Main > Electronics > Telecommunications

How Cell Phones Work

by Julia Layton and Marshall Brain and Jeff Tyson

Millions of people in the United States and around the world use **cellular phones**. They are such great gadgets -- with a cell phone, you can talk to anyone on the planet from just about anywhere!

Digital cell phone from Nokia

These days, cell phones provide an incredible array of functions, and new ones are being added at a breakneck pace. Depending on the cell-phone model, you can:

- Store contact information
- Make task or to-do lists
- Keep track of appointments and set reminders
- Use the built-in calculator for simple math
- Send or receive e-mail
- Get information (news, entertainment, stock quotes) from the Internet
- Play simple games.
- Integrate other devices such as PDAs, MP3 players and GPS receivers

But have you ever wondered how a cell phone works? What makes it different from a regular phone? What do all those terms like PCS,

GSM, CDMA and TDMA mean? In this article, we will discuss the technology behind cell phones so that you can see how amazing they really are.

If you are thinking about buying a cell phone, be sure to check out **How Buying a Cell Phone Works** to learn what you should know before making a purchase.

One of the most interesting things about a cell phone is that it is actually a radio -- an extremely sophisticated radio, but a radio nonetheless. The telephone was invented by Alexander Graham Bell in 1876, and wireless communication can trace its roots to the invention of the radio by Nikolai Tesla in the 1880s (formally presented in 1894 by a young Italian named Guglielmo Marconi). It was only natural that these two great technologies would eventually be combined.

In the dark ages before cell phones, people who really needed mobile-communications ability installed **radio telephones** in their cars. In the radio-telephone system, there was one central antenna tower per city, and perhaps **25 channels** available on that tower. This **central antenna** meant that the phone in your car needed a powerful transmitter -- big enough to transmit 40 or 50 miles (about 70 km). It also meant that not many people could use radio telephones -- there just were not enough channels.

The genius of the cellular system is the division of a city into small **cells**. This allows extensive **frequency reuse** across a city, so that millions of people can use cell phones simultaneously.

A good way to understand the sophistication of a cell phone is to compare it to a CB radio or a walkie-talkie.

- **Full-duplex vs. half-duplex** - Both walkie-talkies and CB radios are **half-duplex** devices. That is, two people communicating on a CB radio use the same frequency, so only one person can talk at a time. A cell phone is a **full-duplex** device. That means that you use one frequency for talking and a second, separate frequency for listening. Both people on the call can talk at once.

- **Channels** - A walkie-talkie typically has one channel, and a CB radio has 40 channels. A typical cell phone can communicate on 1,664 channels or more!

- **Range** - A walkie-talkie can transmit about 1 mile (1.6 km) using a 0.25-watt transmitter. A CB radio, because it has much higher power, can transmit about 5 miles (8 km) using a 5-watt transmitter. Cell phones operate within **cells**, and they can switch cells as they move around. Cells give cell phones incredible range. Someone using a cell phone can drive hundreds of miles and maintain a conversation the entire time because of the cellular approach.

Library

Reference Links

> Cell Phone Batteries
> Phones
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> Canon PowerShot A620
> Canon PowerShot A85
> Cell Phones
> Cell Phone Number Lookup
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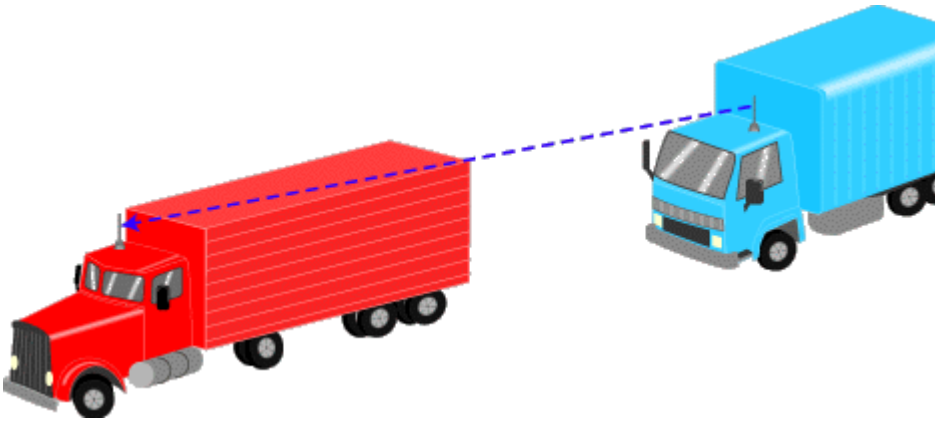
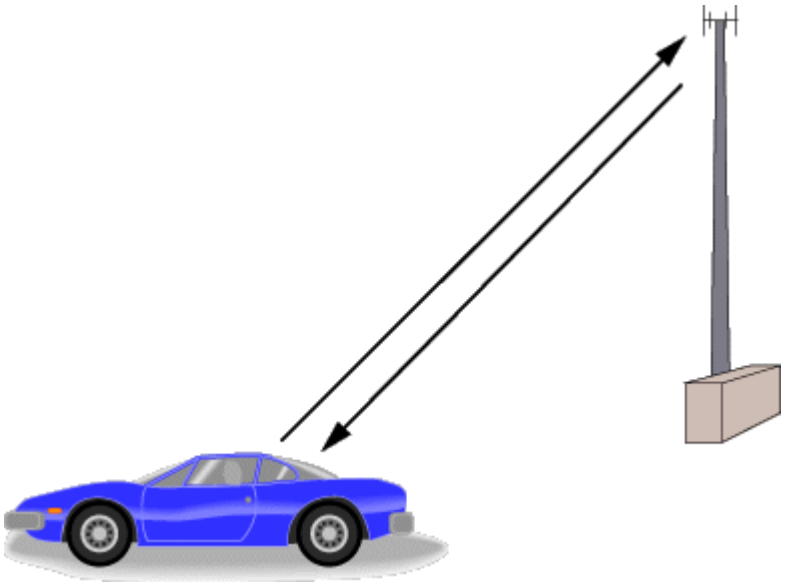
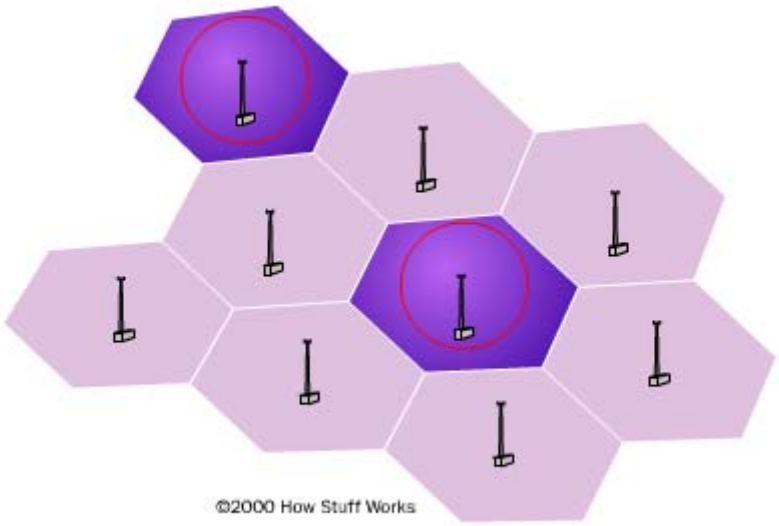


In half-duplex radio, both transmitters use the same frequency. Only on party can talk at a time.



In full-duplex radio, the two transmitters use different frequencies, so bo parties can talk at the same time.
Cell phones are full-duplex.

In a typical analog cell-phone system in the United States, the cell-phone carrier receives about **800** **frequencies** to use across the city. The carrier chops up the city into cells. Each cell is typically sized at about **10 square miles** (26 square kilometers). Cells are normally thought of as hexagons on a big **hexagonal grid**, like this:



Because cell phones and base stations use low-power transmitters, the same frequencies can be reused in non-adjacent cells. The two purple cells can reuse the same frequencies.

Each cell has a **base station** that consists of a tower and a small building containing the radio equipment (more on base stations later).

A single cell in an analog system uses one-seventh of the available duplex voice channels. That is, each cell (of the seven on a hexagonal grid) is using one-seventh of the available channels so it has a unique set of frequencies and there are no collisions:

- A cell-phone carrier typically gets **832 radio frequencies** to use in a city.
- Each cell phone uses two frequencies per call -- a duplex channel -- so there are typically **395 voice channels** per carrier. (The other 42 frequencies are used for **control channels** -- more on this later.)
- Therefore, each cell has about **56 voice channels** available.

In other words, in any cell, 56 people can be talking on their cell phone at one time. Analog cellular systems are considered first-generation mobile technology, or **1G**. With digital transmission methods (2G), the number of available channels increases. For example, a **TDMA-based** digital system can carry three times as many calls as an analog system, so each cell has about 168 channels available (see the section on Cellular Access Technologies for lots more information on TDMA, CDMA, GSM and other digital cell-phone techniques).

Cell phones have **low-power transmitters** in them. Many cell phones have two signal strengths: 0.6 watts and 3 watts (for comparison, most CB radios transmit at 4 watts). The base station is also transmitting at low power. Low-power transmitters have two advantages:

- The **transmissions** of a base station and the phones within its cell do not make it very far outside that cell. Therefore, in the

figure above, both of the purple cells can **reuse the same 56 frequencies**. The same frequencies can be reused extensively across the city.

- The **power consumption** of the cell phone, which is normally battery-operated, is relatively low. Low power means small batteries, and this is what has made handheld cellular phones possible.

The cellular approach requires a large number of base stations in a city of any size. A typical large city can have hundreds of towers. But because so many people are using cell phones, costs remain low per user. Each carrier in each city also runs one central office called the **Mobile Telephone Switching Office** (MTSO). This office handles all of the phone connections to the normal land-based phone system, and controls all of the base stations in the region.