Effective Polarization Filtering Techniques for Ground Penetrating Radar Applications

Abstract The effect of different decomposition techniques on the imaging and detection accuracy for polarimetric surface penetrating data is studied. These techniques are applied to multi-frequency (0.4-4.8GHz) full polarimetric near-field radar measurements of scattering from surface laid calibration objects and shallow buried landmine types.
It is shown in detail how the decomposition results provide effective surface and sub-surface clutter reduction and guide the interpretation of scattering from subsurface objects. Data processing methods assume cross-polar symmetry and a novel bistatic calibration procedure was developed to enforce this condition.

Experimental Setup

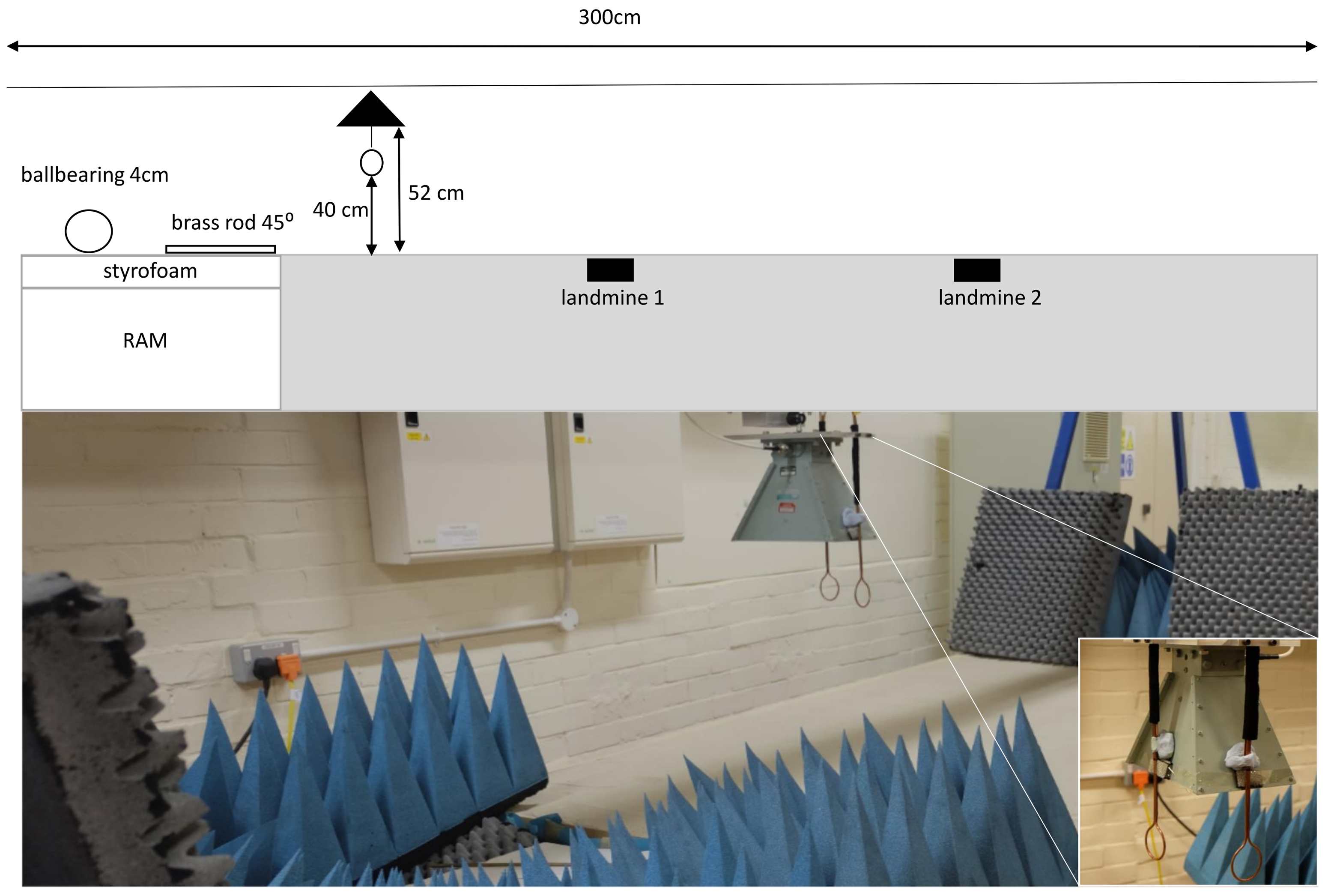

Fig. 1: Sketch and photo of laboratory setup. The antenna head is comprised of a TEM horn as a transmit antenna and two loop antennas as receivers for receiving co- and cross polar backscatter.

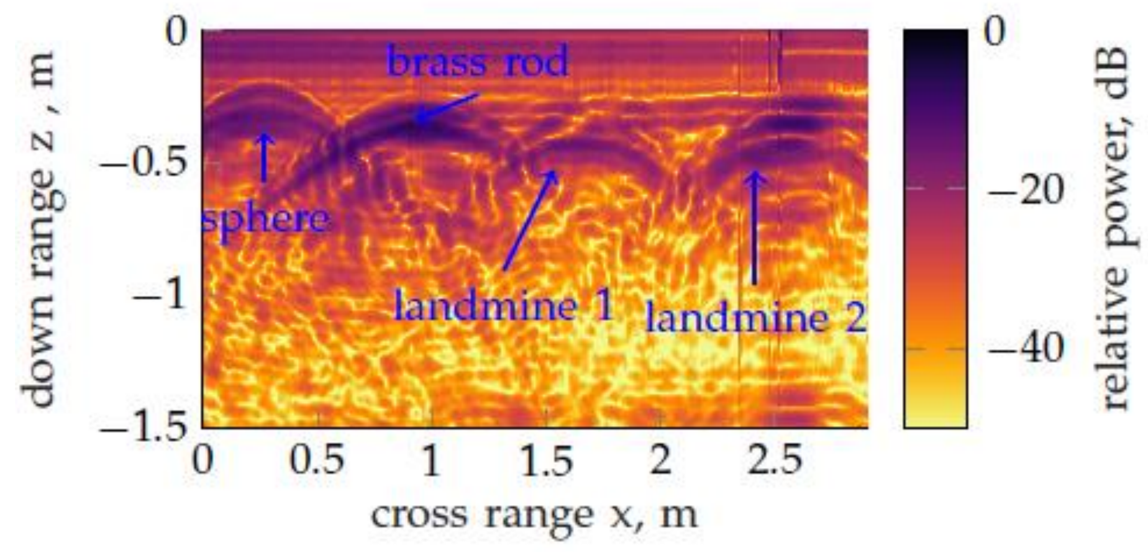

Fig. 2: VV range profile, with targets indicated.

Yamaguchi Polarimetry Decomposition

$$P_{co} = \left| \frac{S_{HH} + 2 \cdot S_{HV}\rho + S_{VV} \cdot \rho^2}{1 + \rho\rho^*} \right|^2 \quad (1)$$

$$P_x = \left| \frac{S_{HH}\rho^* + S_{HV}(\rho\rho^* - 1) - S_{VV}\rho}{1 + \rho\rho^*} \right|^2 \quad (2)$$

$$\rho_{co,1} = -0.7133 \cdot 10^{-2} + 0.4566j \quad (3)$$

Yamaguchi polarimetry decomposition allows to synthesis a radar channel at any polarisation state from the scattering matrix. The polarimetric clutter matrix, is agnostic in the sense that it does not know the type of clutter we wish filtering e.g. it could be antenna coupling, or as here, subsurface clutter in the sand. Equations for co- and cross polar power computation is given in (1) and (2).

Differential Interferometric Polarimetry

Differential Interferometric Polarimetry (DinPol) takes advantage of phase changes between two polarimetry states in this case HH and VV. Equations (4) and (5) illustrate the technique.

$$P(x,y) = \sum_{n=1}^{pol_{state}} \Delta\phi(x,y)_n \cdot |p(x,y)_n| \quad (4)$$

$$\Delta\phi(x,y)_n = \angle\left(\frac{p(x,y)_{n+1}}{|p(x,y)_{n+1}|} \cdot \frac{|p(x,y)_n|}{p(x,y)_n} \right) \quad (5)$$

The images retain all the polarimetric scattering mechanism of Stokes parameters while suppressing random clutter. Hence, the DinPol co-polar almost completely suppressed the air-ground interface and retains targets with single or odd bounce scattering features.

Imaging Results

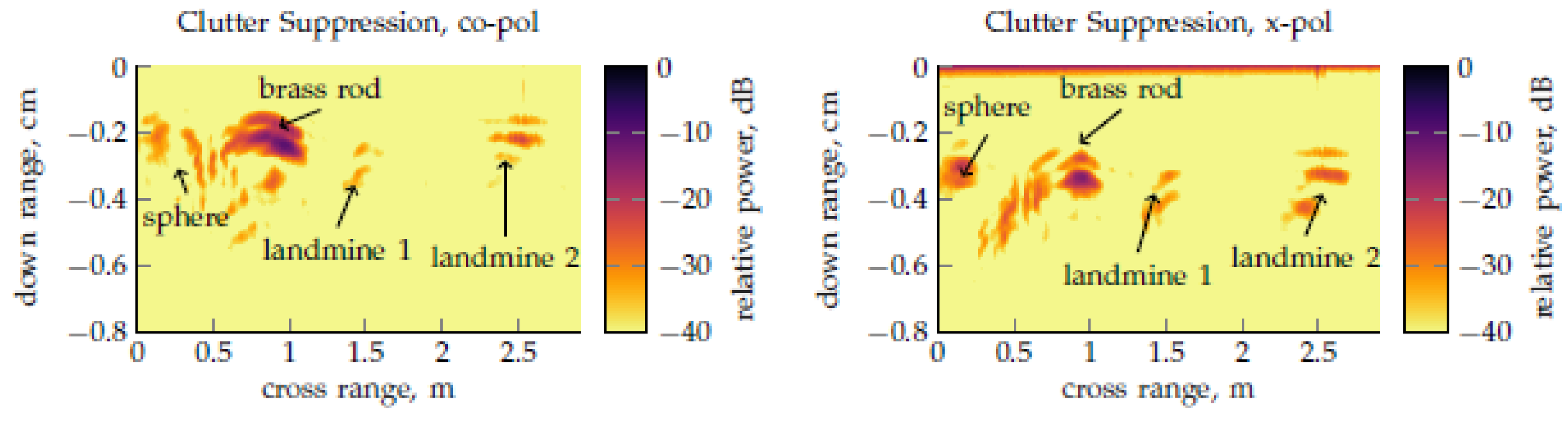

Fig. 3: Co- and cross-polar Yamaguchi polarimetric clutter suppression.

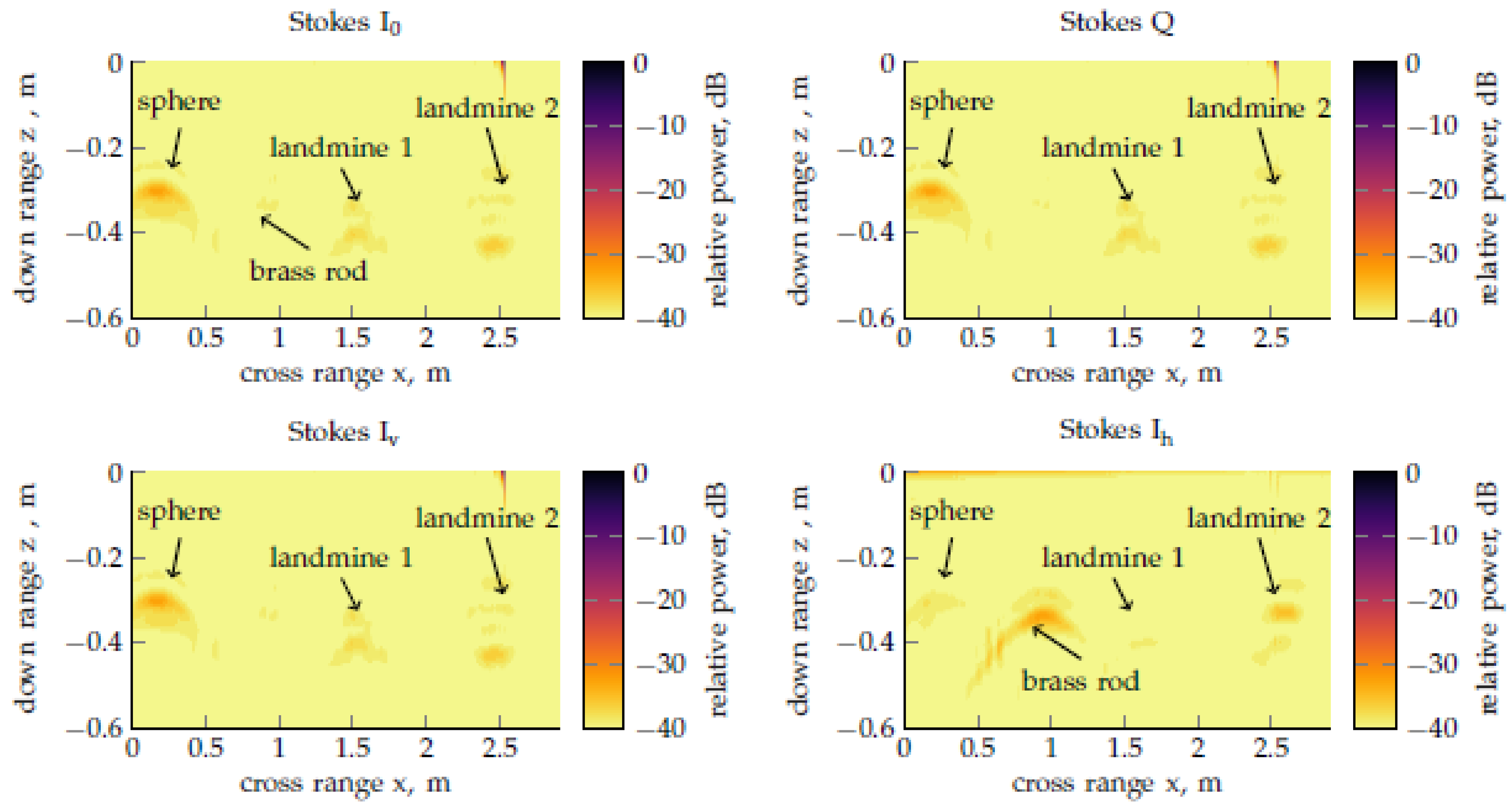

Fig. 4: Top: Stokes parameters I_0 and Q. Bottom: I_v and I_h.

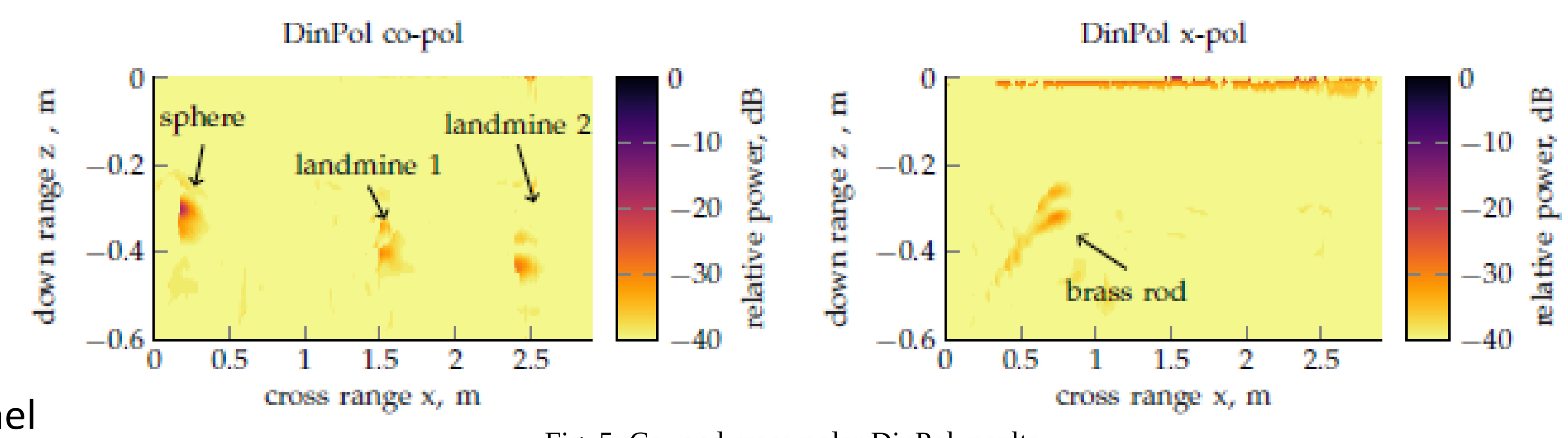

Fig. 5: Co- and cross-polar DinPol results.

Conclusions The Yamaguchi polarimetric decomposition provides significant clutter reduction and image contrast with some loss in signal power; while Stokes parameters also provide imagery localising targets, complementary information on the scattering mechanism is also obtained. Finally, a third novel polarimetric filter was formulated based on differential interferometric polarimetric decomposition. The three combined techniques contribute to a significant improvement of subsurface radar performance and detection image contrast.

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