Tomographic imaging of the magnetically permeable samples with radio-frequency atomic magnetometers

R. Gartman[1], P. Bevington[1,2], W. Chalupczak[1],

[1] National Physical Laboratory, Hampton Road, Teddington TW11 0LW, United Kingdom
[2] Department of Physics, University of Strathclyde, Glasgow G4 0NG, United Kingdom

Implementation of radio-frequency (rf) magnetic fields in non-destructive testing provides a cost-effective option for the detection of structural defects, particularly in cases where there is no direct access to the sample surface. The technique relies on monitoring the material response to the so-called primary magnetic field created by an rf coil. The sample response i.e. an oscillating secondary magnetic field is created by eddy currents in samples with a high electrical conductivity, and magnetisation in the ones with a high magnetic permeability. Conductivity, permittivity and permeability of the object can be mapped via measurement of the secondary field.

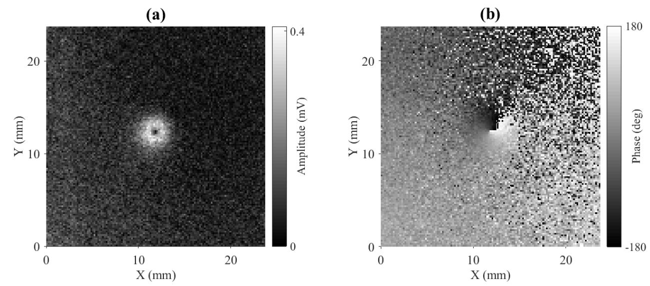

Figure 1. The measured amplitude (a) and phase (b) of the rf signal recorded over a $64 \times 64 mm^2$ area of a 6mm thick aluminum plate, containing a 1 mm diameter recess that is 2.4 mm deep in the self-compensation configuration at 30 kHz. The rf coil diameter, 1 mm.

We will discuss key properties of the imaging technique such as spatial resolution, ability to identify depth of the defect, limits to image acquisition rate. In particular, we show that the spatial resolution is limited by the size of the coil and is not restricted by the vapour cell dimensions [1]. Monitoring changes in amplitude and phase of the rf field enables a 2D re-creation of the magnetic field map produced by the sample and can be used for estimations of the sample thinning. We will discuss the inherent semi-vector nature of this measurement. The tunability of the rf atomic magnetometer allows for the change of the penetration depth.

Additionally, we discuss the methods for increasing the amplitude and phase contrast based on the compensation of components of the resultant rf magnetic field, by either a set of coils or the geometry of the measurement [2].

The work was funded by UK Department for Business, Innovation and Skills as part of the National Measurement System Program. P.B. was supported by the Engineering and Physical Sciences Research Council (EPSRC) (No. EP/P51066X/1).

[1] P. Bevington, R. Gartman, and W. Chalupczak, *Rev. Sci. Instrum.* **90**, 013103 (2019).
[2] P. Bevington, R. Gartman, and W. Chalupczak, *J. Appl. Phys.* **125**, 094503 (2019).