50km Wireless to the Farallon Islands

Tim Pozar and Matt Peterson

NANOG49 – San Francisco

Stakeholders

- Point Reyes Bird Observatory
- U.S. Fish & Wildlife Service
- California Academy of Sciences
- City of San Francisco
- Internet Archive

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Farallons .. Where?

Image courtesy of Google Earth

Photo courtesy Coast Guard Archives

Why do this?

- Island staffed 365 days of the year, need for reliable and economical communications
  - Historically VHF marine radio voice, limited iDEN (Nextel) data and legacy 2.4Ghz 802.11b data (down more than up)
- Data collection is moving from offline (paper) to online
  - Weather, mammals, bird observations
  - Water/sewage, battery/inverters monitoring
- Showcase island in new Academy exhibit
  - Stream SD PTZ webcam, requirement for 1Mbps to the island – a bandwidth upgrade was needed

Design Criteria

- **Requirements**
  - Affordable – all stakeholders are non-profits
  - Weather/Rust proof – salt water, sun
  - Reliable – on-island IP & RF knowledge is limited
  - Easy to fix – See above.
- **Site Survey**
  - Obstructions
  - Access and Security
  - Island and Mainland Infrastructure
- **Modeling**
  - Path Clearance
  - Fade Margin
  - Uptime

Design – Site Survey

- **Island limitations**
  - 100 watts limit in lighthouse
    - Equipment had to be low power (donated retired 'carrier' quality gear would quickly exhaust budget)
  - Limited antenna mounting space
  - "Right of Way" U.S. Coast Guard property mgmt.
- **Mainland**
  - Tower space and fiber to 200 Paul from City of SF
  - Internet transit donation from Internet Archive
- **RF**
  - No trees, buildings obstructions – just water
  - Usual non-intrusive sniffing (KisMAC, netstumbler)

Design – Modeling

- **RF and path modeling**
  - Path engineering software (>$50k to free)
    - EDX
      - $50K to hundreds of thousands, depending on modules added such as interior modeling, etc.
    - PathLoss
      - ~$4K – Does path profile and atmospherics
    - Radio Mobile
      - Free.
      - Amazing on what it does but you get what you pay for.
      - http://www.cplus.org/rmw/english1.html
  - More cash = more accurate
    - Measured in both coverage & uptime predictions

Factors in designing a path

- **Link Budget**
  - Signal strength needed for the data rate requirements for the link
- **Path Profile**
  - Obstructions in the path or in the Fresnel zones
  - Length of path
  - Curvature of the earth (> 7 mile path)
  - Height of antennas
- **Atmospherics modeling**
  - Tries to predict uptime
- **Interference to others or to the path from others**
  - Antennas beam width (directional)

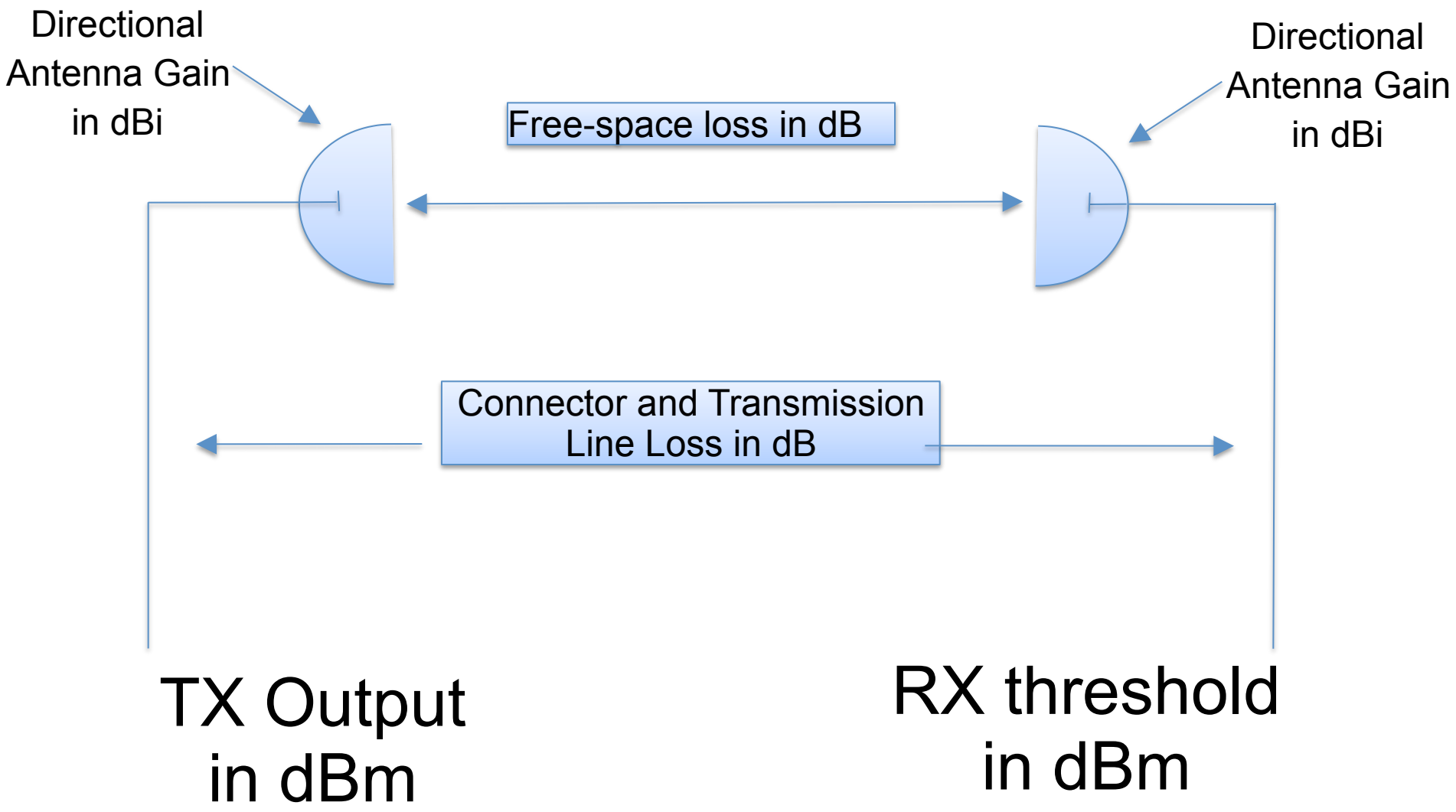
Factors for link (path) budget

- **Gain**
  - Transmitter and receiver amplifiers
  - Transmit and receiving antennas.
  - Transmitter Output Power (TPO) in dBm or Watts

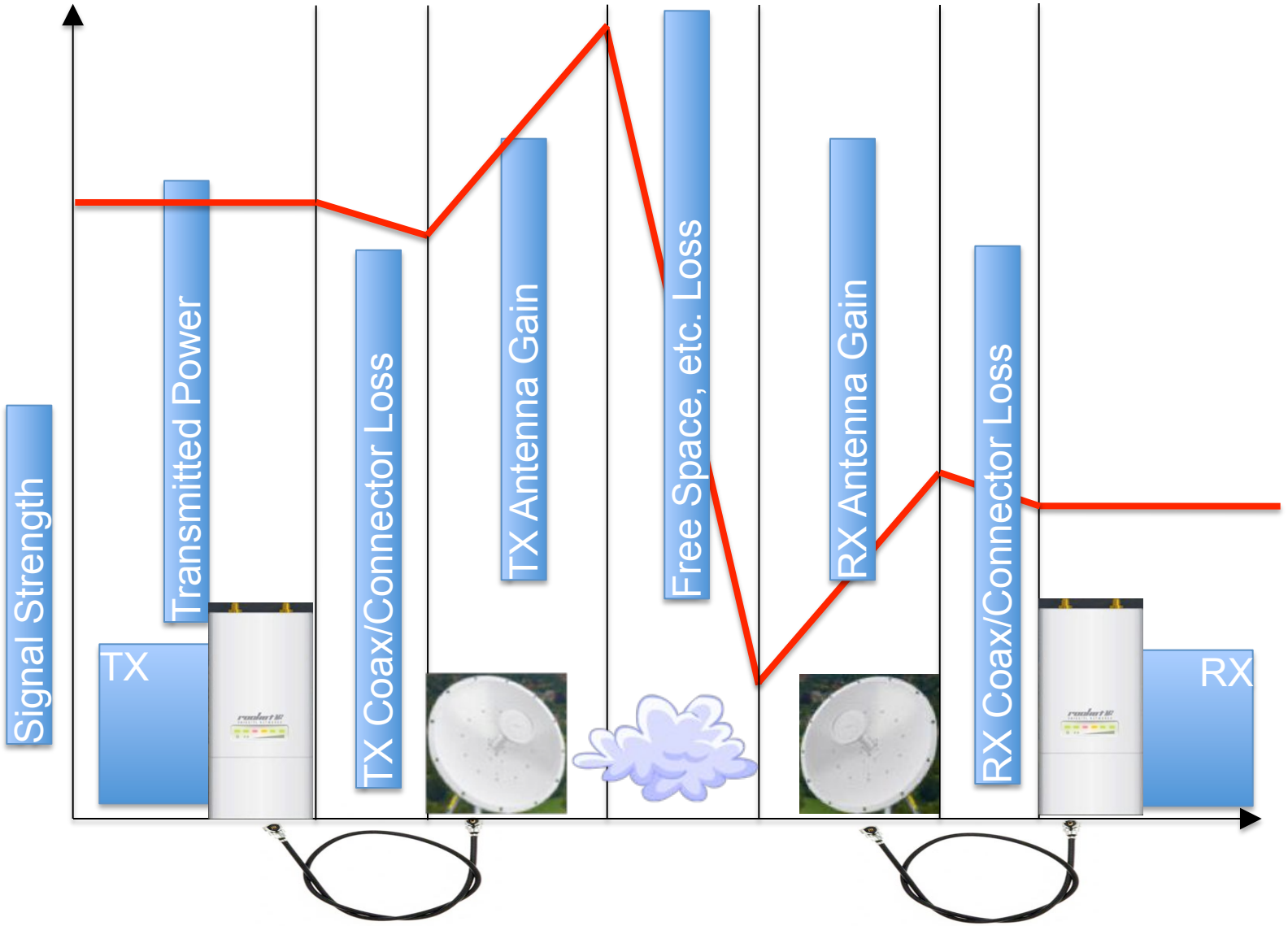
    dBm = $10*\log_{10}$(power in milliwatts / 1 mW)

    0 dBm/1 mW; 15dBm/30mW; 20dBm/100mW; 30 dBm/1 W
- **Loss**
  - Transmission line, Connectors, etc.
    - ie. LMR-400: 1.64 dB per meter at 5.8Ghz.
  - Free-space loss
    - dB = 92.4 + 20 Log_{10} (distance in km) + 20 Log_{10} (freq. in GHz)
  - Obstructions and Diffraction (ie. Trees, rain, etc.)
  - Atmospherics (ie. Snow/Rain, Refraction (ie. Ducting)

Schematic of link budget



Signal Level Though the Link



5.8GHz Path Budget

Frequency	5.8000	GHz
TPO (0.6 watts)	27.7815	dBm
Transmission Line Loss	0.2000	dB
TX Antenna Gain	32.0000	dBi
Path Length	31.0000	miles
Free Space Loss	141.6958	dB
RX Antenna Gain	32.0000	dBi
RX Line Loss	0.2000	dB
RX Signal	-50.3143	dBm
RX threshold	-74.0000	dBm
Fade Margin	23.6857	dB

Path Loss Can Be Caused By:

- Refraction
  - Thermal Ducting
  - Marine Evaporation Boundary Layer
  - Typical Solution: Diversity Reception
- Atmospheric Attenuation
  - Rain/Snow
  - Trees (Spring/Summer vs. Fall/Winter)
  - Typical Solution: Just need to have lots of signal
    - Needed fade margin will increase with distance.
- Fresnel Zone Attenuation
  - Obstructions in the Fresnel Zone
  - Knife-edge Diffraction
  - Typical Solution: Different path or raise the path

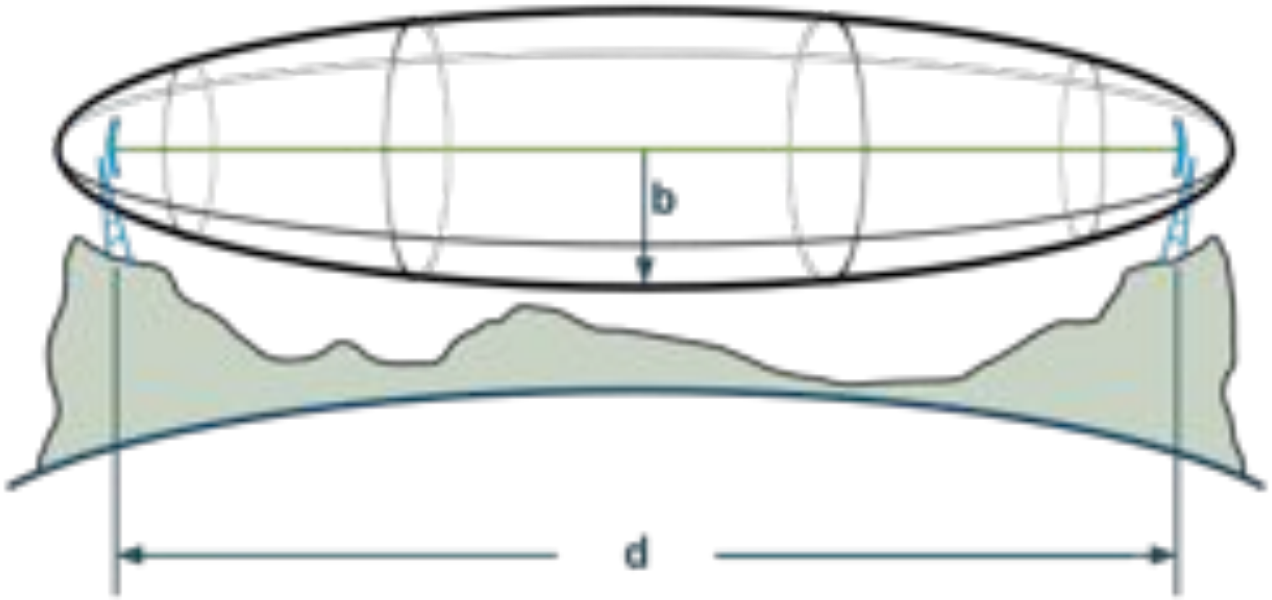
Atmospherics Calculations

	Farallon Lighthouse	Twin Peaks
Latitude	37 41 56.00 N	37 45 16.00 N
Longitude	123 00 06.00 W	122 26 47.00 W
True azimuth (°)	82.65	262.99
Antenna model	UNK	UNK
Antenna height (m)	3.00	10.00
Antenna gain (dBi)	32.00	32.00
TX line loss (dB)	0.20	0.20
Frequency (MHz)	5800.00	
Polarization	Vertical	
Path length (km)	49.34	
Free space loss (dB)	141.60	
Atmospheric absorption loss (dB)	0.41	
Field margin (dB)	2.00	
Net path loss (dB)	80.41	80.41
TX power (watts)	0.60	0.60
TX power (dBm)	27.78	27.78
EIRP (dBm)	59.58	59.58
RX threshold criteria	10-6	10-6
RX threshold level (dBm)	-74.00	-74.00
RX signal (dBm)	-52.63	-52.63
Thermal fade margin (dB)	21.37	21.37
C factor	1.00	
Fade occurrence factor (Po)	4.16E-01	
Average annual temperature (°C)	12.78	
Worst month - multipath (%)	99.69529	99.69529
(sec)	8007.72	8007.72
Annual - multipath (%)	99.91621	99.91621
(sec)	26425.49	26425.49
(% - sec)	99.83241 - 52850.98	
Rain region	C-96 Temp. Maritime	
Flat fade margin - rain (dB)	21.37	
Annual multipath + rain (%-sec)	99.83241 - 52850.98	

Thu, Feb 12 2009

Reliability Method - Vigants - Barnett
Rain - Crane

What is Fresnel Zone?



The radius in the center of the path the first Fresnel zone can be calculated with:

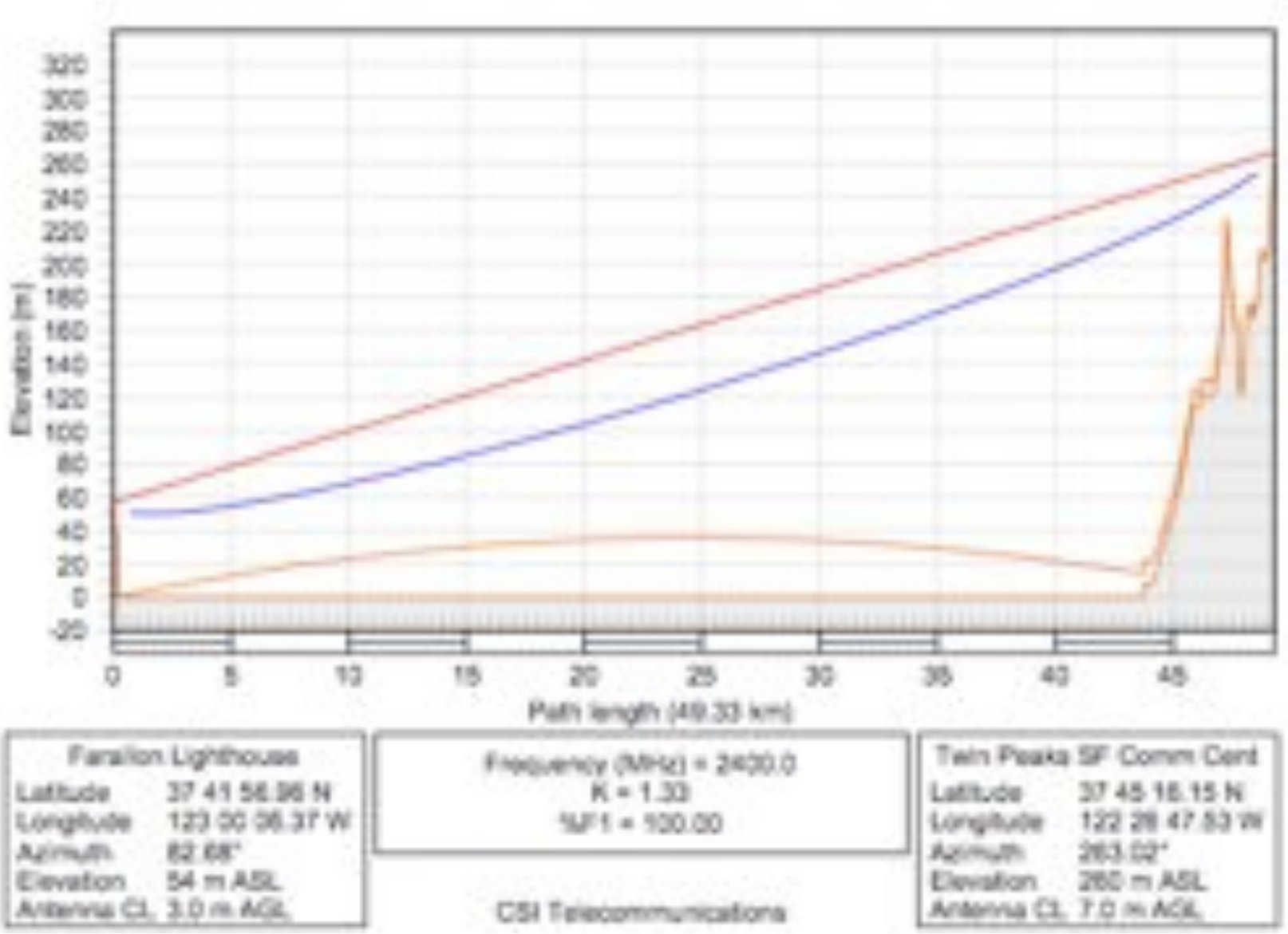
$$r = 17.32\sqrt{\frac{D}{4f}}$$

r = radius in metres
D = total distance in kilometres
f = frequency transmitted in gigahertz.

Fresnel Zone Calculation

Distance from TX to calc point	15.5000	miles
Path Length	31.0000	miles
Distance from RX to calc point	15.5000	miles
Frequency	5.8000	GHz
First Fresnel Zone Radius	83.2280	feet
Second Fresnel Zone Radius	117.7021	feet
Third Fresnel Zone Radius	144.1551	feet
Forth Fresnel Zone Radius	166.4560	feet

Example 2.4Ghz Path Profile



Antenna and Transmission Line Selection

Hardware Specifications:

- What type of connector interface is required?
- What type of coax is needed
- Where will the antenna be mounted? What type of mounting hardware is required? What additional hardware may be required for wind loading?
- Is a radome required to protect the feed from weather, etc.?
- Quality of construction. What is the lifetime of the antenna and line?

Antenna Selection

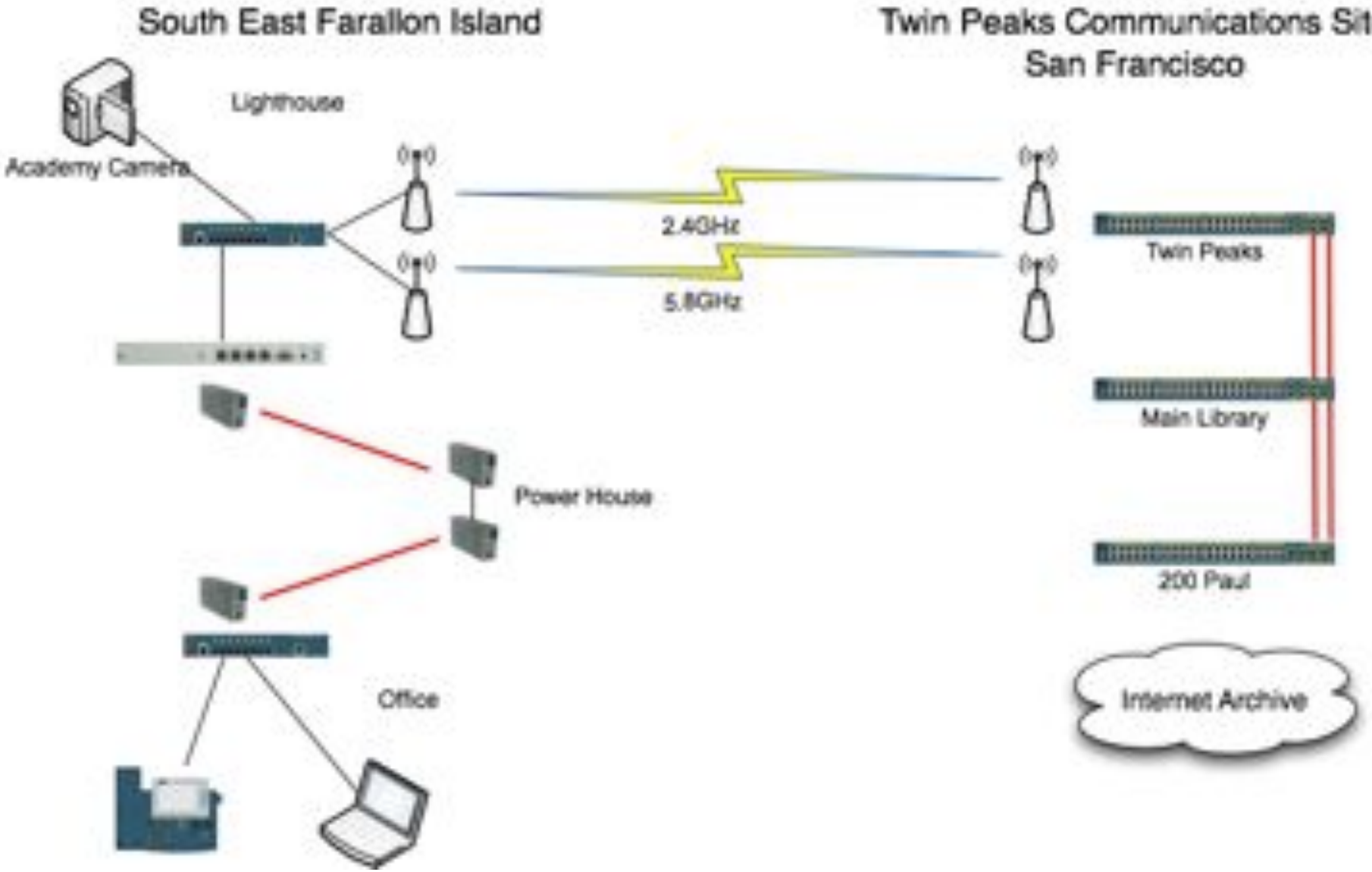
"Electrical" Specifications:

- Operating frequency range of system?
- How much gain is required?
- Preferred radiation pattern?
- Power capability of the antenna.
- Polarization?

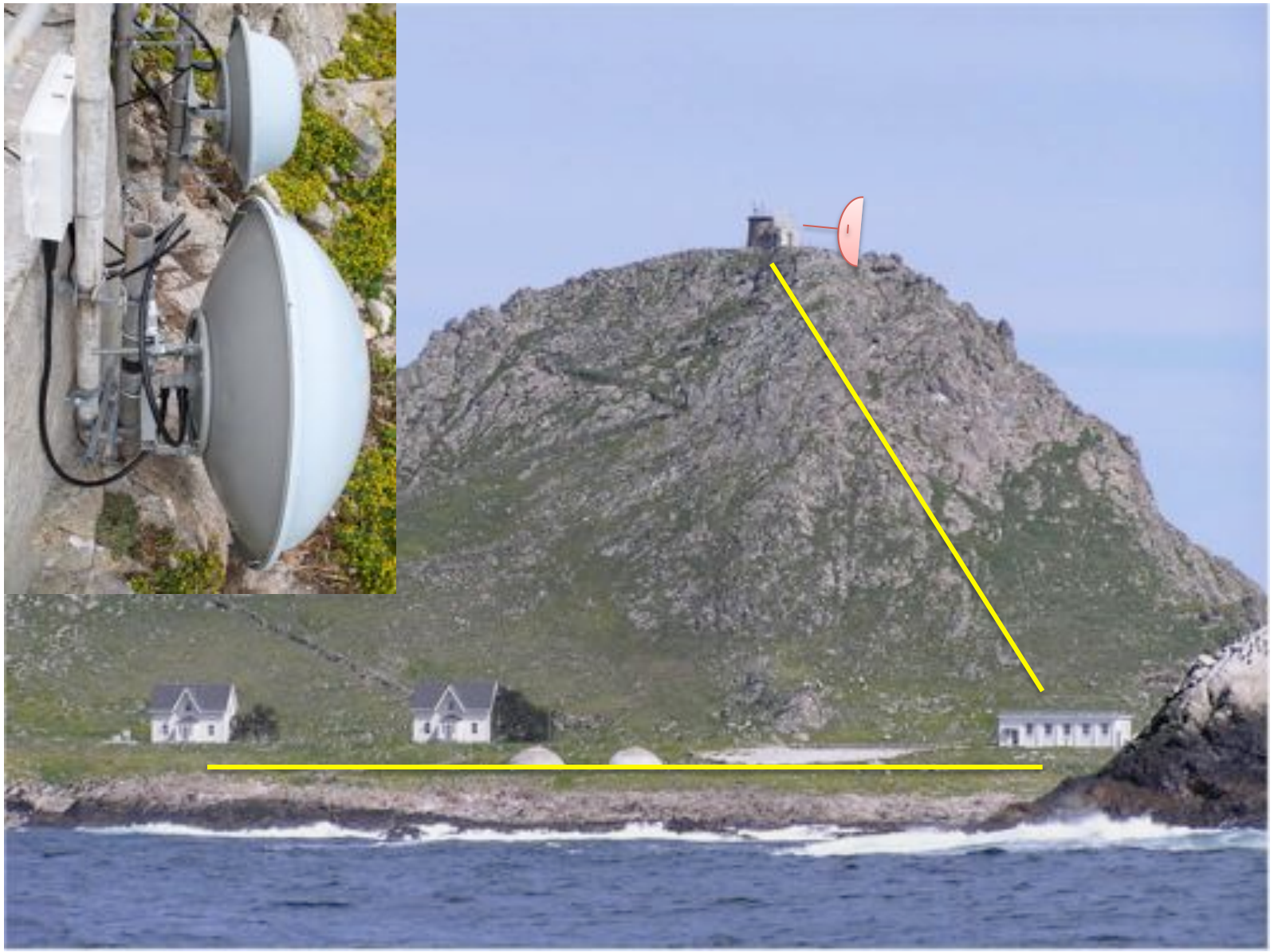
Antenna Polarity

- Polarity is a product of the design of the antenna.
- Each end must match.
- It can be used to minimize multi-path and interference.
- Typical Polarities:
  - Horizontal
    - Avoids multi-path from vertical objects like buildings
  - Vertical
    - Avoids multi-path from horizontal objects like the ground, bodies of water.
  - Circular
    - It can avoid multi-path from “odd-number bounced sources.
    - Left or right handed
- Some antennas can support dual-polarities
  - full duplex links, fail-over, 802.11n with MIMO (2 chains)

Physical & network diagram



South Island Overview



Lighthouse Network

Staff house MPOE

The Kit

- Ubiquiti BulletM2
  - 2.4Ghz
  - Single N connector
    - 802.11N based
    - Atheros MIPS-based, OpenWRT flash'able
    - 24V passive PoE
- Ubiquiti Rocket5
  - 5.2/5.8Ghz
  - Dual RP-SMA
- Pacific Wireless radome antennas
  - Dual polarity 5Ghz, Single polarity 2.4Ghz
- Soekris net5501
  - AMD x86 500Mhz w/128Mb, CompactFlash
  - 5x FastEthernet
- Cisco WS-C2950-12

Embedded BSD

- OpenBSD 4.5
  - **pf** is great – easy syntax, handles NAT tricks well
  - Secure, claims some cranky Canadian & Germans
  - Just works!
- Utilities extremely valuable
  - **flashrd** to strip down base OS, sample kernels
  - **dhcpdump** sniff VoIP phone DHCP vendor tags
  - **ngrep** mainly for –W byline support, debug slow social network site loading

Joys of Ubquiti's 802.11n MIMO

- Disable "AirMAX"; Ubiquiti proprietary polling protocol (TDMA'ish); not needed for Point to Point
- Disable auto-negotiate data rates; frequent changes will loose sync – hard reboot to fix
- Use smallest channel width as possible that satisfies bandwidth requirement
- Long distance links have interference, avoid QAM modulation scheme; which scheme like a BSFK with amplitude component such as MCS0 (1 chain) or MCS8 (2 chains)
- Set "distance" directive to 30% over actual calculated distance; the AirOS auto-magic doesn't work well

Lessons Learned

- pf “scrub” can bite you in asymmetric routing
  - P-MTU like problem, some HTTP sites not loading
- Always have techies buy the cabling
  - Try crimping RJ45 on 22G (yes, not 24) sticky wires
- Bird poop is extremely fowl and wet
  - Blankets clothing, the smell that keeps on giving
- Loaned tools never return or rust’ified in days
- As usual, never enough time
  - 6am to 6pm trips would yield 4hrs of usable on-island time

Future Directions

- We would like to avoid using unlicensed bands
  - Congestion, not “carrier-class”
  - What is preventing us is licensed equipment is limited, expensive, coordination
- Upgrade webcam to HD resolution
- Increase the bandwidth and reliability
- On-island local Nagios weathermap

Thank You / Q&A

Tim Pozar

pozar@lns.com

Matt Peterson

matt@peterson.org

Links

Farallones WebCam (available 6:30 to 19:30 PST)
http://www.calacademy.org/webcams/farallones/

Los Farallones (island staff blog)
http://losfarallones.blogspot.com/

flashrd (OpenBSD embedded installer)
http://www.nmedia.net/flashrd/

Ubiquiti Networks (radio manufacturer)
http://ubnt.com/