Exemplo 1 – cálculo usando unidades logarítmicas da potência recebida na Terra de um sinal enviado por uma sonda espacial

$$A_0(dB) = 32.4 + 20\log_{10} d(km) + 20\log_{10} f(MHz)$$

$$P_R(dBm) = P_T(dBm) + G_T(dB) - A_0(dB) + G_R(dB)$$

$$P(dBm) = 10\log_{10} P(mW)$$

$$G(dB) = 10\log_{10}\left[\frac{P_{out}}{P_{in}}\right]$$

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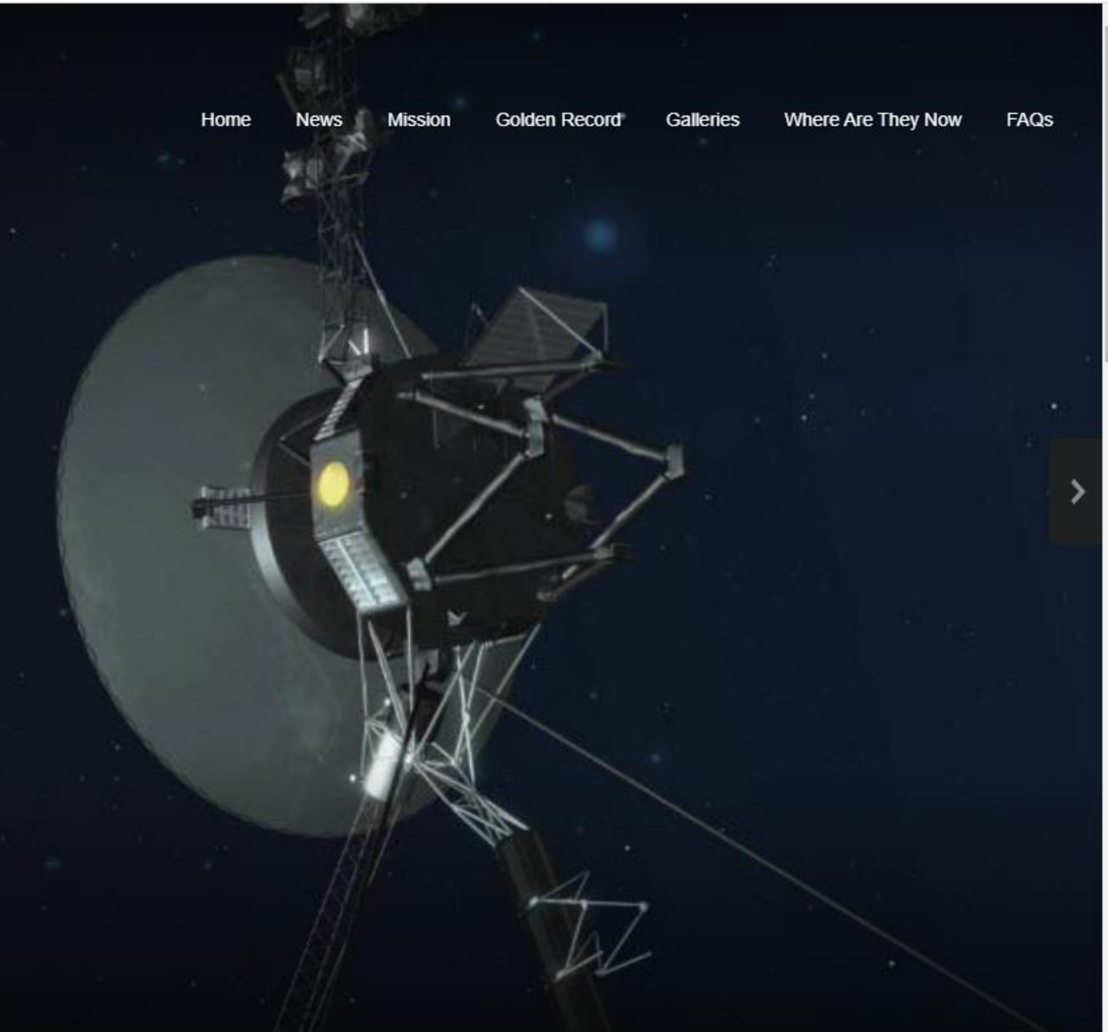

As NASA's Voyager 1 Surveys Interstellar Space, Its Density Measurements Are Making Waves

Voyager 1 DISTANCE FROM EARTH	Voyager 1 DISTANCE FROM SUN	Voyager 1 ONE-WAY LIGHT TIME	Voyager 1 COSMIC RAY DATA
14,464,490,399 mi 155.60614553 AU	14,532,642,769 mi 156.33931534 AU	21:34:08 (hh:mm:ss)	

IMP MET

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HIGH GAIN ANTENNA

The HGA transmits data to Earth on two frequency channels (the downlink). One, at about 8.4 gigahertz (8,400 million cycles per second), is the X-band channel and contains science and engineering data. The other channel, around 2.3 gigahertz, is in the S-band, and contains only engineering data on the health and state of the spacecraft. S-band has not been used since the last planetary encounter. EXPLORE

SSR- Distance measurements to satellites

Figure 1: Voyager spacecraft

Navigation in space, i.e. determination of the position or distance to a satellite can take place only using one of the different radar methods. For very large distances, as for example from Voyager 1 and Voyager 2, a primary radar is not possible due to the huge distances ($2\cdot 10^{10}$ km). According to the fundamental radar range equation, unreal antenna dimensions and transmit powers would be necessary. Therefore, only the secondary radar procedures can be used for very long distances.[1][2]

Voyager has a special transponder on board for these purposes. A ground interrogator transmits the interrogation (“uplink”) in the S-Band, with a carrier frequency of 2.11 GHz. The transmitted power is about 20 kW. A simple keyed on/off pulse modulation, however, would require too large bandwidths in the transmission / reception technique to avoid to loose the pulse edges which are relevant for the run time measurement. Therefore, a special pulse pattern is transmitted, which is converted by the transponder only to a different frequency. The transponder processes this signal fully coherently. This means: the received uplink frequency is used originally and only converted into a different frequency. The conversion ratio is exactly $240/221$, so the downlink is about 2.3 GHz. At the same time it is also converted into another frequency band: The conversion ratio is here $11/3$, the downlink is thus in the X-Band at approximately 8.42 GHz.[3] The high gain antenna on the voyager probe has a diameter of 3.7 m. or 12 feet. Its antenna gain is 36 dBi in S-Band; respectively 48 dBi in X-Band.

Back into the interrogator, the received response is correlated with the copy of the transmitted signal stored in a time grid of an atomic time clock, thus determining the exact run time (plus the well known response time of the transponder). In this way, the distance can be determined very precisely. However, this measured distance was valid only for the time of the transponder activity, since the running time of the signals is already in the range of more than one day and Voyager continues to fly at a speed of 62 140 km/h.[4]

Originally this response was based on two different frequency bands in order to be able to correct the influences of the ionosphere on the propagation velocity of the electromagnetic waves. Later, however, the relativistic gravitational time delay effect (Shapiro delay) for the radar signals could also be measured with a very high accuracy.[3]

Deep Space Navigation Network

In order to measure even a single satellite, an entire system of antennas is needed on Earth, the **Deep Space (Navigation) Network** (DSN). The antennas are distributed in such a way that at least one antenna can always be swiveled in precisely the direction from which the transponder response is expected. Since the run times are so high (currently 1.5 days), the probability be too high, that a single large antenna is on the wrong side of the Earth due to the earth rotation.

If several interrogators or several transponders are used, all hardware must be able to use a standardized protocol. The antennas of the interrogators have got a diameter of 70 m and are located in Goldstone (California), in Madrid (Spain) and Canberra (Australia). The transponders are also standardized and are, for example, called Small Deep Space Transponders (SDST) or only Deep Space Transponders (DST).

A very high frequency band is selected as the carrier frequency (X-Band to Ka-Band), so that the antenna can have as great a directivity as possible for smaller geometric dimensions. Older one transponders use the S-Band, which allows minimal propagation loss through the Earth's atmosphere (less than 1 dB). This is usually quite adequate for Earth orbiting missions.

Only the second NASA spacecraft in history to go beyond the heliosphere, "Voyager 2" has sent data across 11 billion miles. Photo by rangizzz / Shutterstock

NASA said that *Voyager 2* left the atmospheric reach of Sol on November 5, 2018. Around that time, it sent information about the area beyond our sun back to Earth. That data—including figures about the density of plasma in the vast, empty regions between stars—took almost a year to the day to reach us. Even more incredibly, it was sent using equipment that's only as strong as a cell phone tower here on Earth. The science of signals and bandwidth is marvelous.

Directed Broadcasting

"The *Voyager* radio transmitter power is about 20 watts," **Dr. Benjamin Schumacher**, Professor of Physics at Kenyon College, said. "The power that matters, of course, is the power that reaches Earth. If *Voyager* broadcast those 20 watts equally in all directions, the radio signal on Earth would be incredibly weak."

If cell phone towers can only transmit a few miles, how does *Voyager 2* get its info back to us from several billion times that distance? The answer is how specifically *Voyager* directs its broadcasting, which it does using a specialized antenna.

"The large parabolic dish antenna focuses the energy to a beam less than one degree wide," Dr. Schumacher said. "This means that the spacecraft must keep this antenna aimed very precisely at Earth. The narrow beam means that the radio power is greater in that direction."

In order to "catch" this data as it comes in, NASA makes use of several Earth-based parabolic antennae in California, Spain, and Australia called the Deep Space Network. According to Dr. Schumacher, each of these antennae is 70 cefetsaraiva2 | Exemplos - Google Drive | Voyager 2 – Wikipédia, a e | Voyager 2 - Interplanetary | Voyager - The Spacecraft | 3.7m X-band Antenna | | SSR in der Raumfahrt - Ra | DSN Now

eyes.nasa.gov/dsn/dsn.html

Apps | Financeiro | Subscriptions | CEFET | Saúde | Vocabulary

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DEEP SPACE NETWORK *NOW*

LAST UPDATED: MAY 10 6:37 PM (UTC)

DSN home

MADRID
MAY 10
8:37 PM

63 | 65 | 53 | 54 | 55 | 56

M01O | EM1 | LUCY | SPP

GOLDSTONE
MAY 10
11:37 AM

14 | 24 | 25 | 26

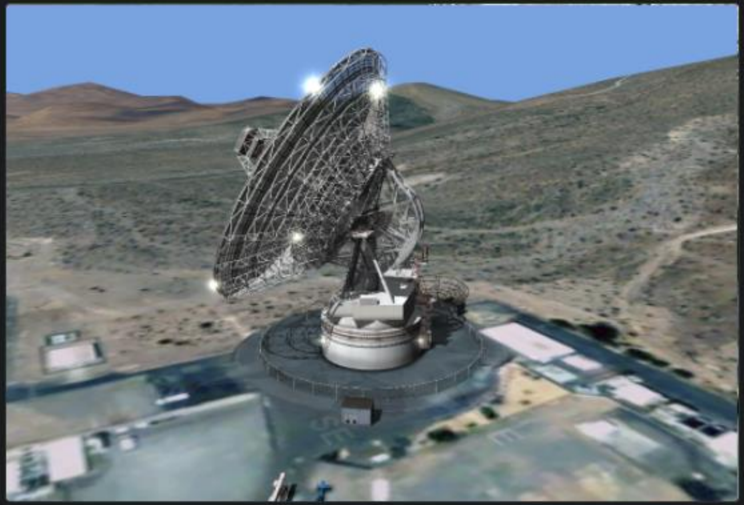
JWST | ORX | DART

CANBERRA
MAY 11
4:37 AM

43 | 34 | 35 | 36

TARGET

MARS ODYSSEY



VIEW ANTENNA | VIEW SPACECRAFT | VIEW WORLD MAP

M01O

-

ROUND-TRIP LIGHT TIME

-

ANTENNA

NAME

DSS 14

AZIMUTH

231.00 deg

ELEVATION

34.24 deg

- less detail

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POR PTB2 15:37 10/05/2022

Table 3.1: 70 m Aperture Efficiencies and Gains

Band	Center Frequency (GHz)	Frequency Range (GHz)	Antenna	Gain (dBi)	Gain (K Jy^{-1})
L[a,b]	1.668	1.628–1.708	all	61.04 ± 0.3	1.18
S	2.295	2.2–2.3	all	63.59 ± 0.1	1.12
			DSS-14 (Goldstone)	74.55 ± 0.1	1.04
X[c]	8.42	8.2–8.6	DSS-43 (Canberra)	74.63 ± 0.1	1.06
			DSS-63 (Madrid)	74.66 ± 0.1	1.07
K	22	18–27	DSS-43[d] (Canberra)	80.2	0.56
			DSS-63[e] (Madrid)	78.2	0.36

The Deep Space Network Radio Astronomy User Guide

https://deepspace.jpl.nasa.gov/files/DSN_Radio_Astronomy_Users_Guide.pdf