Centre frequency and lateral resolution, a practical example

Background

A common question concerns the lateral resolution for a certain antenna. Many people believe that the only important parameter is the centre frequency of the antenna; “the higher frequency the higher resolution”. In fact, though, it is the bandwidth of the antenna that is the most important factor for the resolution. Since most modern GPR antennas have a fractional bandwidth around 100% or more, this is more of an academic question, though. This note gives some background information and shows practically what centre frequency and bandwidth means for resolution capabilities of two common antennas.

Equipment used

For this study we choose to use the 1.2 GHz and the 2.3 GHz antennas. Both of these are commonly used for concrete investigations, and their centre frequencies are separated wide enough to make the results clear and easy to understand. The two antennas are shown in Figure 1 below.

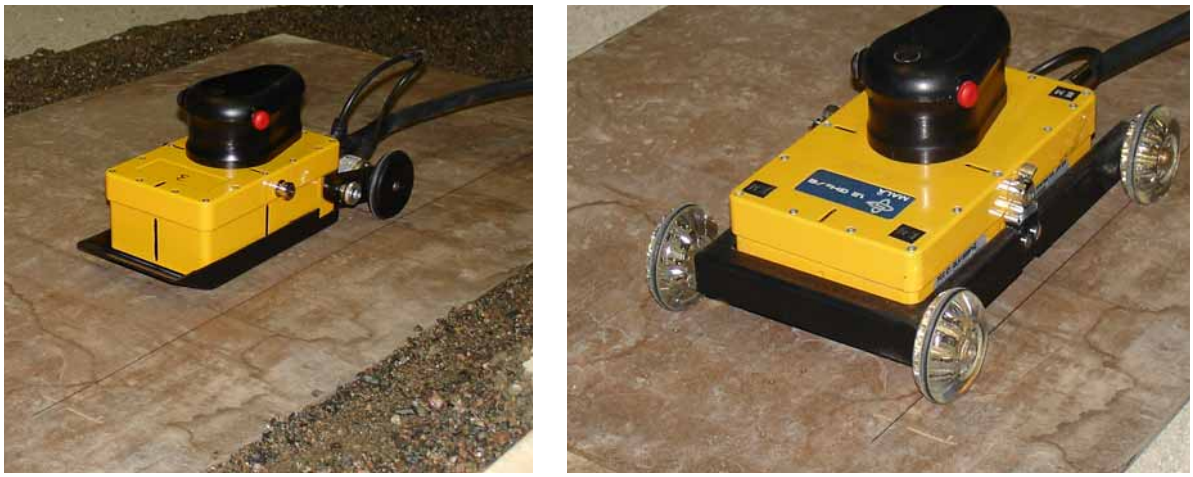

Figure 1. The 2.3 GHz (left) and 1.2 GHz (right) antennas.

In order to make the comparison more clear, exactly the same data collection parameters were used while gathering data with the two antennas.

Equipment characteristics

It is important to have a clear view of how the frequency spectrum of both antennas looks, in order to properly assess their resolution capabilities. The bandwidth is defined as the band above a threshold line located -10dB below the peak of the spectrum. The centre frequency is defined as the midpoint between the points where the spectrum crosses this line. In figure 2 below the spectrum for the two antennas are shown. Note that these spectra were derived from real data acquired at the test site.

As can be seen in figure 2 the 2.3 GHz antenna has a bandwidth of 3750 – 850 = 2.9 GHz, giving a centre frequency of 2.3 GHz. The 1.2 GHz has a bandwidth of 1 GHz centred at 1150 MHz. The small deviations from the nominal values are explained by the somewhat arbitrary way of calculating the spectra. Other positions in the dataset may give other values, although the variations from the nominal values will be small, since the conditions are not extreme.

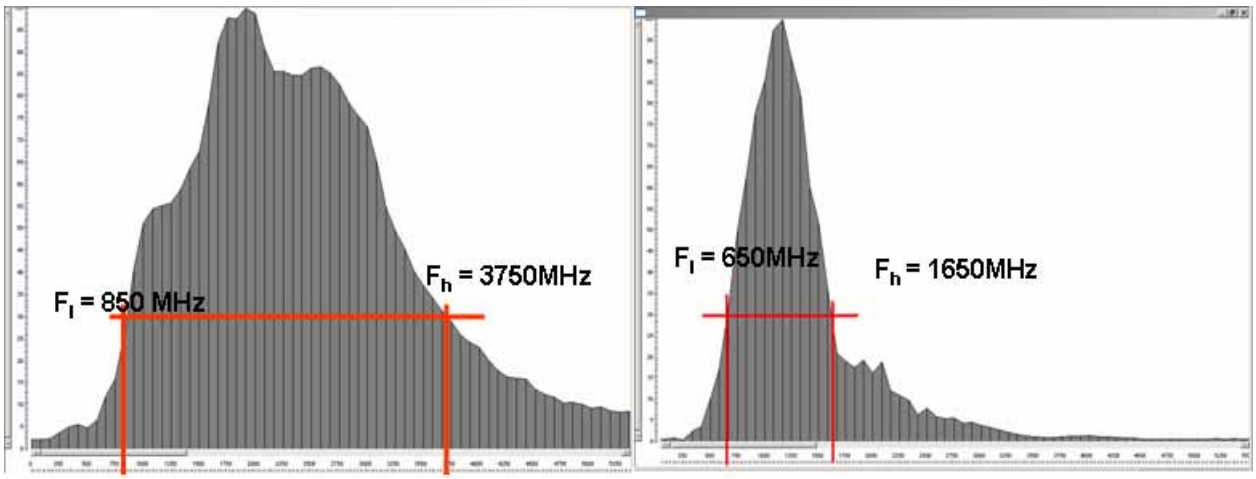

Figure 2. Frequency spectrum calculated from data from the 2.3 GHz and 1.2 GHz antennas respectively.

To further explain the spectra seen in Figure 2 and the conclusions made here, one has to go back to the definition of bandwidth. The two points where the spectrum crosses the -10dB line (0.3 in the scale used in the figure), are denoted f_h and f_l. Bandwidth is defined as f_h-f_l, and centre frequency as $f_l + (f_h-f_l)/2$. The fractional bandwidth is defined as the bandwidth normalized by the centre frequency, as expressed above.

The 2.3 GHz antenna has about twice the bandwidth as well as twice the centre frequency, and therefore one would expect about twice the resolution capabilities as well, as long as everything else are unchanged.

Test specimen

A target was constructed with parallel thin wires, with varying spacing in between. The spacing varied from 1 to 10 cm, and the wires were covered by 5 cm dry sand. Figure 3 illustrates the construction.

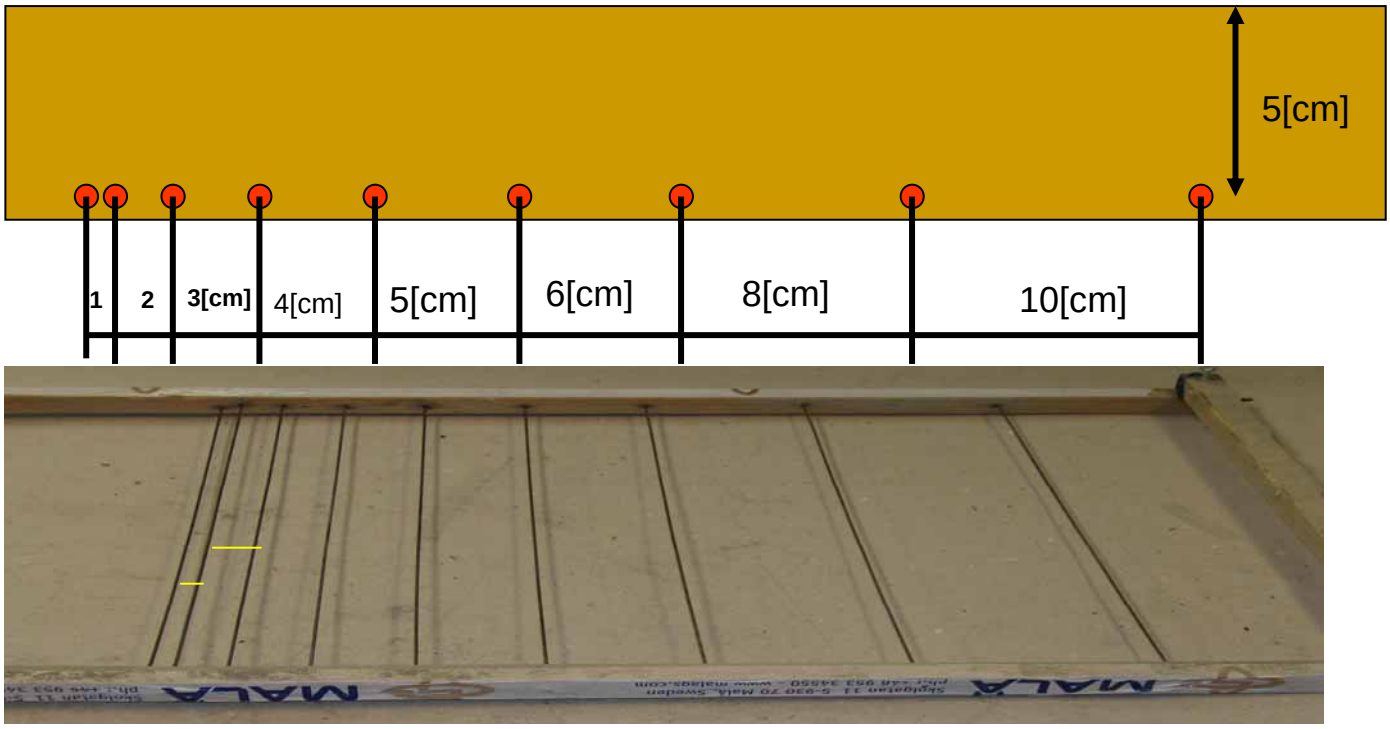

Figure 3. Schematic layout of the test arrangement (top) and a photo of the buried specimen (bottom) without sand.

Results

Already the raw data gives a very clear picture of the difference in resolution between the two antennas. Figure 3 below illustrates that the 2.3 GHz antenna clearly resolves the wires from the direct wave, while the 1.2 GHz antenna almost have the targets within the first arrival.

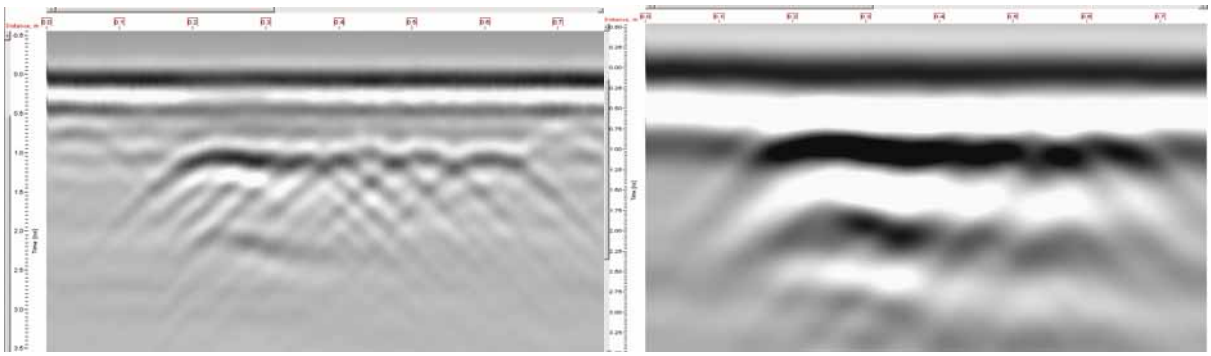

Figure 3. Raw data from the 2.3 GHz (left) and the 1.2 GHz (right).

In the 2.3 GHz raw data, some of the wires can be easily detected, and legs of the diffraction hyperbolas can be seen all along the target. The 1.2 GHz antenna detects the targets, but it is hard to distinguish individual wires, only a fey hyperbola legs can be distinguished.

After processing the data, including migration, the picture becomes clearer for both of the datasets. In Figure 4 below, sections of the processed datasets are shown for both antennas.

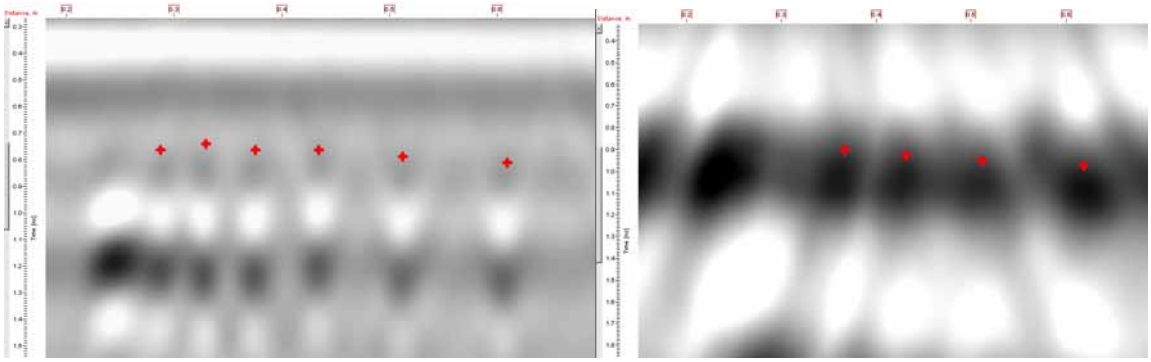

Figure 4. Processed data from the two antennas.

Figure 4 illustrates clearly that the 2.3 GHz antenna resolves all wires except the three separated with 1 and 2 cm. These three wires shows up as one target only. The separation of 3 cm between these three targets and the next is clearly resolved. Thus, one can say that the lateral resolution is between 2 and 3 cm. The same way of reasoning gives a lateral resolution between 4 and 5 cm for the 1.2 GHz antenna.

Conclusions

In dry sand and at 5 cm depth we have a lateral resolution of 2-3 cm for a 2.3 GHz antenna and a 4-5 cm resolution for a 1.2 GHz antenna, as should be expected. The thin wires used and the specific conditions does not compromise the result in any way, but one must keep in mind that the host material as well as the target characteristics can make the real world more complicated.

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