Communication
Communication

Much cheaper than travel

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

\[ E = \frac{1}{2} Mv^2 \]  if \( v \) much less than \( c \)

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

\[ \Rightarrow v = 0.1 \, c \quad \Rightarrow \quad E = 4.1 \times 10^{-9} \text{ ergs} \]

for \( M = M \) (electron)
Photon \quad E = h\nu \quad h = 6.6 \times 10^{-27} \text{ erg-sec} \\
\nu = \text{frequency} \\
E = 6.6 \times 10^{-18} \text{ ergs} \quad \text{if } \nu = 10^9 \text{ Hz} \\
\text{Ratio } \sim 10^9 \quad (\text{and photon gets there in 4 yrs})

100 \text{ Megawatt transmitter - 1 yr} \\
$40 \times 10^6$

\text{Spacecraft to nearest star} \\
\sim $5 \times 10^{16}$

(some analysis questions this conclusion)
Light is an Electromagnetic Wave

Electric Field: Indicates force on charged particle

E field  \[\rightarrow\]  Force

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

Motion of wave

Vertically Polarized

Horizontally Polarized

Circularly Polarized
Wave Properties

Snapshot

Distance or Phase

$A = \text{Amplitude}$

$\lambda = \text{Wavelength}$
Wave Properties

Look at one point along wave

\( \nu = \text{frequency} = \frac{1}{\text{period}} \)

# of cycles per second (hertz, Hz)

1 kHz = 10^3 Hz
1 MHz = 10^6 Hz
1 GHz = 10^9 Hz

Speed of light

\[ c = \lambda \nu \Rightarrow \lambda = \frac{c}{\nu} \]
Wave Demo
Electromagnetic Spectrum (Light)

- **Gamma rays**
- **X rays**
- **Ultraviolet light**
- **Visible light**
- **Infrared light**
- **Radio waves**

**Wavelength** ($\lambda$) decreases as frequency ($\nu$) increases. Higher frequencies require more energy per photon ($E = h\nu$). Gamma rays penetrate better than radio waves.
Noise: Any unwanted signal
Artificial, Natural

Noise (K)

Frequency (GHz)

\( \nu = \text{(GHz)} \)

10^9 \text{ Hz}
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
   \( \nu = 1.42 \text{ GHz} \quad \lambda = 21 \text{ cm} \)
   H atoms

2. Water “Hole” (Sagan and Drake)
   OH 1st molecule discovered at Radio \( \lambda \)
   \( \nu = 1.6 \text{ GHz} \)
   \( \text{H} + \text{OH} \rightarrow \text{H}_2\text{O} \)
   Low Noise “Hole”
   1.4 \quad 1.6 \text{ GHz}
3. Kuiper - Morris

Use fundamental constants

\[ \nu = \frac{c}{\text{length}} \] all very high \( \nu \)

Most plausible is electron “radius”

Scale by powers of “fine structure constant”

\[ \sim \frac{1}{137} \] (if multiply 5 times, get to radio)

\[ \rightarrow \nu = 2.5568 \ \text{GHz} \]
Radio Telescope Principle

Radio waves reflect off the dish and focus at the tip.

Receivers amplify and detect radio signals.
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 might have been ETI
1. Pulsars (LGM)
2. OH Masers

Both are random noise (no coded information)
Recording of Pulsar

Pulsar B1822−09 observed with the Lovell telescope at Jodrell Bank

© Jodrell Bank Centre for Astrophysics pulsar group
Coding the Message

Change the signal with time

1. Amplitude modulation (AM)

AM Radio
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

<table>
<thead>
<tr>
<th>Base 10</th>
<th>Base 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
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<tr>
<td>2</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>100</td>
</tr>
</tbody>
</table>

...
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

\[ 23 \times 73 = 1679 \]  
so 23 rows, 73 columns
or vice versa

Semantics
Can we understand the message?
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