

Error Sources in Digital Leveling

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For **digital levels** we're ignoring:

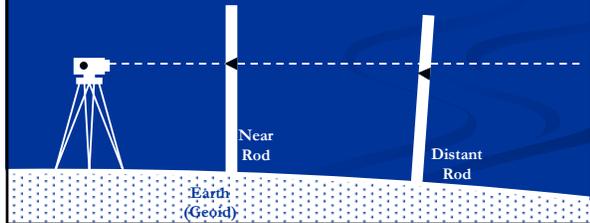
- Booking and math errors
- Parallax and rod reading errors

For **low order** work we're ignoring:

- Shading the instrument
- Invar staffs
- Orthometric correction

Earth Curvature Error

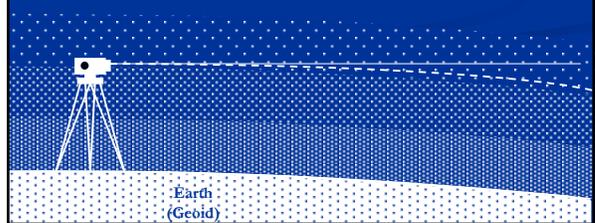
- The earth appears to "fall away" with distance
- Rod reading is too high
- Error increases exponentially with distance



The diagram shows a level instrument on a tripod on the left. A horizontal dashed line represents the line of sight. Two vertical rods are shown: a 'Near Rod' and a 'Distant Rod'. The ground is represented by a curved surface labeled 'Earth (Geoid)'. The line of sight is parallel to the ground surface, but the ground surface curves away from the instrument as distance increases, causing the distant rod to appear higher than it actually is.

Refraction Error

- Air below is denser than air above
- Line-of-sight is bent downward
- Negates earth curvature error by 14%



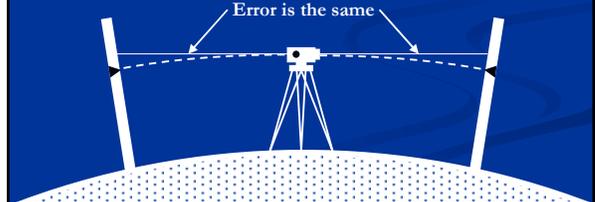
The diagram is similar to the Earth Curvature Error diagram, but it illustrates the effect of atmospheric refraction. The line of sight is shown as a dashed line that curves downward towards the ground. This downward curvature counteracts the upward curvature of the ground surface, reducing the error.

Curvature + Refraction Error

- Error (ft) = $0.0206 \times D^2$ (D = thousands of ft)
- So...
 - 160 ft shot = **.00053 ft error**
 - 220 ft shot = **.001 ft error**
 - 1000 ft shot = **.021 ft error**
 - 1 mile shot = **.574 ft error**

The Correction

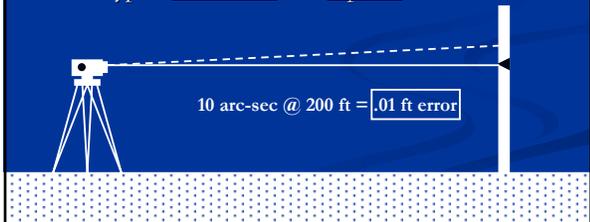
- Apply formula to measurements, OR
- Balance backsight and foresight for each setup



The diagram shows a level instrument on a tripod between two rods. A dashed line represents the line of sight. Arrows point from the text 'Error is the same' to the line of sight at both the near and distant rods, indicating that the combined curvature and refraction error is equal for both rods in a single setup.

Collimation Error

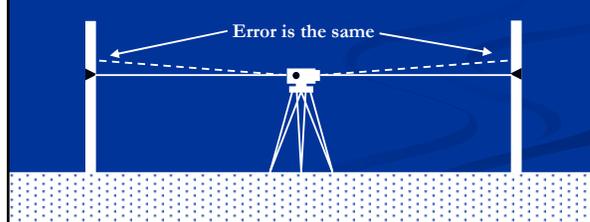
- > Line-of-sight not perfectly horizontal
- > Two types: Electronic and Optical



10 arc-sec @ 200 ft = .01 ft error

The Correction

- > Calibrate with two-peg test
- > Balance foresights & backsights



Error is the same

Settling Error

- > Tripod or rod settles between measurements
- > Can cause systematic error



Correction

- > Quick measurements between rods
- > Avoid muddy or thawing ground
- > Avoid hot asphalt
- > Don't exert pressure on turning point

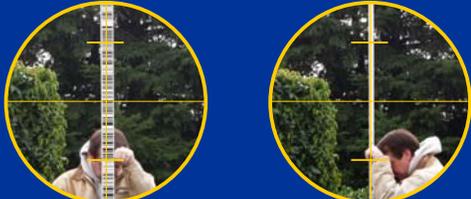
Rod not Plumb

- > Rod reading too high
- > More error near top of rod
- > 0.3 ft out of plumb ...
0.004 ft vertical error



Correction

- > Check and calibrate rods regularly
- > Brace rod firmly; Use head/body



Heat Shimmer

- > Ground heating causes chaotic refraction of light
- > Worst at high noon



Correction

- > Shorten the length of shots
- > Keep measurement 2-3 ft above ground
- > Avoid leveling during noon hours

Vibration

- > Wind
- > Heavy vehicles
- > Vibratory rollers
- > Bridges

Correction

- > Place one hand on tripod
- > Wait for vibrations to stop
- > Use mean/median mode
- > Set rod on bridge, not the instrument



Mismatched rods

- > Rods are not identical
- > Difference can be compounded
- > Proper methods will eliminate

Correction

- > “Leap frog” the two rods
- 
- > Designate one rod for turning points only

Turning points

- When turning the rod between shots, the rod must be returned to exactly the same elevation

Correction

- Set nails and hubs with a prominent point



- Clean the bottom of the rod
- Clearly mark the point

Summary: At the Instrument

- Balance backsights/foresights
- Calibrate for collimation error (two peg test)
- Keep earth curvature correction on
- Setup on stable ground
- Measure 2-3 ft above ground when HOT
- Shorten the distance to rod when HOT
- Use mean/median mode for VIBRATION
- Hold tripod to dampen VIBRATION
- Avoid bridges; place rod on bridge instead

Summary: At the rod

- Check & calibrate bubble level
- Brace rod firmly
- “Leap frog” two rods
- Designate one rod for turning points only
- Clean the bottom of the rod
- Choose a solid, prominent turning point
- Clearly mark the turning point