Jet Propulsion Laboratory
California Institute of Technology
Education

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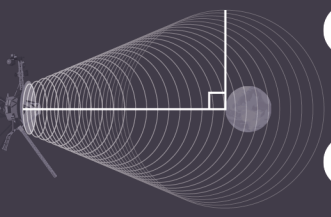
Answer Key

Signal Solution

What fraction of Voyager's original signal is received by a 70 meter antenna on Earth?

1. **Convert astronomical units to meters.**

   $124\ AU \bullet (150{,}000{,}000\ km / 1\ AU) \bullet (1{,}000\ m / 1\ km) = 1.86 \bullet 10^{13}\ m$

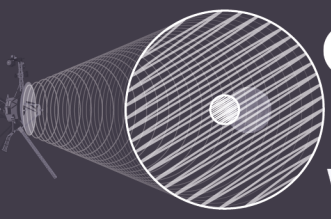


2. **Find the beam radius at Earth using tangent and the distance between Earth and Voyager.**

   $\tan 0.25^\circ \approx x / (1.86 \bullet 10^{13}\ m) \rightarrow 8.12 \bullet 10^{10}\ m$

3. **Find the ratio of the antenna area (radius of 35 m) to the signal area.**

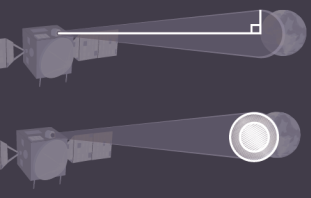
   $\pi(35\ m)^2 / \pi(8.12 \bullet 10^{10}\ m)^2 \approx 1.9 \bullet 10^{-19}$



4. **Find the ratio of received signal versus the sent signal.**

   $1.9 \bullet 10^{-19} \bullet 12.5\ W \approx$ $2.3 \bullet 10^{-18}\ W$ or $1.8 \bullet 10^{-20}\ \%$

What fraction of the signal from a DSOC-equipped spacecraft is received?



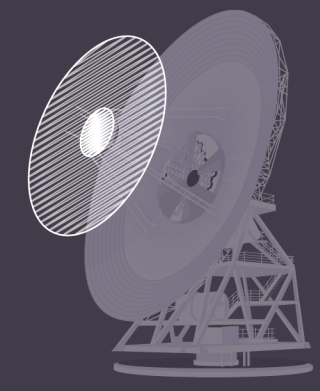
1. **Follow the same process as above with the values for the DSOC-equipped spacecraft.**

   $24\ AU \bullet (150{,}000{,}000\ km / 1\ AU) \bullet (1{,}000\ m / 1\ km) \approx 1.86 \bullet 10^{13}\ m$

   $\tan 0.00045^\circ \approx x / (1.86 \bullet 10^{13}\ m) \rightarrow 1.46 \bullet 10^{8}\ m$

   $\pi(35\ m)^2 / \pi(1.46 \bullet 10^{8}\ m)^2 \approx 5.7 \bullet 10^{-14}$

   $5.7 \bullet 10^{-14} \bullet 4\ W \approx$ $2.3 \bullet 10^{-13}\ W$ or $5.8 \bullet 10^{-14}\ \%$



By what factor is DSOC more effective?

1. **Divide the received wattage of the DSOC spacecraft's signal by that of Voyager's.**

   $2.3 \bullet 10^{-13} / 2.3 \bullet 10^{-18} =$ 10^5 or 100,000 times more effective