# 'Can you hear me now?': getting the message across

Have you ever wondered why some radio stations come in clearly in your radio, while others can barely be heard no matter how you crank up the volume? The reception of a radio signal depends on two very important quantities. The first is how much power the radio station is broadcasting. The second is how far that station is from you.

Some radio stations broadcast only at 100 watts, while others transmit over 50,000 watts of radio power. Imagine a 5-watt light bulb and a 100-watt light bulb. Which one do you think will be easier to see from across the room, or at 100-meters?

The brightness of a lamp, or a radio station, is measured by the amount of power that is delivered to a square-meter of area. We call this physical unit 'intensity' and measure its quantity in watts per square-meter ($W/m^2$). Because most kinds of lights and radio stations broadcast their power over a spherical volume, the intensity of a source is easily computed by dividing its power, P, by the surface area of a sphere whose radius, D, equals your distance from the source. The formula is just $P / 4\pi D^2$.

| Transmitter | Distance (km) | Power (watts) | Intensity ($watts/m^2$) |
|---|---|---|---|
| AM Station | 1000 | 50,000 | **$3.9 \times 10^{-9}$** |
| TV Station | 100 | 50,000 | |
| Cell Phone | 1 | 0.3 | |
| THEMIS P1 | 160,000 | 3 | |
| STEREO A | 15 million | 10 | |
| ACE | 1.5 million | 5 | |
| MESSENGER | 50 million | 15 | |
| Mars Orbiter | 220 million | 100 | |
| Cassini | 1.4 billion | 20 | |
| Ulysses | 800 million | 5 | |
| Voyager 2 | 13 billion | 40 | |

**Problem 1** - Fill out the last column in the table to find the intensity of the radio signal at Earth. (Use Scientific Notation to an accuracy of one decimal place.)

**Problem 2** - The signal from the Voyager-2 spacecraft, located beyond the orbit of Pluto, is just detectable by sensitive receivers of the Deep Space network on Earth. How far away would the AM radio station be to just be detectable by the DSN? Express the answer in kilometers, Astronomical Units (1 AU = 150 million kilometers), and light years. (Note 1 light year = 9.5 trillion km).

# Answer Key

**Problem 1** – Answer in last column

| Transmitter | Distance (km) | Power (watts) | Intensity (watts/$m^2$) |
|---|---|---|---|
| AM Station | 1000 | 50,000 | **$3.9 \times 10^{-9}$** |
| TV Station | 100 | 50,000 | **$3.9 \times 10^{-7}$** |
| Cell Phone | 1 | 0.3 | **$3.0 \times 10^{-7}$** |
| THEMIS P1 | 160,000 | 3 | **$9.2 \times 10^{-18}$** |
| STEREO A | 15 million | 10 | **$3.5 \times 10^{-22}$** |
| ACE | 1.5 million | 5 | **$1.8 \times 10^{-19}$** |
| MESSENGER | 50 million | 15 | **$4.7 \times 10^{-22}$** |
| Mars Orbiter | 220 million | 100 | **$1.6 \times 10^{-22}$** |
| Cassini | 1.4 billion | 20 | **$8.1 \times 10^{-25}$** |
| Ulysses | 800 million | 5 | **$6.2 \times 10^{-25}$** |
| Voyager 2 | 13 billion | 40 | **$1.9 \times 10^{-26}$** |

**Problem 2** - If the radio station were at the distance of the Voyager 2 spacecraft, I = $2.3 \times 10^{-23}$ watts/$m^2$. The desired Intensity = $1.9 \times 10^{-26}$ watts/$m^2$, is 1230 times weaker. Since the signal intensity is proportional to the inverse-square of the distance, the distance would be increased by $(1230)^{1/2}$ = 35 times so that the radio station signal is now only $1.9 \times 10^{-26}$ watts/$m^2$. The distance would then be 35 x 13 billion km or **456 billion km**, which equals **3040 AU**, or **0.001 light years**.