How to Install an Antenna Array for the TrensCenter Telemetry System

...by Tim Bailey

Philosophy of Topology

Installing a medical telemetry system can be difficult, but does not have to be. In fact, the entire procedure can be explained in one sentence:
"The ideal telemetry antenna array is one where each antenna has the same amount of electrical impedance in its pathway back to the receiving station, relative to the other antennas in the array".
How do we achieve this? Well, that is the difficult part. But if you keep repeating this concept over and over like a mantra while you are doing the work, your chances of completing a well performing antenna array will be greatly increased. Every decision you make about the configuration of your antenna array should comply with this general rule.

This article is meant to be a general guideline to installing a medical telemetry array. I will be using some electrical nomenclature, however I will not be going too heavily into explanations of those terms or the electronic theory behind them. I would like to start, by having you look at the following drawing of what I consider to be an ideal antenna array.

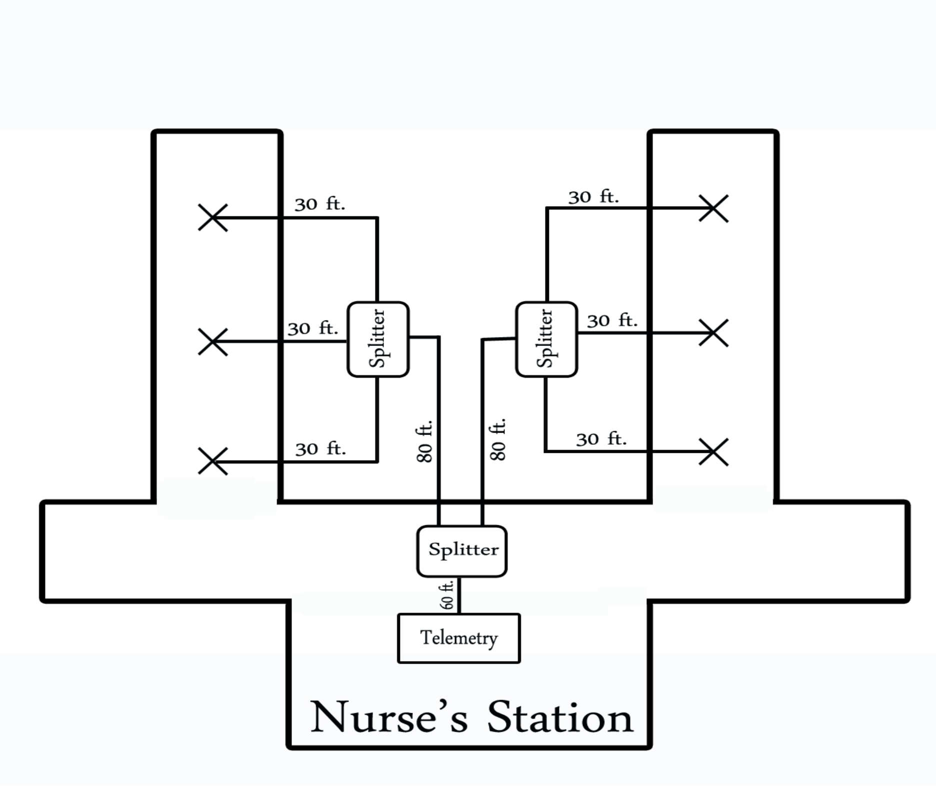

Fig. 1: Note: All cable lengths are the same between the splitters and antennas.
Antenna spacing should be within the range of 25 to 30 feet apart.

Why is this array ideal? Well it isn't, exactly…… A perfect array would have only 2 antennas. Because it takes at least 2 antennas to make an array. This configuration would allow the strongest signal per antenna possible for an array, because each time you add another antenna to an array, you weaken each antenna's ability to receive a signal. Actually, 1 antenna feeding back to the receiver would have the strongest possible signal. But 1 antenna is not an array. And you cannot cover an entire medical facility with just 1, or even 2 antennas. So... we come to our first compromise... We have to distribute multiple antennas throughout the coverage range of the facility, and each antenna has to have the same relative power as seen by the Receiving Station. Take a look at Fig 1. The first thing you will notice is the cable lengths are the same between each antenna to the Receiving Station and the spacing between antennas is 30 ft. You may be saying to yourself, "that's not right", the diagram shows 30 ft lengths here, but over there they are 80 ft., and the cable going to the receiving station is 60 ft. This was done on the diagram intentionally to prove a point. Wire lengths between splitters can be any length, as long as it's companion ports also have the same relative length. Notice the symmetry in the diagram. All wire lengths are the same, that share the same splitter outputs. All the wires feeding the antennas are 30 ft. And the wires that feed each hallway are both 80 ft. Out in the real world, these length values can change dramatically depending on the facility. But as long as you maintain symmetry, your antenna array will remain balanced.

Now lets look closer, and if you will, get a scrap sheet of paper or calculator and start adding together the cable lengths. Starting from one of the antennas, and following its pathway back to the Telemetry Receiving Station. You must always visualize an antenna array like this: "From the Antenna to the Receiving Station", and not the other way round. Remember: The Telemetry Transmitter is your _source of transmission_. It's signal enters the closest antenna and follows its "path of least resistance", to the Telemetry Receiving Station.

Memorize this next sentence: ***"The signal flow path for a telemetry signal is always from the Antenna to the Telemetry Receiving Station".*** With this in mind, lets do the math:

30 ft from Antenna to 3-way splitter.
80 ft from 3-way splitter to 2-way splitter.
60 ft from 2-way splitter to Telemetry Receiving Station
= 170 ft total cable length from the antenna to the Telemetry Receiving Station.

Now, assuming you used the same brand of antennas, cable and splitters, then everything should be the same... electrically speaking, no matter which antenna you start with. *"Everything is perfectly balanced and symmetrical".* And this is what we want in an antenna array. We could have had 4 antennas on each hall instead of 3, but as long as we keep everything in balance we are still alright. We could have had 3 hallways of 4 antennas each, but as long as we keep it in balance and maintain symmetry, we are still alright. That being said, If our antenna array begins to become too large, we should start to consider inserting signal amplification. Which I will briefly explain later. But at this time, I am going to touch on splitters and insertion loss.

Cable, Connectors, and Splitters.

Some of the most popular telemetry systems are based on the WMTS (Wireless Medical Telemetry Services) wavelength in the 600 mhz range. This type of system uses a 75 ohm topology. So it is very important to use components that fit into and comply with this system. The following are the basic components needed to install a successful antenna array.

Cable:

RG-6 *(RG stands for Radio Guide)*…. is a 75 ohm coax cable,(the same type used for cable TV applications) and is what you need for telemetry systems. It comes in many colors and configurations. As far as color is concerned. I like to use whatever color, no one else has used yet. I usually use white, but I am not opposed to using pink with polka dots, if it helps me later when troubleshooting problems and tracing wires. What does matter, is its electrical resistance and impedance. Keep in mind that you will be making very long runs with this cable. The least resistance the better. You will find that some of the cheaper wire has a steel core with a copper coating. This type of cable is not as good and has more resistance than a solid copper core wire. As I will explain later in the amplification part of this document. Sometimes it may be necessary to send a DC Voltage down the RG-6 cable to power "inline amplifiers". Solid Copper cables are the best choice when this type of amplification is employed. Another concept to be aware of is the cable "impedance", which is also a type of resistance that changes with frequency. This vector varies from different cable manufacturers. But is usually somewhere around 5 db per 100 ft in the 600mhz range we are concerned with here.

Connectors:

The main point I want to make here is: Be extremely mindful when installing connectors. Most quality RG-6 cable will have a wire braid shield. Always make sure that the shielding has been trimmed back and is only making contact with the outer collar of your compression connector. **If any of the fine wires that make up the braid come in contact with the center copper conductor, you will have a direct short.** And always use "compression connectors". They won't just come off the cable if someone happens to pull on the cable later. **Never use "Crimp" type connectors! They come off too easily.**

Splitters:

Splitters do exactly what the name implies. They split the signal out into two or more outputs. Notice I used the the term *"outputs"*. This is definitely how splitters are labeled. A 2-way splitter for instance will have 1 input and 2 outputs. But this labeling is not entirely correct. Because most splitters are "bi-directional". Which means that signal flow can go in either direction, Depending on your point of view, an output can be an input, and an input can be a output. And since we are using the paradigm of <u>"signal flow" going from the antenna to the Telemetry Receiver box</u>. Then you will find that the labels on your splitters are labeled

backwards. (Keep in mind that splitters were manufactured to split a single antenna to multiple TV's.) We are doing the reverse of this, by sending multiple antennas to a single Telemetry Receiver. Ok, I hope that clarifies it a bit. Now, lets talk about *"insertion loss"*.
Any time you insert something into the signal chain, there is a loss of signal. How much loss depends on what the component is and how well it is manufactured. I have had arguments with people that claim if you use an inline splice (barrel connector), there is no insertion loss! This belief is flatly wrong. Inserting a barrel connector will require 2 F connectors and 1 barrel connector. Each of these 3 components adds resistance to the circuit. Therefore, inserting a barrel connector will have an "insertion loss" equal to the sum of the 3 component's resistance. But thankfully, this loss is negligible. Usually less than 1db. I bring it up here to make the point, there is always a cost in signal when something is inserted inline. Even an amplifier has insertion loss at it's input. But it more than makes up for it with the amplification it provides. The insertion loss is transferred to a slightly higher noise floor seen at the output. Splitters have a "insertion loss" that differs from different manufacturers. But is usually about 1 db. Splitters also lose about 3db of signal for each doubling of outputs. For example, a 2- way splitter has a 3db drop in signal at each output because the signal outputs have doubled.
A 4-way splitter has doubled the outputs yet again. Therefore, a 4-way splitter will have a loss of 6 db at each output port. But wait….. it gets worse…….. as stated earlier there is "insertion loss" . The total loss is usually around 3.5 db loss for a 2-way splitter and 7db loss for a 4-way splitter due to insertion loss. So I hope you are beginning to see that the more you start to expand your array, the need for amplification becomes necessary. One last thing about splitters, **it is very important that your splitters have the ability to "Pass DC Voltage".**
And you should know the difference between "splitters" and "diplexers" They look very similar, but they do not work the same way. I once spent almost two hours troubleshooting an antenna array. The problem was someone had installed a "diplexer" instead of a splitter.
"When in doubt, read the packaging".

Amplification:

As an antenna array becomes larger and more complex, it becomes a necessity to use some sort of amplification. The type of amplification system that is most effective and introduces the smallest amount of "noise" into the signal chain, is the inline amplifier. I refer specifically to the *"Winegard System of Telemetry Products."* In order for this system to work, a 24 volt DC voltage is inserted at the Telemetry Receiver's end and is sent across the RG-6 cable to the amplifiers for power. This is why it is important that your RG-6 cable be high-quality and have a low DC resistance. **Also all splitters must "pass DC voltage".** Just one splitter that does not pass DC can ruin an installation!
Let's discuss where we will put our inline Amps. The philosophy associated with inline amps, is to put them as close to the antennas as possible. The reason for this can be described as "pre-emphasis". We are amplifying the signal before it encounters all the signal degradation components in it's path back to the Telemetry Receiver. This technique will greatly reduce the signal to noise ratio when it finally makes it's way back to the receiver. I have seen some installers put an amplifier after each antenna. This is overkill, and extremely expensive. It also puts a huge load on the Power Supply and the effective voltage drop from all the amplifiers will result in not enough power to send to the amplifiers. Fortunately there is a cheaper and more effective way to do this. If you put the insertion point of the amplifiers right after the

splitters that feed the antennas. If you refer to Fig 1. ”our ideal array”, the amplifier would be inserted at the 3-way splitter between the splitter and the 80 ft. run that leads back to the 2-way splitter. If fact you will have to install 2 amps. One on each hallway to keep everything symmetrically balanced.

Using this paradigm makes an easy installation. What I like to do is complete all the wiring and save the amplification till the very last. If you have followed the rules so far, this is easily accomplished. Because inline amps can easily be inserted after the splitters. I like to finish the array and test it passively (without amplification). You can’t test for shorts or open lines with the amps installed inline anyway! So after everything checks out passively, I go back and insert the amps. If you have a short, find it and fix it before you plug in the power. Failure to do so will cause the power supply to fail. **Do not plug up the Power Supply or apply power till last! Never work on a powered line! Don’t unscrew anything! Don’t cut any wires! Don’t do anything to the system until you have unplugged the power supply!** This is a very important rule, because you can’t undo some mistakes. And this is most certainly one. As long as you have tested for shorts on the passive system then you should be good to go when you plug in and make the system actively amplified.

What Not to Do.

I would like to close this document with examples of antenna topologies I have seen in the field that clearly just won’t work for telemetry. I will take a more simplified approach using a single hallway and only 3 antennas for these demonstrations.

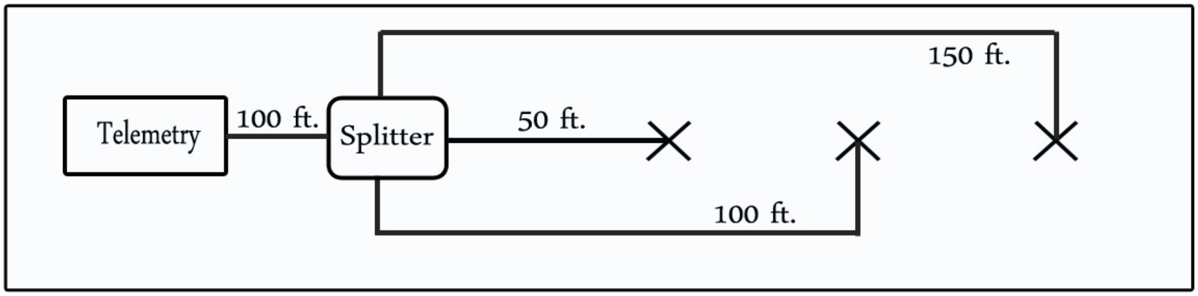

Fig. 2: This topology is the most commonly found non-performing antenna arrays.

Take a look at Fig 2. and right away you can see that it is unbalanced and non-symmetrical. Lets start by adding up the total cable lengths of each antenna’s signal path.

Antenna 1: 50 + 100 = 150 ft. (Best Reception)
Antenna 2: 100 + 100 = 200 ft. (2nd Best Reception)
Antenna 3: 150 + 100 = 250 ft. (Worst Reception)

Can you guess how this antenna array will perform. The answer is: Any transmitter close to Antenna 1 will have the strongest signal because it has the path of least resistance. Antenna 2 will suffer and have less signal strength due to the increased cable resistance. Antenna 3 will have the worst signal strength because it has the most cable resistance of the three. If you keep adding antennas using this paradigm the problems keep compounding. I hope you are beginning to see why this topology should be avoided. Now lets take a look at another common topology mistake.

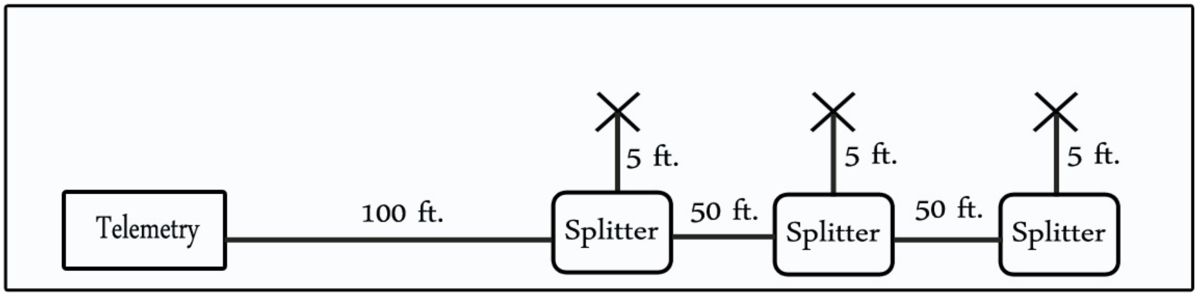

Fig. 3: This topology is very bad because each splitter halves the available signal.

We discussed earlier in the section on splitters and "insertion loss", that a 2-way splitter will effectively half the available signal, which equals about a 3.5 db drop in signal. So taking this into consideration, lets look at what is going on in Fig. 3 . For simplicity's sake, let's ignore the 100 ft of cable connecting the telemetry receiver to the first splitter. This 100 ft of cable is seen equally by all of the antennas in the circuit. So it can effectively be taken out of the equation as a variable. This will allow us to focus on the real problem . Which is using a succession of one splitter per antenna combinations connected in series. Because each splitter drops the signal 3.5db, this problem compounds itself the more splitters you connect in series. And the signal strength gets worse, the further we get from the Telemetry Receiving station. Let's add up the db loss for each antenna. We can also ignore the 5 ft pigtail that feeds each antenna because it's resistance is negligible and it is also seen by each antenna. We will only concentrate here on the variables.

Antenna 1: There is only one splitter in line to Antenna 1 so the loss is 3.5db. So Antenna 1 will receive the best signal.

Antenna 2: There are 2 splitters inline with a loss of 3.5 db. each and a 50 ft. interconnect cable with a loss of about 2.5 db. So the loss at Antenna 2 is around 9.5 db . (3.5 + 3.5 + 2.5 = 9.5) The losses are starting to add up. So antenna 2 will have the 2nd best signal.

Antenna 3: There are 3 splitters inline with a loss of 3.5 each and 2 - 50 ft interconnect cables with a loss of about 2.5 db each. So the loss at Antenna 3 is around 15.5 db. (3.5 + 3.5 + 3.5 + 2.5 + 2.5 = 15.5) Now the losses are getting really bad. So antenna 3 will have the worst signal of the three.

It should be obvious that this topology is unbalanced and non-symmetrical and should not be a consideration when designing an antenna array. That being said, there is a way to use this topology if you substitute the splitters for "low insertion taps" . Taps use attenuators that allow most of the signal to continue downstream through the trunk cable. But to design an array using taps requires detailed planning because the attenuation value of each tap must change the further downstream a tap is placed. Taps are also more expensive. And for these reasons they should not be used for a telemetry antenna array. I only bring it up here because it's topology is very similar to Fig 3 .

Conclusion

I conclusion, I hope the information provided here can help you complete a successful and well functioning telemetry array.