**Extreme Systems Design**

In this section we will apply fundamental limits from antenna physics and information science to define a system limited only by these physical constraints. This analysis will use the concepts shown in Figure 10.7combined with the Shannon Limit.

Sometime in the future we may wish to communicate with a civilization on another planet in the direction of an otherwise empty sky. Another motivation is exemplified by engaging in SETI (Search for Extraterrestrial Intelligence). The actual frequencies, coding, polarization, Doppler wavelength modifications, etc. may be knowns and/or unknowns. Here we will define some details of a possible inter-stellar radio link.

Figure 10.13 clearly points to an optimum frequency range for SETI efforts. From this figure we assume that a radio search would involve pointing at the sky around 45 degrees above the horizon between about 1 and 10 GHz. We should also look away from the Milky Way’s center, where, not surprisingly, galactic noise is maximum. However, at about 8 GHz, even galactic noise from the center becomes very low. This band of frequencies is often referred to as the “water hole,” since both hydrogen and oxygen spectral bands appear within this range and water is the basis of life on earth, which it’s a good guess for alien life as well.

The data rate is kept very low, in this case at 1 bit/second to minimize the required signal level at out receiver(s). Derived from Equation 10.51, a S/N ratio is taken to be 1, and the bandwidth is 1 Hz. If we assume a noise figure of zero (already possible to get close to this) in the receiver, we can also assume we limit the received noise in 1 Hz to be the 2.7-degree K from the Big Bang (there’s nothing we can do about that!). Thus, we can assume that the minimum signal strength will be the same as the noise power, -224 dBW (dB relative to 1 watt, Equation 10.2), or -194 dBm.

Here are the assumptions for our inter-planetary radio link:

*Frequency*: 5 GHz or $λ$=.06 m

*Distance in light years*: 100 to earth, or $947 x 10^{15}m (r for distance)$

*Parabolic antenna diameter* at both ends: 100 m or aperture = $7,854 m^{2}$=74.34 dBi @ 5 GHz, or,

*Noise level minimum*: $37.26 x 10^{-24} watts$, or -224 dBW (from background radiation from the Big Bang)

*Direction of target planet:* located in a very quiet extra-solar direction and at the time of listening, as high above the local horizon as possible.

 We use the Friis equation (Equation 2.8):

$P\_{r=}P\_{t}\frac{A\_{et}A\_{er}}{r^{2}λ^{2}}$

We now want to calculate how much power the transmitter needs to provide for minimum received power at the 100 light year distance. We thus derive from Equation 10.52:

$P\_{t}=P\_{r}\frac{r^{2}λ^{2}}{A\_{et}A\_{er}}= 37.26 x 10^{-24}w\left[\frac{\left(947 x 10^{15 }m\right)\left(.06m\right)}{\left[7854m^{2}\right]}\right]^{2}$=1.955 kw

Equation 10.52

Notice that in the Friis equation, the meters (or any measurement standard) cancel, leaving only a coefficient for power.

The transmitter must output almost 2 kw, but the EIRP is 53.6 *mega*watts due to the antenna gain.