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STLs in the 21st Century

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APRIL 2023

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STLs in the 21st Century

Paul McLane
Editor in Chief

The transport of content — audio, data, control — from studio to transmitters remains a crucial part of the radio station ecosystem. This Radio World ebook explores today's STL.

What are the most common methods of moving that content? What "pipes" can engineers choose from today, and what kind of load can they expect to deliver?

What is the state of radio-based STLs? What role are technologies like Starlink satellite, 5G, fiber broadband, LTE and cloud playing? What best practices should engineers keep in mind?

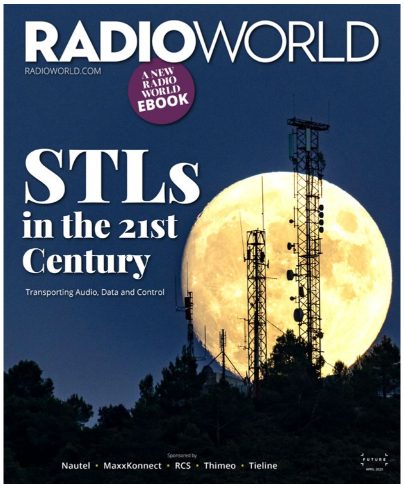
We asked seven experts.

Alex Hartman of Optimized Media Group writes that new technologies offer diversity of choice but come with tradeoffs. Kirk Harnack of Telos Alliance expands on what those choices are in the era of Internet Protocol.

Jacob Daniluck of Tieline explains why the ability to connect over WANs at low bitrates with μMPX is a game-changer. Philipp Schmid of Nautel discusses the benefits of synchronously linking FM MPX and HD Radio content within a DCP framework.

Dee McVicker of Wheatstone describes a way to package the full MPX, HD/FM alignment included, for transport across modern links. Mike Pappas of Orban offers sample case studies of modern STL.

And Josh Bohn of MaxxKonnect shares some frank thoughts based on years of experience with many types of STL arrangements.



THIS ISSUE

The days of the 950 MHz band may be numbered

New technologies offer diversity of choice but come with tradeoffs

Alex Hartman is a partner in Optimized Media Group, which provides broadcast engineering, IT and consulting services; he specializes in the transmission side of the industry and is a vocal advocate of bridging the gap between the IT world and the broadcast facility.

RW Alex, how would you describe the current state of studio-to-transmitter links in the U.S.?

Alex Hartman: It's a mixed bag. A lot of stations still use 950 MHz STL systems, but as they fail or get retired, they're being replaced by some form of IP connectivity.

For more traditional licensed 950 MHz links, the scope is pretty narrow, with manufacturers like Moseley, Bext, RVR and a few others that are mostly international offerings that have gone through FCC approval.

But then there are IP-based systems ranging from 2.4 GHz and 5.8 GHz — both ISM/UNII bands, with no licensing — to 6, 11 and 18 GHz licensed; 24 GHz unlicensed; and even 60 GHz unlicensed systems.

The real-time data and reporting about the health of the connection that's provided by an IP codec is a pretty important metric. Legacy STL systems don't offer those metrics to help troubleshoot.

Below
Alex Hartman

By the way we shouldn't talk about "radio-based" STLs, because be it TDMA, modem or IP, they all use a "radio," it's just a matter of modulation scheme and interface.

I do feel the 950 MHz band is coming to an end, with the need for more metadata and other telemetry reporting from the transmitter site, as well as the FCC wanting to repurpose bands for other uses — C-Band and UHF TV for example.

RW What are the benefits and drawbacks of licensed vs. unlicensed options?

Hartman: The obvious benefits of licensed links are coordination and protections with mediation. Also they tend to have high-level support contracts with specific service level agreements to make sure they always perform in the correct modes and carriers. Unlicensed tends to follow more "industry standard" protocols, and the products can be found in retail stores, making interference a large problem.

In "flyover country," farm implements, of all things, are interfering with unlicensed bands. Tractors and farm implements are using 2.4 and 5.8 GHz WiFi to communicate. Enough of those on a farm can raise the noise floor significantly and even cause errors on a point-to-point link if your STL traverses overhead.

RW What are benefits and drawbacks of wired vs. wireless?

Hartman: They all have their pros and cons. Wired is always subject to third-party reliability and also susceptible to backhoe fade or "coarse vehicle adjustments" — cars crashing into poles!

Wireless can suffer interference from other users, path coordination mistakes and urban sprawl issues. Both are susceptible to Mother Nature, of course — the ultimate winner in all games played.

RW What plotting tools are available to help with STL planning?

Hartman: There are many. If you go licensed wireless, your IP radio provider will typically offer those services as a turnkey. Or something like V-Soft, or radio mobile for the DIY folks. Companies like Ubiquiti offer online pathing tools.

RW On a Nautel webinar, you and other speakers discussed the Fresnel zone. Why does it matter?

Hartman: Trees, houses, water towers, terrain can all interfere. Wireless is not "fixed width," the radio waves spread out when they leave the antenna, and the width is frequency dependent. In a point-to-point application, this Fresnel zone must be kept clear for reliable signals to make it back and forth.

In other words, you may be able to "see" the target, but you also have to consider the midpoint surroundings.

RW What's the distance limit for radio links? We've heard of 60 or even 100 miles or more.

Hartman: There are practical limitations. To select the technology and frequency for a desired application, the height, power, water, terrain, nature and buildings/structures must be considered.

For instance, shooting 18 GHz over a large body of water for more than a few hundred feet can scatter the RF signal enough to make it unusable in the real world, though it should work "in theory."

Look around at your local zoning. Learn about the growth planning and urban sprawl. A forest today might be high rises in five years, or a highway overpass. Or trees in that forest may grow to infringe on your path.

Going 100 miles or more using IP is possible but not practical. Always follow manufacturer's direction on distances, and add some margin window to keep you on the air during bad storms, snow, rain and dust.

What impact on IP STLs did the opening of 6 GHz to unlicensed uses cause?

Hartman: The 6 GHz band being opened up to WiFi 6E devices is a mixed bag. For now it's only indoor devices, and they require AFC technology to keep away from licensed services. But it's only a matter of time before it's authorized for outdoor use, and I think it will cause issues for everyone, including the cellular providers, who use 6 GHz links for cell-to-cell communications and backhaul to point-of-presence sites.

Are licensed STL frequencies safe from FCC auctions and changes?

Hartman: Absolutely not. Again, 6 GHz, C-Band, 7 GHz and even UHF TV are all up for grabs. I mentioned that the days of the 950 MHz band are numbered, not only because of usefulness, but being sub-1 GHz will be enticing to the cell providers for next-generation tech. They'll need 900–1.6 GHz to do it meaningfully. That's the entire ISM and reserved broadcasting bands.

The FCC has proven time and time again that broadcast has fallen to the wayside in favor of bandwidth-hungry cell providers.

How has the evolution of wireless IP links changed the landscape?

Hartman: It has removed a very expensive barrier to entry for broadcasters to have bidirectional data existing at the transmitter site, allowing for telemetry in real time, offsite data backups, offsite automation systems, even mechanical monitoring and intrusion detection with cameras and security systems. With the copper plant being decommissioned by many telephone companies, you can now also fly over a SIP phone line to the site.

And how have composite FM multiplex codec solutions changed things?

Hartman: They've allowed for the last bit of the air chain to be brought back to the studio, minimizing the equipment needed at the transmitter site, reducing risk to other expensive critical air chain devices like processing and HD equipment.

The fewer computers there are in the mostly hostile environment that many transmitter sites tend to be, the better off stations are.

> **"You may be able to 'see' the target, but you also have to consider the midpoint surroundings."**

What role are technologies like Starlink satellite, 5G, fiber broadband, LTE and cloud playing?

Hartman: They're offering a much more diverse selection of pathing between the studio and transmitter sites.

Importantly, though, they also put you in the hands of third parties — big cellular companies in particular — and at their whims of moving things around or causing unknown outages.

In many cases in rural areas, the towers are all linked by other backhaul means to the primary point-of-presence tower, where the large-capacity fiber lines are. So the diversity on the towers is actually not as diverse as one thinks. These towers can be 40 miles apart, end to end, all using the same fiber connection at the point-of-presence tower via licensed or unlicensed links to adjacent towers.

With fiber, as with the telcos, you're at their whim and at risk from outages, upgrades and changes.

Starlink is the newest player to the game, which literally opens up a whole new world of connectivity. Keep in mind that it's still growing and comes with those growing pains. But having low-latency high-speed data to mountaintops or very remote locations opens new possibilities. Putting Starlink on BOTH sides of the link — at the studio and the transmitter site — is in essence a private network. It's using only the Starlink network, it never touches the ground-based public internet!

Eventually the Starlink system will be another large-scale network — a global network — overlaid on the traditional ground-based system, with points-of-presence to get back to the ground. But if you go terminal to terminal, you never need the wireline carrier part of the system!

Again, there's still a third party involved, you're still at their whim. And right now it uses CG-NAT, or Carrier Grade Network Address Translation, meaning that the IP space used cannot have ports opened, VPN hosts, etc.

It does need an intermediary service to make IP connections. It was designed for consumption, not hosting.

What should we know about the state of return links for "telemetry"?

Hartman: This is more important than ever! Copper theft and vandalism are on the rise, so camera and alarms are more and more important — and required for insurance purposes. HVAC systems now can "call home" in case of failure. You can remotely control air inlet/exhaust dampers in case of emergencies if properly equipped, and even fire suppression systems.

Tower light monitoring is now IP-enabled or easily integrated with a site remote control.

You may visit that building only rarely now, so knowing its health can help avoid imminent failures or prompt preventive instead of reactive maintenance. You'll know what you need to bring to the site instead of making multiple trips.

What best practices for security should engineers keep in mind?

Hartman: Stations should be employing IT professionals for this part or outsourcing to a managed service provider to assist.

Firewalls should be restrictive. Multi-factor authentication should be used for any remote access. And everything should be in some form of VPN.

NEVER! EVER! PORT! FORWARD! If the outside world cannot see it, they cannot get in. VPNs are by nature encrypted. The firewall employed should NOT be something you can order off Amazon for 50 bucks or pick up at the local big box stores.

Competent systems are moderately expensive and require subscriptions to maintain current lists of malicious threats. Fortinet, Palo Alto, SonicWall are all reputable brands and available with these features.

Deploy intrusion prevention and detection software and even some AI metric detection for "abnormal behaviors." Speaking of proactive redundancies, any good enterprise should have two firewalls operating in "high-availability" or HA mode, to allow in-place updates and upgrades to assure continuous operation of the business.

Of course external threats are only one type; the other is on the inside. Personal laptops, USB drives, downloading suspicious audio files, all can make for a bad day. Again: Employ an MSP or IT professional on those specifics.

In general, IT security is at the forefront for every broadcaster. Insurance companies are refusing compensation for negligence against ransomware. They're asking you to "prove you tried" with outlines for security protocols, equipment used and measures taken.

Companies that do manage to get access to a policy are often price-adverse to the premiums and decide to run the risks. Sticker shock sets in. But insurance is pretty cheap compared to the value of your company.

What further developments should we be watching for?

Hartman: Single data carrier encapsulation like SRT, or Nautel's development involving HD Radio as well as analog composite MPX encapsulation, are going to eliminate the need for other devices at the transmitter site, to allow diversity and maintain high availability to the transmitter directly.

Also look to the IT sphere with an open mind. See how Amazon and Azure do what they do, then ask if you can apply it to audio or video. Chances are, yes, yes you can. Audio is such a low throughput or bandwidth "ask" compared to everything else these days. Streaming a Netflix movie to your iPad is the same as four stereo audio streams with ancillary data!

Anything else we should know?

Hartman: The world went IP. The vast majority of traditional STL companies are just now getting there. IP should be your future, from audio to email. But broadcasters are still newcomers to the established IT infrastructure business. There's a whole new world to learn, and engineers who are set to retire most likely do not want to learn it.

A business that relies on IP needs to have a competent IT team to maintain a facility. IT includes backups in their designs, whereas broadcast builds backups AFTER a failure happens. Broadcast needs to get serious about this part. If you're still storing your entire music library on the on-air computer, stop. If you're still using DOS-based programs for daily business, stop. If you're still using the free version of Adobe Audition or Cool Edit, stop. Windows XP? STOP.

Like it or not, IT does not have the shelf life of an old Continental transmitter; it has to be updated and refreshed constantly. Invest in your IT future or get left behind like so many others who failed to pivot.

> **The real-time data and reporting about the health of the connection that's provided by an IP codec is a pretty important metric.**

Broadcasters have more STL options than ever

In the era of Internet Protocol, users enjoy the luxury of choice

Writer

Kirk Anders Harnack

Senior Solutions Consultant, Telos Alliance

The vast majority of roughly 22,000 radio stations in the United States (including LPFMs and translators) use some form of audio link from their studio or other origination point to the transmitter site. That's a lot of studio-transmitter links!

Despite old telco services disappearing and the 950 MHz band being congested in some urban areas, engineers actually have more STL choices than ever before. The key to new STL options is Internet Protocol. And the best news about IP is that it can be transported over several different media and services. Plus, many audio codecs support parallel IP paths for increased reliability.

IP packets are commonly used by broadcasters to carry these signal types for STL purposes:

1. Discrete (L/R) audio using IP audio codecs with appropriate IP connectivity
2. Linear, discrete (L/R) audio using AoIP (Livewire+, AES67, etc.) with appropriate IP connectivity
3. FM Multiplex (MPX) using µMPX bit-rate-reduced multiplex technology for FM
4. FM Multiplex (MPX) using linear multiplex technology for FM
5. HD Radio from Importer/Exporter to the HD FM exciter using E2X over IP

> **“Despite old telco services disappearing and the 950 MHz band being congested in some urban areas, engineers actually have more STL choices than ever before.”**

That's quite a list of options we have now. As our society's reliance on IP connectivity grows, so also our options to acquire and use it on a reliable and professional level.

IP-based STL systems

STL systems based on Internet Protocol technology can be generally divided into two categories, linear and “coded.”

Another disambiguation of IP-based STLs could be “wired” and “wireless.” However, we can also use wired and wireless IP transport methods at the same time, or with one backing up the other.

A third differentiation among IP STL schemes is those delivering discrete Left and Right stereo channels versus those delivering the entire FM multiplex (MPX) signal, at least up to and including the 57 kHz RDS signal.

Linear IP STL systems will transport digital audio perfectly with the same 1s and 0s that go into such an STL being delivered to the far end. Twenty-four-bit, 48 kHz-sampled linear audio typically requires about 2.5 Mbps to transport. While this audio delivery is basically perfect, it typically depends on having zero packet loss over the IP path.

Coded audio systems will use a coding algorithm to reduce the bitrate required for transport. The audio codecs in such STL systems are typically configurable for a wide range of bitrates, and perhaps even a selection of coding algorithms. Bitrates typically range from about 128 kbps up to 756 kbps, depending on the chosen codec. Modern coding algorithms offer some “error concealment” as well in case of occasional packet loss.

Linear IP STL systems are absolutely transparent to the audio. Every sample of audio data from the studio arrives exactly the same at the transmitter site. The IP transport path must provide excellent packet delivery performance in a linear IP audio system. Indeed, a common approach to implementation is to simply extend the audio over IP (AoIP) network at the studio out to the transmitter site.

One example of such a system is at Delta Radio LLC, in Greenville, Miss.. The studio and rack room were fully Livewire AoIP already. A robust 5.8 GHz IP-radio link was established to the transmitter site, 13 miles away.

The only audio equipment required at the transmitter site, apart from the IP radio, is a Telos Alliance xNode. Four linear stereo channels are received there via the xNode. For remote monitoring, there are four linear stereo return channels over the same IP connection. All this audio is 20

kHz in bandwidth, using 48 kHz digital sampling and 24 bits per sample. The aggregate data rate across the IP radio link is about 10 Mbps in each direction.

Other examples of IP-radio STL systems transporting AoIP are now commonplace, from stations in rural Australia and small Pacific islands to the largest radio markets in the U.S.

IP radios may be licensed or unlicensed, depending on the RF band selected for operation. Unlicensed IP radio pairs are likely to work well in rural or uncongested areas, but careful consideration and backup planning is critical for unlicensed operation in built-up urban locales.

Coded-audio IP STL systems offer several advantages in terms of bandwidth requirements and recovery from packet loss. While a linear IP STL, as discussed, needs a near-perfect IP transport path to work properly, a codec-based IP STL is more forgiving. Codecs generally offer more packet buffering, error concealment and error correction compared to a linear system. While audio codecs themselves will cost more than, say, a simple "node" AoIP endpoint, they offer more flexibility in their IP connection's requirements.

For example, using audio codecs at each end, one may install an IP radio link pretty much "out of the box" and have a working STL. One may also use the public internet for either the main or backup link between codecs.

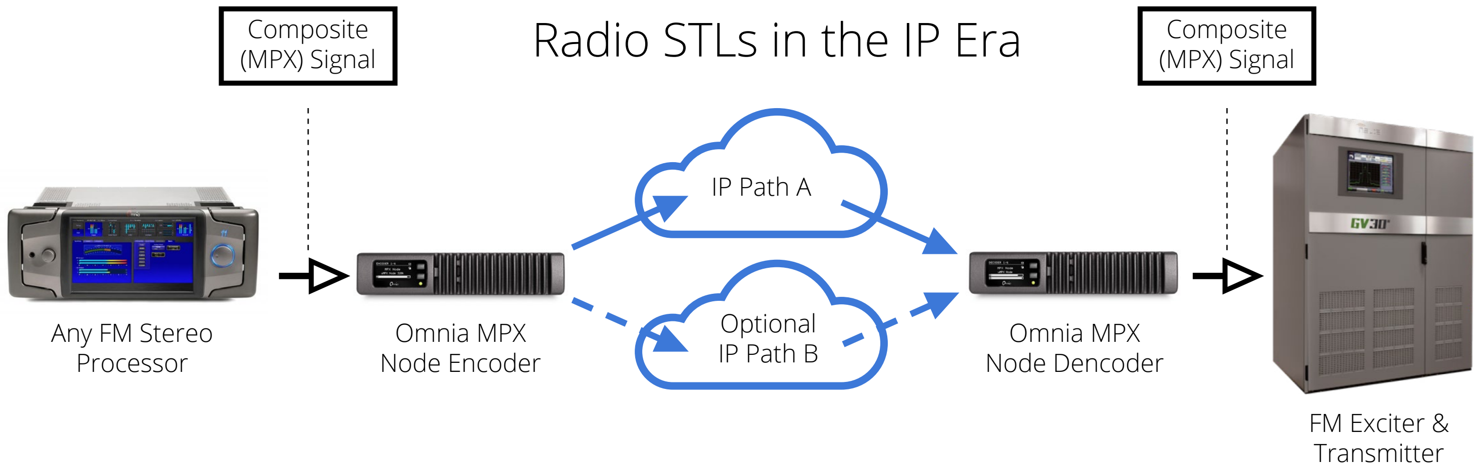
There's yet another IP-based STL method now in popular use. It's an FM MPX transport codec over IP.

This is similar in connection to the audio chain as an MPX RF STL; the FM audio processor is placed at the studio, and the full MPX signal is carried to the transmitter site where it is routed to the FM exciter directly. These MPX-over-IP systems also appear in both linear and coded varieties. Linear MPX STLs require anywhere from 3 to 7 Mbps to faithfully sample and transport an FM processor's MPX output.

More recently, an even more useful method has become popular for coding the FM MPX signal to transport it at a much lower bitrate — about 15 percent of the linear method. The trade name is MicroMPX and it's available in both standalone and built-in form factors from several FM processor manufacturers.

This proprietary method does not use psychoacoustic coding. Rather, it's a novel application of mathematical data reduction that is well-suited for the FM MPX signal. "Well-suited" because artifacts of the MicroMPX algorithm tend

Above
Axia xNode at a tower site.



Analog MPX STL

MicroMPX STL

Above:
FM MPX spectrum from a Nautel AUI, comparing analog vs MicroMPX.

> **Codecs generally offer more packet buffering, error concealment and error correction compared to a linear system.**

to fall in time and frequency where they don't affect the perceived audio. And, unlike psychoacoustic codecs, precise peak control is maintained through a MicroMPX STL system. The minimum bitrate for MicroMPX systems is 320 kbps, with a maximum of 576 kbps. Commercial MicroMPX products may offer dual IP path redundancy as well as Forward Error Correction (FEC) to rebuild occasional lost packets. See the diagram on page 9.

The IP transport(s) for MicroMPX can be public internet, IP radios, wireless ISP, etc. or any combination of those.

A welcome benefit of the MicroMPX technology is the greatly reduced noise floor in the FM MPX spectrum.

The spectrograph at top left shows a properly operating analog FM STL system with the FM MPX signal as delivered to the transmitter. The noise floor across the spectrum is about –70 dB. This is considered normal for analog MPX STL systems, yet this –70 dB noise will be faithfully transmitted by the FM transmitter continuously.

The spectrograph below left shows the same station's audio delivered by the MicroMPX method, which includes effective digital filtering of the FM baseband spectrum. The filtered noise floor is at or near –100 dB resulting in a much cleaner transmitted FM signal.

IP-based STL systems easily offer the most flexibility in terms of connection options. If a private, high-quality IP link, using enterprise-grade IP radios, for example, can be installed, then two-way linear audio is the best option for perfect audio transport. That same high-quality IP connection can also be used for remote transmitter control, remote backup, disaster recovery options, security video surveillance, remote telephony and so much more. If only public internet or lesser-grade IP radio paths are available, then coded audio at the highest available bitrate makes sense.

In either case, having more than one IP path is truly important for redundancy.

Wrapping it up

Radio broadcasters truly have more options than ever for their STL technology. Traditional 950 MHz RF links work well enough in many situations. Analog systems do exhibit some noise, while digital 950 MHz links may be constrained by filters and less bit depth, or by audio coding artifacts. IP-based solutions afford engineers more options, including the possibility of the most pristine linear audio link they've ever experienced. RW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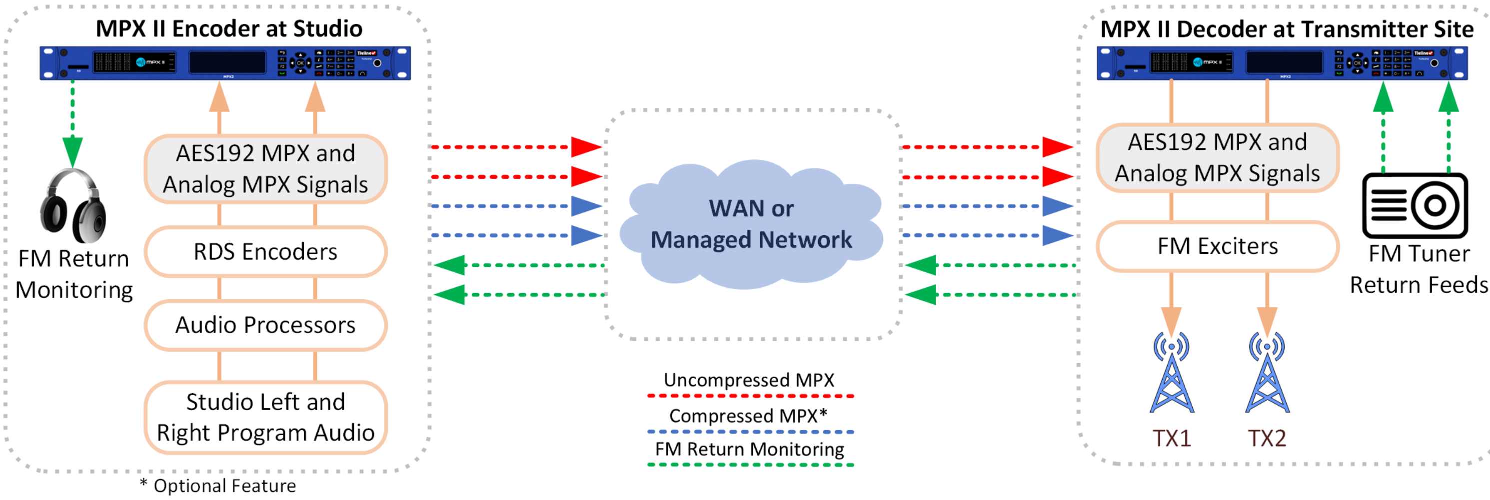


New technologies bring potential massive savings

The ability to connect over WANs at low bitrates with μMPX is a game-changer

Above
An MPX use case.

Among the broadcast audio products made by Tieline are codecs suitable for STL use, and more are coming. Jacob Daniluck is Tieline's technical sales specialist for the Americas.

Below
Jacob Daniluck

RW Jacob how are studio-to-transmitter links different today than in the past?

Jacob Daniluck: The availability of IP in so many regions delivers more options to broadcasters these days, compared to when expensive synchronous data links and satellite transport options were the only available solutions for many networks.

MPX codecs and progressively better IP connections in rural areas will help shift broadcasters to solutions with reduced STL transport costs, while still providing greater flexibility. Plus, IP technologies deliver affordable redundancy options and real-time monitoring and control that was not always possible previously.

RW What is Tieline's involvement in this area?

Daniluck: Tieline specializes in audio codec solutions for STLs with our Gateway and Gateway 4 products. The Gateway 4 supports transmission of two bidirectional stereo STL signals, whereas the Gateway offers up to 16 audio channels, so you can broadcast eight discrete bidirectional stereo streams to multiple STL destinations.

Both also support multicasting and multiple unicasting to distribute IP streams around a network or to affiliates. Program configurations can be remotely changed or adjusted using an automated scheduler, providing flexibility in terms of content delivery and connections.

Tieline also recently announced two new MPX codecs that will be unveiled at NAB2023. Both the MPX I and MPX II support sending the full uncompressed FM signal, or compressed μMPX to deliver high-quality multiplexed FM signals at lower bitrates. They support analog MPX (BNC) or MPX over AES192 to deliver a range of flexible composite encoder and decoder configurations for many applications. Both also offer return FM monitoring options and an optional satellite tuner card supports decoding DVB-S or DVB-S2 signals.

RW What role are technologies like Starlink satellite, 5G, fiber broadband, LTE and cloud playing?

Daniluck: Advancements in modern communications forms, such as the ones you mention, are playing big roles for broadcasters not just throughout the U.S. but the world. These forms of connectivity offer a more affordable solution for transportation, or provide a great means for secondary/back-up connectivity to STL sites.

We've seen clients using Starlink services for primary redundant internet connections to ensure rock-solid connectivity using Tieline's SmartStream Plus technology. We have also seen clients using 5G technology to not only broadcast live from stadiums for remotes, but more importantly set them up for backup standby connections for their tower sites due to the metered nature of some wireless providers.

At the end of the day, newer and more modern communications technologies are something all engineers should consider, especially if they are still paying for services like T1, DSL or cable internet services.

RW What's coming that will further change the landscape?

Daniluck: Bandwidth and latency developments will be the next big advancement within the world of transmitter locations. As these are often on city borders or in rural America, station engineers are no strangers to putting in whatever they can at those sites, whether it is a point-to-point wireless link or a DSL link, as that is all they have access to.

We've seen a number of clients starting to be able to put in fiber lines at these sites, with outrageous costs associated with them. Whether or not ISPs decide to upgrade networks willingly, or if they are forced through legislation, these network advancements will trickle down to the broadcast industry and allow networks and engineers to accomplish more.

RW How have composite FM multiplex codec solutions changed the landscape?

Daniluck: Sending transmission-ready FM-MPX composite signals from the studio allows broadcasters to maintain audio processing and RDS data insertion at the studio. This significantly reduces capital and operational costs by eliminating expensive processors and RDS equipment from transmitter sites, which in turn reduces a network's carbon footprint by lowering on-site power consumption, wiring and rack space requirements. In addition, fewer site visits for service and support are required.

The ability to connect over WANs like the internet at low bitrates with µMPX is also a game-changer for broadcasters, as it dramatically expands the number of STL sites that can receive composite signals, reducing hardware requirements at many STL sites significantly.

The uMPX compression algorithm is designed for FM and maintains perfect peak control, which eliminates the need for an expensive audio processor at each transmitter site. µMPX also allows for multipoint distribution via multicasting or multiple unicasting. This reduces costs further by affordably replicating streams at the studio using a single encoder, similar to how baseband IP audio streams can be replicated in audio codecs. This eliminates the need for multiple encoders, as well as processors and RDS equipment at transmitter sites. When this is multiplied across multiple STL sites the savings can be enormous.

RW How are engineers sending composite baseband at low bandwidth?

Daniluck: Uncompressed MPX over AES (AES192) has a high bandwidth requirement of between 2.3 Mbps (16-bit) and 4.6 Mbps (24-bit). This requires high-capacity IP links like fiber with reliable QoS. Compressed MicroMPX or µMPX is supported at much lower bitrates over both managed and unmanaged IP links. Theoretically any IP network with enough bandwidth available can transport low-bandwidth µMPX signals, e.g. 320 kbps for low-bitrate µMPX composite.

In addition, Tieline's MPX codecs support encoding MPEG-TS over IP to transmit UDP streams over DVB satellite connections, which is another low-bandwidth solution. MPEG-TS is the digital encoding format used in broadcasting over DVB satellite systems. When the satellite signal is received at the decoding MPX unit, a satellite tuner card can decode the DVB-S or DVB-S2 signal and the MPX unit outputs MPX composite directly into the exciter.

RW What are the benefits of a hardware IP codec versus solutions like traditional microwave or newer software solutions?

Daniluck: First let's talk about hardware IP codecs, and microwaves links. Depending on when and who you got your microwave link from, you may have a viable easy-to-

> **MPX codecs and progressively better IP connections in rural areas will help shift broadcasters to solutions with reduced STL transport costs, while still providing greater flexibility.**

use solution for getting audio from A to B. However, not all microwave links support two-way audio support, and nowadays some microwave link manufactures don't offer an audio channel, instead they are opting for a data only channel, which would still require the use of a hardware or software-based codec.

Which brings me to the second part of your question regarding hardware vs. software-based solutions. In my opinion, software starts to fall off in comparison due to the fact that you the user have to do all the component optimizations. This includes picking the proper parts to go together, as well as configuring and ensuring the other software functions on that operating system do not impact what you want the software-based codec to do. Whereas, when compared to a hardware-based solution, you don't have to worry about matching audio cards with certain specs like RAM, CPU and operating system, nor do you have to worry about rogue pieces of software like Microsoft's notorious updater or anti-virus software. In your hardware codec everything is integrated and optimized for 24/7/365 mission critical broadcast operations.

When considering IP codecs for STL, are there best practices you recommend?

Daniluck: STL sites are often remote and far from data centers, but hardware codecs have proven they can deliver reliable solutions over a wide variety of IP transmission paths. Dedicated fiber paths are preferred for STL codec links, with at least one reliable backup path also advisable. However, success can also be achieved with a combination of wireless point-to-point links, satellite connections like Starlink, and cellular.

Often a mix of IP transport options is used, and layers of IP redundancy like SmartStream Plus redundant streaming, Fuse-IP network bonding and FEC mitigate against packet loss to deliver rock-solid performance 24/7/365. Automated jitter buffer management is also advisable over imperfect IP networks with variable jitter. Backup options include alternative connections, Icecast streaming, input bypass to outputs, as well as audio file backup.

A bidirectional transmission path allows for remote audio monitoring and control with software tools like the Cloud Codec Controller, with automated alarms and SNMP providing additional automated monitoring. Remote management software is worth its weight in gold as it helps fix problems fast to reduce time off the air and minimizes remote transmitter site visits.

Security is vitally important, and always ensure you use secure passwords — never the default one! Apart from recommending firewalls and VPNs, some other features we have incorporated include the ability to install SSL security certificates to ensure codecs are trusted devices within your network.

Tieline codecs also have the ability to configure SIP filter lists, which provide filtering of SIP URIs and User Agents to provide greater security when using SIP. Also, Tieline offers firewall settings to enable or disable a range of firewall-related network services, and we have implemented Cross-Site Request Forgery protection, which avoids unwanted attacks on web applications.

Below
Tieline codecs are prominent in a user's rack.

In pursuit of a common framework for 100% IP delivery

The benefits of synchronously linking FM MPX and HD Radio content within the DCP framework

Writer

Philipp Schmid

Chief Technology Officer, Nautel

You may ask, why would Nautel, a world-leading manufacturer in AM/FM broadcast transmitters, be interested in the topic of studio-to-transmitter links?

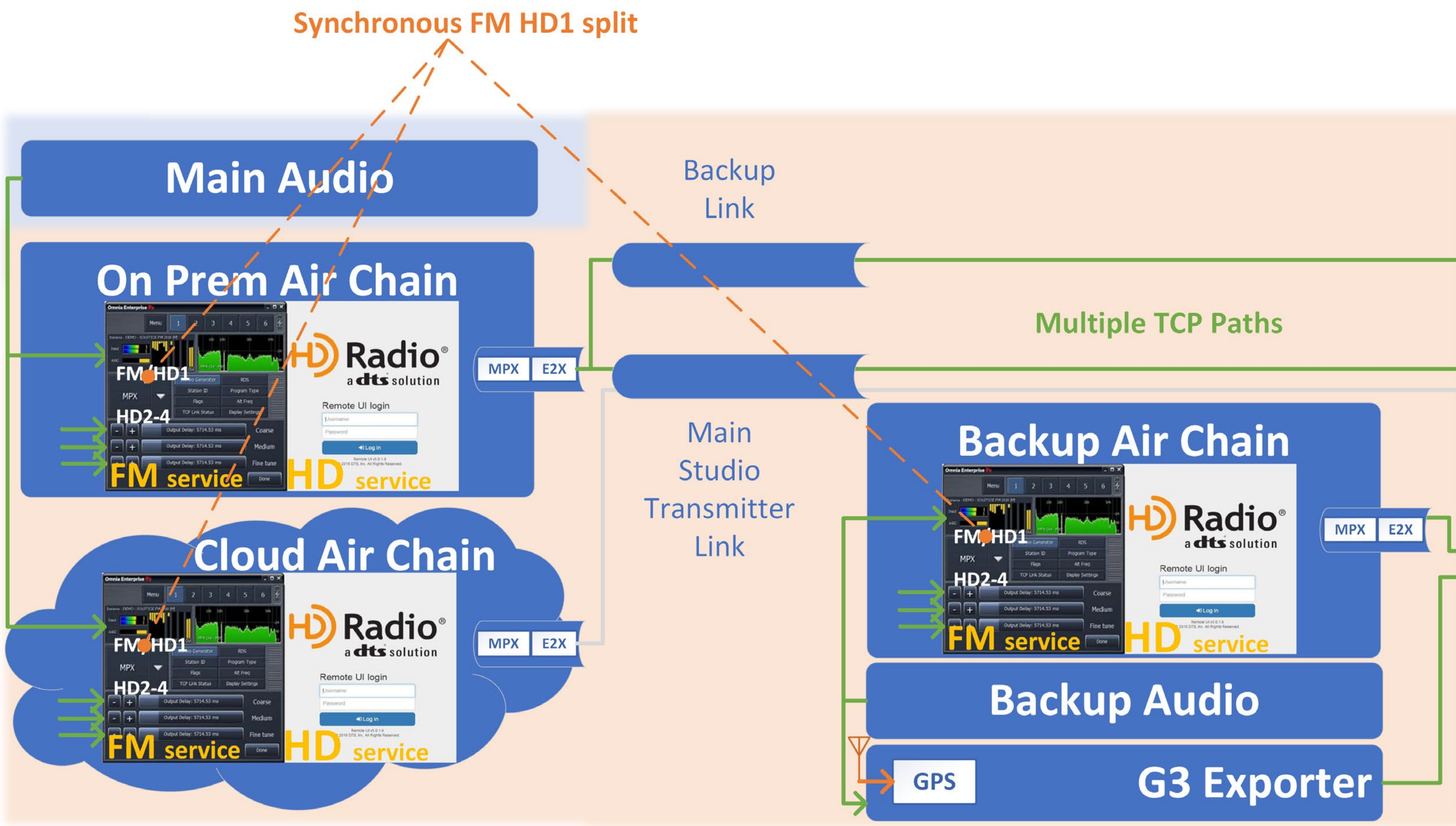
The easy answer is that the "to-transmitter" portion of the STL very much impacts transmitter exciter design, where Nautel provides a unique viewpoint and expertise.

Typically, AM/FM broadcast transmitters provide a standard set of audio and modulation inputs from analog audio, digital AES, composite MPX and RDS inputs. HD Radio was the first system that broke these established norms, when the exporter, an audio encoder and multiplexer, and the exgine IBOC modulator were introduced in third-generation architecture.

While FM audio was still delivered to the exciter using traditional means, now the transmitter exciter required an Ethernet port for the exgine to communicate with an exporter possibly located at a studio or other remote location. To address STL challenges between exgine and exporter for HD Radio, Nautel developed a Reliable HD Transport protocol, addressing packet loss across STLs through a retransmission scheme while ensuring a constant-bitrate IP stream.

The system was successfully applied to HD Radio delivery over satellite, and we extended the protocol to allow for single-frequency network (SFN) synchronization of the HD Radio signal.

The new HD Radio architecture foreshadowed the emergence of IP connectivity for all exciter modulation,



including analog FM content enabling 100% content delivery over IP.

When Digidia joined the Nautel family in 2021, we gained a talented development team with IP STL and FM exciter experience behind the SpanFM and SyncFM product line, targeting analog SFN applications like a highway SFN in France spanning hundreds of FM transmitters.

The Digidia team applied the IP content delivery framework and protocols found within the DAB+ standard to analog FM transmission, allowing for uncompressed composite MPX end-to-end transmission, as well as MPEG2 compression for bandwidth-constrained applications like satellite.

We realized that all common digital radio standards in use today — HD Radio, DAB+ and DRM — share a common protocol framework for content delivery from encoder to modulator: the Distribution and Communications Protocol (DCP) standardized in ETSI TS 102 821.

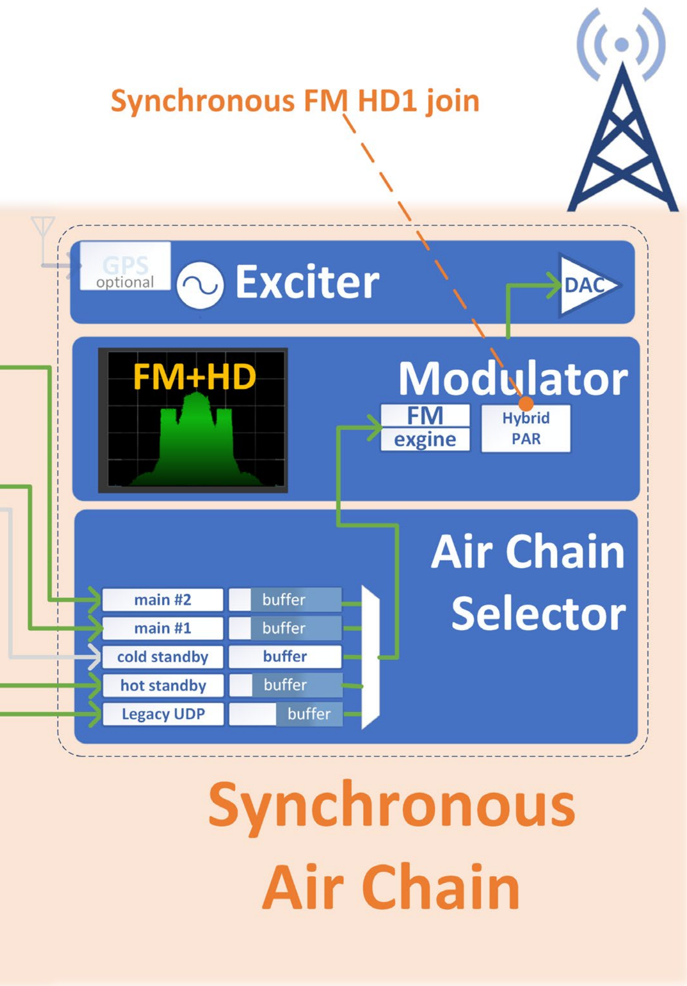
Combining this realization with the Digidia work of bringing composite MPX into the DCP framework, we propose a common framework for both analog and digital radio including HD Radio, enabling 100% IP content delivery for both analog FM-only and hybrid FM/HD Radio stations. The stereo generator creating the composite MPX signal assumes a parallel role to the HD Radio exporter that encodes the HD audio; both operate on the same L/R audio input. We are working with standardization bodies like the National Radio Systems Committee and Institute of Electrical and Electronics Engineers to open our solution for wider application.

In the future this will eliminate intermediate IP audio codecs and allow audio processors and encoders to deliver all modulation content to the broadcast transmitter, just as it has within the DAB framework, where vendor interoperability has been achieved across many encoders, multiplexers and modulators even for large-scale SFN deployments.

By synchronously linking the FM MPX and HD Radio content within the DCP framework, Nautel demonstrated at last year's NAB Show that HD Radio diversity delay alignment can be maintained across time, system restarts or other link interruptions, no matter where the air chain ingest is located: at the studio, at the transmitter site or even in the cloud. No GPS required.

Furthermore, by aligning HD Radio modulation frames stemming from different air chain audio encoders, we can gracefully change the modulator over from one air chain to another with minimal interruption on an HD Radio receiver. Changing from the main air chain to the backup air chain maintains modulation lock in an HD Radio receiver resulting in an HD drop of only 2–3 seconds, and no downtime on the analog FM.

In the future, the only physical equipment in a typical radio station deployment could be the microphone and the broadcast transmitter. With a synchronous framework for content delivery that includes all modulation content for FM and all HD Radio channels, we can virtualize all other air chain components from playout to audio processing as software-only components that can live anywhere, even in the transmitter itself.

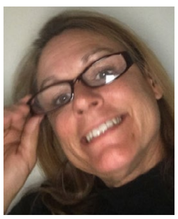


> **The new HD Radio architecture foreshadowed the emergence of IP connectivity for all exciter modulation, including analog FM content enabling 100% content delivery over IP.**

FM MPX and the whole enchilada

Now we have a way to package the full MPX, HD/FM alignment included, for transport across modern links

Writer



Dee McVicker

Marketing Director, Wheatstone

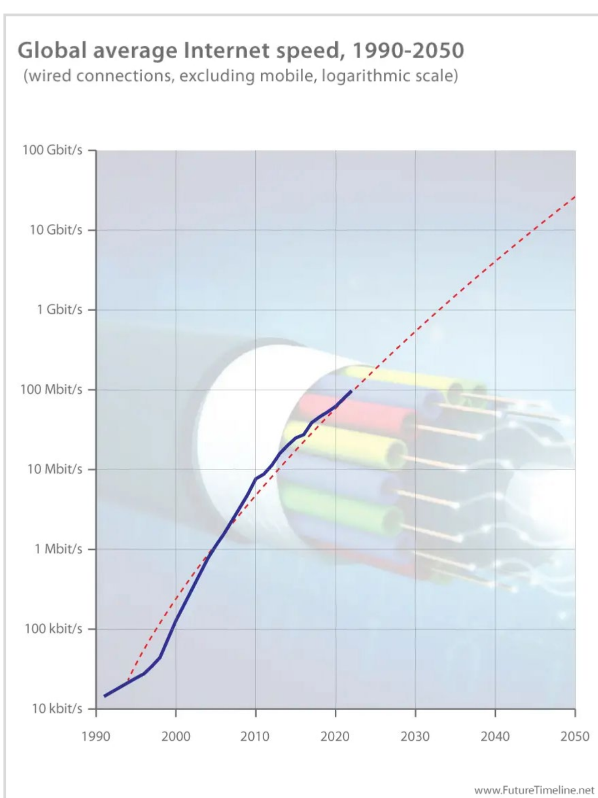
We have been thinking about enchiladas lately. Specifically, the whole FM MPX enchilada, including RDS, pilot and FM/HD alignment, and why we can't have our cake and eat it too.

I can explain.

As we all know, the composite MPX signal with stereo pilot and RDS is packaged in the AES192 format, or AES sampled at 192 kHz. That digitized package is sent from the studio in its entirety across the studio-to-transmitter link and received by the AES192-capable exciter at the transmitter.

That whole MPX enchilada requires about 2 to 4 Mbps, not including the HD or the HD/FM alignment detail that most FMs in the U.S. carry these days.

In the past, STLs and IP links weren't up to speed, and we were forced to fit the entire 2 to 4 Mbps package down a kbps bit stream, which meant that some audio quality was lost in the process. Because we didn't have the high-speed links to carry the payload in its fullness, we were not able to get across the detail necessary for high-quality audio.



Right
With the internet "speeding up," no longer do we have to fit the entire MPX payload into a kbps bit stream. We have more than enough for linear audio and the whole MPX enchilada in many cases. All we needed was a megaplexer capable of packaging the MPX payload, FM/HD alignment included, at 24-bit resolution.

But with today's fiber optic, 5G and other high-speed links, we can now get 100 Mbps or more across these links — more than enough for the whole enchilada. Those links are becoming more ubiquitous and continue to get better with each passing year (see the accompanying graphic).

All we need now is a way to package the whole MPX signal. We need a megaplexer, so to speak.

As it so happens, a few years ago Wheatstone developed an option for our audio processors as a way to keep HD and FM signals in sync from the processor at the studio straight through to the receiver in the transmitter. SystemLink continues to be useful for that purpose, but we began to wonder: Could we use SystemLink as an MPX megaplexer to package the full MPX payload at 24-bit resolution, which would give us all the resolution, and then some, for good quality audio?

The answer is yes. With SystemLink, we can now get linear audio and the entire FM MPX signal, including RDS, pilot and FM/HD alignment, across today's high-speed links with little to nothing lost in the process. And because this 24-bit digital MPX and HD audio megaplexer utilizes RIST, the open-source transport protocol, we can get reliable, real-time audio transport along with error correction at the lowest possible latency.

Being able to package the whole MPX for transport over high-speed data links from cloud data centers to the transmitter site is an important piece of the "audio processing in a cloud" puzzle. Today, we have cloud software for mixing, streaming and processing instances in a cloud data center. We have high-speed data links available between many of those data centers and FM transmitter sites. And now, we have a way to package the full MPX, HD/FM alignment included, for transport across those links.

That's the whole enchilada, in a nutshell.

SystemLink is now an option in Wheatstone's Layers Software Suite as the MPX output of the Layers FM module, which includes multiband processing, PPM watermarking and full RDS capabilities as instances in an onsite server or off-site at cloud data centers. SystemLink can be used with any audio processor, including Wheatstone's flagship X5 FM/HD audio processor, MP-532 multiprocessor and new Lion FM audio processor. RW

Here are some examples of last-mile solutions

Taking a fresh approach to getting to and from the studio and the transmitter

Writer

Mike Pappas
VP Business Development, Orban Labs

A long time ago, in a rack far far away, getting to and from a transmitter site was pretty easy. You tossed up a 950 MHz STL and fed composite (for FM) or audio (for AM), and away you went. You might have used equalized lines for an AM if you didn't want to use an RF STL, but it wasn't complex … certainly nothing to expend a lot of brain cells on.

Inevitably things change. One of the big drivers of that change was HD Radio. Now FM broadcasters have to figure out how to get analog FM and its corresponding HD-1/2/3 E2X data "up the hill"— and that makes the old composite STL look mighty feeble. And then there are the further complications of consolidation and studio moves and perhaps needing to feed distant transmitter sites.

Many of the old options for higher bandwidth are no longer around, such as equalized lines, dry pairs, ISDN, T1 and so on.

Luckily, there are new options to help solve that "last-mile" dilemma. But before we jump in, we need to have a better understanding of what you need to ship and how much data you need to move.

Here are a few questions you need to ask yourself. Where are you going to insert EAS, and do you need to supply it with remote receiver(s) audio? Are you going to do the audio processing remotely or local? And what about remote control, monitoring and any backhaul?

But wait … there are more. Are you encoding Nielsen PPM? Are you doing local insertions? What about localized RDS?

And that leads us to the question of bandwidth. How much do you need? And that answer is usually "MORE!" — especially if you're planning to operate in HD.

Now let's look at your transmitter site. What's available for you to use? Fiber? Switched Ethernet? Fast internet? Microwave? Or do you need to look at something more esoteric such as Starlink … C/Ku Band satellite … or 5G LTE (assuming you have enough bars of service and deep pockets)? Or "none of the above"?

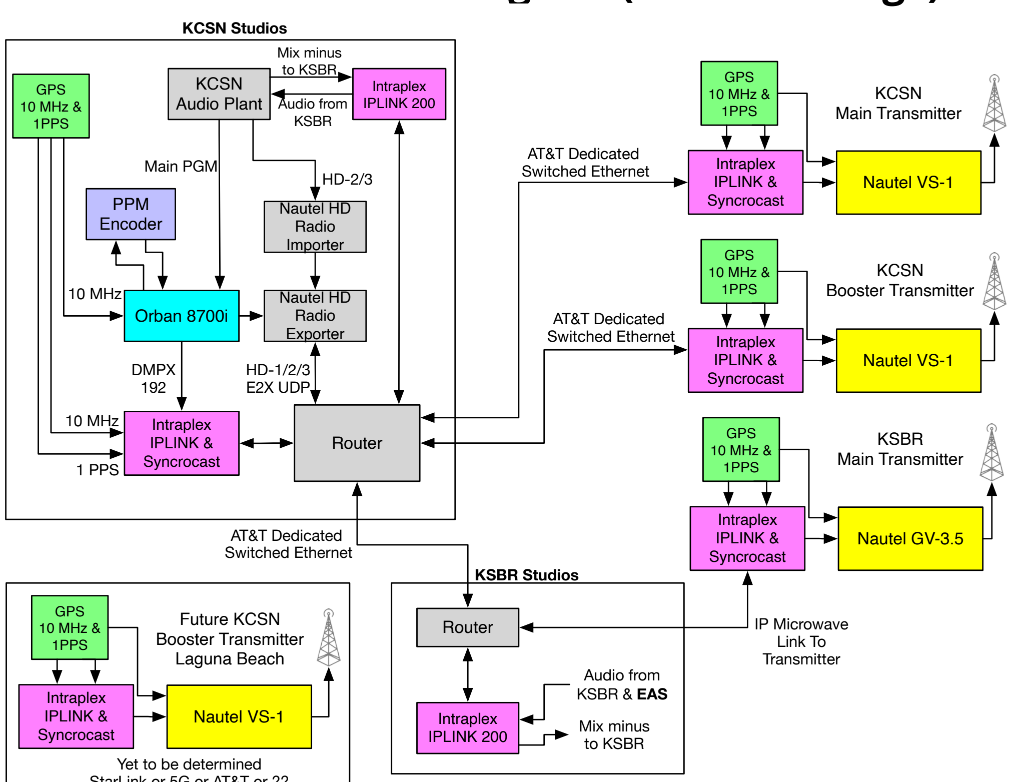
It's all about needed bandwidth vs. your options — and how much reliability you are willing to pay for.

Perhaps we can use a combination of solutions to improve reliability.

For example, we could backup fiber to 5G LTE using the capabilities of most LTE modems. Both Pepwave and Cradlepoint can be programmed to failover to LTE if the WAN port experiences an issue. But be aware that using 5G LTE as a primary for feeding a transmitter site can be very expensive. Carriers' data plans need to be studied carefully. "Unlimited" plans may include throttling or surcharges.

But it's certainly worth looking at and you can use that type of solution to back up just about any primary transmitter site feed, whether it's microwave, StarLink dedicated switched Ethernet or something else. And all of these solutions are fully

KCSN Block Diagram (click to enlarge)



bidirectional, which makes hauling remote control and monitoring including audio easy.

I mentioned Starlink and I have personal experience with this: We looked at using it for a potential customer who had multiple sites across multiple states. I ran a consumer-version Starlink for 90 days running 20 Megabytes per second through it and had very few issues with it (less than a couple of seconds). Although I tested the consumer version, I would recommend the business version, which is more than capable of providing reliable primary STL service under the right circumstances. And, coupled with 5G backup, this might make sense for you.

Case studies

Here's a real-world example of a "last-mile" solution using another option, AT&T dedicated switched Ethernet service.

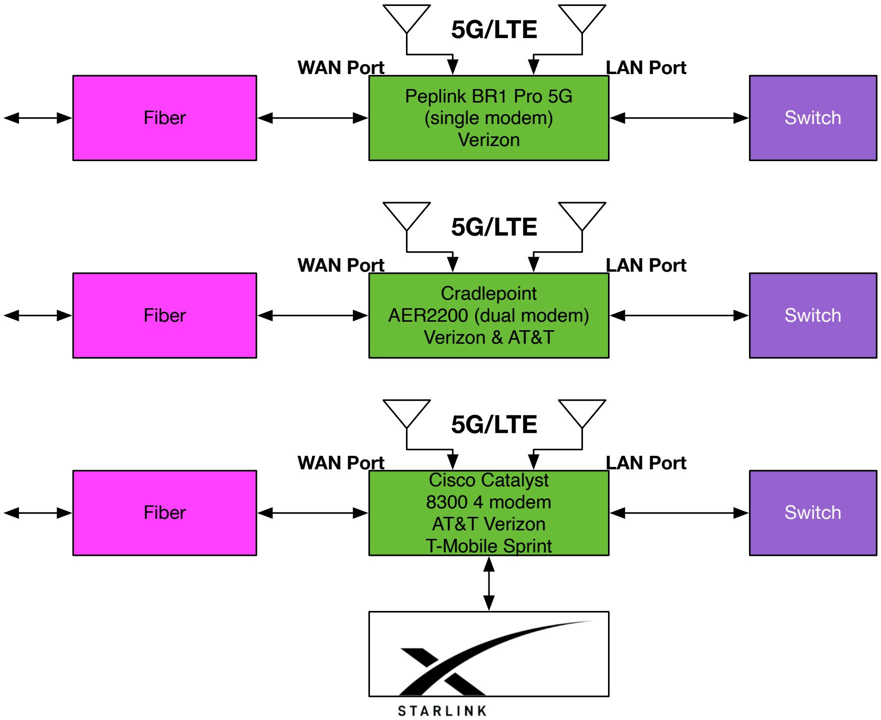
The KCSN/KSBR three-transmitter single-frequency network in southern California covers a population of 12 million people. They are sending Nielsen PPM encoded DMPX from an Orban 8700i at 192K/20 bits (via GPS locked Gates Air Intraplex) along with HD-1, HD-2 and HD-3 as E2X UDP. Those three circuits are bidirectional 10/20 MBps and have been up and running since 2017 with a single outage of one hour. The longest path is almost 80 miles between the KCSN and KSBR studios where it takes an IP-based microwave ride to the transmitter site. EAS is backfed from the KSBR studios via the return and inserted into the main program stream along with KCSN EAS. Cost? Less than $1,400 a month. They are going to add a fourth SFN transmitter this year covering Laguna Beach and they are looking at everything from Starlink to 5G to feed it. I will be out there for that project and will let you know what solution is chosen.

Here is another real-world last-mile solution. WCTS(AM) in Minneapolis/St. Paul needed to feed their remote AM transmitter site from their studios. With AM, processing is typically done at the transmitter site. WCTS has dual processing paths (primary and backup) with an Orban XPN-AM as primary and an Orban 9300 as backup.

It gets interesting as the XPN-AM provides the Nielsen PPM encoding while the 9300 uses external PPM encoding located back at the studios. This requires a fair amount of switching hardware on both ends of the system to make work. The WCTS studios are analog (+4 dB) and the feeds to the AM site are digital, so there are A-to-D conversions being done in a couple of places to make all this work.

Remote control and monitoring for WCTS are handled as backhaul from the carriers. Initially they used CenturyLink DSL as a primary feed, with T-Mobile LTE as backup. They found intermittent dropout issues with the DSL and are now running Viasat VSAT as primary and CenturyLink DSL as backup.

And that brings us to (invariably) lossy compressed audio. If costs and bandwidth are an issue for you, the use of lossy compressed audio feeds might be worth



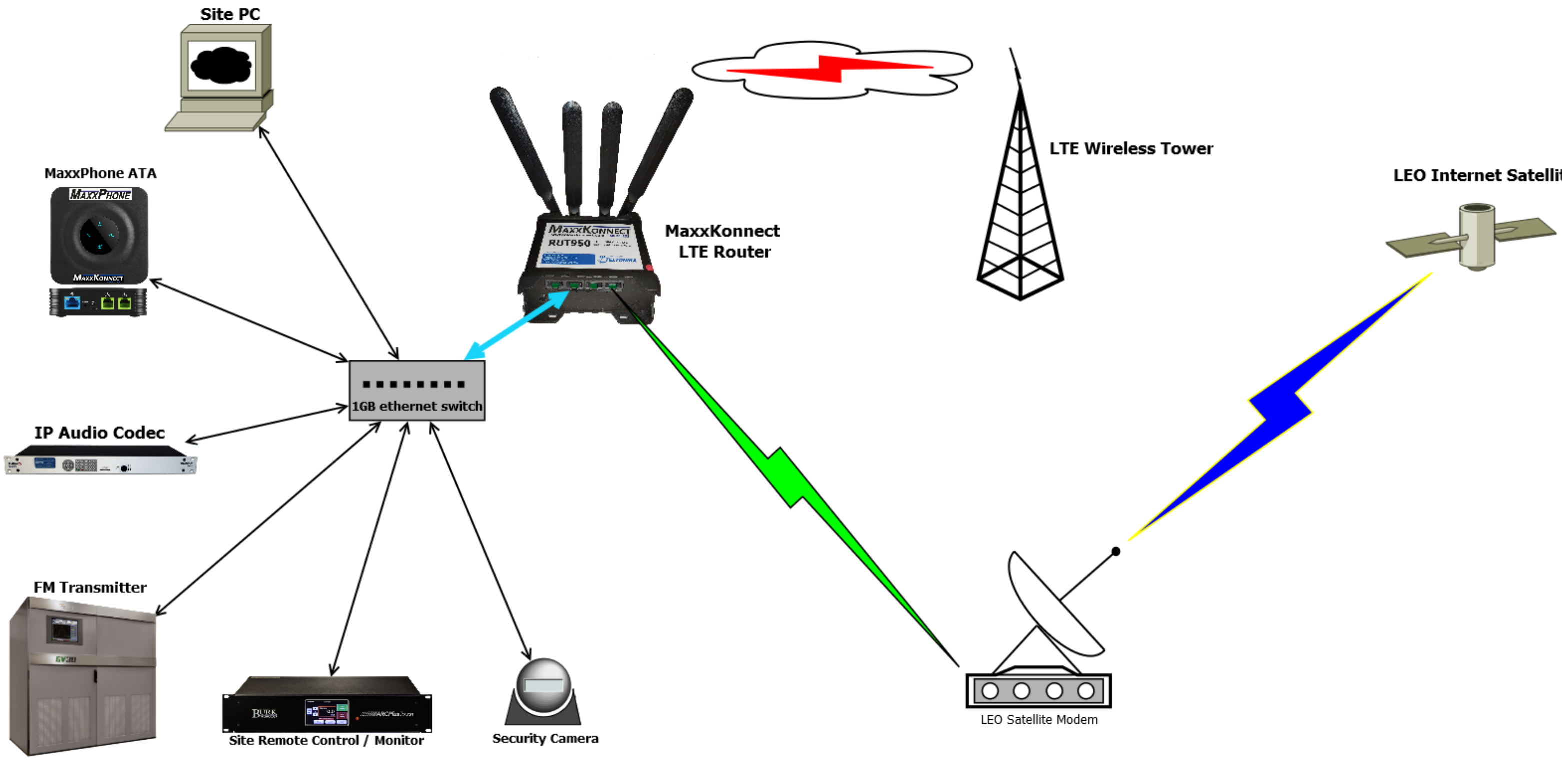
"It's all about needed bandwidth vs. your options — and how much reliability you are willing to pay for."

Above
Backing up fiber to LTE/Starlink for redundancy.

looking at. Please note that most codecs do not "enjoy" 75 µsec pre-emphasis, which precludes sending remotely processed audio to the transmitter sites. And there will be peak control issues with the recovered audio to be dealt with. Unfortunately, these compromises could have an impact on your listenership, so that needs to be factored into your ROI.

So what do I recommend? My non-answer "answer" is: It depends. There are so many good options available. Broadcasters have a myriad of ways to solve last-mile problems. At the NAB Show we will be using a Pepwave MAX BR1 Pro 5G in Booth W2543 of the West Hall to solve our own "last-mile" problem for both our AM and FM processing demonstrations. We invite you to stop by to look at it.

The author recently hosted a webinar for the Society of Broadcast Engineers on "Last-Mile Solutions for Cloud-Based Broadcasting." RW



Above Redundancy in action. This graphic is an example of a modern connected site using MaxxKonnect prioritized LTE service and LEO satellite internet. Other options might include 950 MHz point-to-point or a wireline service.

Josh Bohn preaches the religion of backups

You might think you have full redundancy, but take a closer look

Connectivity is right in the name of Josh Bohn's growing company. He's president and CEO of The MaxxKonnect Group, a broadcast technical firm. One of its products is MaxxKonnect Wireless, a prioritized, high-speed LTE internet service for broadcast applications. Bohn has also worked as an engineer for companies like Radio One, Main Line Broadcasting, Cumulus and what was then Clear Channel.

RW What jumps into your mind when I ask about the state of STL?

Josh Bohn: The proliferation of IP as an STL has become the de facto standard. We've sold maybe three point-to-point 950 MHz STLs, analog or digital, in the last two years. That's it. And fixing Marti and Moseley point-to point STLs used to be the majority of our business, but in the last year, we might have done eight where we used to do five or six a month.

We plan to launch an analog 950 STL after NAB. It's got composite mono natively, but you can do stereo left/right through it or AES. It will have a Web interface on both ends with SNMP and browser-based interactions — to change frequency, change the power, turn it on and off. The SNMP will let you marry it to your remote control, so you can monitor what your receiver's doing. Legacy analog products didn't have that.

Major and large markets might not be using 950 STLs anymore but go into smaller markets and they're still running legacy 950 STLs. There's a need for something that can be monitored with IP, something they can plug their composite cable into, hook the antenna up, plug it in and it's on frequency. Then they can go back to running "Swap Shop" and the funeral report, because that's where they make their money.

Do you have STL words of wisdom?

Bohn: I'm a huge advocate of backups. I got a call an hour ago from a station in Tennessee, a community college that's talking to us about moving to a tower about 10 miles away. I asked what they use now for STL, and he said it's point-to-point 950 microwave, analog composite. But the electric co-op that's building the new tower is putting in fiber in so they're going to go on that.

But what are they going to do when the North American Fiber-Seeking Backhoe comes and takes them off the air for two days? If you're going to do fiber with point-to-point IP, even over the internet, your codec will have the ability to fail over. So whether we put a MaxxKonnect cellular modem or point-to-point IP radios, or if we can get a 950 shot we can relicense their current STL and just put in a composite switch, you've got to have a backup.

People hear "fiber" and think all their problems are solved. Yes, fiber is super reliable — until it's not. If it's buried, you have to worry about "backhoe fade," though that's maybe the only major thing. But if it's aerial fiber? A drunk driver, an ice storm, a windstorm, almost anything external can destroy it. If a pole falls, it's going to shred whatever's connected to it, which includes your fiber. And that's a significant amount of downtime.

We have a client site with MaxxKonnect. They had fiber running into their building. But a housing development is going up across the road, and a plumbing crew came in. They didn't call 811 first, and they cut through the entire bundle. That station had a T1 backup, but the fiber and the T1 run through the same conduit. So in one scoop, all connectivity for that site went down. They were off the air, in a big market in Ohio.

But their chief was smart, he also had Comrex BRIC-Links hanging on MaxxKonnect. So they were only down for the amount of time it took him to drive out, unplug the audio out of the out of the T1 codec, move it over and plug it into the output of those BRIC-Links, and boom, they were back up.

They ran on that for four days and ultimately ended up ditching the T1 and just switching over and using MaxxKonnect and BRIC-Links as their backup.

So figure out two ways to get program audio there. I don't care if you string a piece of wire a quarter mile down the road (though if you do that, put transformers on each end).

If you're doing IP, consider your studio too. You may have three backup connections at the tower site, you may have an LTE modem, DSL and an internet fiber connection, but you have only 10 Gig fiber at the studio. Why is fiber at the studio good enough while fiber at the transmitter needs backups? People get a false sense of security because the studios are in a town and they think the infrastructure is more stable there. But there's just as much of a chance for your IP delivery system to get knocked out in an urbanized area than out the transmitter.

Who does the fiber work, and can you share tips for working with them?

Bohn: It's from a carrier-level provider, whether it's AT&T or a company like C Spire out of Mississippi, or Lumen or Verizon.

Bigger groups like iHeart have moved completely to IP STLs. When iHeart goes in and rebuilds their markets with those four-studio models, where everything's multipurpose, there is no RF in or out of those buildings anymore, not even satellite dishes. They're delivering all their network content via IP, and that's where everything is going.

Again, you've got to have multiple ways of delivering the audio, otherwise you run the risk of being off the air. There are so many external factors. All of this is riding the public internet at some point. You're using public infrastructure, not a transmit dish and receive dish with a path 400 feet in the air. You're going through God knows how many switches and LATAs, crossing between providers, from this mux to that mux. The points of failure have gone from two to as many as 50, most of which you have zero control over.

So the only way you really have control over your broadcast is to have another way to deliver it.

Below
Josh Bohn

> **People get a false sense of security because the studios are in a town … But there's just as much of a chance for your IP delivery system to get knocked out in an urbanized area than out at the transmitter.**

Some people want to use our service as a primary STL. That's great, but get two different carriers — and point their antennas at different towers. You might think "Hey, I've got three carriers on my tower," so you're not worried about it; but if all three carriers are on your tower, they're riding the same fiber bundle. You can take your primary off there, the signal is going to be great; but for your secondary, get a directional antenna and point it at a tower three miles down the road. Then if yours goes down, it will pick that one up, and you won't have a hard off.

Of course, everything is subjective. If you've got a station that makes $5,000 a month in the middle of nowhere in Mississippi and another station in a major metro that's making $60,000 a month, which one gets the backup? The one in Mississippi is three hours way. But the one here in the market is making all the money, so the other one is just going to have to be off the air until we can get there.

RW Is Starlink satellite part of this discussion?

Bohn: I know people that have used it. There's a use case for LEO satellite. But it seems that it's very location-dependent. And also time-dependent.

The Starlink system, from what I understand, is set up as a mesh, and it's very locked down. You can connect from a downlink terminal out to a public static address on a terrestrial service, whether it's LTE or wireline; but you can't connect into a Starlink service, because they don't offer public IP addresses. I believe everything is IPv6, which is why they don't offer public addresses. Most routing equipment still can't handle that.

We're trying to get together a Ka band MaxxKonnect product that you could use as an STL, to go into transmitter sites where cellular may not be a good option or where cellular is the only option but you want something more robust that isn't metered that can run full-time.

But for what broadcasters need, Ka isn't there yet; the infrastructure in the U.S. isn't built out. I can get you Ku band service but it's atrociously expensive.

Still, satellite is becoming more of an option. And when you say satellite internet, people think Hughes; but the average subscriber ratio for HughesNet and the commercial services is 300:1. The latency for an uplink is almost unusable. For downlink it'll work fine, and there are people who use Hughes as an STL downlink. As long as you're running a low-bitrate stream, it'll work pretty well; but don't go out there and try to browse on it.

So LEO is great, but access is a problem because you can't use the Starlink portal to get back into your site through IP addresses. I mean, you could put a jump-box type computer in there, and get into it with ScreenConnect or LogMeIn, and then browse to your stuff at the site. But if you want to be able to directly manage your devices — if you need to connect to your Burk or your transmitter without having to jump into another computer, you've got to have an actual IP address; and that's where the Starlink system currently falls short.

RW Are broadband and radio STLs the most common types?

Bohn: Anything else is still an outlier. What we're doing with LTE has become a lot more common, but it's still in a distant third place to fixed wireline broadband — fiber, cable or whatever — while point-to-point radio STLs are still king because they give you full control over your link.

RW Using IP technology on either end?

Bohn: In some cases, yes. I would lump point-to-point IP and analog into the same category, because you're accomplishing the same thing. It's just a difference in hardware and frequency. IP has become more prevalent in larger markets. Point-to-point links, whether licensed or unlicensed, are more common in larger markets than the analogs. But I still walk into small-market stations that are still using TFTs STLs. That's why we're building one ourselves; because there are lots of them out there pushing 40 years old. And when they die, they die hard.

RW What else do you see coming?

Bohn: The overall concept will never change; it's getting program content from one point to another. There will always be innovations and delivery options — 5G, 6G, 9G, whatever they come up with. But ultimately, we've moved into delivery over the public internet, and that's where we're going to stay for quite a while, until there's a fundamental shift in how the internet operates.

Ten years ago, did anybody ever think that you'd be able to carry composite audio over IP? No, but Hans van Zutphen figured out how to do it in a low-bitrate package with uMPX, and it sounds phenomenal. So, will there be advances and things that are really cool? Absolutely. RW