Wireless Power and Data Acquisition System for Large Detectors

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Motivation for R&D

• With the detectors increasing in its size and complexity, it is complicated to use traditional approach where the power and data are transferred with electrical cables.

• Cabling may represent a significant cost and complication in the experiment.

• Leads to attenuation and deterioration of the signal.

• Cabling is not practical for detectors in remote location or hostile environment.

Goals:

✅ wireless: communication without wires.

✅ Elimination of all cables, no physical connection to the detector.
Approach

- The project is for large detectors with photomultiplier tubes (PMT).
- Our goal is to develop a PMT base that is powered wirelessly and transfers data wirelessly.

Two main components:

- 🔄 Wireless Power Transfer (Radio Frequency and Optical beam)
- 🔄 Wireless Data Transfer (802.11n wireless technology)
Radio Frequency Option

Power transfer using microwave antennas

14 dBi Yagi antenna (0.9 m)
11 dBi patch (/flat panel) antenna

Friis Transmission Equation:

\[
\frac{P_r}{P_t} = G_t G_r \left( \frac{\lambda}{4\pi R} \right)^2
\]

Free space propagation under ideal conditions:

- ✓ no object present to affect propagation
- ✓ no scattering from buildings.. etc.
(RMS voltage is measured by the oscilloscope)

\[ G_{\text{dB}} = 20 \log_{10} \left( \frac{V_1}{V_0} \right) \]

Transmitter: 14 dBi Yagi Antenna
Receiver: Patch Antenna
Frequency: 915 MHz

Power loss is calculated as a function of distance from the transmitter.
20 dB power loss at a distance of five meters from the transmitter

transmitted = 10 Watts (40 dBm)
14 dBi Yagi antenna

received = 100 mW (20 dBm)
11 dBi Yagi antenna
30% loss in RF→DC conversion
20 dB power loss at a distance of five meters from the transmitter

transmitted = 10 Watts (40 dBm)
14 dBi Yagi antenna

received = 100 mW (20 dBm)
11 dBi Yagi antenna
30% loss in RF \rightarrow DC conversion
Optical Option

Power transfer using optical source and receiver

LED: infrared, 940 nm
max current: 1A
optical power: 3.5 W

Receiver: Photovoltaic Panel (10×10 cm²)
four solar cells are in series

heat sink with support on the back

Lens on the front end
Heat sink with support on the back

Four solar cells are in series

Lens on the front end
Technical Specifications

- Wavelength: 940 nm (infrared)
- Optical Power of LED: 3.5 Watt
- Peak power of the beam: 20 mW/cm²
- Beam diameter: 8 inches
- Lens: 8 inch diameter, 400 nm focal length
- **Laser classification: Class 3B**
- Eyewear protection: O.D. 2 or greater at 940 nm

ANL laser safety training and laser eye exam is required.
LED Mount on a Tripod

Room divider

Light tight entrance
Standard Operating Procedures For
(Electronics Lab, F-132, Bldg 362)
Laser Controlled Area

ver #. (4.0)
(06/20/2012)

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Nearly 250 mW D.C. power is received up to a distance of five meter from the source of power 3.5 Watts.
Solar Panel IV Characteristics

IV curve of a solar cell is the IV curve of a diode in dark with a light generated current.

\[ I = I_L - I_0 \left[ \exp \left( \frac{qV}{nkT} \right) - 1 \right] \]

- **dark current** (no light)
- **maximum power**
- **More Light**
Measured IV Spectrum

IV Curve at 5 meter

The configuration for maximum power point: 10 ohm, 1.6 Volt, 156 mA, 248 mW

at 5 meter from the light source
Pro-Cons of Optical and RF

Optical
Positive:
• familiar technology, inexpensive.
• Long distance transmission is possible with collimated beams.
• DC power is received at the receiver end.

Negative:
• High power beams have significant safety issues.
• Line-of-sight is required.
• One receiver to one transmitter.

RF
Positive:
• One RF generator and transmitter antenna for multiple receivers: simple system.
• Does not require line-of-sight.
• Does not require control system, more easily implemented.

Negative:
• Long distance transmission is possible, but requires high power generation with exclusion zone requirement.
• Geometrical inefficiencies due to wider angle emission.
• RF to DC conversion is required at the receiver end.
• RF interference with RF data transfer.
Low power prototype

wireless PMT front-end module

The prototype front-end utilizes an 802.11n module. This is currently in testing.
Summary

-we have developed two options: RF and optical for wireless power transfer (=> working up to 5 meter from the source).

RF option: nearly 20dB power loss at 5 meter.

Light option: nearly 250 mW DC power is received up to 5 meter at the solar panel (=> advantage for small scale prototypes)

We are now exploring the wireless data transfer part.

Laboratory Directed Research & Development
THANK YOU!