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DR. SETI'S STARSHIP

Searching For The Ultimate DX

The Day the Earth Called Out

In a December 12, 2008 publicity stunt, 20th Century Fox, producers of *The Day the Earth Stood Still* (the 2008 cheesy remake, not the 1951 cheesy original) beamed its science fiction opus toward Alpha Centauri, our nearest stellar neighbor. A Fox spokesman called it the first "galactic motion-picture release." Wide discussions ensued within the SETI community as to the technical feasibility and societal implications of such interstellar transmissions. Many opined that the transmission could not possibly be detected (four years hence) by its intended audience (four light years distant). Others argued that we cannot place limits on extraterrestrial technology. I argue that we won't know until we run the numbers. However, since the purpose of this supposed interstellar transmission was to promote the release of a motion picture, one could argue that the intended audience was in fact human, rather than extraterrestrial.

This column concentrates on the medium, not the message. Although I am decidedly *not* a film critic, I cannot resist the temptation to comment briefly on the motion picture itself. One wonders why an advanced extraterrestrial would travel all the way to Earth with a message of warning, and then fail to meet with a single scientist, diplomat, or head of state. Had Klaatu, as portrayed by Keanu Reeves, ever bothered to watch any terrestrial television (which question is, in fact, the very focus of this exercise), he surely would have learned how to say "take me to your leader."

As reported in the media, the transmission in question emanated from "NASA's Deep Space Communications Network at Cape Canaveral." Those news reports are factually flawed; Deep Space Communications Network (henceforth DSCN) is a private company, in no way affiliated with NASA, that transmits private messages into space for a fee. Whether by geographical coincidence or marketing design, this company's uplink facility is located in the municipality of Cape Canaveral, FL, USA, but by no means is it on site at the Kennedy Space Center, which shares that address. Mr. Jim Lewis, proprietor of the company in question, asserts that it was never his intention to imply otherwise, a claim which I am inclined to accept at face value.

DSCN's transmission equipment is in fact a standard, commercial-grade C-band remote uplink facility, such as is commonly used for remote news and entertainment broadcasts via satellite. It consists of a trailer-mounted 5.5-meter diameter parabolic reflector and redundant 1-kW klystron FM video transmitters operating in the 5925–6425 MHz TVRO uplink allocation. The transmitters are typically operated at 500 watts average power (+57 dBm), using 10.25-MHz peak deviation, 30-Hz dithering, and a highest modulating frequency of 6.8 MHz, that being the highest available audio subcarrier frequency. These specifications yield a 99% power bandwidth on the order of: $2\Delta f + 2f_m = 34$ MHz, which is wholly compatible with a full 40-MHz DOMSAT transponder, allowing a reasonable guardband for non-significant sidebands.

Note that DOMSAT video being frequency modulated, the signal's energy components are spread out as sidebands across this entire 34 MHz of spectrum. Thus, to recover and demodulate the transmission, a suitable receiver must be designed with a 34-MHz intermediate frequency (IF) bandwidth.

According to the aforementioned Mr. Lewis, the relevant transmission was made on the frequency band for DOMSAT transponder #1, at the low end of the uplink spectrum—i.e., from 5925 to 5965 MHz. At the center of this channel's passband, transmit wavelength is found as:

$$\lambda = c/\nu = (3 \times 10^8 \text{ m/s})/(5945 \times 10^6 \text{ Hz}) = 5.0 \text{ cm}$$

At that wavelength, the manufacturer's stated gain of the 5.5-meter offset-fed parabolic reflector is +48 dBi, suggesting a commercial-standard 55% illumination efficiency. (The gain of this antenna could be improved by nearly 2 dB through the use of a more highly optimized feed geometry, but that is a subject for another occasion.) The computed antenna half-power beamwidth is on the order of:

$$\theta = \lambda/D = 5.0 \text{ cm}/5.5 \text{ m} = 9.4 \text{ mRad}$$

or just over half a degree. The uplink effective isotropic radiated power is:

$$\text{EIRP} = P_x + G_a = (+57 \text{ dBm}) + (+48 \text{ dBi}) = +105 \text{ dBm}$$

Optical parallax measurements from Earth show the approximate distance to the Alpha Centauri system to be on the order of 1.3 pc, or 4.0×10^{16} km. Free-space isotropic path loss for transverse electromagnetic radiation is found as:

$$\alpha_{FS} = 10 \times \log_{10} (D/\lambda)^2 = 10 \times \log_{10} (4.0 \times 10^{16} \text{ km}/5.0 \text{ cm})^2 = 380 \text{ dB}$$

Given the EIRP and free-space path loss computed above, one can determine the isotropic power incident upon an assumed planetary body in the Alpha Centauri system as:

$$P_{inc} = \text{EIRP} - \alpha_{FS} = (+105 \text{ dBm}) - (380 \text{ dB}) = -275 \text{ dBm}$$

Thus, to recover the transmission, any receiving system at Alpha Centauri must have a detection threshold (receiver sensitivity) at or below this level. That's because in order to be detected and demodulated, a signal in any communications system needs to overcome the omnipresent thermal background noise. This noise power can be quantified as: $P_n = kTB$—where k is Boltzmann's Constant = 1.38×10^{-23} J/K; T is the system thermal temperature; and B is the receiver's bandwidth in Hz. For a DOMSAT video channel, we have already shown the

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required detector bandwidth to be on the order of 34 MHz. Let us optimistically assume a theoretically perfect receiver at Alpha Centauri, whose noise threshold is limited only by the 2.7° Kelvin cosmic background radiation. Noise power now becomes:

$$P_n = kTB = (1.38 \times 10^{-23}\ \mathrm{J/K})(2.7\mathrm{K})(3.4 \times 10^{7}\ \mathrm{Hz}) = 1.27 \times 10^{-15}\ \mathrm{J/s} = 1.27 \times 10^{-12}\ \mathrm{mW} = -119\ \mathrm{dBm}$$

It can be seen from the above that the isotropic signal incident upon Alpha Centauri is weaker than the minimum cosmic thermal background by a factor of:

$$P_n - P_{inc} = (-119\ \mathrm{dBm}) - (-275\ \mathrm{dBm}) = 156\ \mathrm{dB}$$

Therefore, the challenge for the Centaurians becomes one of pulling a viewable TV signal out from beneath 156 dB of excess noise.

As almost all hams and radio astronomers know, there is no substitute for capture area. The previously cited signal-to-noise (SNR) deficit assumes an isotropic receive antenna. By creating a directive antenna, one can minimize the isotropic thermal noise intercepted, by the ratio of the antenna gain as compared to isotropic. Thus, a big dish is in order.

It would appear at first glance that a receive antenna with a gain of +156 dBi would raise the signal-to-noise ratio to within detection threshold. In fact, the picture is a little bleaker than that, because demodulation of FM video requires an SNR somewhat greater than unity. Let us assume that a 10-dB signal surplus is required for sparkly-free video reception. This is a level typical of the best phase-locked-loop detectors available on Earth, and we have no reason to suspect that the Centurians have significantly better detectors for detecting Earth's TVRO uplinks. Thus, an antenna gain of +166 dBi will prove adequate for reception of this particular transmission, with modest fade margin and detector threshold.

Is an antenna with +166 dBi of gain feasible? Consider that the Arecibo Observatory, Earth's largest radio telescope, has a theoretical gain at the frequency of interest of a mere +74.8 dBi. Although nothing even approaching the required level of performance has ever been achieved on Earth, let us not limit extraterrestrial intelligence's (ETI's) technological prowess. The laws of physics suggest that if you build an antenna big enough, any gain figure is achievable.

OK, so how big is "big enough"? The gain of a parabolic reflector antenna, in decibels relative to isotropic, is found from:

$$G_a = 10 \log_{10} \eta (D/\lambda)^2$$

where η represents illumination efficiency factor (on a scale of 0 to 1), D is the antenna diameter, and λ is wavelength in like units. Giving ETI the benefit of the doubt, let's say their engineers can illuminate a big dish to 100% efficiency. Now, solving for D, an antenna with +166 dBi of gain, at an operating wavelength of 5 cm, needs to be a mere 3200 kilometers in diameter!

From the foregoing, I conclude that the challenges of reception, although clearly not insurmountable, are daunting to even the most technologically advanced extraterrestrial civilizations that our (admittedly limited) human imaginations can conceive. Even optimistically assuming that the Alpha Centaurians can build a 100% efficient antenna a continent across, there still remains the thorny problem of aiming it accurately at Earth. That complication will be discussed in our next column.

73, Paul, N6TX

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