"MAXIMIZING THE RELIABILITY OF STUDIO TO TRANSMITTER LINKS FOR RADIO"

PAUL SHULINS
Greater Media
Boston, Massachusetts

ABSTRACT

Recently the way broadcasters use STL's (studio to transmitter links) has changed. Not too many years ago, a typical radio station's STL consisted of a equalized phone line leased from the local phone company, or a traditional 950 MHz unidirectional link from the studio to the transmitter site.

Although that is still the case in many installations, today, with the advent of HD Radio, (and many other data services) broadcasters rely on their STL's for bi-directional audio and data links between their studios and transmitter facilities. An entirely new breed of radios is starting to become popular among broadcasters (especially those in larger markets, and those who have multiple stations under one roof) that enables multiple channels of bi-directional audio and data to occur on a single RF Channel. In many cases these RF Channels are being officially licensed by broadcasters and afforded protection from potential interference from new services both within and outside the radio broadcasting industry.

This paper will discuss ways to maximize the reliability of these types of links and examine the factors that both contribute to, and take away from the ultimate reliability of the link.

FIVE NINES

Reliability or link uptime is measured in terms of the link availability. The most common term for this is usually expressed in percent of time per year that can be expected to be available for trouble free link operation. The standard for data professionals has been the old "five nines" number. That is a link availability of 99.999% of the time, is usually considered by most professionals in the data world to be the minimum acceptable reliability criteria.

Industries other than radio broadcasting have defined different standards and can accept more or less Quality of Service. For example most emergency services links require "six nines" or a 99.9999% reliability rate , while some internet service providers are comfortable with "four nines" or a 99.99% reliability rate.
In a normal (non leap year) there are 31,536,000 seconds. If we look at various scenarios we can see in practical terms how the link "up time" is affected by the reliability rate. Using the widely accepted "five nines" number as a goal, a broadcaster who designs and implements a system with that reliability rate can expect to have an intact STL Link for all but 5 minutes each year. It is of course important to realize that these number are averages, based on theoretical calculations and those "5 minutes" of down time may occur at different times of the year and for different durations. In fact there may be some years where there are no outages, and some where the outages are more frequent and of a longer duration than predicted. The reliability factor is only a scientific estimate based on a number of factors including variable ones like the weather. Therefore an absolutely accurate number cannot be predicted due to the random environmental factors that cannot be anticipated with any kind of precision (such as the weather). It is important to keep in mind that meteorological events like hurricanes, tornadoes, snowstorms, etc. are all factors that reduce the links reliability. Unfortunately for broadcasters when these events occur and the reliability is more likely to be affected, the public often needs the services provided by the radio station the most.

Reliability #	Seconds out per year
99.999%	315.36
99.99%	3,153.6
99.9999%	31.53

Figure 1. Reliability numbers and how they represent seconds of STL Link outages per year based on long term averages.

TRADITIONAL PART 74 RULES

Over the past several decades broadcasters who needed or preferred an RF STL Link worked under the FCC's Part 74 Rules. This set of rules provided for authorizations in the 950 MHz band for unidirectional RF Point to point transmissions with limited bandwidth. In the days when radio stations needed to transport just a couple of audio channels and possibly some remote control connectivity, there systems under part 74 served the broadcasters very well. Today however it has been estimated that just one radio station operating under part 74 would require almost the entire band allocation at 950 MHz to achieve the bandwidth resolution required to pass a typical 100 mbps ethernet circuit! Yesterdays technology is rapidly becoming too narrow for the modern radio broadcaster.

SPREAD SPECTRUM

Recently other options have become available to radio broadcasters. Spread Spectrum or ISM Radios became practical in the late 1990's. Some of these models offered bandwidths equivalent to several T1 Circuits, and were available without licenses. Most operated in the 2.4GHz and 5.8 GHz band. These systems are convenient and easily deployed, but offer no protection or quality of service minimums. In addition these spectrums are today becoming crowded with point to point and point to multi point services and are subject to interference. There are certain situations where these links may still be appropriate today for radio station STL's, but the feasibility of these links (especially in congested areas) is getting worse with time.

DESIGN CRITERIA

The important questions that need to be asked and answered before designing an STL System for your facility are, how much payload capacity am I likely to need today and in the future, and what is my requirement for reliability. Once these questions are answered, the link design choices can be made intelligently by factoring in all of the variables that go into making the decision. These factors include climate, dish size, path length, and system losses.

In general a longer STL path is served better by an STL with a lower frequency. This is due in large part to the atmospheric absorption of RF in the atmosphere. The flip side is often the cost of the system, and the bandwidth available on the radio link. The idea is to examine all the factors and determine what system frequency, power level, and dish size is most appropriate for your needs. These calculations can get involved and are best performed by a consultant with the climatological data, path study tools, and propagation prediction software. An experienced RF STL Design Consultant will have the ability to evaluate your particular situation and put together a proposal that makes sense for your facility.

WATER AND BUTTER

A good analogy that has been used for a while to illustrate the way RF Energy is absorbed is to consider a microwave oven. Inside the oven one locates a shot glass of tap water and a second shot glass with several pads of butter. The microwave oven is switched on high power for sixty seconds. After the oven turns off, the contents of the shot glasses are examined. It is found that the glass with the water in it is warm, but the glass with the butter pads in it is boiling over and is much hotter. The molecules of fat and protein in the butter more efficiently absorbed the RF Energy at the frequency the oven was operating at. This intern excited the protein and fat molecules and created heat. The water was still heated because there was some absorption of energy, but the water is much less efficient than the butter at that particular frequency.

Well this is all interesting but how does it relate to Radio STL's. The above analogy shows that different types of molecules are more efficient at absorbing RF Energy at particular frequencies. What we are primarily interested in is water, and the absorption index at various frequencies. If we choose a frequency for our STL that will be impacted less by water molecules, than we stand a better chance of having a reliable STL, especially if we are in a location where the climate is wet.

case with For the higher the STL Frequency, the more prone to etwork for much more than they used to only a few years ago. With the advent and growing popularity of IP audio transmission throughout a radio facility along with its associated properties and transmitter sites, critical real time broadcast quality audio is being transported over existing business networks. Unfortunately, the audio is not the only thing being broadcast over the network. Business files, internet uploads, and downloads, internet audio streaming, and email are just a few of the constant activities all competing for bandwidth on a typical business network.

In order to insure that the important real time packets of data containing critical information (such as program audio) arrive at their destinations without delay and intact, careful thought and planning must be exercised while planning and maintaining your network.

This paper will review the important principles behind designing a successful network infrastructure to handle prioritized needs. A case study of Greater Media's multi station plant in Boston Massachusetts will be discussed. In this example the facility was ten years old when the decision to modernize the network was made to allow for VLAN Segmentation.

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plant, Now more than ever broadcasters need to make sure their transmitter facilities are in good shape. While it is true that over the years there has been a dramatic improvement in the efficiency, ease of service, and reliability of RF Transmission equipment, the pool of experienced RF Engineers has seen a substantial decrease in population. Some of this has been due to many of the older engineers reaching retirement age, but a more significant reason has been the recent trend of young men and women entering the field to be more geared toward the Information Technology (or computer) side of radio engineering, and why not? The line between computers and transmitters is becoming less defined each day. Most radio transmitters manufactured during the previous two decades contain some kind of micro processor or in some cases are full blown personal computers! With the advent of HD Radio this has become particularly true. In this age of computerized broadcasting, it is vitally important that we not loose sight of some of the basic engineering principles and standards that have always ensured high quality and reliable service to our listeners. This paper will review some of the more important areas of transmitter site engineering and maintenance that have been long established, but sometimes forgotten.

CLEAN IS GOOD

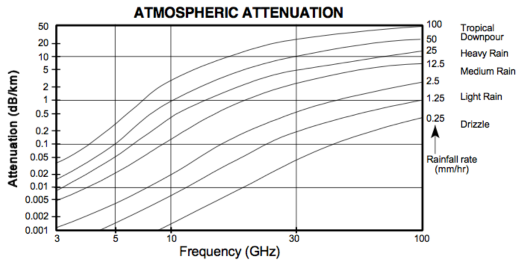
Obviously a clean transmitter site is a good transmitter site. Keeping a site clean and organized has many benefits. It is usually beneficial to employ a redundant closed loop HVAC System. A closed loop system keeps all types of dirt, pollen, and humidity out of your shelter. Transmitters that operate with high voltages will especially benefit from the clean environment because high voltage tends to attract dirt and can lead to unwanted arcing. Proper air flow in transmitters, audio processing gear, and computers is also critical, and dirt and pollen can quickly clog air filters leading to overheating of components and eventual failure of critical systems. In addition, having redundant HVAC systems helps to assure that un-attended transmitter sites will be able to continue to stay cool if one of the air conditioners were to fail, until repairs can be facilitated. It has become a common practice to install a tertiary ventilation system that will simply bring in filtered outside air and draw it across the room to cool the area in the unlikely event that both HVAC Units were to fail. It goes without saying that a system as important as HVAC requires regular service and a contractor should be maintained to perform this service as required (usually at least two times annually).

PRIMARY AND BACKUP VERSES MAIN AND ALTERNATE

An ideal transmitter facility will have redundancy for most all the equipment. In many cases the costs associated with buying "two of everything" are impractical. If you are able to duplicate equipment one strategy that has proven to increase overall reliability is to have a main and an alternate "chain". In other words building a facility where each transmitter is fed by its own set of processing and STL path, helps to insure that in the event of a problem (i.e. RF off the air, audio off the air, or audio problems like distortion etc.) you have the very best chance of bypassing the problem as quickly as possible until the problem an be addressed by simply switching to the alternate transmitter chain, including the RF amplifier.

A "main/alternate" configuration implies that both systems are close to being equal in terms of reliability and quality. An ideal main/alternate configuration will be run on a regular changeover schedule. Depending on your individual circumstances the times will vary, but a popular method has been to alternate systems on a quarterly basis. This helps prove to yourself that both systems are working properly, and in the event of a failure on any one system, you be confident that you can reliably switch to the alternate system and be sure your business will not be compromised.

If you have a primary/backup system, your backup transmitter may not be as modern and therefore may not offer you the efficiency and reliability of your main transmitter. This backup may also not be a full power transmitter. So while you may not want to spend much time with this backup on the air, it is extremely important to test it regularly and maintain it as well as your primary… after all if you need to go to this transmitter, you may be relying on it as your last resort until you repair the primary.



SAFETY FOR PEOPLE AND EQUIPMENT

Often times preventative or required maintenance is performed on transmission gear with lethal voltages present inside. While all manufactures of modern broadcast equipment take precautions to interlock their equipment when a door or access panel is removed, occasionally it is necessary to bypass these safety measures in order to troubleshoot the problem. When this happens the engineer opens himself or herself up to added risks. The consequences of making a careless mistake can be deadly. Compounding the problem is the fact that many of these maintenance sessions are performed late at night at a time when the engineer may be fatigued, and could carelessly make a mistake. The issue is a serious one, and requires one to carefully manage the risks associated with transmitter maintenance. Some of the tools available to the engineer to lower this risk include using checklists, making sure the shorting stick is used before contacting any potential high voltage points, and never working alone. Having a second person double checking your safety measures can be a life saving decision.

The equipment itself needs to also be protected. If you employ an air cooled dummy load make sure that it is interlocked to remove the RF source from whatever transmitter is connected to it, should the cooling fan in the load fail to operate. The same is even more relevant with a water cooled dummy load. If sufficient water flow is not maintained the load element will be destroyed in a matter of seconds. A properly adjusted, high quality external water flow switch is usually required to protect a water cooled dummy load.

Just as the load needs to be protected, those who use a manual or motor driven RF transfer switch need to make sure that these switches are interlocked to any transmitters they are connected to. Usually moving an RF contactor with RF present can cause serious damage to the switch.

Probably the most important and unfortunately one of the widest overlooked interlocks needed at transmitter site are the VSWR Protection Interlocks. Even though modern transmitters provide internal VSWR Fold-back protection, it is absolutely necessary to have an external VSWR meter capable of interlocking the transmitter(s) installed at an appropriate place in the transmission line system, and tested on a regular basis. The cost of installing and maintaining such a device is a small insurance premium to pay for a whole lot of protection afforded to your expensive transmission line and antenna system.

Another vitally important consideration for those using transmission lines with an air dielectric is proper pressurization of the transmission line system with either dry air, or an inert gas such as nitrogen. The object here is to keep the voltages between the inner and outer conductors of the transmission lines from arcing over and destroying the line. Using a dehydrator to dry the air to a very low dew point, guarantees that the moisture content in the line will be low enough to avoid arcing. The other popular method that is very effective is to infuse the line with nitrogen gas (either from a bottle or a nitrogen generator). This effectively removes any moisture in the line and helps to prevent flash over. Keeping the transmission lines full of dry air at several pounds per square inch is just about the best thing you can do to help protect your antenna and transmission line system. It is generally agreed that having an electric pressure switch to monitor the transmission line’s gas pressure (and relay the status to the operator on duty) is imperative so that if an air leak develops, it does not go un-noticed.

Finally for air cooled tube type transmitters a routine testing program for the air flow safety systems is important. Even though all tube type air cooled transmitters employ a safety air flow switch, unless they are tested on a regular basis, it is unknown whether they are actually working to protect your equipment. Some manufacturers provide a set of instructions for testing the air flow switch, and those should be followed if they exist. One popular method is to slowly restrict the air flow to the intake filter on the transmitter under test (with a piece of cardboard), until the air interlock is no longer satisfied, and verify that the filament gets turned off. Having this airflow switch operational when a blower failure occurs may save the transmitter from burning up!

EXTENDING TUBE LIFE

Most tube manufacturers furnish a data sheet with the tube that along with specifications for tube operating parameters also depicts recommended filament voltage settings. Typically it is advantageous for a brand new tube to be run at the rated filament voltage for the first several hundred hours and then at a reduced voltage for the life of the tube. Eventually when the emission drops off the voltage can be increased to a certain point to further extend the useful life of the tube. Since tube characteristics vary widely, the tube manufacturer is the best source of advice on the optimum program for your tube.

GEOGRAPHICAL SITE DIVERSITY

Have a backup or alternate transmitter site is the ultimate in terms of added security for your signal. Such an arrangement is often very expensive, but in many high stakes markets where loss of air time can have huge consequences, many broadcasters have seen the wisdom in providing a backup site. Events as simple and routine as tower maintenance all they way up to actual catastrophes when a tower, antenna or transmission line is damaged by vandalism, earthquake or weather, have resulted in broadcasters being forced off the air for long periods of time. Having another place to go is indeed a saving grace.

Transmitter Maintenance Logs

Running your transmitter facility efficiently and with a minimum amount of down time requires good record keeping. Most engineers accomplish this with maintenance logs. These records help keep an accurate record of service to equipment, as well as regular records of calibrations. Perhaps the most useful aspect is the fact that engineers can refer to a record of what normal parameters are, and thereby easily understand how trends in parameters are affecting the operation. In addition, a well thought out transmitter maintenance log acts as a type of check list, requiring the engineer to go through all the parameters at the facility and record them individually on a routine basis. This of course allows for a complete comparison to the previous entries to determine if any values are drifting. These drifting values can help predict maintenance that will be required in the near future to help avoid unexpected failures.

Normally a paper log template is custom designed by the engineer maintaining the facility. This log acts a check list and a record for each significant visit to the site where maintenance is performed or a log is recorded. These records then are usually kept on a clip board or a loose leaf notebook for easy access. Looking up the previous log can be very enlightening to an engineer when something looks wrong. A record of what is normal compared to today's readings can help pinpoint where a problem may be.

With the availability of smaller computers and PDA's today it is now practical to electronically record and analyze maintenance log data. This has a few advantages over the paper method.

Figure 1. Portable Sony Location Free TV Web Browser being used for data entry into the electronic maintenance log

For example an engineer using a portable electronic device such as a laptop computer, PDA, or other hand held web browser today can directly input information read from the equipment meters for accurate storage, and later retrieval. Information handled in this way has several advantages over the paper method:

1. The data is stored in a logically formatted structure and is always easy to read.
2. The data can be manipulated easily and sorted by field
3. It becomes apparent when trends in readings start to occur and an engineer can more quickly take action to address any equipment shifts in performance.
4. Maintenance Logs can be printed out in a uniform way with color coding and different size fonts to highlight changes the engineer might want to be aware of.
5. Maintenance Logs can also be posted to an internal or external web page so that it is possible to access the data from many different locations.
6. Log fields can be individually sorted by value so the person analyzing the data can see the highest or lowest value in a field.
7. Comment fields in logs can be sorted by keyword. For example search the

comments field for the last time a tube was changed.

8. Mathematical calculations can be routinely done to calculate a running time tally on items such as the time between tube changes in a particular transmitter, or elapsed run time of a dehydrator. These calculations are of course possible to do manually, but to have them done routinely and automatically each time a log is completed can be invaluable especially when an engineer would not have the time to run through each calculation every week. Here the statistics present themselves for the engineer to evaluate and take action if required.

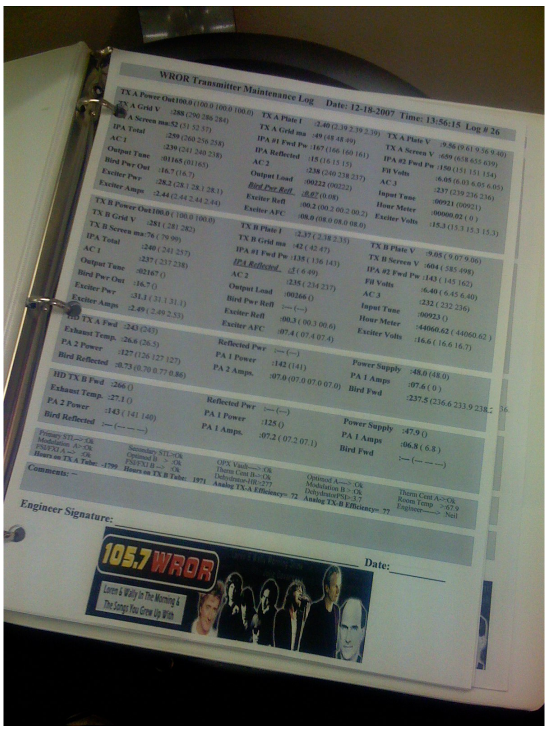
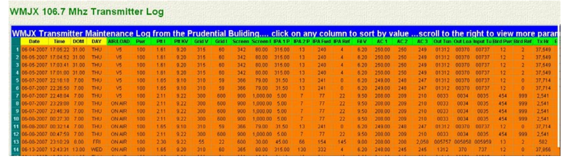


Figure 2. Completed maintenance log in loose leaf notebook at transmitter facility

WEB ACCESS

Even when you are not at the transmitter site, if you write these logs to a web page, it gives you the flexibility to access maintenance data from anywhere. This allows an engineer to more thoroughly analyze the historical data in a cleaner, quieter, and often more relaxed atmosphere (like the office or home) where he or she can spend more time looking at trends and understanding the changes that might be occurring at the transmitter site.



WMJX 106.7 Mhz Transmitter Log

WMJX Transmitter Maintenance Log from the Prudential Buliding.... click on any column to sort by value ...scroll to the right to view more param

	Date	Time	DOM	DAY	AIR/LOAD	Pwr	Plt I	Plt KV	Grid V	Grid I	Screen	Screen I	IPA 1 P	IPA 2 P	IPA Fwd	IPA Ref	Fil V	AC 1	AC 2	AC 3	Out Tun	Out Loa	Input Tu	Bird Pwr	Bird Ref	Tx Hr
1	06-04-2007	17:05:22	31.00	THU	V5	100	1.61	9.20	315	60	342	80.00	315.00	13	240	4	6.20	250.00	250	249	01312	00370	00737	12	2	37,549
2	06-05-2007	17:04:52	31.00	THU	V5	100	1.61	9.20	315	60	342	80.00	315.00	13	240	4	6.20	250.00	250	249	01312	00370	00737	12	2	37,549
3	06-05-2007	17:03:41	31.00	THU	V5	100	1.61	9.20	315	60	342	80.00	315.00	13	240	4	6.20	250.00	250	249	01312	00370	00737	12	2	37,549
4	06-05-2007	17:01:00	31.00	THU	V5	100	1.61	9.20	315	60	342	80.00	315.00	13	240	4	6.20	250.00	250	249	01312	00370	00737	12	2	37,549
5	06-07-2007	22:16:18	7.00	THU	V5	100	1.65	9.10	310	59	366	79.00	31.50	13	241	0	6.20	249.00	248	247	01312	00370	00737	12	0	37,714
6	06-07-2007	22:26:50	7.00	THU	V5	100	1.65	9.10	310	59	366	79.00	31.50	13	241	0	6.20	249.00	248	247	01312	00370	00737	12	0	37,714
7	06-07-2007	22:48:04	7.00	THU	V5	100	2.11	9.22	300	600	900	1,000.00	5.00	7	77	22	9.50	208.00	209	210	0033	0034	0035	454	999	2,541
8	06-07-2007	23:29:08	7.00	THU	ON AIR	100	2.11	9.22	300	600	900	1,000.00	5.00	7	77	22	9.50	208.00	209	210	0033	0034	0035	454	999	2,541
9	06-07-2007	23:46:39	7.00	THU	ON AIR	100	2.11	9.22	300	600	900	1,000.00	5.00	7	77	22	9.50	208.00	209	210	0033	0034	0035	454	999	2,541
10	06-08-2007	00:27:30	7.00	THU	ON AIR	100	2.11	9.22	300	600	900	1,000.00	5.00	7	77	22	9.50	208.00	209	210	0033	0034	0035	454	999	2,541
11	06-08-2007	00:32:14	7.00	THU	ON AIR	100	1.65	9.10	310	59	366	79.00	31.50	13	241	0	6.20	249.00	248	247	01312	00370	00737	12	0	37,714
12	06-08-2007	00:47:59	7.00	THU	ON AIR	100	2.11	9.22	300	600	900	1,000.00	5.00	7	77	22	9.50	208.00	209	210	0033	0034	0035	454	999	2,541
13	06-08-2007	23:10:29	8.00	FRI	ON AIR	100	2.30	9.22	55	22	600	30.00	45.00	66	154	145	9.00	208.00	208	2,050	005757	005858	005959	13	2	582
14	06-13-2007	12:43:31	13.00	WED	ON AIR	100	1.65	9.20	310	60	365	80.00	315.00	130	332	4	6.20	248.00	245	245	1312	370	737	12	0	37,856

Figure 3. Web Page with Log

In figure three, the web page shown uses a java applet to enable the user to sort the individual fields by value. For example, it is possible to show what the entire log looked like on the day when the room temperature was highest, or when the transmitter plate voltage was lowest. Having these tools to analyze the entire plant can sometimes be a helpful diagnostic tool.

CLEAN POWER

It is now becoming more important than ever to supply good clean and un-interruptible AC Power to the equipment at your transmitter site. This is especially true since it is not un-common for transmitter sites to be located in remote areas where utility power is not the most reliable, and physical access to the site can be restricted by weather conditions or other environmental factors. Since almost all the gear used these days is CPU based, a power glitch will end up resetting most equipment used at a transmitter. Most equipment does not reset instantly, and will normally take a minute or two to come back to life. This always seems like an eternity when you are off the air and listeners are dropping like flies! Having a clean source of power available to your mission critical equipment is essential these days. Often it is more economical to provide a single yet redundant UPS System that will be able to provide clean power to all your racks. If your plant has a reliable generator, the battery backup run time on the UPS only needs to be a few minutes in order to allow the generator to come up to full power. Many UPS Units have settings that may need to be fine tuned in order for the UPS to see the "less perfect" generator power as a truly good source so the UPS will not run off batteries during the entire time that the generator is running.

Of course the UPS needs to be maintained from time to time, and during those times the UPS may need to be isolated from the load. In order to do this without going off the air, a properly installed make before break bypass switch needs to be installed to allow the UPS to be bypassed for maintenance or due to a failure. In many cases this type of switch can be purchased through the UPS manufacturer.

In general it is advisable to go to a centralized UPS system if possible. This eliminates the need to monitor and maintain a large number of smaller UPS Units.

TOWER LIGHT MONITORING

The FCC and FAA have recently modernized the rules regarding tower sites. Make sure that the base of the tower and guy wires are secure, and that the tower registration number is displayed prominently not only at the tower base, but at a point that can be easily seen from the street (or a public point) leading to the tower.

Tower light monitoring remains one of the more important rules that the FCC is enforcing. A system must be in place to allow your operators to immediately detect a full or partial failure of the tower lighting system. If your tower lighting system is not operating as specified in the station's authorization, notification to the FAA (through a special toll free number) is required within 30 minutes. Notification is again required when the problem has been resolved and the lights are operating in accordance with the station's license. If you are a tenant on a tower that you do not own, it is generally a good idea to make sure you still have access to tower light telemetry and coordinate with the tower owner or other tenants to make sure there is a plan for notifying the FAA of lighting problems.

CONCLUSIONS

As the broadcasting industry changes both the type of engineer and the type of equipment at the transmitter sites will change. The successful and efficient operator will need to use a combination of traditional good sense and modern tools like those described above to keep ahead of any issues that can be predicted or prevented.

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