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Importance of Automatic Gain Control in Crosshole sonic logging

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Background

In crosshole sonic logging (CSL), the received signal amplitude spans several orders of magnitude where good signals amplitude as high as 5V and as low as 10mV reach the receiver.

The received signal is amplified before being sampled in order to sample the maximal number of significant bits of information.

CSL systems usually offer several levels of amplification, ranging from X1 (no amplification at all) to as high as X500.

[Piletest CHUM](#) introduces a unique automatic gain control (AGC) for a CSL system, which changes the gain level dynamically, in real time, in order to match each samples data with the optimal gain level.

Since AGC was implemented since CHUM V1 - and works seamlessly and transparently behind the scenes, most users do not know or appreciate the advantages it brings.

User advantages of AGC over fixed-gain

Optimal signal acquisition

AGC ensures that low amplitude samples are fully amplified and get maximal number of bits, so that even small features are visible and not get rounded off. AGC also ensures that high amplitude samples do not saturate the A/D and therefore the energy can be calculated correctly and not trimmed-down.

Tomography

When taking diagonal readings, signal amplitude decreases (both because of increased distance, and wave propagation geometry). AGC ensures that both diagonal and horizontal readings are captured at the optimal amplification and FAT picking can be done accurately on them.

Flaw/pile edges

Signal amplitude at the edge of a flaw decreases quickly (and is sometimes totally blocked). AGC ensures that more faint signals at the edge of a flaw can be captured and analysed - hence giving a more accurate understanding of the severity of the flaw.

Always correct, no re-tests

AGC ensures that you never need to re-do a test due to wrong manual gain setting.

One less thing to worry about

Many users who operate CHUM do not even know what "gain" is - and they do not need to - the system takes care of it, and they can focus on more important things

No abuse or data loss due to careless setting

Wrong manual gain setting can make a flawed profile look better, and the other way around. AGC saves the need to re-do a test, due to careless testing and eliminates the possibility of abuse.

Theoretical background

Factors which lower the received energy are: distance, concrete quality, angle

Distance

The energy at the receiver is affected by the distance according to equation 1

$$E_{rx} = E_{tx} \cdot e^{-k \cdot f \cdot d} \quad \text{Equation 1}$$

Where

- E_{rx} Energy received
- E_{tx} Energy transmitted
- k constant
- f signal frequency
- d **Distance traveled**

This exponential nature of energy attenuation was also verified by measurement as seen in Figure 1

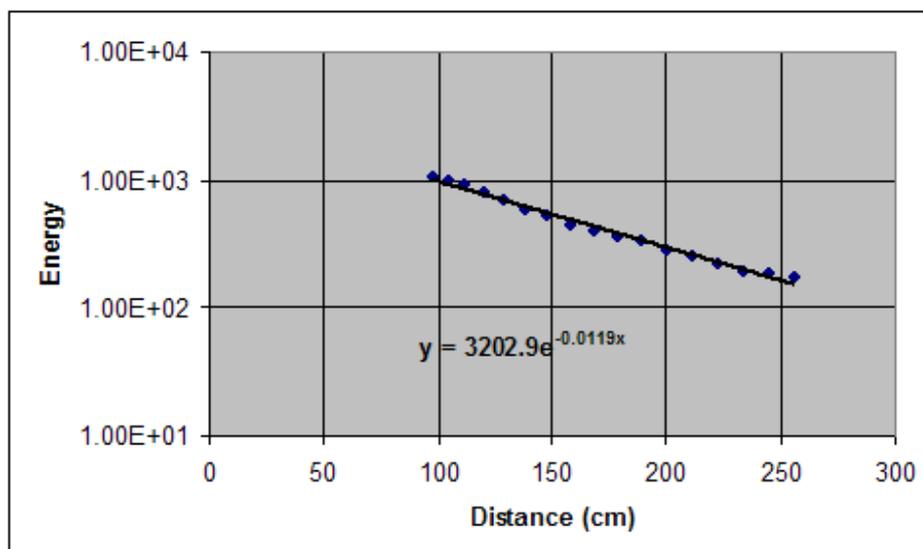


Figure 1: Attenuation of Ultrasonic Waves in Concrete

Concrete quality

Young concrete, honeycombing, soil and slurry inclusions, segregation and similar issues all reduce the amount of energy the concrete absorbs, increase the wave scattering and in general, reduce the received energy

Angle

During [tomography](#), the receiver and transmitter are positioned at different elevations. In order to capture additional information of suspected zones in the concrete, diagonal readings are used to help determine flaws location, size and shape.

The diagonal readings tend to have lower relative energy due to:

- 1) Increased distance
- 2) Snell's law (where the signal passes from water to steel to concrete and back) - the steel tube behaves as a lens which bends the sonic waves towards the horizontal.
- 3) Wave propagation geometry: The ceramic elements are omnidirectional (transmit in all directions in one plane) and produce uniform energy in the direction perpendicular to the access tube, but not in the vertical and diagonal directions.

Summary

AGC in CSL system, is unique for CHUM. It is a hardware feature with all advantages and no disadvantages. Since it works seamlessly and transparently, very few users ever stop to ask what it is and why do they need it at all.