The

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Broadcast Operations

Rohde & Schwarz' THR9 Brings Liquid-Cooled Savings to FM

By Don Backus

[June 2020] Sometimes old technology is new again – at least when it is presented in a modern way to solve size and operating cost issues. Don Backus explains why the Rohde & Schwarz FM transmitters deserve strong consideration.

When the short term outlook is challenging, it can be difficult to look at the long term.

Difficult, yes, but important nonetheless. There have been a number of developments in broadcast engineering over the past few years that have had significant positive impact on long term radio station operations. I call these "constructive technologies."

One high profile example is AoIP (Audio over IP) studio infrastructures. Once implemented, consoles/switchers/control surfaces using IP protocols like LiveWire, Wheatnet and AES67 allow minimal effort and cost for studio reconfigurations and enormously decreased costs in long term maintenance of these studios – not to mention accessibility from home studios and remote locations like never before, something that has come in very handy for broadcasting in a "socially distant" era.

They are improving connectivity and flexibility and saving money, and doing it over the long term.

THE HEAT PROBLEM

Not all such constructive technologies are in the studio, however, and one in particular holds significant benefits for broadcasters both in the short and long-term.

When it comes to transmitter technology, there are a few truths that simply do not change. To create RF energy from electric energy, there is energy consumed and energy wasted, regardless of the device being used, tube or solid state device. That energy is typically expressed as heat, and one way or another, a transmitter needs to account for that heat.

If you look back in radio history long enough, you find that high power transmitters used to be liquid-cooled, as liquid is much more efficient at removing heat than air.

THE COOLING PROBLEM

Those liquid cooled transmitters had flaws, however. They required extensive external infrastructure, including cooling lagoons and fountains. They were also open systems, introducing contaminates into the system requiring complex filtration and constant monitoring of the water levels. Also, because the RF devices were much less efficient, there was a lot of heat to be dealt with, which increased the water pressure which then decreased system reliability.

Not surprisingly, water cooling like this "evaporated" from modern radio transmitter designs, instead being replaced by air cooling fans – in some cases, a few very large fans, others, a large number of very small fans, and sometimes, a combination of large and small fans. This worked adequately but did place a significant HVAC load on the transmitter building, even if much of the waste heat was directly ducted outside.

BRINGING BACK THE LIQUIDS

While FM transmitters were universally air-cooled, the higher power required by TV transmitters encouraged design engineers to consider alternatives that would result in better cooling and increased performance.

One constructive technology that Rohde & Schwarz engineers developed was a fully liquid-cooled and solid state transmitter design.

This design used a "closed loop" system that never allowed the liquid to be exposed to external environmental contamination, so excessive filtration was not needed and evaporation was eliminated as a potential maintenance issue. Solid state RF devices meant no tubes – and that meant fewer single points of failure and an easier design to remove heat from devices via heat sinks.

BETTER THAN WATER

Furthermore, while water is a better heat conductor than air, a mix of glycol and water is a better choice than plain water since the mixture acts as a corrosion inhibitor. Plus, with the cooling system being a closed loop, station engineers would not have to constantly check levels and top off the coolant, so using something other than pure water made good sense.

By choosing a glycol-based coolant with specific properties mixed with de-ionized water combined with utilizing non-reactive metals inside the transmitter and cooling system, our design engineers were able to insure that the coolant would not cause any galvanic corrosion degrading the integrity of the cooling system over time, thereby allowing it to truly be virtually maintenance free.

One argument in favor of fans moving air, or at least a design with a number of fans, is that a fan could fail and the transmitter would continue to operate, albeit likely at a reduced power level.

To address this, Rohde & Schwarz engineers designed a cooling system with two redundant pumps and a heat exchanger with two redundant fans, so that should there be a failure, the transmitter would continue to operate at full power regardless.

BRINGING IT TO FM

The advantages that this fully liquid-cooling system design brings to TV was also seen as a significant advance over the state of the art for FM transmitters, and so the Rohde & Schwarz THR9 FM transmitter was born. It is the only fully liquid-cooled high power solid state FM transmitter on the market.

One of the biggest advantages of liquid over air for removing heat from a device is how much more efficient liquid is.

In a typical air-cooled transmitter, air is either blown or sucked across the RF and power supply devices, then expelled into the cabinet and eventually outside. With a fully liquid-cooled transmitter, we use a liquid-cooled heat sink in place of the fan(s), drawing heat away from the device and transferring it to the liquid coolant.

Then, we pump the coolant directly out of the unit, the cabinet and the room, all in one step, to heat exchangers outside of the transmitter building. Liquid transfers a lot more heat than air with less flow volume. In fact, air needs to flow 3,000 times faster, volume-wise than liquid to remove the same amount of heat.

That efficiency is very important, and we will get back to that, but there are other significant advantages to a fully liquid-cooled transmitter.

HIGH POWER DENSITY
SMALL FOOTPRINT

The THR9 can handle 40 kW of TPO in a single rack, so power density is much higher than with air-cooled transmitters, and that reduces the required footprint (and space costs) significantly.

Even at 40 kW, the THR9 heat dissipation into the room is much lower, with less than 1 kW of heat going into the room.

The fan noise an air-cooled transmitter gives off is replaced by the almost imperceptible hum of twin redundant pumps. How imperceptible? The pump noise would likely be drowned out by a single desktop tower PC.

SIMPLE SYSTEM

Often though, people worry about liquid cooling being more complicated than air cooling, but really, nothing could be further from the truth.

The THR9 is fully liquid-cooled, with each RF and power module liquid-cooled and the combiner liquid-cooled as well. There are no cooling fans needed. In fact, the heat sink in each module has channels cut within it to insure that the coolant is evenly distributed so that there are no "hot spots" in the module, allowing the power and RF devices to operate more reliably over the long-term.

Modules are hot swappable (just like the redundant pumps and heat exchanger fans) so even in the unlikely case of a failure, the transmitter stays on the air.

Each module has a quick dis-connect fitting for both the intake and outflow of coolant, backed up by a manual valve, as well as an internal expansion chamber to insure that, regardless of any pressure mismatch when re-moving or installing a module, that no liquid escapes.

And while all of that may seem complicated to design and build, once in operation, it requires no interaction by engineers in the field.

It bears mentioning that Rohde & Schwarz has shipped more than 10,000 liquid cooled transmitters worldwide, so this is proven design, engineering and manufacturing.

OPERATING COST COMPARISON

Earlier, I mentioned efficiency, and there are two ways to look at that topic.

The first way is a simple comparison of electric power consumption between an air-cooled FM transmitter and the fully liquid-cooled THR9 FM transmitter.

The second way takes into account the amount of HVAC required to handle the excess heat of the air cooled transmitter. This comparison requires more guesswork as the local climate conditions need to be allowed for as well as duty cycle of the HAVC system. It is still an important consideration though.

Let us start with the easy one – the efficiency as shown in a manufacturer's literature. We will use a 40 kW analog FM transmitter as a base line.

The THR9 has an efficiency of 74% while the largest manufacturers of air cooled transmitters claim an efficiency of 72%. How does that translate into real world numbers?

Brand "A" claims a power consumption of 61.1 kW while brand "B" claims a power consumption of 66 kW. (I will leave it to the reader to explain how both air-cooled transmitters claim the same efficiency while one consumes nearly 10% more electricity that the other!)

At the same time, the Rohde & Schwarz THR9 has a power consumption of 55 kW – a pretty clear difference between liquid cooling and air cooling.

The numbers are similar for Analog+HD Radio, both -14 dBc and -10 dBc, with the THR9 holding a two to four percent advantage in efficiency in each of those configurations as well.

Taking transmitter site cooling into account is a bit more complicated.

Besides the transmitter TPO and electric energy usage, you have to take into account the amount of waste heat and then make some assumptions as to how you would handle that heat. It is also important to make assumptions regarding duty cycle of the air conditioning system.

After all, even in environments where average temperatures exceed 90 degrees for months, there are still times where it is much cooler and the load is reduced.

COUNTING THE KILOWATTS

Here is an example using the same transmitter configurations that we used in the above comparison.

For this exercise, we assume that that energy must be compensated for with air conditioning. The accepted formula for this is that one ton of air conditioning can handle 3.5 kW

The Brand "A" transmitter

- generates 40 kW and consumes 61.1 kW.
- a minimum of 7 tons of HVAC will be required to handle the waste heat.
- at typical HVAC efficiency, we can assume the energy required for the HVAC system will be 9.35 kWh.
- taking into account the duty cycle, which we assume conservatively at 40%.
- thus, the total energy consumed, including cooling, in this example would be 64.84 kWh.

When we do the same calculations and assumptions for the Brand "B" transmitter, we arrive at total energy consumption, including cooling, of 70.27 kWh.

What about the THR9? Since the THR9 does not require air conditioning, we add the energy consumed by the dual pumps and heat exchanger, in this case, approximately 700 W. Since the liquid cooling system runs all the time, the duty cycle is 100% – so we end up with total energy consumption, including cooling, of 55.7 kWh.

KILOWATTS INTO DOLLARS

The next step is to take the hourly consumption and multiply it by the 8,760 hours that make up a year (non-leap year) and then multiply that number by the local electric utility rate for the site. That gives you the annual energy cost comparison which allows you to look at 5, 10 and 20 year comparisons after applying an estimated factor for future electric power cost increases.

We have come this far on efficiency, so let us look at a specific 40 kW analog FM example in California, where electric rates are a bit higher than the national average, but not excessively so.

Assuming a 40% duty cycle, the first year cost for operation would be:

- Brand "A" transmitter $100,703
- Brand "B" transmitter $109,142
- The THR9 would cost $86,510

The difference in this example would be a savings of between $14,000 and $22,600 per year.

When you factor in electric power cost increases along with HVAC maintenance over 10 years, those cost savings increase to between $169,000 and $266,600, with the fully liquid-cooled THR9 FM transmitter!

INSTALLATION AND MAINTENANCE

There are other economic considerations as well, including a simpler installation and less transmitter maintenance required due to fewer moving parts, simpler internal designs leading to fewer points of failure, and having redundancy in the cooling system with the THR9.

Installation is simpler than with forced air cooling because there is no need of ductwork and large fans, along with trained HVAC men to fabricate the ductwork.

The major installation issue is deciding where to place the heat exchanger with its two coolant hoses.

With the built-in redundancy of each section of the transmitter, many engineers using the THR9 report significantly less ongoing maintenance is required.

SUPPORT

The THR9 is manufactured in Germany by Rohde & Schwarz, a world leader in communications and testing technology for over 80 years. Technical support for the THR9 is provided by the same large US-based technical team that supports our hundreds of installed TV transmitters in the US.

An important note is that more than 90% of the THR9 components are made by Rohde & Schwarz, preventing cases of unavailability of parts, or 'unobtainium' from third party suppliers.

With an inventory of more than $2.5 million of spare parts just in our Columbia, MD USA headquarters, all parts are readily available should the need arise.

Looking to the future, we have developed technologies like our HDR900 HD Radio Generation 4 hardware/software platform Exporter/Importer with R&S HD Sync, providing future-proof performance for HD Radio as well as analog service.

To summarize: the liquid-cooled Rohde & Schwarz THR9 FM transmitter

- takes up less floor space
- consumes less electricity than any air-cooled alternative.
- never is held hostage to a failing HVAC system nor pollution, dust or smoke.
- requires less maintenance and actually saves money, short-term and long-term.

The fully liquid-cooled THR9 will have a significant positive impact on long-term radio station operations – saving you money the first day you place it in service and continue doing so well into the future.

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