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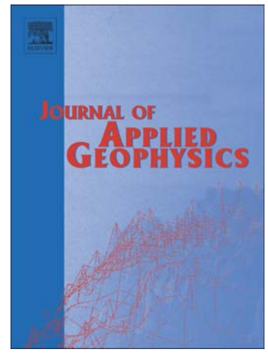

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Optimal digital filters for Sine and Cosine transforms

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Abstract: The Sine and Cosine transforms implemented with digital filters has been used in the Transient electromagnetic method for a few decades. However, Hankel transform pair with a fixed parameter (c=1 or 3) usually is used in the process of obtaining the digital filter coefficients of Sine and Cosine transforms. First, this study investigates the influence of parameter c on the digital filter algorithm of Sine and Cosine transforms based on the digital filter algorithm of Hankel transform and the relationship between the sine, cosine function and the ± 1/2 order Bessel function of the first kind. The results show that the selection of parameter c highly influences the precision of digital filter algorithm. Second, upon the optimal selection of the parameter c, it is found that an optimal sampling interval s also exists to achieve the best precision of digital filter algorithm. Finally, this study proposes four groups of sine and cosine transform digital filter coefficients with different length, which may help to develop the digital filter algorithm of sine and cosine transforms and promote its application.

Key words: sine transform; cosine transform; digital filter algorithm; sampling interval; transient electromagnetic method

1 Introduction

Transient electromagnetic method is an important branch of geophysical methods, and has been widely used for problems associated with resource exploration (Beka et al., 2017; Flores and Peralta-Ortega, 2009), as well as in environmental and geotechnical applications (Chongo et al., 2015; Costabel et al., 2017; Ezersky et al., 2011). Numerical simulation of transient electromagnetic method has always been the focus of many scholars for decades, especially its forward calculation commonly needs to conduct sine and cosine transforms which are integrals of high oscillation functions (Bin, 2011). Therefore, the calculation of these integrals is significant to complete the sine and cosine transforms. Digital filter algorithm is an effective method to conduct such calculation. This algorithm usually has a length ranging from a few tens to several hundreds and thereby is much faster than the common direct numerical integrals.

The digital filter algorithm of sine and cosine transform can be converted to the digital filter algorithm of Hankel transform due to the relationship between the sine and cosine functions and ± 1/2 order Bessel functions of the first kind. So far, several methods have been developed to calculate the coefficients in the Hankel transform digital filter. Firstly, in the frequency domain the spectrum of the output function is divided by the spectrum of the input function to obtain the spectrum of the digital filter response, and then such response in the sample domain is obtained by using inverse Fourier transform (Johansen and Sørensen, 1979). This method has been used by Wang Hua-jun (2004) to obtain 250 digital filter coefficients of the sine and cosine transforms. Secondly, in the sample domain the Wiener-Hopf minimization method is used to obtain the digital filter coefficients by considering input and output values of the digital filter algorithm. This method was firstly proposed by Koefoed and Dirks (1979), and later improved by Guptasarma (1982), Guptasarma and Singh (1997). Finally, in the sample domain the direct method is used to obtain the digital filter coefficients by solving a matrix equation formed by 2L+1 groups input and output values. This method was firstly used by Kong (2007) via constructing the matrix equation of the convolution equation of Hankel transform.

In the digital filter algorithm of sine and cosine transforms, there are two important factors, one is the accuracy of calculation, the other is the length of the digital filter algorithm which determines the calculation speed. Based