Novel Cooling Expected to Reduce Costs and Carbon Footprint

Cox Media's installation of a GatesAir liquid-cooled transmitter

BY ROSWELL (ROZ) CLARK

For several years, Cox Media had been discussing with manufacturers the benefits of liquid-cooled technology versus air-cooled for FM/HD transmitters. Although there was an attempt many years ago to liquid-cool FM tube transmitters, manufacturers seemed to think it wasn't worth the effort, given the challenges of working with tubes. In TV, though, liquid cooling is commonplace.

The more recent development of solid-state FM transmitters using advanced LDMOS-FET power amplifier technology changed the conversation; the ability to generate higher HD Radio power levels along with FM inside a single transmitter improved the argument for liquid cooling, since the heat generated inside the transmitter room increases in one-box configuration. In addition, the "forgotten cost" of the HVAC systems that have to be redundant and serviced frequently becomes an important consideration in the total cost of ownership calculations.

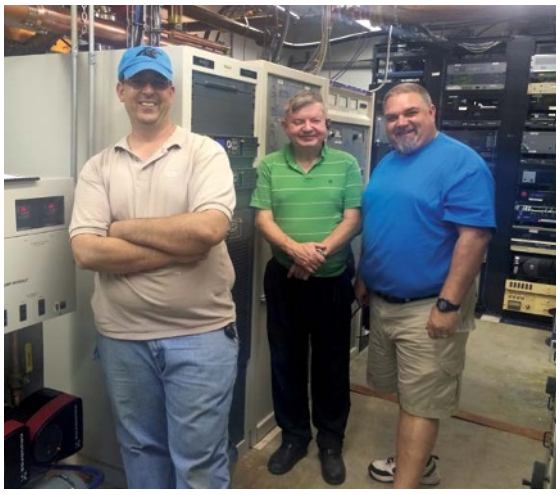
The desire for directly cooling a transmitter with liquid instead of air was fostered by these and a few other observations. For instance, Jed Wilkinson, our Houston engineer, developed a creative method of heat removal at one of his transmitter sites that uses air-cooled transmitters. He designed a solution that uses an air-to-liquid heat exchanger located directly in the transmitter exhaust, which effectively removes the heat from the transmitter air output and sends it outside in the liquid cooling loop. The liquid is then cooled using a geothermal loop before returning to the transmitter room. Using this method, his AC power consumption inside the transmitter room for cooling was reduced substantially, even though the transmitter itself is still air-cooled.

THE NEED TO MOVE THE HEAT

Moving heat around has become a bigger concern for our FM stations that also broadcast HD Radio. There is more heat coming out of the transmitter when you inject the HD Radio signal, especially at higher injection levels. Certainly, there is a way to address this with air-cooled transmitters, but it generates substantially more heat when you inject –14 dBc HD with a 30 kW transmitter. In an air-cooled system, it usually means adding another HVAC unit to maintain room temperatures in a closed-loop air conditioning system.

The capital investment, operational investment and electrical costs — everything associated with moving heat around — become very noticeable. The fact is, liquid can cool a transistor far more effectively than air. We entered into discussions with several transmitter manufacturers, noting the advances in LDMOS-FET and low-voltage solid-state technology. Most manufacturers didn't feel there was a significant return on their investment or a real advantage to using liquid-cooled transmitters. GatesAir was one that did, and they quickly started down the path to develop a solution.

Cox Media Group has a very strong desire — not a mandate, but a desire — to reduce our carbon footprint. Our parent organization will invest in technology that



Roz Clark's transmitter installation team: From left, Dan Carcopo, GatesAir Field Service; Ed Allen, Transmitter Chief Engineer, Cox Tampa; Dylan Scott, Director of Technical Operations, Cox Tampa.

adds efficiency to our operations, especially as it relates to electricity and waste. They recognized a strong potential for return on investment when it came to a liquid-cooled solution. We will pay a little more up front if there is realistic payback period that also reduces our company-wide carbon footprint.

GatesAir developed and implemented this technology, and we received the first liquid-cooled Flexiva FLX transmitter. I was quite surprised how quickly they developed this solution. GatesAir applied the existing technology from their Maxiva TV transmitters and mated it with their FAX transmitters for FM/HD. Now that it's a product, there is a lot of interest among other radio engineers that previously wasn't there.

MIXING WATER AND HIGH VOLTAGE … NOT

People have a certain comfort zone; the idea of cooling a transmitter with liquid is unfamiliar to many engineers, and some say there is no way they want liquid inside the transmitter. But once they understand it's not about mixing high voltage with water, they recognize the benefits: The transmitter footprint is much smaller; moving the heat is done more efficiently; and you don't need large redundant air conditioners to handle all this heat that is inefficiently moved outdoors. The capital expenditure, investment for HVAC and overall operating expense for those systems are reduced. When you run the numbers, you realize, too, that the return on investment is reasonably fast, especially for a high-power transmitter system running low-level HD.

The return on investment is a bit longer for lower-power versions, but other advantages like reduced footprint remain. Since you can run the transistors harder because they're cooled more efficiently, you get more RF output per cubic inch of transmitter. You can also transmit HD and analog from a single box more efficiently.

There's another side benefit to liquid-cooling that no one ever talks about, and that's the noise. You can walk into a transmitter site and have a conversation without shouting over the sound of blower noise from the transmitter and the HVAC noise from the air handlers. These days, you can barely hold a conversation at a conventional transmitter site that runs multiple transmitters at full tilt. The FLX is remarkably quiet in comparison.

I look forward to the day where all of our transmitters are this quiet.

ANALYZING THE ROI

As we have worked on this for a few years now, we've made lists of all the associated costs between a typical FM/HD operation using air-cooling and the same scenario one supported through liquid cooling.

The challenge was to come up with a direct comparison of all costs despite the multitude of implementation scenarios now in the FM/HD field. Some FM/HD stations might have an analog tube transmitter paired with an HD solid-state transmitter, combined at either high-level, split-level or space-combining. Alternatively,

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a station with a lower transmitter power might use a solid-state FM/HD transmitter using low-level combining at some level of injection.

We needed to simplify this analysis so an apples-to-apples comparison could be made to better quantify the heat-management efficiency.

Cox decided some time ago that all transmitter purchases would be solid-state, with maintenance being a leading reason; we no longer had to change tubes, and the skills required to maintain those tube devices are much less risky and hazardous. Solid-state gives built-in redundancy, so we can change a module and stay on the air.

We also wanted low-level HD within a single FM transmitter wherever possible, and we wanted to size the transmitters so we can do elevated HD on the order

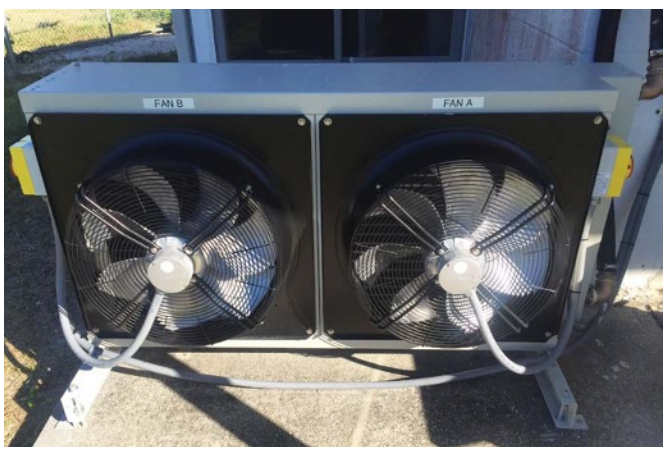

Fig. 1: The outdoor heat exchanger. A protective screen was added to the intake side to prevent dirt and grass from being ingested into its car-like radiator.

of typically –14 dBc.

We also assume that the transmitter rooms are fully HVAC cooled and do not use outside air to cool the equipment. We could then look at the numbers it takes to move heat around: An air-cooled, solid-state FM/HD transmitter system has a quantifiable amount of waste heat dumped into the room that will require a known amount of HVAC to remove. If the existing HVAC system does not have the capacity for that heat load, additional capacity will need to be added. The capital expenditure and operating expense related to that HVAC is known and would be typically included as part of a transmitter upgrade project.

Compare that scenario to a liquid-cooled transmitter installation. We don't need to add additional HVAC or to run existing systems as much, which doesn't add to the overall project costs. Future HVAC replacements for the site can be smaller sized units as well.

With these findings, the cost differential between air- and liquid-cooled transmitters is easier to calculate. Projecting a FM/HD 10 kW transmitter power output, liquid-cooled, we found that we had to add a certain amount of HVAC to the room. The cost savings of running and maintaining that HVAC system equates to an approximate three-year payback at 10 kW.

This is the case with our first FLX installation at WSUN-FM, Tampa, Fla. We specified this transmitter to run at –10 dBc low-level HD injection, and GatesAir was able to make that possible in one 10 kW system because of the improved ability to remove heat from the transmitter so efficiently with liquid. Previously, it would have taken a 20 kW air-cooled transmitter to achieve the same specifications.

The return on investment is much shorter at a higher-level 30 to 40 kW transmitter power output. Our calculations put the return on investment at about one year or slightly more. Cox has a lot of transmitters operating in the 30 kW range, so this is a great benefit for the company.

TRANSMITTER SIZE DOES MATTER

In the case of WSUN-FM, the size of the transmitter is important to us. This particular transmitter site has a small transmitter room shelter that supports two radio stations. Like our other sites, we have main and backup transmitters, and all the associated gear, so we needed to fit all this into a very tight space.

We also wanted this transmitter to be in a shorter rack. The ceiling height in this room is lower than most transmitter sites, so the overall space restrictions were important for us. The height was important because we don't have much ceiling space to run RF plumbing. We also don't have room for multiple cabinets.

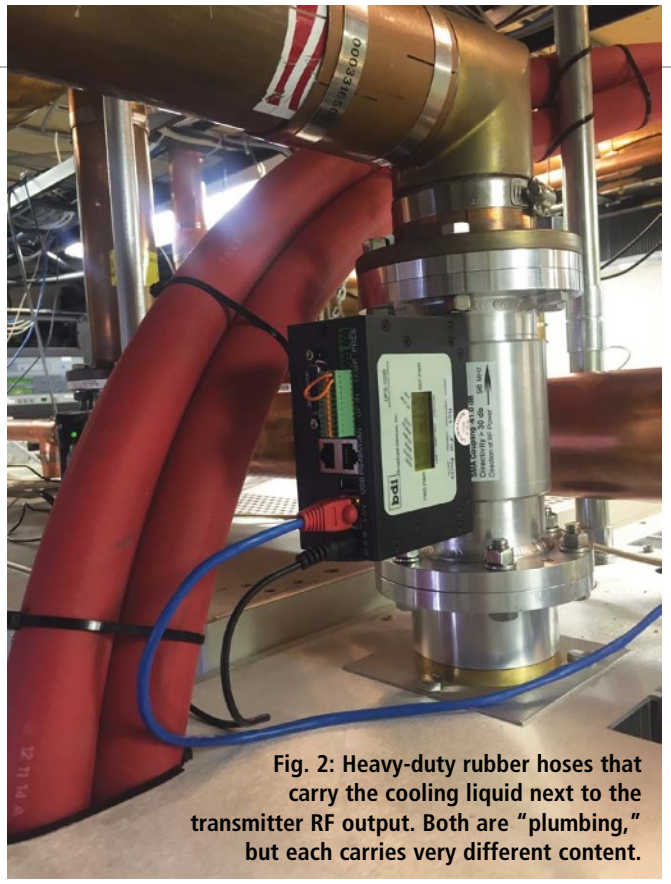

Fig. 2: Heavy-duty rubber hoses that carry the cooling liquid next to the transmitter RF output. Both are "plumbing," but each carries very different content.

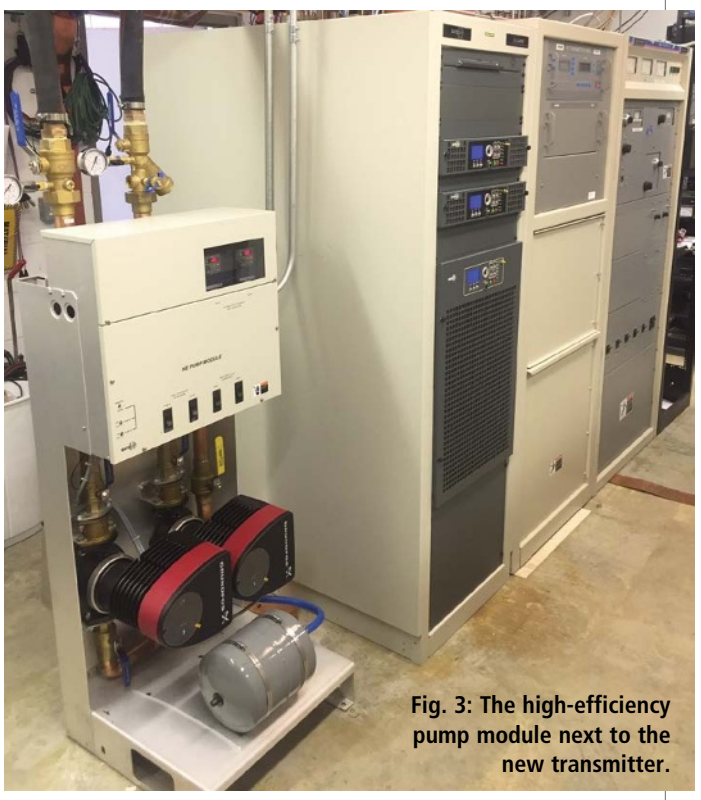

Fig. 3: The high-efficiency pump module next to the new transmitter.

GatesAir was able to work with our specifications and put the transmitter in a shorter rack, which is slightly shorter that of the Z series transmitters. With the liquid-cooled efficiency, we can run this in a 10 kW frame instead of 20 kW to support our FM/HD requirements. We are reducing the footprint in height as well as the square footage. As a result, it fits into this space better than most air-cooled transmitters.

INSTALLING THE NEW LIQUID-COOLED TRANSMITTER

At Cox, we install our own transmitters, so we are in a great position to talk about the differences. The transmitter itself had the usual RF, control and audio connections, but the liquid cooling does change a few things. We had to run and support all liquid plumbing lines, and find a place outside to install the heat exchanger, which resembles a radiator, as seen in Fig. 1.

With FM liquid-cooling, we are not dealing with the copper or brass piping found in TV cooling systems, but instead we have heavy duty flexible rubber hoses, as seen in Fig. 2. This is analogous to Heliax for RF plumbing versus hardline for RF plumbing; the lines are relatively easy to run, but the challenge was about dressing those hoses and figuring out how to support them as they run through the building to the outside area. We strategized a path where the lines were not running over critical equipment, in the unlikely event that one of the lines would spring a leak. We dressed them appropriately, ran them outside and made the connections. It was not complicated.

There were some interesting differences in connecting the pump assembly to the transmitter. There is an apparatus called an H valve to cycle liquid through the transmitter and pump assembly out to the heat exchanger. That had to be plumbed in, and we had to position it at the highest spot of the liquid lines. Figuring out a way to physically mount it was the most challenging part, but hooking up the lines, running them in and connecting them was straightforward — kind of like connecting a radiator in a car.

Dylan Scott, our Tampa engineering manager, and I handled all the RF plumbing and liquid-cooling installation while Ed Allen, our chief engineer in the market, worked on the interconnections of control, low-level RF and all the operational things that make the transmitter function in the plant. GatesAir was onsite to do the full official startup. They have a startup procedure where they flush the system with distilled water, ensure the contaminants are out of the system and then reintroduce glycol into the system. That is called the liquid-cooling qualification, and we will be getting more training from GatesAir on that process for future installations. Cox is committed to purchasing more FLX transmitters in 2016, and we want to grow our internal knowledge across every element of this technology.

A REFRESHING INSTALLATION

I would describe the installation as refreshing. FM transmitters have gotten to the point where installations are fairly straightforward. Assuming we don't have to rebuild a site completely, swapping out an old transmitter for a new one isn't difficult. We know how to ensure that grounding, electrical, RF and control is all properly prepared.

In this case, it is still a new and developing product. Ed Allen worked with GatesAir on the management information base they published for Simple Network Management Protocol monitoring and control to ensure we could see inside the system as deeply as needed. It's refreshing to have something new, and exciting to have something we believe will return great value to the company and the industry in general. Fig. 3 shows the cooling pump next to the new transmitter.

WHAT'S IN THE FUTURE?

We're hopeful that as the technology develops, we see more refinements and improvements. For example, for the heat exchanger outside, we added a screen to the intake side of the unit to avoid having debris sucked into it. That keeps grass and dirt from getting deep inside the radiator fins, and makes cleaning them easier. We are also looking at ways to more effectively mount some of the plumbing components inside the building, such as the H valve system that goes up into the cooling tray.

I am thankful that GatesAir partnered with Cox to go down the road of investigating the benefits of liquid-cooled FM/HD transmitters and that they felt it was worthwhile. I believe this will spark a change the industry, and other manufacturers will start developing their own liquid-cooled FM/HD transmitters in the future.

Roz Clark is senior director of radio engineering for Cox Media Group and has chaired several Cox Media technical committees. He is the technical representative for Cox Media Group to the Broadcasters' Traffic Consortium, the NAB Radio Technical Committee, the Nielsen Technical Advisory Committee and the National Radio Systems Committee; he has co-chaired and chaired the IEEE-BTS annual Symposium.