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# *Riding the Waves*

Alex Hills

Courtesy of Alex Hills

**Key Concepts**
**from Previous Chapters**

- 18 Radiation
- 25 Signals

My whole life, I've been driven by a desire to explore unknown lands and cultures. When I was a teenager growing up near New York City, I started using shortwave radio to "travel" to exotic destinations—without ever leaving my home. My friends and I sat in my bedroom and sent out Morse code messages to other "ham" radio operators around the world. Little did I know then that my passion for radio would contribute to a revolution in the way people communicate.

My name is Alex Hills, and I'm a professor of engineering and public policy at Carnegie Mellon University in Pittsburgh, Pennsylvania. I've spent a lot of time in Alaska, though, where I've worked on developing satellite communications systems. I'm also one of the originators of wireless fidelity, or "Wi-Fi"—the technology that allows you to access the Internet from your laptop without wires.

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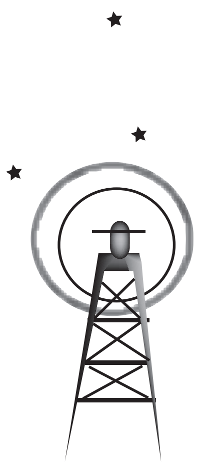
Here I am in the 1970s.

I studied electrical engineering and communications at Rensselaer Polytechnic Institute in New York. Soon after graduation, I got a job working as a design engineer for IBM on a "super computer" called the System 360 Model 95. At the time, it was the largest and fastest computer in the world, and it occupied almost an entire room. But working in an office didn't satisfy my urge to travel or my quest for adventure.

After receiving a graduate degree in electrical engineering from Arizona State University, I was offered a chance to build and manage one of the first public radio stations in Alaska. How could I possibly turn down an opportunity that included adventure, radio, and engineering? So, at the age of 28, I headed to Alaska. Two years later, I became the field leader of an RCA Alaska Communications Project, building a telephone network for people living in the Alaskan bush. My job was to provide a way for people in these remote regions of Alaska to communicate with the rest of the state.

In 1970, Alaska did not have a telecommunications network, except in cities like Anchorage, Fairbanks, and Juneau. In the cities, people lived close together, so it was economically practical to install telephone cables and build a telephone system similar to those in the rest of the country.



But in the small outlying villages in the bush, the residents—who are mostly Native Alaskans such as the Inuit and Aleut—did not have telephone service. Their villages are small and separated by great distances. The villages are too far apart to lay telephone cable, so communicating with a relative often meant a long journey, perhaps over several hundred miles, and often by dog sled.

Because radio waves could find their way over the rough terrain to nearby towns, rural Alaskans would sometimes broadcast messages to their distant friends and families through a local radio station. They'd send messages out for all to hear. The messages would be about anything from asking for supplies to reminding relatives to take their medication.

The only other communication device that could transmit signals from village to village was shortwave radio. But simply outfitting all rural Alaskans with shortwave radios wouldn't solve the problem. Shortwave radio doesn't always work well in rural Alaska, because of the Aurora Borealis, the Northern Lights, which can interfere with shortwave radio signals.

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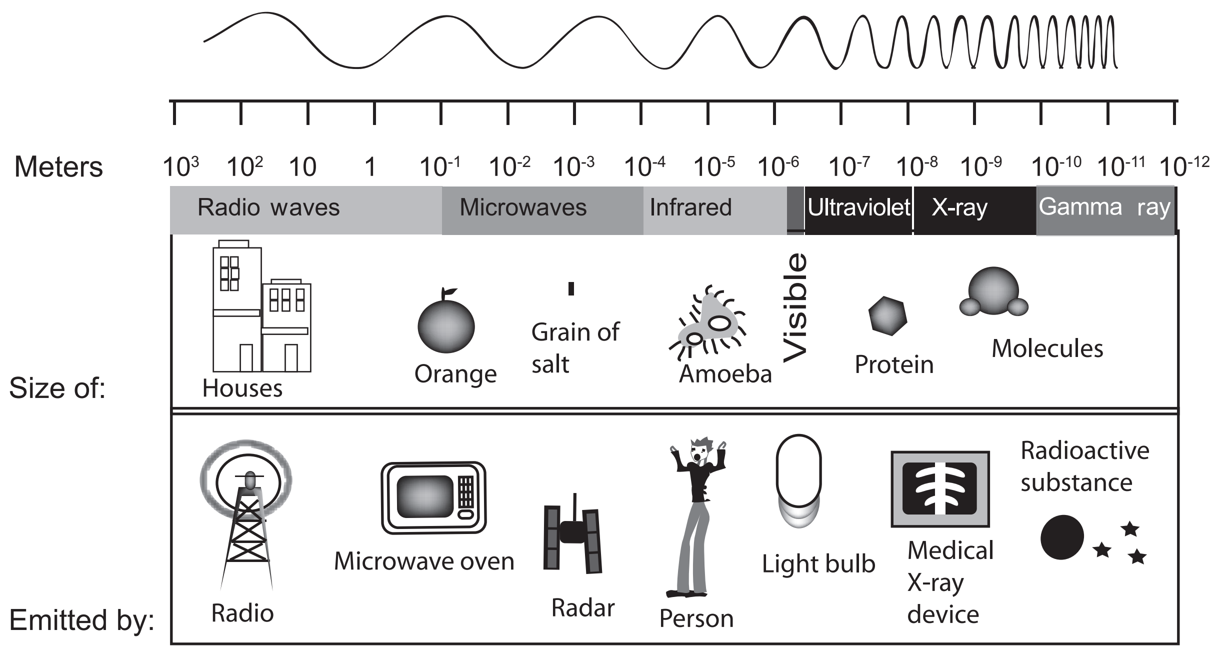
### The Electromagnetic Spectrum




To understand the problem, you have to take a closer look at what radio waves are. Radio waves are a type of electromagnetic radiation. As you can see in the chart above, there are many types of electromagnetic radiation, including visible light, X-rays, microwaves, and gamma rays. Electromagnetic radiation starts at a source, and then travels outward from the source in all directions.

***Electromagnetic radiation*** is often described as waves of energy. In the same way that electricity can carry an encoded signal, electromagnetic waves can also carry encoded signals. Electromagnetic radiation is very useful for transmitting information because it travels very fast. All electromagnetic radiation—from radio waves to gamma rays—travels at the speed of light, about 300,000 kilometers per second. And unlike electrical signals, electromagnetic radiation does not require wires. That's why it's ideal for wireless communication systems, such as radio, cell phones, satellites, and Wi-Fi systems.

In the drawing of a radio signal on the next page, you'll see that one ***wavelength*** is one complete wave, labeled as the distance from the peak of the one wave to the next peak. Radio wavelengths can be the length of a football field or the length of your foot. Radio waves have the longest wavelength of any wave on the spectrum.

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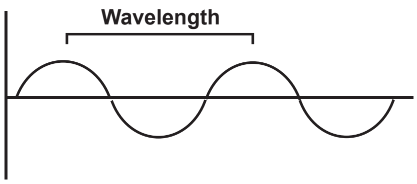
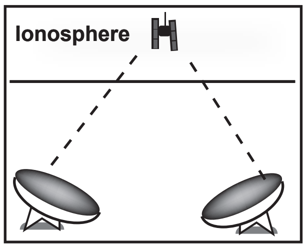
Radio waves also have the lowest frequency. Frequency refers to the number of complete wave cycles that occur in a unit of time, usually measured in Hertz, which is the number of cycles per second. When you listen to a radio station and hear the announcer say something like, “This is 93.9, The River,” the announcer is identifying the radio station broadcasting at a frequency of 93.9 megahertz (MHz). A megahertz is one million Hertz, so 93.9 megahertz means that the transmitter is sending out a radio wave at a frequency of 93,900,000 cycles per second.




Frequency and wavelength are inversely related. So, as the frequency of a wave increases, its wavelength decreases, and vice versa. If you look at the chart of the Electromagnetic Spectrum, you can see that very-low-frequency waves have wavelengths up to hundreds of meters long, while high-frequency waves have wavelengths of only a billionth of a meter!




**Wavelength**
is the length of one complete wave.

**Frequency**
is the number of waves per second.

As wavelength decreases, frequency increases.

Frequency and wavelength are important when designing a communications system that uses electromagnetic radiation. Wavelength certainly was an important piece of the puzzle in Alaska. Shortwave radio can travel long distances by bouncing off of a layer of the atmosphere called the ***ionosphere*** and angling back to Earth. The ionosphere contains many electrically charged particles. If the wavelength of a radio signal is greater than the spacing between charged particles, the radio signal arriving from the surface of the Earth can be reflected, or bounced off the ionosphere and sent back toward the Earth. However, in Alaska, the Aurora Borealis can interfere with this bounce. The Aurora Borealis is a disruption in the ionosphere caused by solar flares, storms on the surface of the sun.

Because these disruptions are unpredictable, shortwave radio was not a dependable solution for providing 24-hour communication in Alaska. Our team looked for another solution. We needed to find a wavelength that would work, but which one? The wavelength had to be small enough and the frequency high enough to be dependable. After researching many possibilities, we decided to use a satellite communication system.

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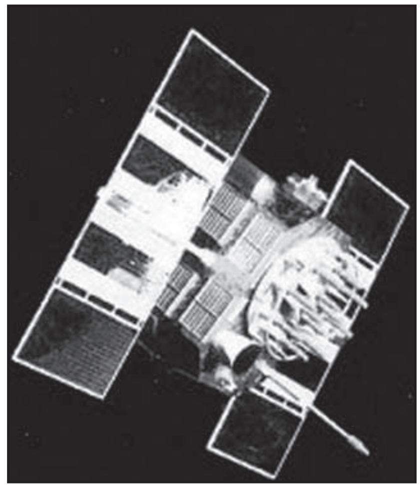
What's different about satellite systems? The satellites we used were located well above the ionosphere, approximately twenty-two thousand miles above sea level. And they operated at a frequency of four to six gigahertz (GHz)—four to six billion cycles per second—much higher than 30 MHz of the highest shortwave frequency. A higher frequency meant a much shorter wavelength, one that was not disrupted by solar flares. The radio signals sent at these high frequencies pass freely through the ionosphere to the satellite, which relays the signals back to an Earth station in Alaska.

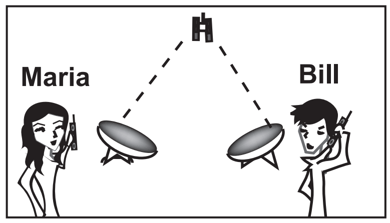


Courtesy of NASA

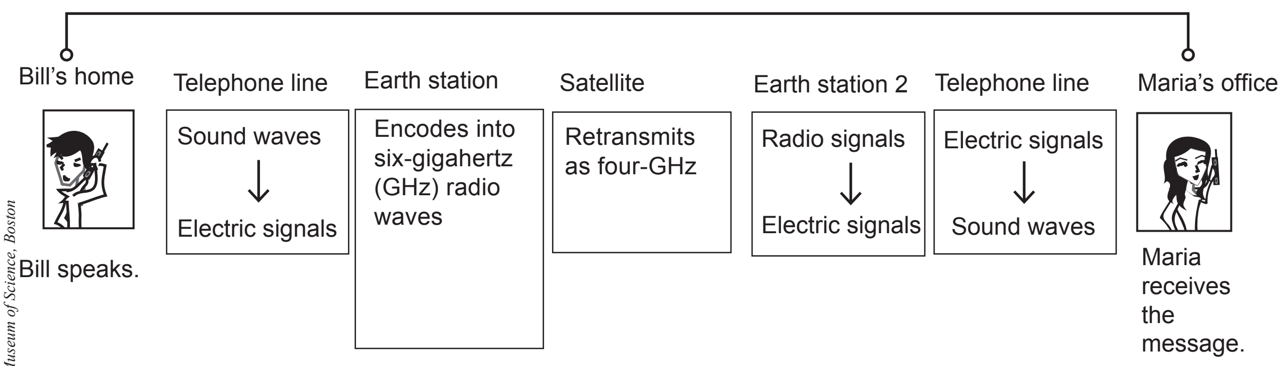
This satellite is used for Global Positioning Systems.

## How a Satellite Phone Call Works

Let's say that a bush pilot named Bill lives in an Alaskan village and is able to use a modern satellite network. Bill wants to call a biologist named Maria, who flies to remote regions of Alaska to observe polar bear populations. Maria lives 150 miles away from Bill in the city of Anchorage. When Bill calls Maria, the sound waves from his voice are encoded by the telephone into electrical signals. The signals are transmitted through telephone wires to an Earthbound transmission station. At the station, the transmitter translates the encoded electrical signal into six-GHz radio waves and attaches a receiving address for the second Earth station. Any type of information may be encoded in the signal. It could be research data, a CNN video stream, or music.




The six-GHz signal is sent to the satellite, which has a receiver that "listens" at that frequency for Earth station transmissions. As soon as the satellite receives the message, the satellite relays or retransmits that signal as a four-GHz signal. A second Earth station in Anchorage receives the signal containing Bill's words and converts the radio signal back into an electrical signal. The signal is sent by telephone line to Maria's office, where her telephone decodes the electrical signal back into sound waves that she can hear. The conversation continues this way in both directions: Bill's Earth station transmits his words at six-GHz, and the satellite sends them back down to Maria's Earth station at four-GHz.

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## Designing Outside the Box

Using satellites to communicate worked very well in Alaska, because the solution fit the circumstance. Faced with sparse population, long distances, and rough terrain, we needed to look for innovative ways to solve the communications problem.

Our solution solved the problems with providing telephone communications in the region. It also became the foundation on which we built the first Internet in Alaska. In 1987, the University of Alaska connected its fourteen remote campuses across the state using our satellite network. When telephone cables were unavailable, satellite communication links were used for long distances. In some cases, microwave systems moved information over shorter distances where no telephone cables could be laid. All of this was done between campuses in the same fashion as Bill and Maria's phone call.

Putting Alaska's information pipeline into place made many things possible. Doctors in rural areas were able to consult with doctors in cities using video connections. Satellite transmissions and Internet access made it possible for teachers in the cities to teach courses to students in remote villages. In many ways, the combination of wired and wireless communication technologies in Alaska gave us a glimpse of how wireless would later be used in computer networks.

Because of my experience in Alaska, I later advised Australia and Russia on how to improve their networks. I've also lectured on the subject at universities around the world, from South Africa and New Zealand, to Chile, and many more. Radio let me to travel to many unknown foreign lands in a way I never dreamed.

Courtesy of Carnegie Mellon University

To test the Wi-Fi system I developed, I moved my laptop around campus to see if I could stay connected to the Internet the whole time.

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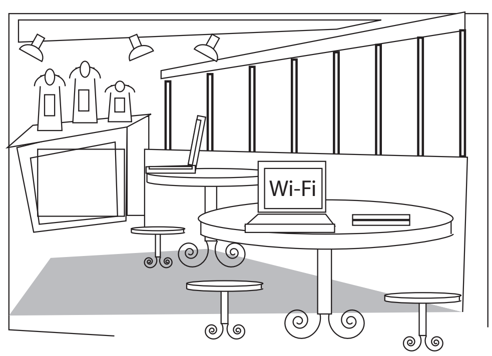
## Building a Wireless Network

If we could use radio waves to communicate wirelessly over long distances, it would make sense that we could use them over short distances as well. This idea led to the birth of Wi-Fi. In 1993 I started a project at Carnegie Mellon University in Pittsburgh called Wireless Andrew, which was the first wireless computing network.

Wireless Andrew allows anyone to carry a laptop computer anywhere on campus and connect to the campus network and the Internet. The laptop is equipped with a wireless network card—a transmitter-receiver combination that can send a signal by radio to a nearby access point. An access point is a radio transmitter-receiver that converts the radio waves into electrical signals and sends the signals to the wired part of the network. Access points may be placed anywhere in a room or building and can communicate with nearby computers.

Radio waves have become a very popular way to transmit information. Radio and television stations, cell phone networks, air traffic control systems, cordless telephones, and even garage door openers all use radio waves to communicate. How all of these different systems with millions of different users can all use radio waves without crossing signals very often is one of the beauties of the electromagnetic spectrum. Each device communicates using a specific frequency. You can observe this when you tune your radio in to a specific frequency to pick up a certain radio broadcast.

These technologies allow people to communicate between the most remote regions of our planet. I truly believe they are improving the quality of life for people all over the world by giving them access to medical information, educational resources, business contacts, and a lot more. And making the world a smaller place, at least from my perspective, only brings the adventure home.

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## What's the Story?

1. When Alex arrived in Alaska in 1970, why didn't people in the Alaskan bush have telecommunications services? How did rural Alaskans communicate over long distances?

2. How did Alex draw on his earlier work in Alaska when developing Wi-Fi technology?

## Designing with Math and Science

3. Why wouldn't shortwave radio solve the communications problem in rural Alaska? How did satellites solve the problem? Be sure to define the term "wavelength" in your response.

4. What is the frequency of the broadcast by your favorite radio station?

## Connecting the Dots

5. Draw a communications diagram of a typical Wi-Fi network call. Label the parts with the following terms: sender, receiver, signal, encoder, and decoder. Label where the signal is an electrical signal and where the signal is a radio wave.

6. Some rural Alaskan villages are not on the Alaskan power distribution grid. List a few ways that the towns might power the communications technologies they now use.

## What Do You Think?

7. Using the Internet and the library, find other common communications technologies that use radio waves. List at least three in addition to those mentioned in this chapter.

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