Laser Range Finding

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Concept

- Measure ranges between pieces of equipment in geodesy stations.
- Goals: accuracy, 0.1 mm over 100 m path; cost, $1k/leg.
- GPS – multipath error.
- Radio ranging – same, plus antennas need to be large.
- Use amplitude-modulated laser, as in surveying.
- Standard surveying instruments only good to 1 or a few mm (and cost >~$30k).
- Investigate accuracy of air path correction and stability using standard ranging instrument: 0.1 mm resolution, $2k.

There is ample sensitivity

- Using 1 mW, 1 cm optics, at 100 m distance, 100 MHz modulation.
  - Main random error is detector noise: limits sensitivity to 10 nm (10^{-8} m) in 1 s!
- Main systematic error is variation of air index.
  - For 100 m path, 0.1 mm, need temperature to 0.3°C, pressure to 1 mbar, and water partial pressure to 8 mbar.
  - Field testing to determine how well temperature, pressure, and relative humidity (RH) along the path are represneted by available measurements.
  - Severe case: at 35°C, need RH to ±17%.
    - At 20°C, need RH to ±34%.

This idea is not new

- John Payne, "An Optical Distance Measuring Instrument," RSI **44**, 304-306 (1973).
  - Precision 0.04 mm.
  - Range 60 m, for use with rad.io astronomy instrument.
  - HeNe laser, sine-wave modulation at 550 MHz.
    - *In 2007, modulate a diode laser directly – less costly.*
    - *Modulation frequency could be higher, but this may not help – it requires a wider-bandwidth detector, which has more noise in the same bandwidth.*
  - Long-term tests were not performed.

Off-the-shelf Instrument

- Leica “DISTO” sold as Dimetix DLS-B series, PMS-200 series in US. $1.9k.
- 0.1 mm resolution, 1.8 mm accuracy, range up to 500 m.
  - Over limited range, accuracy may be higher.
  - Limited by knowledge of air temperature and pressure.
- Module requiring 9-30 vDC. Reports distances over serial computer interface.
  - 54×80×150 mm, 665 g.
- Alternatives not yet explored.
- T, P, & RH monitor: ~$1k, e.g., purchase from Hotek Technologies.

… or we could spend a lot of money and develop it.

Proposed Work

- Identify and compare available distance meters.
- Identify temperature, pressure, and relative humidity sensor(s).
- Purchase and set up these instruments.
  - First test: in lab, spaced with Invar, to test stability.
  - Second test: Outdoors, path of 100 m between stable points.
    - Both points near ground.
    - One point on telescope pedestal.
  - Record optical range, temperature, pressure, RH for ~1 week.
    - What measurements are needed to reach the 0.1 mm goal?

Possible Future Work

- Plan larger deployment.
  - Explore collaboration with manufacturers, if modifications are needed.
  - Purchase several modules (distance, temperature, pressure, RH), or purchase sensors and integrate them into a custom unit.
    - Sensors with specifications that far exceed requirements are available inexpensively.
    - Several possible semi-custom vendors.