Transmission Topics

Line Sweeping

by Gary A. Minker

[LAKE WORTH, Florida - May 2004] OK, so you have been in the broadcasting business all your life and you have "been there, done that and seen it all," right? That is like telling an avid Amateur Radio Licensee that Ham Radio suffers from a lack of new things to do or learn. In this case, let me introduce you to Line Sweeping; it is more than just fault locating.

What is it? What do you do with it? What can you learn from it? What earthly good does it do for you to bother having it done? Questions, questions. So, even if you have been in the R.F. business all your life and you truly are the know all, see all, and tell all, continue reading these next several articles and we will see if we can teach you a thing or two.

WHAT WE USE

Before we can get to the technical part, we need to know something about the equipment that will be used. The most basic of test sets is known as the Time Domain Reflectometer or TDR. This device comes in two basic flavors: half sine pulse and stepped (or square) pulse types. The half sine pulse models are good for telling you whether an object in the line is inductive, capacitive, or just resistive – and it does an A-OK job of telling you where that bump in the line is.

The stepped/square pulse models will tell you the actual impedance of the transmission line, and the impedance of that little anomaly that you just located. The step pulse units tend to be a bit more accurate but both are very commonly used in the practice today. Unfortunately both of these units do not offer testing in the frequency domain and utilize a complex characteristic called the surge impedance of an object which is very much related to a DC response. Frequency sensitive parts all come out testing like big lumps, which is nice if you like your mashed potatoes that way and are only looking to identify "things" in your line.

The big gun of testing is the Vector Network Analyzer with an accompanying "S" parameter test set. This unit comes in only one basic flavor: expensive. Here are two examples of such of units.

This type of analyzer will deliver 14 types of graphs and tell you virtually everything that you could possibly need to know about your system.

LINE SWEEPING BASICS

Let us spend a brief moment on the basics, for those souls that do not have the experiences of a lifetime. Line Sweeping is the art of testing a transmission line (of any kind) and the load (of any kind) for proper operational characteristics as far as the electrical specifications are concerned, covering the absolute impedance as far as 50 j0 Ohms is concerned (which is the theoretically perfect number in a typical 50 Ohm transmission system).

Line Sweeping can also be used for other impedance systems: wave guide, twisted pair, small diameter coaxial cables and every other concentric type of distribution system known on the planet – even open wire feeders for you AM guys. The type of system involved and the operating criteria will dictate the type of testing equipment to be used and the test parameters that need to be utilized. We will talk briefly in this article about the basic types of line testing equipment and the goals for this exercise.

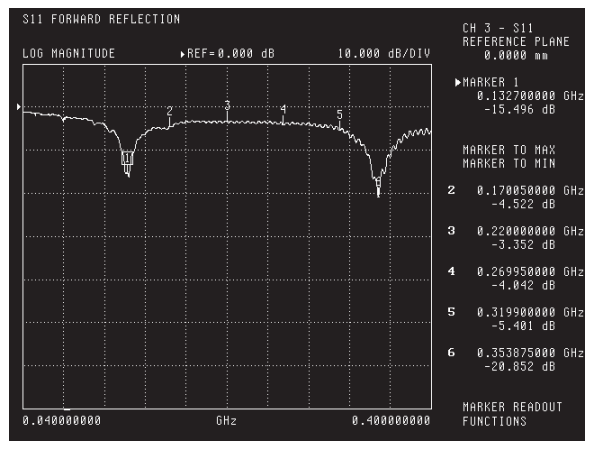
Among the important questions you should ask when considering doing a proper line sweep are:

1. What do I look for in a Contractor?
2. What kind of equipment should he have?
3. Does he have the right kind of equipment?
4. Does he know how to use the equipment?
5. Does he have references?
6. Does he display knowledge about your type of system from experience?
7. What are my responsibilities to this endeavor and how can I make the experience count and maximize the effort on every ones part?
11. What do I know about my own system?
12. Do I have adaptors that might be required to test my system?
13. Will I need to shut down any systems on my tower or other adjacent or co-located systems nearby?
14. What Impedance is my system? (No, that is not a joke question.)

These and many more questions will be touched upon as we move along. We will concentrate our initial focus on coaxial systems.

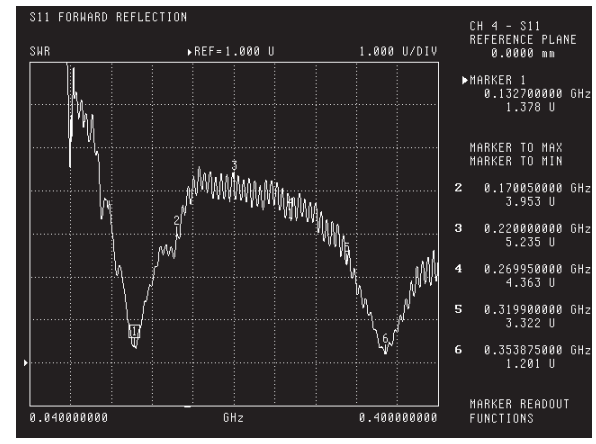
LOOKING AT A SWEEP

In a perfect world a great line sweep will tell you two things: the quality and characteristics of the transmission system in question – and it will do it with four basic types of print outs. The first, the Log Magnitude Return Loss graph, answers "What is my VSWR?"



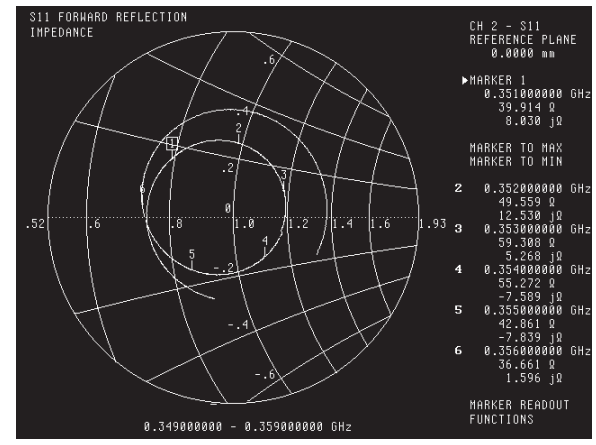
This graph has a scale that runs from 0 dB toward the bottom of the graph with increasingly negative numbers to indicate better responses. You can expect a negative number such as -15.7 dB for a translated VSWR of nominally 1:1.5 – or in English 1.5 to 1. This Log-Mag graph is set up in frequency from lower to higher (left to right) and from the top of the scale being 0 dB or infinite VSWR downward to the better numbers. The bigger the negative number, the better your line. -37 dB is a very nice number.

The next graph will be the simple VSWR graph. This graph is also set up from lower frequency to higher frequency, however unlike the Log-Mag graph, the reference line is at the bottom of the graph.



Excursions toward the top of the graph are bad and amblings around the base line are good. VSWR readings of less that 1:1.1 or (1.1 to 1) are considered good, with typical readings of 1:1.02 being much better.

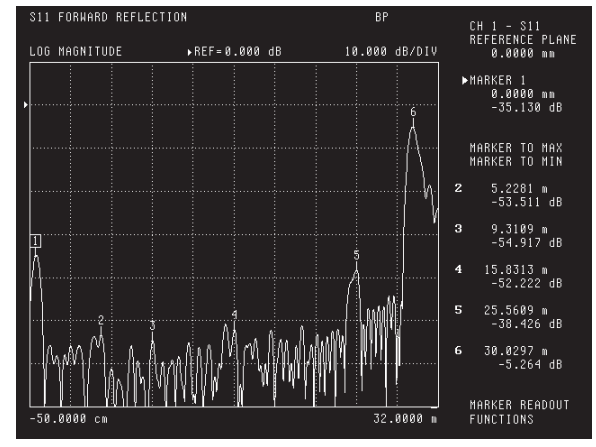
Our third graph is a very technical graph but it will tell you a great many things about your system. This graph is the mysterious Smith chart, displayed in impedance.



The theoretically perfect system will display nothing more than a small dot or very small arc or circle. This small arc or circle will be in the very center of the graph at the region known as 50 j0 Ohms. This graph will tell you the real impedance of the system along with the actual capacitive or inductive reactance.

The fourth Graph is in a Log-Mag format but the lower left to right graph is in distance or in time.

This graph is generically referred to as the TDR or Time Domain graph. This graph will tell you the relative health and return loss of every component in your system both in band and out of band.



It is amazing, with four simple pieces of paper the entire mystery of your antenna system is laid out before you. So, you have these four graphs and hopefully your new friend the line sweeper will be able to answer all of your questions about the system he has just shot. OK, in defense of all line sweepers around the world. We are not clairvoyant. We need some help from you, the system engineer.

(Continued on Page 12)

Transmission Topics

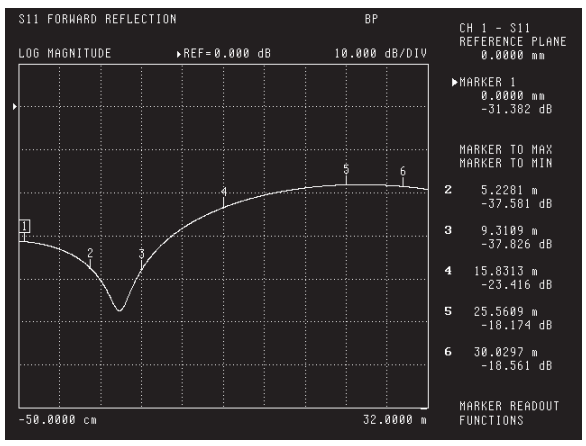
Line Sweeping

Continued from Page 10

UNDERSTANDING THE PICTURE

Your line sweeper will need some input from you to interpret these graphs. The first three are pretty stand-alone but the TDR graph needs some interpretation. If you look at the fourth picture, you will see what is a full line length shot of a small and typical system. The trace is shown in great detail. In order to show this kind of detail, the test equipment needs to be calibrated over about a 400 MHz frequency spread that encompasses the target frequencies as well as adjacent frequencies.

Because you are hitting the system with out of band frequencies, any tuned items such as elbows, adaptors, gas barriers, or antennae will show up very poorly. The idea with this trace is to depict every system component and *then* to determine if it is performing properly or has an in-band response that is in keeping with the impedance of the system. Here is just such a performance trace.



You will notice that it is not well defined but because the trace is "in-band" the tuned objects should behave more appropriately. Traditionally a segmented or sectionalized series of documentation traces are taken of the system in 50 meter segments in order to properly document the components and health of the system. The TDR mode traces shot out-of-band will depict every system component such as slugs and elbows.

The in-band trace will depict the fact that an elbow with a slug in it will now be essentially invisible because it has been optimized. Even the probes on a tuner adjacent to an antenna will all but disappear in favor of the entire tuning unit and accompanying antenna being rendered a single bulge in the trace which should be quite low in return loss or VSWR

Hopefully in this first article you have had a glimpse as to the complexity of the world of your antenna system and that even if you have seen it all, perhaps you will realize that there is a lot to this mystic art. In the next article we will look at why you should have an annual line sweeping session and what you can do with the results.

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Maintenance Guide

by Gary A. Minker

Line Sweeping

Part 2 – Why it is Important

*Last spring (**Radio Guide**, May 2004), Gary Minker briefly explained the concept of line sweeping, and what it can reveal. This month, he returns with a discussion of why a line sweep should be a part of a station's regular maintenance schedule.*

[LAKE WORTH, Florida] If you are truly the curious type and on top of your game, you realize there are many basic questions associated with the great unknowns of the *quality* of your transmission system. Some of them should be gnawing away at your very core on a daily basis.

The reason is simple: No transmission system, no station; no station, no paychecks.

WHAT YOU SHOULD KNOW

When you break it down, the issues are really pretty simple. Most stations have no earthly idea just how good their system is electrically – certainly as far as the Return Loss is concerned – other than the generally poor excuse for a Wattmeter that comes with most transmission systems.

An important starting point is to realize that virtually every wattmeter on the planet has an accuracy of only 20 dB. This means that if you are stuffing 20,000 watts of power up that shiny copper pipe (or aluminum rectangle, for some TV folks), you will be given the gift of a reflected power slug that says "2,000 Watts" on it. In terms of accuracy, it could be likened to measuring seconds with only an hour hand on your watch.

For those of you who never learned to solder big pipes, you should realize that just one or two hundred watts of power, combined in the wrong place with the existing 20,000 watts going the opposite direction, can give you a hot spot that has nothing to do with your laptop logging on to the Internet.

The resulting damage can consume a lot of money, not to mention the potential for lost airtime.

BASE LINE DATA

Why should you perform Line Sweeping at least on an annual or semi-annual basis? The answer should be self-evident. Just like the photographer at the wedding, your last line sweeping certified that the system is healthy *at that point in time.*

You regularly should take a full set of meter readings on the transmitter, and a full set of readings on your wattmeters, noting these readings in the log. That way you have a "base line" record of the readings "when installed" (or last tested), and these readings equal such and such of a Return Loss (which is mathematically calculable to VSWR) and that the system is performing properly.

Any changes in your system performance that deviate from this complicated set of corroborative readings can – and usually do – spell trouble. Defining that trouble is the tricky part, as I found in Atlanta last year at a SBE meeting demonstration test. The host station's backup antenna, which was our demonstration antenna, had iced over and the station had no idea. The return loss was fantastic 1-1/2 channels away, but on-frequency, the transmitter had no prayer of operating without tripping off.

KNOWING WHEN THINGS CHANGE

Most changes in your reflected power are not good. In order to help you diagnose an impending problem more quickly and accurately, I wholeheartedly recommend you discard that 2,000-watt slug and order yourself a pair of 200-watt slugs.

Sure, the Wattmeter Company will pitch a fit and tell you that those slugs are not calibrated, they are not going to be accurate and they will not make you look prettier. But what the manufacturer will not tell you is that the readings will be close and the actual number delivered for reflected power is totally irrelevant!

The fact is they really are a calibrated and matched pair. You should alternate using them at least once per month, if not more often, and when you come to the transmitter to take your daily readings and find the reflected power is different from the day before, you simply put in the alternate slug. If they are *both* elevated, your next phone call should be to your favorite factory or your favorite line sweeper to schedule an overnight outage before it becomes a show-stopping event.

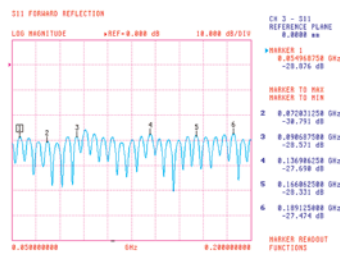

Figure 1: Healthy Return Loss

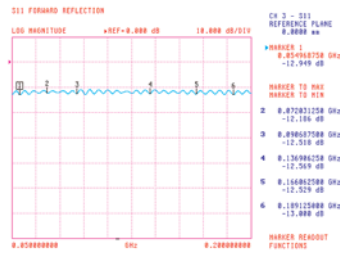

Figure 2: Poor Return Loss

COMPARING THE DATA

In order to have a good grasp on the results of your next planned line sweeping, you should have the report generated by the previous line sweeper on hand. This data is critical to performing an accurate comparison of the system back then and now.

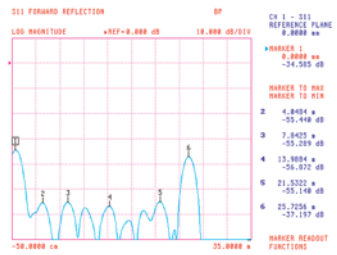

Figure 3: Healthy TDR/FDR

Thinking back to those wedding pictures, perhaps you recall that after the photographer left the party the bride's maids started a food fight. That is just what happened to your transmission system; it was healthy and now it needs some help.

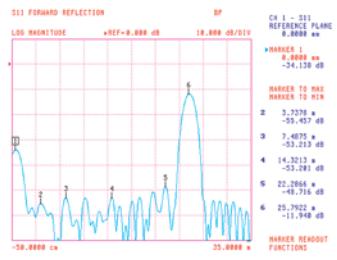

Figure 4: Damaged TDR/FDR

The report data generated during the previous inspection should have a number of critical components in it. This report should be accompanied by the installation drawings of the system and it should be kept at the transmitter site, with a copy kept in the Engineering office.

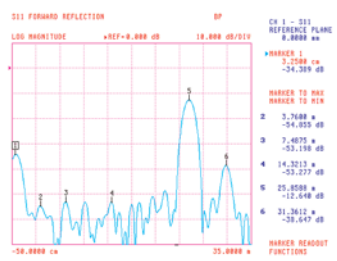

Figure 5: Line Problem Anomaly

Let us take a look at these documents. It is easier than maintaining your public file.

ENGINEERING FILES

Installation Drawings: This document should have a complete parts list for your system. The parts list should contain the total number of every piece of apparatus installed in your system from spring hangers to line segments to elbows and possibly most importantly, where any slugged sections or components are located.

The drawings should give a complete and obviously accurate stick-type drawing of the system from the output of the transmitter to the tippy top of the antenna.

The components for every foot, the distances to them, and the line section parts count, and if there are cut or custom fabricated pieces involved, the line-section parts count should be included. With this drawing and data sheet grouping from the installation of the system, your line sweeper can make informed decisions about the results of the tests that he is about to perform.

The Line Sweep: The two basic trace tests that you will need are the Return Loss graph taken in Log Mag, and the system TDR or Time Domain Reflectometer test. The Log Mag graph (or if you are more comfortable, you can also print this graph out in VSWR) tells you about the absolute electrical health of the system.

While TDR is the common vernacular, it is more accurately a frequency-driven test developed numerically by the analyzer as a result of looking at the swept frequency applied to the system within prescribed bandwidth parameters, and analyzed in the time mode to ascertain the location in linear distance of each component in the system and how each of these components reacts to the frequencies applied to them.

Sometimes this test will be called FDR. In a down and dirty system test, the TDR or FDR could consist of only one trace that encompasses the entire system from input to the top of the antenna. But this is not sufficient.

You should be presented with a full system trace and "zoomed-in views" of the specific areas of interest such as the input complex connections and switches, suspect anomalies located in the testing, upper area complexes, confirmation of slugged component locations and any other points of interest.

I like to see these points developed by shooting the system in TDR/FDR in 50-meter segments. Fifty meters is a good slice to bring out the system components, without taking a chance of missing some small hidden item such as a dent or that chance drywall screw.

Hopefully when your line sweeping event is completed, you will have a report that makes sense and agrees with the one done previously. If there are discrepancies of any kind, an attempt to replicate that previous testing set up should be made to insure there was no procedural or special circumstance that gave the differing results.

SAMPLE TRACES AND ANALYSIS

Some examples of before and after traces are shown here. In **Figure 1** there is a Return Loss graph in Log Mag that shows a healthy system. **Figure 2** shows a failure of the system as evidenced by the poor Return Loss.

Figure 3 is the TDR/FDR trace of the healthy system and **Figure 4** shows the TDR/FDR graph of the damaged system. In this example, the failure was in the antenna itself. The contrast is shown by the good return loss at the end of the TDR/FDR graph (in **Figure 3**) and the poor return loss at the end of the graph in **Figure 4**.

Now, let us contrast this antenna failure with a line failure. **Figure 1** is used again and shows the healthy graph in Log Mag and **Figure 2** once again shows the poor Return Loss of the damaged system. The difference is shown by comparing the TDR/FDR of the healthy system in **Figure 3** with the one from **Figure 5**, which clearly shows the anomaly of the problem in the line itself.

As you can see with these five traces, you can have the *same* poor return loss result generated by two *different* types of failures.

UNDERSTANDING THE SYSTEM

This is where interpretive skills are greatly aided by having the complete installation drawings available for your line sweeper. With these drawings he can determine if that nifty spike in your line is a point of suspicion or a slugged component. It is a waste of time, money and embarrassment to have a crew go up the tower, only to find that the spike in the system is just a slugged line section, installed while no one was looking, to try to solve some other problem in the installation.

Please remember that your line sweeper put his crystal ball in the shop about the same time you did, and neither of you is going to get it back any time soon. Your help can dramatically assist your line sweeper in providing you a quick and accurate diagnosis of a system problem, or – we hope – more pleasantly, a very clean bill of health.

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Maintenance Guide

by Gary A. Minker

Line Sweeping

Part 3: When Should You Do It?

[LAKE WORTH, Florida] Be honest now; the Managing Engineer of any transmission system should know the answer. The previous two articles (**Radio Guide** May 2004/February 2005) should have given you the really big clues.

Answer 1: Annually or at least semi-annual line sweeping sessions often will warn you of any impending problems that could affect your system, provided they are the slow growing type due to age and not some EMP related nuclear event like a lightning strike.

Answer 2: Whenever the last set of corroborative transmitter readings, your most recent line sweep results, and your eagle eye on your reflectometer tell you: "Houston, we have a problem."

From lecturing around the country on this topic, I know some of you are sitting there saying: "I've been in this business since I had lunch with Marconi and I know when I'm in trouble." Good for you. But some of the guys out there do need a little help.

ANALYZING THE SITUATION

Consider some of the trouble signs: Does your Wattmeter do the Watusi with varying modulation levels or black levels? Do your ammeters wander inappropriately? Does your reflectometer dance? Do you have a new ghost in your recovered in-line sampled video? Did your stereo separation suddenly go south? Are you having trouble making AM synchronous noise specs? Is your DTV signal "invisible?"

And then there is the really big one: did someone call you, and ask you when you added a little red light at the top of your tower when you just finished installing that new white strobe system?

Yes, these are dramatic examples, but I see them every day.

Fortunately just like backing up your computer (you do, right?), you have the copy of your last line sweeping event and can make an informed decision to bring in an inspection crew and your favorite Line Sweeper before your suspicions turn in to an expensive unplanned outage.

The technical symptoms that can arise may be subtle at first. Diligence and accurate monitoring equipment are your closest allies here. The subtle changes are the tough ones. Seasonal changes having to do with temperature and icing, small flying creatures living inside the antenna or radome en masse, or humidity are often tough to see coming.

Slow growing problems like bullet connections and other joint issues can be insidious. On the other hand, a sudden loss of pressure, or the confirmation that you used to flow 0.2 cubic feet per hour up the pipe and *now* you are flowing 2 cubic feet per hour, is a much more sure sign that something is amiss.

DECISION TIME

You have choices at this point. You may see the need to be proactive, or you could dawdle, allowing a cost cutting issue to become a seriously sore point between you and your Manager and ending up as an expensive reactive issue. Yes, I *am* trying to get your attention!

There is a patent out there for a Transmission Line Safety Monitor that claims to be able to observe a line failure before it becomes a reactionary event, but like the 100 mpg carburetor, it is not on the market. So you need to really have your decision-making wits about you and decide to be proactive.

GOING INTO ACTION

I do not know about you, but I would rather a problem in my plant be anything except the antenna system. Referring back to the graphical Time Domain Reflectometer traces from last month, you can see the line sweeping event you just called for can reveal many issues for you.

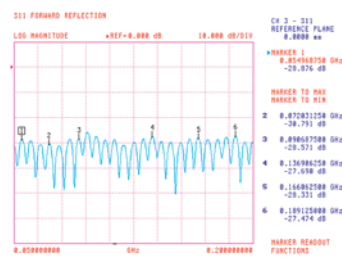

Figure 1: Healthy Return Loss

In **Figure 1**, we see a return loss trace shot in Log Mag that gives the warm fuzzy feeling of a great antenna system with the average return loss hovering around 30 dBm.

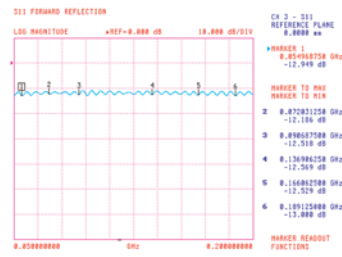

Figure 2: Poor Return Loss

This translates out to a nominal 1.05:1 VSWR. This is a great return loss in just about any arena. Your problem would be located somewhere else in your system. Perhaps a simple metering error.

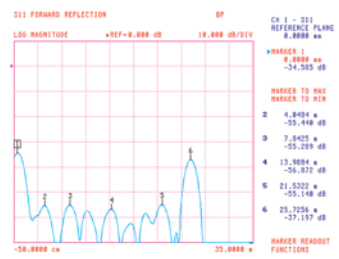

Figure 3: Healthy TDR/FDR

Figure 2 unfortunately confirms your worst suspicions. You have a transmission system failure and the Wattmeter, though usually not a clear indicator, comes through in this case.

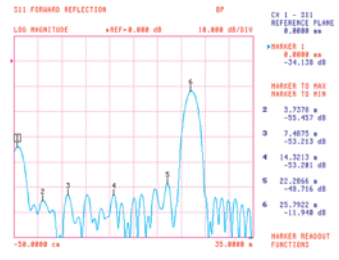

Figure 4: Damaged TDR/FDR

Veterans of this industry can attest to the fact that a charcoal briquette that used to be your flange 17 bullet can handle tens of thousands of Watts before it gets to be an issue that the Wattmeter will ever see.

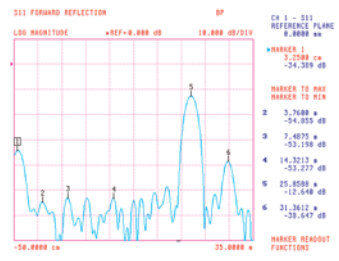

Figure 5: Line Problem Anomaly

Now, where is this pesky problem? You have 2,000 feet of line and a 12-ton pylon up there. Some tower crews will have you just break the line open here and there, take a whiff and – providing the accompanying air leak has not migrated all that soot, smoke and toxic fluorine gas out some gaping hole – look for charcoal parts.

I do need to add a note here and state that anyone who opens up a transmission line for no good reason (i.e., there was no problem at that location) will probably create one for the future. In short, do not just open your line whereever and whenever you want.

LOCATING THE PROBLEM

I defer to **Figure 3**, which pops out of the Vector Network Analyzer, operated by someone in whom you have faith. This is the TDR trace of a healthy line. Coupled with **Figure 1**, **Figure 3** will be telling you that the problem is not in the transmission system. A good input-coupled connection along with a good-looking load usually equal **Figure 1**. Today is not your lucky day. You are the proud owner of **Figure 2**, which is the *very* poor fire-prone return loss.

Now you have a sinking knowledge that your upper complex or your antenna has bit the dust. It is time to get a crew up the tower with a mating reducer to N-type female and a precision load, remove the last element of the complex and cap the line. Whew, what a relief, the return loss trace settles in again to look something like **Figure 1**. A cry of joy rings through the room, until it suddenly dawns on you that if the line is fine, the 12-ton pylon is the culprit; your next 60 days look pretty bleak.

A DIFFERENT OUTCOME

OK, let us change things a bit, and make the news better. You are the unhappy recipient of the poor result trace of **Figure 2**. The TDR/FDR trace that pops out of the Vector Network Analyzer looks like the one in **Figure 5**. Up the tower goes the crew armed with the reducer and load. Off comes the complex and on goes the cap. The return loss in **Figure 2** changes just a skosh but essentially stays the same. The TDR trace of **Figure 5** stays essentially the same.

In this scenario, you can breath a sigh of relief, realizing the pylon is fine and you just lost a bullet – or perhaps you found the one your neighbor just shot at you. At this point whether it is an age failure or a simple case of lead poisoning, the rest is no big deal: two inners, a bullet, an "O" ring and some new bolts, perhaps an outer, and silicon grease for parts. Do a serious disassembly session to wipe out any resulting soot, and you are back in business on your terms, for minimal monies and as a planned outage.

Congratulations, you are a hero.

Looking back to the thrust of this article, ask yourself again: "When should I Line Sweep?" The answer is easy to justify. Data is good. You can reassure your Manager that *more* data is better, and now that you made a potentially devastating and expensive problem into a cheap and managed one, no one will argue this point with you ever again.

That is a much better outcome than your manager finding you with a deer-in-the-headlights look when you are off the air and that extra little red light is flickering at the 3/4 elevation of the tower.

LEARNING FROM THE DATA

Just like learning how to read schematics, it is not too difficult to gain some ability to interpret the graphical traces from the Network Analyzer. It is important to be familiar with these graphs; the interaction between you and the Line Sweeper is critical.

It is not sufficient in this case to simply leave the driving to the technician, and stand and smile when he points to various markers on the screen and attempts to tell you what is going on here. As Managing Engineer or Chief Engineer, you need to have this informed interaction with the technician in order to promote efficiency in the diagnostic and repair process.

There are many great primer books on these theories that are available from the NAB and the Amateur Radio Relay League. Some of the information is petty rudimentary, but the notes will get you thinking. This new information, added to the before and after traces provided by your Line Sweeper, you can add a new item to your list of skills.

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Maintenance Guide

by Gary Minker

Line Sweeping

Part 4: Selecting a Line Sweeper

We continue our series on Line Sweeping with some helpful information on how to find and choose a line sweeper

[LAKE WORTH, Florida] Today is the day. You realize you need to employ the services of a Line Sweeping diagnostic professional. Now that you have crossed that line of indecision, you are faced with the task of selecting the right person for the job.

Sure, you can run to the factory of your choice (probably the manufacturer of your particular system, provided that you bought the entire thing from the same company) or you can go the third party route. There is merit in both choices. Let's talk about the pros and cons.

LOCATING A LINE SWEEPER

This is a terrifying and wondrous thing. If you have a monolithic system such as all Brand "D" antennae components and Brand "D" line as opposed to a Hatfield and McCoy set up, you can certainly call that provider.

They should have a ready trained group of people who either work directly for them in the plant and look at these things every day (and eat them for lunch and dinner), or they should employ predictably reliable independent contractors that are just as familiar with the products that the manufacturer builds, but have the advantage of seeing the *real world* failures and successes.

The advantages of the factory personnel are that many of the little nuances of the assembly and R&D issues are often tightly held and such information rarely gets circulated out to the field. Little things like the understandings of manufacturing glitches, tuning or slugging of components, assembly and re-assembly (which is important during a re-hab), test range behaviors and other esoteric issues are sometimes distant to the outsiders.

The advantages of having outside contractors who are groomed and supported by a particular factory include the advantage of their having seen the products in actual use – including (fortunately or unfortunately) in their failure modes. The latter is a scenario that factory personnel rarely get to experience. In essence, there is no clear-cut reason to give your favorite factory a call.

On the other hand, as the good book of knowledge says, you can call your "factory familiar and often relationship related" independent Line Sweeping professional contractor. These independents are often well equipped with the latest and greatest test equipment because they like to present themselves and their abilities as on a par with the factory folks.

You have heard it said that the underdog has to be better than ordinary because the market requires this for recognition. Sure, it is true that in some cases the factory guy might literally get away with "antennacide" (no slander intended), while the independent is only as good as his last fix-it episode. While this may be an industry faux pas, it is human nature nonetheless.

FACTORING THE CHOICE

Like any other professional who yields to the term "practice," the Line Sweeper is a rare breed. Some climb, most do not. Some have an electronic background; others do not.

Here are some random issues to think about. Is your candidate *(not the company)* an Amateur Radio Operator – and if so, what Class? Does he come from an electronic background? Is he familiar with grounding techniques? Has he met Marconi? Has he ever worked a solder sucker, manual or electric? Is he mechanical?

Is this a long-term career or his third retirement from the insurance business? How long has he been working with antennae or filters and transmission line? How many systems has he tuned up? How long has he been driving the piece of test apparatus that he brought? Does he keep referring to the manual and staring into the screen wondering what that little bump means?

Does he understand the forensics of line and system failures? Is he able to determine from the forensic data if the chicken or the egg caused your fire? Is he familiar with rigging and lifting? Does he climb? Will he suit up and go up in the elevator? Is he afraid of heights or the dark? Does he work well with the tower crew (if you have or need one).

I hope you get the picture here. Selecting the right guy is tough. If you are asking for factory assistance you should ask these questions and *not* accept the stock answer that "this is our guy, and you can just about take him or forget it." My first thought is to not just hang up quickly but run as fast as you can for the list of other competent folks in the business.

THE RIGHT TOOLS

While these are just the human aspect questions, you should also be asking what he uses to diagnose the deal with. Is it a big battery, capacitor and fast oscilloscope (for you olde timers), a bridge and tracking generator with separate TDR, or a smallish handheld device from a large Japanese manufacturer.

Or does he bring a real piece of test equipment called a Vector Network Analyzer. Yes sir, you have got to use the right words and ask the right questions or you are going to get whatever you are going to get. And it might not be pretty in the end

WHAT IT WILL COST

This is purely hearsay: I hear that the range of charges is a hodgepodge of costs, charges, percentages, burden fees, shipping and insurance numbers.

Your charges may include some or all of these little numbers: Daily rates run from $800 to $1,500 per day. Some have travel or mobilization charges from $200 to $500 per day to go and come from the barn.

Then sometimes there are extra per-man charges or add-ons of $300 to $700 per day. Expenses are often billed at the cost plus 15 to 20 percent. There is sometimes a Per Diem cost per guy. Shipping of test equipment is extra and sometimes there are insurance charges. And do not even think of what it takes to work out of country or off shore.

All work should include at least two copies of the work in a printed or electronic report. The report should include graphical print outs and a letter from your guy as to what went down and why it happened that way, along with a blessing of good health and long life – at least until he hits the door.

As I have said before, your Line Sweeper is the wedding photographer. He takes the pretty pictures and then the food fight starts.

GETTING GOOD DATA AND REPORT

One hopes that after the grilling and inquisition of the selection, your Line Sweeper will arrive and his performance will give you the confidence in his presentation that you desire.

It is important that he has a positive interaction with you and his dialog is tempered to your speed and level of understanding.

You deserve a satisfying experience. It is not a good sign if the answers to your questions do not make sense to you. It is equally a bad sign if, when problems arise, the sweeper is back to reading the manual of operations for the test apparatus or the source of a good many strange sounds begin emanating from the guy.

When your report arrives, the first thing to do is to check it carefully to make sure it is neat and orderly. Is it really *your* system and data? (Yes, I have seen that one!). Is there sufficient data in the printouts and in the letter to allow a subsequent Line Sweeper (or heaven forbid, the same guy) to come back and perform your testing again a year later?

Every report should include graphical data. Tabular data or endless columns of numbers are for the really retentive and do not give a good picture of the Return Loss of the system.

In all cases the printed graphs should be in Return Loss/dB, Time/Frequency Domain, and VSWR. In some cases you might be able to wangle a Smith or Polar chart from your Sweeper, too.

I know all of this sounds a bit like selecting your family physician, but in some respects, it really is the same thing. You need to develop a relationship that you are comfortable with and – unfortunately because people change – you need to be wary of future problems even with the same guy.

HOW GOOD IS GOOD?

When you analyze the data, the Line Sweeper should be able to help you put it all in the proper perspective so that you can use the data confidently. You need to be able to trust his judgment as to what is acceptable and what is not acceptable.

For example, in analyzing the VSWR report, the acceptable numbers can vary from FM to TV, but the answer is 1.05:1 is a wonderful number. Where VSWR comes into play, you have to remember that a 25-watt soldering iron in the right place will cause some significant damage if left to play long enough.

Take care, though. There is a wide range of opinions out there from the old school to the new, and in discrepancies from the analog theories to digital.

Here is some conventional wisdom from which you should draw a conclusion. Listen carefully, and question any statement you do not understand. Some very misleading things can be "tossed" at you. "Sure, anything that radiates 98% of the RF is great." "VSWR is not important in analog." "VSWR is not important in digital."

Why then, did SCSI cabling require a terminator for the end of line? Why then, did Lan/ThinNet require that neat little 50 Ohm precision termination at the end of the line? Why do the PCS industry construction specs require the 1.8 GHz systems to have an aggregate return loss of greater than 24dB and connector values in Time Domain of 30 dB or better?

Are you confused yet? Weigh all the answers and ask more questions. You will be glad that you did.

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Maintenance Guide

By Gary Minker

Part 5: Planning to Benefit from Line Sweeping

[LAKE WORTH, Florida] Some engineers have recognized the value of sweeping their antenna system, turning such testing into an annual budget item instead of an unplanned event.

However, there still is a political mine field to navigate: the dreaded memo from Mr. Personality. And he wants to know the answers to the tough questions.

1. Why is this low number good and what is this 1.006:1 VSWR all about?

2. Do you know how to read the report that you will get?

3. Has this been done here before and where is that report?

4. Other than the Line Sweeper, do we have to have any other contractors?

5. How long will we be off the air and will it happen again?

6. Did your crystal ball come back from the shop yet?

7. What are you going to do with this report?

You start to think the list will never stop but fortunately it does.

JUSTIFYING THE DECISION

By preparing, you can give your good friend in the front office an ear full. Sure, he is justifiably concerned about spending budgeted or un-budgeted funds for something that he does not understand. But the goal is to make sure Mr. Manager realizes Engineering is actually revenue producing and not revenue draining, and that you and your department are every bit as valuable as his prized herd of sales suits.

There are many approaches, but here is one suggestion: unless Mr. M. is technically inclined, just forget the jargon and explain why the antenna is more than a metal object d'arte hanging on the tower.

Just like a car needs to be checked out regularly to prevent overheating, for example, the same applies to that hunk of metal radiating thousands and thousands of watts. You may use some jargon ("here are the numbers on the Return Loss or VSWR Voltage to Standing Wave Ratio"), but be sure to focus on need to prevent "extra tower light syndrome," where the antenna appears as a small ("small" from 1,000 feet below) fire due to system deterioration.

Even more simply put: "High sales number good, Low return loss and VSWR numbers good, fire in antenna bad."

DETAILS

Of course you can tell him all the details from the report and what all the little wrinkles mean because your Line Sweeper (will take) took the time during the event to explain them to you; the material in the NAB Engineering Handbook also helps put the current inspection (and previous ones, if they were done) in proper perspective.

The other contractor question is a simple answer. If you are performing Line Sweeping as a maintenance issue you can justify a tower crew for the physical inspection very easily. Just tell Mr. M. it is imperative the antenna be visually inspected for damage, burns, lightning marks, loose or missing hardware, air leaks, bird dirt, salt crystals or other dusty minerals that corrupt the insulators when wet, and mechanical integrity to make sure that it is not going to fall off the tower and dent something.

And then take a deep breath.

ANOTHER BENEFIT

By planning ahead and having the tower folks on site, you only take the station down for one evening. If you find anything "funny" electrically, or there actually is a mechanical problem, they can make everyone a hero by identifying those problems and quite possibly even fixing them on the spot.

Even if more has to be done, you can plan the next outage instead waiting for the dreaded 2:00 AM phone call reporting "the field is on fire from flaming molten antenna parts dripping onto the dry grass."

All in all, here is hoping your visual inspection is clear and the photographs taken of the entire system are very boring; may your Return Loss, Time Domain, VSWR and Smith charts be flat like a mackerel.

USING THE DATA, LOOKING AHEAD

Now that Mr. M. is a happy camper, it is your turn. Keep your department is his good graces (as well as at the home office) by justifying the money spent on this dreaded maintenance. Set up a plan.

You need to lay hands (yours or your contractors') on everything at least one time per year, including the antenna and tower. Although the FCC only mandates that you inspect your lights quarterly for integrity and daily for proper operation, sleeping well at night comes from knowing there is nothing in your entire physical plant that has gone un-inspected for over a year at a time.

Anything that you cannot easily walk up to and touch should have its picture taken in detail (preferably in the daylight) but you "do what you gotta do." The word tower includes everything from the paint to the guy anchor foundations.

By the way, the word "guy wire" not "guide" wire, or the phrase "I have guide wires on my tower." Every time I see that I cringe, so please repeat after me: "I have guywires on my tower; I have a guyed tower." Thanks, I feel better now.

DOCUMENT IT ALL

Over and over again, you hear engineers preaching about documentation. Get as much as you can down on paper, even if you plan to be at the same job next year. After all, memories fade. Or, just remember this: while you are cursing your predecessor for not leaving you great records, is your successor at your last station saying the same things about you?

Regarding line sweeping, let us recap a bit about what should be in the report. Your report from the sweeper should contain some critical printed graphical data (see **Radio Guide**, March 2005, page 18). These graphs should include, Return Loss in Log Mag/dBm scale, Time Domain in linear distance (not useless "time in nanoseconds"), VSWR (which is electrically calculable from the Return Loss but easier for some people to read), and a Smith chart.

These four graphs provide a very concise view of the electrical health of the antenna. Return Loss and VSWR are the measurement of how much energy goes out to the world and how little of it comes back to you down the pipe to confuse your transmitter, and in the land of video make ghosts or no digital pictures.

Add to this your pictures of the antenna and its mounting, the tower condition, and any other data that helps show the status of the transmission system as a "snapshot in time." The combined report should be in your office and at the transmitter site itself.

WHY THIS IS IMPORTANT

In FM, high reflected power can louse up your stereo separation, warble like a birdie, cause synchronous AM noise, give poor tube life and of course cause the obvious system fire. (In NTSC TV, high reflected power can cause the usual FM problems for the audio and cause ghosts, poor color, or in digital, corrupt your data to the point that all the adaptive error correction in the world will not give the viewer a picture to watch.)

You might remember in the days of SCSI and Thin Net coaxial LAN that the data lines required those little terminations. These terminations helped to insure that the wire medium was as close to 50 Ohms as possible. This insured that the system VSWR was low enough so no aberrant reflections existed, so that there were no electrical collisions in the form of VSWR to corrupt the data.

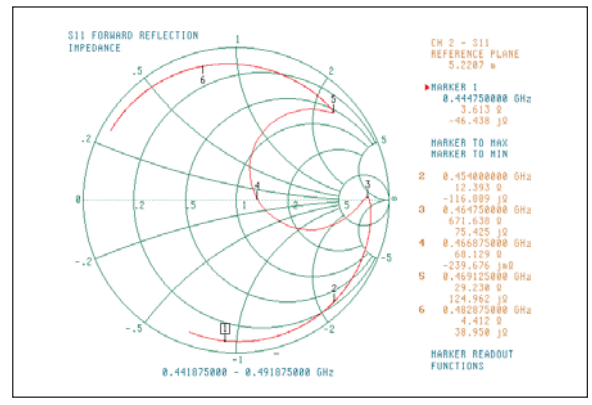
PCS, GPRS and all of the new forms of digital over-the-air services all require system return losses of better than -24 dBm. This is a real stretch in the world of RF communications considering that most manufacturers only guarantee their antennas to have a Return Loss of about -15 dBm or 1.5:1 – that with connector groupings having a value of greater than -30 dBm to insure the integrity of the data.

It is not that the loss of one or two percent efficiency of radiated power will make or break the signal, it is the corrupted information that the poor Return Loss generates that causes the problems.

Worse, a concentrated extra 100 Watts in a bad place such as a line section joint may – over time – cause super heating like a soldering iron. You know the rest.

TDR DATA

Ideally an antenna should be 50 Ohms j-0. This means that you have a resistivity of 50 Ohms and no reactances of any kind. For the more technically minded, the Smith chart is a round looking chart that has the ability once completed to tell you the actual complex impedance of your antenna system.



Time Domain graphs are actually a throw back from when time Domain Reflectometry was exactly what it said. A determination of the health of a component of the system was "pinged" by a square or half sinusoidal pulse from the TDR and a display would pop up showing the linear location of the parts in a time format. From this machine, you could tell the reactive value of a component to some degree and something about the impedance, but it was far from perfect.

The new TDR work from Vector Network Analyzers such as the Anritsu or other units and are actually frequency swept reflection readings of the same components in the system but the display tells you how they react electrically at the actual operating frequency instead of a pulsed signal. Arguably this difference in what some folks call the surge impedance verses the swept impedance can tell the whole story about your lower elbow and that slug that is in it.

Either way, you now have plenty of background information to embark on your great adventure – getting to know how your antenna system is operating in every detail. We both know that you will sleep better for it.

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Maintenance Guide

by Gary Minker

Line Sweeping as a Cost Effective Maintenance Item

[LAKE WORTH, Florida] There is a nagging question Mr. Three Piece Suit is going to ask you because your engineering budget is an expense to him and not a tool as valuable as the sales staff.

It might even be this is partly your fault.

THE MEMO

TIME: 16:52.47

TO: Chief Fix-It-When-It-Breaks

SUBJECT: Is this Line Sweeping thing you asked for an effective tool as a maintenance item? If so, wasn't it a regular planned for expense as part of your last budget? What are we going to get in return for this *expense*? Let me know by 16:59:59 today or we'll just forget the whole thing, and maybe your department too.

Do you smell the smoke yet? Is it coming from your ears or the front office? You might surmise that there are a couple of problems brewing here.

FAILURE TO COMMUNICATE

In previous articles, we touched on the possibility that you need to be a bit more proactive in your communication with the Suit up front.

In his mind, Engineering usually is not a valuable tool because you geeks sit back there cleaning your pocket protectors, show up when stuff breaks, speak to no one in understandable sentences, and then skulk back to your inner sanctum where all those weird meters and rosin smoke plumes live. This segregates you from the rest of the tribe – and most importantly Mr. Suit.

When you last talked with the guy you should have assured him things such as Line Sweeping *will* be included as a regular expensed Maintenance line item starting next year. Unfortunately, he has conveniently forgotten that thought.

COMMUNICATION NECESSARY

It is critical to consistently – and as kindly as possible – remind the Suit and the rest of the staff that while you and your staff (if it exists) may be different, you are people, too, and your department is a part of the solution and not the problem (unlike those clucks in programming).

However, you still are on the block for the memo. OK, here is the help you need. The question is pretty direct. Is Line Sweeping a cost effective tool as a maintenance item? This is best answered through consideration of the following documentable questions:

1. Did you receive a booklet of proof of performance on your antenna system when it was installed?

2. Why should you save your line sweeping reports?

3. What are the pros and cons of testing; why test?

4. Do you really like to be off the air?

DEVELOPING THE RIGHT RESPONSE

Did you receive a booklet of "proof of performance" data on your antenna system when it was installed?

When your system was built, a data booklet with the system drawings and the factory test data on the antenna at the test range was supplied. (You did have that new antler range-tested, right?) Also attached is the test data from when you installed the system, and the factory or your other favorite Line Sweeper came out and tested the system for you. (You did have it swept when it was installed, right?)

This booklet of data is your system bible and it must be updated like a clean bill of health every year or your job could expire. Mr. Suit needs to know about this very impressive compilation of letters charts and graphs – the EKG of the system – and that without a current report, all bets are off because that nice shiny Watt meter is always the last thing to know that you are having a system problem and the on air jock is the first.

You should try to get Mr. Suit to see that you understand what the report says – in five minutes or less due to GM ADHD deficiencies – and you are really on the ball.

SYSTEM DOCUMENTATION

Why should you save your Line Sweeping Reports?

This is the CYA (cover your "posterior") portion of the drill with Mr. Suit. You were the happy and lucky recipient of a great Line Sweeping adventure when your system was put in 17 years ago, yet you have not had the system tested since then. Mr. Suit wants to know why not – and *why now*?

You could tell him that this was an oversight. Of course, you may well be looking for a job in about five minutes. Or, you can tell him that it is now the industry recommendation that such things be conducted annually.

Alternatively, from your intensive involvement in the new standards, and as part of your self-avowed continuing education, the practice and art of Line Sweeping has come to your attention. Having saved the initial report in the station files, it is high time to have a new one this Sunday night during the maintenance window in order to avoid catastrophic damage from a sudden creeping failure.

BENEFITTING FROM DOCUMENTATION

What are the pros and cons of performing these tests?

This gets easy. First the cons: Without continuing maintenance, things at the transmitter site get really really loud, and then they get really, really quiet.

Indeed, after the fire trucks leave from extinguishing the fire that started in the grassy field and woods next to your tower from the flaming molten metal and plastic shroud parts dripping from your previously good old antenna, the GM will hold you are up for the "silence is golden" award and the ensuing tens of thousands of dollars that the repairs will cost, which will immediately precede your being fired for losing your crystal ball (and your gross negligence and obvious incompetence).

The proactive stance in order to avoid these things is to make the case that the most frequent cause of antenna and line failure is not lightning, but actually the slow and methodical mechanical wear of the bullet joints.

These joints which include the actual fingers themselves and most importantly the watch band springs, wear down and make silver dust which is highly conductive; the now bare joints, which often consist of dissimilar metals of brass, stainless steel, and beryllium/copper, eventually fade to fatal.

This is not what you want to see, but often is the result of maintenance-free operation.

The silver coatings wear off or pit from the thermal expansion and contraction every 24 hours for years at a time and – oops! – you have smoke. This smoke often comes from the high resistances that develop in these bare metal joints from the lack of silver and/or the arc path that develops from the silver and other metals dust that has landed on the next lower insulator in the system.

Line Sweeping can see these joint failures. In many cases you will see the corrupted insulator that the conductive metal dust has landed on or the small carbon path that has started to burn the surface of the next lower insulator. The eventual generation of high heat, smoke and toxic Fluorine gas, which is also highly corrosive, spells the end of anything in the system with which it comes in contact, including your lungs.

What is going on up there?

Line Sweeping will also let you know if your antenna tuning has slipped due to any of a number of problems on the tower. A "favorite" is when some goof mounts another antenna in your aperture without telling you.

Other things that *do* happen: a giant buzzard bends your elements; slot covers rot off and wet minerals splash on the gas barrier face, porcelain insulator/centering pins, and the ensuing arcing in the antenna sets the gas barrier on fire; or the three wraps of magic tape dried out and your slug slipped a few inches.

By bringing in your favorite Line Sweeper you can usually catch these things before they turn in to a problem.

TO AIR OR TO ERR

This one is the family favorite of all time: **Do you really like to be off the air?**

Even with off-the-air insurance and a back up facility, is the expense and grief really worth it if you are burnt to the ground? I have heard of only one instance where the station made out on the insurance claim, otherwise the off-the-air part is pretty bad.

This is where Mr. Suit gets to realistically question your competency and could actually have a point there. As I have said before: there should be no space, thing, place or procedure that you do not touch at least one time per year in your plant. If you blow this point you are up for the Engineering Darwin Award – and face it, rightly so.

SHARING THE CREDIT

All in all, here is where you tactfully turn the tables. It should not be a stretch to get Mr. Suit to agree with you that the idea of Line Sweeping that he just came up with is really a great idea to secure his job, and that you will get right on it.

Even if the reverse psychology does not work with him, he will have to agree with you that in the interest of everyone keeping their jobs this is a necessary expenditure and the station and the owners are best served by the annualization of this activity.

By the way, when all else fails and you truly have problems integrating engineering into the main stream of the station society, designate a readily accessible drawer in your desk (or bowl on the desk) as the community candy drawer and you will be amazed at who drops by for a nice visit and chat.

Be sure it has good stuff in it like chocolate and Gummy Worms. Instill a policy that, "if you take candy, you bring candy" and be prepared to stock it occasionally with more good stuff. Suddenly you and yours will be more popular than the promotions guy or gal!

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