Communication

Communication

Much cheaper than travel

Energy needed for Mass (M) at speed (v)

$E = 1/2\ Mv^2$ if v much less than c

e.g., travel to nearest star (4 ly) in 40 yr

$\Rightarrow$ $v = 0.1\ c$ $\Rightarrow$ $E = 4.1 \times 10^{-9}$ ergs

for M = M (electron)

Photon $E = h\nu$ $h = 6.6 \times 10^{-27}$ erg-sec

ν = frequency

$E = 6.6 \times 10^{-18}$ ergs if $\nu = 10^{9}$ Hz

Ratio ~ 10^{9} (and photon gets there in 4 yrs)

100 Megawatt transmitter - 1 yr

\$ 40×10^{6}

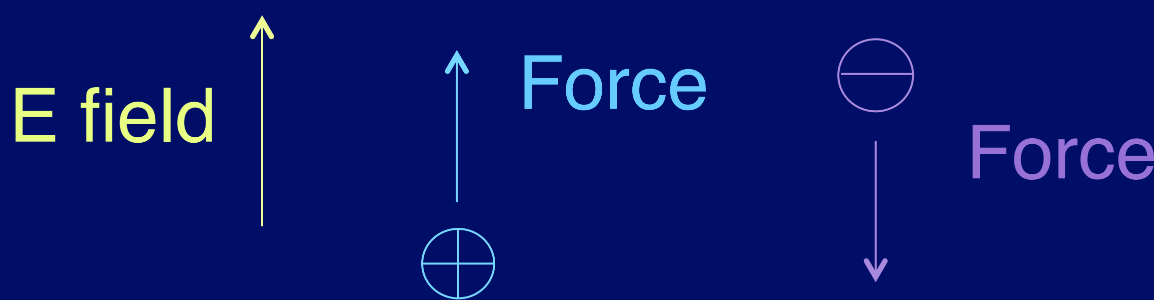
Spacecraft to nearest star

~ \$ 5×10^{16}

(some analysis questions this conclusion)

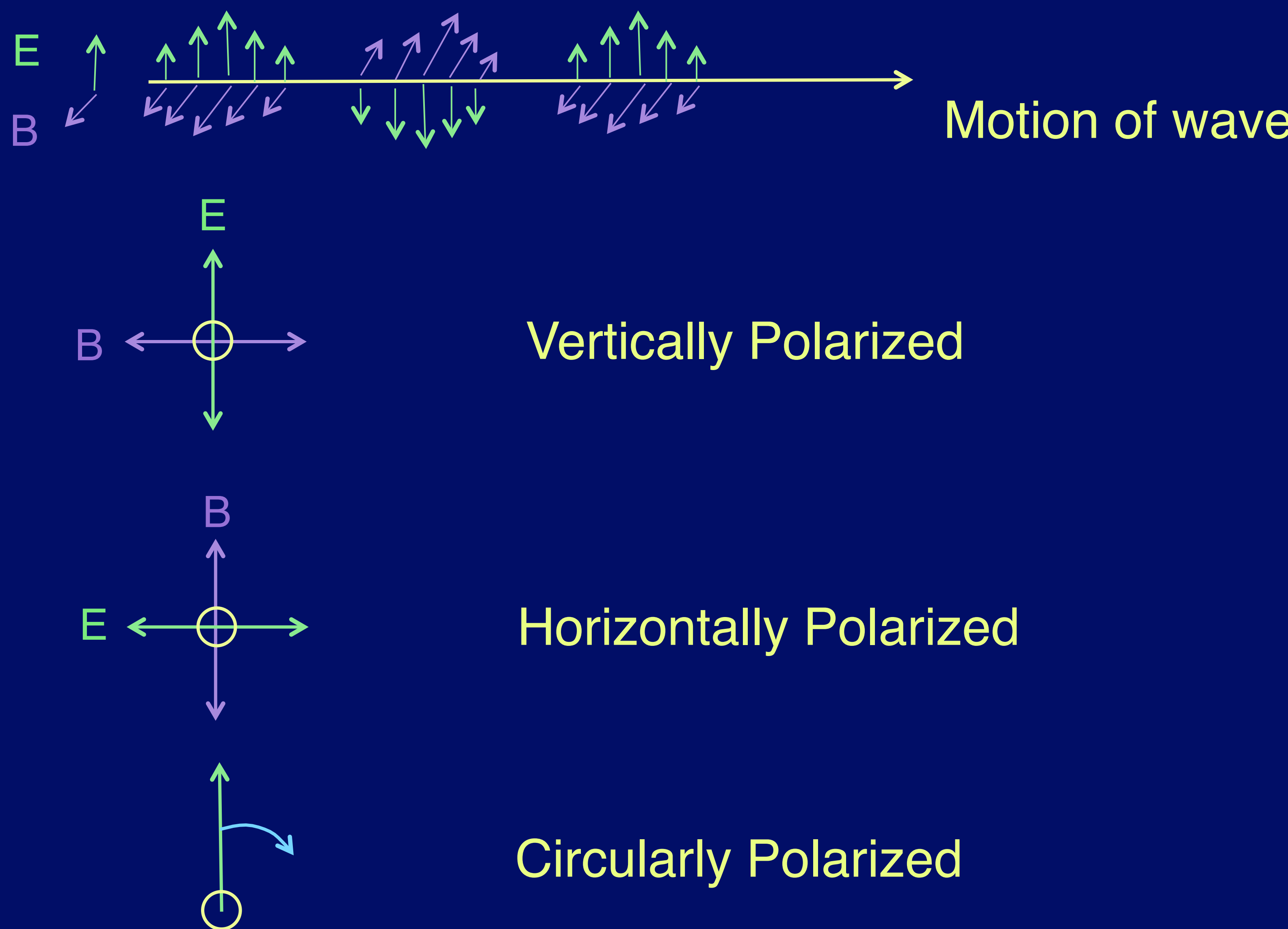
Light is an Electromagnetic Wave

Electric Field: Indicates force on charged particle



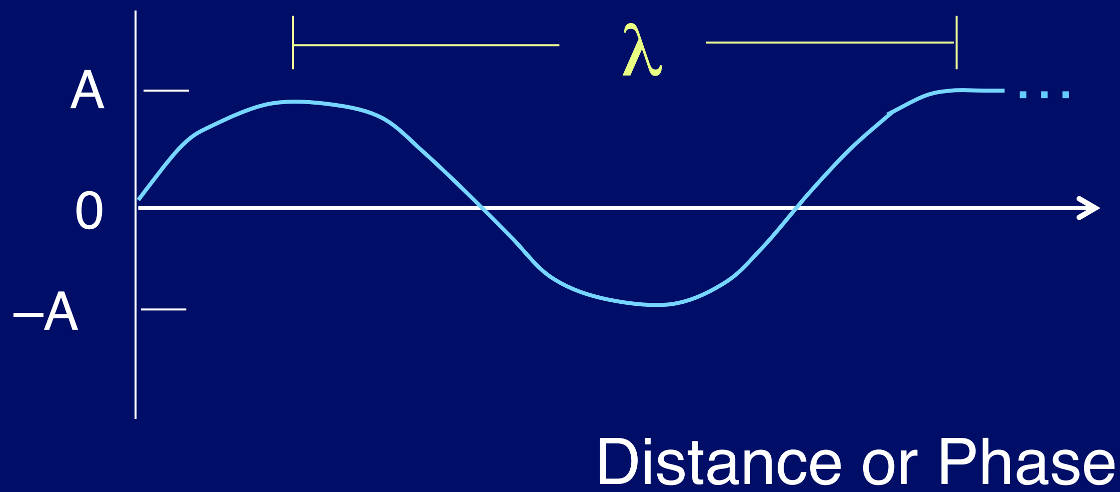
Magnetic field: created by changing electric field. At right angle to electric field.

Electromagnetic Wave



Wave Properties

Snapshot

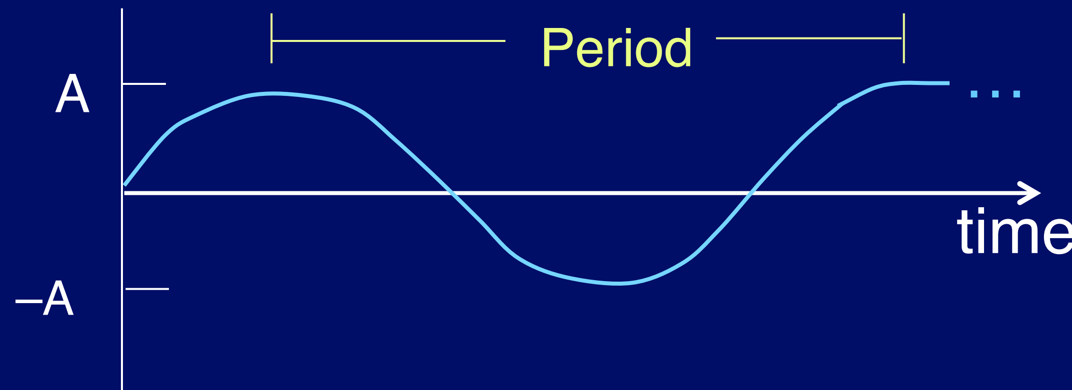


A = Amplitude

λ = Wavelength

Wave Properties

Look at one point along wave



ν = frequency = $\dfrac{1}{\text{period}}$

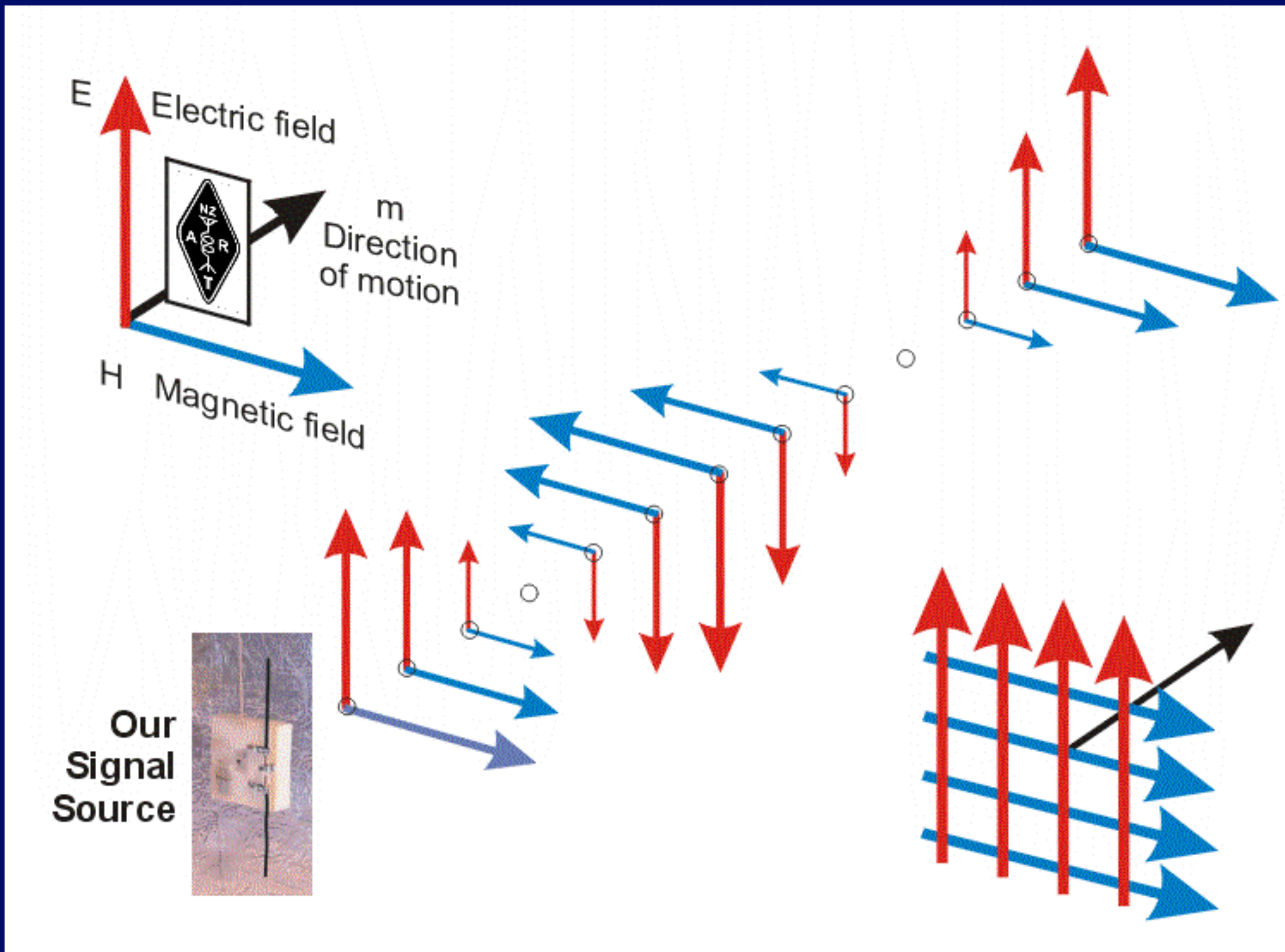
# of cycles per second (hertz, Hz)

1 kHz = 10^3 Hz   1 MHz = 10^6 Hz

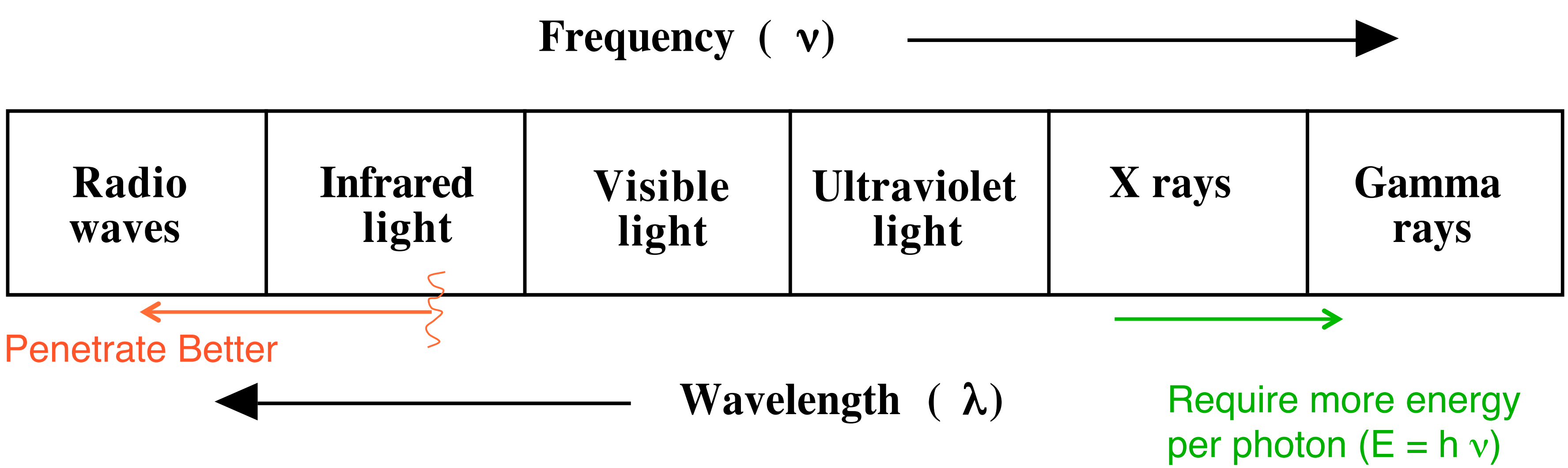
1 GHz = 10^9 Hz

Speed of light $c = \lambda\nu \Rightarrow \lambda = \dfrac{c}{\nu}$

Wave Demo

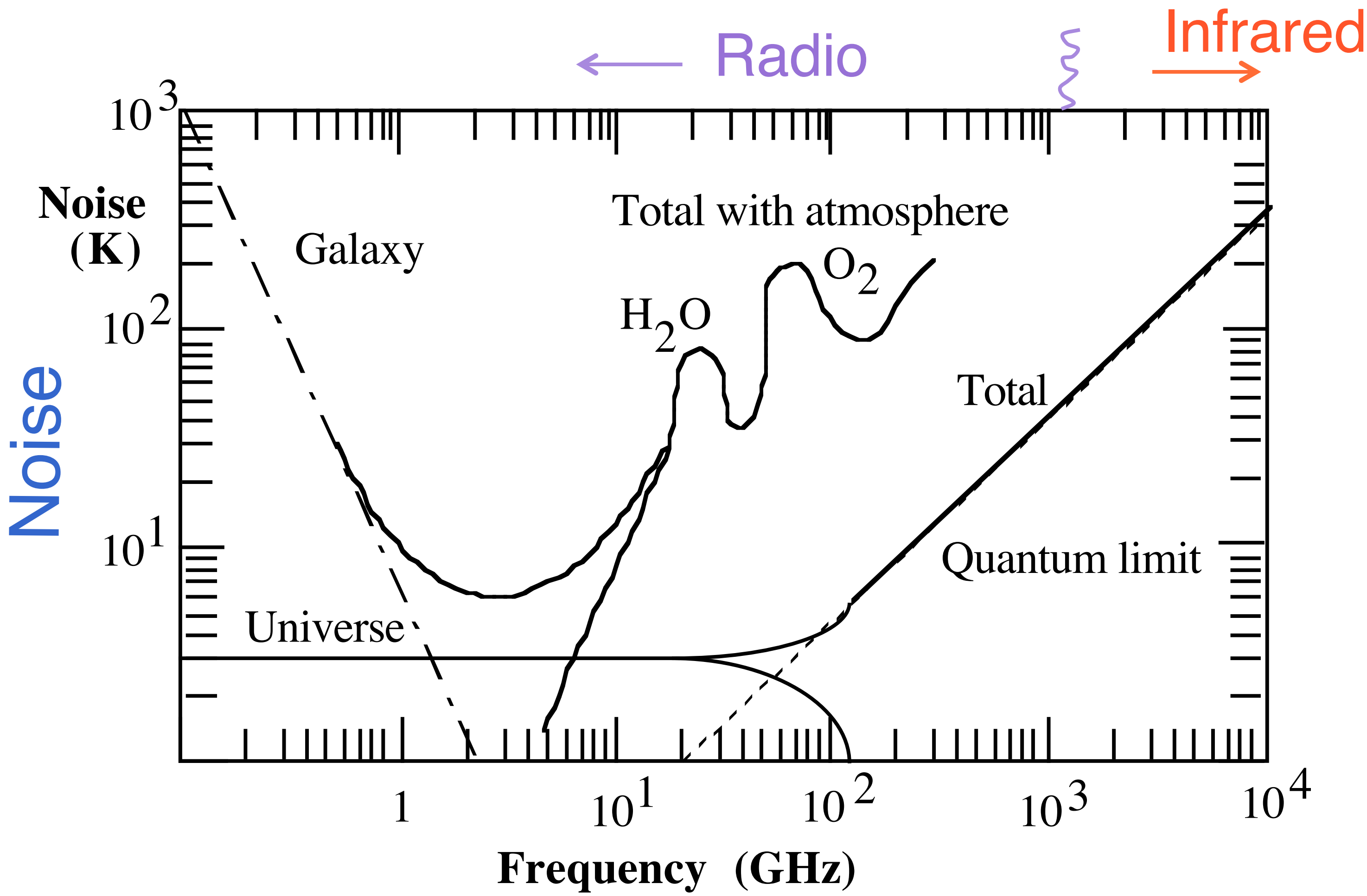

E
Electric field
m
Direction
of motion
H
Magnetic field
Our
Signal
Source

Electromagnetic Spectrum (Light)



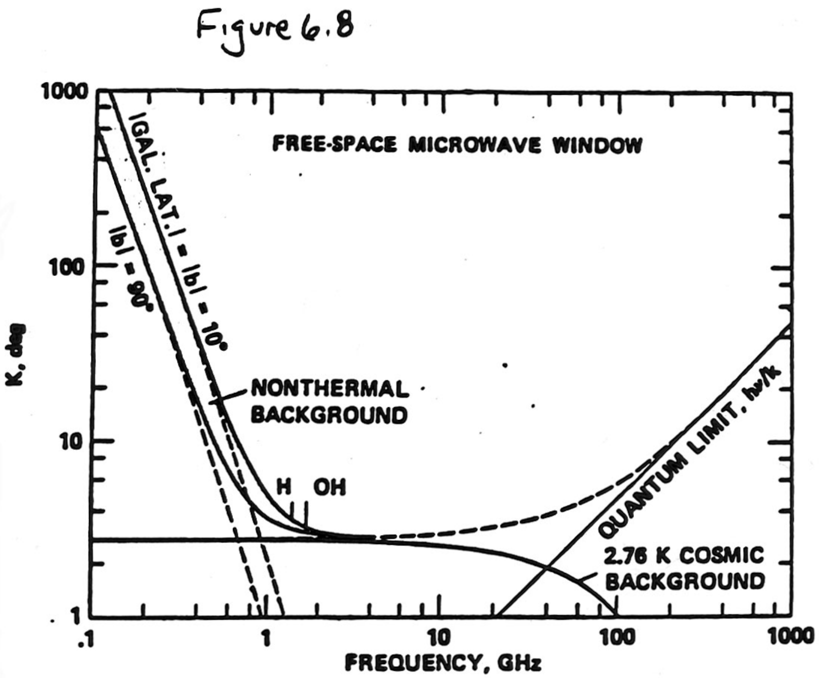
Noise: Any unwanted signal

Artificial, Natural

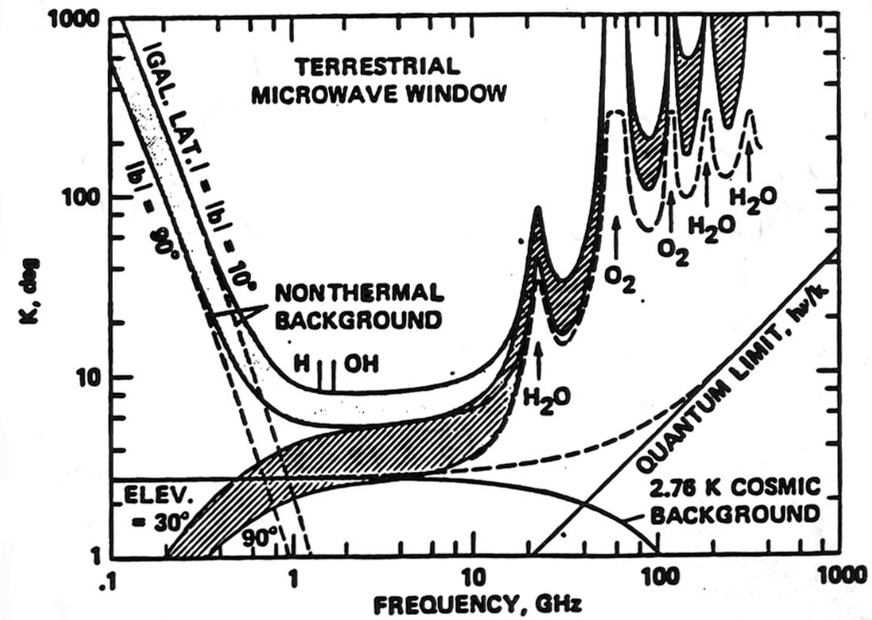


ν = (GHz)

10^9 Hz



Free-space microwave window, in which the basic noises that limit radio communication over interstellar distances are least disruptive.



Terrestrial microwave window. Atmospheric water vapor and oxygen degrade the upper end of the microwave window for receivers on Earth's surface and raise the temperature in the lower portion of the window.

Search Range: 1-100 GHz if no atmosphere

1-10 GHz if atmosphere like ours

Can we narrow it down?

Magic Frequencies

1. Morrison & Cocconi 1959

   $\nu = 1.42$ GHz $\lambda = 21$ cm

   H atoms

2. Water "Hole" (Sagan and Drake)

   OH 1st molecule discovered at Radio λ

   $\nu = 1.6$ GHz

   $H + OH \longrightarrow H_2O$

   Low Noise "Hole"

   1.4 1.6 GHz

3. Kuiper - Morris

Use fundamental constants

$$\nu = \frac{c}{\text{length}}$$

all very high ν

Most plausible is electron “radius”

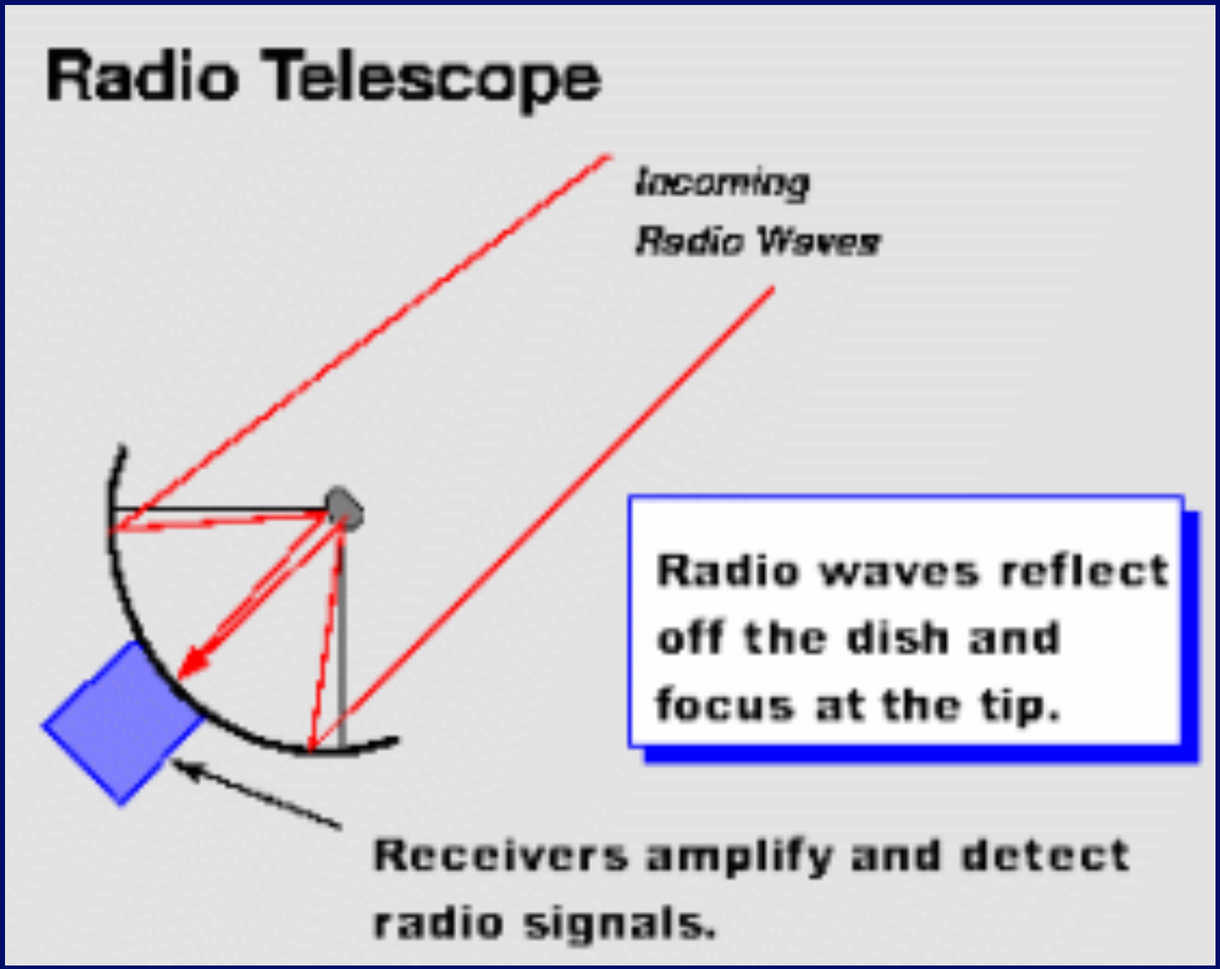
Scale by powers of “fine structure constant”

$$\sim \frac{1}{137}$$

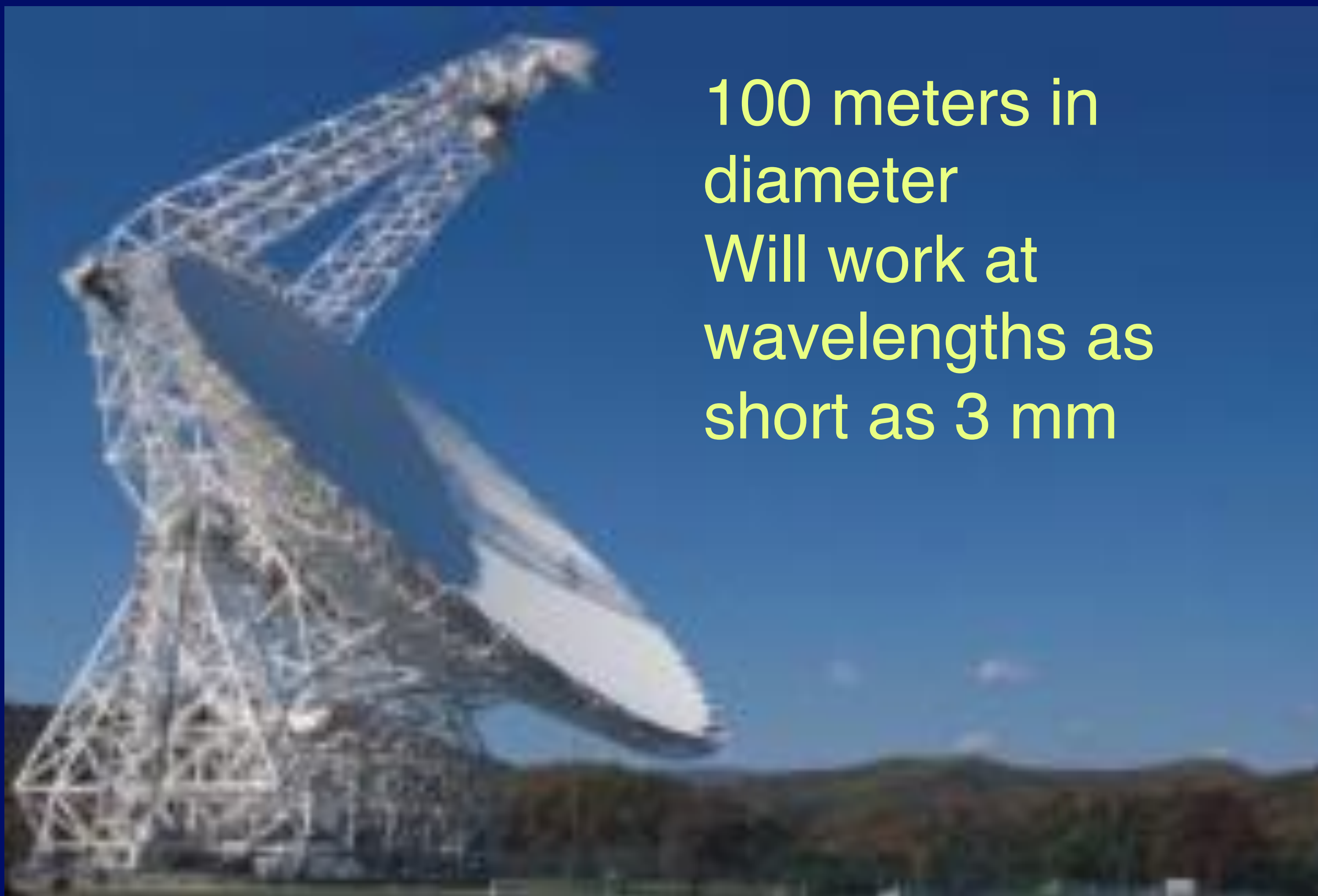
(if multiply 5 times, get to radio)

$$\longrightarrow \quad \nu = 2.5568 \text{ GHz}$$

Radio Telescope Principle



Green Bank Telescope (GBT)



100 meters in diameter
Will work at wavelengths as short as 3 mm

Arecibo Telescope

300 meters in diameter,
Will work at wavelengths as short as 6 cm.

Very Large Array (VLA)

26 telescopes each 25 meters in diameter
Will work at wavelengths as short as 7 mm

Very Long Baseline Array (VLBA)

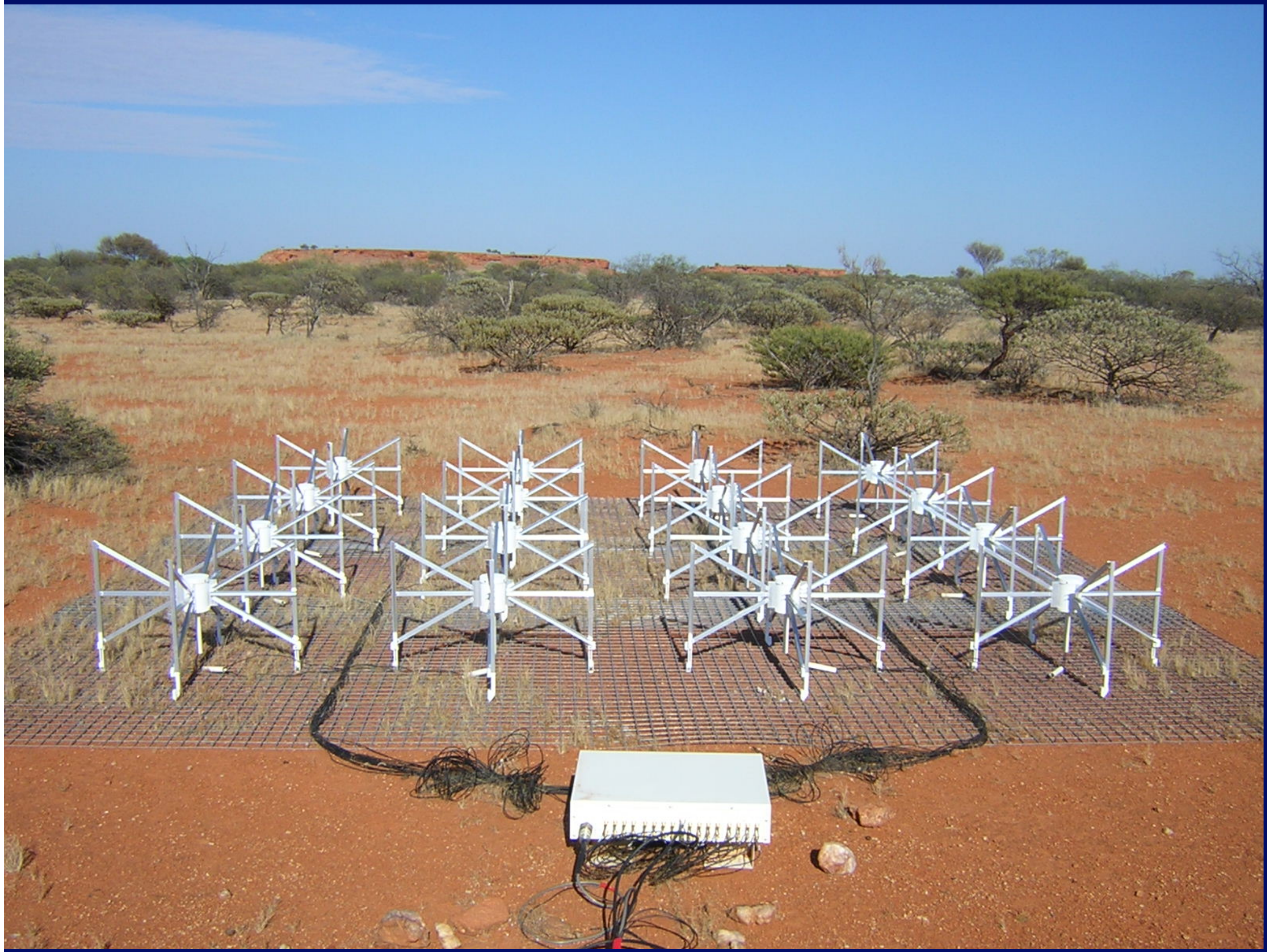
Atacama Large Millimeter Array (ALMA)

50 telescopes, each 12 meters in diameter, at 16000 feet
Will work at wavelengths as short as 0.35 mm

Allen Telescope Array (ATA)

First major telescope designed for searching for signals from other civilizations.
Initial funds from Paul Allen (Microsoft)

MWA: Western Australia



Works at low frequency
Biggest problem is artificial noise.
Locate in very remote region of W. Australia
No radio, TV, mobile phone, …

Recognizing the Message

Distinguishing from natural "signals":

Expect: Variation with time, narrow band (small range of freq.)

Crucial → Not random noise

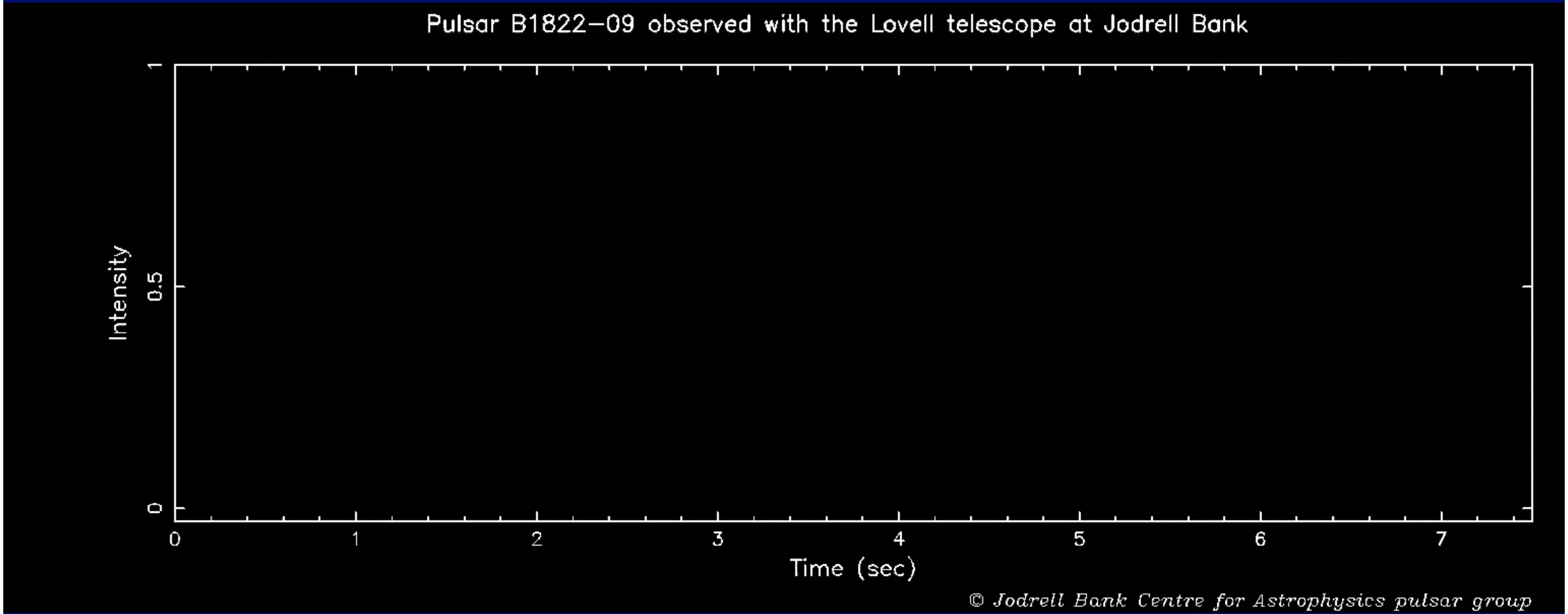
If not random, it is artificial (ETI or Human)

Examples of natural signals that <u>might</u> have been ETI

1. Pulsars (LGM)
2. OH Masers

Both are random noise (no coded information)

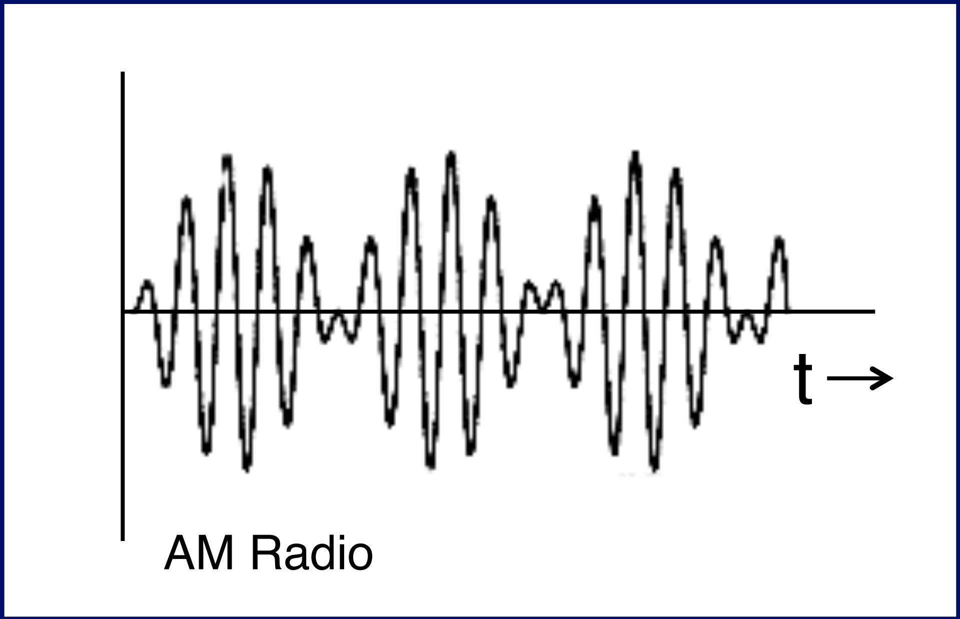
Recording of Pulsar



Coding the Message

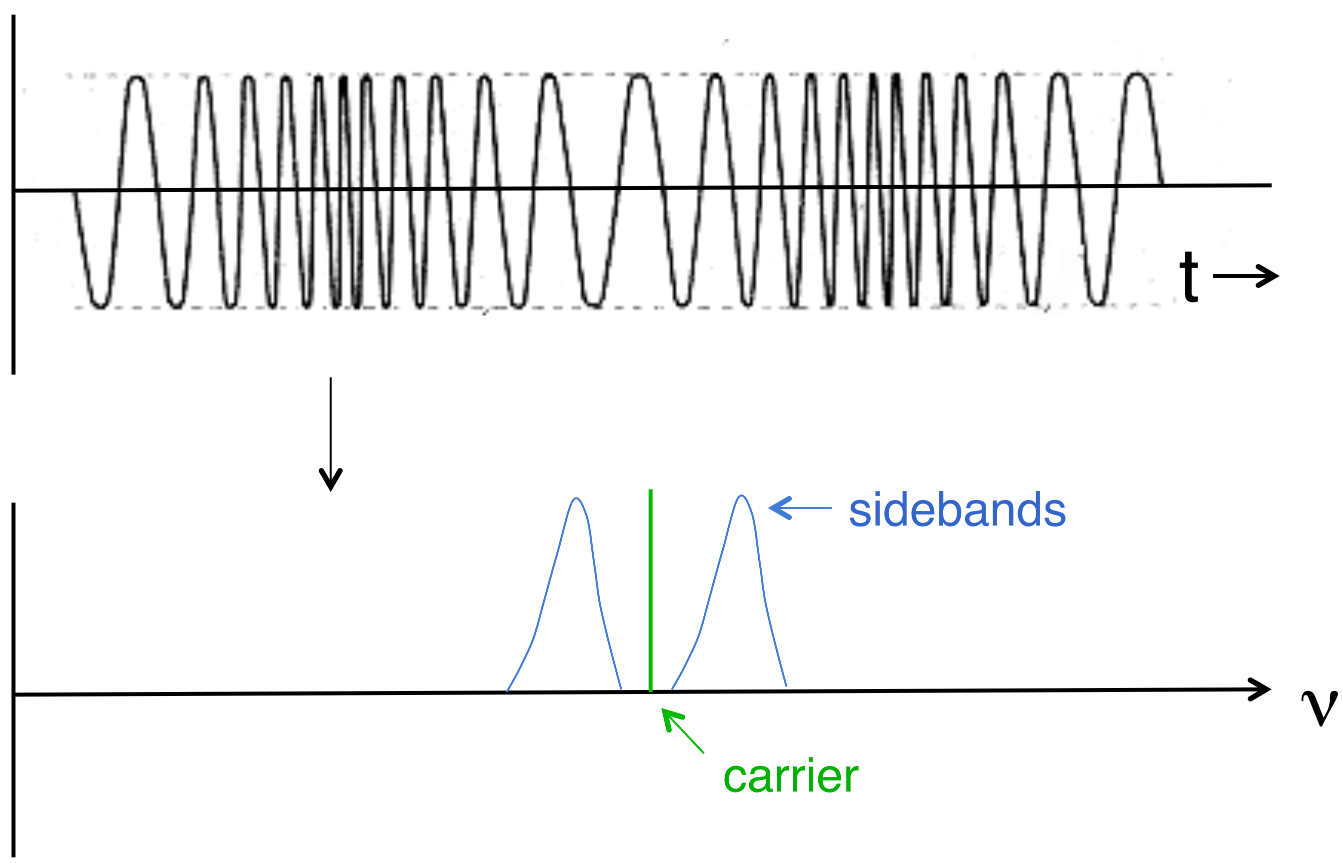
Change the signal with time

1. Amplitude modulation (AM)

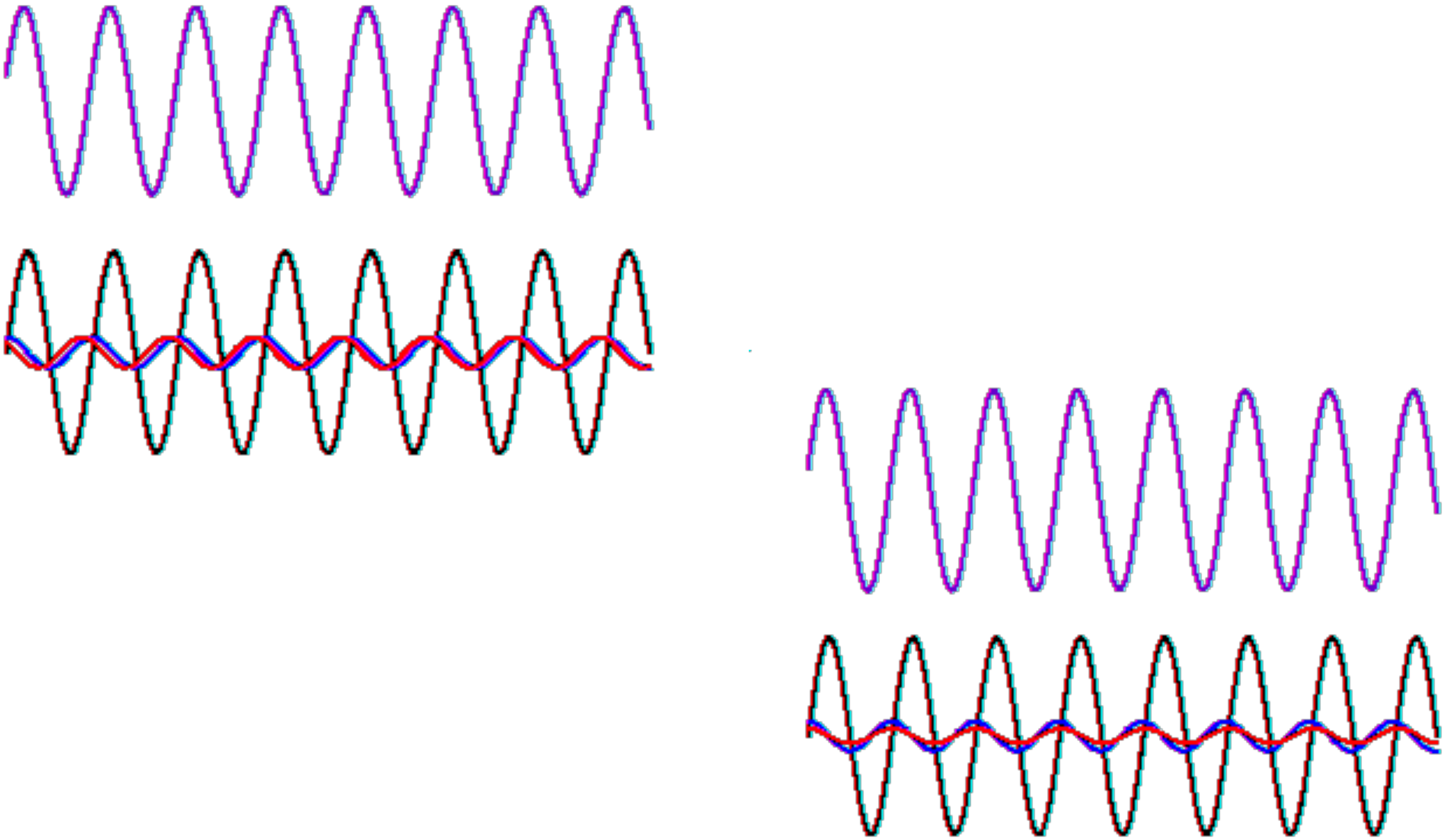


Coding the Message

2. Frequency Modulation (FM Radio)



Coding the Message



http://www.chem.tamu.edu/rgroup/north/FM.html

Analog vs. Digital

1. Analog - need accurate amplifiers, etc.
   to avoid distortion
   e.g. radios, television (until recently), records, analog tapes

2. Digital - “digitize” signal
   Represent by Base 2 Number

Base 10	Base 2
0	0
1	1
2	10
3	11
4	100
⋮	⋮

Analog vs. Digital

Send one digit at a time so electronics just need to Distinguish 1 from 0

Can use 2 very different voltages, amplifiers do not have to have “high fidelity”

Need fast digital electronics, now available

e.g. CD’s, DVDs, MP3, iPods, Computers, Digital Tapes, Digital TV, … just about everything!

Decoding the Message

Assume Digital

Repeat to Establish Pattern

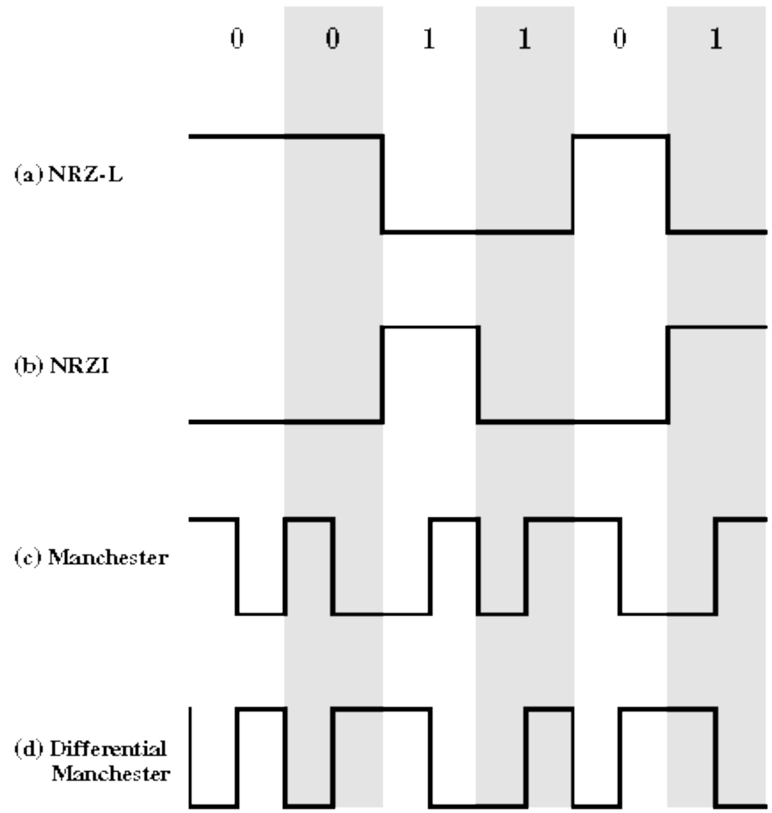


Figure 5.5 Examples of Digital Signal Encoding Schemes

Image? 1 dimension (string of bits)

↓

2 dimensions

Rows + columns

Make product of # rows + # of columns

each a prime number

e.g., $23 \times 73 = 1679$ so 23 rows, 73 columns

or vice versa

Semantics

Can we **understand** the message?

0 0 0 0 0 0 1 0 1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1 0 1 0
0 0 0 0 0 0 1 0 0 1 0 0 0 1 0 0 0 1 0 0 0 1 0 0 1 0 1 1 0 0 1 0 1 0 1 0 1
0 1 0 1 0 1 0 1 0 1 0 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
1 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 1 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0
1 1 1 0 0 0 1 1 0 0 0 0 1 1 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 1 0
0 0 0 1 1 0 1 0 0 0 1 1 0 0 0 1 1 0 0 0 0 1 1 0 1 0 1 1 1 1 1 0 1 1 1 1 1
0 1 1 1 1 1 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 1 0 0
0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 1 1 0 0 0 0 1 1 0 0 0 0 1 1 1 0 0 0 1 1 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0
0 0 0 0 0 0 1 0 0 0 0 1 1 0 1 0 0 0 0 1 1 0 0 0 1 1 1 0 0 1 1 0 1 0 1 1 1
1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0
0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0
1 1 1 1 1 1 0 0 0 0 0 1 1 0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 1 1 0
0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1
0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 0 0 0 0 1 1 0 0 0 0 0 0
1 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 1 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 1 1 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 1 0 0 0 0 1 1 0 0 0 0 0
0 0 0 0 1 1 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 1 0 0 0
0 0 0 0 0 1 0 0 0 0 0 1 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0
0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0
1 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0 0 0
0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0
0 1 0 0 0 1 1 1 0 1 0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 1 0 0 0 0
0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0
0 1 0 1 1 1 0 1 0 0 1 0 1 1 0 1 1 0 0 0 0 0 0 1 0 0 1 1 1 0 0 1 0 0 1 1 1
1 1 1 1 0 1 1 1 0 0 0 0 1 1 1 0 0 0 0 0 1 1 0 1 1 1 0 0 0 0 0 0 0 0 0 1 0
1 0 0 0 0 0 1 1 1 0 1 1 0 0 1 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1 1 1 1 1 1 0 0
1 0 0 0 0 0 0 1 0 1 0 0 0 0 0 1 1 0 0 0 0 0 0 1 0 0 0 0 0 1 1 0 1 1 0 0 0
0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0
0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 1 0 1 0 0 0 1 0 1 0 1 0 1 0 1
0 1 0 0 1 1 1 0 0 0 0 0 0 0 0 0 1 0 1 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 0
0 0 0 1 1 1 1 1 1 1 1 1 0 0 0 0 0 0 0 0 0 0 0 0 1 1 1 0 0 0 0 0 0 0 1 1 1
0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 0 0 0 0 1 1 0 0 0 0 0 0 0 1 1 0 1 0 0
0 0 0 0 0 0 0 1 0 1 1 0 0 0 0 0 1 1 0 0 1 1 0 0 0 0 0 0 0 1 1 0 0 1 1 0 0
0 0 1 0 0 0 1 0 1 0 0 0 0 0 1 0 1 0 0 0 1 0 0 0 0 1 0 0 0 1 0 0 1 0 0 0 1
0 0 1 0 0 0 1 0 0 0 0 0 0 0 0 1 0 0 0 1 0 1 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0
0 1 0 0 0 0 1 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 1 0 0
0 0 0 0 0 0 0 0 0 0 0 0 1 0 0 1 0 1 0 0 0 0 0 0 0 0 0 0 0 1 1 1 1 0 0 1 1
1 1 1 0 1 0 0 1 1 1 1 0 0 0

Figure 19.12 The message sent in 1974 from the Arecibo telescope in the direction of the globular cluster M13 consists of 1679 bits of information, either "on" or "off," shown here as 0's and 1's.

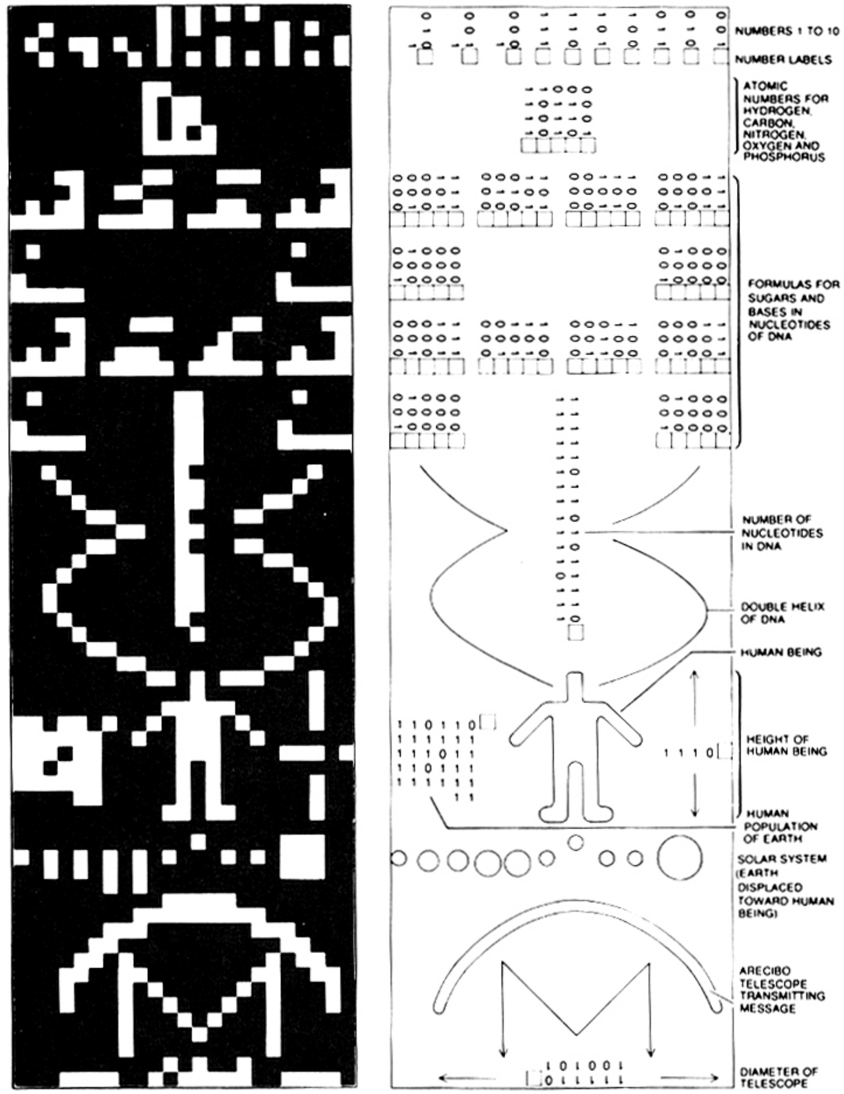


Figure 19.13 If the 1679 bits of the Arecibo message are arranged into 23 columns of 73 rows each, and if the on and off bits are given different colors, a picture emerges that is loaded with information—for those who can decipher it.

Summary

- Electromagnetic radiation (light) is much cheaper than sending material objects
- Radio waves have advantages
  - 1-100 GHz (ignoring atmosphere)
  - 1-10 GHz with atmosphere like Earth
- Digital coding likely, can make 2D (or 3D)
- Prime numbers