Aliens Are Not Watching *I Love Lucy*

It is still a common misconception among science fiction writers (eg, *Contact*, by Carl Sagan), and SETI researchers, that television signals (as well as radio, cell phone, and other signals) can reach interstellar distances and potentially be recognized by extraterrestrial beings. This is simply not possible, as some basic calculations with the radio link equation will show. Ironically, it is the 4K microwave background radiation that ultimately puts a fundamental limit on the maximum distance that radio and television signals can be detected.

Let's take a specific example of a television station with a very high radiated power, a very optimistic receive signal-to-noise ratio, and a very large receive antenna with no losses:

$$\text{Television channel 4: frequency } = \text{ 67 MHz, wavelength } = \lambda = 4.5 \text{ m}$$

$$P_t G_t = \text{transmitter power} \times \text{transmitter gain } = 5 \text{ MW} = 5\times 10^6 \text{ W}$$

$$\text{Receive antenna: square kilometer array, aperture area} = 8\times 10^{11} \text{ m}^2$$

$$G_r = \text{receive antenna gain} = \frac{4\pi A_e}{\lambda^2} = 5\times 10^{11} = 117 \text{ dB}$$

The desired signal-to-noise ratio for a good-quality analog video signal is generally taken to be about 30 dB, but let's assume the very best case and use an SNR of 0 dB (so the signal power is equal to the noise power). The bandwidth of the old analog TV signal is 4 MHz, so the received noise power, assuming a very best case of a 4 K antenna noise temperature (due to the microwave background temperature) is, from eq (14.16) of [1],

$$P_r = N = kTB = \left(1.38\times 10^{23}\right)\left(4\right)\left(4\times 10^{6}\right) = 2.2\times 10^{-16} \text{ W}$$

Then, from the Friis equation, relating the received power of a radio link to the transmit power, antenna gains, frequency, and distance *R* between transmitter and receiver (14.24 of [1]),

$$P_r = \frac{P_t G_t G_r \lambda^2}{\left(4\pi R\right)^2},$$

we can solve for the largest distance between the television transmitter and a receiver before the transmit power falls below the noise floor:

$$R = \sqrt{\frac{P_t G_t G_r \lambda^2}{16\pi^2 P_r}} = 3.8\times 10^{16} \text{ m} = 3.8\times 10^{13} \text{ km}$$

Since $1 \text{ light-year} = 9.5\times 10^{12} \text{ km}$, the maximum receiving distance is about 4 light-years. The nearest star to Earth is Proxima Centauri, at a distance of about 4.2 light years from Earth. So our old analog television signals are highly unlikely to ever be detected even at our closest stellar neighbor, and will certainly be impossible to be detected at farther stars. Keep in mind that this analysis does not even include the possible difficulty of ETs being able to demodulate the video or sound information, nor does it include the fact that there are likely a number of superimposed signals radiating at this same frequency from our planet, which would further increase the effective received noise level.

It is true that a receive antenna with larger gain will add some distance, but this is slow in coming: an increase in gain by a factor of 100 only increases distance by a factor of 10. But along with this advantage comes the disadvantage that a higher gain results in a narrower receive antenna beamwidth, which increases the number of positions that must be searched in the sky. For example, the receive antenna used in the above calculation has a beamwidth of about 2.5×10^{-4} degrees. Since the spherical sky has a solid angle of $41,253\deg^2$, there are about 7×10^{12} 'spots' to search with this antenna. And this would have to be done at all frequencies of interest, and for a long enough period to (possibly) extract signal from noise.

[1] D. M. Pozar, Microwave Engineering, 4th edition, John Wiley and Sons, 2012.

David Pozar (Emeritus Professor)
Electrical and Computer Engineering
University of Massachusetts Amherst
Amherst, MA 01003