Physical Limitations on Detecting Tunnels using Underground Focusing Spotlight Synthetic Aperture Radar

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Detecting and imaging the presence of tunnels in any given region of ground is possible because the air that fills them is materially quite different from anything else underground, but challenging because the unknown variation of underground media, the randomly rough ground surface, and the cross section of the tunnel often being very small compared to its depth. There are many sensing modalities which use wave-based probes which easily penetrate earth, but ensuring that the signal from the tunnel target is sufficiently strong and distinct relative to those due to other underground inhomogeneities is the key to being able to find tunnels in the field. One of those technologies is the Spotlight Synthetic-Aperture-Radar (SL-SAR) with underground focusing, which is an appealing modality for the tunnel detection problem since it is able to sense large areas of terrain in short amount of time.

The UF-SL-SAR concept has the potential to focus to surface targets with ideal scenarios. For instance, cases where the shape of the ground and its constitutive parameters are precisely known are amenable to underground focusing. The main problem in general arises since this kind of ground configuration is never found in realistic scenarios. Indeed, in most cases the permittivity, permeability and conductivity are unknown even at fixed frequency, and the ground surface is not flat but rough and characterized by an unknown random distribution. These uncertainties make the problem of underground focusing difficult to solve. An additional complication exists with the fact that for relatively lossy ground, the amount of energy that is transmitted/coupled from the air into the soil, then scattered by an anomaly, and finally transmited/coupled from the soil into the air, can be too small for underground sensing.

This work presents the scattered field, synthesized by using underground SAR techniques, for the cases where there is a tunnel underground, compared to when there is not. It demonstrates that a successful detection depends on the type of soil for which the sensing is performed.