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## **GPR ANTENNA BANDWIDTH**

I was really surprised and somehow confused the first time I heard about a half wave dipole with bandwidths in excess of 100%. Two things didn't quite fit my previous knowledge about antennas; first, for any bandwidth exceeding 60% I was used to talk in terms of ratios. Secondly, I had never heard of any half wave dipole antenna with bandwidth greater than 10% and that only for a well manufactured and tuned device. It was of course all a big misunderstanding; we were using the same words but meaning different things. This tutorial tries to explain what do GPR (ground penetrating radar) people mean when they talk about bandwidths in excess of 100%.

### **BANDWIDTH DEFINITION OF TERMS**

There are different definitions for antenna bandwidth and it all depends on whom are you talking to or about which device the definition is valid. For instance, I was used to think of bandwidth as a measure of how much frequency variation is available while still obtaining an acceptable VSWR (2:1 or less) and minimizing losses in unwanted directions.

So, what is it after all, the bandwidth? Balanis [1] gives a better definition for bandwidth: "The bandwidth of an antenna is defined as: the range of frequencies within which the performance of the antenna, with respect to some characteristics, conforms to a specified standard". In other words, there is no unique characterization of the bandwidth and the specifications are set to meet the needs of each particular application.

All in all, that means different field of antenna applications can define their very own bandwidth specifications as long as is understood among all professionals within that specific field.

What is then called antenna bandwidth in ground penetrating radar? I haven't found anywhere a clear, in terms of exact figures, definition of antenna bandwidth for GPR antennas. It seems to be, and often quoted as: "industry standard", "commonly accepted", etc, that antenna bandwidth in ground penetrating radar is defined as follows.

Antenna Bandwidth (GPR): Is the ratio of the difference of the upper and lower frequencies of acceptable operation to the center frequency of that band multiplied by 100.

$$BW = \left( \frac{Fh - Fl}{Fc} \right) * 100 \quad (1)$$

*BW* – GPR bandwidth, sometimes called antenna fractional bandwidth and is expressed in percentage.

*Fl* - Lower frequency limit where the magnitude of the spectrum is 10 dB weaker than of the strongest frequency component in the whole occupied spectrum.

*Fh* - Higher frequency limit where the magnitude of the spectrum is 10 dB weaker than of the strongest frequency component in the whole occupied spectrum.

*Fc* – Center frequency defined as the difference between the higher frequency limit and the lower frequency limit divided by 2 and then added to the lower frequency limit.

One thing is worth noting in the above equation, both higher and lower frequency limits are taken at – 10 dB levels. In this way one can say that, the “commonly accepted GPR antenna bandwidth” is specified as the range of frequencies over which the antenna is capable of transmitting and/or receiving signals above – 10 dB relative to the strongest frequency component in the entire spectrum.

## **BANDWIDTH MEASUREMENT**

Now that we know what the GPR antenna bandwidth is, how do we measure it? There are many ways of measuring antenna bandwidth including using sophisticated equipment as FCC does for issuing compliance certificates. But, we are trying to achieve here an easy way of measuring relative bandwidth without spending a fortune in lab tests. We want to use what we already have, the radar system or at least the collected under known conditions data set.

Before going any further there are two things to make clear. First, GPR radar systems store in their data sets values corresponding to voltage values not power. Second, the frequency response obtained from a data set of GPR file is not only representing the bandwidth of the antenna but of the whole system. That includes also the media where the data set was acquired. In other words, before attempting to define for comparison purposes the bandwidth of the “GPR antenna” take as long files as possible and specify the geology of the survey site.

Here is what we do in six easy steps:

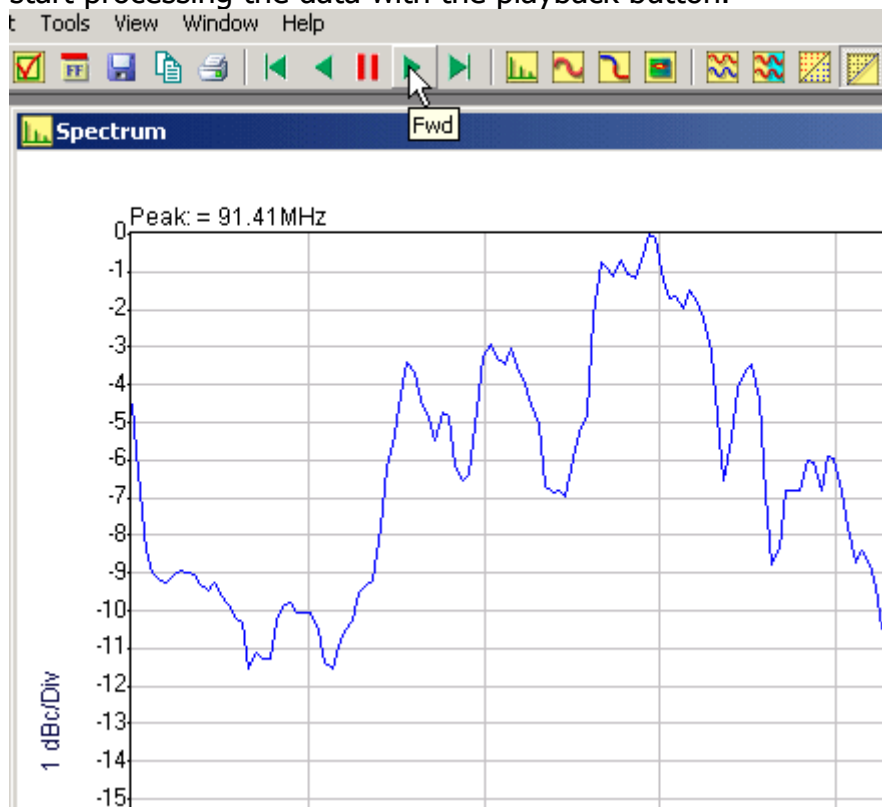
1. Collect the data set with the antenna you are trying to measure. Preferably with the radar system the antenna was designed for. And no, not all antennas are designed for a specific radar system and there are even compatible radar systems.

Make sure the survey area has no disturbing elements in the vicinity, for instance mobile phone transmitters, TV towers etc. If your system has cables for running the control signals from the radar unit to the antenna, make sure they are tidy and not hanging all over, they can and certainly will couple with


the antenna elements causing wrong readings. That is particularly important if the antenna you are trying to measure is unshielded.

Take notes on the geology of the survey site; it can be useful later on to compare with other tests. Set up the radar unit so a power of two number of samples per trace is obtained. If your radar system has hardware gain capabilities set the gain so around 75% of the available data range is occupied, do not saturate the AC/DC converters. And finally record the data using the antenna according to the manufacturer specifications but using no filters or any kind of signal processing that might produce false results.


2. Import the collected data into GaiaSpectrum®, select peak hold mode and start processing the data with the playback button.

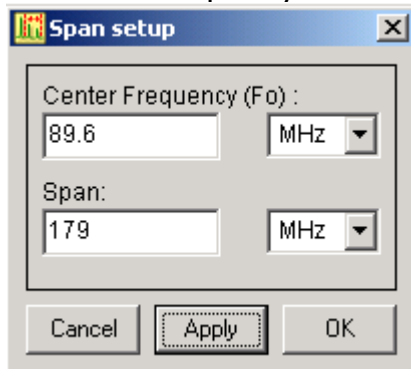


**Fig. 1 Start processing the data**

3. Press the level button in the utilities toolbar.  This will activate the level window, enter -10 and press the button "apply". A red horizontal line will appear on the -10 dB level on the spectrum data view. Pay attention to where the signal and the level line intercepts and put the cursor approximately in between the two interceptions over the red line and press the left button of the mouse. In the right upper corner of the spectrum data view appears the level and frequency of the selected point. Take a note of the frequency value.



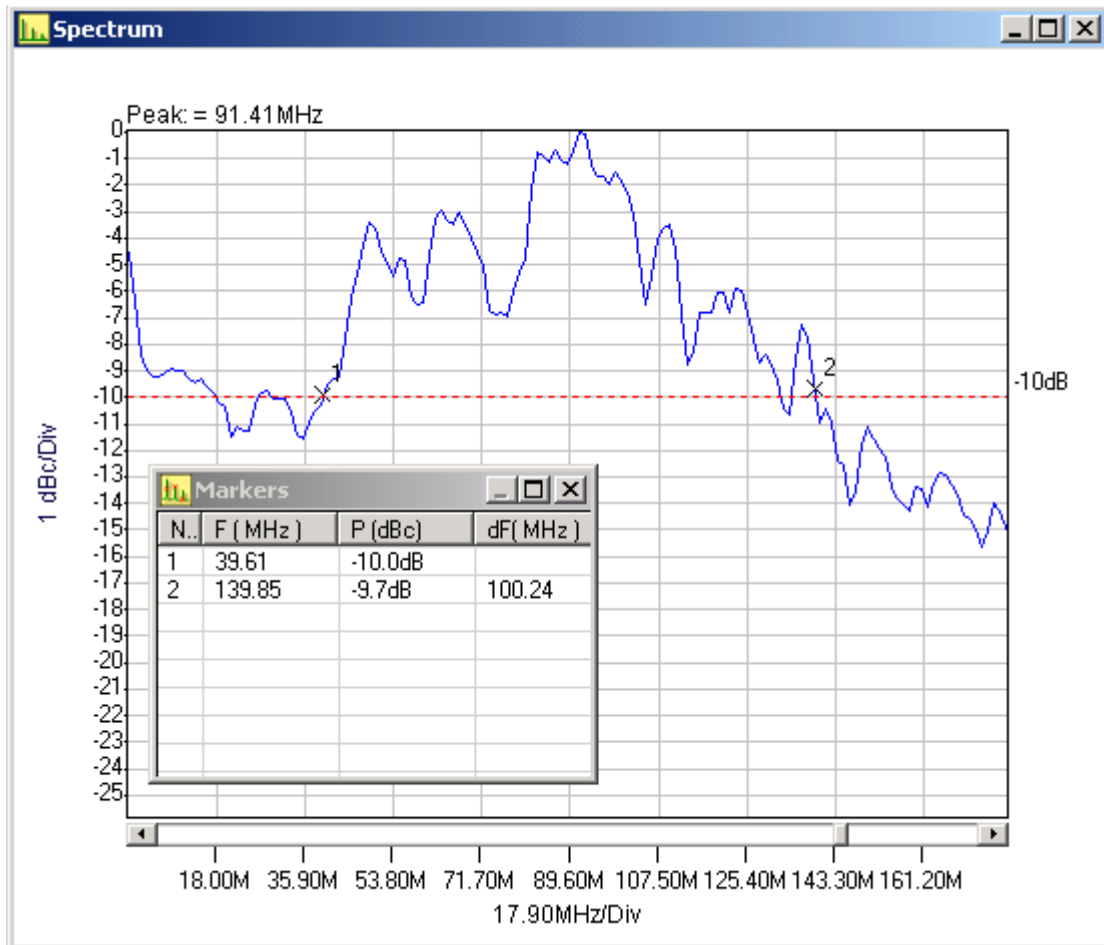
4. Press the span button in the editing toolbar.  This will bring up the span setup window. In the center frequency text box enter the value of the frequency that you read before. Make sure to select the correct units in the units drop down menu. In the Span text box enter the previous frequency times 2. Press the button "apply" and check the resulting plot. If the span is too large a message box appears telling you to reduce the span or increase the center frequency. Reduce the span until the spectrum fits in the window.



5. When the file has been completely processed activate the markers from the main menu or with the marker button in the toolbar.



The markers window appears indicating marker mode and allowing for entering markers directly on the active spectrum view. Going to the left from the peak frequency, press the left button of the mouse where the level line and the spectrum line intercept. That's the first marker and its frequency and magnitude values appear in the markers window. Now, going to the right from the peak frequency, press the left button of the mouse where the level line and spectrum line intercept. That will be the second marker, press the right button of the mouse and select exit marker mode. You should get something similar to figure 2.



**Fig. 2 Markers and level line**

- The marker's number one frequency value is the lower frequency limit " $F_l$ " and the " $dF$ " value is the difference between the upper and lower frequency limits. Calculate then the bandwidth using the following formula:

$$BW = \left( \frac{2 * dF}{dF + 2 * F_l} \right) * 100 \quad (2)$$

In the above example it yields an antenna with a -10 dB bandwidth of 111.7%, which is the kind of performance one would expect from a bat-wing antenna like the one tested here.

## CONCLUSIONS

This tutorial presented an easy and affordable way of testing antenna bandwidth without having to rent expensive equipment. And while I would not recommend to anyone to go to the FCC test site based only on these results, they are accurate enough to check antenna performance, manufacturer's claims, etc.

It would be nice if everyone specifying their hardware, test results, or anything that includes the term bandwidth specifies that it is a -10 dB bandwidth or something else. It is very difficult and at times disappointing and frustrating when the claims do not meet reality. That alone would remove lots of confusion and misunderstandings in a field that is already difficult for most of the end users.

**References:**

- [1] Balanis C.A. Antenna Theory, Wiley Interscience 2005.

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