STANFORD STUDENT SPACE INITIATIVE

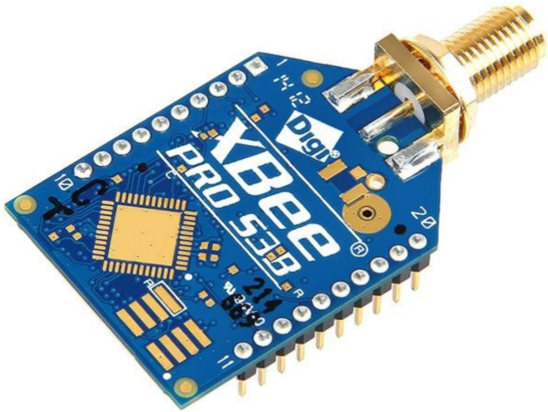
Long-Range SRAD Radio Telemetry System (SRADio)

Spaceport America Cup Team 111

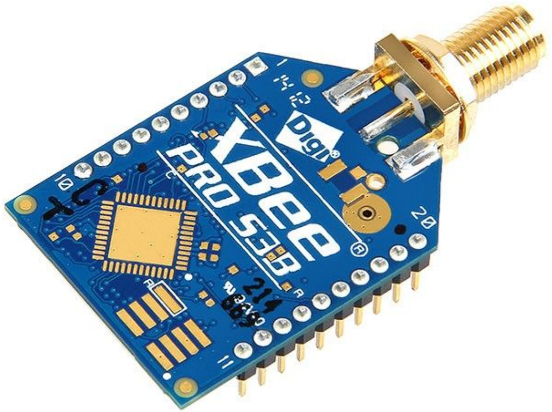
S. Platt, S. Maldonado

Status Quo

XBee



XBee



SSI Projects

SSI Project Radio Needs

Capabilities*	Range (km)	Electrical Power (mW)	Data Rate (bit/s)
XBee 900HP	15	750	10000

Needs	Range (km)	Electrical Power (mW)	Data Rate (bit/s)
IREC	10	≤750	5000

*using low gain, omni-directional antennas with no need for tracking

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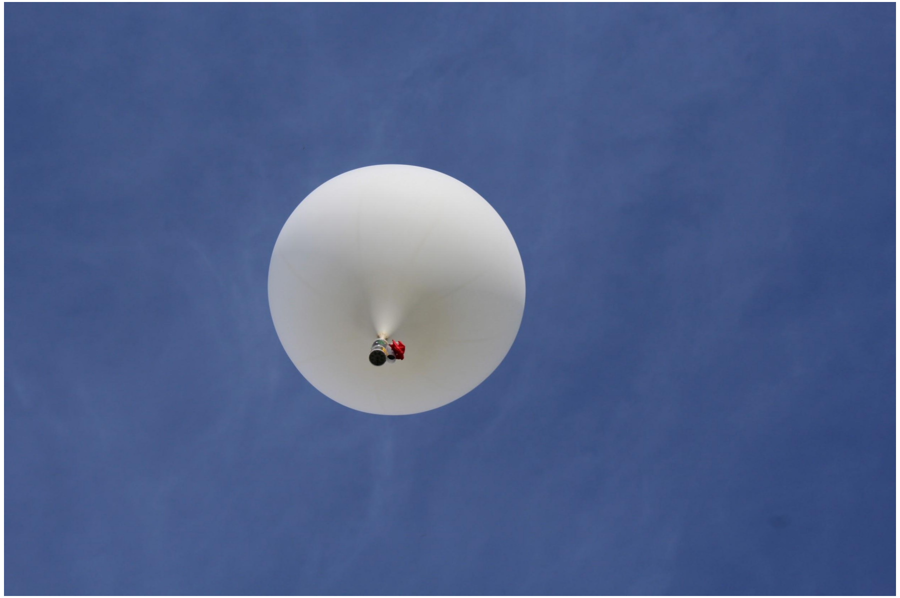
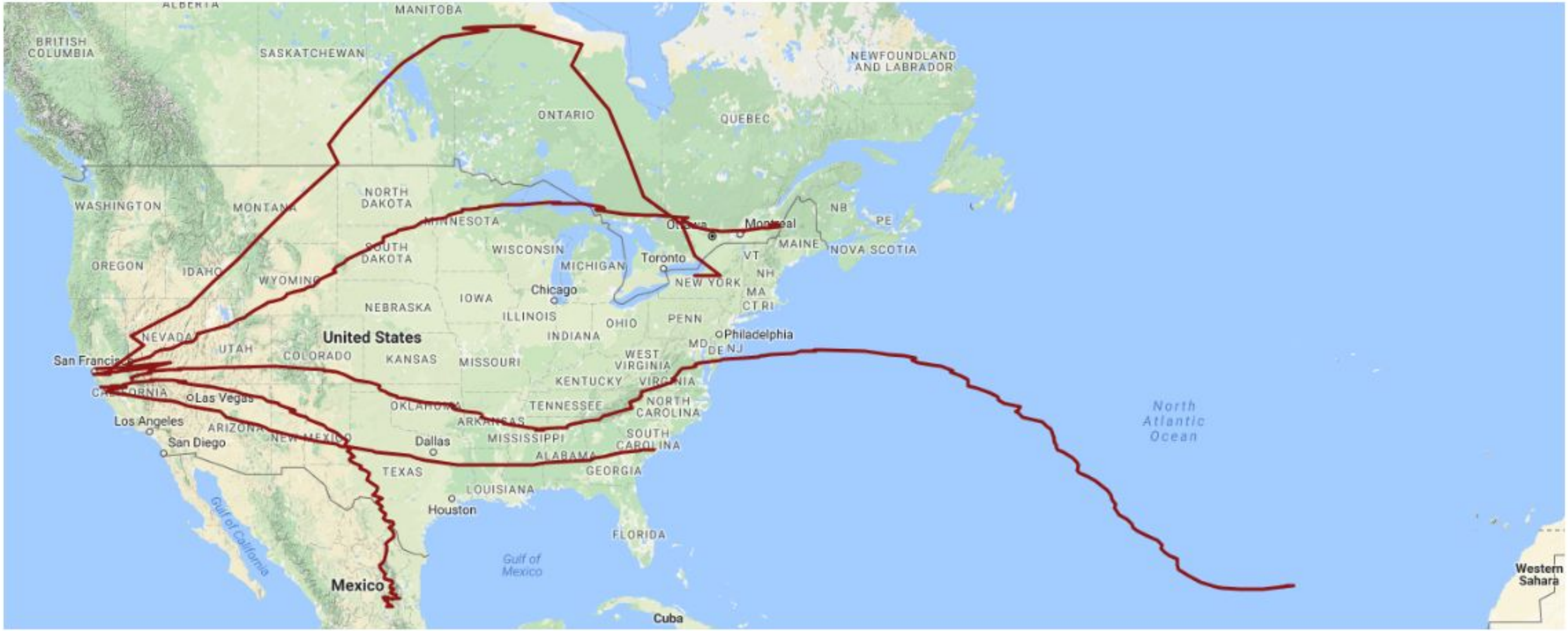
ValBal



ValBal



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MANITOBA
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San Diego
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SOUTH CAROLINA
ALABAMA
TEXAS
GEORGIA
LOUISIANA
Houston
Gulf of California
FLORIDA
Gulf of Mexico
Western Sahara
Mexico
Cuba

SSI Project Radio Needs

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SSI Program Radio Needs

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Spaceshot

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SRADio

Friis Transmission Equation

$$P_r = P_t D_t D_r \left(\frac{\lambda}{4\pi d} \right)^2$$

Friis Transmission Equation

Wavelength

$$P_r = P_t D_t D_r \left(\frac{\lambda}{4\pi d} \right)^2$$

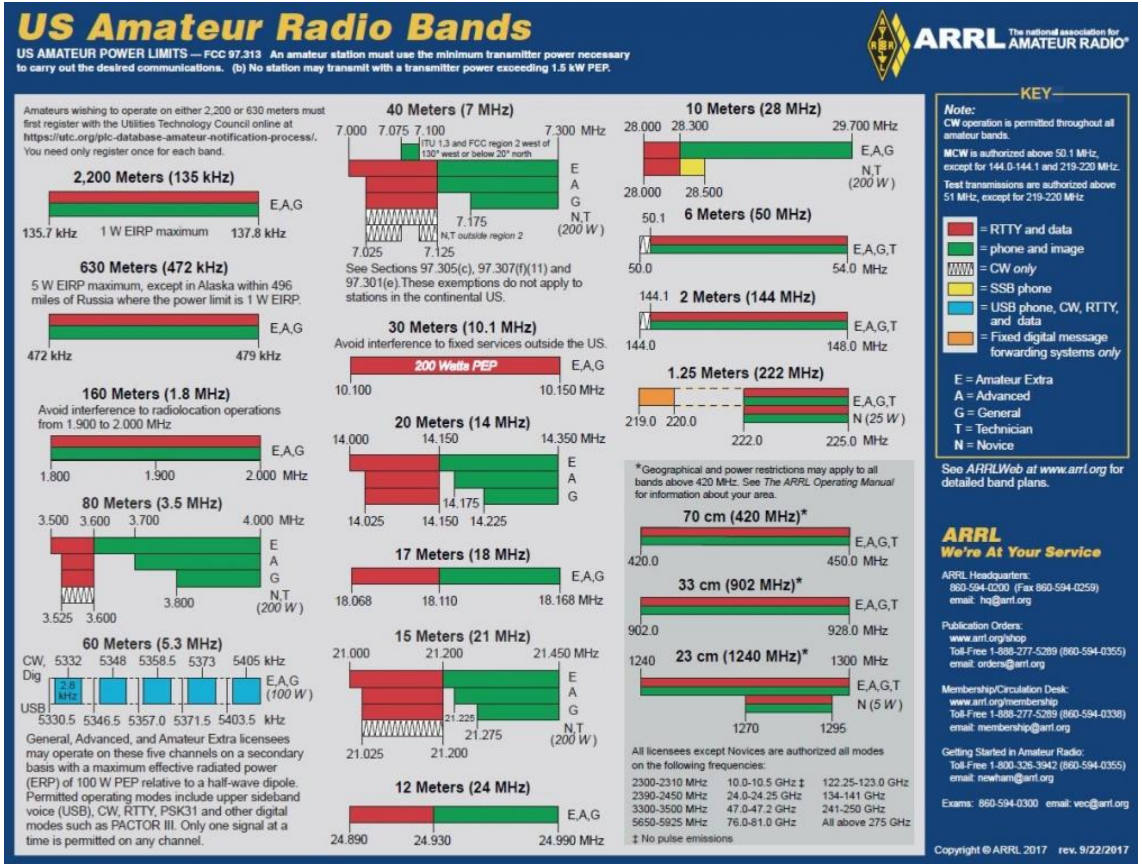
Received Power

Transmitted Power

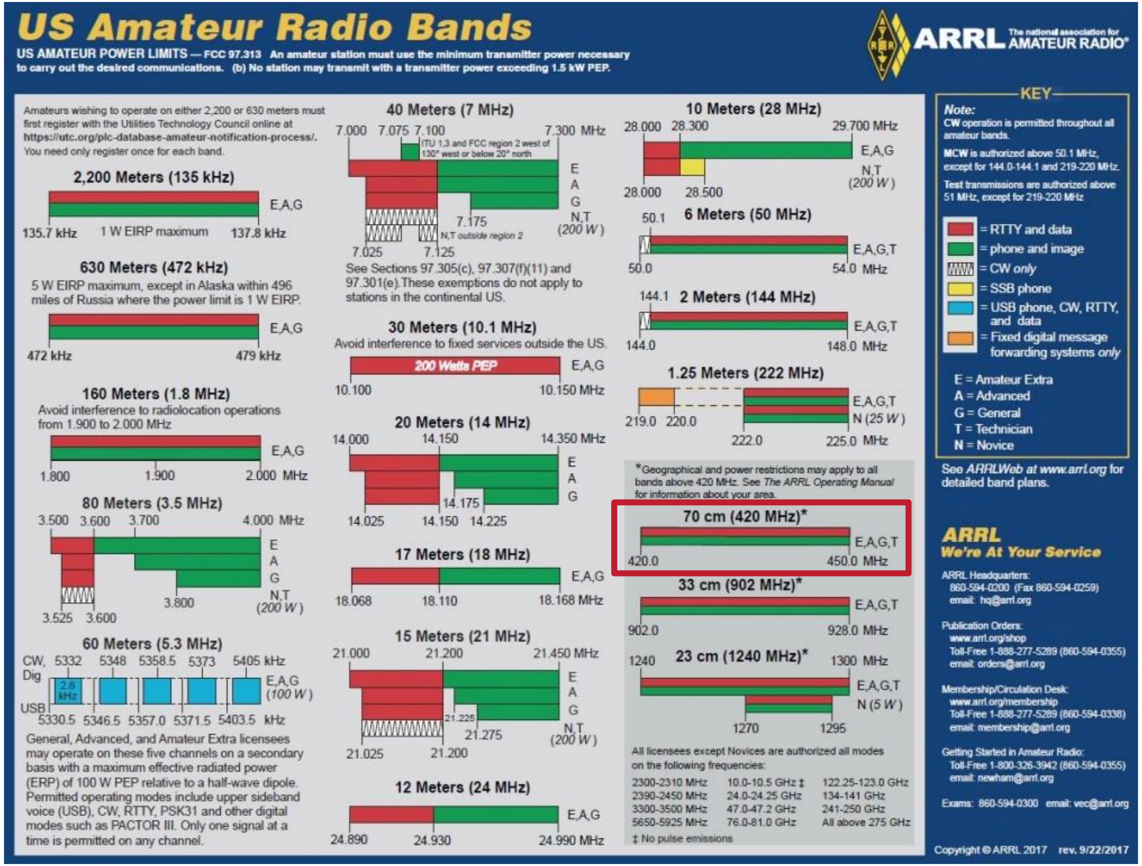
Antenna Gains

Link Distance

Amateur Radio



Amateur Radio



Friis Transmission Equation

33 cm → 70 cm = +6 dB

Wavelength

$$P_r = P_t D_t D_r \left(\frac{\lambda}{4\pi d} \right)^2$$

Received Power

Transmitted Power

Antenna Gains

Link Distance

Friis Transmission Equation

33 cm → 70 cm = +6 dB

Wavelength

$$P_r = P_t D_t D_r \left(\frac{\lambda}{4\pi d} \right)^2$$

Net: +2 dB

Received Power

Transmitted Power

Antenna Gains

Link Distance

250 mW → 100 mW = -4 dB

Friis Transmission Equation

33 cm → 70 cm = +6 dB

Wavelength

$$P_r = P_t D_t D_r \left(\frac{\lambda}{4\pi d} \right)^2$$

Net (100 km): -18 dB
Net (400 km): -30 dB

Received Power

Transmitted Power

Antenna Gains

Link Distance

250 mW → 100 mW = -4 dB

10 km → 100 km = -20 dB
10 km → 400 km = -32 dB

Shannon-Hartley Channel Equation

$$\text{bitrate} = B \cdot \log_2 \left(1 + \frac{P_r}{P_n} \right)$$

Shannon-Hartley Channel Equation

Received Power

$$\text{bitrate} = B \cdot \log_2\left(1 + \frac{P_r}{P_n}\right)$$

Bandwidth

Noise Power

Signal-to-Noise Ratio

$$\mathrm{SNR} = \frac{P_r}{P_n}$$

100 km: -18 dB
400 km: -30 dB

Si4463

SILICON LABS

Si4464/63/61/60

HIGH-PERFORMANCE, LOW-CURRENT TRANSCEIVER

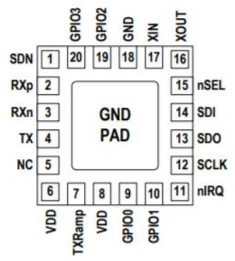
Features

- Frequency range = 119–1050 MHz
- Receive sensitivity = –126 dBm
- Modulation
  - (G)FSK, 4(G)FSK, (G)MSK
  - OOK
- Max output power
  - +20 dBm (Si4464/63)
  - +16 dBm (Si4461)
  - +13 dBm (Si4460)
- PA support for +27 or +30 dBm
- Low active power consumption
  - 10/13 mA RX
  - 18 mA TX at +10 dBm (Si4460)
- Ultra low current powerdown modes
  - 30 nA shutdown, 50 nA standby
- Data rate = 100 bps to 1 Mbps
- Fast wake and hop times
- Power supply = 1.8 to 3.6 V
- Excellent selectivity performance
  - 60 dB adjacent channel
  - 75 dB blocking at 1 MHz
- Antenna diversity and T/R switch control
- Highly configurable packet handler
- TX and RX 64 byte FIFOs
- Auto frequency control (AFC)
- Automatic gain control (AGC)
- Low BOM
- Low battery detector
- Temperature sensor
- 20-Pin QFN package
- IEEE 802.15.4g compliant
- FCC Part 90 Mask D, FCC part 15.247, 15,231, 15,249, ARIB T-108, T-96, T-67, RCR STD-30, China regulatory
- ETSI Class-I Operation with SAW

Applications

- Smart metering (802.15.4g & MBus)
- Remote control
- Home security and alarm
- Telemetry
- Garage and gate openers
- Remote keyless entry
- Home automation
- Industrial control
- Sensor networks
- Health monitors
- Electronic shelf labels

Pin Assignments



Signal-to-Noise Ratio

$$\mathrm{SNR} = \frac{P_r}{P_n}$$

100 km: -18 dB
400 km: -30 dB

Sensitivity: -10 dB

Net (100 km): -8 dB
Net (400 km): -20 dB

Signal-to-Noise Ratio

$$\mathrm{SNR} = \frac{P_r}{P_n}$$

100 km: -18 dB
400 km: -30 dB

Sensitivity: -10 dB
Tuning:
5 kbit/s: -18 dB

Net (100 km): +10 dB
Net (400 km): -20 dB

Signal-to-Noise Ratio

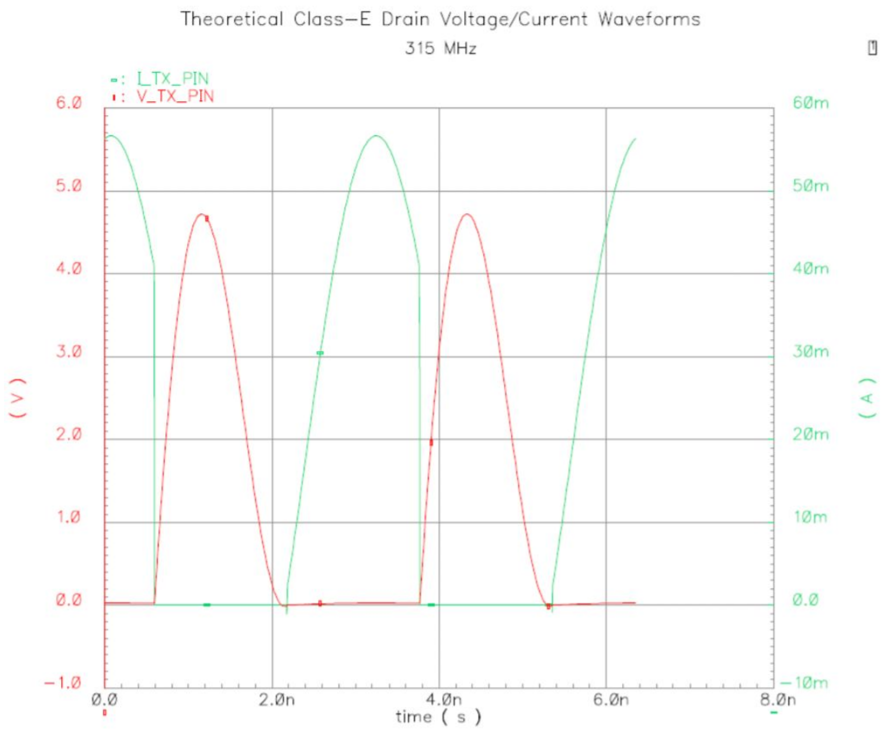
$$\mathrm{SNR} = \frac{P_r}{P_n}$$

100 km: -18 dB
400 km: -30 dB

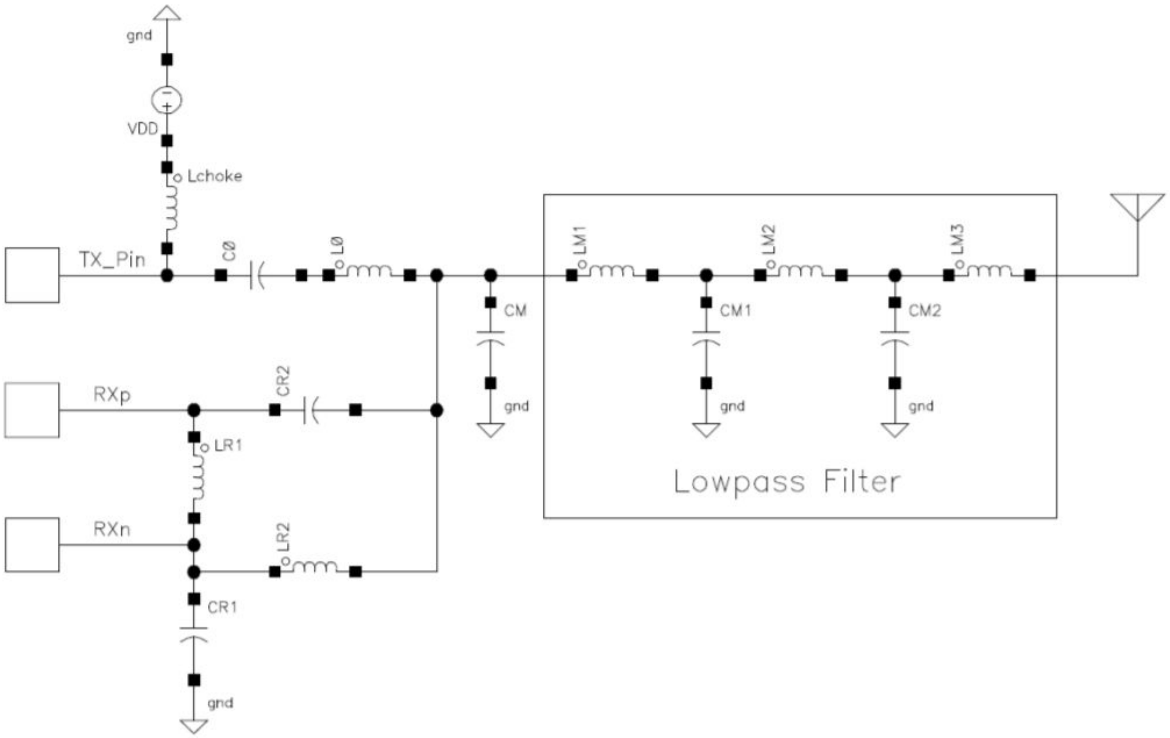
Sensitivity: -10 dB
Tuning:
5 kbit/s: -18 dB
500 bit/s: -25 dB

Net (100 km): +10 dB
Net (400 km): +5 dB

Class E Power Amplifier



Hardware Implementation



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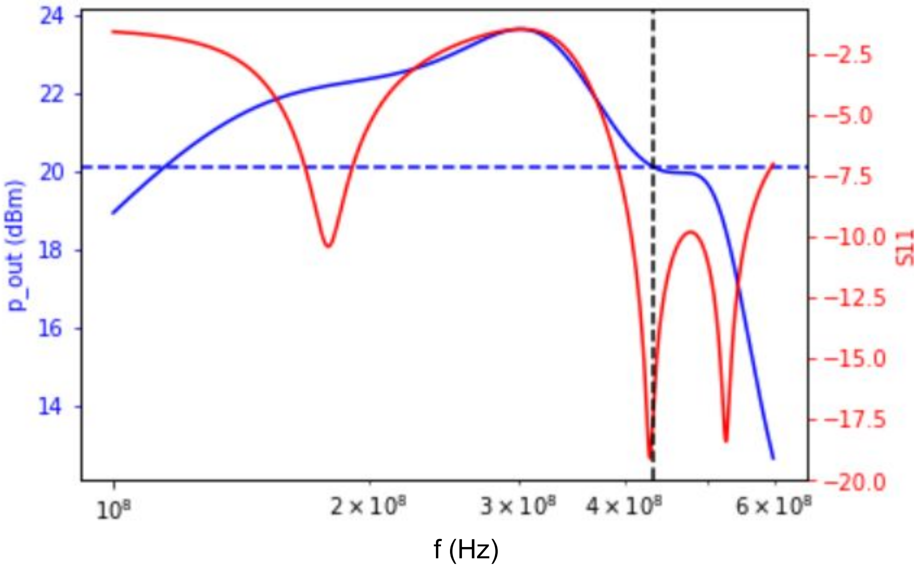
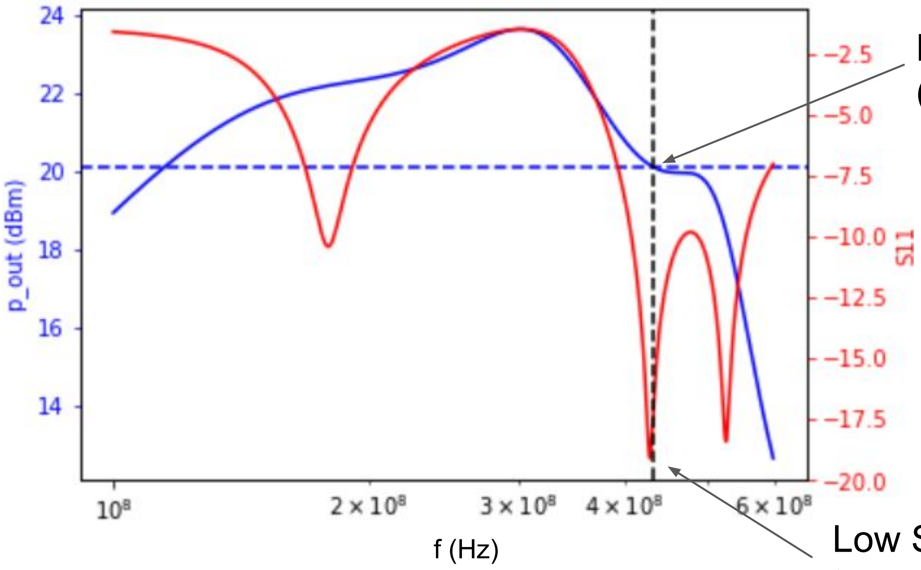


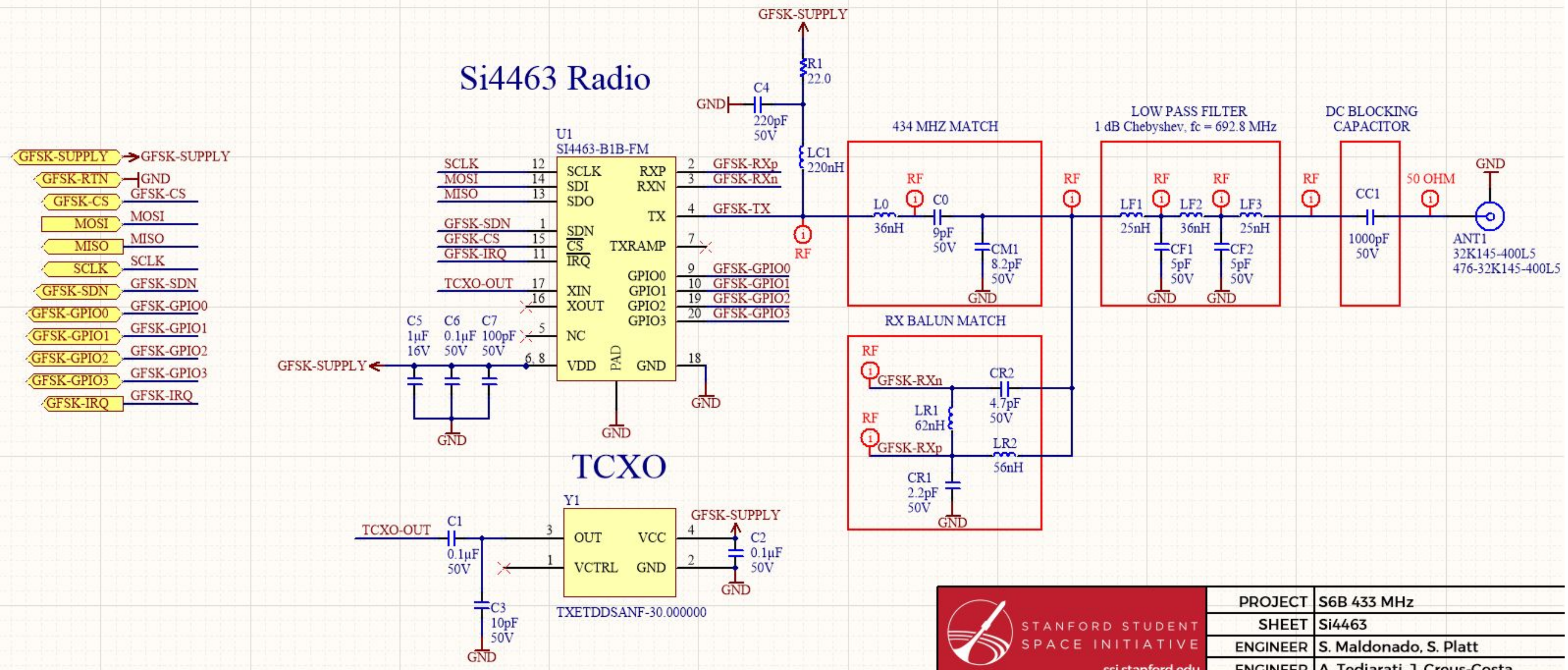
Hardware Implementation



Expected power output (20 dBm = 100 mW)

Low S11 indicates low-loss transmission of power into antenna

Hardware Implementation



PROJECT	S6B 433 MHz
SHEET	Si4463
ENGINEER	S. Maldonado, S. Platt
ENGINEER	A. Tedjarati, J. Creus-Costa
REVIEWER	A. Tedjarati
REVIEWED ON	12/27/17

STANFORD STUDENT SPACE INITIATIVE
ssi.stanford.edu
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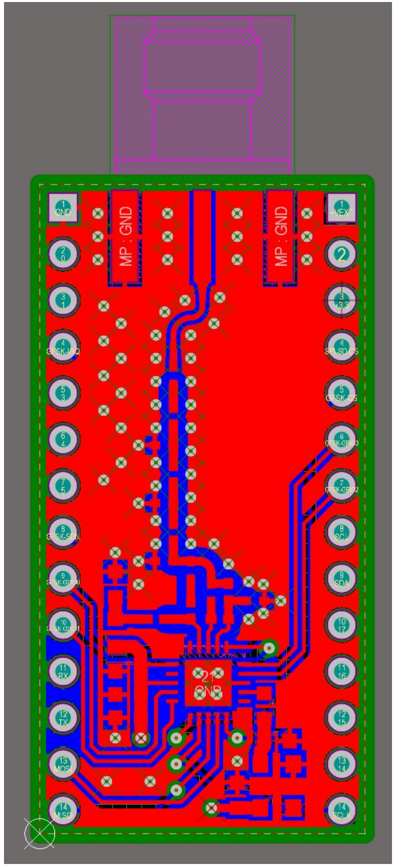
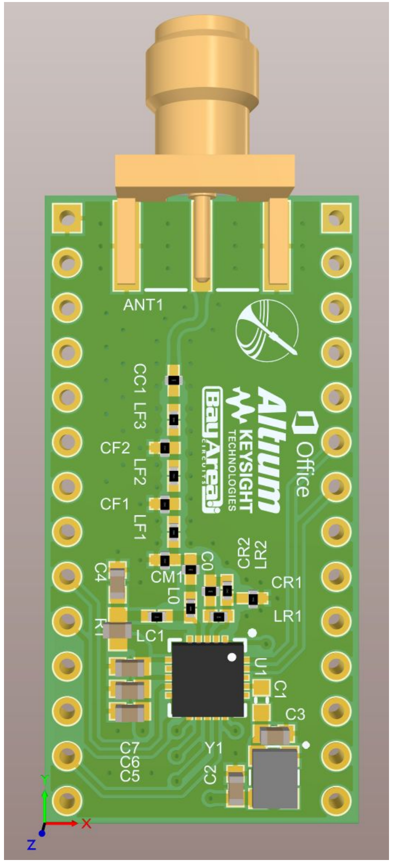
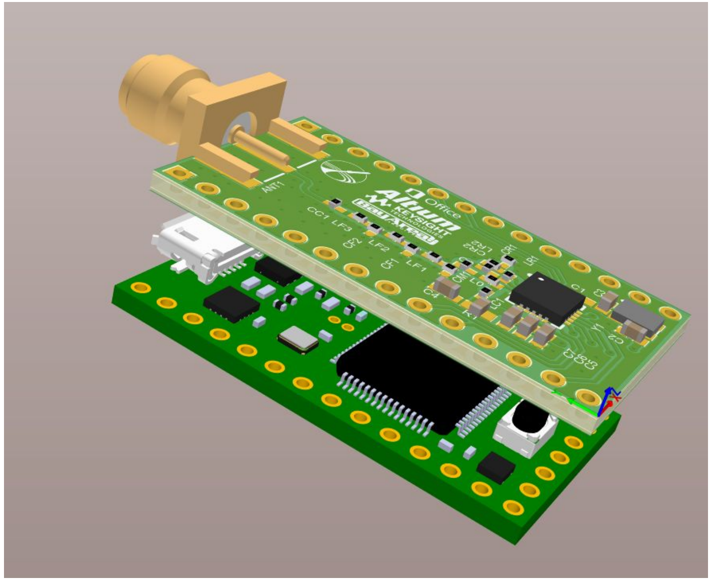
REVISION 1
Sheet 2 of 2

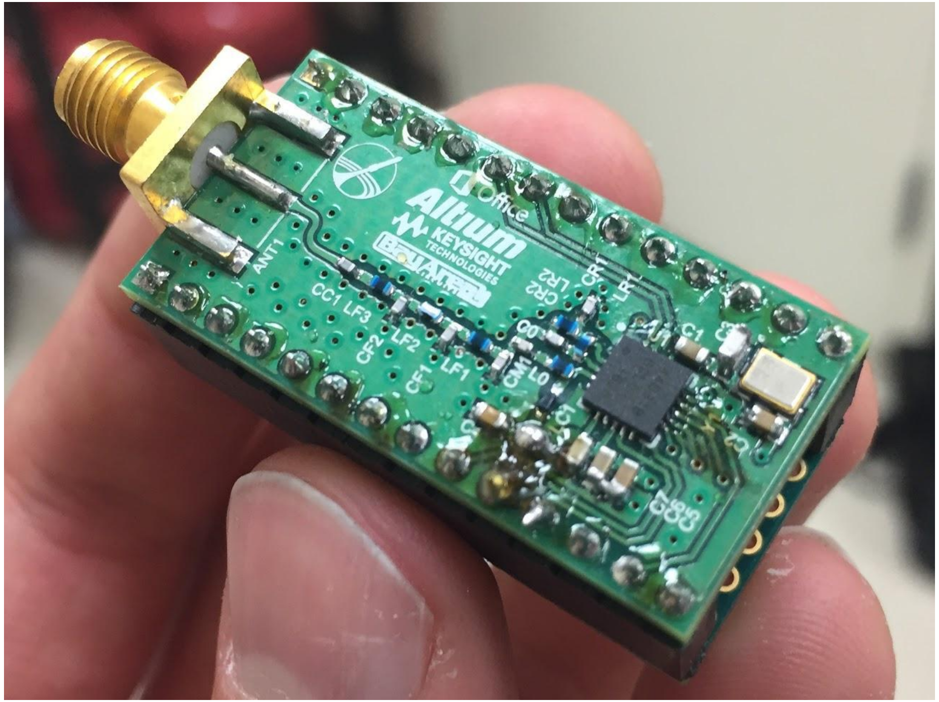
Hardware Implementation



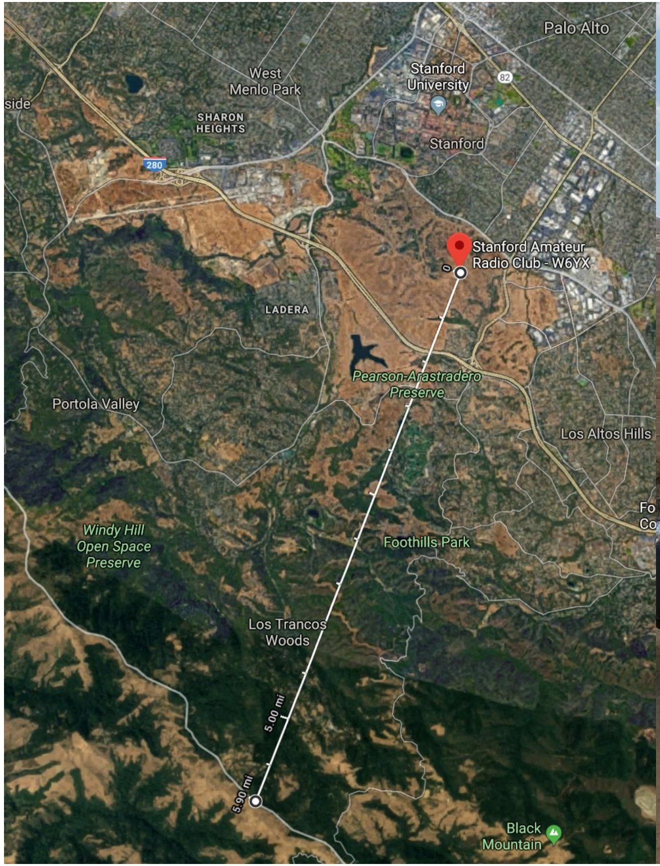




Hardware Implementation



Testing



Palo Alto
West Menlo Park
Stanford University
side
SHARON HEIGHTS
Stanford
280
82
Stanford Amateur Radio Club - W6YX
0
LADERA
Pearson-Arastradero Preserve
Portola Valley
Los Altos Hills
Windy Hill Open Space Preserve
Foothills Park
Los Trancos Woods
5.00 mi
5.90 mi
Black Mountain

SSI Project Radio Needs

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"SSI XBee"

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“S SIX Bee”

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In Development...

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SRADio S6C	*400*	*175*	*5000*
Needs	**Range (km)**	**Electrical Power (mW)**	**Data Rate (bit/s)**
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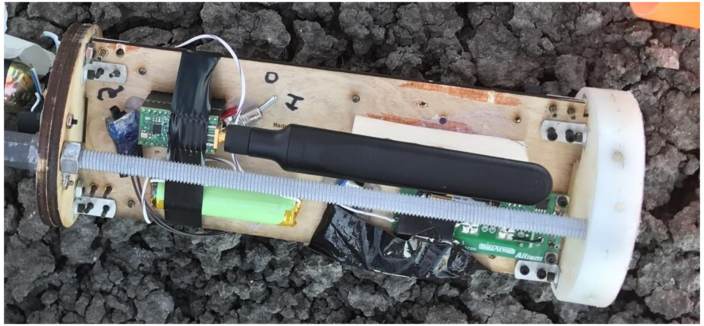
Acknowledgments and References



CONTRIBUTORS:

A. Tedjarati, J. Creus-Costa, T. Vrakas, C. Glikbarg, S. Vandeleest

SPONSORS:

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