The LASP Radio JOVE Project

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Significance and History

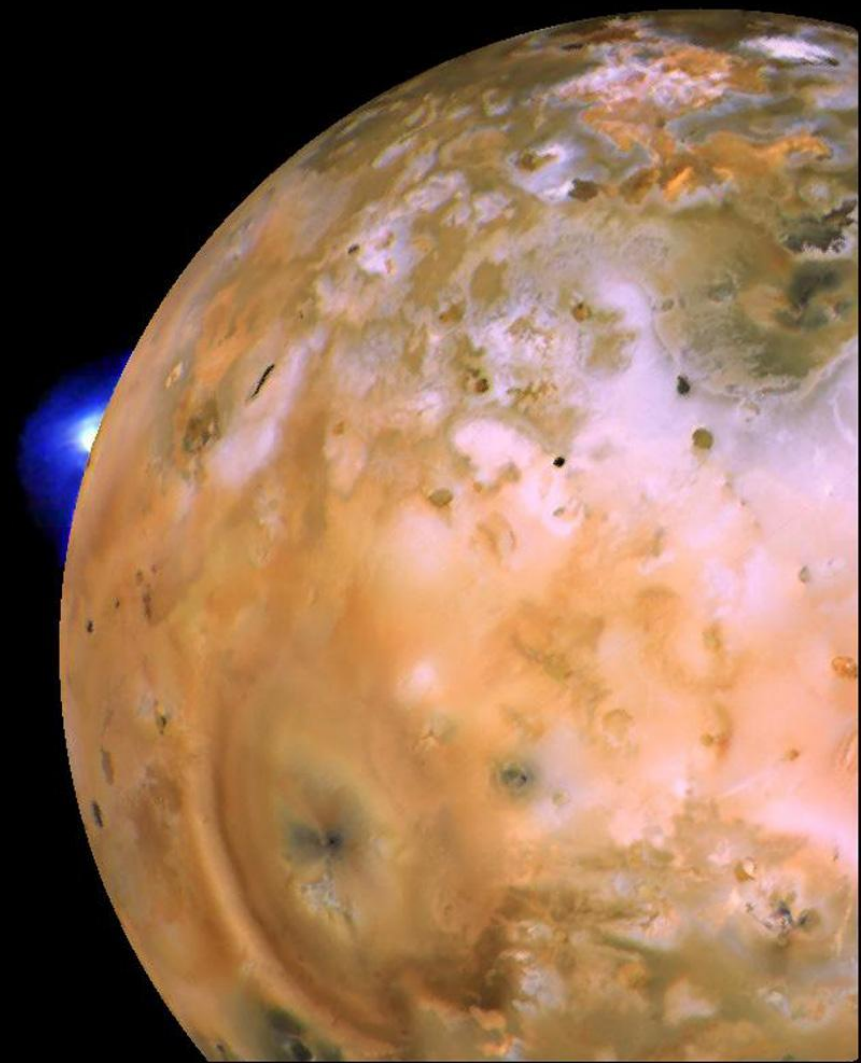
The 'Mills Cross Array' used by Burke and Franklin to detect radio emissions from Jupiter [1].

- Jupiter is one of the most significant sources of radio emissions in our solar system.
- Emissions were first discovered in 1955 by Bernard Burke and Kenneth Franklin in Washington D.C. [1].
- Patterns in Jupiter's emission spectrum were observed here in Boulder in the 1960's by James Warwick and George Dulk – later confirmed by measurements from both NASA Voyager missions [2].
- These early experiments were done using a similar technique (see figure on the left) as the Radio JOVE telescope here at LASP.
- Radio emissions are an important part of astronomy as they can reveal information about astronomical bodies that can't necessarily be detected by optical means.

[1] http://radiojove.gsfc.nasa.gov/library/sci_briefs/discovery.html
[2] 'Listening to Jupiter' by Dick Flagg

Influences on Jupiter's Radio Emissions

NASA edit of image taken by Voyager I: Eruption of Volcano Loki on moon Io.



- Early observes noticed that the orientation of Jupiter with respect to Earth has an effect on whether we can hear radio emissions or not.

- Rather than sending waves out in every direction, Jupiter is beaming radio waves into space, therefore only when certain parts of Jupiter are facing us are we able to detect them [3].

- However, the most significant impact on the detection of Jupiter's radio emissions is the effect that its moon, Io has.

- The volcanic nature of Io leads to the creation of the "Io torus", an electrically conducting ring of electrons, sulphur and oxygen ions, around the planet.

[3] http://radiojove.gsfc.nasa.gov/library/sci_briefs/decametric.htm

Types of Emission and Their Sources

- The movement of Io through the Ion torus can be compared to the moving of a conductor through a magnetic field generating a current. Io's conducting atmosphere acts to generate a large current between Io and Jupiter [3].

- This disturbance of Jupiter's magnetic field by Io triggers the emission of Decameter radio waves (waves measured in tens of metres).

- An inner belt of radiation (10 MeV electrons) also gives rise to Decimetric radio emissions (waves within the range of centimetres in length) as electrons gyrate around Jupiter's strong magnetic field in what is called "sychrotron radiation".

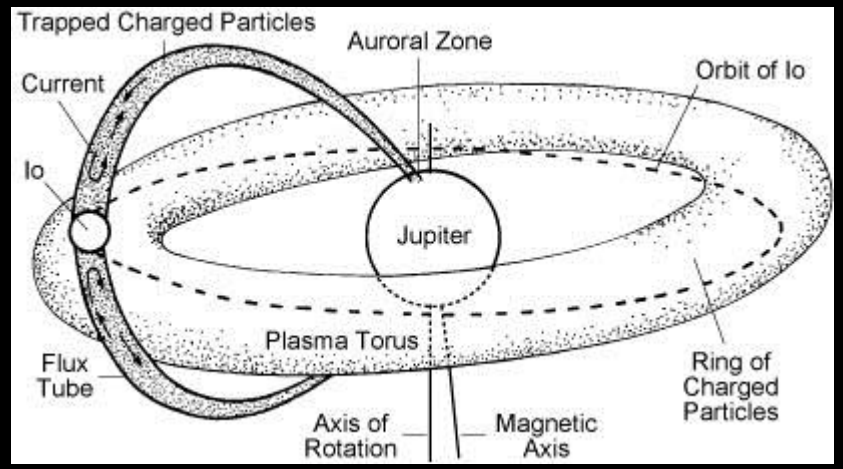
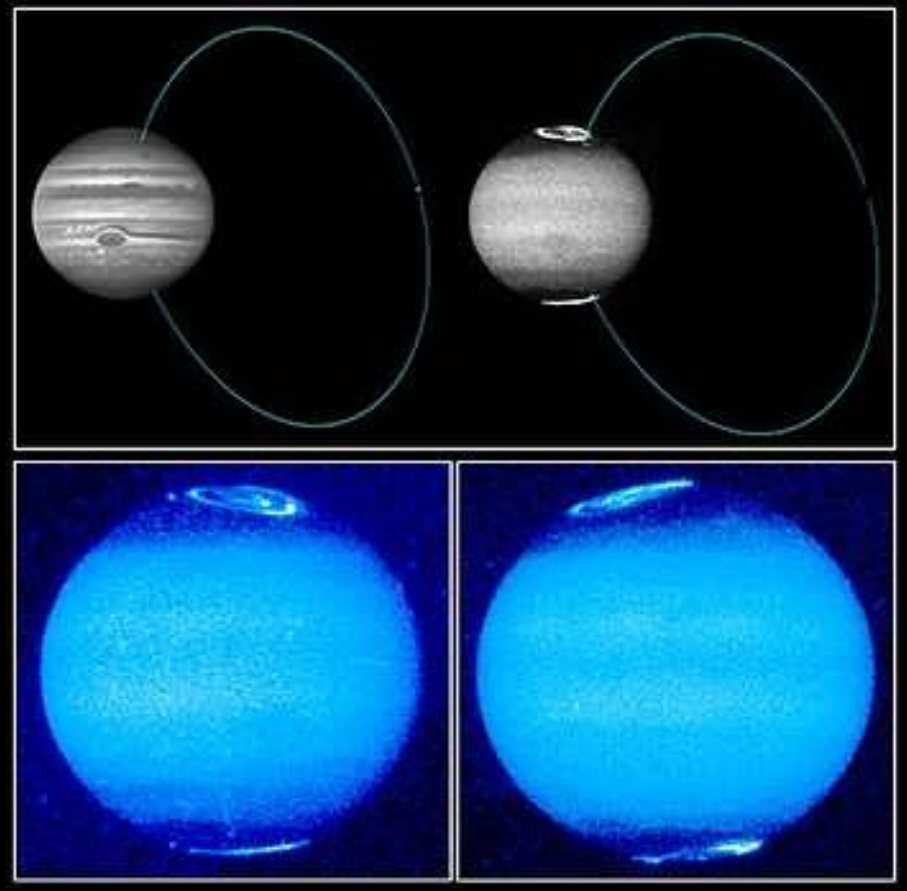


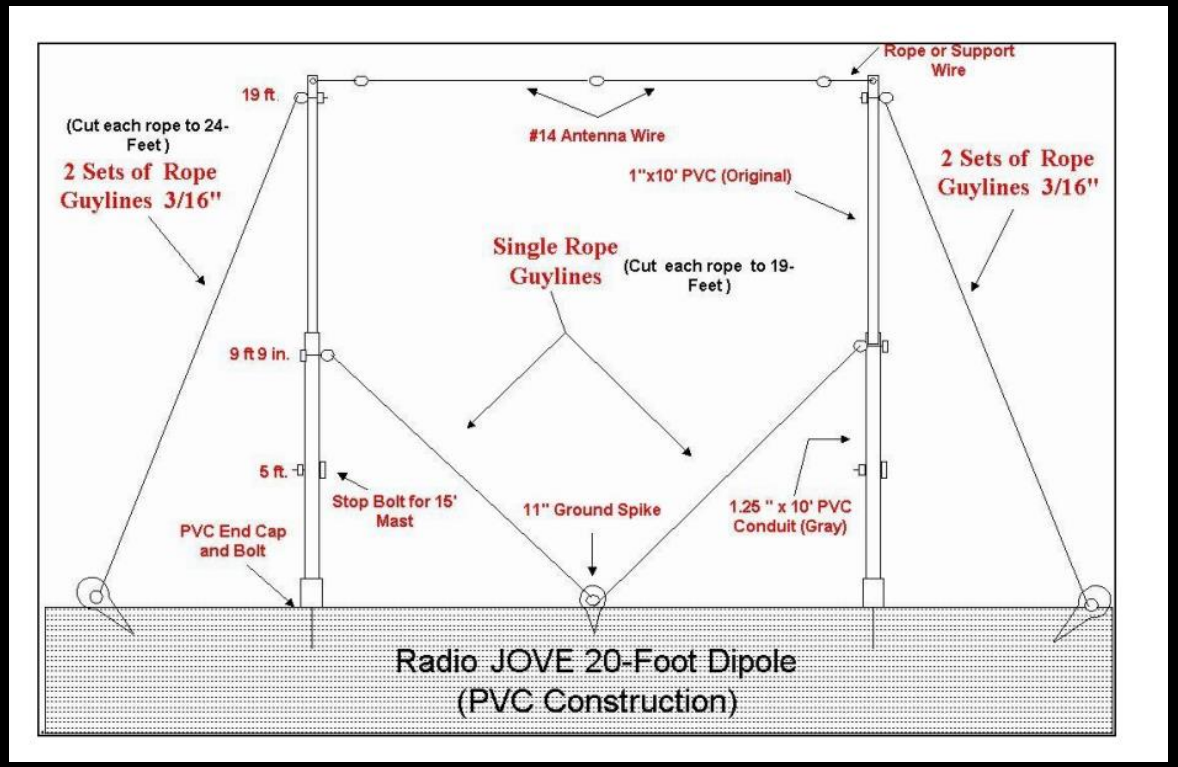
Diagram depicting the current generated between Jupiter and Io [5].

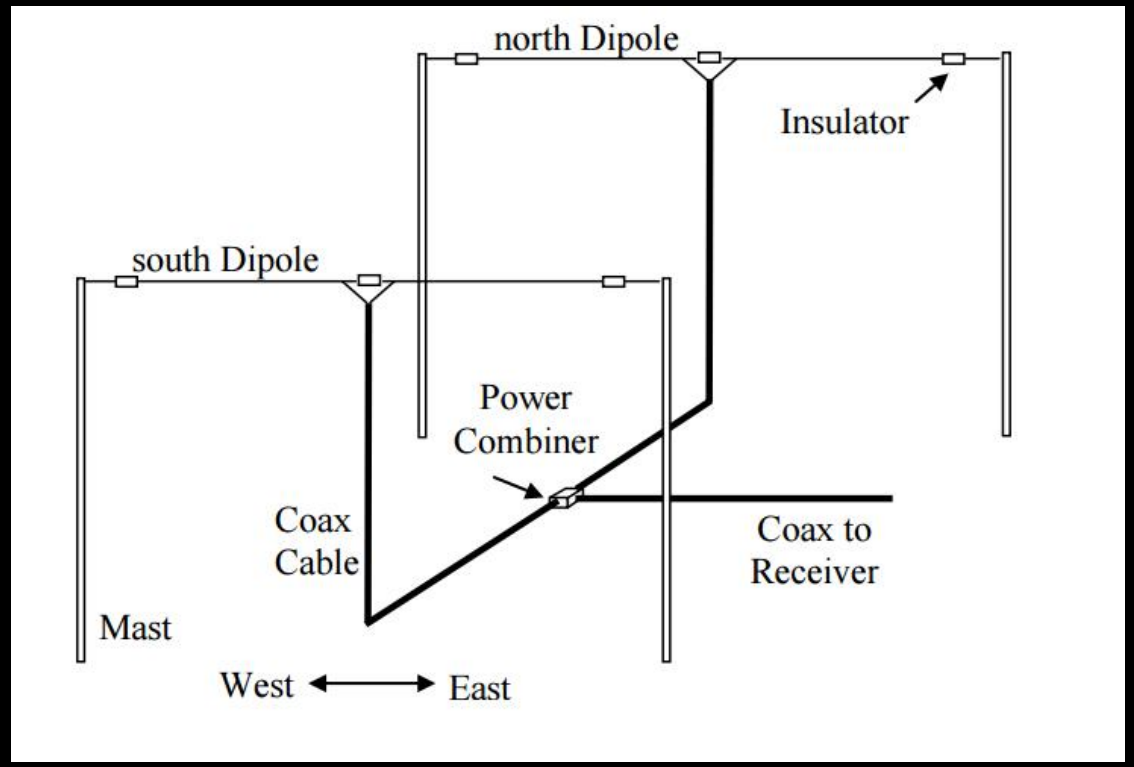


Images taken by Hubble Telescope which show the distortion effect of Jupiter's aurora caused by the current generated by Io [4].

[4] http://hubblesite.org/newscenter/archive/releases/1996/32/image/a/format/web/
[5] https://ase.tufts.edu/cosmos/view_picture.asp?id=1174

How does the telescope work?





Images taken from Radio JOVE Antenna Manual

- Each dipole was constructed as shown in left image with approximately 20ft high PVC masts staked in place with nylon rope.
- The antenna consisted of two of these dipoles to form a dual dipole array system (see right image).

How does the telescope work?

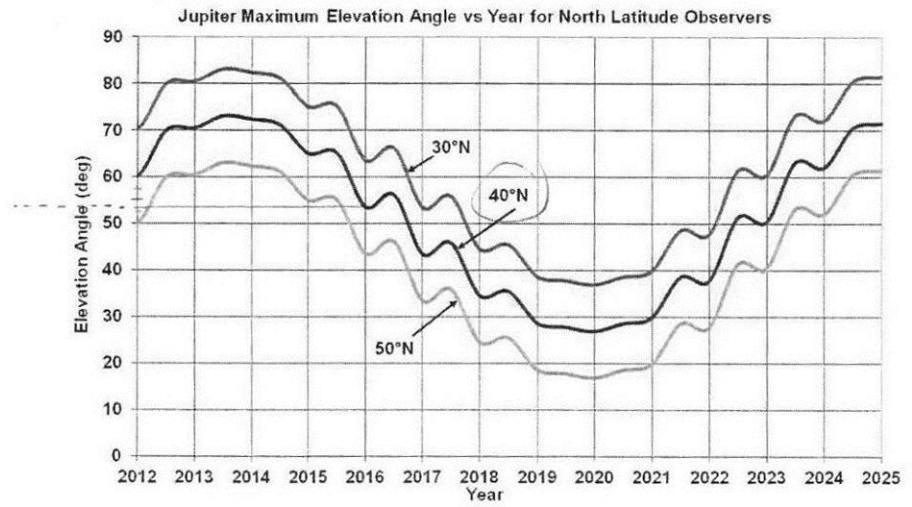
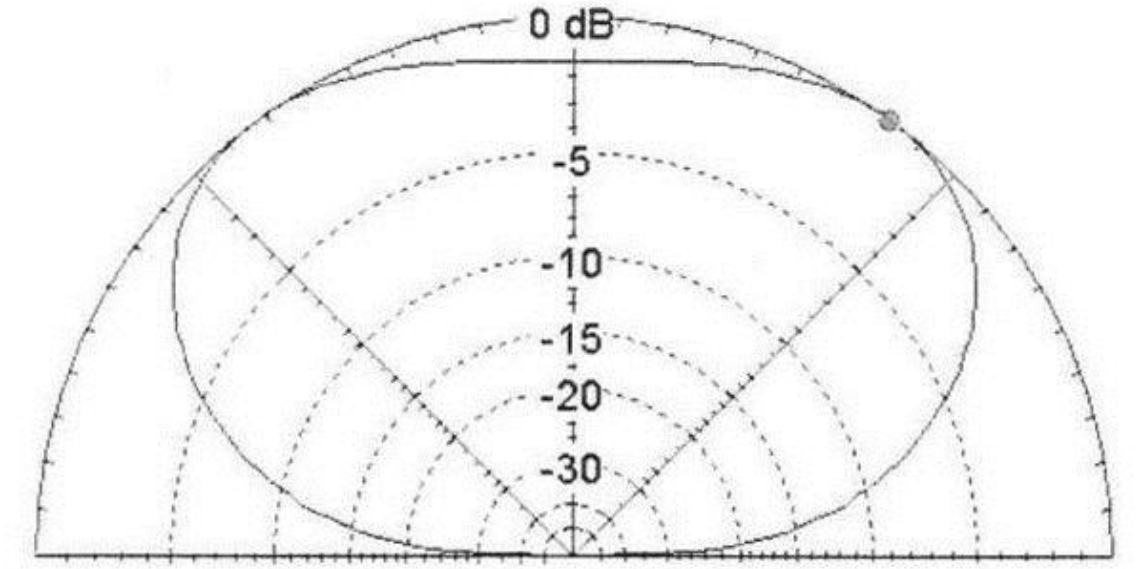


Figure 1.3. In 2013 an observer at 30°N will see Jupiter's elevation peak at 83°, while Jupiter will only reach 63° for an observer at 50°N. Each year is labeled at the January location.



Dual dipole, 20 ft, no phasing, gain = 4.5 dBi at el = 54 deg

Images taken from Radio JOVE Antenna Manual

- An antenna amplifies a signal due to a beaming pattern that is associated with it, i.e. it will amplify signals from certain directions more than others.

- According to the image on the left, to have a beaming pattern best suited to the current elevation of Jupiter (54.5° at the latitude 40°N in Boulder), 20ft high masts are needed (see right image).

How does the telescope work?

- For an incoming radio signal directly overhead (right figure) the wave-fronts will arrive at each diploe at the same time and will therefore be in-phase. The signals are added together by the combiner and so the resulting signal at the receiver is twice as strong.

- Depending on the elevation of Jupiter, the incoming signals may not be directly overhead. In which case a “phasing cable” would have to be installed to compensate for the extra distance travelled by one of the incoming waves.

- For example, incoming emissions could hit the South dipole first and then after travelling a certain distance, hit the North dipole. This means the waves are out of phase.

- In this case, a phasing cable equivalent in the length to the extra distance travelled would have to be installed on the South dipole to make the waves in phase.

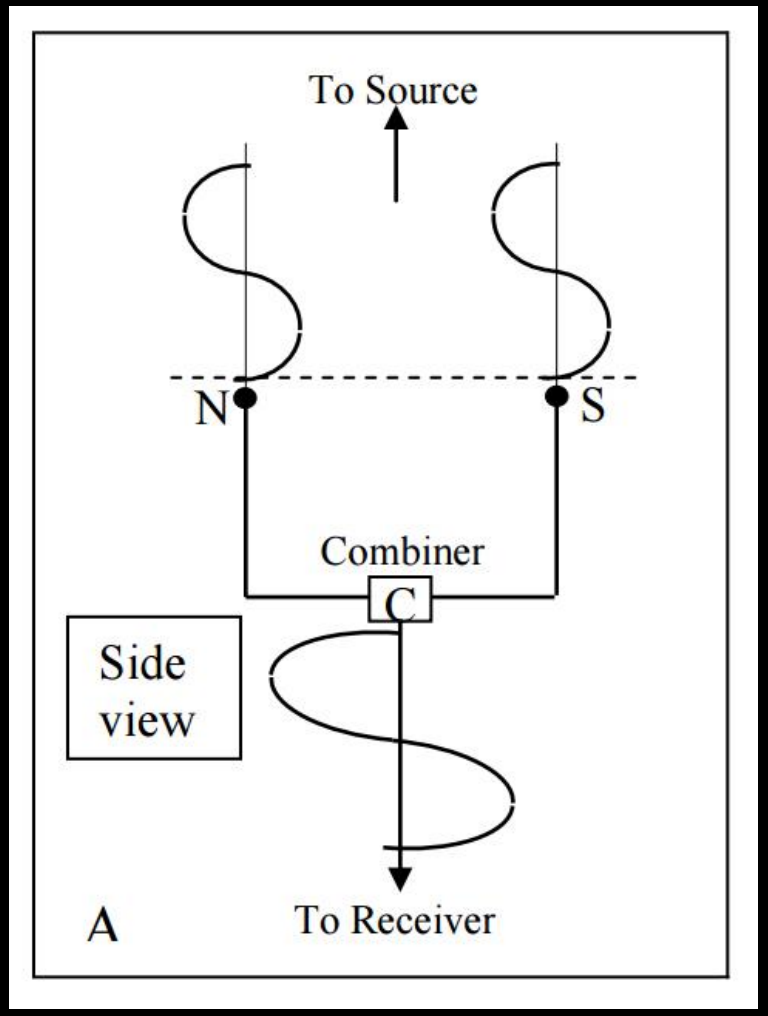
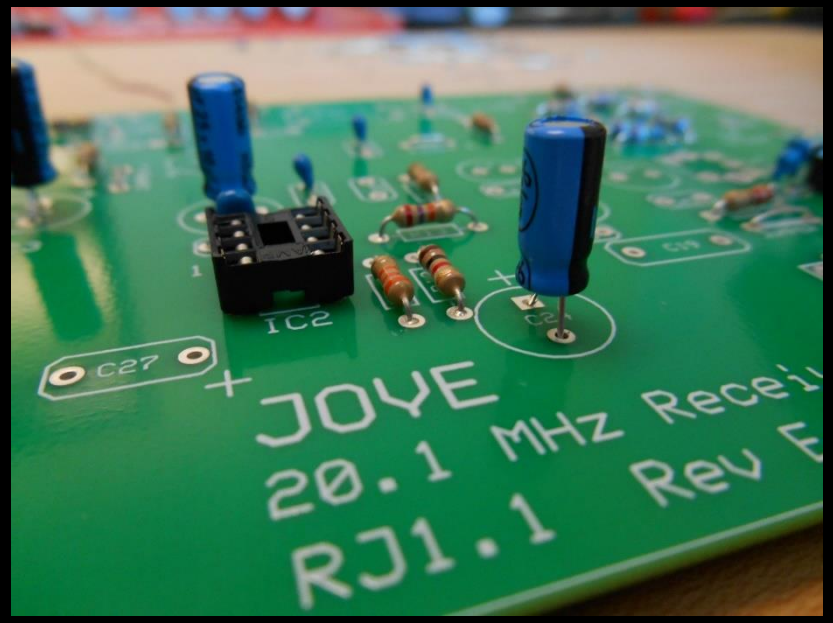
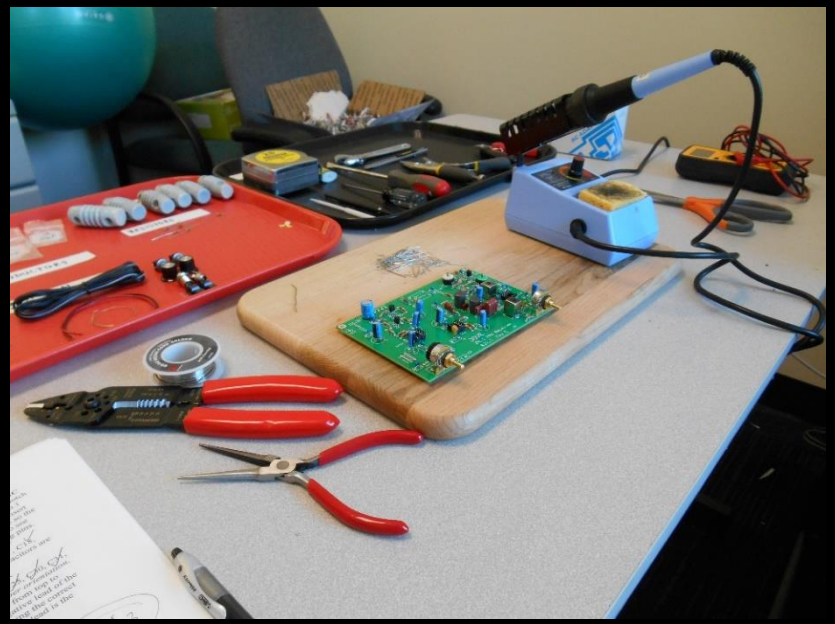
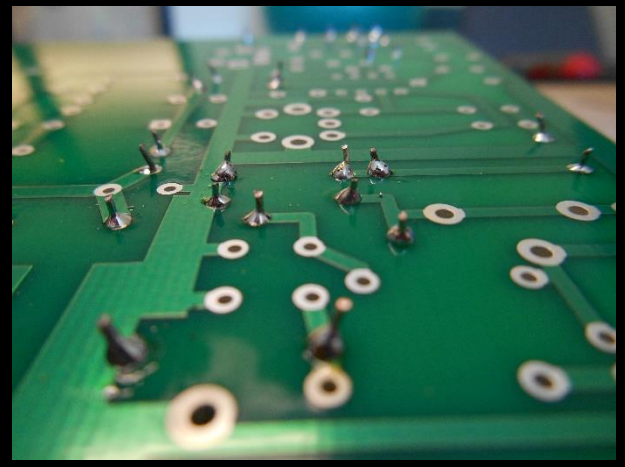


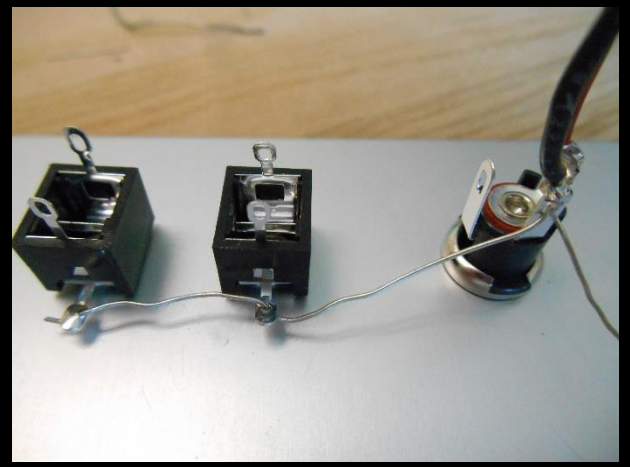
Image taken from Radio JOVE Antenna Manual

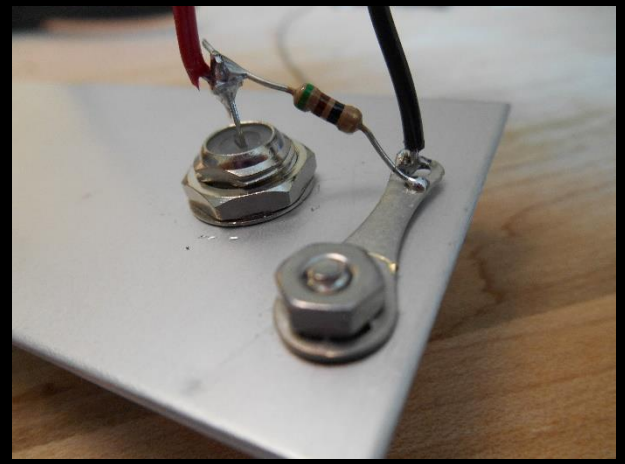
Building Receiver



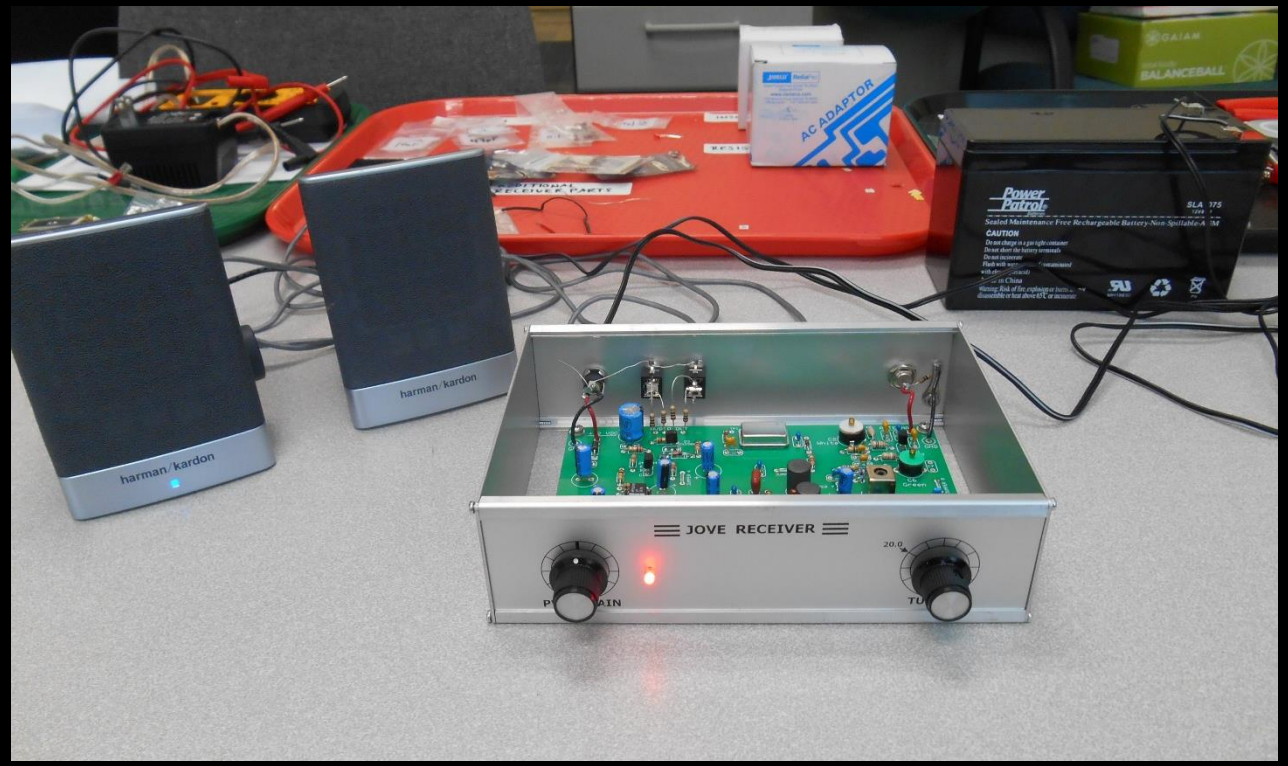




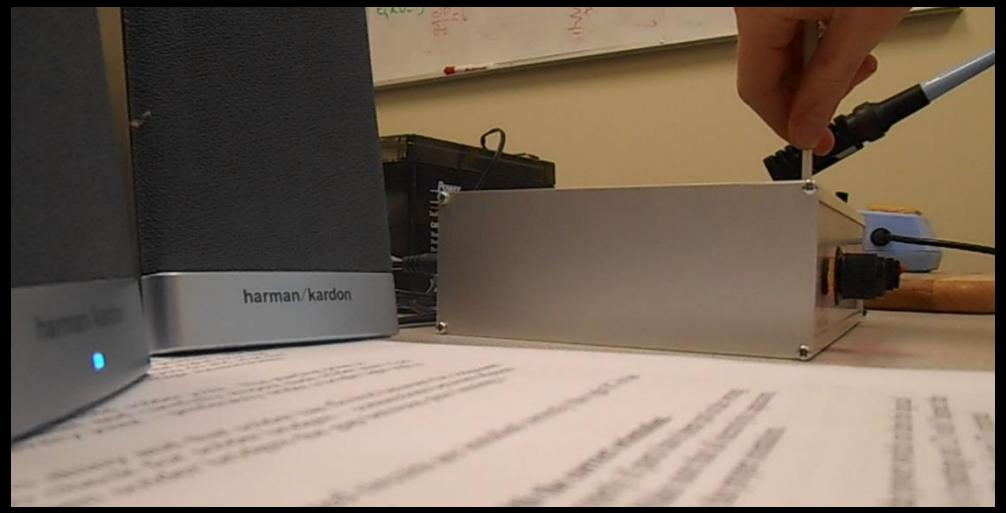




Tuning the Receiver



- Powered by a 12V battery, the receiver was tuned using a ‘tune by ear’ method.
- With the tuning dial set to 20Hz, the inductors L5, L4 and capacitors C2, C6 were adjusted using a plastic tuning stick until the loudest possible tone could be heard through the loud speakers.



How does the receiver work?

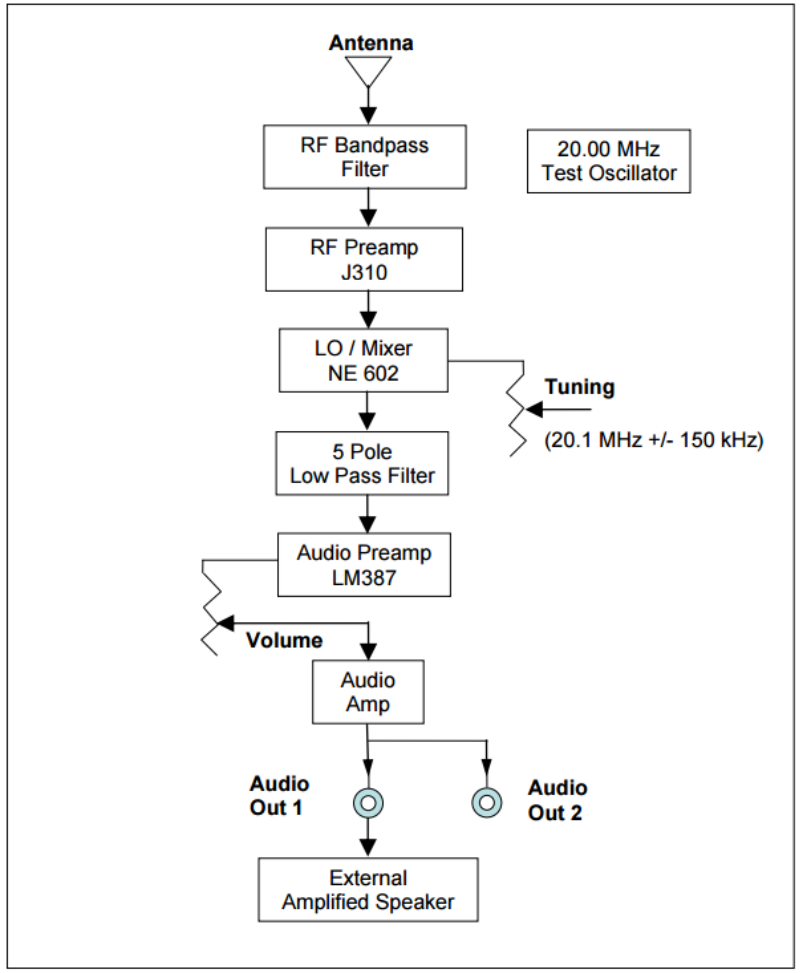


Figure 1. JOVE receiver block diagram

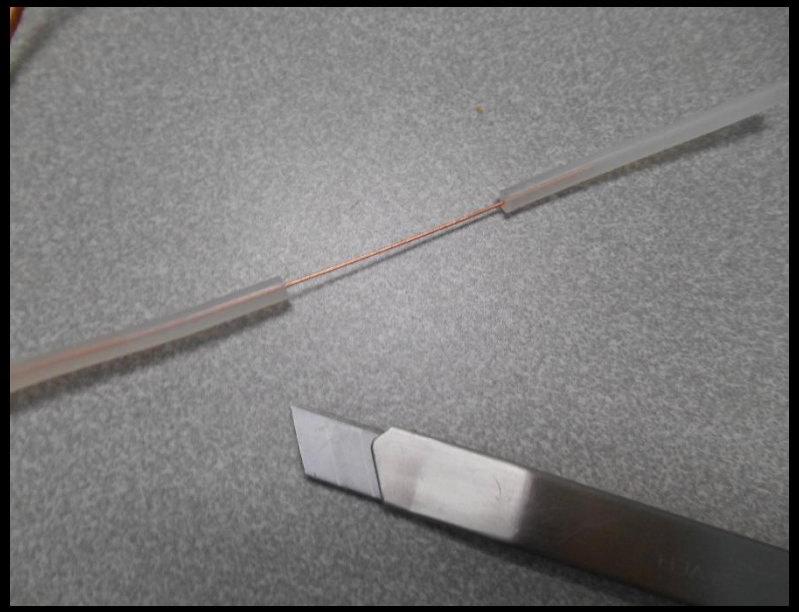
- A radio signal passes from the antenna into a bandpass filter. This rejects strong interference and the signal is then amplified by a Junction Field Effect transistor. This provides additional filtering and amplification by a factor of 10.

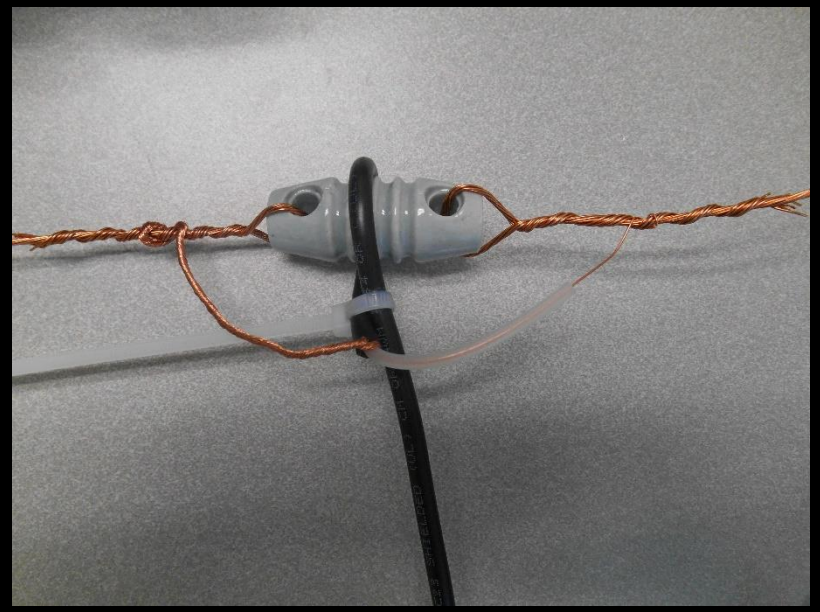
- A local oscillator and mixer then work to convert the desired radio frequency down to a range of audio frequencies. The local oscillator generates a sinusoidal voltage wave form at frequency 20.1 MHz. This signal along with the amplified signal from the antenna feed into the mixer which develops a new signal based on the arithmetic difference between the two.

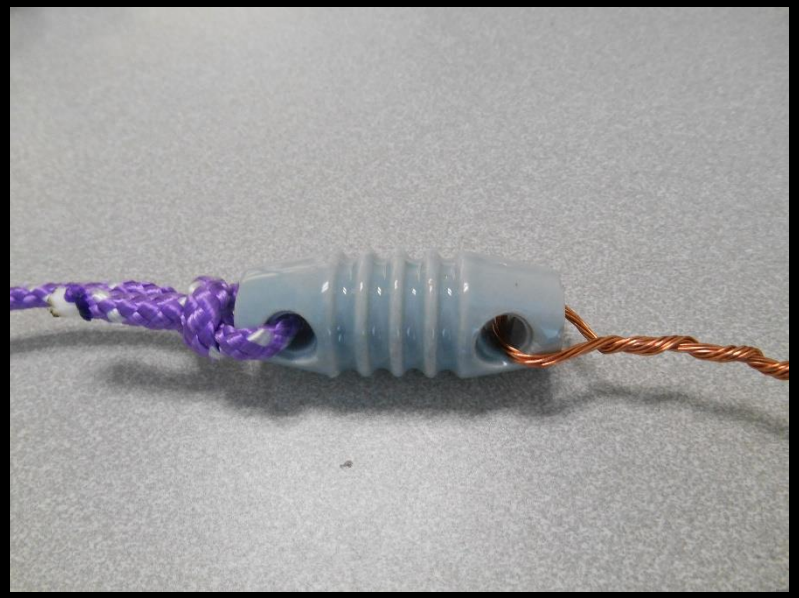
- A low pass filter is then used to eliminate interfering radio stations at nearby frequencies by creating a narrow window that Jupiter emissions can enter. This creates channels that are “clear” for the receiver to be tuned to.

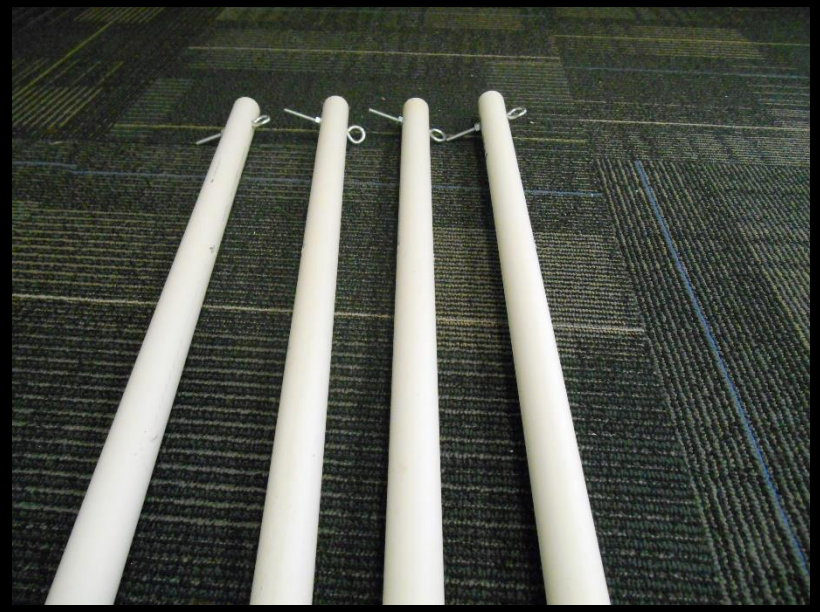
- Lastly, audio amplifiers are used to amplify the final signal enough for it to driver either headphones or speakers directly.

Making the Dipoles









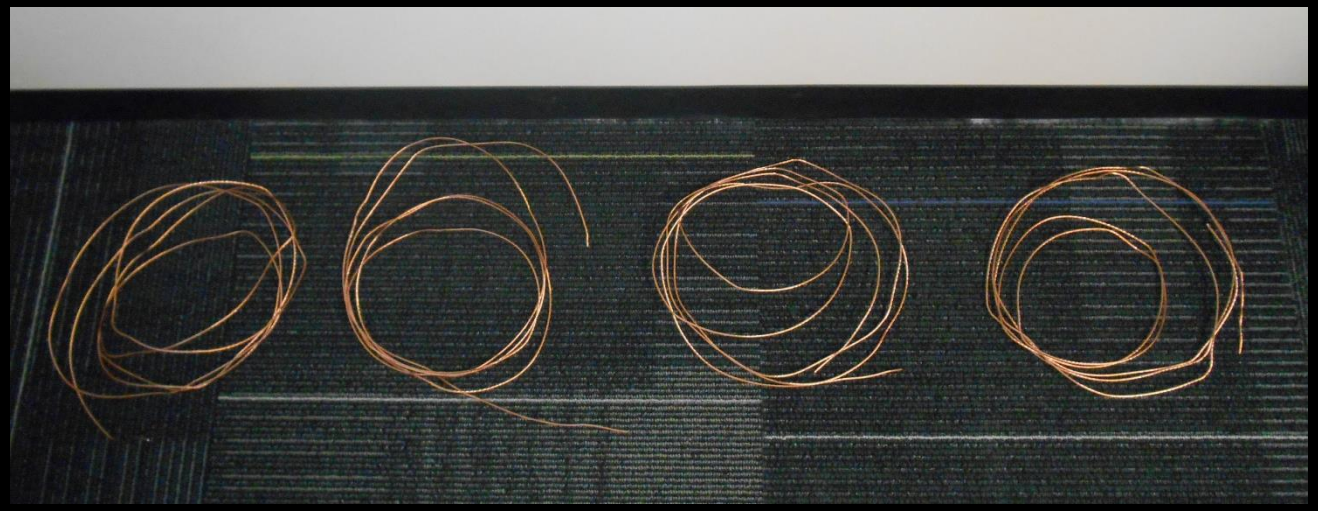
Importance of Dipole Length

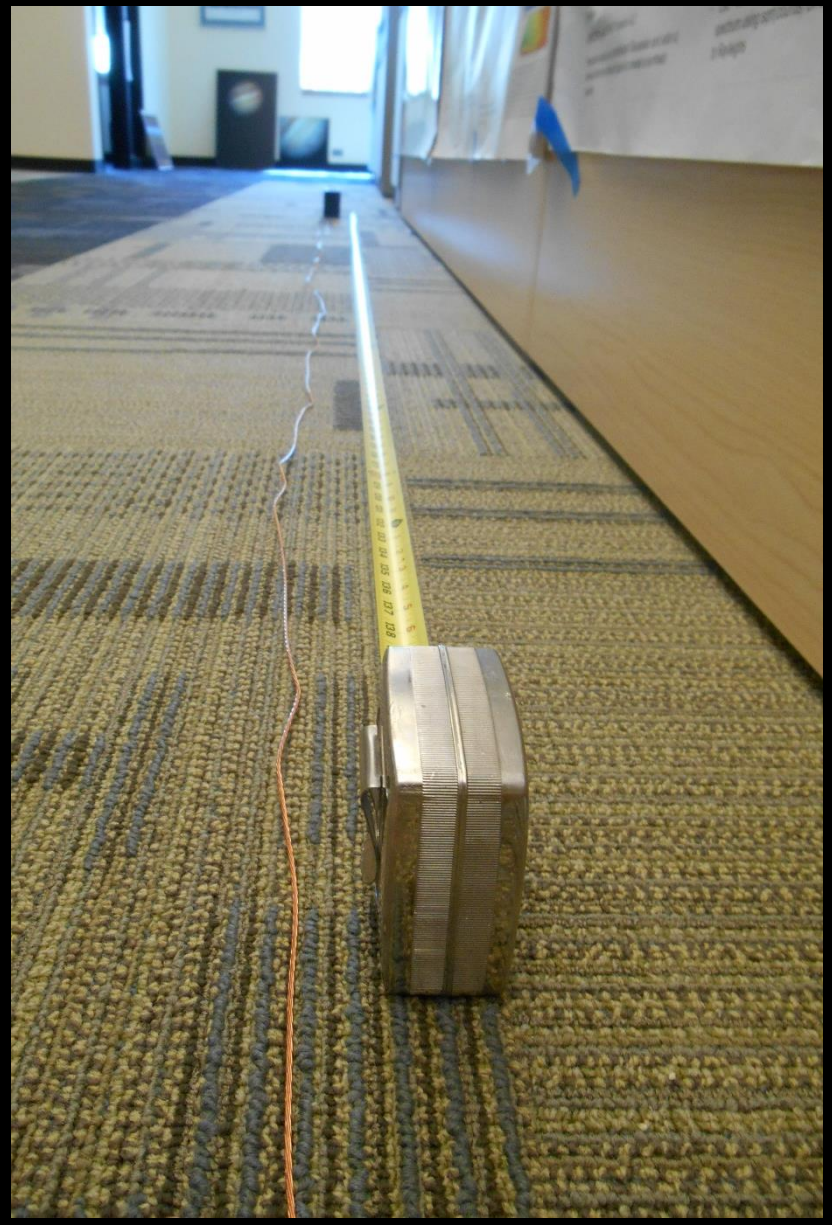
- Each dipole consisted of two 12ft copper wires, three inductors, one 32.31ft RG-59/U coaxial cable and two lengths of nylon rope at 2ft each.

- The length (λ_{cable}) of the coaxial cable was important, as it is related to the operating centre frequency of 20.1MHz of the JOVE receiver. It is derived from:

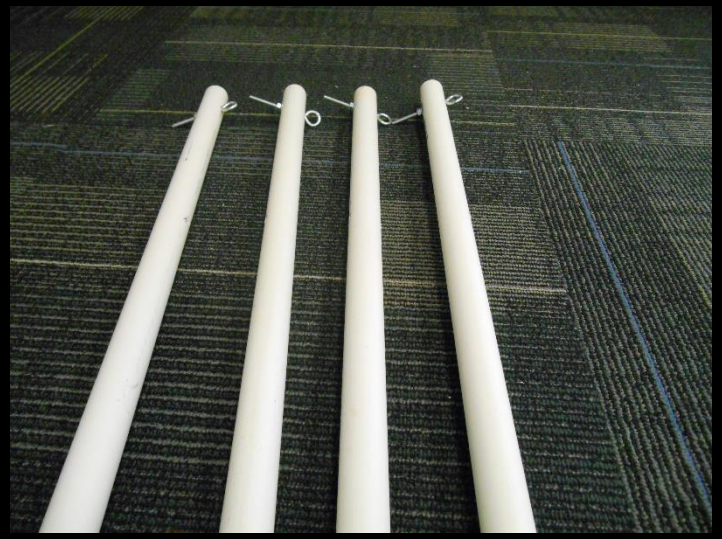
$$\lambda_{cable} = V_f \times \lambda_{free\ space}$$

where V_f is the velocity factor (0.66) of the coaxial cable and $\lambda_{free\ space}$ is 14.925m (speed of light 'c' divided by the centre frequency).





Constructing the Antenna



Constructing the Antenna

Choosing the appropriate site and materials

- The antenna was constructed on a ground area of approx. 30ft N-S and 45ft E-W and situated as far away as possible from buildings and powerlines to avoid electrical interference.
- PVC was chosen instead of metal to avoid unwanted conduction and was more lightweight.
- The downsides however were that the PVC masts were more prone to bending and distortion.
- The condition of the ground was also important as it needed to be flat and firm enough for the stakes to hold in place.
- In order to be the right orientation to receiver Jupiter emissions, the dipole wires had to run from east to west.

How and When Do We Acquire Data?

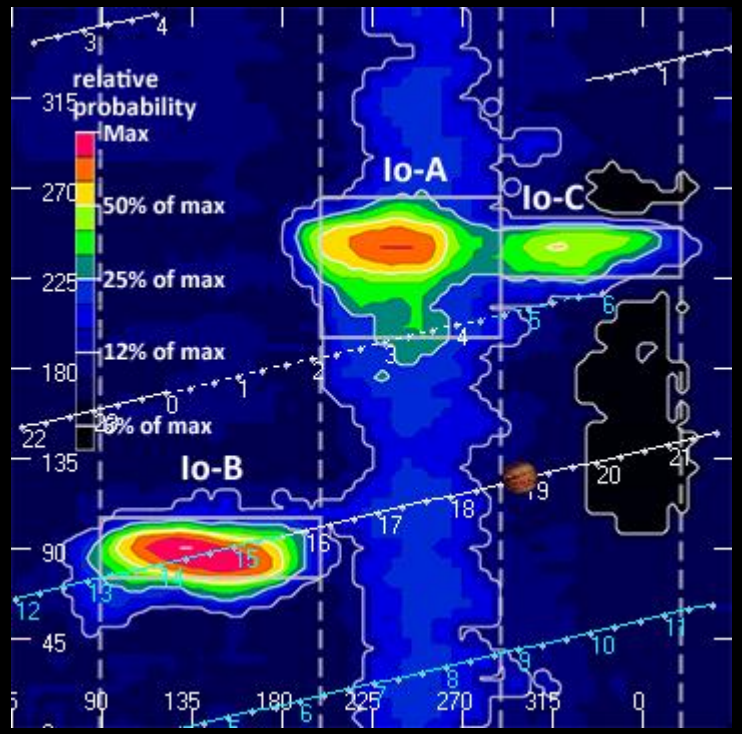
- By inputting information such as observer latitude (40°N in the case of Boulder) into Radio-Jupiter Pro 3 software, Jupiter's radio noise storms can be predicted and yearly visibility charts seen.

- Then by using Radio-SkyPipe II software, graphical and audio data can be recorded

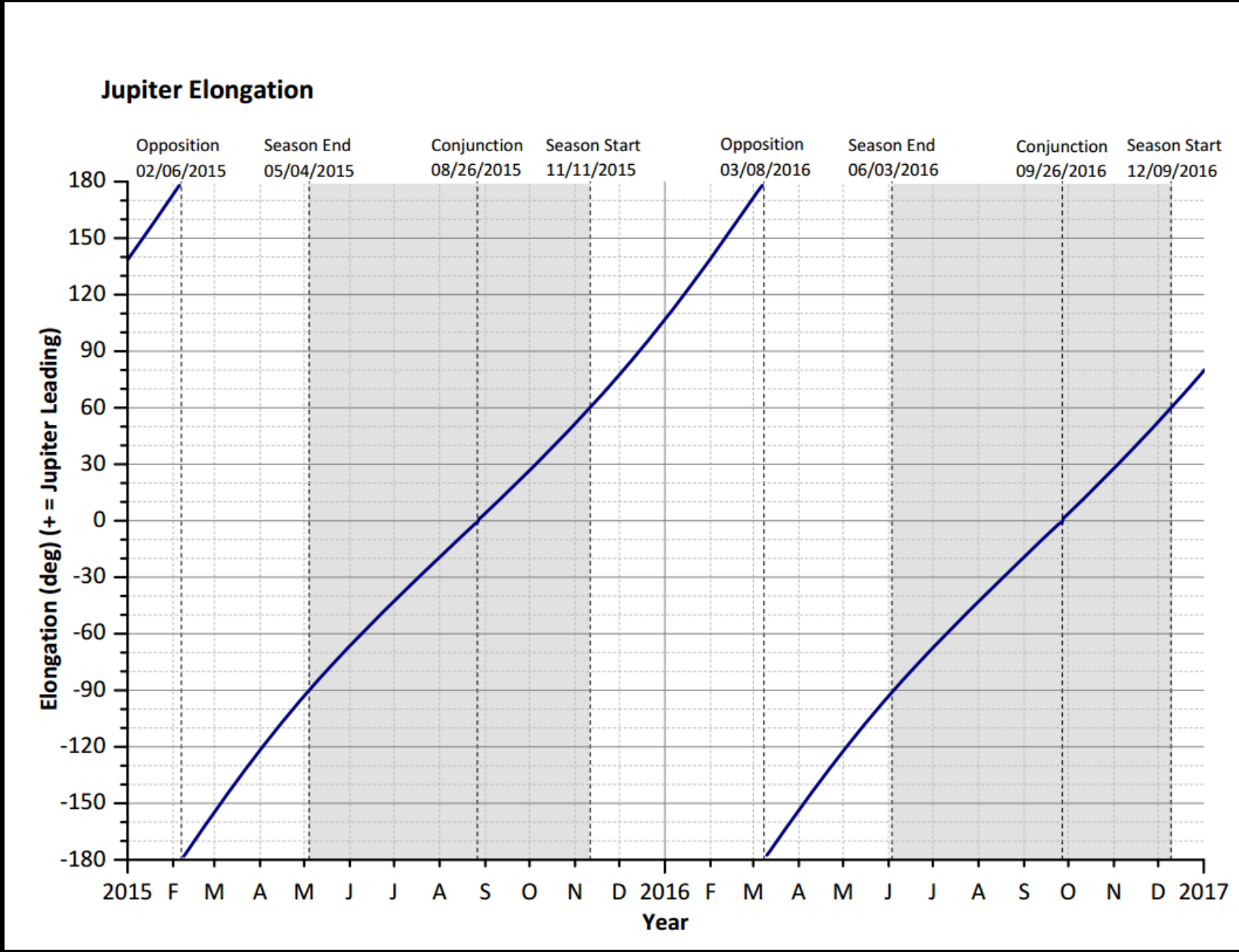
- As the Sun ionises the upper layers of the Earth's atmosphere, this will cause strong interference with the signals from Jupiter. This is because this ionosphere can attenuate and reflect signals away from the antenna. Observations therefore must be done in the evenings and night.

- However, the predicted 'Jupiter Observing Season' (time of year at which Jupiter's noise storms can be received on Earth) ended on June 3rd of this year, meaning that radio emissions will not be able to be observed until the start if the next season, 9th of December 2016 (see graph on next slide).

- The length of this observation season is determined by the geometry of the Earth, Sun and Jupiter itself.



An example of a CML Io-Phase Chart produced by Radio-Jupiter Pro 3.



Graph taken from: http://www.radiojove.org/SUG/Ephem/Jupiter%20Ephemerides%202015-2016.pdf

Expected Results: L-Bursts

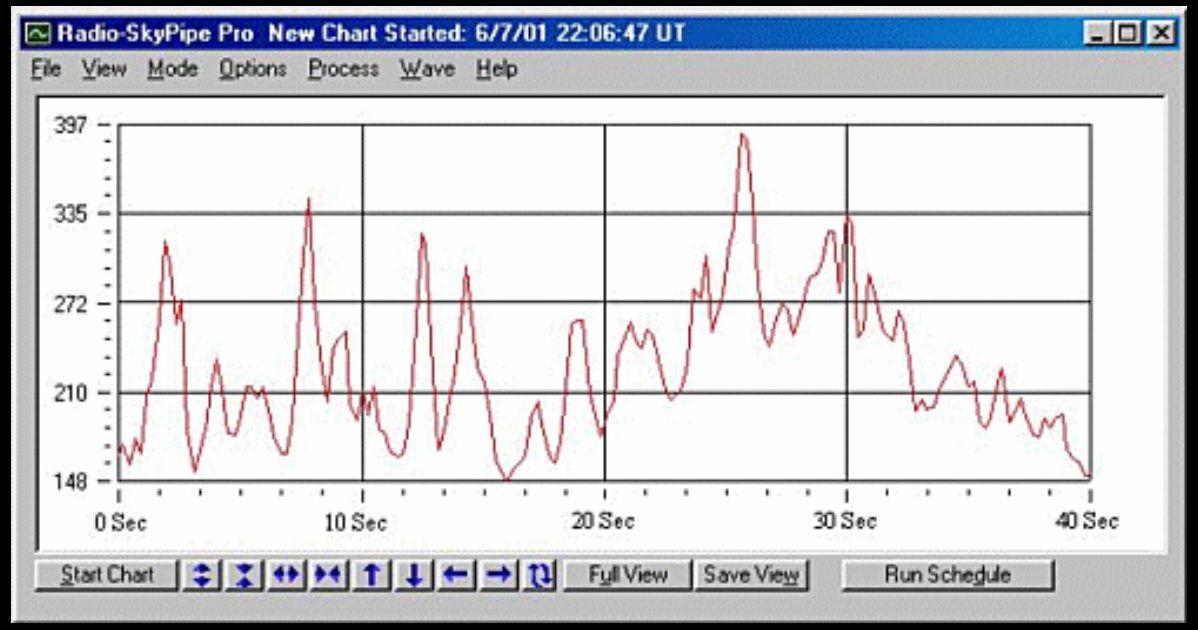


Image and sound sample taken from: http://radiojove.gsfc.nasa.gov/observing/sample_data.htm

Expected Results: S-Bursts

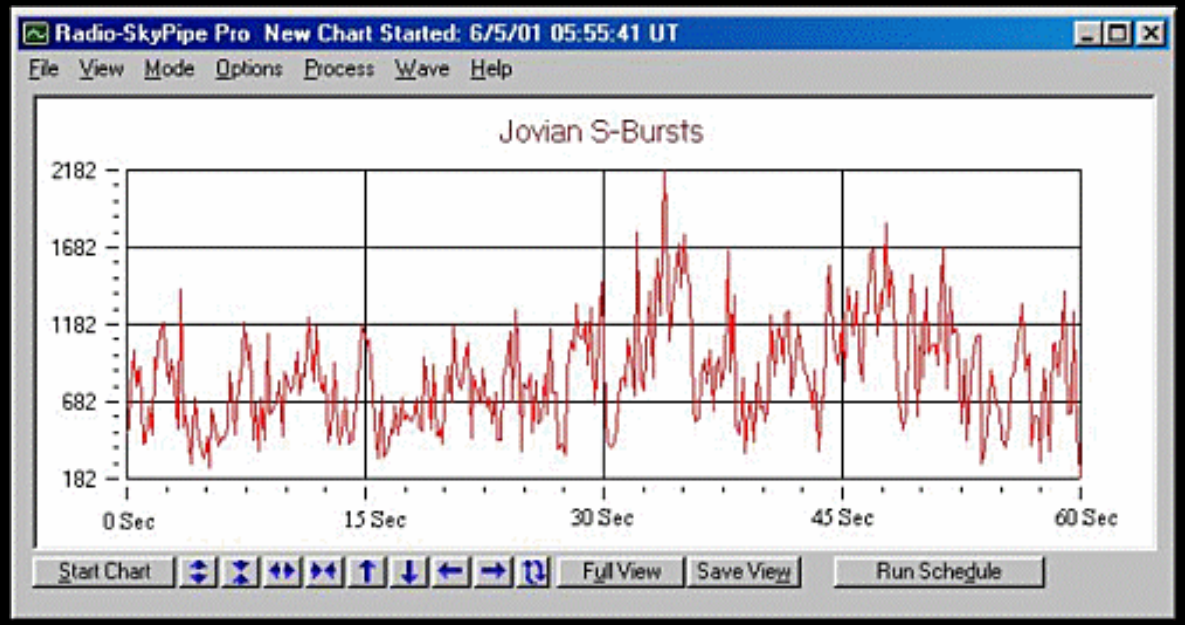


Image and sound sample taken from: http://radiojove.gsfc.nasa.gov/observing/sample_data.htm

Expected Results: Galactic Background

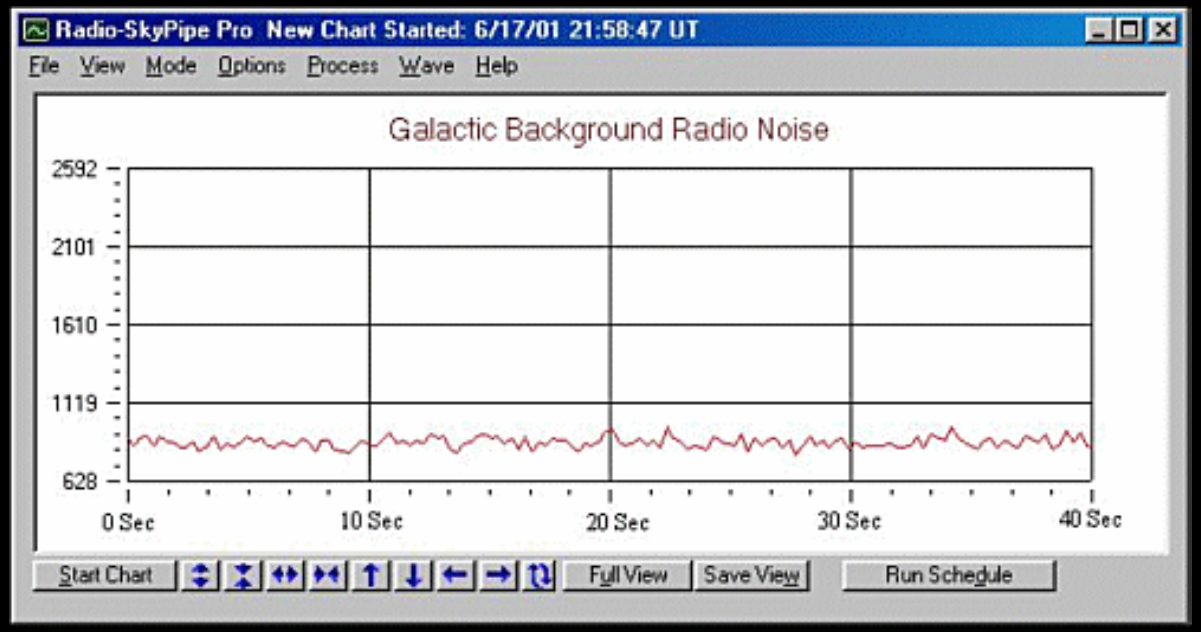
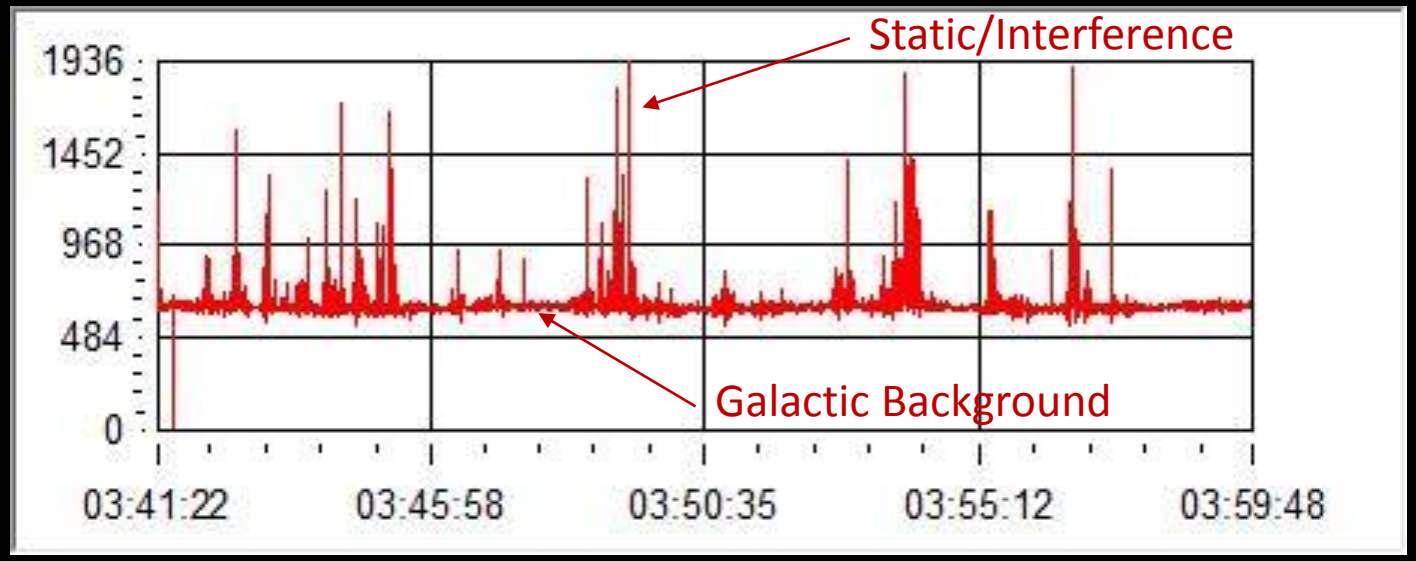


Image and sound sample taken from: http://radiojove.gsfc.nasa.gov/observing/sample_data.htm

Observations Made



Example Radio JOVE output chart showing constant Galactic Background signals (generated by relativistic electrons spiralling in the galactic magnetic field) and peaks indicating static caused by the interference of other radio emissions from other sources. This chart obtained during observations on 07/18/16.

Although no Jupiter emissions could be detected, during observations after sundown, the graphical and audio data recorded showed good signs of detecting the Galactic Background signal as well as other radio signals (such as stations) when the receiver dial was tuned.

Future Work

During Juno's 2 year mission, 37 close approaches are planned to occur. It is likely that the next few Jupiter Observing Seasons will overlap with these close approaches. In this case, it will be of interest to gather data from Radio JOVE at the same time as Juno and compare observations to see if the emission patterns the telescope is receiving is consistent with what Juno sees.

Acknowledgements

This project was funded by the Juno mission grant. Help with the construction of the telescope was provided by the researchers, graduates, undergraduates and associates of the LASP Magnetospheres of the Outer Planets Group listed below: Evan Sidrow, Kaleb Bodisch, Logan Dougherty, Eddie Nerney, Frederick Thaye, Drake and Emily Ranquist, David Malaspina and Vaughn Hoxie.

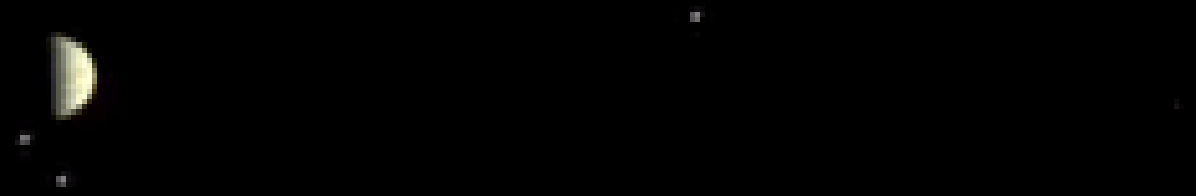
The Radio Jove 1.1 Radio Telescope Kit was sold and distributed by the Radio JOVE Project Inc. and used in conjunction with Radio-SkyPipe II software and Radio-Jupiter Pro 3 software.

More details and photos on the construction process at LASP can be found at:

http://lasp.colorado.edu/home/mop/missions/juno/radio-jove-at-lasp/radio-jove-blog/

JUNO

Questions?



Gif Source: https://www.youtube.com/watch?v=XpsQimYhNkA