Tower Top Amplifier Advantages and Limitations

By Cheryl Hornberger
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The purpose of a tower top amplifier (TTA) is to improve receiver sensitivity at a site by compensating for the loss of the coaxial cable that connects the receive antenna to the system. This increase in sensitivity can make up for the imbalance between mobile and handheld users in critical systems. The TTA generally consists of a TTX box and A CMU (control monitoring unit) or a multicoupler unit.

Many believe that TTA's can solve a variety of issues at any given site. This is not the case for many circumstances and here are some reasons why.

One misconception of using a TTA is thinking that it will improve an already noisy site. Using a TTA, at a noisy site, will only amplify the noise and will result in more interference in the receiver. Less site noise yields better system sensitivity, which means the receiver will be able to pick up a lower level signal.

The main purpose of the TTA is to compensate for the loss of the feedline that runs down the tower. The amplifier in the TTA, amplifies the weak signal that is received before it enters the lossy feedline. A TTA is more prevalent up at 700/800MHz since the transmission line losses are higher at 700/800MHz than at lower bands. A TTA will not improve sensitivity, other than reducing the effects of the line loss. This is why it doesn't usually have any benefit to use a TTA down at VHF/UHF.

The noise floor at the site should be measured to help determine if adding a TTA will provide the increase in system sensitivity that is desired. Once measured, you should ask yourself if the increase in system sensitivity is worth the added price of the TTA. The sensitivity at any given site is limited by the noise floor, so A TTA will not improve the sensitivity higher than the noise floor.

For example, the noise floor of a site is measured at -115dBm. ½" LDF cable is being used to connect the antenna to the rest of the system with 300'of LDF cable. The specs for ½" LDF cable are 2.21dB of loss per 100ft of cable, which means the total loss of the cable would be 6.63dB. The calculated system sensitivity, if a TTA was to be used, is estimated to be -110dBm. With a 6.63dB line loss, the receiver sensitivity, without using a TTA, would be approx. -104dBm, so in this case, a TTA would be beneficial because it increases the sensitivity, but it's still above the noise floor of the site. Where a TTA wouldn't be beneficial, is when, per say, your noise floor measures approximately -115dBm, but the calculated system sensitivity if a TTA was used is approximately -123dBm. If you subtract the line loss of 6.63dB, then your system sensitivity would -117dBm without the use of a TTA. This is higher than the noise floor (of -115dBm), so the TTA would not be of any benefit since we indicated that the sensitivity is limited by the noise floor.

The TTA will set the overall noise figure and system sensitivity of the site. The overall noise figure represents the bottom line on how well the system will perform. Lower noise figure yields better system receiver sensitivity. At sites where only a receiver multicoupler is used, the NF will be high, thus reducing the receiver sensitivity of the site. This is because there is no front end LNA (or low noise amplifier) to reduce the effects of the feedline. The noise figure increases proportionally to the increase in feedline loss. The receiver multicoupler is located at the base of the tower, so the loss of the transmission line is not being compensated for by the LNA in the TTA before it enters the feedline. This loss increases the overall NF of the system.

The first stage in a communication system (which would be the TTA) will be a low noise/high gain amplifier and any noise after this stage will have a negligible effect on the system. The total NF of a receive system is largely determined by the NF of the first stage. This is why low noise devices are frequently used in the RF amplifier of a receive system.

Once the signal has passed through the first stage, it has been amplified enough that noise contributed by the rest of the receiver is too small to have any impact on the system. The Friis formula shows how this is possible.

$$F_{total} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_1 G_2} + \frac{F_4 - 1}{G_1 G_2 G_3} + \ldots$$

The overall noise figure, $F_{receiver}$, is dominated by the noise figure of the LNA, F_{LNA}, if the gain is sufficiently high.

$$F_{receiver} = F_{LNA} + \frac{(F_{rest} - 1)}{G_{LNA}}$$

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The **F** denotes the noise factor of the system. Use the following formula to convert noise factor to noise figure (in dB's):

10 LOG (noise factor) = (NF) dB .

This shows that it is essential to have an LNA as the first stage in your communications system that has high feedline losses. This prevents the line loss from degrading the signal-to-noise ratio.

Here are two examples of receive systems that uses an RX multicoupler only (no TTA) and one system using a TTA. You will see how the TTA is beneficial to a site that has high feedline losses.

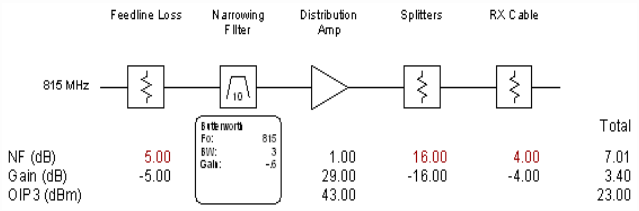

Figure: 1

Figure: 1 shows a system that uses an RX multicoupler only. Without having the front end LNA to compensate for the feedline loss, the overall system NF is approximately 7.0dB. Please note that the receiver sensitivity will degrade proportionally to the increase in NF.

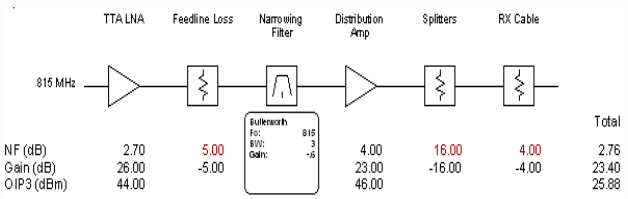

Figure: 2

Figure: 2 shows a system that uses a TTA. The front end LNA compensates for the feedline loss in this case, so the overall system NF is only approximately 2.8dB.

As you can see, there is a big difference in NF between a system that uses a TTA and one that does not.

I have indicated that one of the advantages of using a TTA is how it compensates for high feedline loss while keeping a low NF. Another advantage that should be considered is that smaller diameter, less expensive, and higher loss cable may be used since the TTA will compensate for this loss. The smaller diameter cable will help reduce tower loading, along with saving money.

Coverage prediction maps were created on a test site in Florida:

Figure: 3 Prediction map generated without using a TTA

Figure: 4 Prediction map generated with the use of a TTA for this site.

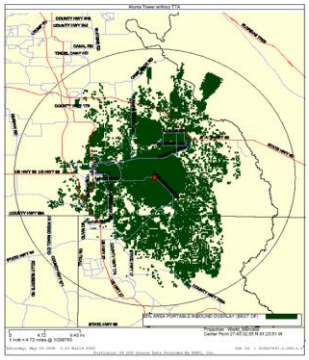

Figure: 3

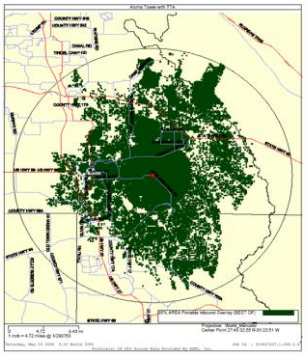

Figure: 4

As you can see, the predicted coverage for this site was improved significantly with the use of a TTA.

Once the TTA was installed, different parts of the county were measured, using hand held radios, with the TTA inactive and then, again, when it was active. The results indicated a substantial increase in coverage. It was calculated that we received almost a 30% increase in coverage when the TTA was active. See **Figure: 5**, below, for results. Green dots represent coverage when the TTA was inactive and fall within the inner circle. The Red dots represent measured coverage when the TTA was active and fall within the outer circle and indicates how much the coverage increased once the TTA was turned on.

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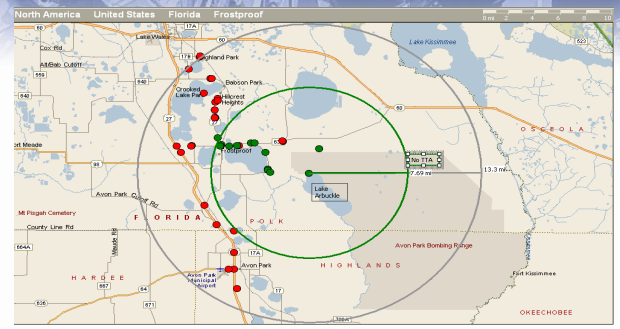

Figure: 5

I have indicated all of the advantages of using a TTA. Now let's show you some of the limitations to using a TTA.

I have already named one of the biggest limitations of using a TTA. A TTA will not improve an already noisy signal. It will only amplify the noisy signal, degrading the sensitivity of the receiver. Remember, noise in = even more noise out.

Another limitation of a TTA, that should be avoided, is where your inbound coverage is substantially better than the outbound coverage. Balanced is always best! A good example of when a TTA may not be beneficial, is when a TTA improves your inbound coverage more than your outbound coverage. In this case, a Dispatcher would hear a mobile, but the mobile may not hear the dispatcher. This is not a good situation to be in when you're dealing with public safety. Important calls can be missed and lives could be at stake, so try to avoid these situations at all cost.

Another limitation, that may not be desirable, is having too much range or coverage. You are probably asking yourself… How can having too much range possibly be a bad thing? If a TTA makes your coverage area too large, it could result in overlapping coverage with adjacent areas, which will put calls on top of one another, ultimately resulting in missed or dropped calls. It can also limit the use of some frequencies since neighboring towns, cities, counties or states may use the same frequencies for different usages.

See an example of overlapping coverage in **Figure: 6**.

In other words, too little coverage is bad because you may not cover the desired areas that need to be covered, but too much coverage can also be bad because of overlapping coverage, so finding the right amount of coverage is essential.

In conclusion, there are many advantages in using a TTA as part of your receive system. When high towers are being used, they will compensate for the high feedline losses and they can also help keep tower loading at a minimum. A TTA will also provide a low system NF for better system receiver sensitivity. They can also help improve the current coverage at a given site, when necessary.

TTA's also have disadvantages that must be considered. They cannot improve an already noisy site. They may provide too much coverage or possibly boost your inbound coverage more than your outbound coverage.

It is important to keep these factors in mind when deciding if a TTA will be beneficial to your receive system or not. In public safety, ensuring reliable communications is critical. If a TTA is operating under unfavorable conditions, public safety may be at risk.