Optimal Radio Wave Distance for Interstellar Communication

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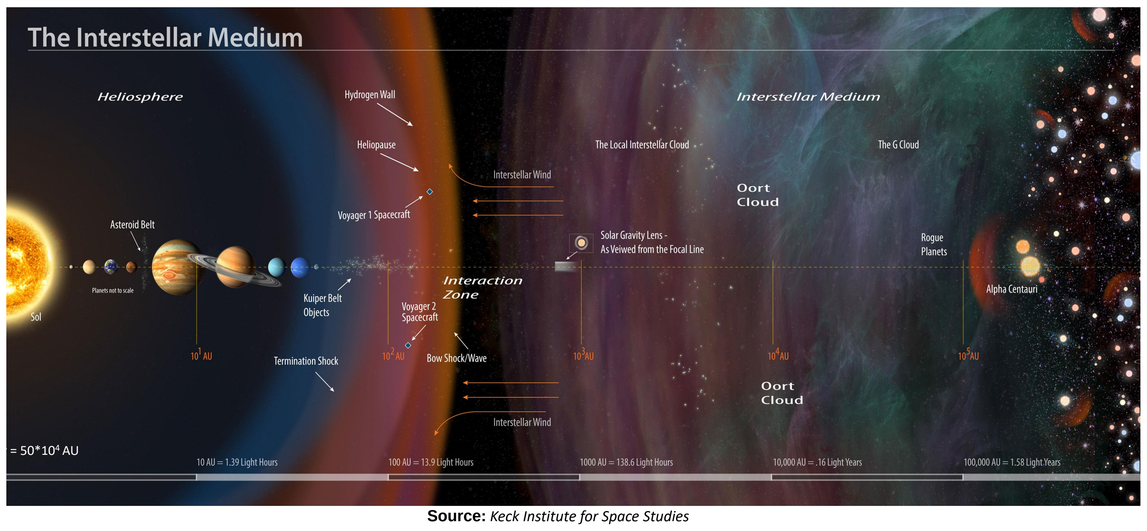
Introduction

Due to the world's current technology in spacecraft and propulsion, it will take several centuries until humanity can travel to our solar system's nearest star. The DeepSpace lab aims to take a different direction in the evolution of such technology by creating a spacecraft, known as a waferSAT, which ways less than a gram that can travel at relativistic speeds. (speeds relative to that of the speed of light)

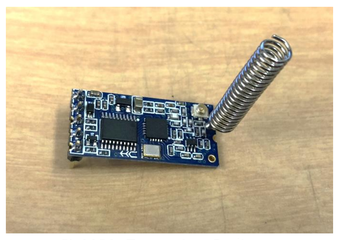
While there are obstacles that concern to the physics of this concept, one that is potentially being addressed is the issue regarding long distance communication. Since the current technology for satellites allow for mass of at least 1.5 kg, we are hoping to bridge the gap between what is current and the ultimate goal by creating a satellite spacecraft that weights 10-30 grams and analyze its performance under low altitude orbit. With this, we plan to test the limits of radio frequency communications by exploring the tradeoff space between the bit rate, power usage, and communication distance.



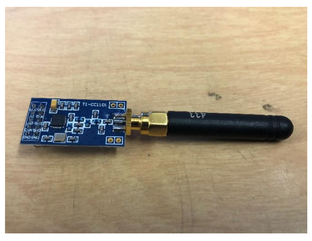
Source: *Keck Institute for Space Studies*

Choosing TI-CC1101 / SI-4464x based on Power use and range in initial design

In order to configure the functions and commands for the satellite, it is programmed in the computer through Serial Peripheral Interface. The radio would establish a connection channel with a laptop and run radio range tests to analyze how far each radio can communicate with the laptop before the connection gets cut off. Both the communication and the power rate will be measured.



SI-4464x Transceiver Radio



TI-CC1101 Transceiver Radio

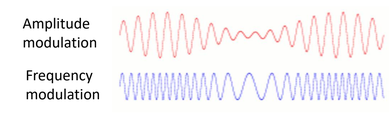
Optimizing radio chip to effectively increase comms distance

After a radio has been chosen to be more efficient for the spacecraft based communication range and minimal power usage, that radio will be further optimized by modifying the transmitter power output to provide more distance for the wave to travel in free space. (Friis's free-space propagation) Afterwards, the signal-to-noise ratio (the difference between the wanted signal of the source and unwanted noise signal) will be analyzed based on the bandwidth and the power transmission between the receiver and transmitter, along with modulations involved in the carrier wave.

Friis's free-space propagation:

$$P_R = P_T \frac{G_T G_R \lambda^2}{(4\pi)^2 d^2}$$

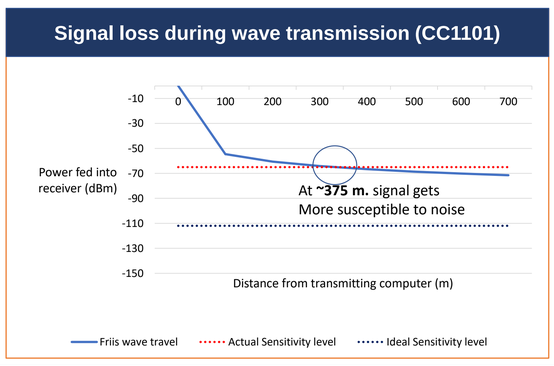
•As signal is traveling from receiver to transmitter, energy from that signal is being lost over time.

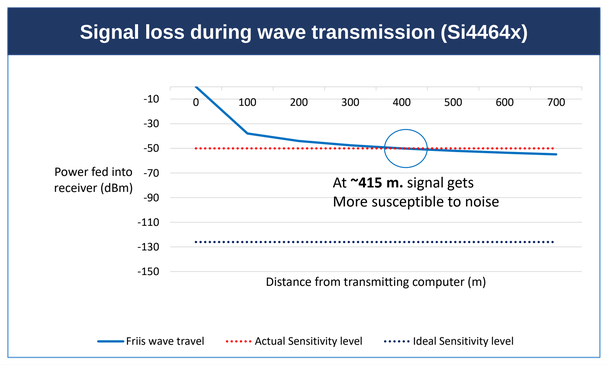


$$\frac{S}{N} = \frac{p_s\,(energy\ of\ signal)}{P_N(energy\ of\ noise)} / \frac{S}{N}(dB) = 10log\frac{p_s}{P_N}$$

•There is an inverse relationship b/w wanted and interfering signal; **signal can be controlled, noise not so much**

Theoretical radio range calc. shows that Si446x can communicate farther than CC1101





The data represents the expected distances between both radios based off of the friis equation. The sensitivity levels here show the level at which minimum power is required to transmit the data, but also where it becomes exposed to noise. The Si4464 has greater distance before noise arises, but it uses more power.

Type of noise that is physically Impossible to bypass:

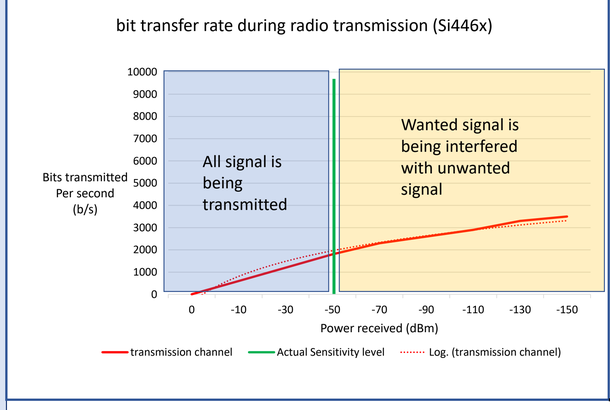
Thermal noise

Power: $P_T = \mathrm{kTB}$
Voltage: $V_T = \sqrt{4kTBR}$

Limit at which electrons in radio Become agitated, causing those Charges to interfere with signal

k = Boltzmann's Constant
T = temperature*
B = bandwidth
R = resistance*

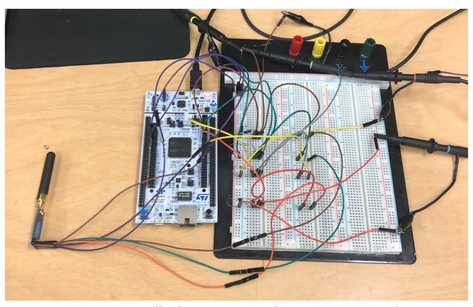
Minimizing the effects of noise to absorb as much wanted signal as possible

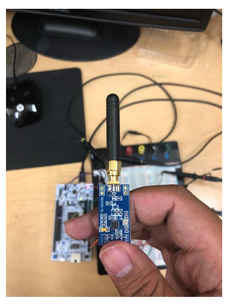


The bit rates show that at the region where sensitivity is not yet intercepted, the rate is constant, but afterwards the bit rate transmission starts to decrease. Currently, different variants of F.M. are being tested to test bandwidth efficiency with respect to distance.

This shows that higher bit rate must occur in blue before it goes towards orange region. Some noise can also be adjusted.

Current stage: testing CC1101 Radio to communicate with SPI



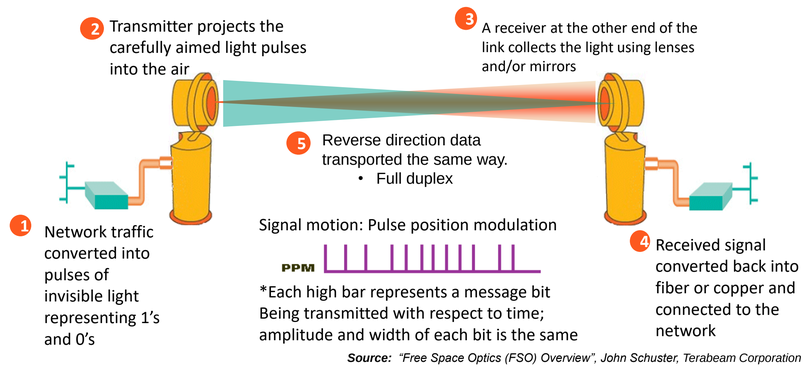


CC1101 radio is connected to a STM32 microcontroller to allow for commands and functions to be given to radio

Currently, the CC1101 radio is being set up to communicate with an STM32 Nucleo microcontroller board, the commands are being sent through the computer and the SPI program is being set up. Soon, range tests will be run after the code for the SPI program has been completed and debugged.

Future plans and conclusion

Free-Space laser communications for interstellar distances



Source: *"Free Space Optics (FSO) Overview", John Schuster, Terabeam Corporation*

Overall, the results show that a sub-1Ghz low power radio like the Si-4464 is capable of long distance communication to near outer orbit, which will open a way for the waferSAT to talk at light years distance, however the aspect of noise needs to be further addressed, especially when cosmic noise gets involved.

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