STEPPED FREQUENCY SEISMIC METHOD WITH ACQUISITION TIME OPTIMIZATION

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Abstract

Vibroseis technology is a seismic method for geological exploration and it is often applied in the search for underground oil reservoirs. Current methods vibrate the earth with a swept frequency "chirp" signal and results are obtained through correlation. This paper proposes a new stepped frequency method that will produce similar results with increased resolution [1, 2]. Resolution is improved by compensating for dispersion and by using coherent detection to eliminate harmonic components caused by non-linearities. In addition to the reflection magnitude, the new technique is able to measure reflection angle which might assist in determining the type of subsurface discontinuity.

This proposed technique energizes the ground with sinusoids in the frequency range of 5 Hz to 150 Hz where frequency is incremented in discrete steps. The amplitude of the reflected signal that is in phase with the transmitted signal is then recorded for each individual frequency step. Fourier transformation of the recorded data then shows the locations of subsurface discontinuities. Stepped frequency measurements take much longer than the current swept frequency measurement and ideas for minimizing this time are discussed in the paper.

Keywords— *Stepped Frequency, Seismic, Vibroseis, Frequency Domain Reflectometry*

1 Introduction

Both the scientific community and industry have great interest in mapping the subsurface of the earth in order to better understand our planet and to exploit our many resources. Impulsive source methods, such as dynamite and mass-drop, have been utilized in subsurface exploration but are destructive and this limits their applicable areas of use to remote locations. This lead to Conoco developing the Vibroseis^{TM} system in the 1960's for subsurface exploration [3]. This new system allowed researchers to create a controlled set of waves that would penetrate the earth, reflect off geological discontinuities and be detected in the same manner as impulsive sources. Due to the advances in computers and digital signal processing, Vibroseis is now a common tool used in subsurface research although the current vibroseis method is susceptible to both dispersion and harmonic interference. The Vibroseis method employs a swept frequency sinusoidal input source and uses correlation techniques for data analysis.

In addition to being destructive, impulsive sources also introduce unwanted non-linear effects close to the source [4]. In a 1979 paper [5], it was shown that the frequency content of dynamite based sources was dependent on the size of the charge. As the charge size was increased, the energy tended to be concentrated at lower frequencies and there is a loss of input bandwidth when using large explosives to perform deep penetration. Resolution is lost due to the low source signal bandwidth. The Vibroseis method is able to counter these problems by spreading the input energy over time. Vibroseis can maximize the input signal bandwidth while mitigating the destructive and non-linear effects caused by an explosive source. Seismic exploration is now able to enter populated and protected areas without causing the damage inherent to impulse sources.

This paper proposes a stepped frequency technique as a potential improvement to swept frequency Vibroseis. As shown in [2], the Frequency Domain Reflectometry (stepped frequency) method has shown a marked improvement over Time Domain Reflectometry techniques when applied to telephone lines. Potentially, the Frequency Domain Reflectometry method will provide a similar benefit in seismic exploration.

2 Vibroseis

The Vibroseis system utilizes large trucks that serve as the vibrating input source. This vibrator, typically a large hydraulically controlled plate, is used to input a swept frequency chirp signal to the earth. The input frequency range is typically in the 5 Hz to 150 Hz range. Along with the vibrating source, the system also consists of many surface mounted geophones that capture reflected signals from the subsurface geological features. A disadvantage of the Vibroseis method is that complex signal processing is required to understand the received signals.

2.1 Signal Processing

The transmitted and reflected signals are cross-correlated to produce a brief "wavelet" that indicates the magnitude and depth of a geological discontinuity [4]. This is equivalent to the brief impulse response that we see in both dynamite and mass drop systems. The trace received from Vibroseis geophones, $x(t)$, can be mathematically represented