

FEDERAL COMMUNICATIONS COMMISSION

APPLICATION FOR Experimental Radio Station Authorization

Background

30,000 lives are lost and an estimated 2.3 million injuries are caused each year due to traffic accidents in the US alone. Over 90% of those fatalities are caused by human error. Autonomous vehicles offer the potential to significantly reduce those fatalities. For the military, autonomous vehicles offer new capabilities and allow soldiers to reduce risk and increase productivity.

Autonomous ground vehicles navigating on road networks require robust and accurate localization over long term operation and in a wide range of adverse weather and environmental conditions. GPS/INS (inertial navigation system) solutions, which are insufficient alone to maintain a vehicle within a lane, can fail because of significant radio frequency noise or jamming, tall buildings, trees, and other blockage or multipath scenarios. LIDAR and camera map-based vehicle localization can fail when optical features become obscured, such as with snow or dust, or with changes to gravel or dirt road surfaces.

Localizing ground penetrating radar (LGPR) is a new mode of a priori map-based vehicle localization designed to complement existing approaches with a low sensitivity to failure modes of LIDAR, camera, and GPS/INS sensors due to its low-frequency RF energy, which couples deep into the ground. Most subsurface features detected are inherently stable over time.

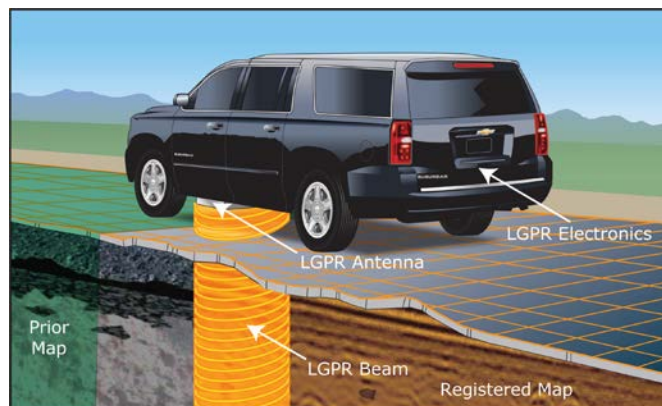


Figure 1: The LGPR array is shown mounted under the vehicle in this concept drawing. Radio frequency (RF) signals bounce off of underground features to localize a vehicle using a prior map of the subsurface.

Purpose of Experiment

The purpose of this experiment is to demonstrate and test the ability of autonomous vehicles to accurately lane-keep using an ultra-low power ground penetrating radar to localize the vehicle based on a prior subsurface map. Specifically, we are focusing efforts on making current optical (lidar and camera) approaches robust both in nominal fair weather operation over a wide range of environments and in poor weather conditions. We plan to increase the emissions to 400 μ W expected radiated power, if needed, to compensate for attenuation from rain and snow. The experiment will involve driving a vehicle to take measurements on roads and highways with the ground-facing radar strapped underneath (6" from the road surface) in snow, rain and other test conditions.

To date, we are unaware of other investigations along the line of using ground penetrating radar maps to localize ground vehicles using subsurface prior maps. Our program will explore and document this novel capability and its ability to improve the safety and robustness of autonomous vehicles localization

Timing of testing will be variable and generally sparse. Typical operation will be a few days of operation a month. A few one-week tests would be expected over the course of the experiment.

Description of System



Figure 2: Miniature Localizing Ground Penetrating Radar

Table 1: Key Localizing Ground Penetrating Radar Parameters for nominal operation.

Key Parameter	Value
Radar type	Stepped frequency continuous wave
Frequency range	100–400 MHz
Frequency spacing	51 tones spaced by 6 MHz
Array dimensions	152 cm × 61 cm × 7.6 cm (5.0 ft × 2.0 ft × 3.0 in)
Array offset from ground	15.24 cm (6 in.)
Number of antenna elements in array	12
Number of channels (number of pairs of elements)	11
Total radiated power	40 μ W continuous (one element at a time)
Leakage power (radiated above-ground)	4 μ W
Radar sweep rate (all 11 channels)	126 Hz
Depth of penetration	2 m–3 m (New England soil)
Radar range resolution	20 cm–30 cm

The Localizing GPR design differs from traditional GPR systems to allow localization to be achieved. The LGPR consists of four basic functional components: a unique antenna array, a 2×12 switch matrix, a custom VHF stepped frequency continuous wave (SFCW) GPR, and one single-board computer (SBC). These components are shown in Figure 2 (the radar electronics and SBC are within the chassis shown). The switch matrix switches the individual transmit and receive channels of the radar to each of the array elements. Data sent to the SBC are processed using standard SFCW radar techniques to generate data as seen in Figure 3.

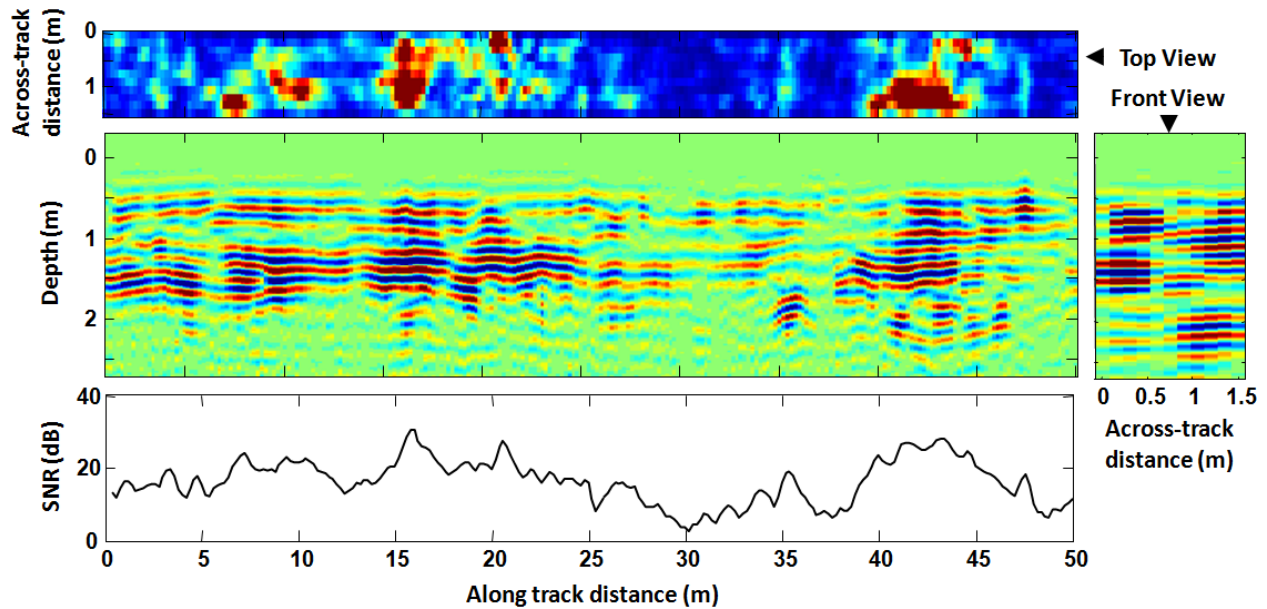


Figure 3: Typical Localizing Ground Penetrating Radar Data

One key difference between the LGPR array and traditional GPR array designs is the spacing between the elements (12.7 cm), which is approximately one tenth of a center frequency wavelength. This resolution is finer than typically seen in GPR arrays and is driven by a desire to allow for high-fidelity matching to baseline data. In addition, the elements and array cavity are designed so that every element has identical near-field (and thus far-field) patterns. This is required to allow path retraversal in which pass-to-pass offset or misalignment is present. This element similarity requirement is especially difficult to meet for our close element spacing (relative to wavelength), which, in traditional GPR arrays, ordinarily results in significant mutual coupling and array end effects.

Government Contract Information

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Station Location

Operation is confined to the road and highway network within a 200 mile radius of 44°16'32.0"N 70°49'16.0"W (an arbitrary center location near Stoneham, Maine (Oxford County) chosen to create a circle that includes the tips of interstate 95 in Maine, West Point in New York, and Woods Hole in Cape Cod). Primary operations will be in the greater Boston area, inclusive of Lexington, MA (Middlesex County) and Cambridge, MA (Middlesex County) and connecting roads. All operations will be confined to the United States.

Frequency Description:

This is a Stepped Frequency Continuous Wave (SFCW) Ground Penetrating Radar. As it is mounted underneath a vehicle and pointing at the ground from a distance of 6", most of the energy is absorbed by the ground.

Frequency MHz	Mean Power/ERP	Instantaneous Bandwidth	Emission Designation	Modulating Signal
103-403 at 6.0 MHz intervals (103,109,115...) Stepped Frequency Continuous Wave (51 frequencies emitted one tone at a time)	4μW-400μW ERP (40μW-4mW emitted towards ground at 6" clearance)	100 KHz	100KN0N	None

Table 1

Each frequency is emitted on a 1.7% duty cycle (e.g. 109MHz is emitted for 17ms in total per second), so the mean power at any one frequency is small. During any one second the system is operating, the GPR will transmit at each frequency for 1390 individual 12.288us single frequency transmit intervals, yielding a total transmission time of 17.08ms per second per frequency.