Chapter 1

HOW CELLULAR WORKS
AND HOW TO IMPROVE RANGE

Overview:

Wireless (Cellular) Communication is a complex and very technically advanced science with many rules, standards and regulations that are continually evolving and changing. The following is a condensed and simplified explanation and overview of how cellular works.

A Cellular Base Station (tower) transmits a constant signal commonly known as a “pilot” signal or “control channel signal” and this signal is received by the cellular handset (phone). One can think of this signal as a constant sound or voice that is transmitted by the tower and is heard by the phone. When the phone receives this signal the user sees signal bars on the phone’s display. If the phone receives a strong signal, many bars are displayed and when the signal is weak few bars appear. The phone measures all the pilot signals it receives from all the cell towers that it hears, and transmits these measurements to the tower. These measurements report receive signal level (loudness) and signal quality (clarity) of all the towers’ signals received (heard) by the phone.

This information is transmitted by the phone to the tower hundreds of times per second, virtually constantly. The information is received by the tower and sent by the tower to a land-based device known as the “switch”. The switch uses the information received from the phone to create commands based on preset parameters that are programmed in the data banks of the switch. These commands are sent back to the tower and the phone. These commands include the frequency and channel to communicate on, the tower that the phone is to connect to, and the power level at which the phone should transmit (essentially, how loud the phone should be). One can think of the switch as the conductor of a symphony that is made up of cellular towers and cellular phones.

The switch/tower combination controls the phone’s output power and generally commands the phone to reduce power as it approaches the tower and increase power as the phone leaves the tower. (One could think of this as the phone whispering when it is close to the tower and yelling when it is far away). This exchange of information is what keeps a phone connected to a network and allows the phone to travel from place to place successfully. For a cellular conversation to connect and stay connected two things must occur: the phone must receive signal from the tower and the phone must transmit with enough power to reach the tower, in other words, the phone must hear the tower and the tower must hear the phone, as long as this condition occurs, cellular communication is successful.

The Urban Environment:

Cellular communications in cities are usually very reliable because cellular providers deploy numerous towers and transmitter/receiver stations in close proximity to each other. Urban towers are spaced close together and their range is usually quite short, sometimes only a few city blocks or less. This condition exists because a cellular provider has a limited number of channels and each channel has a maximum number of users that it can support at the same time, therefore, when the provider reduces the range of the tower the provider can use the same channels at numerous locations and accommodate more users. The provider controls the range of a tower by increasing or decreasing the pilot signal and pilot signal in cities is typically quite low.

The Rural Environment:

Cellular communication in rural environments is usually less reliable than cities because there are fewer towers covering larger geographic areas. Cellular providers try to maximize the range of a rural tower because towers are expensive and users are few. To maximize the range of the tower, the provider will increase the power of the pilot signal. This allows phones to receive signal from a given tower at a greater distance; essentially, the phone can hear the tower from further away. Under these conditions a phone can be far enough away from a tower to display “signal bars” maybe one, two or three, but despite this a call cannot be completed. The reason that this occurs is simple: the phone can hear the tower because the tower has a powerful transmitter that is turned up to be quite loud, however, the phone has a less powerful transmitter than the tower and even at its maximum transmit output power, the phone’s signal will not reach the tower. Basically, the phone can hear the tower but it is not loud enough to be heard by the tower, hence, no connection or dropped call.

Chapter 2

How Boosters Work: Their Effect on Range and Limitations

Smoothtalker boosters are bi-directional radio frequency amplifiers. They will amplify the receive signal and the transmit signal of the phone. The “receive side” amplifier uses electrical energy to increase the amplitude of the signal that is in the air, thus giving the signal more energy, essentially making it louder. The “transmit side” amplifier does the same thing to the signal that is generated by the phone and sent out to the air. If the phone was a person, adding a booster, would be the equivalent of a hearing aid being put in its ear and a megaphone to its mouth… the phone will hear better and it will gain the ability to be heard from greater distances.

Using a booster increases range substantially, however, there are limitations. The signal coming from the tower must be at a high enough level (louder than other signals like interference and electromagnetic and thermal noise) in the air, that when it is amplified by the booster, the phone can process it (understand it). If the desired signal is not greater than the noise, then amplification does not help.

When the signal coming from the tower is adequate, then the signal generated by phone that is being amplified by the booster must be strong (loud) enough to reach the tower, and it must be clear enough in order for the tower to recognize (understand) it. If the phone receives signal and the call fails, it means that the transmit signal from the phone is not strong enough and the and the signal from the phone did not reach the tower.

Range:

A Smoothtalker booster can increase the range of a cell phone to 60 miles or greater. Increases in distance from a tower are dependant on several factors:

Geographic terrain- Flat terrain (ocean, lake, desert, plains) with the tower on the horizon will allow communication from greater distances than terrain with obstructions.

Type of antenna: location of antenna- Antenna choice and location are covered further in this document.

Pilot signal level- the signal strength being transmitted by the tower is directly related to the distance that a phone can communicate with the tower. Remember, the phone is listening to the tower and even if the tower signal is amplified by the booster, a distance will be reached where the pilot signal is low enough where amplification is of no help. Pilot signal strength is set by the cellular provider and is not always the same strength from one tower to another, therefore it is possible to get greater or shorter range depending on the strength of the pilot; for example, it is reasonably common for a tower on the coast to be set to transmit stronger signal towards the ocean than the signal from the same tower pointing towards land.

Chapter 3

How Antennas Work: Their Radiation Patterns, Their Affect on Range and their Limitations

External Antenna vs Phone antenna:

External antennas for cellular phones are usually beneficial for two reasons. Firstly, a well designed external antenna is usually a better radiator than the phone's own antenna. Phone antennas have limitations because of size limitations and they must comply with federal electromagnetic radiation exposure requirements; as such there is a limit to the amount of power a phone/antenna can transmit.

Secondly, an external antenna benefits by usually being in a better RF environment than the phone's antenna. Cellular signal on the outside of a vehicle or structure is better than on the inside of the vehicle or structure.

Thirdly, all radio frequency signals benefit when the antenna is placed on a metal surface. An antenna's signal benefits when it is placed on a metal surface that has a diameter greater than one wavelength (of the desired frequency). This effect is called "groundplane" and the beneficial effect increases with the increase of the area of the groundplane. An antenna can be designed to have its own groundplane if a metal surface is not available to place it on.

Benefit from RF Environment (antenna location):

Cellular signal is always better on the outside of a vehicle than it is on the inside a vehicle. The signal that the phone transmits and receives is attenuated (made quieter) by the sheet metal and steel frame of the vehicle. RF (radio frequency) signal is electromagnetic energy that is measured in watts and usually expressed in db (decibels). Measured cellular signal is usually 8 to 10 db better outside of a vehicle than it is when measured inside of a vehicle. In relative terms, this means that the signal on the outside of the vehicle is about 20 % better than it is on the inside. In absolute terms, this means that when the signal is low, a call from inside the vehicle will fail before a call from outside of the vehicle.

Factors Effecting Antennas:

Gain: Type of Antenna and Radiation Pattern:

In absolute terms there is no such thing as one antenna that is better than another because antennas do not create energy, however, antennas are most often rated in “gain” and as such, most people believe that a gain antenna is better or more powerful than another antenna with a lower number, for example a 3db gain antenna versus a 0db gain antenna.

In reality, there is no energy increase with a gain antenna. An antenna without gain (0db) radiates energy in all directions and antenna with gain re-directs or concentrates energy in a certain direction. In very simplistic terms it can be said that a low gain cellular antenna will perform better in geographic areas where signal is bouncing, reflecting or is generally located vertically from the antenna mast (cities, mountains, areas with obstructions). A vertically mounted high gain antenna will generally concentrate energy parallel to the earth and will generally perform better when the tower is unobstructed and located on the horizon (oceans, lakes, deserts.)

It is advisable for people who travel to remote areas of poor cellular signal to have both types of antennas because of this phenomenon.

Factors That Effect Antenna Performance:

Cables and Connectors :

Regardless of the gain rating of the antenna there are several factors that are critical to signal improvement when an external antenna is connected to a cellular phone. The most important component effecting antenna performance is the co-axial cable that connects the antenna to the phone. Co-ax cables and the connectors that are used to connect them have losses commonly termed “line loss” (cable) and insertion loss (connector).

All cables and connectors have loss. The amount of loss is measured in db and cable loss increases when cable length is increased. Losses from cables and connectors also increase when the frequency of the signal increases. For example: a 15 foot long cable that has 4 db of loss in the 800 mhz frequency of the cellular band will have a loss of 8db or more in the 1900 mhz frequency of the PCS band. If the cable is of low quality, it is possible to have a small improvement when the phone is in the lower frequency cellular band (usually in rural areas) and have a substantial degradation in signal when in the high frequency PCS band (usually in urban areas).

Note: most RG58 size cellular antenna cables with a connector at each end have losses of 3.8 dB loss at 850 Mhz and 7.4 db loss at 1900 Mhz or greater for every 15 ft. of cable. Smoothtalker RG58 cable has 1.8 dB loss at 850 Mhz and 3.25 dB loss at 1900 Mhz.

Antenna Location:

There are several popular locations to mount cellular antennas. The best location is the center of a vehicle roof where it is unobstructed and has a large metal surface known as a groundplane under it.

A second choice would be a mirror mount or fender mount using a “thru-hole” type antenna that passes through a metal mounting bracket. When this type of mounting is used it is recommended that an antenna with a built-in groundplane is used.

A third and very popular mounting type is known as "on-glass". This type of antenna mounting configuration is the least efficient of all. This type of antenna does not have the benefit of groundplane and transfers the signal by an electrical phenomenon that is called "capacitive coupling". There is signal loss between the antenna and the coupling box on the inside of the glass hence this type of antenna configuration will have inferior performance when compared to the same antenna with same antenna cable that is connected directly to the co-ax cable.

Chapter 4

The Cellular Landscape (USA , Canada , Mexico): frequencies, systems, providers

Frequencies:

There are two main frequency ranges used for wireless telephony in North and South America , the "Cellular Band" which is operates between 824 and 896 Mhz and the "PCS Band" which is in the 1850 and 1960 Mhz. The cellular band was the first to be deployed, was the only frequency for use with wireless telephones and originally was used by all providers and covered all of North America , Canada , Mexico and South America . As cellular phones became more popular the providers had more subscribers and more bandwidth was required. In the early 1990's the governing bodies (FCC, ICAN etc.) offered licenses for sale in the PCS band to existing service providers and new service providers. The existing providers that already had Cellular Band licenses purchased PCS licenses only for the areas where they needed more spectrum (primarily urban areas) and deployed PCS towers in the urban areas and left Cellular Band towers in the rural areas. The smaller rural cellular providers did not make any change to their frequency and also left the Cellular Band active. To make urban and rural wireless communication, the service providers needed, and the handset manufacturers provided, dual-band handsets to the public. When in the city the handset worked on the PCS Band and when in the rural areas the handset worked in the Cellular Band. By and large that is the cellular landscape as it exists today but there some exceptions.

When the FCC offered licenses in the PCS band new companies, like Sprint and T-Mobile purchased licenses in the PCS Band and deployed systems only in this frequency band. In the case of providers like T-Mobile, they chose and continue to offer handsets that operate only in PCS and only one type of transmission (GSM). This means that this handset will only work in an area where PCS signal, operating in GSM is available; even if there is strong Cellular Band signal or PCS signal that is not GSM present, this type of handset is incapable of transmitting and receiving.

Other PCS providers, like Sprint, decided to provide dual band handsets that would operate on the Sprint PCS Band network and if they are out of their home service area these handsets will operate on other service provider's Cellular Band systems, albeit, usually at a higher cost called a roaming charge.

The other exceptions are Nextel, Southern Linc and Mike. These providers use a frequency in the 800 Mhz range called the trunking band which is unique to the type of handsets used by these service providers and the handsets they offer are incapable of using any other cellular providers Cellular Band or PCS Band networks, in other words, when you are out of their service area signal is absent until you re-enter this network. As such this network has the smallest geographic footprint in the land.

It is noteworthy to mention that some countries in Latin and South America and Jamaica have deployed GSM1800. This frequency band
has traditionally been the higher frequency used in Europe, Asia and Africa and is not licensed for use in USA or Canada, but is deployed in mexico for example. So far it has only been deployed by cellular providers that use GSM signal.

Systems:

Analog (AMPS)- Originally all cellular communications was done in the Cellular Band and the all signal was an analog modulation called AMPS. This means that a certain piece of frequency was open and devoted to a particular handset when a conversation was taking place, one can think of this as one lane on a multi lane highway on which only you drive while on this road. Analog systems still exist in many rural areas and most cell phones have analog capability except GSM phones. This type of modulated signal uses much more electrical energy to produce the same amount of power and is a much a less efficient use of frequency spectrum than digitally modulated signals. AMPS analog signal is only permitted in the 800 Mhz cellular band.

Types of Digital:

Digital signals operate in the PCS and Cellular band. There several types of digital systems using digitally modulated signals in use at this time. Digital systems and phones use less electrical power (battery) because they only use power to transmit when the coded bits of information that represent the spoken word or data being transmitted are actually sent, a burst as opposed to a constant stream. The same channel or frequency can be also used to accommodate multiple users therefore more information (data or calls) can be made without the need for more spectrum.

TDMA- The oldest type of digital system is known as TDMA (time division multiple access). This type of system was widely deployed and currently exists in urban and rural areas by many cellular providers including Cingular, AT&T and the majority of the smaller rural cellular providers, however, TDMA is not capable of the high speed data transfer capabilities of competing digital systems. Wireless high speed data transfer like pictures from your phone and many more applications have become popular enough to make TDMA cellular providers begin to change their systems.

GSM- this type of digital system is the most widely used worldwide because all of the European and most of the Asian service providers agreed to use it in the early days of digital in order to achieve interoperability. GSM is also the type of system that has recently been chosen by Cingular and AT&T and most of the existing small rural cellular providers that used to or still have TDMA systems. GSM is currently being added to existing TDMA networks throughout the land and cellular providers are replacing TDMA phones with GSM phones when the customers need a

new phone. The cellular network providers are offering lower priced cellular plans and other incentives to encourage people to change to new GSM phones.

CDMA- this type of digital system has the highest capability for high speed data transfer and is deployed by large and small cellular providers. Most service providers that use CDMA systems have been using this type of system for several years and they have worked the bugs out for the most part.

Chapter 5

Service Providers And How To Choose One:

There are many service providers, large and small and using different types of systems, offering ever more different handsets and service plans and trying to make a choice of who to go with is difficult. Here are some guidelines that may help.

Types of Service Providers:

Dual Band Provider- these providers started at the onset of cellular service, built out and or purchased smaller cellular band providers and subsequently purchased PCS licenses from the FCC and deployed PCS in urban areas. This group of providers includes Cingular, Verizon, and AT&T. They are the largest and generally have the largest footprint that covers large geographic areas of America . Typically they also have more roaming agreements with other small and large providers.

Cellular Band Only Provider- these providers started at the onset of cellular service and includes most of the rural area service providers. These providers typically offer home service in the original Cellular Band but they offer dual band handsets with analog capability that allow their subscribers access to roaming partners networks when they are out of the home service area.

PCS Band With Dual Band Handset- this category includes Sprint. The Sprint home network is PCS only and is primarily deployed in cities and major highways. Sprint typically offers their subscribers lower priced rate plans when the phone is used on their home network, but provides dual band handsets that are capable of using another provider's digital or analog network (roaming) at an added cost.

PCS Band Only Provider- this type of provider is mostly urban-centric. An example of a PCS only provider is T-Mobile. They offer service and phones that work in only one frequency and one mode GSM. This type of provider will have their own service areas and also have roaming agreements with other providers that operate GSM systems in the PCS band. Typically coverage

is in cities and some major highways. This type of system and handset will have coverage in fewer geographic areas than a dual band.

Iden Provider- Nextel, Southern Linc and Mike are the only users of this system in North America . This system works on its own frequency and has no capability of connecting to other cellular systems around the land. It is often used by business that has a need for the two-way radio capability it offers, however coverage is only available in its home networks and coverage is more limited than a dual band provider.

Which Service To Choose:

Urban user near work and home- If you use have a cell phone for use around your local area where you live and work, then choose a provider who has good coverage in that area and a plan that suits your needs. Coverage will probably be very good no matter which provider is chosen and the need for external antennas or boosters is not likely. The choice of handset is also less critical and you may not need a handset that has dual band or analog capability.

Urban Traveler- If you are a user who travels from city to city either by air or major highway, then your choices of provider and handset are plentiful because most urban areas are well covered by most service providers and even if you travel to an area where your service provider does not have coverage, it is likely that they have a roaming agreement with a provider that covers that area. The need for external antennas or boosters is not likely. Mostly any provider and handset should be acceptable, but find out if coverage exists on your route if you are going to choose a PCS only service provider.

Rural user near work and home- In rural areas coverage may be less reliable than urban areas and use of external antennas or boosters may be required but it is a good idea to get a handset that has dual band and analog capability because there are still many rural areas where analog is prevalent; also make sure to pick a cellular provider that covers all of your local area.

Travel by land or work in remote areas- If you travel frequently by land and your travels take you to many destinations that cover large areas of North America or you work in remote areas, then it is advisable to get service from a large dual band carrier that has coverage in many parts of the land, get a handset that is capable of digital in both bands and analog also. Depending on how much you use the phone it may be advisable to get a plan that includes long distance and roaming charges. If you are with a CDMA provider, make sure to get a cell phone that has analog capability if you travel to remote areas because many of these areas still remain analog only. If you are using a GSM provider you cannot get a GSM phone with analog capability because GSM providers no longer offer any phones with analog capability. It is almost a given that cellular service will be spotty and the requirement of external antennas or boosters will be high.

Chapter 6

Types Of Boosters: choices and matching to your needs and cellular provider

Overview- boosters are radio frequency amplifiers and as such they are dependant on the signal that is input to them to be of use. Cellular handsets and base stations transmit many types of modulated signal (analog, CDMA, TDMA, etc.) and the handsets transmit these signals at different power levels depending on the type of system they are designed for. For example: A CDMA phone has maximum transmit power of about 250 milliwatts and transmit a signal is known as “spread spectrum”. A very powerful amplifier is required to amplify it without destroying the signal in the process of amplifying it, a GSM phone on the other hand can transmit 2 watts but its signal is not as difficult to amplify. Added to these differences are also the different frequencies that are used in cellular.

Because of all of the differences boosters must be made to match the phone, the system and the frequency that they are to amplify if they are going to be beneficial. There are several boosters available on the market that are advertised as “dual-band one size fits all” devices. It is impossible for these devices to perform their advertised capabilities and purchasing or using one for a period of time will show their limitations.

Booster Choices:

Iden- this category includes Nextel, Southern Linc and Mike. This system and the handsets for this system use only one frequency and the same digital standard. The choice is only one, an Iden booster.

GSM 1900 (PCS)- this category includes service providers T-Mobile and Fido and all GSM1900 only capable handsets from providers like Cingular, AT&T and others. They only use one frequency and one digital standard. The choice is only one, a GSM1900 booster.

Dual Band CDMA- this category is more complicated than the two above and requires some consideration before a choice of booster is made. Most CDMA handsets are capable of digital PCS band, digital Cellular band and analog communication.

CDMA coverage is normally deployed in major cities using the PCS (1900 Mhz band) and cities are normally covered with large numbers of towers and repeaters and coverage is usually very good. Because of the large numbers of towers and their close proximity to handsets, towers (which control the transmit power of the handset) rarely command a handset to transmit at maximum power, therefore using a PCS 1900 Mhz booster in this case would be of no benefit because the network would command the handset to power down to the level that is acceptable to the tower, however, if you have a Sprint phone that you have set to “home only” and use this

phone only in the PCS band, then a PCS 1900 Mhz booster for CDMA phones is your only and logical choice.

CDMA coverage in non-urban areas is usually in the Cellular (800 Mhz band) and this is where towers are spaced at greater distances from each other and also the frequency band in which analog operates. This is the band where spotty coverage exists and using a Cellular 800 Mhz booster is advisable. A dual band CDMA phone with Analog capability used with a Cellular 800 Mhz booster will get coverage in as many places as possible and have the best coverage of any CDMA phone/booster combination.

Dual Band TDMA- this category is the same as the dual band CDMA. TDMA coverage is normally deployed in major cities using the PCS (1900 Mhz band) and cities are normally covered with large numbers of towers and repeaters and coverage is usually very good. Because of the large numbers of towers and their close proximity to handsets, towers (which control the transmit power of the handset) rarely command a handset to transmit at maximum power, therefore using a PCS 1900 Mhz booster in this case would be of no use and the network would command the handset to power down and since PCS only TDMA phones do not exist, a Cellular Band 800 Mhz TDMA booster that will improve coverage for both digital and analog in rural areas is the only choice.

Dual Band GSM- GSM coverage is normally deployed in major cities using both the 800 Mhz cellular band and the PCS (1900 Mhz band) and cities are normally covered with large numbers of towers and repeaters and coverage is usually very good. Dual bnad operators urban networks use a method called "channel hopping". The phones are constantly to hop channels and frequencies, giving priority to the 1900 Mhz fequency band primarily and the 800 Mhz channels when 1900 Mhz is low, in other words, GSM networks back down to 800 Mhz when signal is not good enough in 1900 Mhz and if a call fails it will fail at this frequency. Even so, because of the large numbers of urban towers and their close proximity to handsets, towers (which control the transmit power of the handset) rarely command a handset to transmit at maximum power, and the need for a booster or external antenna in this environment is rarely required. GSM networks in rural areas are almost always in the 800 Mhz band and this is where most weak signals are found. A Cellular Band BST850 booster that will improve coverage in rural areas is recommended for Dual band GSM handsets. It will also reduce urban area call drops that are normally associated with unsuccessful "channel hop"

Special Note for Dual Band GSM as of March 2004- this category is the one that requires the most consideration if you travel by land to many geographic and remote areas. GSM systems are relatively new to the North American cellular scene and as such there are problems and deficiencies with both the networks and handsets. These problems are being worked out and will be eventually fixed throughout the land but for now one must carefully consider his or her choices. Most of the GSM service providers are existing TDMA providers that have both digital TDMA and analog systems in place and full use with very comprehensive voice coverage all over the land, however, TDMA data transfer speeds are not fast enough to compete with CDMA networks therefore GSM is being added to the existing TDMA/Analog networks. It is normal for cellular providers to deploy new systems where they have the most subscribers and as such, GSM is being deployed firstly in cities, secondly on major highways and lastly in rural areas. This method of deployment serves the most people in the shortest period of time and all should be good, however there is a shortfall. A GSM phone user can find him/herself in an area where their

old TDMA phone worked but the new GSM phone does not work and even though the cellular provider is the same and their TDMA/Analog coverage is present the GSM phone cannot receive or transmit on this system.

Special note as of September 2005- GSM coverage has greatly increased since the above note of 2004, however, defficiencies still exist especially in very remote areas where there is no GSM infrastructure or Providers. Although this is rare, one can find themselves in an analog area where a neighbor is communicating with an analog capable phone from a CDMA provider and the GSM phone will not operate.

Having said this, if you are a GSM subscriber who travels to remote areas and you use a dual band GSM phone with a Cellular Band BST850 booster, your coverage will be as good as it can possibly be.

Chapter 7

Voice and data choices and availability in remote areas and what to expect

Voice calls and data transmissions use the same frequencies, channels and modulation, however, data is only available when the phone is within a digital signal area, therefore, you may find yourself in an area where voice calls are possible on Analog but data is not functional. An 800 Mhz booster will expand coverage area for both Analog and Digital and as long as the digital signal meets the minimum signal strength and signal quality a cellular switch will command the phone to stay on digital. In essence when using a booster the digital coverage is expanded and preferred, therefore it is possible to make data transmissions when using a booster in areas where they were not possible without the booster.

Wireless data cards have lower transmit power than handsets, therefore it is even more important to have a booster in remote areas when using a data card with a laptop for data over cellular networks.