around’ panel antenna so that the resultant coverage is essentially uniform and is of a broadband design such that we may accommodate several stations.”

Calculating the TPO

So we begin the calculations:

- 100 kW ERP, as specified by the FCC license

Looking at the manufacturer's specifications for the transmission line, we find:

- 1,600 feet of 6-1/8-inch rigid line, loss of 0.83 dB, or an efficiency factor of 0.826 or 82.6%
- Combiner loss of 1 dB or an efficiency factor of 0.794 or 79.4%

What is the required TPO? We work the problem "backwards," starting from the target ERP.

An antenna power gain of 4 means we need an antenna input power of 25 kW (100 kW/4). The transmission line efficiency of 0.826 implies our transmission line power input requirement is (25 kW/ 0.826) = 30.3 kW (rounded to the nearest 100 watts).

Next, we factor in the combiner loss of 1 dB, or 0.794, stated as an efficiency factor.

So now we can determine the required TPO as 30.3 kW/0.794 = 38.2 kW (rounded to the nearest 100 watts).

Check your work by reversing the process: (38.2 kW * 0.794 * 0.826 * 4) and we obtain 100.2 kW or 100 kW (rounded).

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We've got Decibels!

If we were to run these calculations in dB, we find the process is simple algebraic addition:

100 kW = 20 dBk ("dBk" which is decibels above 1 kW). dB = 10 log (P_{ACTUAL}/P_{REF}) = 10 log (100 kW/1 kW) = 10 log (100) = 20 dBk (decibels above 1 kW)

Therefore, we simply add the gains in losses given in dB. Note the signs of the numbers:

20 dBk – 6 dB (RMS antenna gain) + 0.83 dB (line loss) + 1 dB (combiner loss) = 15.83 dBk TPO

Now, using the decibel formula and solving for P_{ACTUAL}:

$10^{(15.83/10)}$ *= 38.28 kW* (slightly different than the earlier result due to rounding).

Here's another way to look at it, in tabular form:

Parameter	Numeric	dB/dBk
ERP	100 kW	20.00
Ant. Gain	4.0	6.00
Line Loss	0.826	0.83
Comb. Loss	0.794	1.00
TPO	38.3 kW	15.83 dBk

Well-rounded answer

You can use either method to determine TPO, but be consistent in the method you use. 47 CFR §73.212 specifies that in the issuance of FM broadcast station authorizations, the FCC will specify the transmitter output power to the nearest 1 kW for FM power levels between 30 and 100 kW, so the licensed TPO will be 38 kW.

A 40 kW transmitter, such as a Nautel GV40, would be a good choice for this facility.

It isn't necessary to obsess over these numbers. Minor differences in the manufacturing of the antenna, combiner, transmitter, transmission line, etc. as well as the tolerances of the equipment used to perform the test measurements all "creep in" to lead to a built-in error in the process, and depending on the power level, the FCC will round your TPO to the nearest 100, 500 or 1,000 watts anyway.

All you as the project engineer can do is make use of the provided data and make a best effort to arrive at a solution. Be sure to document how you arrived at the transmitter power for future reference.

For our final example, let's look at a simple single-station FM facility.

We will examine a Class A FM station with 6 kW ERP at 100 meters or 328 feet HAAT. We will use a three-bay full-wave-spaced antenna with a power gain of 1.5, or 1.76 dB.

We will use 1-5/8-inch foam-dielectric flexible line that has a power handling rating of 16.2 kW at 98.1 MHz and a loss for 400 feet of line of 0.83 dB or an efficiency of 82.7% (a factor of 0.827). What is the required TPO? I will show both methods of calculation below. (Note, the use of foam line negates the need for a dehydrator as long as we use a sealed, unpressurized antenna.)

[6 kW (ERP) / 1.5 (RMS antenna power gain)] / 0.827 (line efficiency factor) = 4 kW / 0.827 = 4.84 kW TPO.

Always work the problem in reverse to check your work:

*4.84 kW (TPO) * 0.827 (line factor) * 1.5 (RMS antenna power gain) = 6 kW ERP.*

It checks out!

Here's the same problem using dB:

An ERP of 6 kW = 7.781 dBk, so:

7.781 dBk (ERP) – 1.76 dB (antenna gain) + 0.83 dB (line) = 6.851 dBk = 4.84 kW.

Using our table:

Parameter	Numeric	dB/dBk
ERP	6.00 kW	7.781
Ant. Gain	1.5	1.760
Line Loss	0.827	0.830
TPO	4.84 kW	6.851 dBk

FCC rounding for power levels between 3 and 10 kW would put the TPO at the nearest 100 watts or 0.1 kW, so the licensed TPO would be 4.8 kW.

For this facility, a 5 kW transmitter would be a good choice.

Use whichever method of calculation of TPO you wish, just be consistent.

Homework

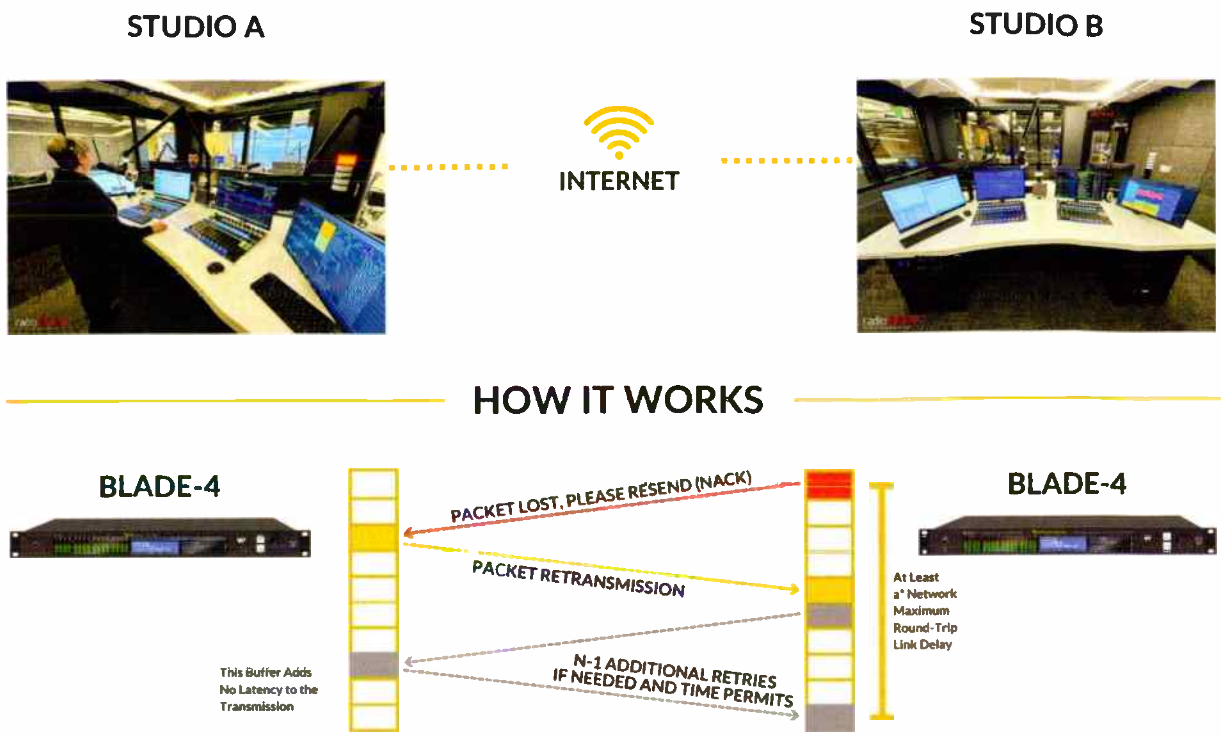
As we wrap up this topic, I'll leave you with this exercise to work on your own:

What is the required TPO for an FM-only station at 100.9 MHz with a required ERP of 50 kW, with 650 feet of 3-1/8-inch rigid 50-ohm transmission line (the brand of your choice), antenna RMS power gain of 2 (3 dB) and which has a band pass filter with an insertion loss of 0.8 dB, or 0.831 loss factor? What transmitter would be an appropriate model for this station?

Writer

Dominic Giambo

Manager of Technology, Wheatstone



What is RIST and why do you need it?

Learn what it means for live streaming and moving media across the public internet

Above
Fig. 1: RIST used for transporting real-time audio between two broadcast facilities across the public internet.

If you've been working with networks for a while, you're familiar with Transmission Control Protocol and its fast-talking cousin User Datagram Protocol. You might even have wondered, as we have, if it's possible to combine TCP and UDP into one.

One is more reliable and the other is faster, which is why we use TCP as the IP transport layer for web browsing, email and other enterprise applications and we use UDP as the IP transport layer for AoIP, streaming and other real-time media applications.

Their main difference is that TCP uses a bigger buffer (read: more delay) to guarantee that data packets are accounted for and delivered reliably, whereas UDP is a simple message-oriented protocol that can transport audio and control data at very low latency. We can reduce WheatNet IP audio network packet timing to 1/4 msec for minimum latency in part because of UDP multicasting, which means that local audio transport and studio controls are almost instantaneous.

But what if we go beyond the studio network and want to live-stream audio and control data in real time across the public network, where links are less reliable, and distance adds more delay? Is it possible to have both the reliability of TCP and the speed of UDP?

Enter Reliable Internet Stream Transport, or RIST, an open-source transport protocol developed for reliable transmission of video and audio in real time.

RIST adds error correction and packet recovery to UDP multicasting similar to TCP, but without the huge buffering time. It uses things like RTP sequencing to identify potential packet losses and multi-link bonding to guarantee media delivery over these public links with very little delay and without having to compress or reduce the bits, and hence the quality, of audio being transported.

Right
Fig. 2: The impact of packet loss on decoded audio.

Impact of Packet Loss

PACKET LOSS RATIO	DROP ONE PACKET IN	PRODUCES A GLITCH EVERY
10^{-3}	1,000	2.6 seconds
10^{-4}	10,000	26 seconds
10^{-5}	100,000	4 minutes 23 seconds
10^{-6}	1,000,000	44 minutes
10^{-7}	10,000,000	7 hours 19 minutes

Established by our industry

RIST is based on established protocols widely adopted by the broadcast industry. It uses the interoperability profiles found in VSF TR-06-1 and VSF TR-06-2, the technical recommendations of the Video Services Forum (VSF), giving us important features like link bonding, forward error correction, seamless switching and many of the specifications found in SMPTE 2022-1.

All of this makes it highly interoperable with broadcast-grade equipment, yet gives manufacturers the freedom to innovate within our own product implementations. Fig. 1 on the previous page shows RIST use for transporting real-time audio between two broadcast facilities across the public internet.

We added it to our protocol list for Wheatstone AoIP and streaming products for these and other reasons. RIST is a relatively new arrival in the media transport world, and it's especially timely given the growing number of high-speed links now making it possible to stream at full audio bandwidth as part of a low-cost contribution network or transport between regional centers.

More and more high-speed links are popping up on the public network, and RIST now gives us a way to get it there. We are using RIST, for example, to get streams back and forth between studios and AWS data centers.

> **"Reliable Internet Stream Transport is an open-source transport protocol developed for reliable transmission of video and audio in real time."**

How it works

RIST adjusts in real time to achieve the lowest latency and fastest performance for a given link, whether the link is closer to an AWS data center or several hops away. In our test runs, RIST doesn't seem to degrade performance like TCP does.

TCP is designed to be error correcting; it waits to see that packets are received correctly and if not, it will issue a retry to the sender. If too many retries are issued, TCP will throttle down its transmission speed. It doesn't help that TCP uses large data packets, so by the time it figures out that the packet needs to be resent, it's already been a half-second.

All of this makes TCP packet timing unpredictable and requires deeper buffering, making it unsuitable for real-time transport. When you click a page on your web browser, it can take a second or two for the web page to appear. That works for most applications, but when you're mixing or streaming live, even 100 milliseconds is too much delay.

Comparatively, RIST uses smaller packet sizes and therefore can hold to a much better tradeoff threshold between latency and speed.

RIST also uses RTP under the hood, which means it gives us RTP time stamps critical to real-time audio or video transport. We've been able to add RTP to UDP streams, but sequencing of the RTP time stamps using UDP is not reliable over long distances. Depending on distance and the quality of the link, there's no guarantee that packets will arrive in the proper order; with RIST, RTP time stamps get sequenced by the protocol in the correct order, making it ideal for real-time transport of audio and video.

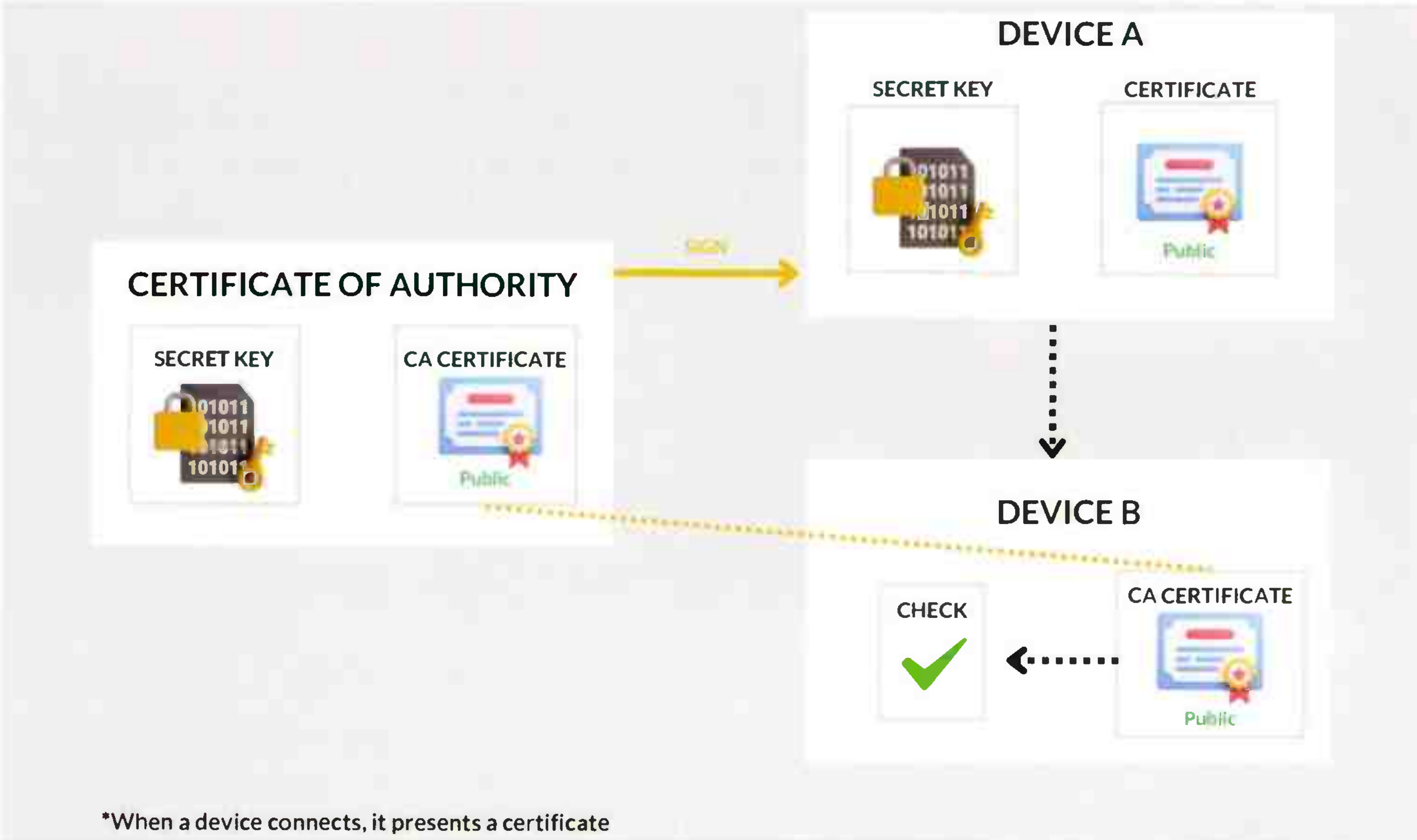
RIST supports IP multicast natively, which means it combines the ability to provide one-to-many transmission with very low latency and lower network overhead. RIST also supports load sharing and seamless switching so that should a link go down, it can route around that link and use the alternate link without interruption.

With RIST, you can dial up a 100-millisecond delay for a live event like a concert and know that you have about 100 milliseconds of delay and you're not going to have a problem getting it delivered. It's as easy as opening up a RIST stream session between two points — in our case from a WheatNet streaming appliance or software — and establishing a dedicated communication between the local IP address and an IP address on the far end.

Bank-level security

One little-known, but increasingly important, benefit of RIST is its encryption and validation technology.

Going from a closed AoIP network in your building to a third-party cloud provider like AWS changes everything about security measures. Your media becomes a much more likely target sitting on a public server in the open Internet.



Above
Fig. 3: The RIST certificate authentication process using DTLS specifications. When a device connects, it presents a certification that, unless trusted, will be rejected.

Similar to Secure Reliable Transport or SRT, another protocol you might have heard about, RIST uses a pre-shared key (PSK) method provided in the VSF TR-06-2 specification for access control, which has long been a problem for standard IP multicast delivery. This specifies that all receivers be configured with a secret passphrase, which can change on the fly as necessary. But unlike SRT, RIST augments PSK with a secure remote password protocol and also offers a DTLS (Data Transport Layer Security) mode with certificate-based authentication. This is fundamentally the same security technology used by banks; it's almost impossible for a third party to listen in or pirate your broadcast streams.

Fig. 3 shows the RIST certificate authentication process using DTLS specifications. When a device connects, it presents a certification that, unless trusted, will be rejected.

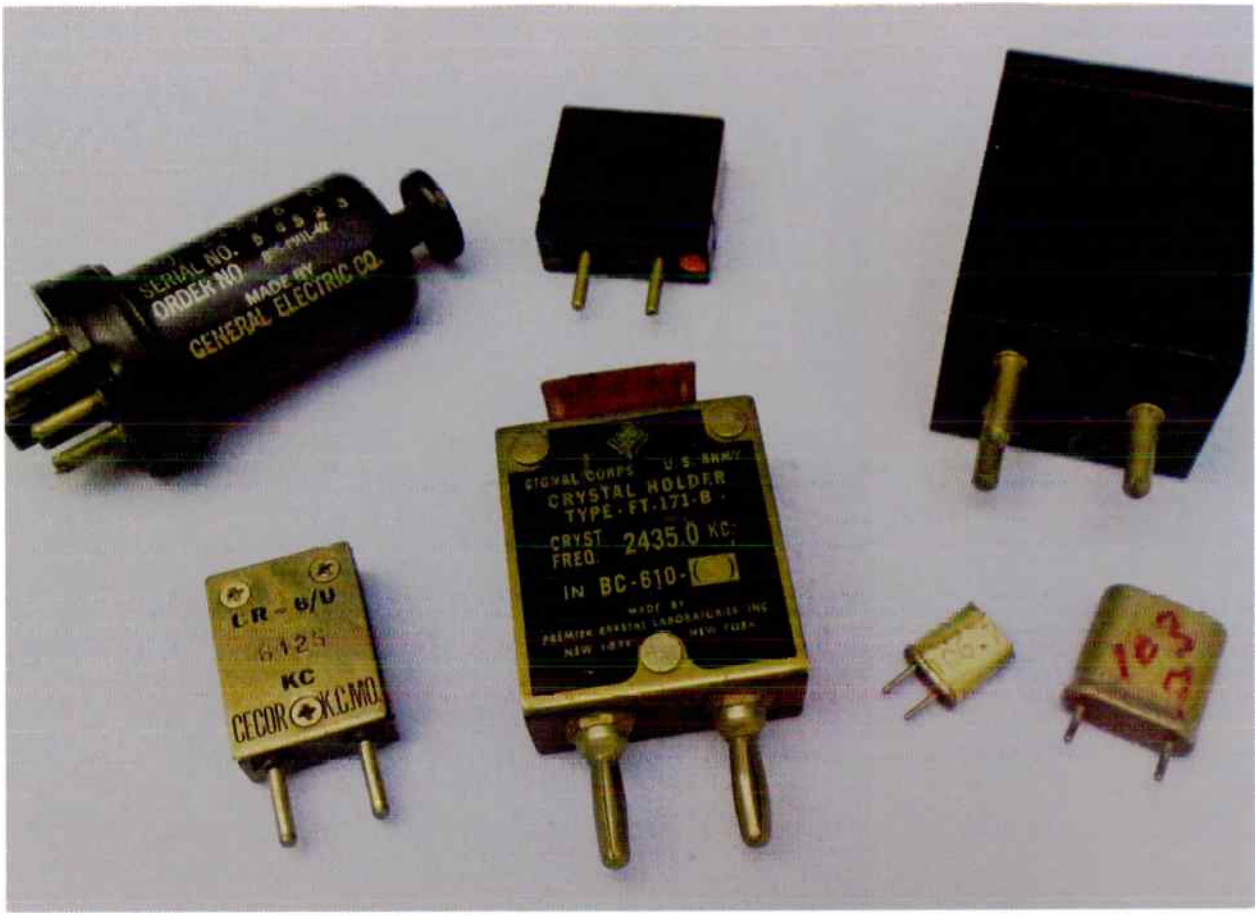
For these and other reasons, RIST is being adopted by a variety of media companies, including Wheatstone. RIST is now included in our streaming appliances and software as well as our WheatNet-IP Blade 4s, and it is used by our industry partners such as StreamGuys.

Dominic Giambo is responsible for Wheatstone's WheatNet-IP audio network and routing applications. He has a background in embedded Linux technology and extensive experience with networking and distributed control systems.

“RIST is now included in our streaming appliances and software as well as our WheatNet-IP Blade 4s, and it is used by our industry partners such as StreamGuys.”

Writer

Charles S. Fitch
P.E.
Longtime Radio World contributor



A rock for the ages

How crystals became such an important part of broadcast technology

Above
Crystal packaging formats through the years. The FT-243, lower left, was a favorite of the military; it became a ham standard thanks to a mounting scheme that allowed the crystal blank to be removed easily for "etching," while the pin spacing matched the cost-effective octal tube socket, allowing convenient two-crystal pairing.

The poet in me (and our illustrious editor knows I am a poet at heart) cries out that I first tell you that in ancient times, folks believed that quartz crystals were eternal ice sent by the heavenly gods.

In the late 1500s, the cognoscenti dismissed the poets and stated that these stones were actually fossilized ice. Score one for the poets. First with the most imaginative.

In present-day parlance, etymologists believe that *quartz* comes to us from the German, as much of the early work was done in central Europe, and *crystal* from the Greek for ice. Okay, both the poets and the cognoscenti got that part of it right.

Quartz crystal is a mineral, one of the most abundant in the earth's continental crust, composed of silicon and oxygen (SiO_2).

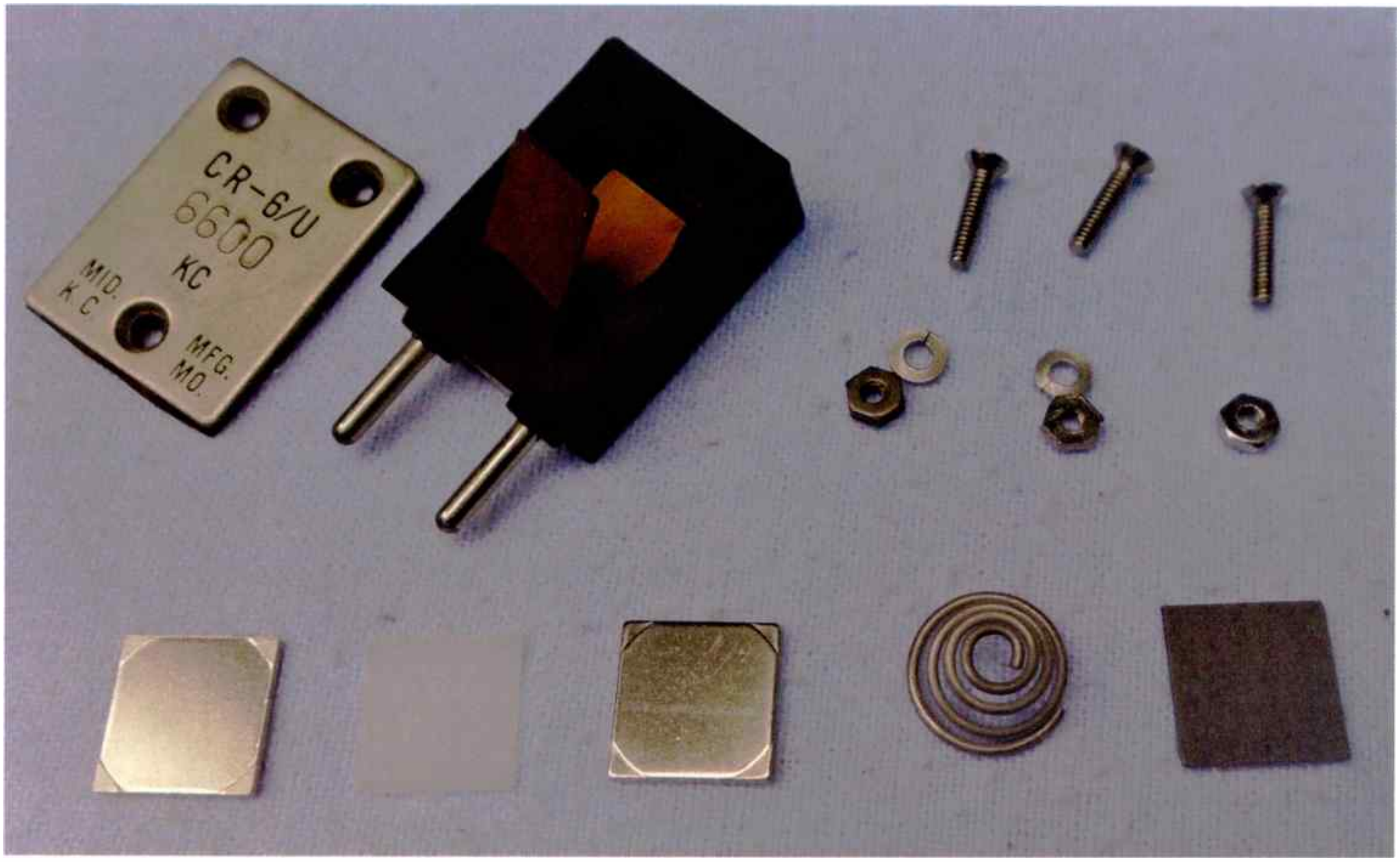
Putting the poetry and the beauty of these gems aside, quartz crystals have a unique quality useful to engineers and especially communications engineers: the piezoelectric effect.

The Curie brothers were an extraordinary pair who through their love and knowledge of math and physics were first to recognize in about 1880 that when pressure was applied to a body, in this case quartz, electricity was generated. The piezo portion of piezoelectric is a western bastardization of *piezein*, from the Greek for "squeeze."

Shortly thereafter, a contemporary mathematician, Gabriel Lippman, postulated that there should be a converse piezoelectric effect, whereby applying an electric field to a crystal should cause that material to deform in response. Stimulated by this inverse phenomenon concept, the Curies quickly confirmed that Gabriel was correct.

With the emergence of the electronic era, we had better test and analysis gear to investigate, and in the 1920s, we are able to identify that certain crystal sections have a resonant aspect, electrically mimicking a series LC (inductor–capacitor) combination.

In the 1930s, broadcasting, communications in general and especially the military really got going on crystals. The



problem this substance could solve ... getting things exactly on-frequency ... was real and the solution critical if radio was to advance and expand.

In a crystal, this action is a combination physical and electrical event. Reviewing the early, purist form of this technology, to optimize the effect, the first step was to select the coarse material in its natural form (basically a rock, which is where the vernacular slang of "rock" for a crystal comes from).

Next would come the mechanical preparation where the rock would be cut along the appropriate and/or ideal axis, sliced into "blanks," the surface roughly prepared (tapering the delicate blank edges is a technology in itself), and finally a check of its resonant frequency.

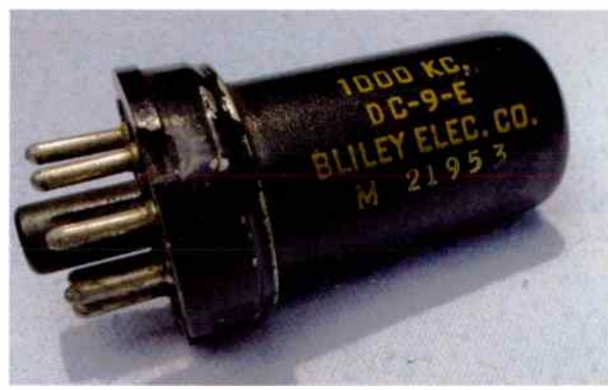
From a lower frequency, the crystal is ground down (gross error) or acid etched (fine error) until the desired frequency of operation is reached.

As this resonant phenomenon is repeatable and stable over time, a properly utilized crystal can be the basis of a frequency standard.

Working within the limitations of the industrial mechanical tools available during the first half of the 1900s, the crystal blanks started out to be physically quite large, placing a practical limit on the highest frequency that would be stable. The top of the AM dial (1500 kHz in1930) was well within reach, and in 1926, AT&T's WEAF in New York

Above
A breakdown of the FT-243 holder. The actual crystal is the opaque square at lower left.

Right
The crystal that helped win the war. A 1000 kHz crystal standard was used to confirm the accuracy of wartime receiver dials and transmitter operating frequencies such that rendezvous on special channels could be made with confidence.



City became the first radio station in the United States to control its frequency with a quartz crystal unit.

This pseudo resonant effect finds many uses and solves many problems including bandpass filters, etc., but our industry's greatest use is in oscillators.

An oscillator is basically an amplifier with sufficient feedback to find and settle at its resonant (maximum gain) point, hopefully developing a single frequency output. The crystal is introduced into that feedback path as the controlling element, and with proper attention to current flow, temperature, loading, stray capacitance etc., that crystal will begin to physically vibrate, and when it achieves its natural resonance will be passing the maximum

Above
Time marches on. For a few dollars these DIP IC from sources such as CTS and Cardinal contains a high stability frequency standard, a divider chain, quadrant multipliers, voltage regulator and buffer output (square wave). They can be computer cut from 1 MHz to just about any one specific programmed frequency even beyond 50 MHz.

current, bringing the oscillator to the intended frequency ... reliably, stably, continuously.

By their very nature, crystals are brittle and can be damaged by physical impact or destructive impressed current. Early broadcast crystals for that reason were well supported, quite often in glass enclosures that were expensive and hence needed a little showoff presentation.

During the AM domination period when the ±20 Hz frequency tolerance standard came in, the crystal also had to be maintained in a temperature-controlled, heated environment to enhance its stability even more to keep it inside that ±20 Hz window.

Technology has moved forward, and modern-day crystals are mass-produced, using all sorts of breeding techniques to avoid the cutting and grinding of yesteryear. Modern devices such as computer-cut oscillators and synthesized frequency generators using VCOs and divider schemes have given us advanced, accurate and cost-effective design tools never imagined by the earliest of our broadcast technocrats.

Do not be fooled and accept no substitutes, as almost all of these derivative concepts start out with a crystal in the device providing the base frequency.

The loaded 1900s ships arriving from Brazil, where most of the classic quartz crystals came from, are long gone replaced by artificially produced, high performance, very exact, stable at all temperature "rocks."

However, the crystal, with the piezoelectric effect found in that eternal ice, remains an important building block after all these years.

The Brothers Curie

Brothers Jacques and Pierre Curie were research colleagues in their nascent days as renaissance-style scientists.

Like the Varian brothers, co-inventors of the klystron, the Curies bounced off one another intellectually. With Pierre leading the way and after considering several other materials, they firmly identified the piezoelectric effect in quartz around 1880 while still in their 20s.

Putting pragmatics before theory, we again come upon one of Buc Fitch's universal mantras: It's not what you've got but what you do with it that counts. Using their new knowledge, they did do something with it, and shortly invented the piezovoltmeter and a derivative, the piezoelectrometer, which later became the basic instrument used by Pierre and his wife Marie Curie in their second-act work, which led to the discovery of radium.

Writer

James E. O'Neal

The author is a longtime contributor to Radio World and former technology editor of TV Tech.

IEEE Broadcast Symposium examines industry issues

Program spotlights VM advances, cybersecurity, signal transport and more

Following four years of being on a pandemic-driven "hold," the IEEE Broadcast Technology Society's Fall Symposium resumed, with a return to its original Washington, D.C., home. The presentations took place at the new headquarters of the National Association of Broadcasters.

The Nov. 14–15 event attracted attendees from broadcast engineering, equipment manufacturing and academic sectors, and featured a variety of presentations on both technological advances and problems common to broadcasters.

Above
The NAB's meeting room was packed, with attendees traveling from as far away as Italy and Argentina to participate in the first post-pandemic BTS Fall Symposium.

Compression artifacts

With compression technology now commonplace in transporting broadcaster's FM multiplexes from studio to transmitter, Worldcast Systems' Tony Peterle became curious about possible signal degradation, and this was the topic of his presentation.

Peterle said that while the focus of his testing was really on "what actually reaches a listener's ears," it included measurements of frequency response, distortion and stereo separation. He credited engineers Paul Shulins and Shane Toven for their assistance with the project.

The testing involved a representative sample of codecs, including units from 2wcom, APT, GatesAir, Omnia and Thimeo Audio Technology.

Peterle initially ran a "baseline" test without a codec, followed by runs with the various codecs and data rates. Speech, music and PPM information were all part of the testing.

BTS IEEE Broadcast Technology Society

Tests showed some amount of high frequency roll-off, along with slightly increased distortion, with some variations observed among units under test. Stereo separation was generally acceptable.

Peterle did report inconsistencies, though, especially with PPM measurements, saying that in some cases, confidence scores were higher with compression than without.

"You can run the same signal through an encoder five times and you get five different results," said Peterle. "There's no consistency. More work needs to be done."

Clockwise from top left
Nicole Starrett and Dan Glavin, Tony Peterle, Jaap Dekkinga and Shave Toven

Keeping systems secure

In the "good old days," the only thievery broadcasters worried about was in losing their top-rated DJ to a competing station or record albums disappearing during overnight shifts.

Now thievery can take place from half a world away with a computer and a few key clicks. Educational Media Foundation's Shane Toven provided pointers on keeping what's yours out of the reach of hackers in his presentation "Common-sense Cybersecurity for Broadcasters."

Toven noted that such intrusions not only result in lost revenue and payment of ransoms to cyber thieves, but can also result in financial and legal penalties, loss of consumer trust, and loss of control over company data.

In addition to such physical security measures such as keeping rack doors locked, Toven advocated encryption of important information, strong passwords, two-factor log-in authentication, secure firewalls and creation of access control lists for routers and switches. He said, however, that the greatest cyber vulnerability involves humans.

"Social engineering is one of the biggest threats to your infrastructure. It's very easy for employees to unintentionally click on bogus email hyperlinks or give out information that could be valuable to a hacker during scam phone calls. Even the best security can be defeated by a well-meaning employee," he said.

"Train your people, train them again and then train them again. You can't over-train people to spot intrusion attempts."

Numbers count, especially at ratings time

A new methodology for obtaining feedback from radio listeners was described by TuneURL's Jaap Dekkinga in his presentation "Audience Measurements and Coding Technology."

Dekkinga observed that while radio is great for reaching mass audiences and delivering commercials, it's a "one-way street," with limited means for tracking audience engagement. His company has developed technology that allows almost instant audience feedback via an "audio trigger" and an application running on listeners' cellphones.

As explained by Dekkinga, the short-duration audio trigger — analogous to a QR code or audio hyperlink — is transmitted; a short-duration "window" then opens, allowing the listener to respond.

"Following this audible 'call to action,' listeners are asked if they are interested (in responding)," he said. "They can do that with a click, shake or voice command (picked up by the cellphone) 100 percent safely."

> **"Train your people, train them again and then train them again. You can't over-train people to spot intrusion attempts."**

The technology allows determination of listener impressions to content and engagement, and can aid advertisers as to the best time and station for running their messages.

A new type of container for broadcasters

Telos Alliance's Kirk Harnack brought symposium attendees up to date on the latest technology for boosting efficiency and cutting costs in broadcast operations with his presentation "Real Radio Hosts Working Virtually: How Engineers Work with Containerized Broadcast Systems."

Harnack noted that the industry has been moving away from dedicated-function equipment to generic platforms — apps running on servers to emulate physical devices.

"We can now even do all audio console functions on a generic computing device and control it via a user interface," he said, adding that other elements of a broadcast chain, such as playout devices, processors and talk show systems, can be virtualized.

Harnack observed that "containerization" has now entered the broadcast arena, explaining that a "container" amounts to a software package with all necessary elements for running in any computing environment. With such technology, the operating system is itself virtualized, allowing the container to run on platforms ranging from a laptop to the cloud.

"Instead of virtualizing the whole machine, we share the operating system with 'buckets' or 'containers' that hold the one application in isolation, but allow it to share the resources of the platform," said Harnack.

"It's a matter of 'containers' versus virtual machines (VMs). The container achieves the same goal as a VM, but you don't need to buy another physical computer."

Above
Kirk Harnack

Right
S. Merrill Weiss

"Instead of virtualizing the whole machine, we share the operating system with 'buckets' or 'containers' that hold the one application in isolation, but allow it to share the resources of the platform."

When to rebuild? When to replace?

Shared transmission sites have been part of the broadcasting landscape for quite a while, and some now are candidates for refurbishment or possibly replacement. Dielectric's Nicole Starrett and American Tower's Dan Glavin examined considerations involved in updating sites in their presentation "Retrofitting Community Transmission Systems, Supporting Legacy Broadcast Systems."

They explained that a shared or "community" transmitter site provides several advantages, including reduced construction/operating costs and better coverage, but time can take its toll on antennas, transmission lines and combining systems. Complicating this is that some equipment manufacturers are no longer in business, making it difficult to obtain replacement parts.

While it might be cheaper to keep some legacy systems in operation, full replacement could be in order in certain situations.

"If the existing baseband system is no longer needed, with only single channel or dual channels left, replacement is cleaner and more cost-effective over retrofitting," said Starrett.

Other incentives for replacement include systems unable to meet new bandwidth and coverage requirements, as well as those with recurring outages caused by aging components.

In concluding their presentation, they observed that "retrofitting and reconfiguration are great options with many systems, expansion with software-developed solution is possible in some cases and a full replacement may not be necessary. However, if a full replacement is mandated, new technology can provide better performance, lower antenna/tower wind loading, and can be more cost-effective in the long run."

Adding radio to Next-Gen TV

In moving away from the older ATSC 1.0 DTV standard, architects of the latest standard, ATSC 3.0 or "NextGen-TV," made sure it would be futureproof, allowing new features to be added as needed.

Building on this concept, S. Merrill Weiss, principal at the Merrill Weiss Group, described incorporation of a digital

Above
Guy Bouchard

radio service to ATSC 3.0 television transmissions.

In his presentation "Integrating Radio Services With Television and Data Transmission on the ATSC 3.0 Platform," Weiss said the motivation for this came from countries now interested in ATSC 3.0 that wanted it to include digital radio services. The Digital Radio Mondiale standard was selected, as it's being used in those countries.

Weiss said that in addition to stereo and mono audio, the project involved addition of advanced text-based services, icons and other graphics, along with and support for a service selection guide.

As explained by Weiss, integration of DRM with ATSC 3.0 involves incorporation of a "radio gateway," along with other additions and changes, and that the DRM implementation could provide a large number of audio services and Journaline text services.

Weiss noted that the DRM addition would require addition of documents to the ATSC standards list involving its A/330 link layer protocols and A/324 scheduler and studio-to-transmitter protocols. Also, "two new standards need to be created, one for the radio gateway, and another to (describe) recommended practices for ATSC 3.0 radio."

SRT solves a C-Band issue

RF spectrum for broadcast use keeps shrinking, and Guy Bouchard, formerly with Canada's Télé-Québec public broadcasting operation and now a consultant, described a solution to problems created by reassignment of C-Band satellite spectrum to wireless carriers.

Bouchard explained that while only a relatively small percentage of the Télé-Québec 's audience receives programming over the air, it's necessary to maintain this service, which is provided by 18 transmitter sites linked to the ops center via satellite.

"Two-thirds of those transmitters are in remote locations without access to fiber or high-speed internet connectivity," said Bouchard, explaining that all had 4.5-meter dishes, with the original design providing a 4 to 6 dB link margin, but the addition of the 5G filtering ahead of the LNBs reduced gain, effectively reducing dish aperture.

He said although the reduced margin doesn't impair signal delivery in good weather, a snowfall can severely degrade reception.

Due to the small terrestrial broadcast audience, the expense of installing larger antennas couldn't be justified, so another solution was needed. This came in the form of Secure Reliable Transport protocol, which utilizes advanced error correction to enable uninterrupted data flow over less-than-perfect Internet paths.

Bouchard said he was skeptical at first about SRT's ability to deliver programming reliably to transmitter sites, but test results proved otherwise.

"In the initial trial, no artifacts were reported and no alarms were received."

He said that the SRT-enabled terrestrial delivery is now only being used to back up s atellite delivery, with no plans currently to discontinue satellite linkage, but that could change in the future.

Marketplace Tieline Adds Dante Cards

Tieline is offering Dante cards for its Gateway and Gateway 4 codecs.

"Customers can now order a Gateway or Gateway 4 codec with the optional Dante card fitted, which delivers compatibility with Dante devices," the manufacturer said.

"Dante Controller software facilitates simple stream management, as well as discovery of devices and streams."

VP Sales APAC/EMEA Charlie Gawley said the cards have been a common request from users who want to integrate seamlessly with Dante devices across their networks.

Gateway and Gateway 4 codecs include native support for AES67, ST 2110-30, ST2022-7, AMWA NMOS IS-04 and IS-05, Ember+, Ravenna and Livewire+. An optional WheatNet-IP card or the new Dante card can also be installed.

Tieline codecs are used in STLs, network audio distribution and remote broadcast applications.

"Interoperability between multiple AoIP protocols delivers greater flexibility when integrating IP audio streams into the broadcast plant from a range of sources," the company notes.

Info: *http://tieline.com*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