Fast Imaging of Void Defects in Conductive Half-space

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Abstract— In line with preliminary studies [1] and in harmony with a set of investigations led on fast, non-iterative MUSIC-type imaging algorithms in electromagnetics, acoustics and elasticity, by the authors' research group and others, e.g., [2], among many references, we are presently considering such an approach in the case of diffusive electromagnetic fields.

That is, let us assume that some thick highly-conductive horizontal plate has been somehow damaged, the resulting defects being a small collection of isolated 3-D bounded voids, hidden inside the plate or opening in air at the top interface of the plate (top, as seen vs. the position of the sources, described next), which might also get close to one another in limit cases, e.g., in crack-like fashion. A time-harmonic, eddy-current probe array, which consists of a small number (say, a few tens at best) of identical electric current loops that are either closely packed or well separated from one another within a given planar surface is placed close to and parallel with the plate, above the zone where the defects are assumed to be found; each current loop (assimilated with an ideal magnetic dipole orientated vertically) is excited one after another, the anomalous vertical magnetic field observed at all loop centers (in effect, it is proportional to the variation of impedance which is traditionally measured) being collected, yielding us a multi-static response matrix in a rather restricted polarization mode (vertical magnetic dipoles and vertical components of the magnetic fields) however.

The method of imaging itself relies on a first-order asymptotic formulation of the anomalous magnetic field as is induced by the defects. The latter is valid when those appear small enough with respect to the skin-depth at the frequency of operation, yet we still expect to get some useful information when sizes are not so small (but always well smaller than the skin-depth, which is a realistic hypothesis in eddy-current non-destructive testing). Then, a singular value decomposition of the multistatic response matrix collected as indicated in the above is carried out. Discrete singular values and vectors emerge in so doing, which can be separated into quantities respectively associated to a signal subspace and a noise subspace; from that distinction, which means also that the level of noise is not such that the singular spectrum is too corrupted, we can compute a MUSIC indicator (in effect, several indicators can be introduced, as it will be shown in the presentation) expected to peak at the location of the defects.

After a brief presentation of the mathematical formulation behind the approach, and some reminder of the validity and limits of the asymptotic field formulation via a comparison with results provided by means of the modeling CIVA platform from CEA, we will exhibit singular value patterns and MUSIC images. Here, a high-level Gaussian distributed noise is added to the data, and a number of arrangements of the source array and locations and distributions of the defects, at various frequencies (usually a low, median and high one, in effect allowing close-to-surface, median and deep imaging), will be considered. This will enable us to highlight pros and cons of the approach, as well as signaling paths of further research, notably in terms of thin perfectly-isolating cracks, for which so far only 2-D models in the frame of scalar scattering and for propagative fields appear to have been dealt with via non-iterative methods similar to the one herein, refer, e.g., to [3].

REFERENCES

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