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Data Preconditioning with Gabor Nonstationary Deconvolution for Radar Imaging of Highly Dissipative and Dispersive Media

Kay Y. Liu [(1)], Elise C. Fear* [(1)], and Mike E. Potter [(1)]
(1) Department of Electrical and Computer Engineering, University of Calgary
2500 University Dr. NW, Calgary, Alberta, Canada T2N 1N4

Extended Abstract

In medical microwave imaging applications, electromagnetic (EM) waves propagate through human tissues, which are inherently attenuative and dispersive. The attenuation of microwave signals is typically dependent upon frequency; higher frequencies are attenuated more significantly than lower ones during propagation. As a result, the microwave wavelet often undergoes a significant change in shape as it travels through the media. This is known as “nonstationarity” in wave propagation. In the image, this results in a characteristic blurriness or lack of resolution that increases with time/distance. To produce microwave images with high resolution, there is a strong need for a technique that is able to compensate for the energy loss and correct for the wavelet distortion.

Microwave imaging shares a number of similarities with seismic imaging. Various techniques have been developed in the field of Seismology to compensate for energy loss, to correct for wavelet distortion, and to produce image with high resolution. Among those, the Gabor nonstationary deconvolution method [1] has been successfully tested with industrial seismic data and ground penetrating radar data. Gabor deconvolution is essentially based on the assumption that the anelastic attenuation of seismic waves can be described by a constant Q theory [2]. Issues with porting this technique over to microwave imaging arise because the wavelet attenuation and dispersion in EM wave propagation through the human body is much more severe than that in seismic wave propagation through the earth subsurface. In other words, the constant Q assumption might not hold for EM waves.

We investigate the Q characterization of EM wave propagation and attenuation in tissues, understand the frequency-dependent characteristics of Q in this context, and assess the ability of Gabor nonstationary deconvolution to deal with the attenuation and wavelet dispersion in EM waves. Our study reveals that the Q for EM waves is not constant over the microwave frequency of interest; however, a parameter Q* [3], which is closely related to Q, can be approximated as constant for highly lossy dispersive biological tissues. Q and Q* differ in the order to magnitude; however, these quantities describe the attenuation and dispersion in the same manner. Our test results indicate that the Gabor nonstationary deconvolution is able to sufficiently compensate for attenuation loss and correct phase dispersion for EM waves that propagate through lossy and dispersive media. Specifically, this approach can work effectively for materials with a constant Q* characteristic.

On the other hand, since Gabor deconvolution is not designed to distinguish between noise and data, the algorithm may enhance noise when compensating for attenuation. Our observation indicates that, in the case of strong surface reflection, the antenna characteristic response may interfere with the reflections from the subsurface. A dual deconvolution process is proposed to deal with this issue. First, a stationary deconvolution is executed to remove the antenna characteristic response from the signal; then, Gabor deconvolution is applied for attenuation compensation and phase correction. The key to the success of this approach is finding a deconvolution operator that introduces small error in the stationary deconvolution. Metrics are developed for quantitatively assessing the signal and the image in this regard. Our test results indicate that Gabor deconvolution is able to enhance the subsurface target response relative to the noise floor.

References

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