

## ALIENS CAN WATCH 'I LOVE LUCY'

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### ABSTRACT

The earth is at the center of an expanding bubble of electromagnetic radiation. The bubble, expanding at the speed of light, contains all of the man-made electromagnetic transmissions of the earth - radio, TV, radar, and so on. In theory, an alien civilization could receive these signals, and form their opinion about the earth by analyzing them. To most people, it is quite discouraging to think that some alien civilization would form their opinion of earth based upon our situation comedies.

Upon a slightly deeper analysis, the conventional wisdom says: 'Aliens might detect our TV signals, but at least they can't form their opinion of our civilization from our TV transmissions. Decoding the transmission is so much harder than detecting it that we don't need to worry about this.'

In this paper I argue that this view considerably underestimates the technologies that aliens might employ. By looking at likely technical improvements - better receivers and feeds, bigger antenna, signal processing, and perhaps stellar focusing, any civilization that can detect our radiations might well be able to decode it as well. Thus aliens can form their impression of Earth from 'I Love Lucy'.

### INTRODUCTION

In the SETI literature, and the SETI community at large, it is widely thought that even if another civilization detects our TV transmissions, they would not be able to watch the shows. This is a relief to many, since some of the earliest powerful transmissions were television shows that (arguably) do not present a very flattering portrait of humanity. The American situation comedy "I Love Lucy"<sup>1</sup> is almost universally used in this argument, since this show was very early, very popular, and very silly.

The dismissal of the possibility of decoding TV begins with the Cyclops report<sup>2</sup> which in chapter 6 discussed how ETs could glean information from the detected carrier. Not explicitly stated, but clear from the discussion, is that if they could actually watch the show, then they would not need to rely on careful measurements of the carrier to determine the signal was artificial (though they might need this to tell if our civilization is intelligent, since this cannot be easily determined from most TV content.)

Frank Drake, the father of modern SETI, has expressed the same idea in some of his lectures:

They will probably not be able to see the Earth with visible light, but they might, with equipment somewhat

more sensitive than what we possess, be able to pick up our television carrier signals.

The same idea is expressed in the FAQ (Frequently Asked Questions) list for Seti@home<sup>5</sup>, clearly the most popular SETI project yet:

Detection of broadband signals from Earth such as AM radio, FM radio, and television picture and sound would be extremely difficult even at a fraction of a Light-Year distant from the Sun. For example, a TV picture having 5 MHz of bandwidth and 5 MWatts of power could not be detected beyond 0.01 Light-Years of the Sun even with a radio telescope with 100 times the sensitivity of the 305 meter diameter Arecibo telescope.

The SETI league, a group of technically savvy SETI enthusiasts and amateur radio astronomers, has expressed a similar opinion<sup>4</sup>.

Why does TV reception from astronomical distances seem so difficult? It is much, much harder to decode an analog TV signal than to merely detect that it is present. And since even detecting the carrier is hard, then demodulating and watching the show must be nearly impossible. For example, let's look at how well we could do with our radio technology. A powerful UHF TV transmitter in the United States has about 5 MW effective radiated power (typically 170 KW power with an antenna gain of about 30). Most of this power is concentrated in the lowest megahertz, leading to a spectral power density of about 5 W/Hz. The carrier, though, is about 10<sup>6</sup> times stronger in spectral terms. Perhaps 10 percent of the power goes into the carrier, and the bandwidth is about 10<sup>7</sup> times smaller (0.1 Hz). Thus the spectral power density is about 5 MW/Hz. So once you detect the carrier, you need another factor of 1 million more signals to watch the video. Alternatively, the distance at which the carrier can be detected is 1000 times greater than the distance at which the same equipment could decode the video.

How far away could our best technology receive a high power UHF TV signal? A state of the art radio telescope has a noise temperature of about 25 degrees K. The biggest existing telescope is Arecibo, with a diameter of 305 meters. The feed pattern means this area is about 70 percent utilized. Plugging in the numbers, we find that even for a very marginal signal to noise ratio of 1, we can only detect the carrier out to 0.81 light years. We can only watch the program out to a range of 0.00081 light years, or about 51 AU. So our best technology can't even detect

our strongest television signals out to one measly light year, and can only receive our signals out to a little past the orbit of Pluto.

It's easy to imagine that alien radio telescopes are a few orders of magnitude better than earth telescopes. Such telescopes, across interstellar distances, could detect UHF TV carriers but not decode the modulation. Decoding the modulation out to a distance of 1000 light years, for example, would require 12 orders of magnitude better telescopes. This seems impractical even for aliens. However, let's look at the possible improvements. These include better receivers and feeds, bigger antennas, signal processing, and stellar focusing. The combined improvements are quite impressive!

### Better receivers and feeds

These are straightforward improvements we are likely to make ourselves in the next few decades. First, improve the system noise temperature to 3 degrees K (about the best possible because of 2.7 K cosmic microwave background). Next, improve feed efficiency to near 100 percent. The result is a signal to noise improvement of nine for a range improvement of three. Range is now up to 0.0028 ly.

### Bigger antennas

Presumably more advanced civilizations might well have bigger radio telescopes than we have. The question is how much bigger. The two types of limits that might factor into this are physics and economics.

First, look at the physics. From a physical perspective, using antenna tolerance theory, we need about 1-10 cm stability to coherently receive UHF radio signals. A planet can easily provide this stability over 10000 km distances (as shown by VLBI astronomy). However, a body such as the moon might well be a better site, since it is not big enough to have significant internal heating, and so is seismically dead. It also has no atmosphere, another advantage for radio astronomy. So if we restrict ourselves to moon sized bodies, we could easily have (from a physics perspective) an antenna about 1000 km on a side.

The next limit is economics. Presumably alien radio astronomers, like earth radio astronomers, do not have the entire resources of their civilization at their disposal. So let's look at some more 'practical' proposals.

Arecibo has an effective area of about 50000 square meters. There is active research into the 'Square Kilometer Array'<sup>6</sup>, which would have an effective area of 1 square Km, or about 20 times as big as Arecibo. The earth's economy also supports other scientific instruments, such as particle accelerators, that have sizes of 10-50 km.

It is certainly possible that the biggest antennas are best built in space, with an absence of wind loading and much smaller gravitational forces. This is currently economically impractical for earth, but might be practical for a space dwelling civilization. With easily foreseeable

technology, an alien civilization might well build an Arecibo style antenna in a crater on the back of the moon, or perhaps in a crater on an asteroid such as Mathilde. There are many suitable craters of size 30 km and up.

At least one of these methods is surely possible for an advanced civilization, so for the rest of this paper we will assume the aliens are using either a small (30 km) antenna or a large (1000 km) antenna.

The 'small' 30 km antenna has a collecting area 10,000 times that of Arecibo, for a demodulation range of 0.28 ly, and a detection range of 280 light years. Since we have only been sending out UHF TV signals for 50 years, this is more than enough range. This antenna, aimed at earth, could easily see our UHF TV carriers from any location the signals have gotten to so far.

The large (1000 km on a side) antenna has a collecting area  $2 \times 10^7$  times bigger than Arecibo. This gives a range improvement of  $4.5 \times 10^7$ . Now a TV signal can be detected out to 10300 ly, and demodulated out to 10.3 ly.

### Signal processing

Aliens will probably receive the same show many times. Imagine an alien civilization somewhere in the plane the earth's equator, receiving signals from North America. First, the civilization would get the east coast stations - on many different channels and almost all of them at the same time. Then the Midwest stations would rotate into view. Because the shows are delayed for each time zone, the alien civilization might see the same shows again, delayed by 1 hour, again from many stations. This will happen yet again for Mountain Time, then Pacific Time. Individual networks often have more than 100 affiliates in the USA alone, all broadcasting the same show, so the aliens might record this many copies of the same show during one observing session.

Could the aliens actually make use of all these copies? Assuming their signal processing and storage is only slightly better than ours; they might well record all the signals from earth for later signal processing. This is a lot of data (say 2 GB/sec if they want to cover all UHF TV channels), but on the verge of being practical even for earth technology. The major advantage of this approach is that near optimum signal processing can be applied, off line if need be, and all the historical data can be used.

Once the aliens realize that they are getting the same show again and again, on many different channels and at different times, they can use this to improve their signal to noise ratio, and hence range. Unfortunately they cannot use coherent summation of the voltage waveforms. (Only the modulation is the same - the actual waveform is not since the programs are broadcast on different channels, and the carriers are not locked to the frame rates in any case.) They can, however, average in the power domain. TV signals have several characteristics that make coherent summation of the modulation easy, such as strong synchronization signals.

From the arguments above, (plus re-runs), it seems plausible that an alien civilization might accumulate at least 1000 copies of the same broadcast. If they can sum over 1000 copies, their S/N goes up by 31, and their range by 5.5. Then they can receive our signals out to 1.5 ly with the small antenna, and 58 ly with the big one.

Furthermore, there is lots of internal redundancy in analog TV transmissions. Frames are same as proceeding frames; scan lines are similar to preceding lines. Compression using these ideas can achieve 100:1 compression without much loss of quality. This is similar to getting 100 copies to average over. In the long run, alien astronomers might model the underlying objects and lighting. Then they can fiddle with the coefficients to get the best match to the data (similar to maximum entropy methods in astronomy). This should yield at least another factor of 10, for a total redundancy of least a factor of 1000. This increases the signal to noise by another factor of 31, for another range increase of 5.5. Now we can demodulate the signals out to 8.6 ly with the small antenna, and 327 ly with the big one.

### Stellar focusing

For any particular source, the aliens can gain still more range by locating the antennas at the point of gravitational focusing of a star. This focuses all the energy from a ring extending entirely around the sun onto an antenna. The width of the ring is half the diameter of the antenna. The sun is about  $1.4 \times 10^6$  km in diameter, so for a 1000 km diameter antenna, we would focus all energy going through a ring of width 500 km and length  $\pi \times 1.4 \times 10^6$  km. This is a gain of about 2000 in collecting area. This is good for about another factor of 45 in range. Now we are up to about 16300 light years for decoding the signal.

The smaller antenna gets a higher relative gain from focusing, about 9300 in collecting area. This is enough to demodulate the signal out to about 2600 light years.

Note that stellar focusing is good only for one specific target star. In this case it's not a serious disadvantage since the aliens can detect the carrier from a much larger distance without using focusing. Once found, they can move an antenna to the focusing point and begin to decode the transmissions if they cannot already.

### Speculation

There appears to be almost no limit from physics to the largest size antenna that could in theory be built. We ourselves combine pulsar radio signals taken from all parts of the earth's orbit, though we do not do so coherently (yet). An antenna or group of antennas, with a collecting area the size of the Earth's orbit might be an easy project for a civilization that can create a Dyson sphere. With a collecting area of  $10^{17}$  square kilometers, such an antenna could decode our shows from

100,000,000 light years, or about 25 Mpc. At a local density of galaxies of about 0.005 per Mpc<sup>3</sup>,<sup>7</sup> this volume includes roughly the nearest 100 galaxies.

### CONCLUSIONS

We've only been sending out significant electromagnetic signals for less than 100 years. Therefore, if they can get our signals at all, they are less than 100 ly away. From this distance, using likely alien technology, they can easily reconstruct our TV programs. So if aliens exist, and they even know we exist, they can probably watch our TV if they want to.

### REFERENCES

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