TDR (Time Domain Reflectometers)

Pictures of different TDR probes

- http://www.sowacs.com/sensors/tdr.html

- A **time-domain reflectometer (TDR**) was developed to characterize and locate faults in metallic cables

Plus Generator

- A TDR transmits a short rise time pulse along the conductor. This can be a square wave plus

- If the conductor is of a uniform impedance (constant resistance for a plus single) and properly terminated (use of a resistor on the end of the cable)
- The entire transmitted pulse will be absorbed in the far-end termination and no signal will be reflected toward the TDR.

- If a impedance discontinuities occurs (broken wire) some of the signal will be sent back towards the source.
- Increases in the impedance creates a reflection that reinforces the original pulse while decreases in the impedance create a reflection that opposes the original pulse

- The resulting reflected pulse that is measured at the output/input to the TDR is plotted as a function of time.
- Because the speed of signal propagation is relatively constant for a given transmission medium, the time can be read as a function of cable length.

Soil impact on reflectance time

- When the two metal rods are put in soil the reflected pulse time and amplitude is a function of the soil dielectric constant which is a function of the soil moisture content
- Increased water slows the pulse reflectance time

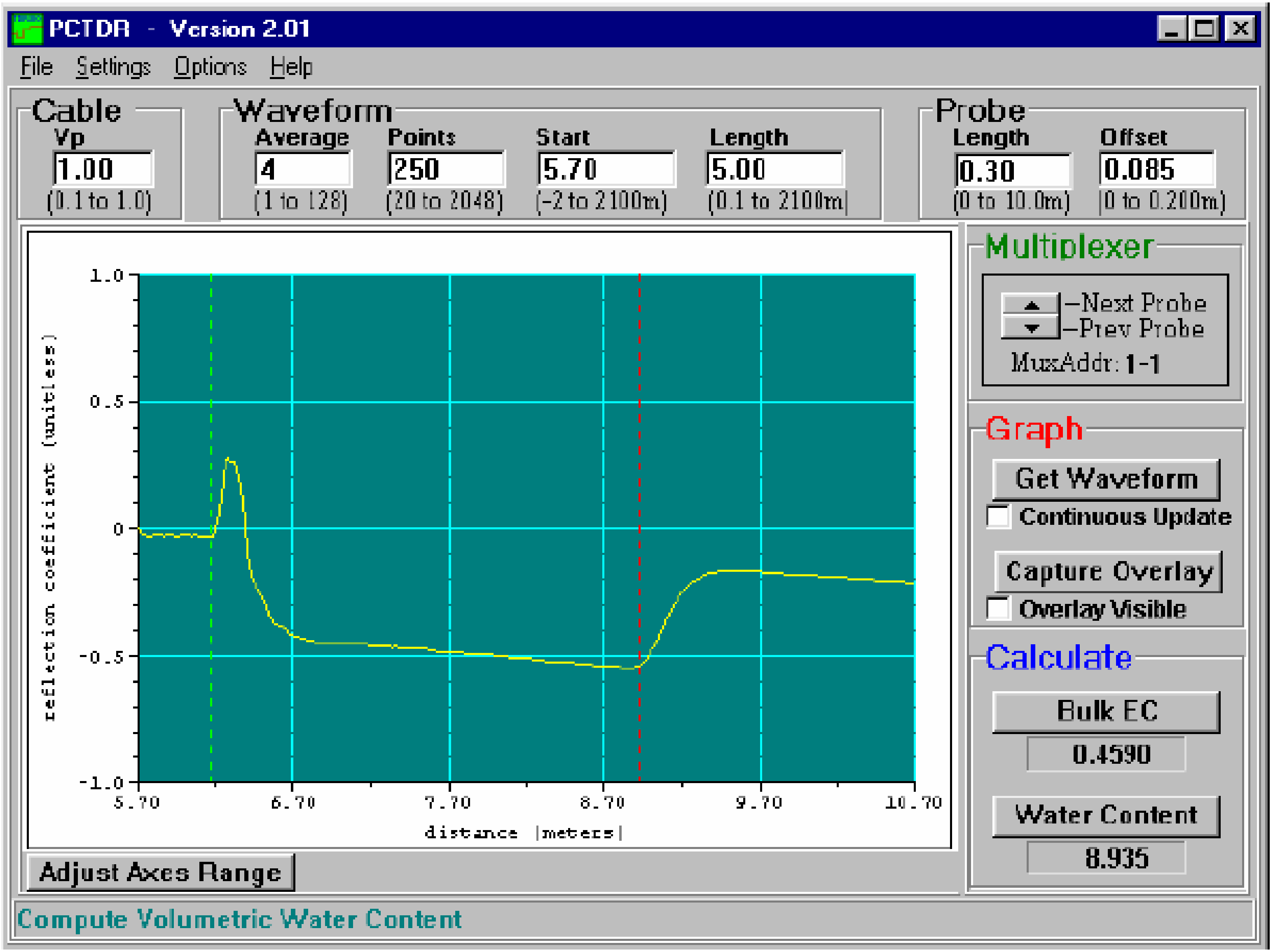


FIGURE 3-2. Waveform of CS610 in water after changing Start and Length parameters to display relevant portion of reflected signal.

Measure travel time

$$\Delta t = \frac{2L\sqrt{K_a}}{c} \qquad [1]$$

where K_a is the apparent dielectric constant, c is the velocity of electromagnetic signals in free space, Δt is the travel time, and L is the waveguide length. The dielectric constant of water relative to other soil constituents is high. Consequently, changes in volumetric water content can be directly related to the change in the dielectric constant of bulk soil material.

- Dielectric constant of air 1
- Dielectric constant of water 80
- Delta t= 2 * 0.5 m 1^0.5 / 299 x 10^6 m/s air
- = 3.3 x10^-3 s
- Delta t= 2 * 0.5 m 80^0.5 / 299 x 10^6 m/s water
- =30 x10^-3 s

Rearrange equation 1. L is length of probe or wave guide

Equation [1] can be simplified to express the apparent dielectric constant as the ratio of the apparent probe length ($L_a = c\Delta t/2$) to the real probe length.

$$\sqrt{K_a} = \frac{L_a}{L} \qquad [2]$$

Volumetric water content function of dielectric constant

$$\theta_v = -5.3*10^{-2} + 2.92*10^{-2} K_a - 5.5*10^{-4} K_a^2 + 4.3*10^{-6} K_a^3 \qquad [3]$$

and that presented by Ledieu et al. (1986) is

$$\theta_v = 0.1138\sqrt{K_a} - 0.1758 \qquad [4]$$

Principle of Campbell cs616

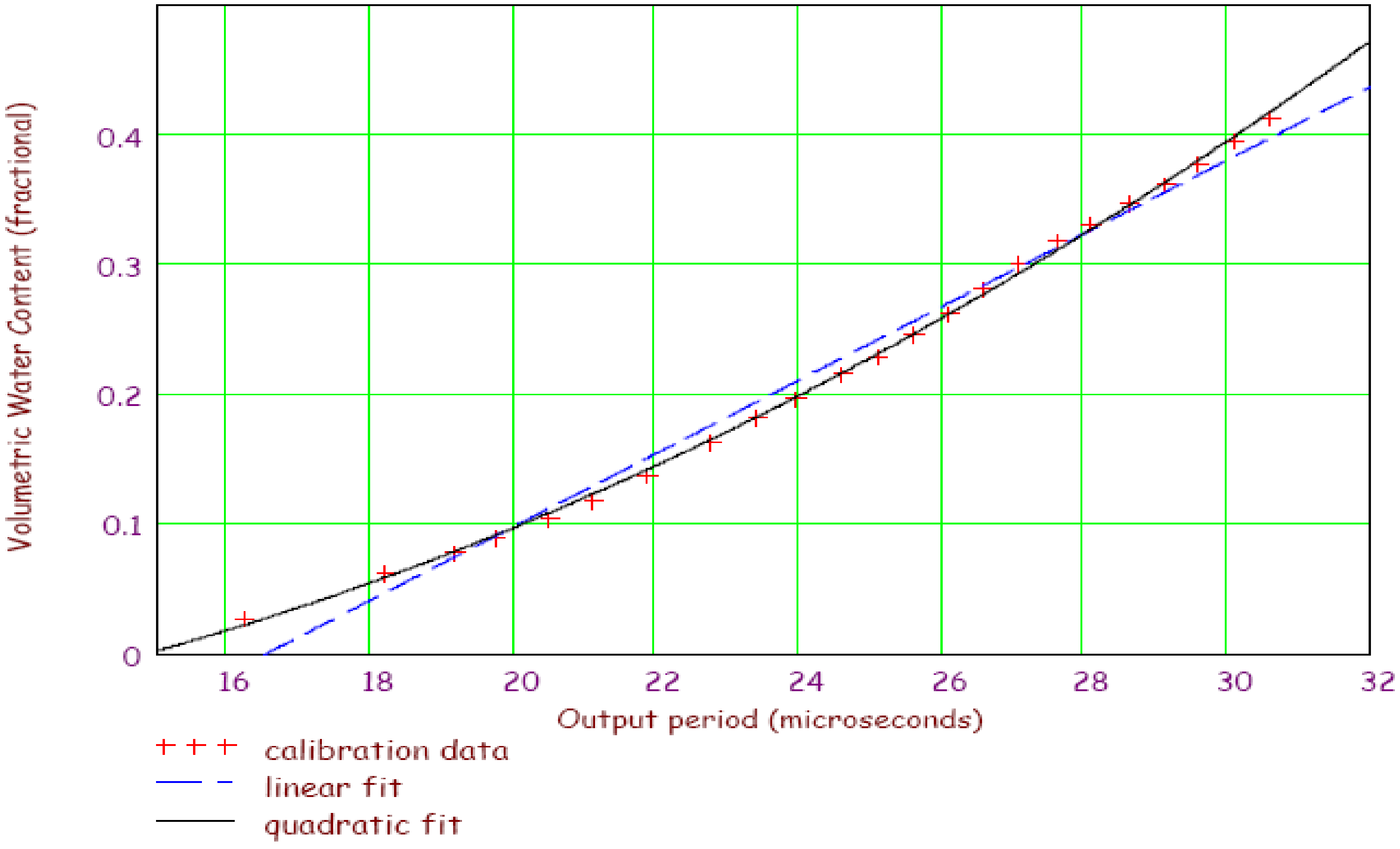
The applied signal travels the length of the probe rods and is reflected from the rod ends traveling back to the probe head. A part of the circuit detects the reflection and triggers the next pulse.

The frequency of pulsing with the probe rods in free air is about 70 MHz. This frequency is scaled down in the Water Content Reflectometer circuit output stages to a frequency easily measured by a datalogger. The probe output frequency or period is empirically related to water content using a calibration equation.

- 70 HMz= 70x10^6 8 cycles/seconds for CS616 in air.
- 70 cycles/ microseconds   =
- 1/70 cycles/microseconds   =
- =0.014 microseconds /period or cycle
- Because water slows cycles and increases time by   8.9 -the time for water is 0.124 microseconds/period

- The data logger scale these numbers by 1000 so a dry measurement in air has a time of 14 microseconds
- The time for wet 100 percent water is 124 microseconds
- For 40% water the value is around 50 microseconds.

CS 616 Campbell probe



Salinity

- The TDR technique is relatively insensitive to salinity as long as the salinity level is low enough that a useful wave form is returned
- As salinity levels increase, the signal reflection from the ends of the rods in the TDR probe is lost (amplitude is less).
- This occurs because of conduction of the signal through the saline soil between the rods. The amount of conduction increases as the soil wets.
- one can obtain a good wave forms in a very dry saline soil and useless wave forms in the same soil when wet.

Advantage /Disadvantage

- Accurate when calibrated and continuous measurements
- Affected by high salt content
- Not as accurate as neutron probe which is not a continuous measurement of soil moisture