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How Cell Phones Work

by Marshall Brain, Jeff Tyson and Julia Layton

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Introduction to How Cell Phones Work

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!

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:

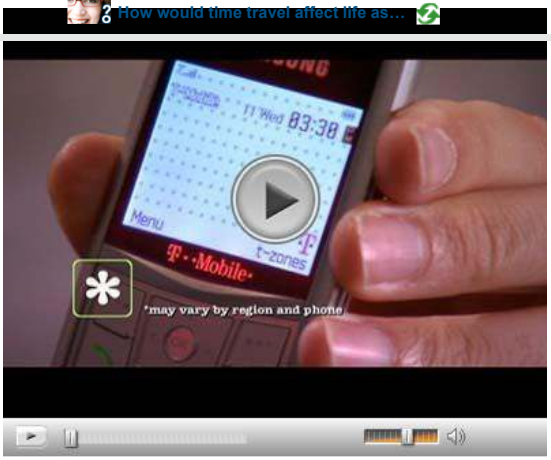
- Store contact information
- Make task or to-do lists
- Keep track of appointments and set reminders
- Use the built-in calculator for simple math
- Send or receive e-mail
- Get information (news, entertainment, stock quotes) from the Internet
- Play games
- Watch TV
- Send text messages
- Integrate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

Cell Phone Image Gallery

Nokia
The internal display of the Nokia 6555 has more colors than you can actually see at once. See more cell phone pictures.

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.

To start with, 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.



It's All Geek To Me: Cell Phone Tricks
Tech expert David Pogue explains some simple cell phone tricks to cut money and time. Learn more in this clip from The Science Channel's "It's All Geek To Me" series. (October, 2008)

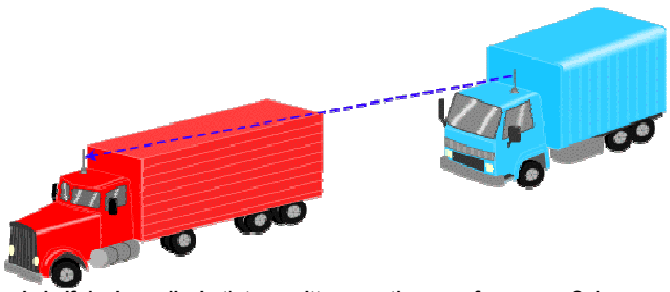
Cell-phone Frequencies

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.

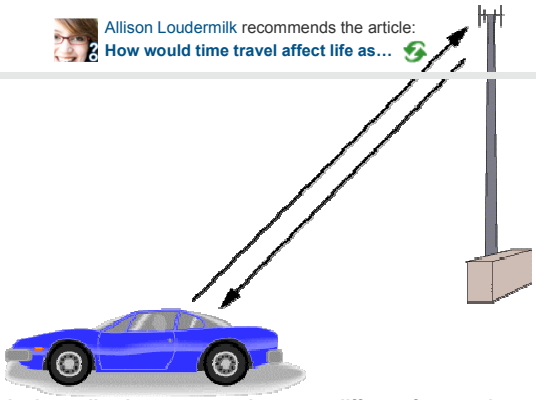
The genius of the cellular system is the division of a city into small **cells**. This allows extensive **frequency reuse** across a city, so that millions of people can use cell phones simultaneously.

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.

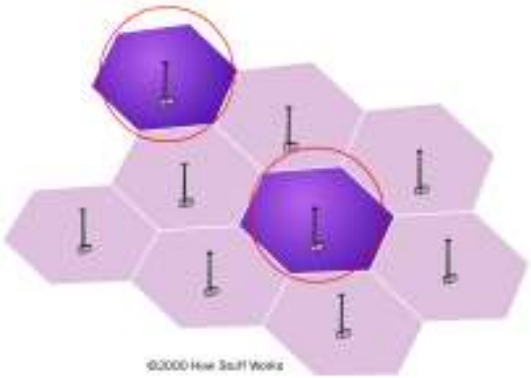


In half-duplex radio, both transmitters use the same frequency. Only one party can talk at a time.



**In full-duplex radio, the two transmitters use different frequencies, so both 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. We'll get into base stations later. First, let's examine the "cells" that make up a cellular system.

Cell-phone Channels

A single cell in an analog cell-phone 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 (more on TDMA later) can carry three times as many calls as an analog system, so each cell has about 168 channels available.

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. Lower 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.

Cell-phone Codes

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:

Cell Phone Codes

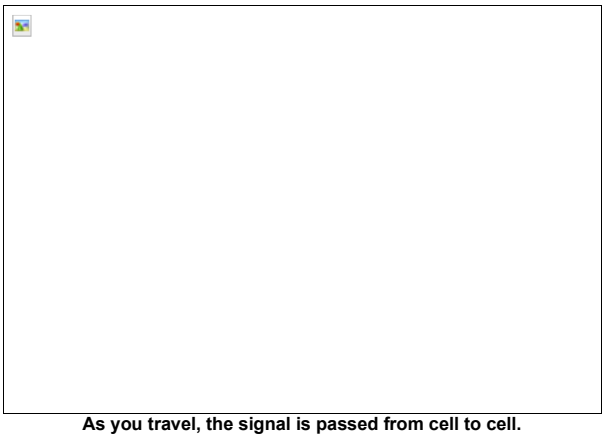
Electronic Serial Number (ESN) - a unique 32-bit number programmed into the phone when it is manufactured

Mobile Identification Number (MIN) - a 10-digit number derived from your phone's number

System Identification Code (SID) - a unique 5-digit number that is assigned to each carrier by the FCC

While the ESN is considered a permanent part of the phone, both the MIN and SID codes are programmed into the phone when you purchase a service plan and have the phone **activated**.

- 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**. Now, 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.

Let's say you're on the phone and you move from one cell to another -- but the cell you move into is covered by another service provider, not yours. Instead of dropping the call, it'll actually be handed off to the other service provider.

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.

The less amazing thing is that you may be charged insane rates for your roaming call. On most phones, the word "roam" will come up on your phone's screen when you leave your provider's coverage area and enter another's. If not, you'd better study your coverage maps carefully -- more than one person has been unpleasantly surprised by the cost of roaming. Check your service contract carefully to find out how much you're paying when you roam.

Note that if you want to roam internationally, you'll need a phone that will work both at home and abroad. Different countries use different cellular access technologies. More on those technologies later. First, let's get some background on analog cell-phone technology so we can understand how the industry has developed.

Analog Cell Phones

In 1983, the analog cell-phone standard called **AMPS** (Advanced Mobile Phone System) was approved by the FCC and first used in Chicago. AMPS uses a range of frequencies between 824 megahertz (MHz) and 894 MHz for analog cell phones. In order to encourage competition and keep prices low, the U. S. government required the presence of two **carriers** in every market, known as A and B carriers. One of the carriers was normally the **local-exchange carrier** (LEC), a fancy way of saying the local phone company.


Photo courtesy Motorola, Inc.
Old school: DynaTAC cell phone, 1983

Carriers A and B are each assigned **832 frequencies**: 790 for voice and 42 for data. A pair of frequencies (one for transmit and one for receive) is used to create one **channel**. The frequencies used in analog voice channels are typically **30 kHz** wide -- 30 kHz was chosen as the standard size because it gives you voice quality comparable to a wired telephone.

The transmit and receive frequencies of each voice channel are separated by **45 MHz** to keep them from interfering with each other. Each carrier has 395 voice channels, as well as 21 data channels to use for housekeeping activities like registration and paging.

A version of AMPS known as **Narrowband Advanced Mobile Phone Service** (NAMPS) incorporates some digital technology to allow the system to carry about **three times as many calls** as the original version. Even though it uses digital technology, it is still considered analog. AMPS and NAMPS only operate in the 800-MHz band and do not offer many of the features common in digital cellular service, such as e-mail and Web browsing.

Along Comes Digital

Digital cell phones are the second generation (2G) of cellular technology. They use the same radio technology as analog phones, but they use it in a different way. Analog systems do not fully utilize the signal between the phone and the cellular network -- analog signals cannot be compressed and manipulated as easily as a true digital signal. This is the reason why many cable companies are switching to digital -- so they can fit **more channels within a given bandwidth**. It is amazing how much more efficient digital systems can be.

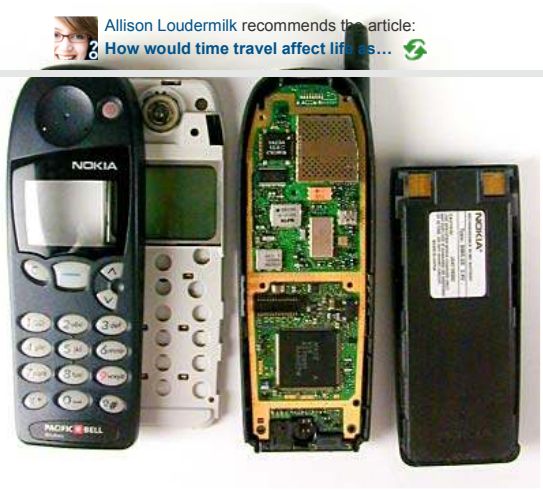
Digital phones convert your voice into binary information (1s and 0s) and then compress it (see How Analog-Digital Recording Works for details on the conversion process). This **compression** allows between three and 10 digital cell-phone calls to occupy the space of a *single* analog call.

Many digital cellular systems rely on **frequency-shift keying** (FSK) to send data back and forth over AMPS. FSK uses **two frequencies**, one for 1s and the other for 0s, **alternating** rapidly between the two to send digital information between the cell tower and the phone. Clever modulation and encoding schemes are required to convert the analog information to digital, compress it and convert it back again while maintaining an acceptable level of voice quality. All of this means that digital cell phones have to contain a lot of processing power.

Let's take a good look inside a digital cell phone.

Inside a Digital Cell Phone

On a "complexity per cubic inch" scale, cell phones are some of the most intricate devices people use 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 basic digital 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:

The front of the circuit board

The back of the circuit board

In the photos above, you see several computer chips. Let's talk about what some of the individual chips do. The **analog-to-digital** and **digital-to-analog** conversion chips translate the outgoing audio signal from analog to digital and the incoming signal from digital back to analog. You can learn more about A-to-D and D-to-A conversion and its importance to digital audio in How Compact Discs Work. The **digital signal processor** (DSP) is a highly customized processor designed to perform signal-manipulation calculations at high speed.

The **microprocessor** handles all of the housekeeping chores for the keyboard and display, deals with command and control signaling with the base station and also coordinates the rest of the functions on the board.

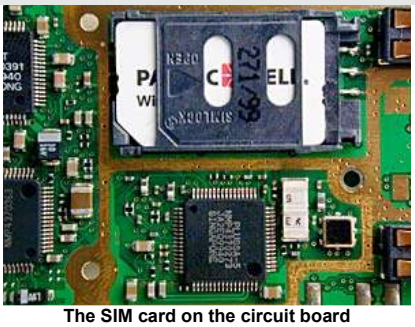
The microprocessor

The **ROM** and **Flash memory** chips provide storage for the phone's operating system and customizable features, such as the phone directory. The **radio frequency (RF) and power** section handles power management and recharging, and also deals with the hundreds of FM channels. Finally, the **RF amplifiers** handle signals traveling to and from the antenna.

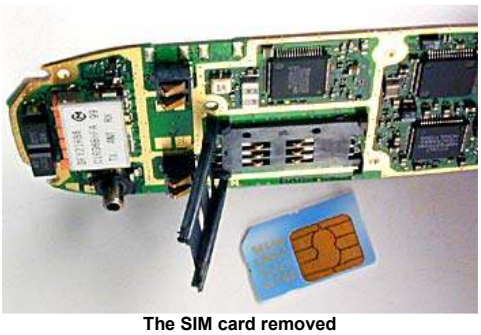
The display and keypad contacts

The display has grown considerably in size as the number of features in cell phones have increased.

Most current phones offer built-in phone directories, calculators and games. And many of the phones incorporate some type of PDA or Web browser.



The SIM card on the circuit board



The SIM card removed

Some phones store certain information, such as the SID and MIN codes, in internal Flash memory, while others use external cards that are similar to SmartMedia cards.

The cell-phone speaker, microphone and battery backup

Cell phones have such tiny speakers and microphones that it is incredible how well most of them reproduce sound. As you can see in the picture above, the speaker is about the size of a dime and the microphone is no larger than the watch battery beside it. Speaking of the watch battery, this is used by the cell phone's **internal clock chip**.

What is amazing is that all of that functionality -- which only 30 years ago would have filled an entire floor of an office building -- now fits into a package that sits comfortably in the palm of your hand!

In the next section, we'll get into the cell-phone networking methods.

Cell Phone Network Technologies: 2G

There are three common technologies used by 2G cell-phone networks for transmitting information (we'll discuss 3G technologies in the 3G section):

- **Frequency division multiple access** (FDMA)
- **Time division multiple access** (TDMA)
- **Code division multiple access** (CDMA)

Although these technologies sound very intimidating, you can get a good sense of how they work just by breaking down the title of each one.

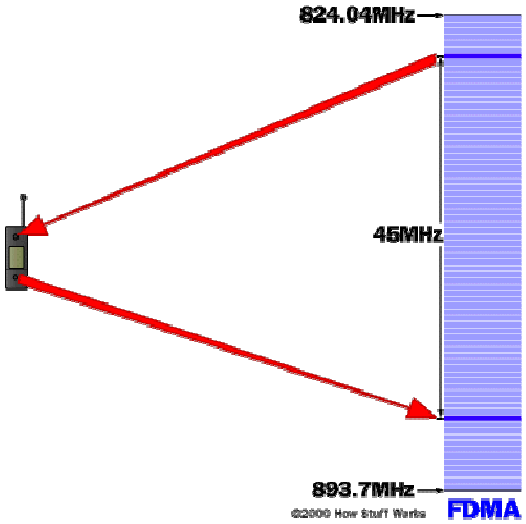
The first word tells you what the **access method** is. The second word, **division**, lets you know that it splits calls based on that access method.

- FDMA puts each call on a separate **frequency**.
- TDMA assigns each call a certain portion of **time** on a designated frequency.
- CDMA gives a unique **code** to each call and spreads it over the available frequencies.

The last part of each name is **multiple access**. This simply means that more than one user can utilize each cell.

FDMA

FDMA separates the spectrum into distinct voice channels by splitting it into **uniform chunks of bandwidth**. To better understand FDMA, think of radio stations: Each station sends its signal at a different frequency within the available band. FDMA is used mainly for **analog transmission**. While it is certainly capable of carrying digital information, FDMA is not considered to be an efficient method for digital transmission.

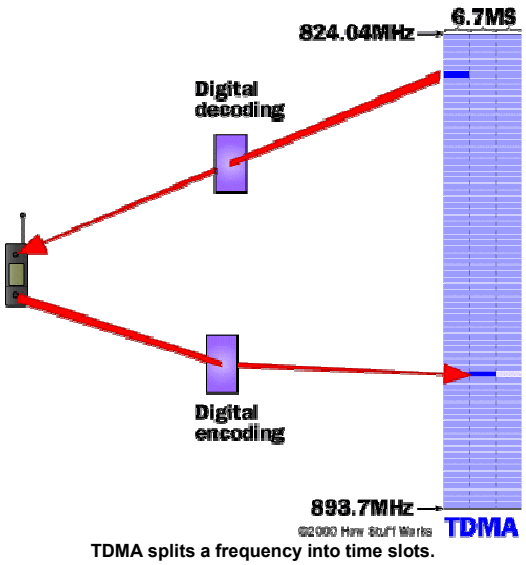


In FDMA, each phone uses a different frequency.

TDMA

TDMA is the access method used by the Electronics Industry Alliance and the Telecommunications Industry Association for **Interim Standard 54** (IS-54) and **Interim Standard 136** (IS-136). Using TDMA, a **narrow band** that is 30 kHz wide and 6.7 milliseconds long is split time-wise into **three time slots**.

Narrow band means "channels" in the traditional sense. Each conversation gets the radio for one-third of the time. This is possible because voice data that has been converted to digital information is compressed so that it takes up significantly less transmission space. Therefore, TDMA has **three times the capacity** of an analog system using the same number of channels. TDMA systems operate in either the **800-MHz** (IS-54) or **1900-MHz** (IS-136) frequency bands.



TDMA splits a frequency into time slots.

GSM

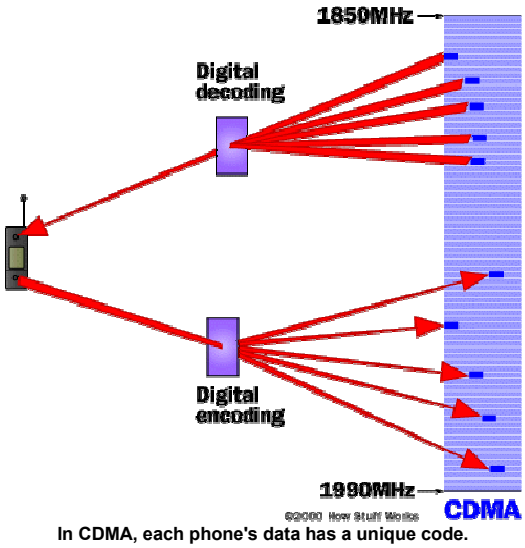
TDMA is also used as the access technology for Global System for Mobile communications (GSM). However, **GSM** implements TDMA in a somewhat different and incompatible way from IS-136. Think of GSM and IS-136 as two different operating systems that work on the same processor, like Windows and Linux both working on an Intel Pentium III. GSM systems use **encryption** to make phone calls more secure. GSM operates in the 900-MHz and 1800-MHz bands in Europe and Asia and in the 850-MHz and 1900-MHz (sometimes referred to as 1.9-GHz) band in the United States. It is used in digital cellular and **PCS-based** systems. GSM is also the basis for **Integrated Digital Enhanced Network** (IDEN), a popular system introduced by Motorola and used by Nextel.

GSM is the international standard in Europe, Australia and much of Asia and Africa. In covered areas, cell-phone users can buy one phone that will work anywhere where the standard is supported. To connect to the specific service providers in these different countries, GSM users simply switch **subscriber identification module** (**SIM**) cards. SIM cards are small removable disks that slip in and out of GSM cell phones. They store all the connection data and identification numbers you need to access a particular wireless service provider.

Unfortunately, the 850MHz/1900-MHz GSM phones used in the United States are **not compatible** with the international system. If you live in the United States and need to have cell-phone access when you're overseas, you can either buy a tri-band or quad-band GSM phone and use it both at home and when traveling or just buy a GSM 900MHz/1800MHz cell phone for traveling. You can get 900MHz/1800MHz GSM phones from Planet Omni, an online electronics firm based in California. They offer a wide selection of Nokia, Motorola and Ericsson GSM phones. They don't sell international SIM cards, however. You can pick up prepaid SIM cards for a wide range of countries at Telestial.com.

CDMA

CDMA takes an entirely different approach from TDMA. CDMA, after digitizing data, **spreads it out** over the entire available bandwidth. Multiple calls are **overlaid** on each other on the channel, with each assigned a **unique sequence code**. CDMA is a form of spread spectrum, which simply means that data is sent in small pieces over a number of the discrete frequencies available for use at any time in the specified range.



In CDMA, each phone's data has a unique code.

All of the users transmit in the same **wide-band** chunk of spectrum. Each user's signal is spread over the entire bandwidth by a **unique spreading code**. At the receiver, that same unique code is used to recover the signal. Because CDMA systems need to put an accurate time-stamp on each piece of a signal, it references the GPS system for this information. Between eight and 10 separate calls can be carried in the same channel space as one analog AMPS call. CDMA technology is the basis for **Interim Standard 95** (IS-95) and operates in both the 800-MHz and 1900-MHz frequency bands.

Ideally, TDMA and CDMA are transparent to each other. In practice, high-power CDMA signals raise the noise floor for TDMA receivers, and high-power TDMA signals can cause overloading and jamming of CDMA receivers.

2G is a cell phone network protocol. Click here to learn about network protocols for Smartphones.

Now let's look at the distinction between multiple-band and multiple-mode technologies.

Multi-band vs. Multi-mode Phones

Dual Band vs. Dual Mode

If you travel a lot, you will probably want to look for phones that offer multiple bands, multiple modes or both. Let's take a look at each of these options:

- **Multiple band** - A phone that has multiple-band capability can **switch frequencies**. For example, a dual-band TDMA phone could use TDMA services in either an 800-MHz or a 1900-MHz system. A quad-band GSM phone could use GSM service in the 850-MHz, 900 -MHz, 1800-MHz or 1900-MHz band.
- **Multiple mode** - In cell phones, "mode" refers to the **type of transmission technology** used. So, a phone that supported AMPS and TDMA could switch back and forth as needed. It's important that one of the modes is AMPS -- this gives you analog service if you are in an area that doesn't have digital support.
- **Multiple band/Multiple mode** - The best of both worlds allows you to switch between frequency bands and transmission modes as needed.

Changing bands or modes is done automatically by phones that support these options. Usually the phone will have a **default option** set, such as 1900-MHz TDMA, and will try to connect at that frequency with that technology first. If it supports dual bands, it will switch to 800 MHz if it cannot connect at 1900 MHz. And if the phone supports more than one mode, it will try the digital mode(s) first, then switch to analog.

You can find both **dual-mode** and **tri-mode** phones. The term "tri-mode" can be deceptive. It may mean that the phone supports two digital technologies, such as CDMA and TDMA, as well as analog. In that case, it is a true tri-mode phone. But it can also mean that it supports one digital technology in two bands and also offers analog support. A popular version of the tri-mode type of phone for people who do a lot of international traveling has GSM service in the 900-MHz band for Europe and Asia and the 1900-MHz band for the United States, in addition to the analog service. Technically, this is a dual-mode phone, and one of those modes (GSM) supports two bands.

In the next section, we'll take a look at 3G mobile-phone technology.

Cellular vs. PCS

Personal Communications Services (PCS) is a wireless phone service very similar to cellular phone service, but with an emphasis on ***personal*** service and extended mobility. The term "PCS" is often used in place of "digital cellular," but true PCS means that other services like paging, caller ID and e-mail are bundled into the service.

While cellular was originally created for use in cars, PCS was designed from the ground up for greater user mobility. PCS has **smaller cells** and therefore requires a **larger number of antennas** to cover a geographic area. PCS phones use frequencies between 1.85 and 1.99 GHz (1850 MHz to 1990 MHz).

Technically, cellular systems in the United States operate in the 824-MHz to 894-MHz frequency bands; PCS operates in the **1850-MHz to 1990-MHz** bands. And while it is based on TDMA, PCS has **200-kHz channel spacing** and **eight time slots** instead of the typical 30-kHz channel spacing and three time slots found in digital cellular.

Cell-phone Network Technologies: 3G

3G technology is the latest in mobile communications. 3G stands for "third generation" -- this makes analog cellular technology generation one and digital/PCS generation two. 3G technology is intended for the true multimedia cell phone -- typically called smartphones -- and features increased bandwidth and transfer rates to accommodate Web-based applications and phone-based audio and video files.

3G comprises several cellular access technologies. The three most common ones as of 2005 are:

- CDMA2000 - based on 2G Code Division Multiple Access (see Cellular Access Technologies)
- WCDMA (UMTS) - Wideband Code Division Multiple Access
- TD-SCDMA - Time-division Synchronous Code-division Multiple Access

Photo courtesy Amazon.com
Sony Ericsson V800 3G phone

3G networks have potential transfer speeds of up to 3 Mbps (about 15 seconds to download a 3-minute MP3 song). For comparison, the fastest 2G phones can achieve up to 144Kbps (about 8 minutes to download a 3-minute song). 3G's high data rates are ideal for downloading information from the Internet and sending and receiving large, multimedia files. 3G phones are like mini-laptops and can accommodate broadband applications like video conferencing, receiving streaming video from the Web, sending and receiving faxes and instantly downloading e-mail messages with attachments.

3G is a cell phone network protocol. Click here to learn about network protocols for Smartphones.

Cell-phone Towers

A cell-phone tower is typically a steel pole or lattice structure that rises hundreds of feet into the air. This cell-phone tower along I-85 near Greenville, SC, is typical in the United States:

This is a modern tower with three different cell-phone providers riding on the same structure. If you look at the base of the tower, you can see that each provider has its own equipment, and you can also see how little equipment is involved today (older towers often have small buildings at the base):

Here is the equipment owned by one of the providers:

The box houses the **radio transmitters and receivers** that let the tower communicate with the phones. The radios connect with the antennae on the tower through a set of thick cables:

If you look closely, you will see that the tower and all of the cables and equipment at the base of the tower are heavily **grounded**. For example, the plate in this shot with the green wires bolting onto it is a solid copper grounding plate:

One sure sign that multiple providers share this tower is the amazing five-way latch on the gate. Any one of five people can unlock this gate to get in.

Cell-phone towers come in all shapes and sizes, but I do believe this one in Morrisville, North Carolina, is one of the weirdest looking.

That is one tall, ugly tree!

Like all consumer electronics, cell phones come with their share of problems. In the next section, we'll take a look at some of the issues facing cell phones.

Problems with Cell Phones

A cell phone, like any other electronic device, has its problems:

- Generally, non-repairable internal **corrosion** of parts results if you get the phone **wet** or use wet hands to push the buttons. Consider a protective case. If the phone does get wet, be sure it is totally dry before you switch it on so you can try to avoid damaging internal parts.
- Extreme **heat** in a car can damage the battery or the cell-phone electronics. Extreme cold may cause a momentary loss of the screen display.
- Analog cell phones suffer from a problem known as "**cloning**." A phone is "cloned" when someone steals its ID numbers and is able to make fraudulent calls on the owner's account.

Here is how cloning occurs: When your phone makes a call, it transmits the ESN and MIN to the network at the beginning of the call. The MIN/ESN pair is a unique tag for your phone -- this is how the phone company knows who to bill for the call. When your phone transmits its MIN/ESN pair, it is possible for nefarious sorts to listen (with a scanner) and capture the pair. With the right equipment, it is fairly easy to modify another phone so that it contains your MIN/ESN pair, which allows the nefarious individual to make calls on your account.

For more information about cell phones and related topics, check out the links on the next page and be sure to read How Buying a Cell Phone Works for loads of helpful consumer tips.

Lots More Information

Related HowStuffWorks Articles

- How Buying a Cell Phone Works
- How the iPhone Works

- How Smartphones Work
- Cell Phone Quiz
- How TV Phones Work
- How Radio Works
- How Microprocessors Work
- How Telephones Work

More Great Links

- Cell Phone Reviews and Stuff Guide
- 3G Newsroom: What is 3G?
- Cellular Telephone Basics
- Digital Wireless Basics
- The Travel Insider: Global Roaming
- Wireless Communications Glossary

Sources

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- The Travel Insider: Global Roaming
  http://www.thetravelinsider.info/2002/1101.htm
- The Travel Insider: Dual, Tri, or Quad Band GSM Phone?
  http://www.thetravelinsider.info/roadwarriorcontent/quadbandphones.htm
- The Travel Insider: Unlock Your Cell Phone
  http://www.thetravelinsider.info/roadwarriorcontent/nokiaunlocking.htm

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