

## The Cell Phone Technology

It would be useful to give an overview of the cell phone technology here as this is quite inline with our installation. Let's see how a cell phone works? What makes it different from a regular phone? What do all those confusing terms like PCS, [GSM](#), [CDMA](#) and [TDMA](#) mean?

Let's start with the basics: In essence, a cell phone is a radio. 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. 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:



A digital cell phone from [Nokia](#).

**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 on the next page.)
- 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. With digital transmission methods, 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 [this page](#) 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.

Now let's analyse what happens we as you (and your cell phone) move from cell to cell.

## From Cell to Cell

All cell phones have special **codes** associated with them. These codes are used to identify the phone, the phone's owner and the service provider.

Let's say you have a cell phone, you turn it on and someone tries to call you. Here is what happens to the call:

- When you first power up the phone, it listens for an **SID** (see sidebar) on the **control channel**. The control channel is a special frequency that the phone and base station use to talk to one another about things like call set-up and channel changing. If the phone cannot find any control channels to listen to, it knows it is **out of range** and displays a "no service" message.
- When it receives the SID, the phone **compares it** to the SID programmed into the phone. If the SIDs match, the phone knows that the cell it is communicating with is part of its **home** system.
- Along with the SID, the phone also transmits a **registration request**, and the MTSO keeps track of your phone's location in a database -- this way, the MTSO knows which cell you are in when it wants to ring your phone.
- The **MTSO** gets the call, and it tries to **find you**. It looks in its database to see which cell you are in.
- The MTSO **picks a frequency pair** that your phone will use in that cell to take the call.
- The MTSO communicates with your phone over the **control channel** to tell it which frequencies to use, and once your phone and the tower switch on those frequencies, the call is **connected**. You are talking by two-way radio to a

friend!

- As you move toward the edge of your cell, your cell's **base station** notes that your **signal strength** is diminishing. Meanwhile, the base station in the cell you are moving toward (which is listening and measuring signal strength on all frequencies, not just its own one-seventh) sees your phone's signal strength increasing. The two base stations coordinate with each other through the MTSO, and at some point, your phone gets a signal on a control channel telling it to change frequencies. This **hand off** switches your phone to the new cell.

**As you travel, the signal is passed from cell to cell.**

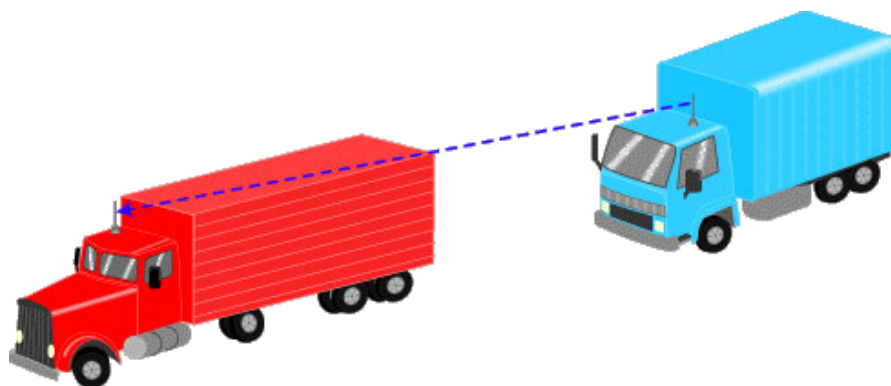
## Roaming

If the SID on the control channel does not match the SID programmed into your phone, then the phone knows it is **roaming**. The MTSO of the cell that you are roaming in contacts the MTSO of your home system, which then checks its database to **confirm** that the SID of the phone you are using is valid. Your home system **verifies** your phone to the local MTSO, which then tracks your phone as you move through its cells. And the amazing thing is that all of this happens within seconds!

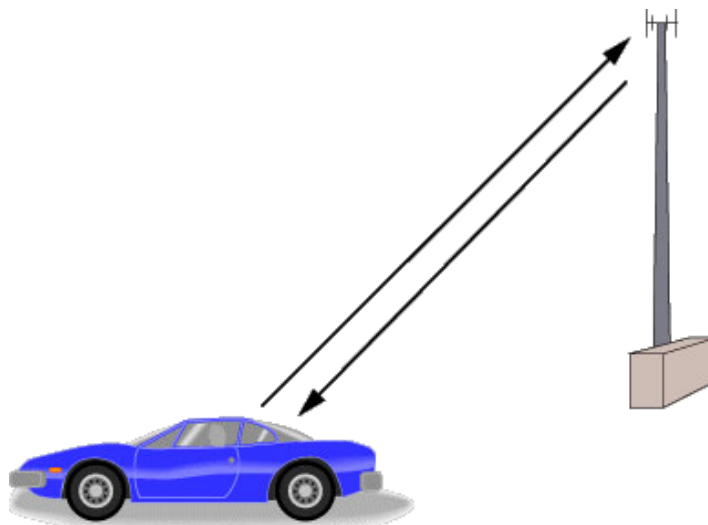
## Cell Phones and CBs

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

- **Simplex vs. duplex** - Both walkie-talkies and CB radios are **simplex** 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 **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.



In simplex radio, both transmitters use the same frequency. Only one party can talk at a time.



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

In the next section, you'll get a good look inside a digital cell phone.

### Inside a Cell Phone

On a "complexity per cubic inch" scale, cell phones are some of the most intricate devices people play with on a daily basis. Modern digital cell phones can process **millions of calculations per second** in order to compress and decompress the voice stream.



The parts of a cell phone

If you take a cell phone apart, you find that it contains just a few individual parts:

- An amazing circuit board containing the brains of the phone
- An antenna
- A [liquid crystal display](#) (LCD)
- A keyboard (not unlike the one you find in a [TV remote control](#))
- A [microphone](#)
- A [speaker](#)
- A [battery](#)

The circuit board is the heart of the system. Here is one from a typical [Nokia](#) digital phone:



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