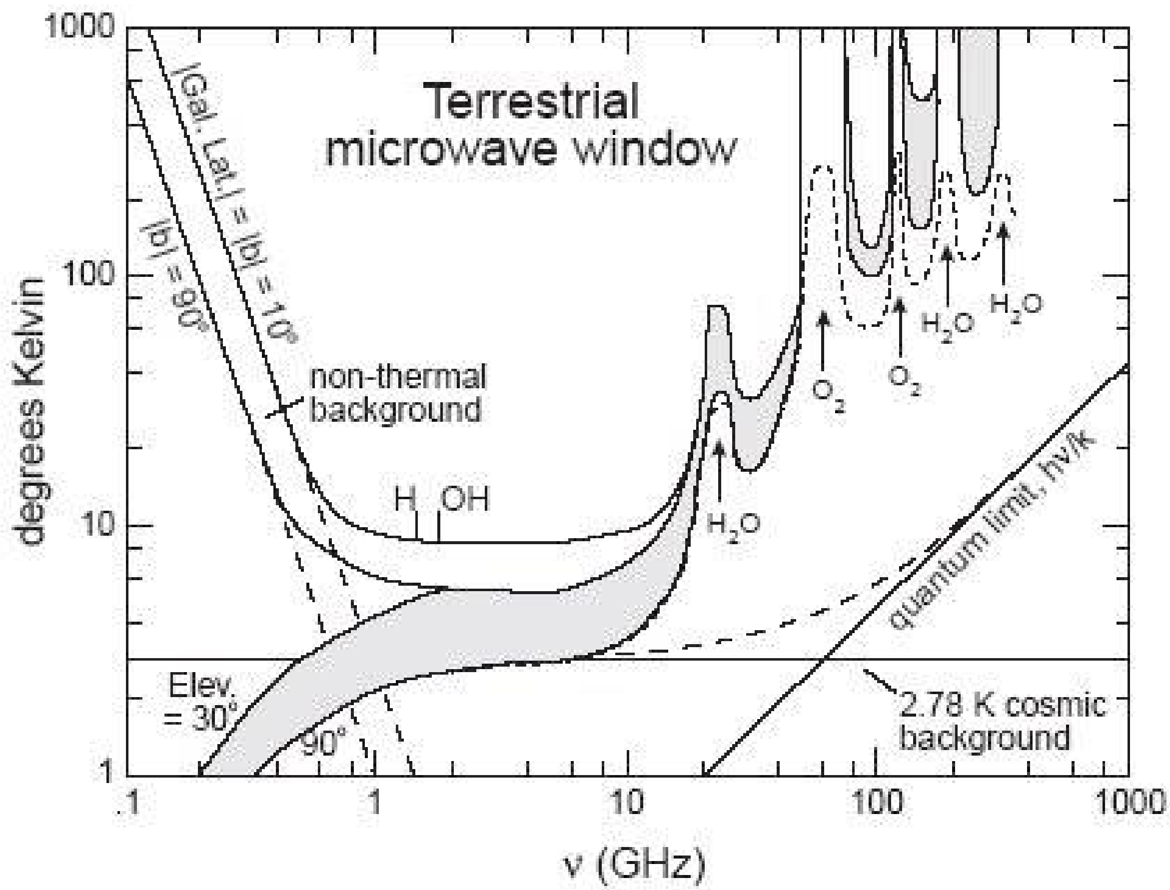
Justification for the use of Radio Frequencies in SETI

Our local environment is largely transparent to radio signals (in the range of frequencies above that of optical frequencies), especially in the 1-10 GHz range.
The plot below shows the level of noise (in Kelvins) in the environment. Also shown is the noise level given the elevation of the telescope relative to the horizon as well as relative to the galactic equator (quick way to find the galactic equator – look along the Milky Way).
Which is why radio telescopes and antennae are used in SETI.

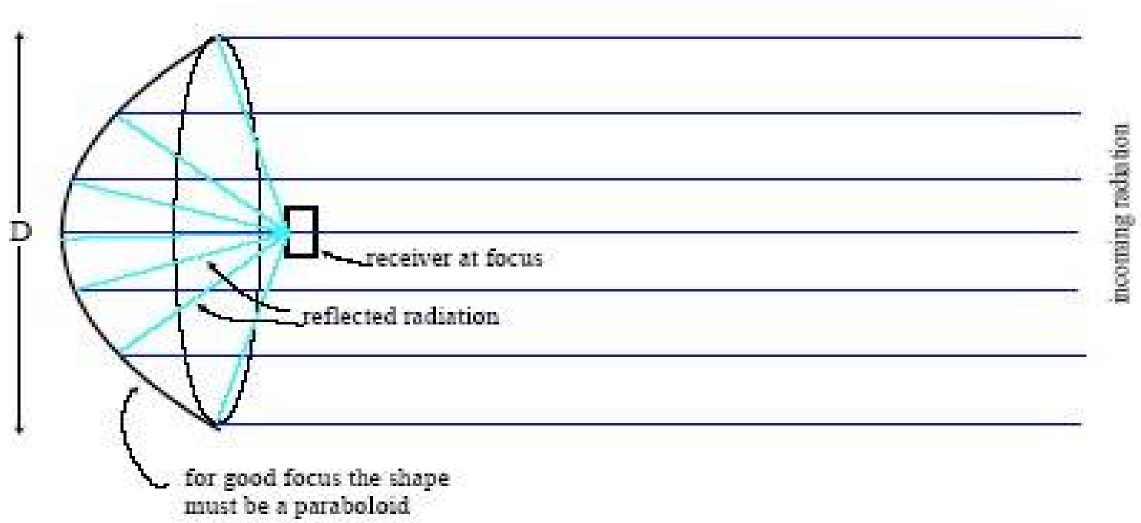


Furthermore, radio telescopes can do the following

- Measure the radiation from a specific direction of sky.
- Measure how the intensity varies with direction, thus making a map of an extended part of the sky
- Measure intensity as a function of frequency – getting a spectrum.
- Measure the polarization of light waves – magnetic fields in the source or intervening medium or artificiality (?) of source.

Observations with Radio Telescopes

A typical radio telescope is a paraboloid dish – similar to paraboloid lenses in



optical telescopes.

The collecting area of your dish (receiver) is proportional to D^2.

Typical radio telescopes for astronomical use are these types of paraboloid dishes ~ 100 meters in diameter. Thus, the angular resolution of these telescopes at 1 GHz (or 0.3 m wavelength radio)

$$\theta = \frac{0.3}{100} = 0.003 \text{ radians } = 10.3'.$$

The size of the moon is approximately 30' (30 arc-minutes), so compared to our eyes the single resolution of a big telescope is not that good.

These radio telescopes would need to be a paraboloid to an accuracy such that any bumps << λ. Otherwise the angular resolution is reduced even further due to the fact that all the radiation is not centered on the focus.

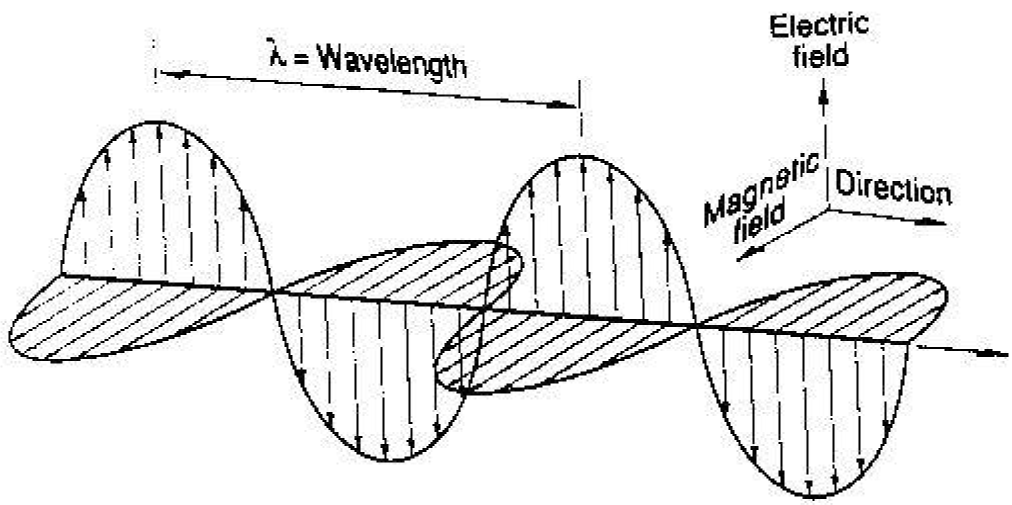
Since the angular resolution is so bad, radio telescopes need to raster across the sky in order to get an image.

Polarization and Some Features of Light Waves

Light is a medium that travels in the vacuum of space at "the speed of light" $c = 3\times10^8$ m/s. The frequency ν and wavelength λ are related by $c = \lambda\nu$.

Light travels at speeds less than c through any materials. This velocity $v = c/n$, where n is the index of refraction.

Light is a manifestation of an electromagnetic theory – the theory of charged particles, both static and moving. It consists of an electric and magnetic fields:



If we look in the direction of the light beam at a specific location, the electric (or magnetic) field – but almost always electric – traces out a pattern in time.

- If it traces out a **line** – *linearly polarized.*
- If it traces out a **circle** – circularly polarized.

All light consists of particles with circular polarization – either left-handed or right-handed – that can then be combined into linear, elliptical, or random polarizations.

Other Issues that are Important for Radio Frequencies

Radio waves are relatively low frequency to what we observe. Furthermore, although space is largely a vacuum, it consists of *free charged particles* (esp. electrons), *magnetic fields*, and some turbulence. Although these effects are not that important for optical SETI, they do play an important role in the radio.

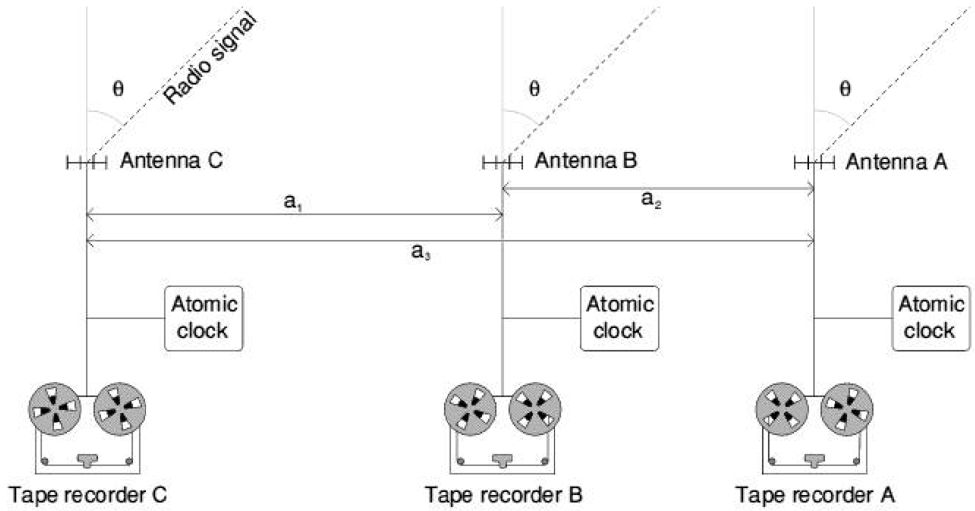
- Space consists of free charged particles – electrons play the most important role. What other material consists of large quantities of free (as in not bound to atoms) – a **METAL**. Space, like a metal, will distort those waves traveling through it – this is especially important in waves of a few GHz or smaller.

- Space also consists of charged particles embedded in a magnetic field. Waves undergo **Faraday rotation** – the polarization of the light waves will change direction as they pass through charged particles in a magnetic field.

- **Scintillation** – like the twinkling of stars in our atmosphere, space also has large-scale turbulence. These are changes in density on the scale of a few AU in size, resulting in "twinkling" of a few minutes to hours.

Arrays

To get resolutions on the order of 1'' or much better (which is possible), one can use arrays of telescopes and **interfere** (combine the signals).



To get comparable resolutions of the human eye, approximately 0.1'' at 1 GHz (0.3 m) radio, one would need a single dish of size:

$$D = \frac{\lambda}{\theta} = \frac{0.3}{\pi/180/36000} = 618 \text{ km}.$$

However, one can get the same resolution if one has a **baseline** (separation between individual radio telescopes) of this distance.

The total collecting area of this telescope becomes, however only the total collecting area of the individual telescopes.

Furthermore, the distance to each telescope must be known to an accuracy $<<\lambda$ -- otherwise, the "focus" in getting a signal is degraded. This is done in one of two ways.

- Through laser, electrical, or other direct physical connections between the radio dishes in the array. The VLA (Very Large Array), operated by NRAO out of New Mexico, uses this.
- Calibration by atomic clocks and tape recorders of the signal received from each source. This is how VLBI (Very long baseline interferometry) operates – uses the entire earth (12000 km diameter) as baseline, getting resolutions of 10^{-6} arc-seconds in the radio.

SETI is not limited by angular resolution – just getting a signal would be "good enough" for now – but rather by total collecting area.

Close-up view of the Very Large Array (VLA) in New Mexico.

Map of the locations of telescopes of the VLBA (very long baseline array), an example of VLBI.

Typical candidate SETI signal – What are we looking for?

We are generally looking for a "bright" (can be observed) narrow-bandwidth (1 Hz) signal from somewhere outside of the confines of Earth. A good way to do this is to point to somewhere in the sky, and see if the signal has a 24-hour period.

Should be unambiguously above the signal. A typical value is about 7.55 times the background (noise) level.

Should remain above background for a few minutes or longer after receiving the signal – the SETI institute has a criterion of signal to be 300 seconds above the background in order to be considered.

The multiple confirmation of signals from many sites around the world is not effective or particularly accurate (as was shown in the movie *Contact*) – it would most certainly be hidden in the reams of "data." We do not have the computing power to analyze the data received by various SETI detectors in the world currently operating in real time, nor do we really know what part of the spectrum an alien intelligence would use.

Currently, there are several correlated searches of signals going on currently, and there have been several (such as OZMA) in a few decades ago.