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Dual-Polarization Coherence Factor for Clutter Reduction in Forward-Looking Ground Penetrating Radar Imaging

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1. Extended Abstract

Over the last decade, there has been growing interest in the development of ground penetrating radar (GPR) systems that provide standoff sensing capability. This has led to a new class of GPR systems, called Forward-looking GPR (FL-GPR), which permit fast detection of shallow buried targets over wide areas by using oblique and near-grazing incidence sensing. Major challenges facing this technology arise from the reduced backscattered power from the illuminated targets and the clutter generated by the rough ground surface [1]. The latter is of comparable strength to the target backscattering, which can result in a high false alarm rate. As such, effective clutter suppression is highly desirable for enhanced target detection performance of the FL-GPR.

In this paper, we present a coherence-factor (CF) based clutter mitigation technique, which employs co-polarized measurements (HH and VV polarizations). The CF is a dimensionless quantity, defined as the ratio of the total coherent received power (generated by the presence of fixed scatterers in the region of interest (ROI)) to the total incoherent power (produced by the rough surface clutter for the case under consideration) [2]. For the dual-polarization case, the CF is mathematically expressed as

$$CF(q) = \frac{|\sum_n \sum_m (O_{nm}^{VV}(q) + O_{nm}^{HH}(q))|^2}{NM \sum_n \sum_m |O_{nm}^{VV}(q) + O_{nm}^{HH}(q)|^2} \quad (1),$$

where N and M are the number of transmitters and receivers, and $O_{nm}^{VV}(q)$ and $O_{nm}^{HH}(q)$ are the complex amplitudes corresponding to the qth pixel in the ROI obtained by applying matched filter to the mth recorded VV- and HH-polarization measurements, respectively, over the bandwidth of interest with the nth transmitter active. The CF is applied as a correction factor to the coherent combination of dual-polarization images, $O^{VV}(q)$ and $O^{HH}(q)$, of the ROI as

$$O_{CF}(q) = CF(q)O(q);\ O(q) = O^{VV}(q) + O^{HH}(q) = \sum_n \sum_m O_{nm}^{VV}(q) + \sum_n \sum_m O_{nm}^{HH}(q) \quad (2).$$

We model a stepped-frequency dual-polarized FL-GPR, mounted on top of a vehicle, in AFDTD software [1]. The radar system operates over 0.3-1.5 GHz, with a forward-looking coverage angle spanning 5-20 degrees with respect to the horizon. The system consists of 2 transmitters and 16 uniformly-spaced receivers, distributed over a 2-m wide aperture. The transmitting and receiving antennas are placed approximately 2 m above the ground, which is modeled as a non-dispersive and non-magnetic homogeneous medium with dielectric constant = 6 and conductivity = 10 mS/m. A two-dimensional zero-mean rough surface profile is assumed, which is represented by Gaussian statistics (rms height = 1.6cm and correlation length = 14.27 cm). Thus, the scattered electric field is considered to be a random process and evaluated by means of a Monte Carlo simulation. The ROI is populated by a total of nine metallic and non-metallic targets at distinct locations. For more details about the simulation setup, refer to [1]. Fig. 1 shows both the coherently combined dual-polarized image and the corresponding CF-corrected image. Clearly, the clutter has been significantly mitigated, which would lead to a reduction in the false alarm rate.

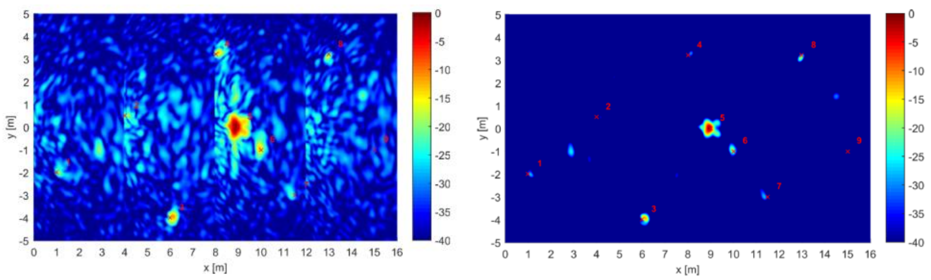

Figure 1. Coherently combined dual-polarized image (left) and corresponding CF-corrected image (right).

2. References

1. D. Liao, T. Dogaru, and A. Sullivan, "Large-scale, full-wave-based emulation of step-frequency forward-looking radar imaging in rough terrain environments," Sens. Imaging, 2014, pp. 15–88.

2. R. Burkholder, and K. Browne, "Coherence factor enhancement of through-wall radar images," IEEE Antennas Wireless Propag. Lett., vol. 9, pp. 842–845, 2010.