# Ground Penetrating Radar Antenna Alignment for Potato Detection

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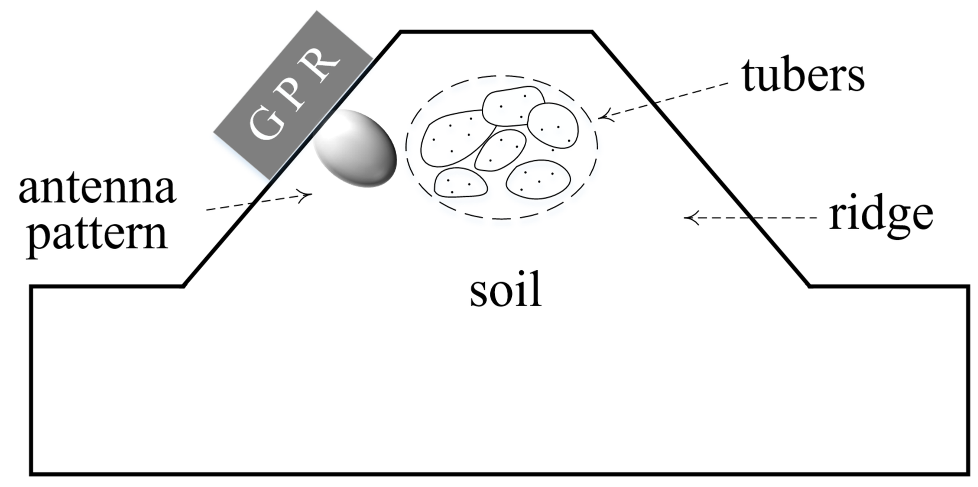
## INTRODUCTION

Ground penetrating radar (GPR) technology has been recently used to monitor tuber growth and predict potato yield. In the tuber formation stage, the majority of new tubers develop around and above the seed potato within an ellipse region, as shown on the right figure. Due to foliage blockage and large ground reflection, it is quite challenging for air-coupled GPR to detect potatoes from the top side of the ridge. Alternatively, the side of the ridge can still be used for ground-coupled GPR. However, this approach suffers from weak signal return if antenna is positioned too low. This is partly because the tubers are no longer positioned in the antenna's main beam direction. Therefore, it is necessary to investigate the effects of antenna pattern and alignment on potato detection from the side of the ridge.

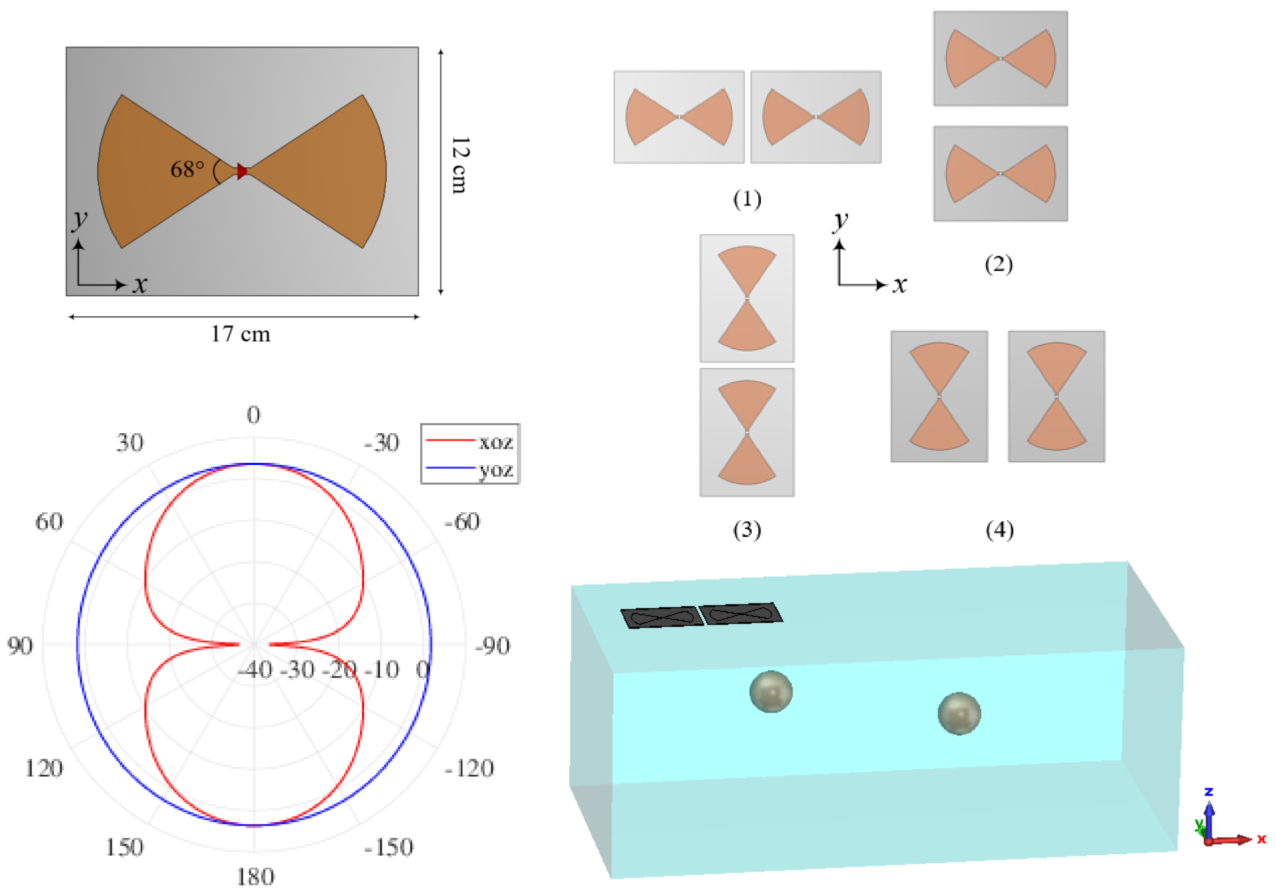



Schematic of GPR scanning on the side of a potato ridge (cross section view)

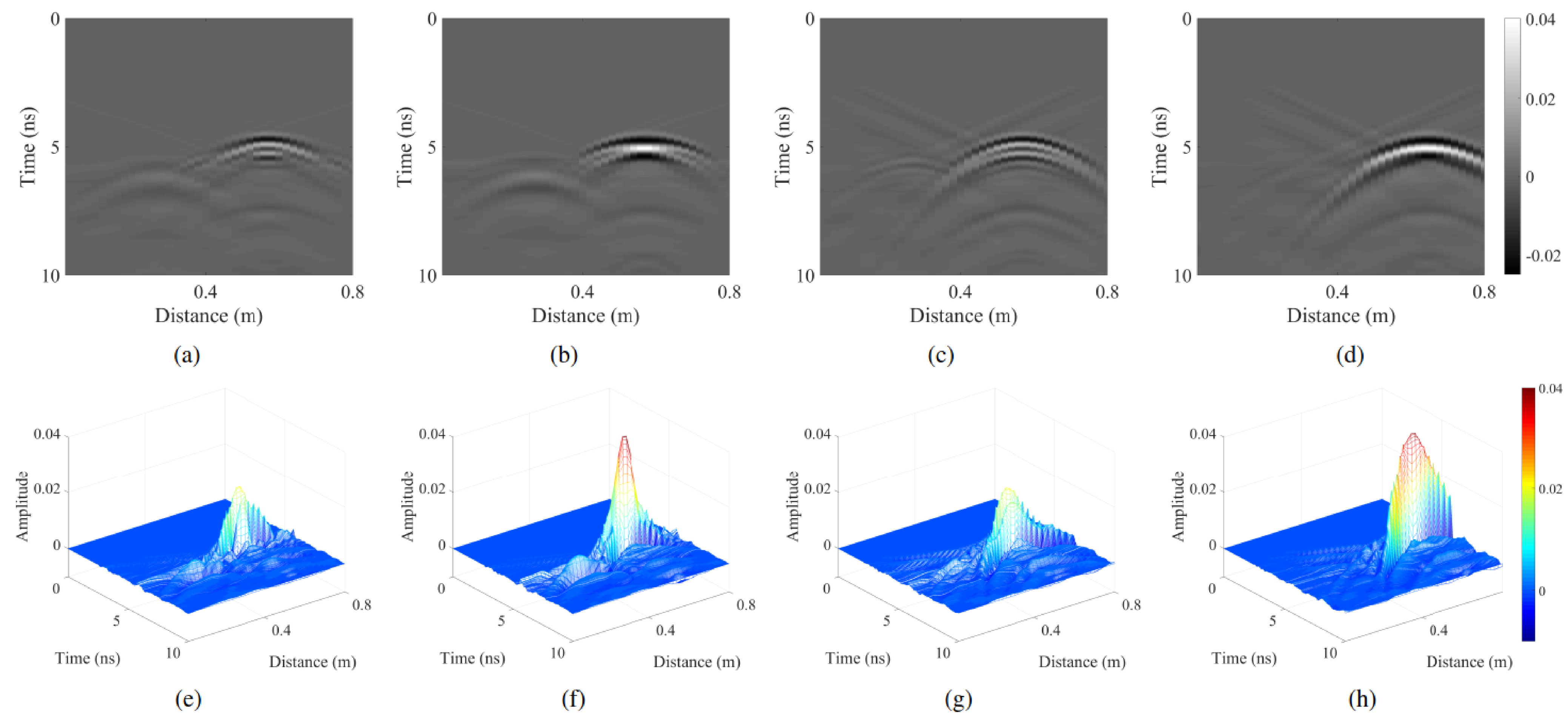
## SIMULATION RESULTS

This paper considers a bi-static GPR set-up with two bowtie antennas. The antenna pattern in the xoz plane is narrower than the pattern in the yoz plane. As the antenna gain is directly related to the GPR transmitting and receiving power, the GPR will have lower detection sensitivity for side targets in the xoz plane. To understand the effects of antenna alignment on the performance of side targets detection, 4 alignment schemes were simulated using CST Microwave Studio. For simplicity, a rectangular box was used as the soil layer where the relative permittivity is 10, permeability is 1 H/m, and conductivity is 0.1 S/m. Two perfect electric conductor (PEC) sphere with radius of 0.05 m were buried 0.25 m deep in the soil. One is right below the survey line which is refereed to as the centred target. The other one is 0.2 m away from the survey line (y=0.2) and refereed to as the side target. Antennas were placed 2 mm above the soil box and scanned from left to right for all 4 alignment schemes.

All figures were plotted in the same range for direct comparison. It can be noticed that scheme 1 and scheme 3 show considerably weaker amplitude than scheme 2 and scheme 4. This is readily understandable as antenna has narrower pattern in the xoz plane (long axis direction in scheme 1 and 3) than in the yoz plane (short axis direction in scheme 1 and 3). Consequently, the GPR results in bad coverage if antennas are stacked along the long axis. Therefore, scheme 1 and scheme 3 should be avoided in GPR scans. Furthermore, the side target is less visible than the centred target in all 4 schemes. This can be attributed to mainly two factors. Firstly, being on the side of the survey line means the total signal path is longer than the centred target even they have the same depth. Therefore, the GPR signal experience more attenuation due to soil loss. Secondly, side targets are at the side of antenna's main beam direction. The larger the angle the less the power being received. However, the first two schemes do offer better visibility than scheme 3 and scheme 4. This shows the importance of using the broader yoz plane pattern for side targets by aligning the antenna's long axis with the scanning direction. While scheme 2 and scheme 4 show similar sensitivity on detecting the centred target, the latter shows a more complete hyperbola with longer tails. This can be useful for hyperbola detection where longer tails leads to more accurate hyperbola fitting. On the other hand, scheme 4 completely missed the side target due to its low signal coverage in y direction. Ideally, scheme 4 is preferred if multiple survey lines are allowed to cover the whole area. However, in our case, the available space for multiple survey lines is quite limited. It is desirable to adopt scheme 2 so as to get more information on side targets within limited space.



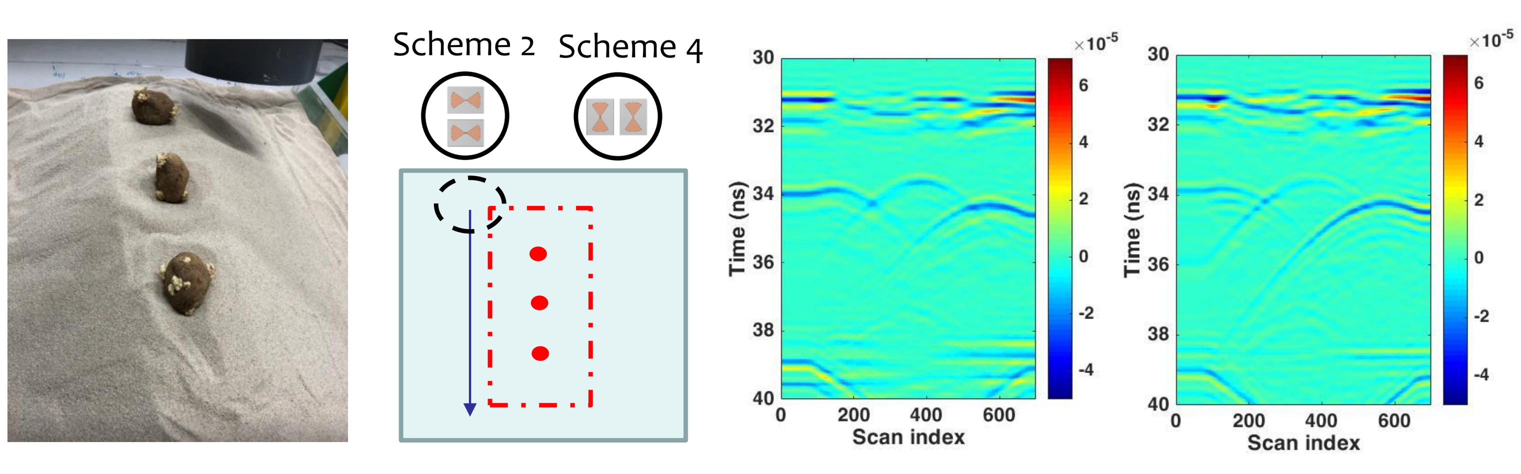

Antenna pattern and CST simulation




Bscan images of four antenna alignment schemes

## EXPERIMENT RESULTS

Experiments were carried out to verify the effectiveness of scheme 2 and scheme 4. Three potatoes were buried in a ridge-shaped sandpit with different depths. The GPR consists of two bow-tie antennas and an S5065 analyzer from Copper Mountain Technologies. As can be noticed from the bscan comparison, scheme 2 shows all potatoes with three clear hyperbolas while scheme 4 only show one clear hyperbola. The left two potatoes are less visible due to shallower depth and hence further away from the antenna main beam. On the other hand, the rightmost potato has longer hyperbola tails in scheme 4. These observations agree well with the simulation results.




Experiment verification of scheme 2 and scheme 4

## CONCLUSION

In this paper, we investigated the effects of bowtie antenna alignment for potato detection while scanning on the side of the ridge. The antenna pattern difference at two planes result in distinct detection sensitivities. Both simulation and experiment results confirm that it is easier to detect side targets by placing the bowtie antenna's long axis inline with the scanning direction.