Communication by Radio

Advantages:
- Speed: velocity of light exceeds physical transportation speeds
- Cost is small compared to space voyages or probes

Commonly used bands in the radio spectrum.

What determines the choice of communication frequency?
1. Economy: cost per photon proportional to energy and frequency
2. Freedom from interference: sum of galactic background, cosmic background quantum limit; atmospheric absorption eliminated from space-based radios
3. Cosmic guideposts: e.g., “cosmic waterhole” between H spin-flip (1420 MHz) and OH lines (1600–1700 MHz)
UNITED STATES FREQUENCY ALLOCATIONS
THE RADIO SPECTRUM

RADIO SERVICES COLOR LEGEND

ACTIVITY CODE

ALLOCATION USAGE DESIGNATION

U.S. DEPARTMENT OF COMMERCE
FCC

Lattimer, AST 248, Lecture 24 – p.2/16
Radio Telescopes

Grote Reber, first parabolic dish
Wheaton, IL 1937

Green Bank Telescope
Largest fully steerable dish
Radio Telescopes

Arecibo Radio Telescope
Largest single-aperture telescope

VLA - Very Large Array
Socorro, New Mexico
Communication by Radio

Sources of interference. “Total” is the sum.
Communication by Radio

Signal and Noise, Bandpass
Need to select particular frequency (channel center) and bandpass (channel width).

• An optimum receiver has bandpass equal to signal’s. Too large bandpass admits extraneous noise. Too small bandpass excludes some signal.

• Narrower signal of given power has higher signal-to-noise.

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\text{Number of channels} = \frac{\text{Frequency range}}{\text{Bandpass}}.
\]

The cosmic waterhole alone has frequency range 1721 MHz - 1420 MHz = 301 MHz. With 1 MHz bandpass, number of channels = 301. With 1 Hz bandpass, number of channels = 301 million.

• Minimum bandpass width of about 0.1 Hz set by electron density in interstellar medium. In window from 1000 MHz to 100,000 MHz, there are 1 million million channels of .1 Hz width. Also must consider frequency drift caused by Doppler shifts due to relative velocities of home and alien planets.
History of SETI

• Early pioneers were Guglielmo Marconi (1874 - 1937) and Nikola Tesla (1856 - 1943), Marconi made radio practical and sent first transatlantic radio communications. Tesla invented fluorescent lights and developed AC as an energy delivery system. Both felt they were receiving radio signals from Martians.

• Giuseppe Cocconi and Philip Morrison began modern SETI around 1959, and developed the idea of the cosmic waterhole hypothesis, that civilizations would use the hydrogen spin-flip frequency of 1420 MHz as a guidepost for their own signals.

• Separately, Frank Drake began using the Green Bank Radio Observatory in 1960 to search for radio signals from \( \tau \) Ceti and \( \epsilon \) Eridanii, two solar-like stars about 12 light-years away (Project Ozma).

• In 1963, NASA funded a SETI program at Ohio State University, later taken over by the University itself.

• NASA developed a small SETI program in 1971, and developed sophisticated radio technologies to search for it. In 1974 a symbolic attempt was made to send a message to other stars from Arecibo.

• In 1979, Berkeley launched a SETI project SERENDIP, replaced in 1986 by SERENDIP II. These were followed by SERENDIP III, IV and V.

• In 1980 the US Planetary Society was founded and has supported SETI.

• Project Sentinal was started at Harvard and MIT in early 1980’s using the first multi-channel analyzers. This was followed by project META, META II and BETA.
History of SETI

• Congress cancelled the NASA program, called Microwave Observing Program, in 1992. Since then work has continued with private funding as Project Phoenix at the SETI Institute.

• The SETI League was formed in 1994 and converted backyard satellite TV dishes into radio telescopes to run an all-sky survey for signals. This is being continued under Project Argus as a complement to Project Phoenix.

• SETI@HOME began at Berkeley in 1999.

• The first part of the Allen Telescope Array started in 2007 by Berkeley and the SETI Institute. It supports a large number of simultaneous observations using multibeamng and DSP technology to sort out individual signals from multiple directions and dishes. Full array planned to consist of 350 or more Gregorian radio dishes, each 6.1 m diameter, equivalent to a single dish 114 m diameter.

Signal Categories

• Broadcast of local communications on world where aliens live.
• Signals used for communication between alien’s home world and another site.
• Intentional signals or beacons
Eavesdropping: Detection of “stray” radio signals from extraterrestrials.

Left: “Leakage” of radio waves from the surface of the Earth.

Right: Simulated pattern of radiation that repeats on a daily basis.
Decoding a Signal

- Assuming we figure where in the sky to look, at which frequency, and what bandpass, we still need to decode the signal.

- Large number of ways to encode a signal: amplitude and frequency modulation, for example. Simplest choice is to use a pulsed beam containing bits of information which is repeated at intervals.

- There is an advantage in conveying information using pictures, i.e., 2-dimensional patterns of black/white bits. “A picture is worth a thousand words”, and we don’t know what the words mean anyway. Two prime numbers for the dimensions is an obvious way to show that a data stream containing that number of bits was a picture.
Decoding the M13 Message

• The radio message beamed to globular cluster in Hercules was composed of 1679 bits arranged into 23 columns of 73 bits each. If it is decoded as 73 columns of 23 bits each it appears jumbled. This indicates that the decoding is unambiguous.

• The top rows show binary counting with an error bit at the end of each number.

• Next is a single block containing the sequence of numbers: 1, 6, 7, 8 and 15, representing the elements of life: H, C, N, O and P.

• Next are 12 groups of 5 numbers, each being the numbers of these 5 atoms in the monomers deoxyribose sugar, phosphate and bases in DNA.

• The next central vertical clump is a long number (about 4 billion) representing the number of nucleotides in DNA. It is surrounded by a graphical representation of the double helix structure which points to a pictograph of a human.

• His/her height is given as 14 units, indicated by the architectural arrows and the number 14 on the human’s right-hand side. The length unit is 12.6 cm, the wavelength of the radio message.

• The total population of humans is indicated by the number 4 billion shown to the left of the human.

• Then comes a pictograph of the Solar System with the crude relative size of each planet. The Earth is displaced toward the human, showing their origin.

• Below this is a pictograph of the radio telescope.

• The center of the lowest rows contain the number 2430 which represents the telescope’s diameter \((2430 \times 12.6 \text{ cm}=306 \text{ m})\). On each side are “architectural” arrows to show this is a diameter measurement.
Non-Radio SETI Strategies

- Optical SETI
  - Proposed using lasers as long ago as 1961.
  - Although lasers are monochromatic, making it difficult to figure out what frequency to use, pulsing them spreads the signal out in wavelength.
  - A disadvantage is that lasers are highly directional; Earth would have to be in the direct line of site to see the signal.
  - Initially thought to be too energy expensive and limited by dust absorption, studies show that an infrared laser pulse coupled with a large focus mirror would appear tens of thousands as times as bright as the Sun and could penetrate for thousands of light years.
  - Pulses could carry information as bits.
  - A system could automatically target a list, correcting for proper motions.
  - Soviets have done short optical SETI searches.
  - Harvard-Smithsonian has operated a piggyback optical SETI search on a conventional all-sky survey, and is now building a dedicated system.
  - Berkeley is also conducting optical SETI searches.

- Probe SETI
  - Interstellar message probes could be cheaper and more efficient, suggesting that a Search for Extraterrestrial Artifacts (SETA) is favored over SETI.
  - Lagrangian points are favored parking places as opposed to random orbits.
  - Dyson spheres or swarms would be infrared luminous and unambiguous.
  - SETA projects were undertaken as early as 1979 and continue to the present.
UFO’s

Classification Scheme (Hynek)

- Nocturnal lights
- Daylight disks
- Radar-visual sightings
- Close Encounters of the First Kind—detailed visual sightings of an unidentified object
- Close Encounters of the Second Kind—visual sightings plus physical effects on living or inanimate objects.
- Close Encounters of the Third Kind—these also include visual sightings of “occupants” in or around a UFO.
- Close Encounters of the Fourth Kind—where there is physical contact with occupants
Evidence

What evidence would be sufficient from scientific viewpoint?

- Occupants visible to crowds of people.
- Examination of a device, such as an antigravity machine, an interstellar spacecraft, a positronic robot, or a phaser
- Indisputable photographic or spectroscopic evidence of a spacecraft

Related Issues:

- Enormous distances to other civilizations, both in space and in time.
- Lack of numerous UFO reports in China and India
- Lack of UFO reports by professional and amateur astronomers, who probably spend more time examining the sky than any other groups
- Government coverup?
- The fact that 90% of well-documented UFO cases are explainable as earthly phenomena does not signify that the remaining 10% are due to alien visitations.
- Previous visits by extraterrestrials?
- Difficulty in interpreting writings and pictures of ancient civilizations underscores difficulty in deciphering any extraterrestrial communications
Some Case Studies

1947 - Washington State  
Kenneth Arnold, from a private plane near Mt. Ranier, spotted 9 shiny objects having wings but no tails streaking across the sky. A UP reporter described these as “flying saucers” and it became headline news. Ironic, since Arnold didn’t describe them as discs at all. Now thought to have been due to a meteor swarm penetrating atmosphere.

1947 - Roswell, New Mexico  
Just a few weeks later, a rancher found debris in a pasture near Roswell Army Air Field. Military personnel recovered debris, first reported as being due to a flying disc, but quickly retracted and replaced by a crashed weather balloon. Nothing came of this for 31 years, when Stanton Friedman (ufologist) claimed alien occupants were also recovered. All evidence came from testimonies, not hard evidence. Declassified government records say the crash was a secret military balloon experiment from Project Mogul, designed to detect distant nuclear explosions. This has been verified by the scientist in charge at the time. There is no evidence for alien recovery. How could such a cover-up conspiracy have remained secret for 60 years in spite of the hundreds of people who would have had to take part in it?
Some Case Studies

Crop circles  Geometric patterns usually made in wheat fields, most often in England. Despite the speed with which they appear and the condition of the matted-down wheat, said to be inconsistent with trampling, nearly all circles can be shown to be easily made using boards, ropes and other simple tools; indeed, many have been shown to be deliberate hoaxes. It is suspicious that the designs are getting more complicated each year, hardly the pattern of aliens bringing sophisticated technology from light-years away, and that the circles are made only at night.

Cattle mutilation  Despite a long history of attacks on farm animals by humans and predators, aliens have often been implicated. But no real evidence for this exists.

Abductions  Americans lead in this phenomenon, despite a small percentage of the world’s population. Nearly all abductees are taken while sleeping, and returned in the same state. Actually, such phenomena have often been reported dating back to ancient cultures, but the culprits then were witches, ghost babies and goblins rather than aliens. Many psychologists attribute the stories to sleep paralysis. No artifacts or sophisticated surgeries have ever accompanied the abductees.

Ancient visitations  Evidence offered consists of ancient drawings that supposedly show alien visitors or spacecraft, or ancient wonders apparently beyond the means of ancient cultures. Examples are the giant drawings on the Nazca plains of Peru, which were certainly not beyond the means of the Nazca Indians, and the patterns could easily be costumes. Another often-cited example are the Egyptian pyramids, which is insulting to the ancient Egyptian culture. It has been well-documented that such structures were well within their capabilities, especially considering the vast supplies of slaves in the society. Similar arguments pertain to the Mayan pyramids, Stonehenge and the stone heads of Easter Island.