Time Domain Reflectometer Analysis of Coaxial Feedlines for Variouis Repeaters in The Kansas City Room

Having the opportunity to install Fusion repeaters at several towers in the Kansas City Metro region it was decided to run an analysis of the antenna feedlines at each tower. The reason for this was because the antennas and corresponding feedlines had been in operation for a long time and the current condition of these lines was unknown.

Having access to a Rig Expert AA-600 Antenna Analyzer gave us the option of doing more than just an SWR or Return Loss check. This device has a test option known as a Time Domain Reflectometer that will attempt to analyze the feedline between the feedpoint and the termination point.

The process consists of attaching the AA-600 to the feedpoint of the feedline and a personal computer. Then starting the Rig Expert software. Once started all the functions of the AA-600 are available on the computer screen. One thing to understand about the AA-600. When you do a TDR scan it automatically selects 300 Mhz as the center frequency and scans 300 Mhz above and below that frequency. You will see the frequency in the upper left corner of the graph. It will also indicate it is set to scan 50 ohm feedline.

Several options must be set before running the TDR analysis. First the Velocity Factor of the feedline must be entered and a suitable number of points must be selected. The Velocity Factor value can be changed after the analysis is run so if you don't have it exact prior to execution don't worry. The number of points selection however is another matter. These points can be loosely related to the estimated length of the feedline under test.

For example if you have a 400 foot tower a good number of points to start with would be 3000. You will not get an accurate graph if the number of points is too small. After you run one TDR at 3000 points you will have a better idea of the exact length of the feedline and can adjust the number of points up or down to get a more detailed graph.

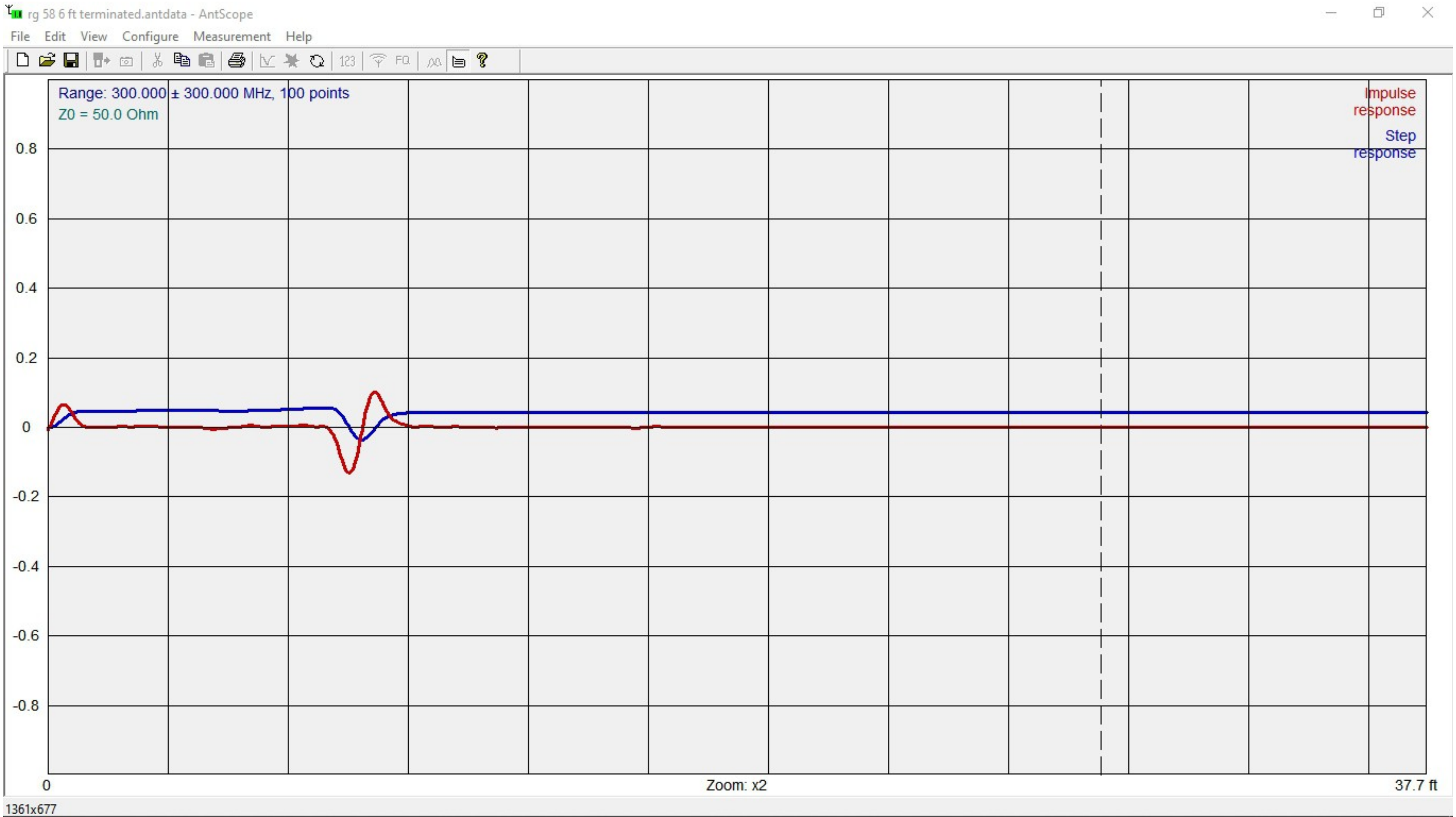
Examples of this will be given later.

Interpretation of a TDR graph is not an exact science. Many factors will affect the results of a TDR scan. Factors such as how the end of the feedline is terminated, is the antenna in a high RF field from other close by transmitters and is there a lightening arrestor in the feedline.

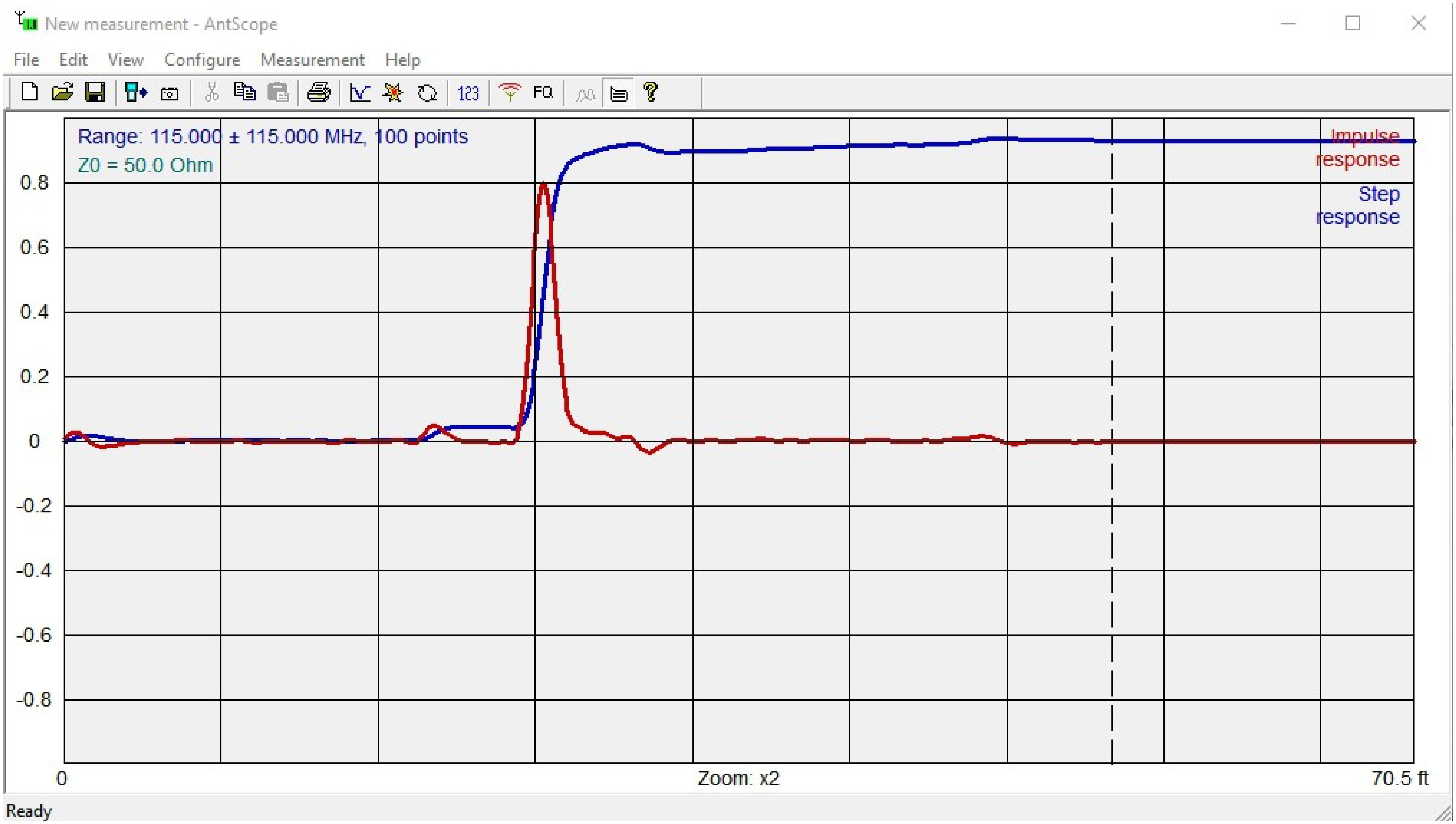
The purpose of this document is to give you a rough idea of how some factors affect the display and what the display is trying to tell you. We use the graphs as pass fail indicators. If the graph indicates anything other than a good line there is not much you can do to fix it. With the length of the feedlines being several hundred feet up a tower it is cost prohibitive to inspect it. Sometimes feedline clamps are tightened too tight, sometimes there may be a cut in the feedline, sometimes there may be water in the feedline or there can even be a bullet hole in the feedline. Each of these will be indicated on the graph but without visual inspection how are you able to tell what it is.

In order to get an idea of how these factors are represented on the graph, a test was run with a 6 foot piece of RG-58 cable. Three tests were run. One with the end of the cable terminated into a 50 ohm load, one with the end of the cable open and one with the end of the cable shorted. The results of these tests are displayed on the following pages.

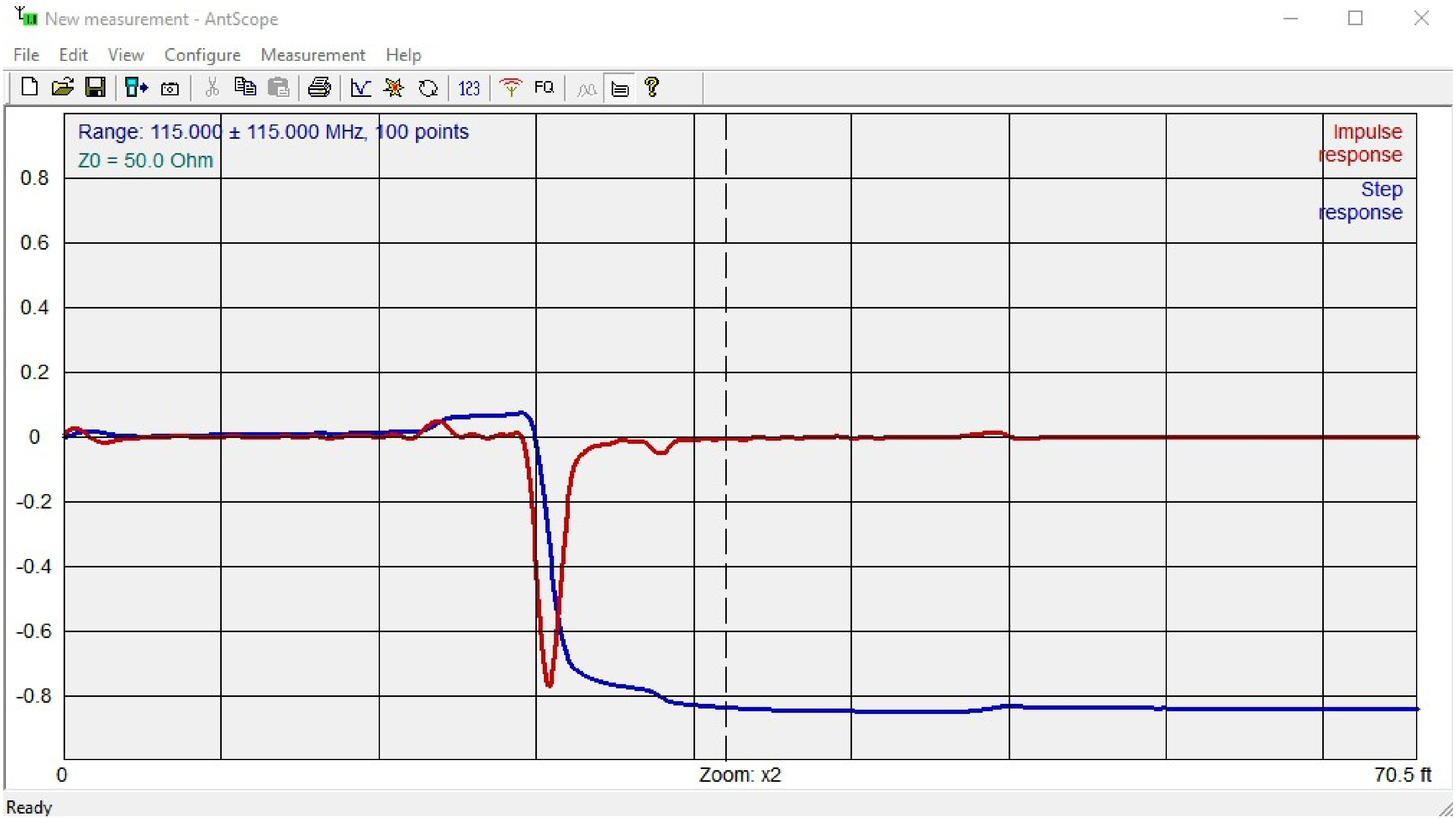
Don't pay any attention to the Zoom: X2 on the bottom of the graph. It says that no matter what your zoom setting is.



This graph represents a 6 foot piece of RG-58 coax terminated into a 50 ohm load. Notice the number of points is 100 and the total length represented on the graph is 37.7 feet. It is imperative that the number of points allows the graph to represent at least twice the length of the cable under test which in this case would be 12 feet. I would have used less than 100 points but that is the minimum allowed by the AA-600.



This is the same 6 foot piece of RG-58 coax but the end is open. You can see how the step response trace (blue line) turns upward at the end of the cable. This is also indicative of a capacitive connection. This scan and the one on the next page were done using a Rig Expert AA-230 Zoom. It's minimum number of points is also 100 but you can see that 100 points represents 70.5 feet instead of 37.7 as on the AA-600.



This is still the same 6 foot piece of RG-58 coax but the end is now shorted. You can see how the step response trace (blue line) turns down at the end of the cable. This is indicative of an inductive connection.

The first site we did a TDR analysis on consisted of a 400 foot free standing tower that had multiple antennas at the top. Co-located at the site was a low power TV station as well as a commercial 4 channel DMR system. We knew there would be some desense from these other systems but thought we could overcome that with numerous filters.

The top of the tower has a small platform where all the antennas are mounted. The system had one feedline running up the tower with a VHF/UHF splitter located on the ground and one at the top of the tower. Initial testing showed that both repeaters could be heard for miles but both were deaf as a post.

Initially we ran the usual SWR checks and those looked good. But we knew the AA-600 would do something called a TDR analysis so we decided to try that. None of us knew anything about TDR analysis so we didn't know how to interpret the results we were getting.

After searching the internet we found some information that gave us an idea how to interpret some of the graphs. About all we could agree on was that the graph we saw showed a feedline that was somewhat less than optimal.

One thing we found out was that it was better to test the feedline either shorted, open or terminated into a 50 ohm load. Since we had no one to climb the tower we knew our results would be somewhat skewed having the antenna connected but we persevered.

During this testing we contacted the owner of the tower and discovered there was another feedline running up the tower that we were unaware of. Testing that line gave us results that were different than the original line. This new feedline looked better than the original one.

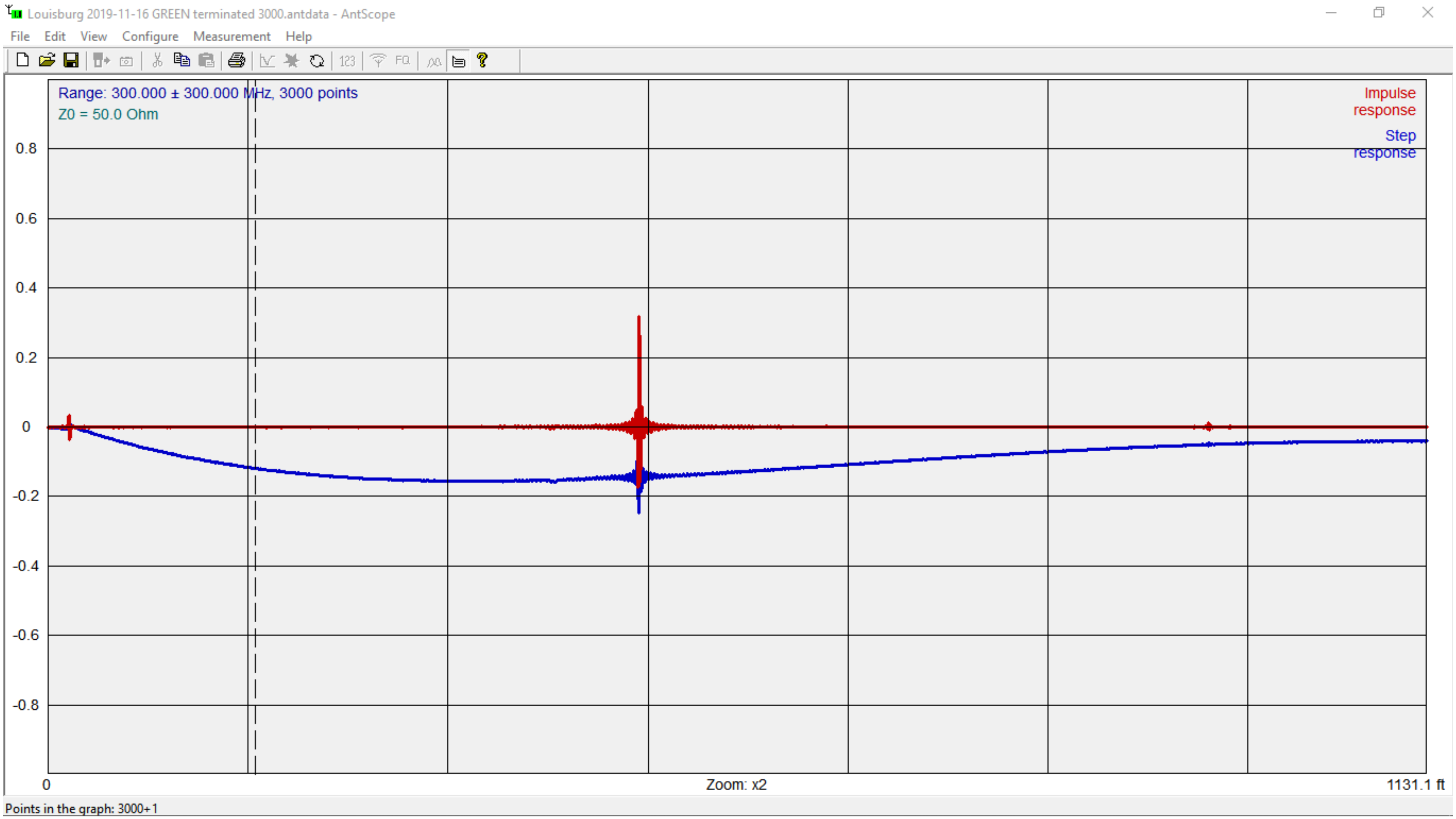
We knew we needed to make changes at the top of the tower so we found someone who would climb the tower and make the changes. That is when we started to make real progress.

To make a really long story short, through our TDR analysis we found that we had one good feedline and one bad feedline. We also discovered we had one good antenna and one bad antenna. As luck would have it the good antenna was on the bad feedline. So we moved the good antenna to the good feedline and that improved our reception immensely.

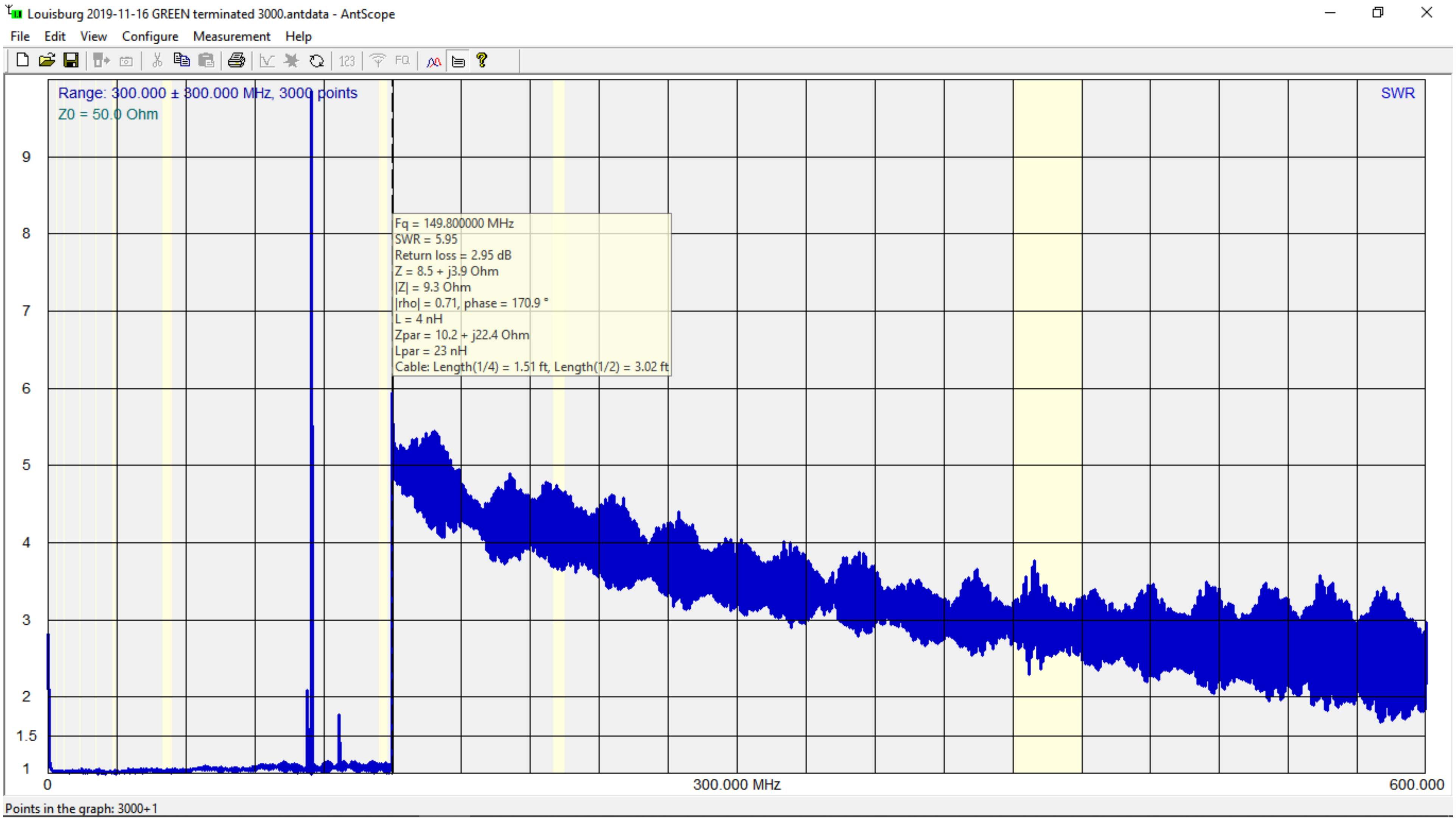
We only have a VHF repeater at the site and it's likely that is the way it will stay. The second feedline is bad and we don't have the finances to replace it. By using a number of specially built filters we have been able to reduce the desense from the adjacent transmitters to an acceptable level. It's still not optimal but works as well as can be expected in the current environment.

The takeaway from all of this is that without running the TDR analysis on the feedlines and learning from the results we would never have discovered the problems with the feedline and the antenna. These problems do not show up on a simple SWR measurement of the antenna. Without doing a TDR analysis of your feedline you really won't know how good or bad it is.

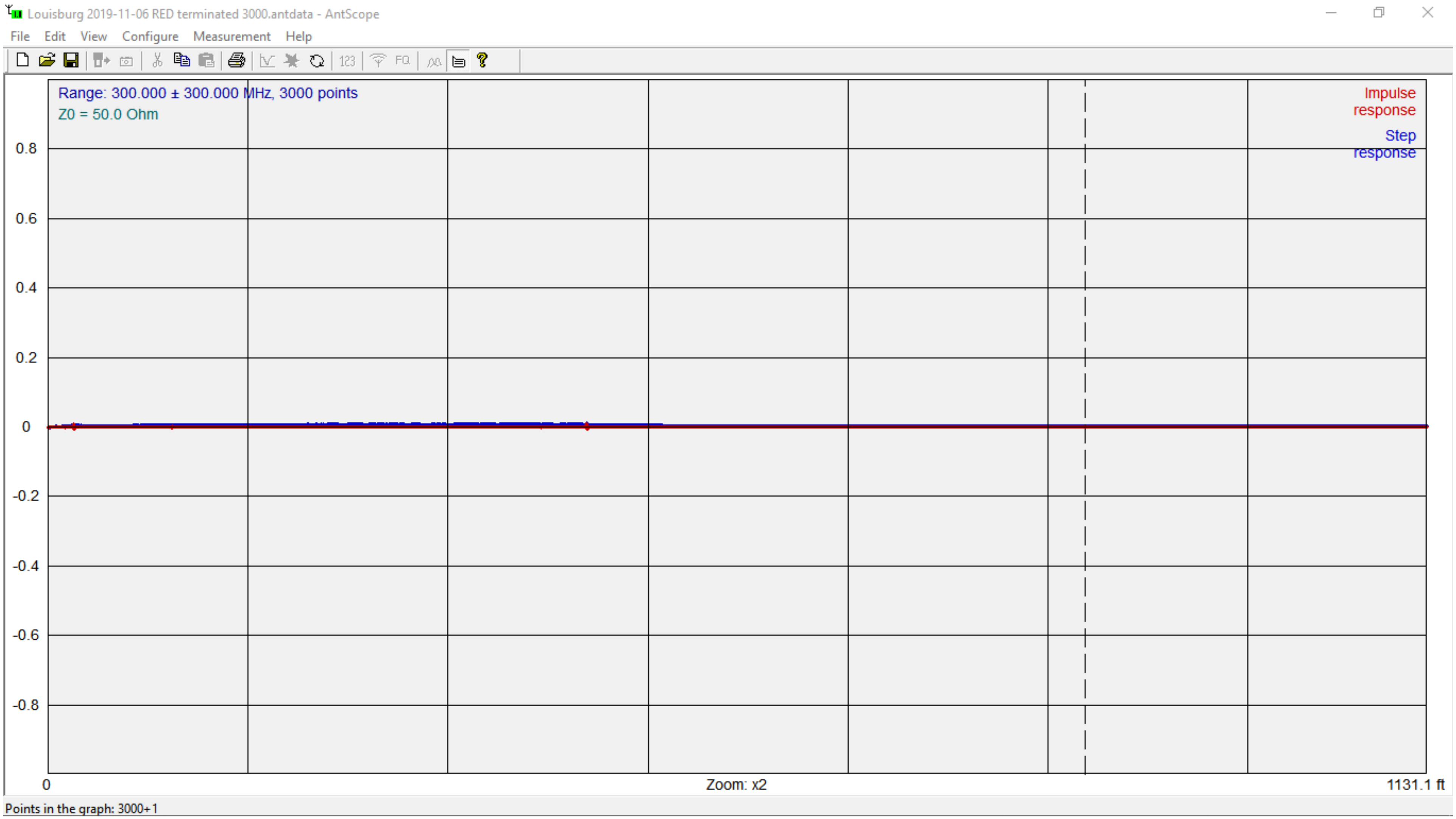
The graphs from multiple site analysis are on the following pages with brief explanations.



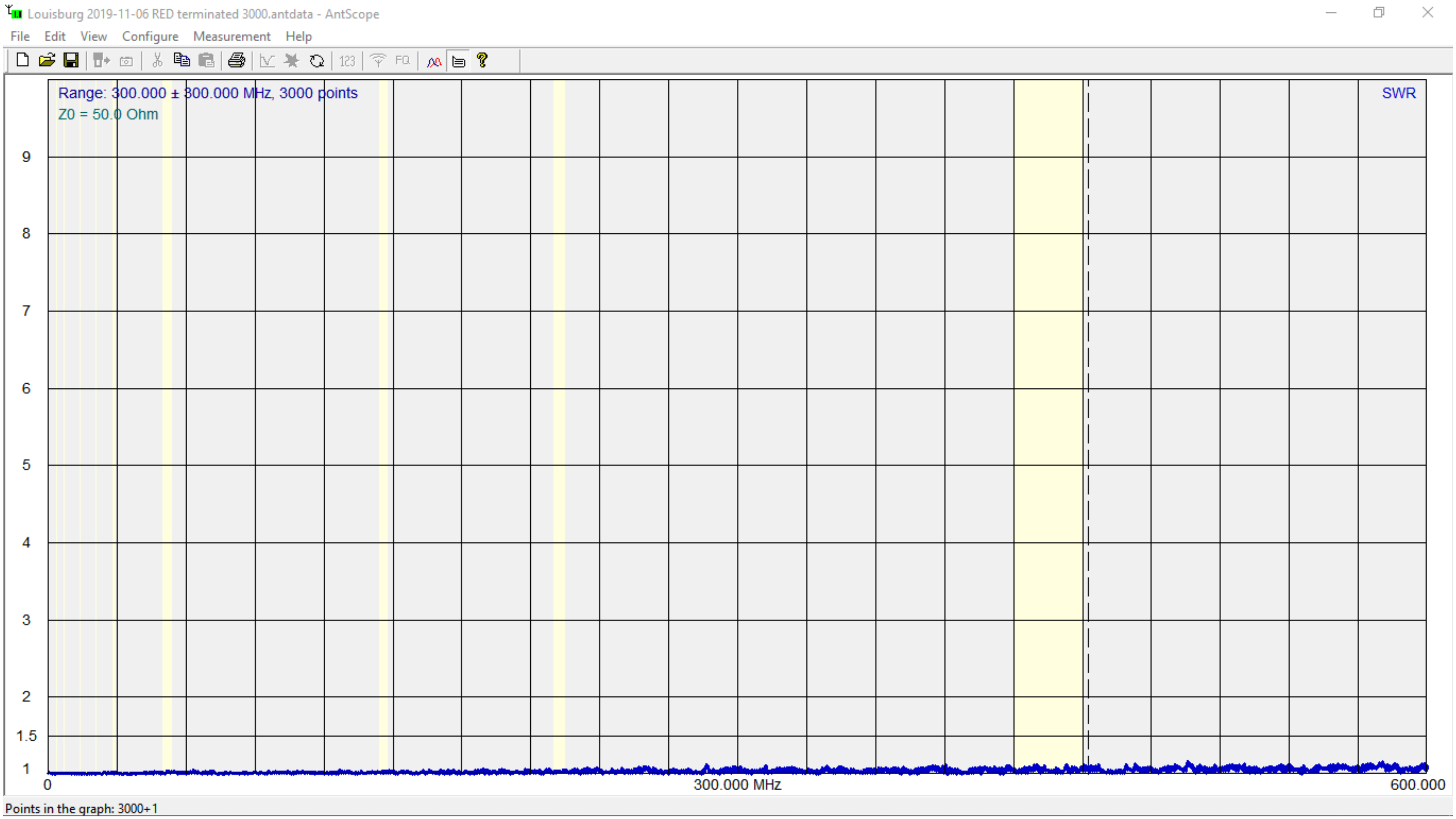
This is the scan of the bad feedline terminated into a 50 ohm load at the top of the tower. The red and blue lines are supposed to run parallel to each other. As you can see there is a problem with this feedline. We don't know what the problem is, just that it's not normal. Check out the SWR plot on the next page for this feedline.



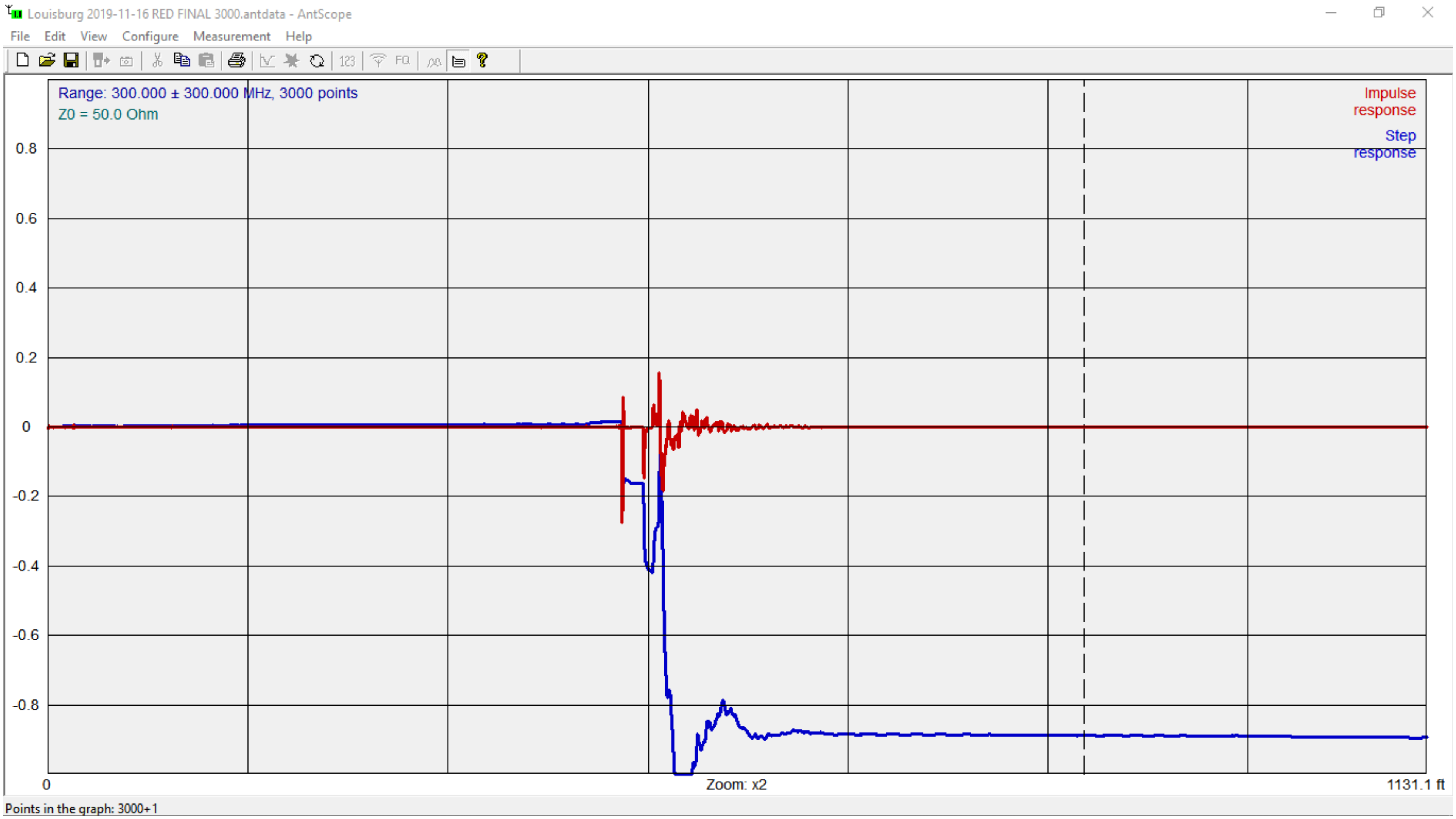
This is the SWR plot of the previous page. Since the antenna is terminated into a 50 ohm load the SWR should be flat over the entire frequency range. However notice how the SWR jumps from 1.12 to 5.95 at 149.800 Mhz. Definitely a problem with this feedline. If all you did was take an SWR reading at your VHF frequency you would think this feedline is fine. We think the thickness of the plot line is because of the high RF environment and RF coming back down the feedline.



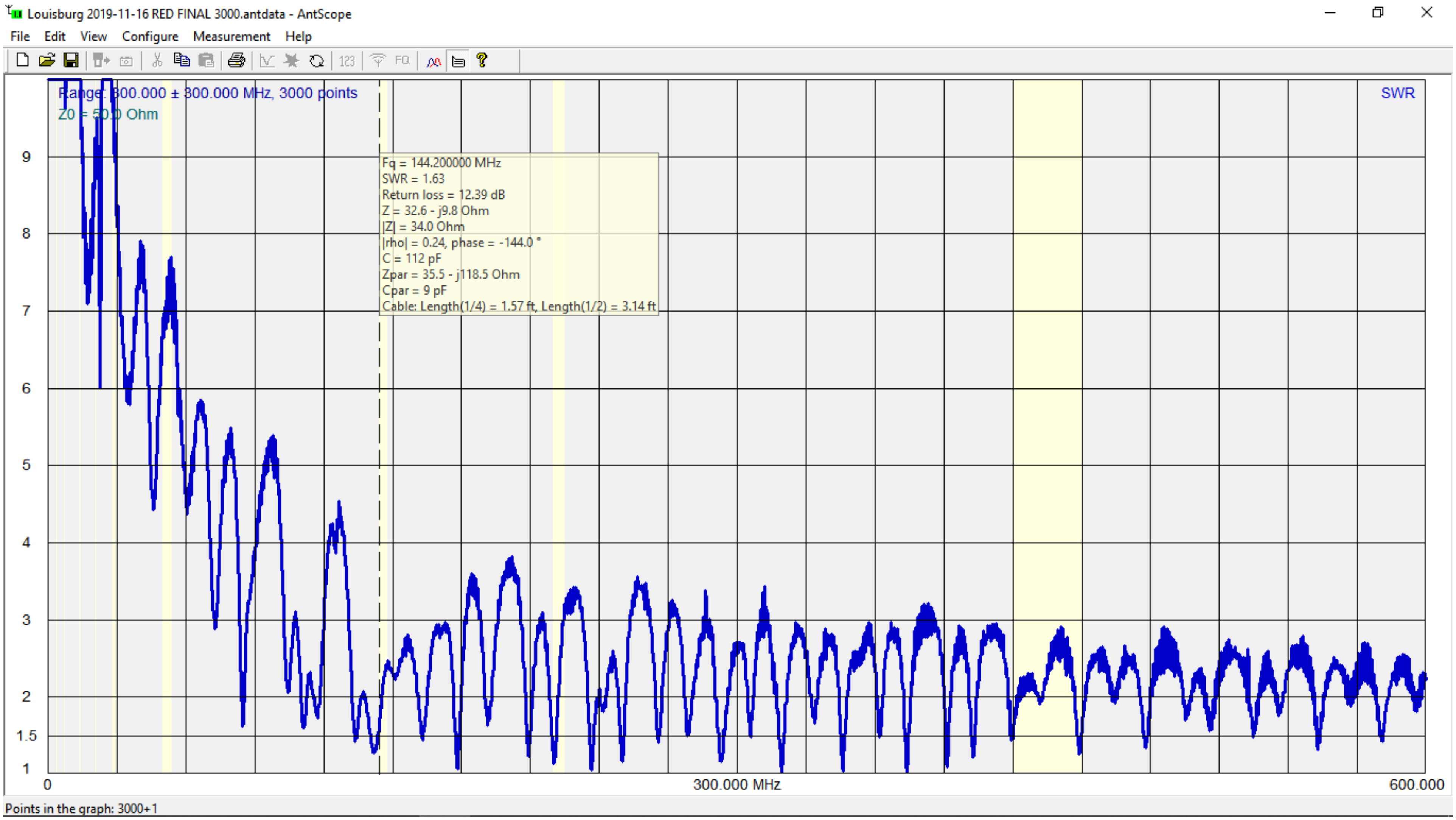
This is the scan of the good feedline terminated into a 50 ohm load at the top of the tower. As you can see the red and blue lines are parallel to each other. This indicates that the feedline is good with virtually no loss in the line.



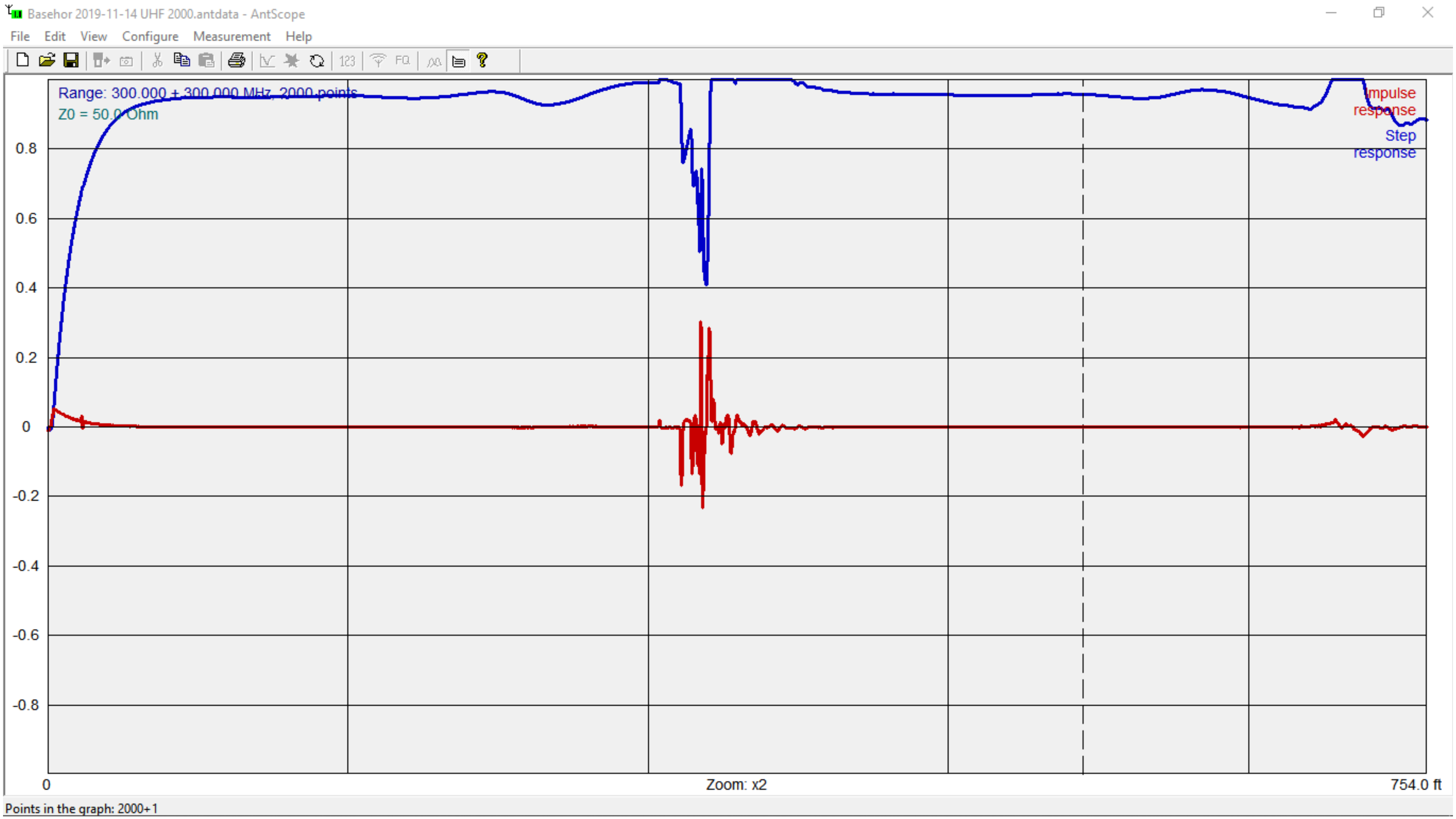
This is the SWR plot of the previous page. The feedline is terminated into a 50 ohm load and the SWR is flat almost across the entire frequency spectrum, going up slightly as it reaches the upper frequencies. This is definitely a good feedline.



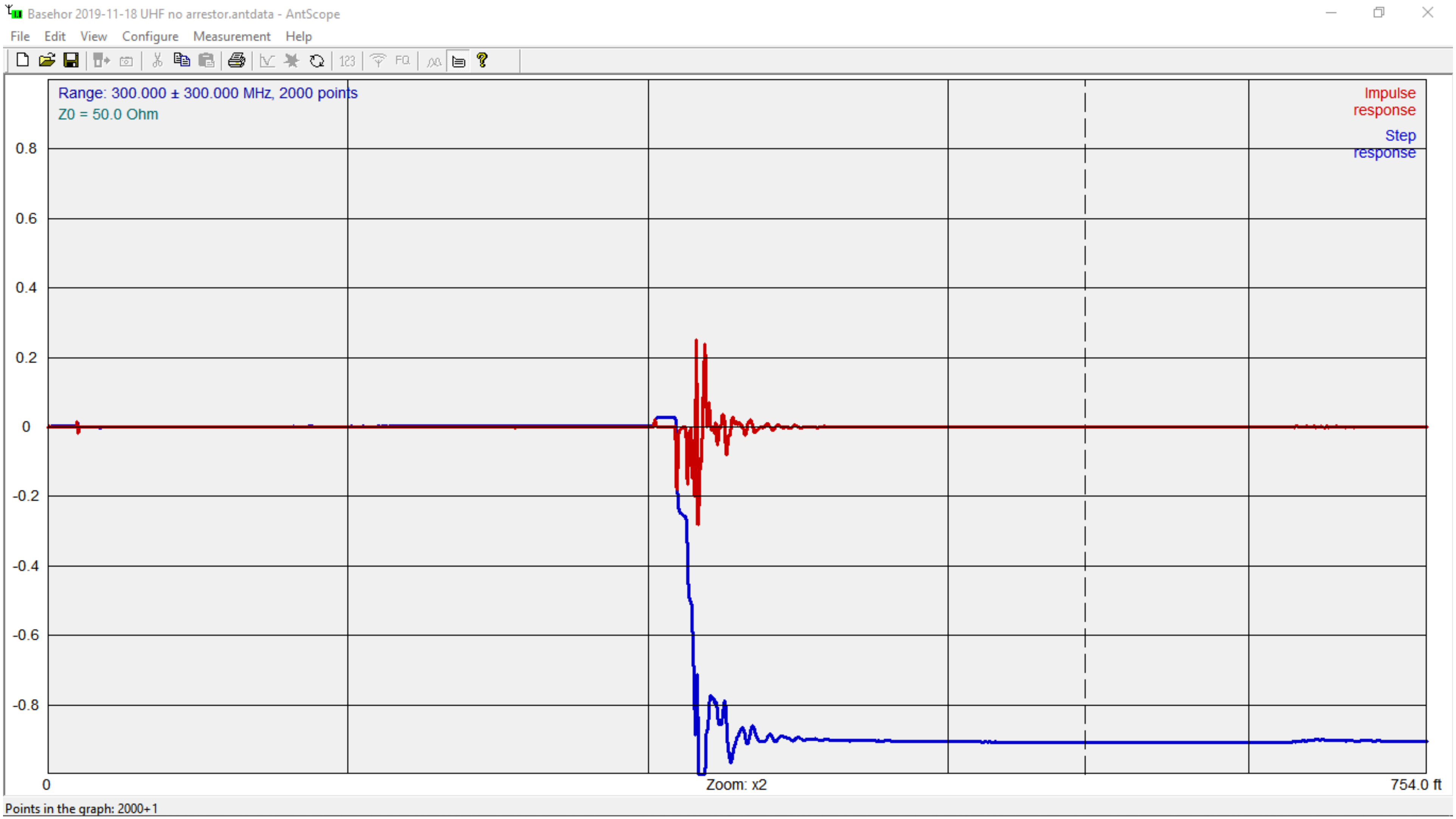
This is the good feedline connected to the good antenna. The red squiggles are the reflection from the antenna itself and do not indicate a problem. The blue line indicates a grounded antenna.



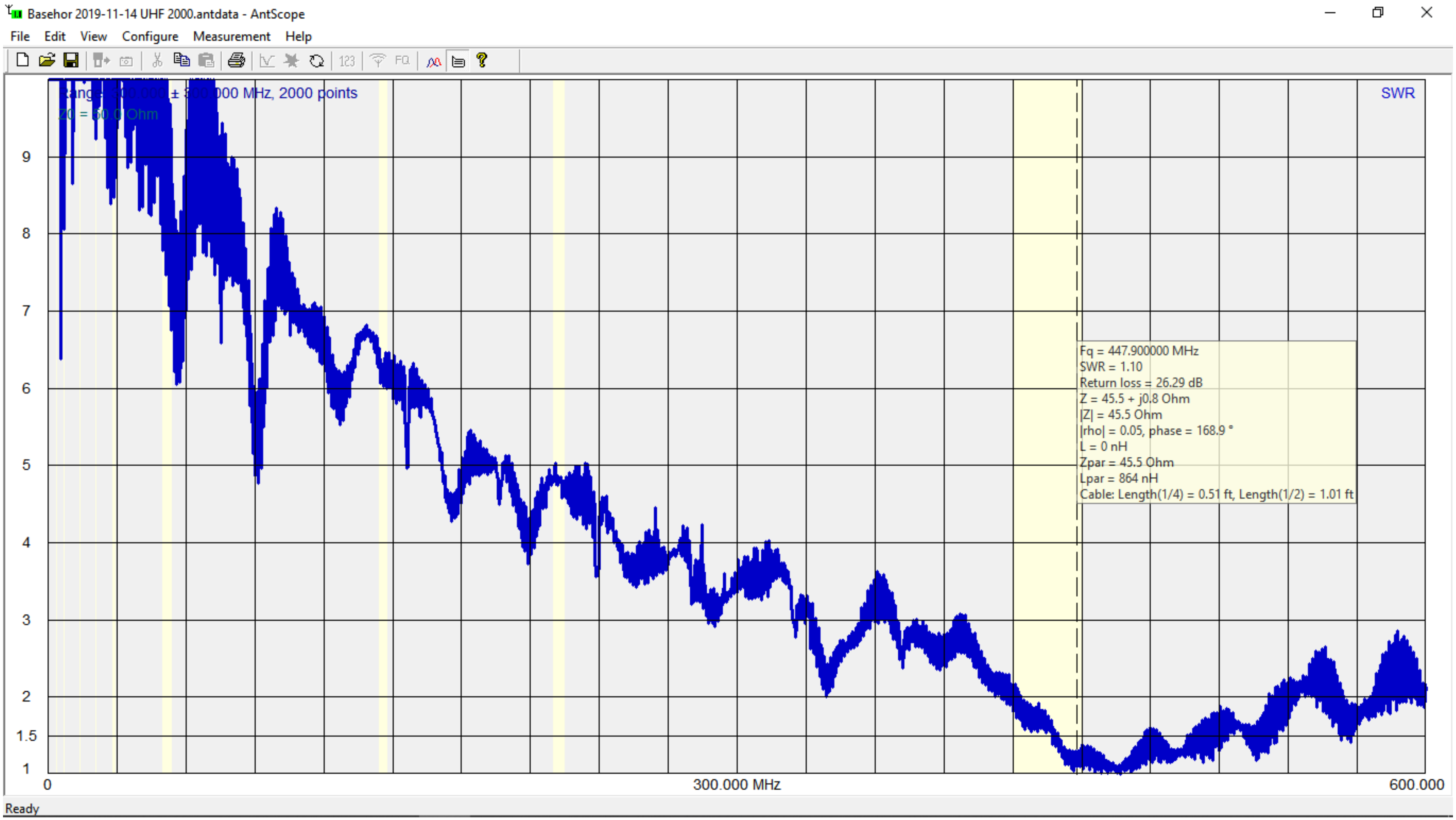
This is the SWR plot of the previous page. The feedline is now connected to the antenna. Notice the SWR at 144.200 Mhz is 1.63:1. Our repeater frequency is 145.410 Mhz. We can have confidence that the antenna and the feedline are performing adequately.



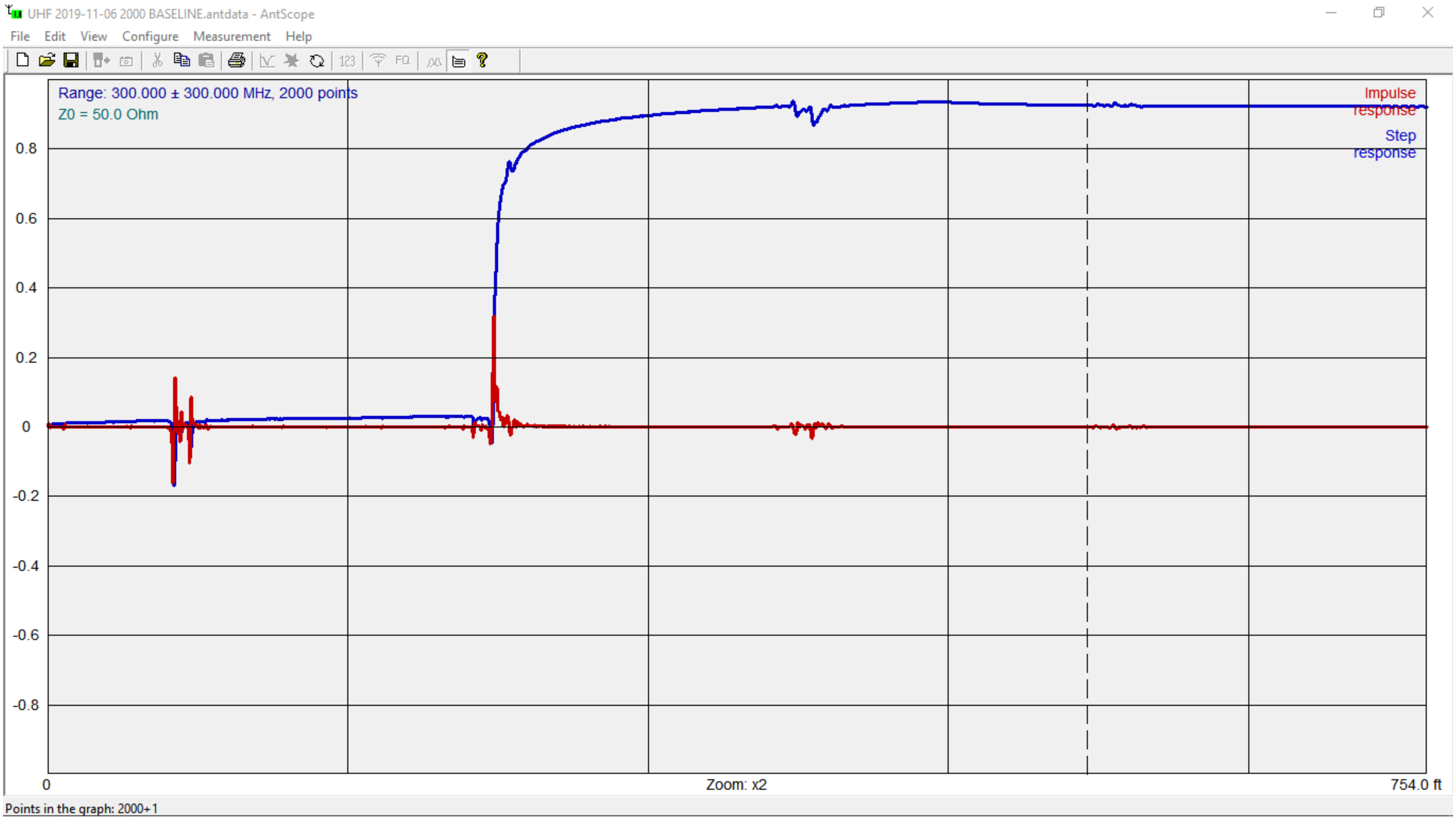
This is a scan of a feedline at another of our repeater sites. This one threw us for a loop initially because we were confident that the feedline was good. It turns out that this step response is because there is a lightening arrestor in the feedline where it enters the building. We removed the arrestor and did another scan and it is shown on the next page.



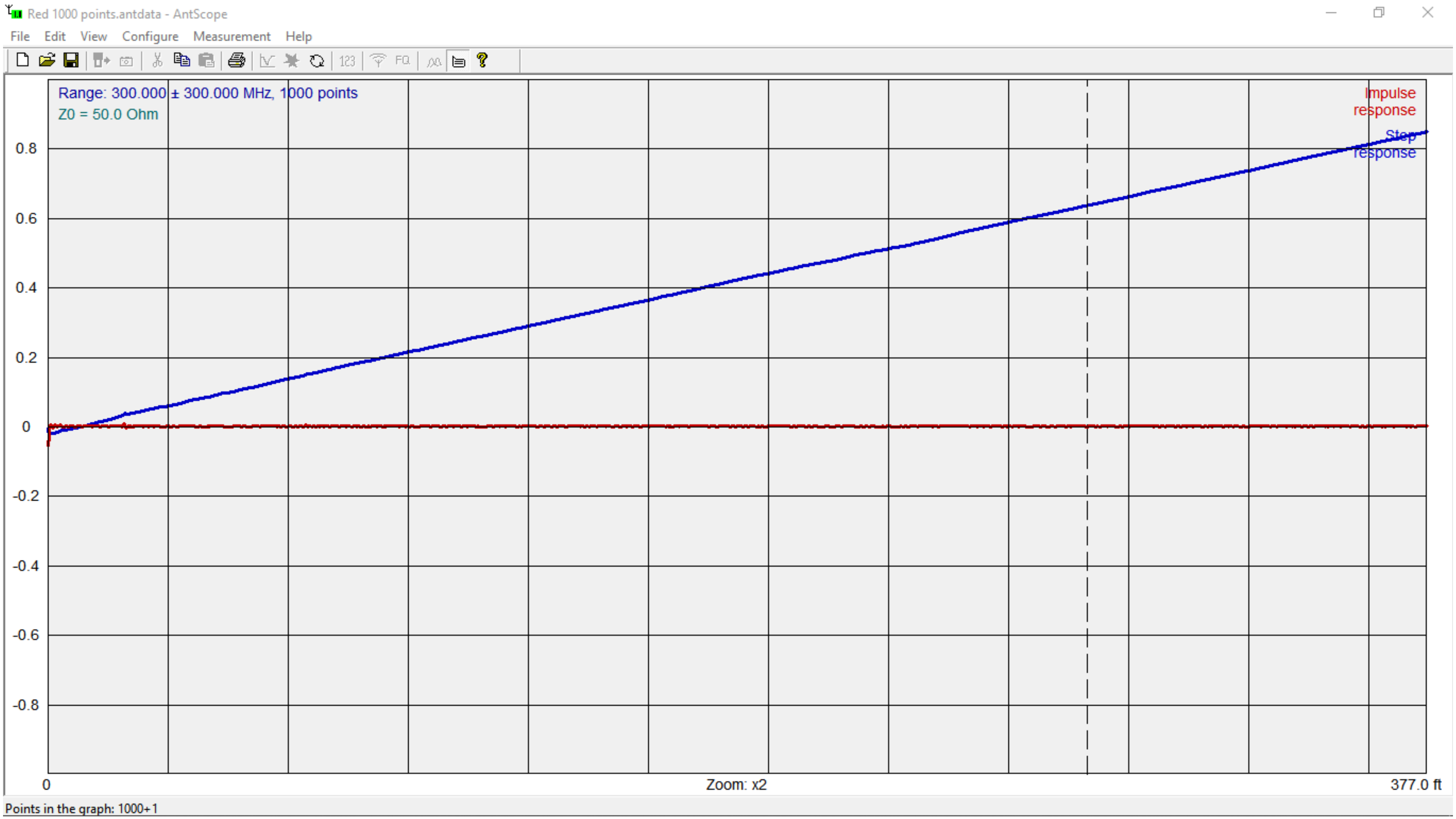
This is the same feedline with the lightening arrestor removed. The little red squiggle at the far left is indicative of a connector in the line. The red squiggles in the middle are returns from the antenna and the blue line going down is indicative of a grounded antenna.



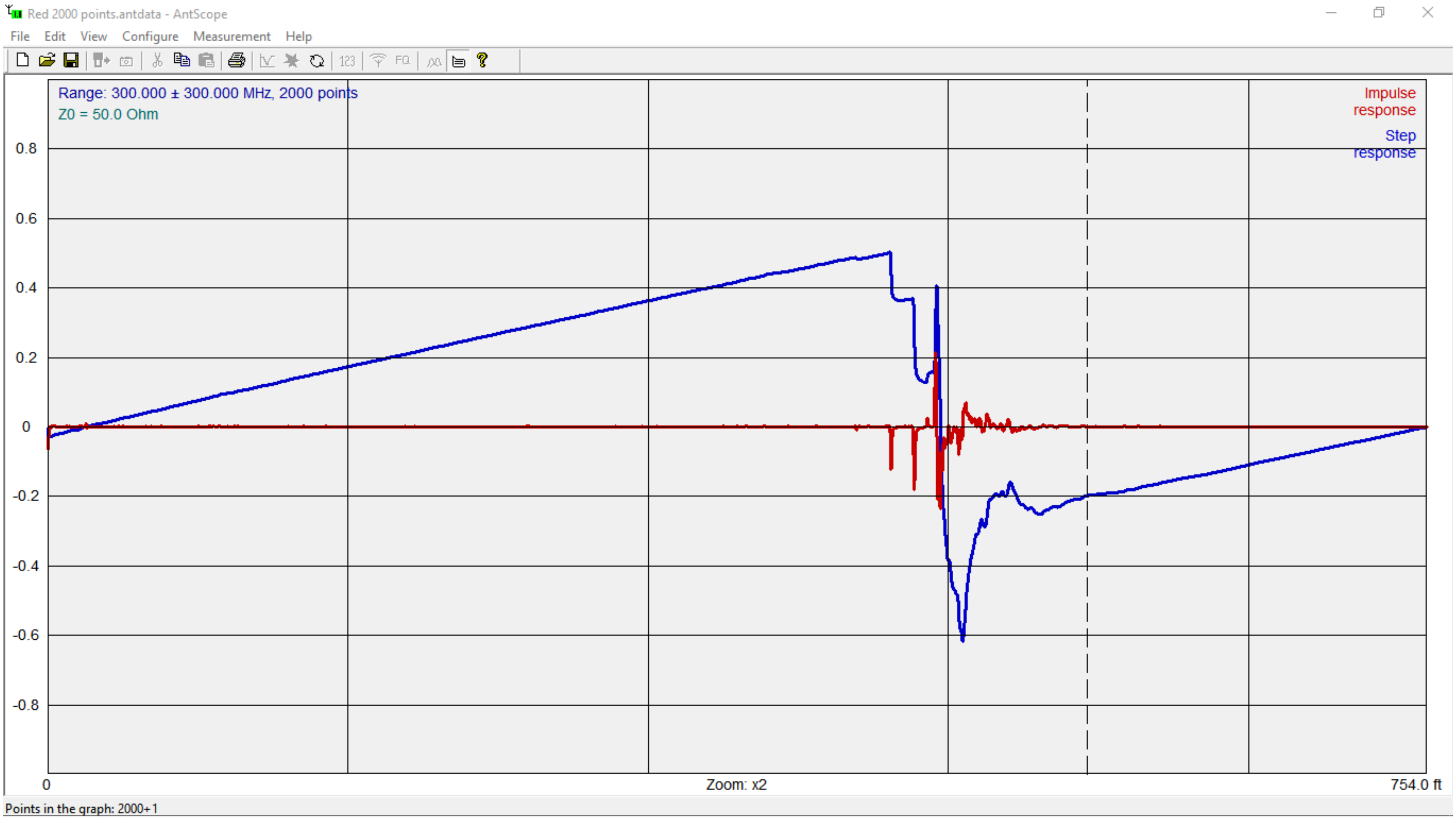
This is the SWR plot of the previous screen. You can see that the SWR in the UHF band is more than acceptable for a UHF repeater. Again we believe the thickness of the plot line is due to RF coming back down the feedline. There is a low power TV station co-located on the same tower.



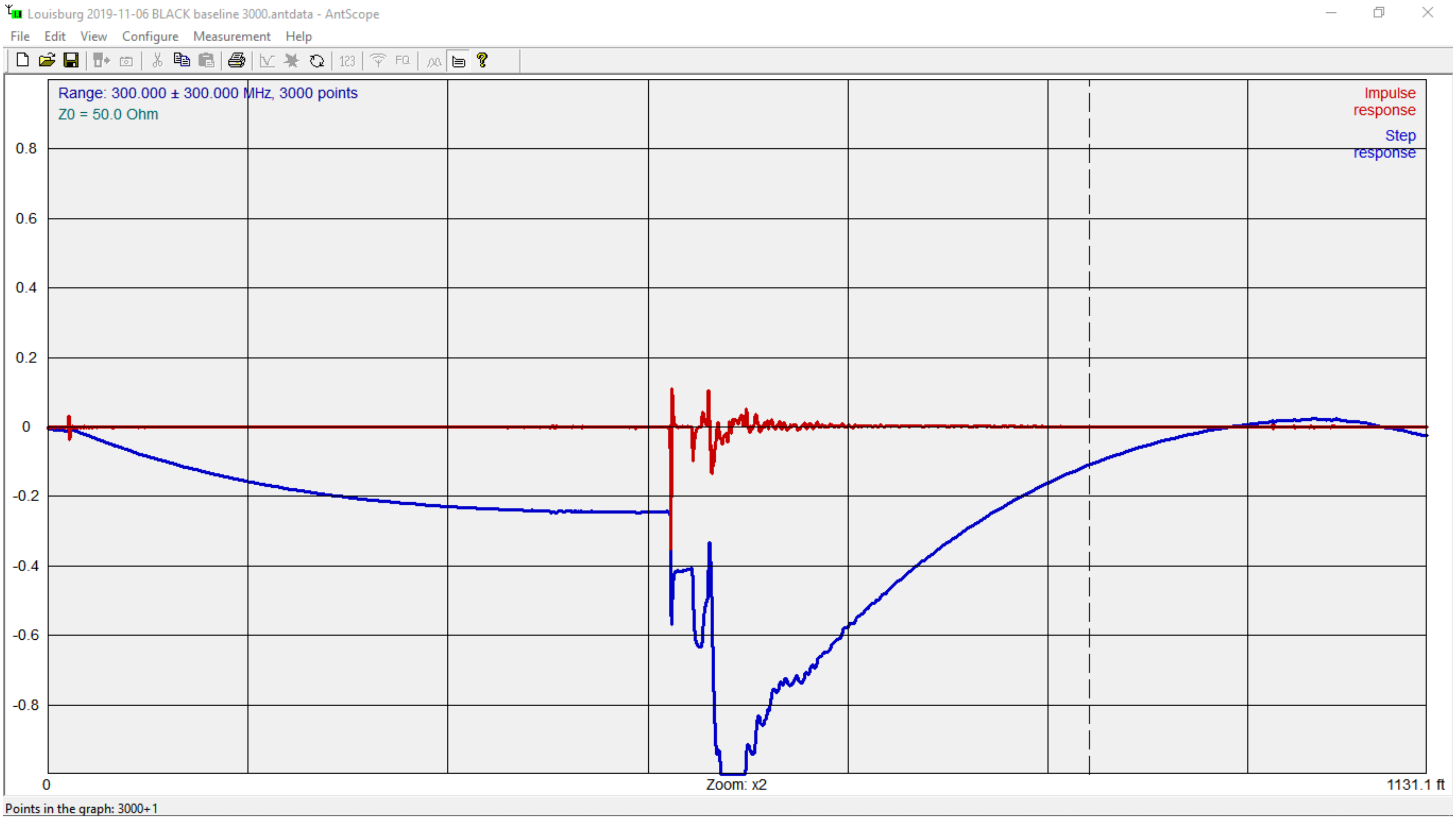
This feedline looks good from a loss perspective however there is something major wrong about a third of the way up the line. Without visual inspection we don't know what the problem is.



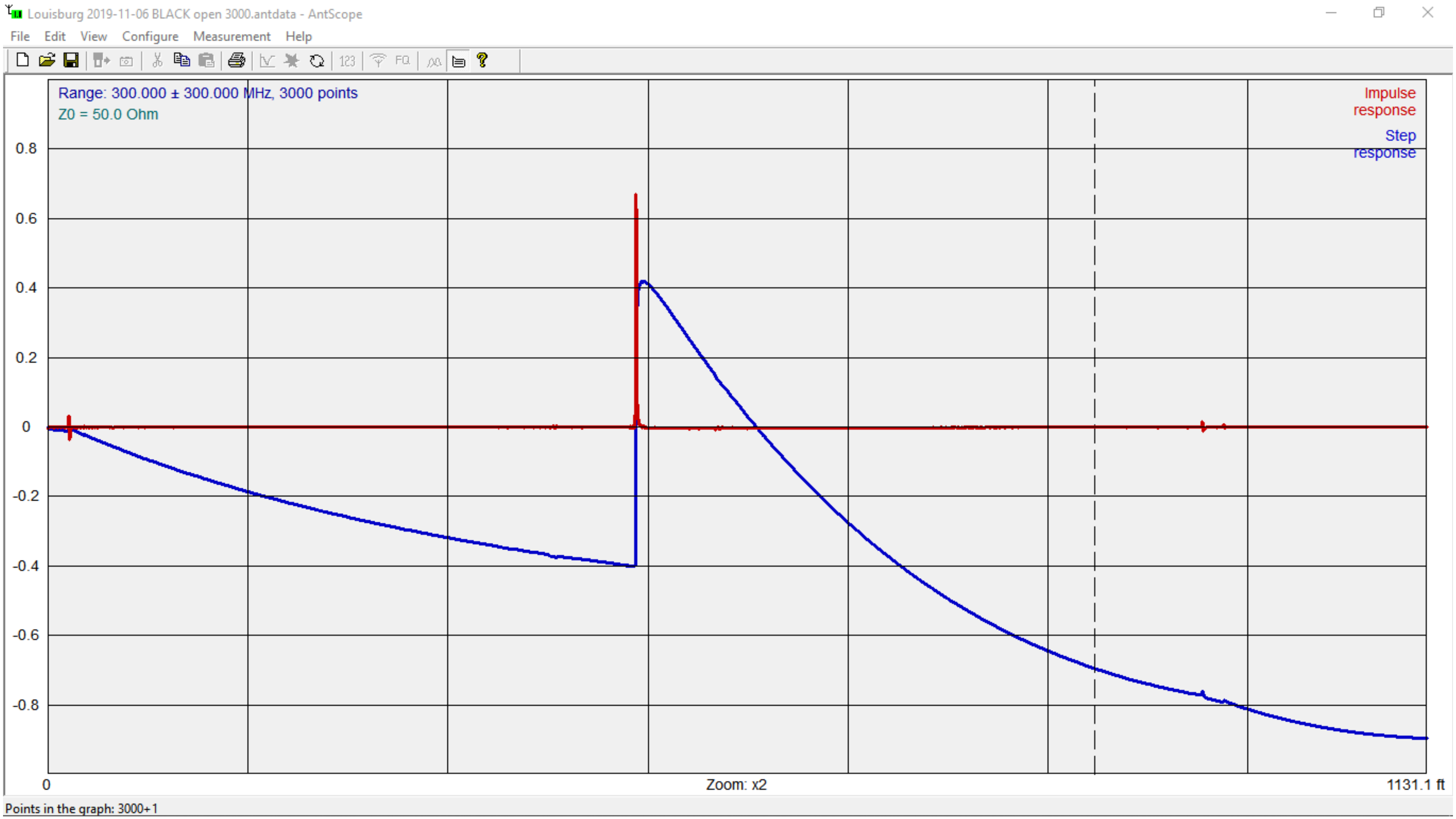
This is an example of not using enough points in the scan. The entire feedline is not represented in the graph. Increasing the number of points from 1000 to 2000 results in the graph on the next page. Notice the distance indicated on the graph is 377 feet. We know that the feedline is longer than 400 feet.



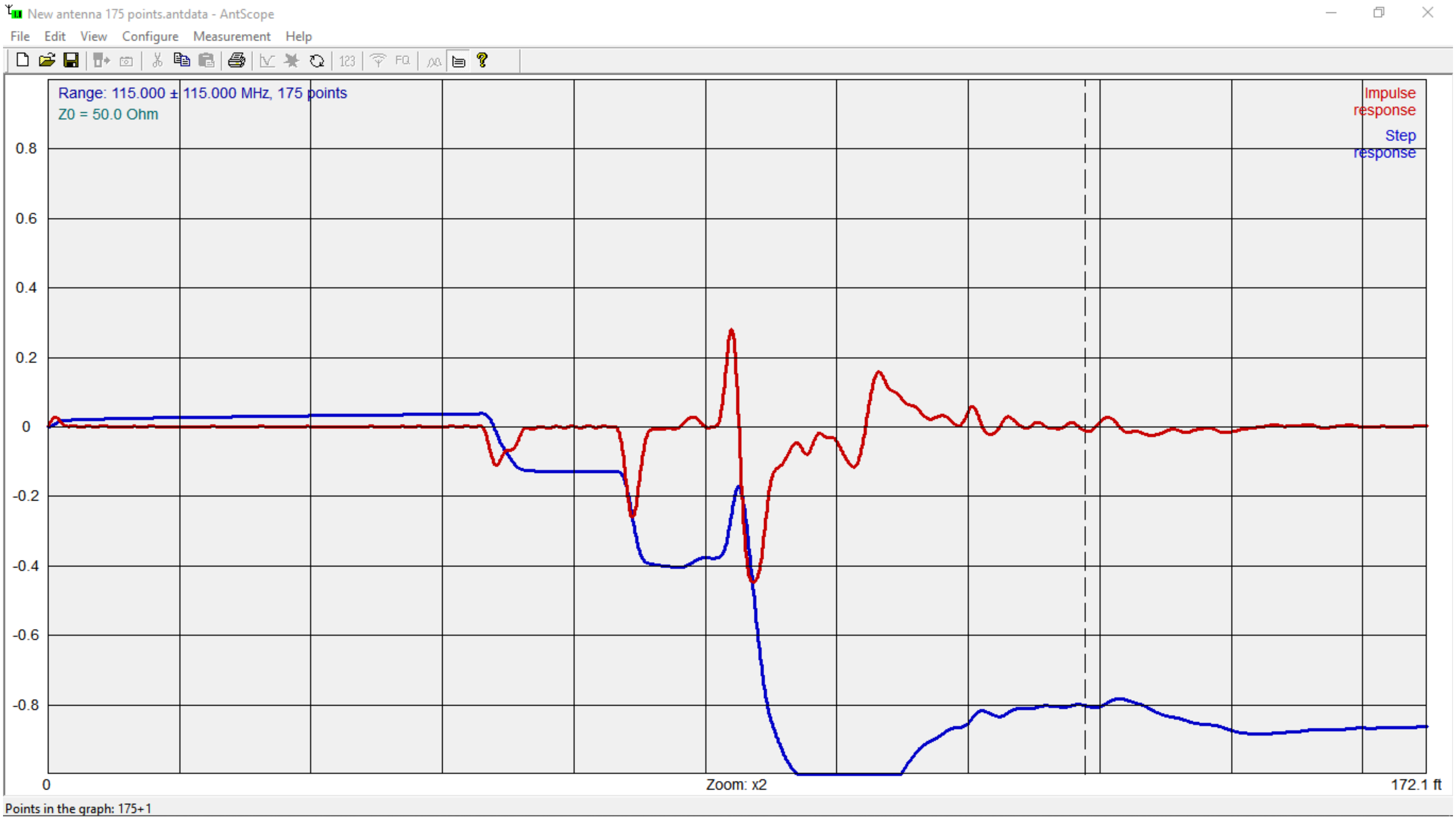
Increasing the number of points from 1000 to 2000 now displays the entire length of the feedline. This indicates an extremely lossy feedline and one that you wouldn't want to use. The higher the blue line goes the more the loss increases.



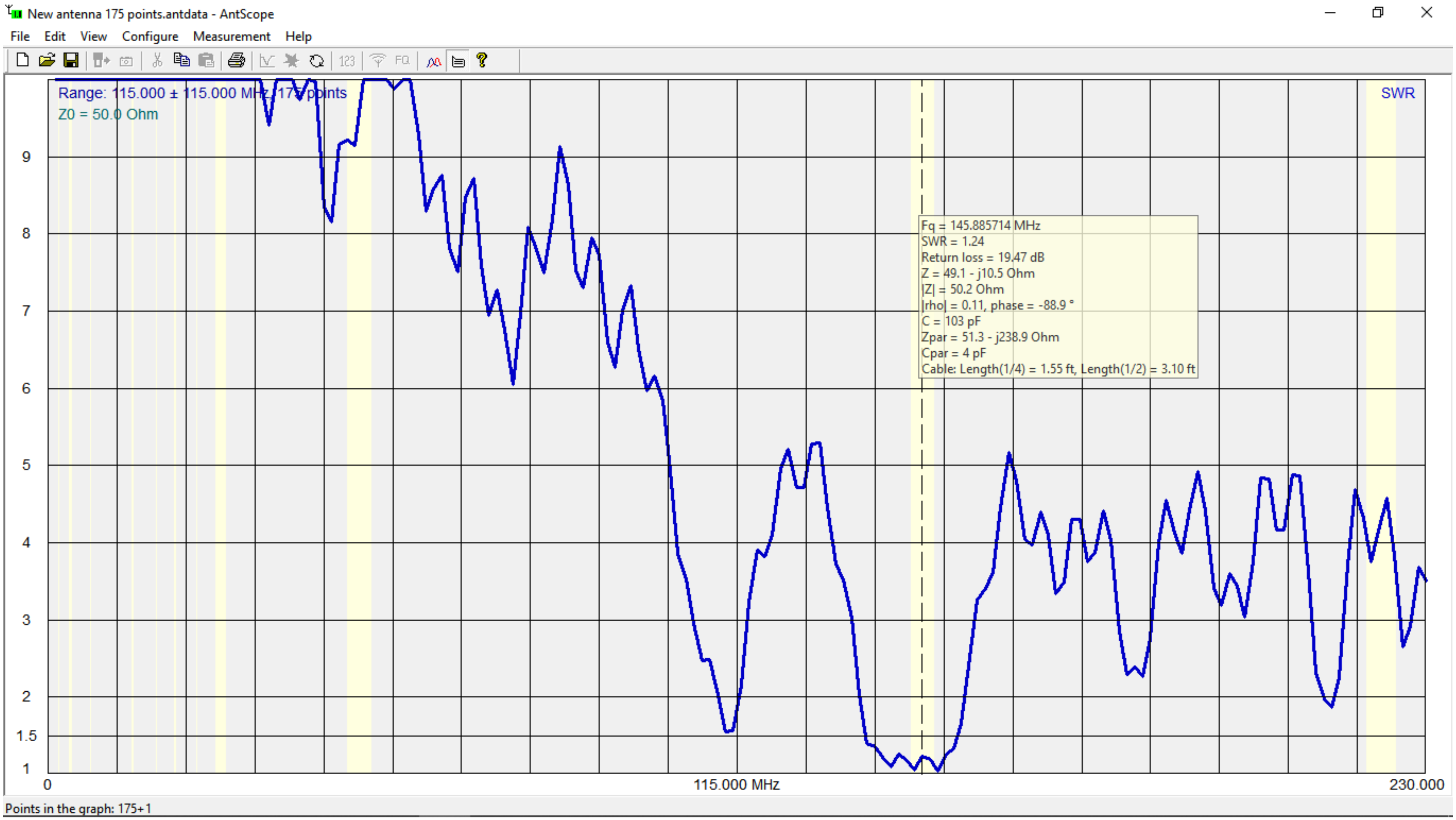
This is another scan that shows a feedline with problems. We didn't know what the problem was but after the termination was examined at the top of the tower it was determined that the coax connector had pulled partially apart at the antenna. After the feedline was disconnected from the antenna we ran another scan. It is on the next page.



This is the same feedline shown on the previous page but the antenna has been disconnected and the feedline is open. It still shows a major problem with the feedline. Our determination was that this feedline was bad and unusable and we have no idea what is wrong with it.



We tested a VHF 4 pole antenna by mounting in on a wooden fence post out in the open and connecting it to the AA-600 with 50 feet of coax. You can see that the coax becomes lossy as it approaches the antenna connection. The four red peaks and valleys may represent the 4 poles of the antenna. The red squiggles to the right are what is called ghost reflections. This scan was done with the AA-230 Zoom.



This is the SWR plot for the antenna tested on the previous screen. Not a bad SWR in the VHF range. The antenna checks out fine. Notice the plot line is thin since it is not being tested in a high RF environment.

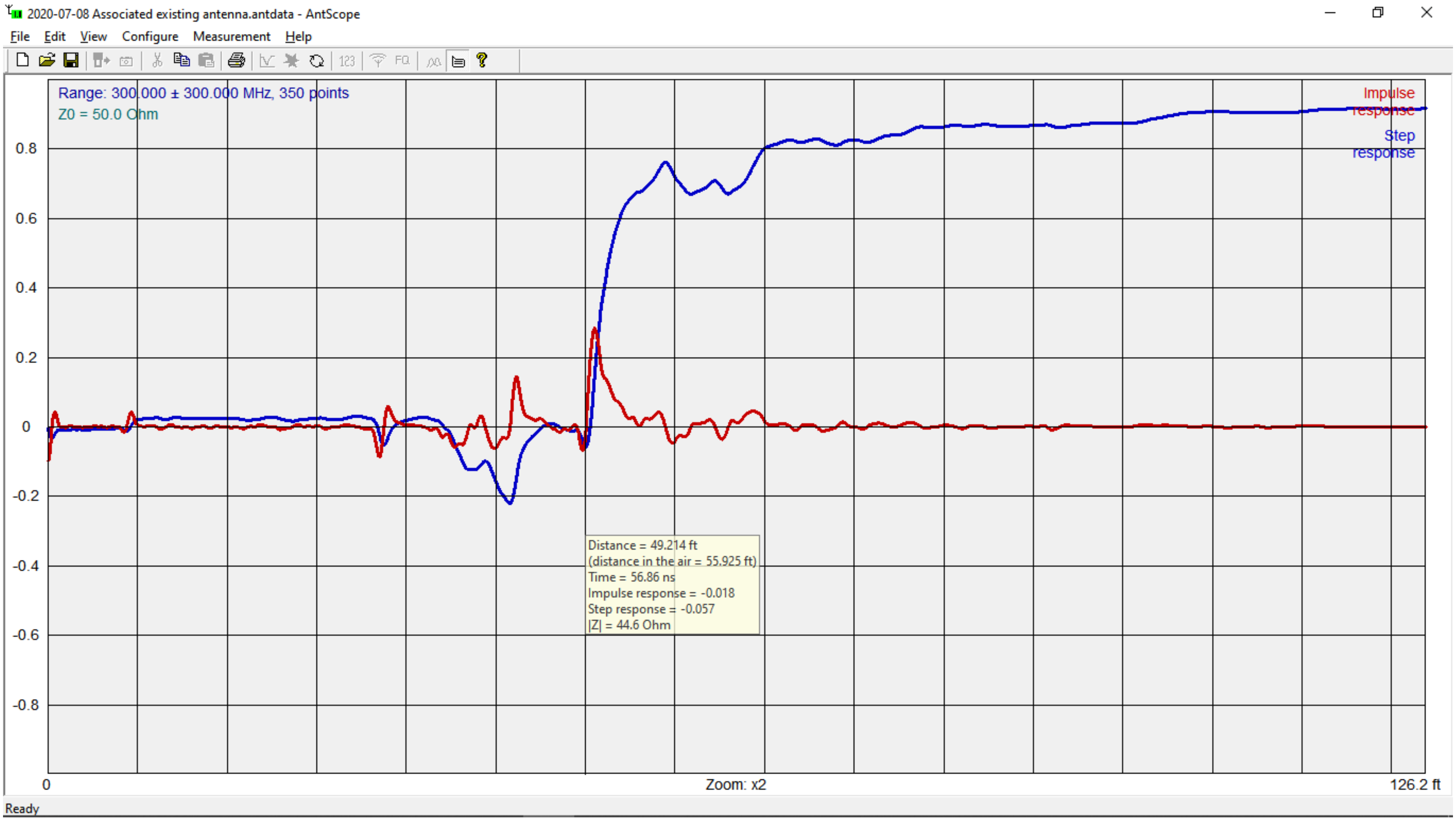
There are a few things we learned in this process. The most important one being to always use enough points to allow for a complete scan. If the number of points is not enough your graph will not be correct. I would always start with 3000 points and then reduce them as you observe each graph.

As I stated before you cannot always tell what the problem is by viewing the graph, but it will give you a pass fail indication whether or not the feedline is good, marginal or bad.

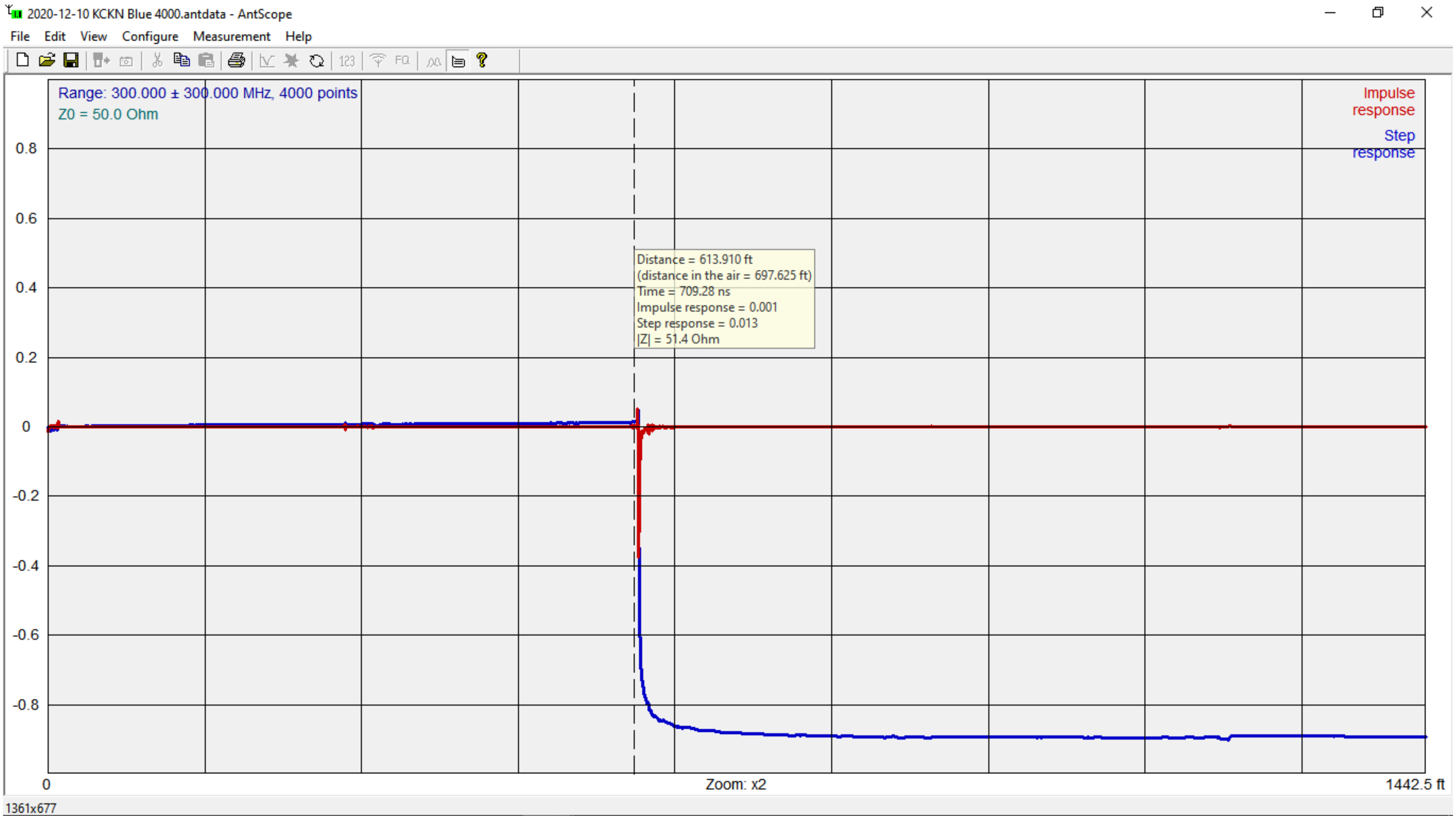
Do not rely on just an SWR measurement to determine if your antenna system is good.

It's now over a year since I first published this document. We have had several more opportunities to run a TDR on antennas and their feedlines.

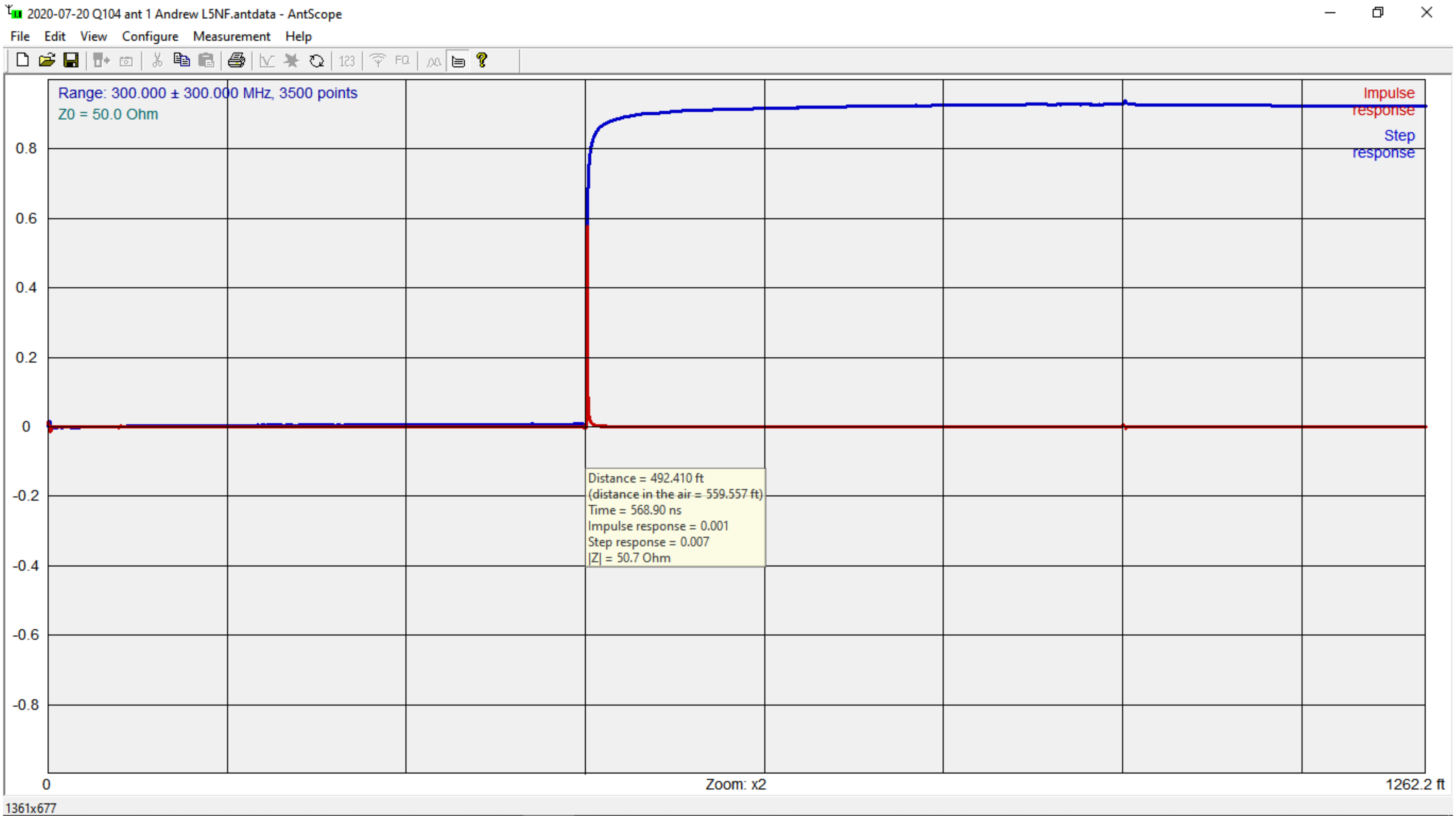
I have added some of those, with explanations, starting on the next page.



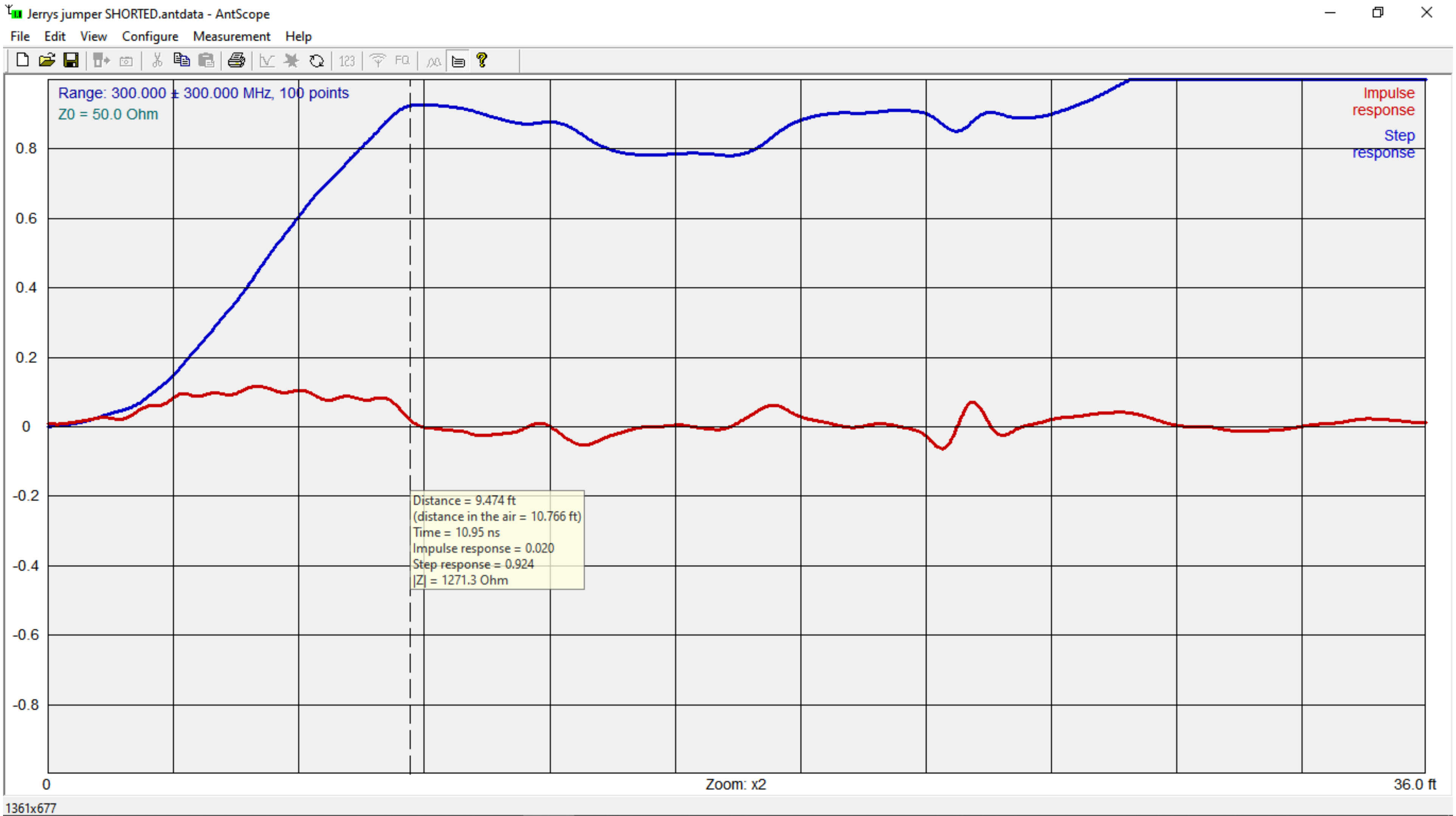
This is a relatively short feedline to a dual band antenna. We believe this to be a good indication of water that has seeped into the coax.



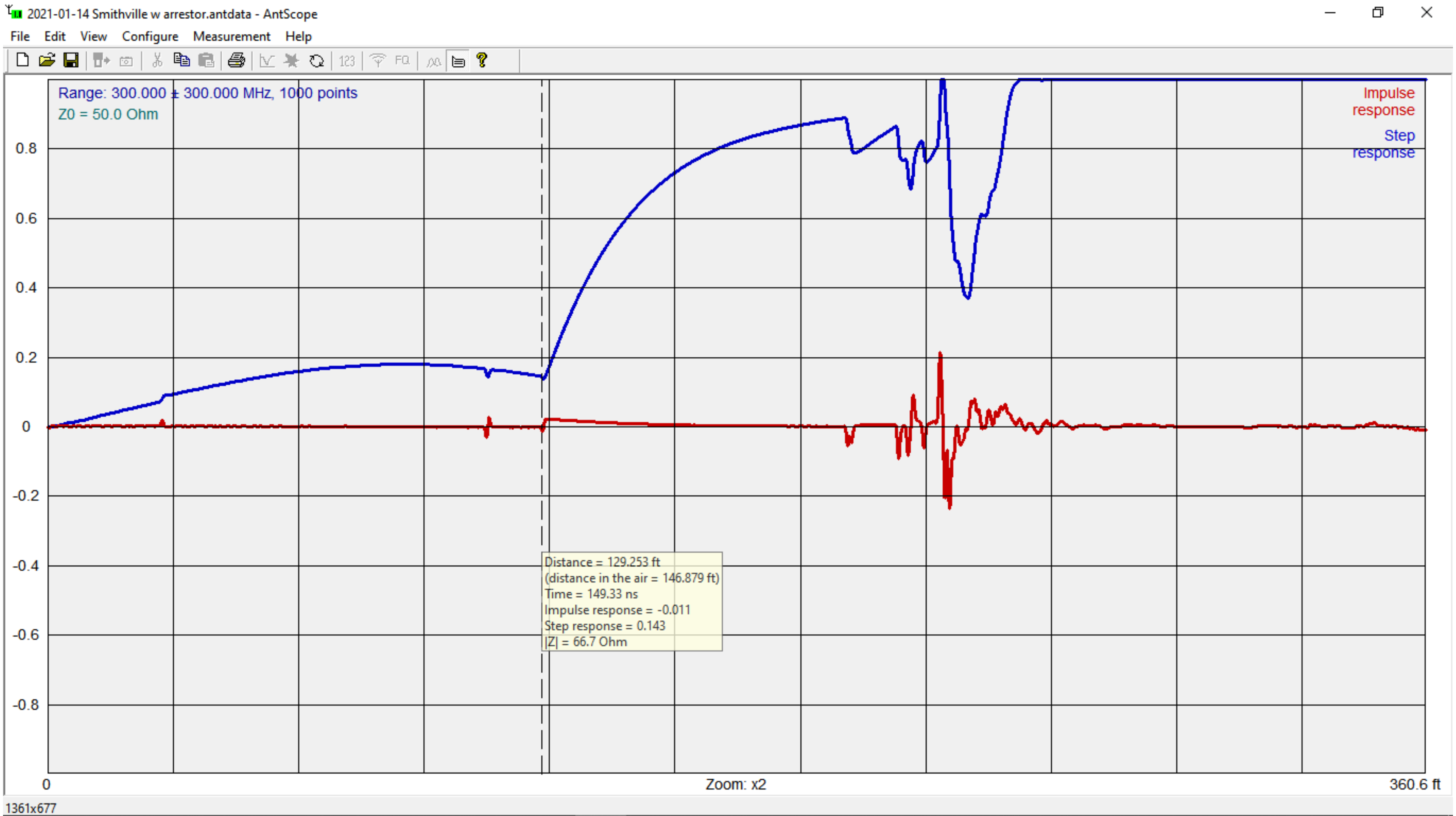
This is a 600 foot run to a grounded UHF "stick" type of antenna. It has a few minor issues but none of which would prevent using this antenna.



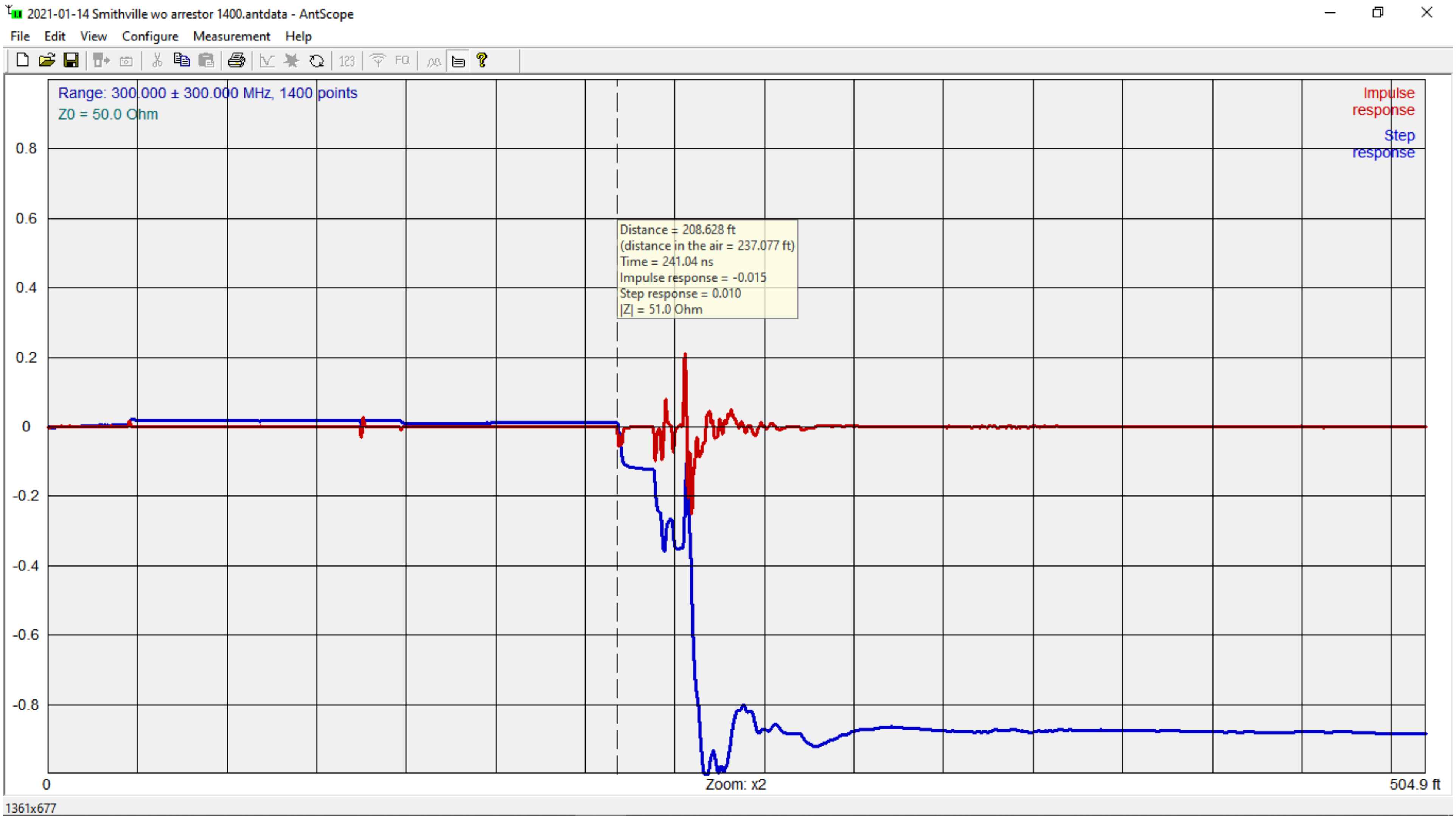
This is a 500 foot run to an ungrounded UHF “stick” type antenna. There are no problems using this antenna.



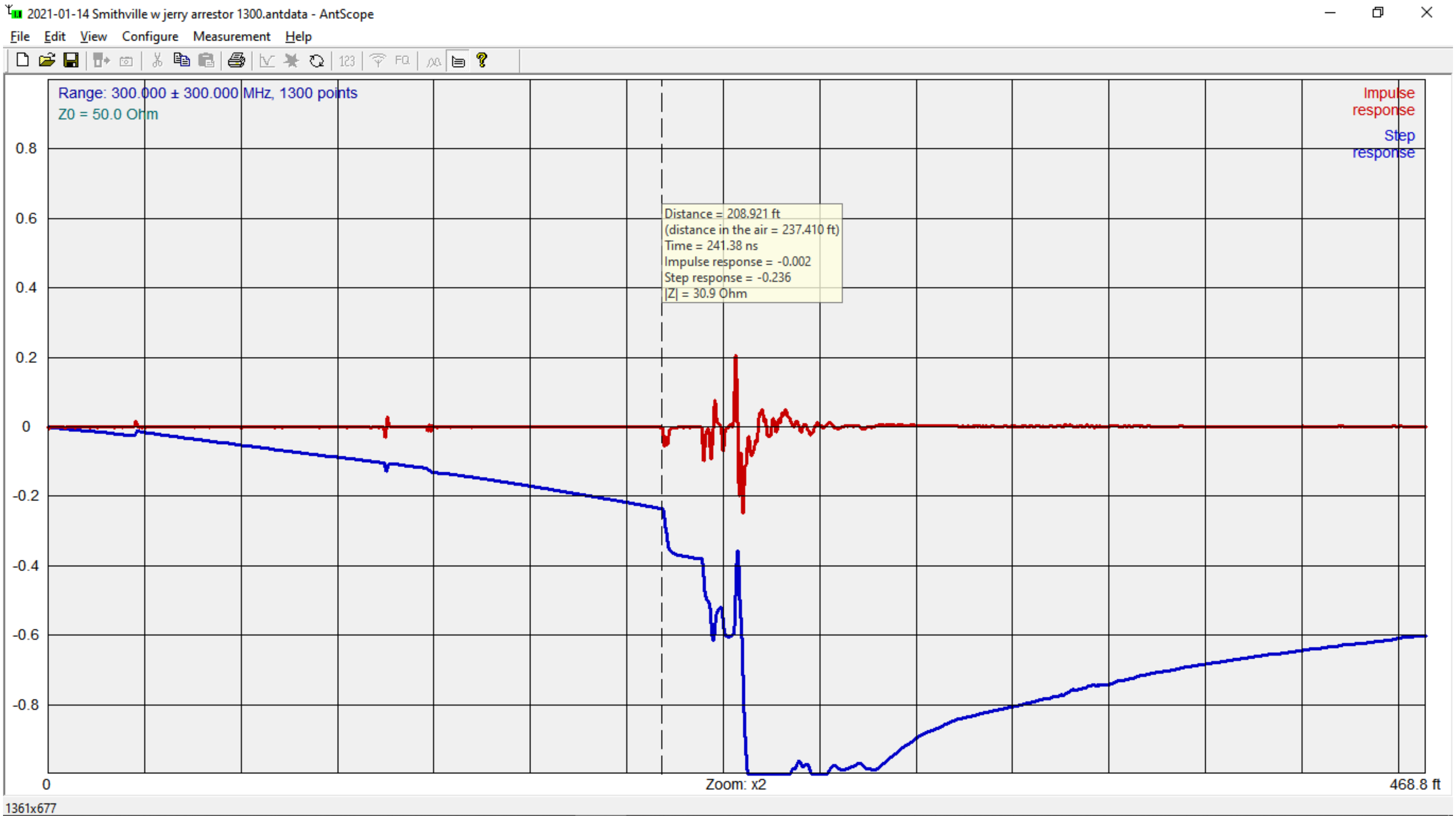
This is a 17.5 foot jumper we tried using from the Rig Expert AA-600 to the connector on the antenna feedline. The resulting scan produced a graph so unusual I decided to check the jumper. This is the scan of that jumper with the far end shorted. As you can see the cable is totally unusable. Upon further examination the braid of the cable appeared to have deteriorated to the point it did not pass a continuity test from one end to the other. There was no water egress into the cable and no determination was made as to why it failed the continuity test. This cable was cut up and discarded.



This is our latest installation. It is a DB-224 antenna mounted at 80 feet. Based on previous experience, we determined that there was a lightening arrestor in the line. We found a Polyphaser lightening arrestor at the cable entrance to the building. We replaced it with a bullet (or barrel) connector and reran the scan. It is on the next page.



This is the feedline without the arrestor. You can see several blips in the red line indicating connections from one piece of feedline to another. The large red blip in the fourth square from the left could be a kink or a compression of the feedline at that point. Without visual inspection there is no way to tell the exact cause. This is a DB-224 commercial antenna being used in the VHF ham band. The blue line signature is indicative of an out of phase condition caused by using the antenna at a frequency is was not constructed for. The antenna will still function and has a relatively low SWR but the radiation pattern will be adversely affected by the out of phase condition. We inserted a different brand of lightening arrestor and ran the scan again. It is on the next page.



This is the same feedline but the bullet has been replaced by an Array Solutions lightening arrestor. You can see how the scan result is affected by a different brand of arrestor. This shows us that we can tell what type of arrestor is in the feedline by the signature on the scan.