SETI below 1 Ghz

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ABSTRACT: The choice of frequencies for SETI other than the water-hole is discussed, with an emphasis on the frequencies below the 21cm band. Consideration is given to range, beamwidth, Doppler, natural and man-made noise, propagation in the atmosphere, scintillation and receiving equipment. A short note on transmit-side frequency choice is also given.

Keywords: SETI frequency choice, UHF SETI, 70cm band

1. Introduction

Since the first ever published paper on radio SETI, there has been a consensus that the best frequencies to look at are around the 21cm hydrogen line. Besides being a kind of natural 'magic' frequency, it also lies in a band where natural radio noise is low and the Earth atmosphere is transparent. Moreover, this band is reserved for radio astronomy by international agreements, and should be protected from man-made interference.

The 'magic frequency' argument is valid only for signals that have been transmitted with the explicit purpose of signaling to an unknown receiver. The situation is different if one looks for 'leaks' from things like asteroid or interstellar radars. In this case, the little green engineers will choose their frequency based on a totally different set of design trade offs, maybe even intentionally avoiding 21cm for the benefit of their own astronomers.

When deviating from the 'water hole', where should one go? Up or down? A popular movie proposes PI (3.1415....) times the H frequency. I suggest that maybe it would be better to go in the opposite direction, toward lower frequencies, for example H divided by PI.

2. Range and beamwidth

For a non-targeted general search, the detection probability is among other things proportional to the instantaneous search volume. This volume is proportional to the solid angle of the beam and to the third power of the range.

With the same size antenna and the same sensitivity receiver, the range will be the same, but the solid angle will increase with the square of the wavelength. For a PI times lower frequency, that means almost ten times the detection probability.

On a drift-scan system the broader beam also means a longer transit time, proportional to the wavelength. This longer transit time can be used for more signal integration giving better sensitivity, or to scan more frequencies.

A less economical alternative is to increase the size of the antenna according to the wavelength for constant gain/beamwith. In this case, the range is proportional to the wavelength, and PI times longer waves bring you 31 times the volume/probability.

3. Doppler

Doppler is proportional to the frequency. Lower frequency means less Doppler, allowing narrower channels with easier de-chirping and/or longer post-detection integration for better sensitivity.

4. Natural noise

Most natural noise sources increase in intensity with wavelength. However, on 452MHz most of the sky is still reasonably 'cold', the average is around 35K. Outside the galactic plane (most of the sky) the temperature is about 20K, and the galactic plane is 60..100K. There are a few point sources, Sagittarius will give you 400K and Cassiopeia 200K in a 5 degree beam (7m dish), or 200 and 100K respectively in a 7 degree beam (5m dish).

For a drift-scan system, the average sky noise temperature will be about 20K higher on 452 than 1420MHz. Comparing this to the 50..100K of receiver noise plus ground pickup, the decrease of sensitivity will be 1.5 dB or so on average. This can be easily compensated by slightly narrower channels/longer integration or a 20% increase in the diameter of the antenna. Below about 200MHz, the sky will generally be above 100K, so this is probably a practical lower limit for SETI. However, this is not to say that one should under no circumstances attempt any SETI below 200 MHz.

5. Man-made interference

This is the worst enemy of UHF SETI. 'Wireless' is the rage, and the UHF band is extremely popular as a good compromise still offering some 'around the corner' propagation while keeping the antenna sizes compatible with portable equipment. Besides wireless car keys, doorbells, CD headphones and similar fashion accesoires, whose frequencies are at least somewhat regulated, personal computer noise and cable TV leakage are the biggest broadband jammers. UHF TV broadcast probably makes frequencies between 0.5 and 1 GHz useless in any populated area. Below that, there are analog cellular phone nets in some countries.

Some interference can be rejected because it lacks the Doppler signature of an extraterrestrial signal. Another thing one can do, at least against intermittent interference, is a dual-channel receiver with an additional omni antenna, and software which rejects any signal appearing in both channels at once.

6. The neutral atmosphere

The effects of the neutral atmosphere are not significantly dependent on frequency below about 20GHz, so there's no difference between 452 and 1420MHz in this respect.

For signals coming in with at least a 10 degree elevation, the neutral atmosphere is negligible. One should avoid low elevations because of ground noise pickup anyway.

An occasional tropo duct might bring in some remote terrestrial interference that is otherwise beyond range, but these don't happen very often.

7. The ionosphere

Around 400MHz, the ionosphere is transparent, the loss is less than 0.01 dB. The only significant effect is the Faraday rotation. It can rotate the plane of a linear polarized wave by more than one full turn at 400MHz. Since the polarization of the ETI signal is unknown in advance, this is irrelevant for the first detection.

Strong Es or aurora might cause some modulation and spread the signal in frequency a few tenths of a Hz, but these phenomena don't happen very often either.

Depending on time of day, time of year and solar activity, the ionosphere becomes opaque for radio waves somewhere between 10 and 50 MHz, setting an absolute lower frequency limit on what can be received from the Earth surface. At these frequencies, the natural sky noise is already in the (tens of) thousands of kelvins.

8. Interstellar scintillation

Scintillation time is a little more than proportional to the frequency (power of 1.2). This means that the minimum usable receiver bandwidth is about four times bigger on a PI times lower frequency. But the time scale is still long enough, at least tens of seconds up to many minutes, that this does not present a problem with the current practical bandwidths of 1..10Hz.

On the other hand, the shorter scintillation time combined with the longer transit time means a higher probability that a signal will be caught on the peak of its scintillation envelope.

9. Receivers

In general, receivers for lower frequencies are simpler and cheaper. One exception here is the low-noise preamplifier. The impedance of available GaAs FETs and HEMT's tends toward the outer edge of the Smith charts as one goes down with frequency. This requires a high impedance transformation ratio that is hard to achieve in a low-loss way. It also tends to be very narrow band - but this can be a plus in frequency bands polluted with interference.

10. Antenna alternatives

A lower frequency relaxes the requirements on reflector surface accuracy, allowing a cheaper construction or a bigger antenna for the same money. For a small SETI station working around 450MHz, going for less than 30dB of antenna gain, there are some alternatives to the parabolic reflector as well. Reflectors will work somehow for sizes between 5 and 10 wavelengths, but their performance will be degraded. Especially in terms of gain to metal ratio, a Yagi or helix array might be a better solution. These also offer lower wind resistance and might be aesthetically less intrusive. But they require a complex feeding harness with precisely cut cables and impedance transformers, with many connectors where water can creep in. A Yagi gives the most gain for the metal, but the circular polarization of a helix may be more desirable.

On a lower frequency, the same size array will have less elements, the number decreasing with the square of the wavelength. For an active array, where the price is predominately determined by the number of the elements and not their size, this could be very important.

With a simultaneous multi-beam array, the bigger beamwidth on the lower frequency means one has to synthesize less beams to cover the same patch of the sky, needing less processing power. The need for it decreases with the square of the wavelength.

11. Transmit-side view

Until now I have discussed the choice of frequency only from the receiving point of view. Since it's more or less impossible to reckon on which frequencies the strongest unintentional leaks will happen, only deliberate interstellar beacons will be discussed in this section.

When going for the same EIRP (same range for same receiver) with the same TX power, the antenna gain must be constant. This means a bigger antenna for the lower frequency, proportional to the wavelength. Even with reduced tolerance requirements for the bigger antenna, the more accurate smaller antenna will probably still be cheaper. For an active array, the number of elements will stay the same for the same gain, and the price difference will be smaller.

The same TX power tends to be cheaper on lower frequencies. The expected receiver's preference of lower frequencies might also bias the transmitting party towards longer waves.

The decision about the transmitting frequency will probably depend on whether one targets a specific solar system, or just wants to set up a general broadcast beacon. In the first case, the higher frequencies will win, like in our terrestrial point to point microwave links. Taken to the extreme, this leads to lasers and optical SETI. In the second case, lower frequencies might be chosen, because power is cheaper there and because of the receiver's point of view benefits.

12. Conclusion

Considering the above arguments, from the receiving point of view, when deviating from the 'magic frequencies', it seems that one should go as low in frequency as the external noise will allow, with the man-made electromagnetic pollution being the major limiting factor.

13. Literature

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