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In-Car Cellular Signal Boosters

White Paper Prepared for:

Wilson Electronics

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In-Car Cellular Signal Boosters

Executive Summary

No doubt you have experienced a dropped call or had your data rate slow to virtually no data access while using your cellular phone or data card in your car. You might be in a rural area, far from the nearest cell site, and distance from the cell site causes a weak signal. Or perhaps you are driving where there are hills between you and the cell site, blocking the signal. If you are in an urban area, buildings can likewise block cell signals, and entering structures such as parking garages are often sure ways to end a phone call. How many times have you warned the person to whom you are talking, "I'll call you back if I lose you here"? Cell phones are amazing devices, but cars with their metal bodies do a great job of blocking radio waves. Thus dropped and missed calls or slow data rates are all too common.

The solution to this problem is to boost or amplify the signal between the phone and the cell site. An in-car or mobile cellular signal booster consists of two components: a booster that is placed inside the car (perhaps incorporated into a cradle for the cell phone) and an antenna that is placed outside of the car. The booster amplifies both the signal that the phone receives from the cell site and the signal the phone transmits to the cell site. Thus the phone always has a strong signal (more "bars") and dropped calls are virtually eliminated. If your phone is using its data connection, such as with a navigation application, the rate of data downloaded to the phone will be faster.

However, designing a quality mobile cellular signal booster is not a simple matter. There are two important design principles to which any booster should adhere. It must:

1. Work as advertised for the customer.
2. Do no harm to either the network with which the cell phone is communicating or to any other nearby network.

More specifically, there are three problems to be overcome in the design of a booster.

1. Oscillation due to feedback must be avoided. If the external antenna is placed too close to the in-car cradle (which has its own internal antenna), oscillation due to feedback can occur, similar to when a microphone is placed too close to the speaker of a public address system and a howling whine comes out of the speakers. In a cell phone booster, feedback oscillation causes the system to generate noise that can interfere with nearby cell sites' ability to receive signals from other cell phones, causing disruption of service to other users.
2. Overload of the cell site with which the phone is communicating must be prevented. When you are far from the nearest cell site, the booster needs to transmit at the maximum allowable power. If you then drive close to the cell site, it must appropriately adjust itself so as not to overwhelm the cell site and to avoid any type of network overload or potential interference.

3. Interference to adjacent cell sites must not occur. A more subtle variation of the previous problem occurs when your cell phone is communicating with a distant cell site, but there is another cell site (operated by a different provider) close by. If the booster transmits a strong signal in order to reach the distant site, it could potentially interfere with the nearby cell site. This must not happen.

To our knowledge, Wilson Electronics is the only company producing cell phone boosters that adhere to these design principles. They are designed and built to avoid the problems described above.

The Wilson cell phone booster protects the network by detecting any oscillation. Within 10 milliseconds (1/100th of a second), the booster reduces gain (amplification) or shuts down if needed to prevent network interference.

The Wilson cell phone booster measures both the transmit signal strength from the phone and the incoming signal strength from the cell site. It uses these measurements to determine how close the phone is to the cell site, and adjusts its operation accordingly. As you approach the cell site, the amplifier reduces the gain, or if necessary, shuts off completely. Thus at no time is the cell site overloaded with too strong a signal. Then, as you move away from the site and signal amplification is required, the booster comes back on (if it shut down) and continually varies its gain for optimal performance. Similarly, by continuously monitoring the signal strength of nearby cell sites, the Wilson cell phone booster adjusts the transmitting signal gain (amplification) to avoid the possibility of interference with the nearby cell site, even though that site may use different frequencies or technologies.

In Canada, Wilson Electronics has worked cooperatively with the wireless network operators TELUS and Bell Mobility. They worked closely with Wilson on the design and testing of its booster to ensure its use would not cause interference with their cellular networks. In addition, TELUS developed its own standards for cellular boosters and had Wilson products tested against these standards by independent laboratories.

Wilson Electronics looks forward to working with the network operators, the CTIA, and the FCC to demonstrate that cell phone boosters are a needed product for many customers, and that they can be safely used without causing interference to the cellular networks.

Existing booster products that do not have the protections described in this white paper are known to cause interference with cellular networks. This is why Wilson believes the FCC should amend its certification of cell phone boosters to ensure that all cellular networks are protected. All cell phone boosters should be required to incorporate oscillation (feedback) detection and protection, booster shutdown, or gain reduction to prevent interference with nearby cell sites, and bi-directional signal amplification of the signal from the cell site to the mobile phone, and from the mobile phone to the cell site.

The FCC certification should document tests that will ensure that any device receiving certification successfully operates as described above. Wilson also believes that the FCC should require that all existing cell phone boosters be re-certified to the new tests within one year of the rule adoption. Wilson is prepared to work with the network operators, the CTIA, and the FCC to develop such tests. We believe that such a course of action will maximize cellular phone customer satisfaction while ensuring that all cellular networks are free from interference from poorly designed boosters.

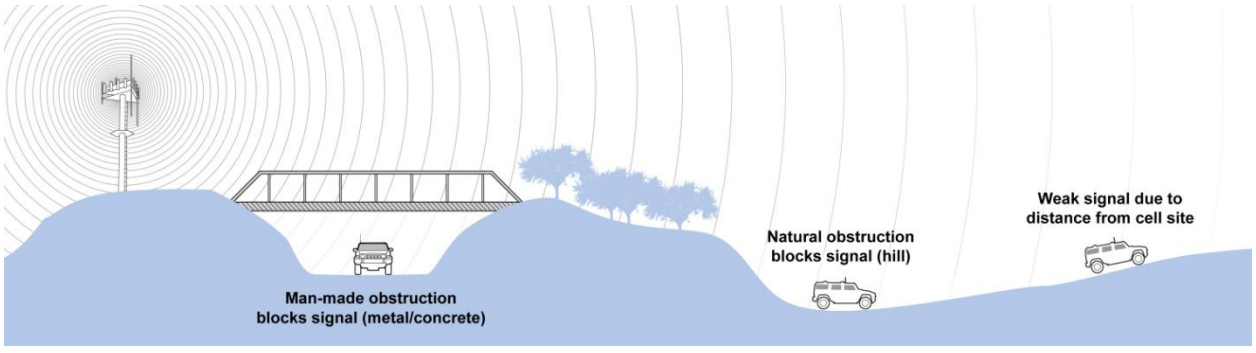
In-Car Cellular Signal Boosters

You're on your phone and you get into your car. Shortly after you close the door, you begin the familiar routine, "Can you hear me?" Your call has been dropped. You are in your car on a conference call, using the built-in Bluetooth hands-free equipment. As you travel to your destination, your call is dropped several times, and you must repeatedly dial back in. Or you may be driving from one location to another and during the drive your phone indicates that you have voice mail waiting but your phone never rang.

The problem is not only dropped calls. If you are using the Internet, you may find it takes longer than expected to access a web page or download an email. Using your phone in a car can significantly lower the speed at which data reaches your phone. And in some cases, you can't even access a website or send that important email because a data connection cannot be established.

Why This Happens

There are two main reasons for a poor quality signal on your cellular phone. The first is simply distance from the nearest cell site. The farther you are from it, the weaker the signal. This is particularly true in rural areas, where those sites are widely spaced. The second reason is that there may be an obstacle between you and the cell site. Cellular phones communicate using radio waves, and those waves cannot travel through hills or concrete and steel buildings. And even if the signal is not blocked, it is attenuated, or reduced, by metal, glass, and even tree leaves. Thus when you are in an underground parking garage, receiving a good signal can be difficult. Likewise, if your car or office has tinted windows, you will likely have worse reception than if not, for tinted windows typically contain a metal oxide that interferes with radio waves. Further, if your phone is clipped to your belt, inside your purse, or even sitting on the seat next to you, there is even more loss of the signals to and from your phone.



Poor signal strength has another effect on your phone's performance. Wireless networks are designed to minimize the amount of power necessary for your phone to communicate with the cell site. The closer you are to a site, the less power required from your phone and the longer your battery life. Conversely, the further you are from a cell site, or the more obstacles between your phone and the cell site, the more power the phone must use to communicate, and this will shorten its battery life

dramatically. This is why your car's AM/FM radio has an external antenna; it receives the signal before it is blocked by the metal in your car.

The problems described above are not uncommon. According to market research firm Harris Interactive, 67% of cell phone subscribers have at least occasional trouble with their service, such as dropped calls or no service. Allen Nogee of media research company InStat says that 35% of cell phone subscribers have switched networks because of coverage issues. And for the 59 million Americans who live in rural areas, poor coverage can be a daily problem.

The Solution

One might think that the solution is for the wireless phone companies to build more cell sites. Unfortunately, it is simply not practical to guarantee coverage everywhere you might want to use a cellular phone. Wireless service providers are constantly expanding their networks and adding more cell sites, however this is a lengthy process, taking several years for each new tower to be permitted and built.

Recently, network operators and others have started selling devices designed to be installed in your home or office to provide you with in-building coverage, but little has been done to address the issues identified above, providing better transmission and reception within your car or truck. Ten years ago, most phone manufacturers offered in-car mounting kits that included an external antenna as well as a power booster to improve the range of your phone when it is inside your vehicle. However, when the wireless technologies were updated to digital voice and data, the use of these types of amplifiers could actually interfere with the networks and so were discontinued.

Wilson Electronics has spent years analyzing how digital cellular networks operate. Through this work, it has developed a deep understanding of the types of problems that occur when trying to amplify cell phone signals. Wilson has created a unique and smart device that enables you to take advantage of an external antenna and power booster to strengthen the signal to and from your phone. Wilson's booster will not cause interference to any of the cellular networks.

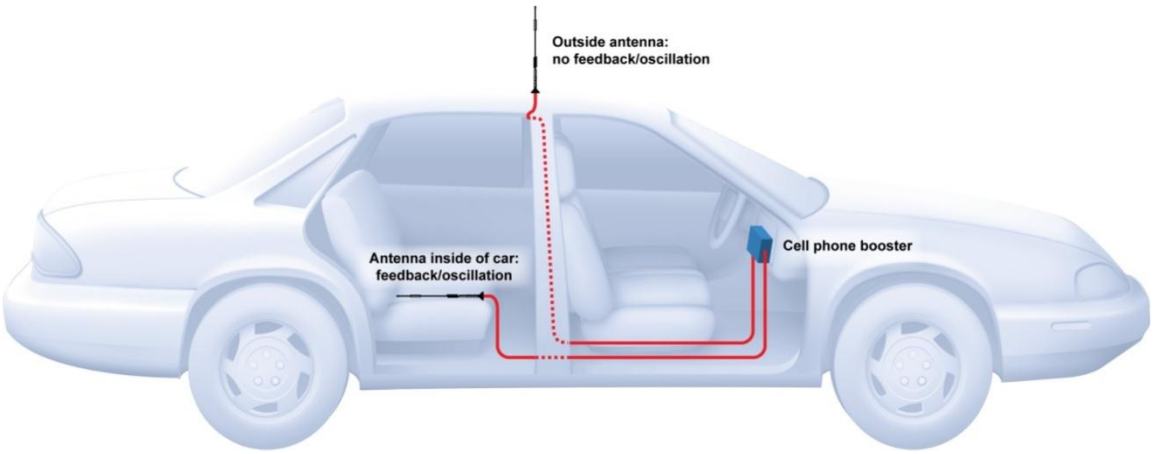
Connected to a booster and the external antenna, your phone thinks there is always a cell site close by. Dropped calls are virtually eliminated and data rates are increased. Your phone's battery lasts longer as well, because the phone is no longer transmitting at full power to send its signal to the cell site. The booster's antenna, which is mounted on the outside of your car, receives the network's signal before it is attenuated by the metal and glass.

Issues

Designing a booster for a cellular phone is not a simple matter. There are a number of issues that must be overcome or the booster will cause harm to the network and/or not provide the type of increased reception that is required. Unfortunately, there are cell phone boosters available today in the United States that are not well designed and that have been shown to cause problems. Currently, Wilson sets about the complex task of designing and building its boosters guided by two principles: Make sure the booster works as advertised for the customer and do no harm to either the network with which the cell phone is communicating or to any other nearby network. It is important to note that some of the protections described in this paper and available in Wilson's current products were not built into some of its previous "legacy" products. It is undoubtedly the case that most of the interference wireless network operators have experienced from signal boosters was caused by devices without this adequate protection built in.

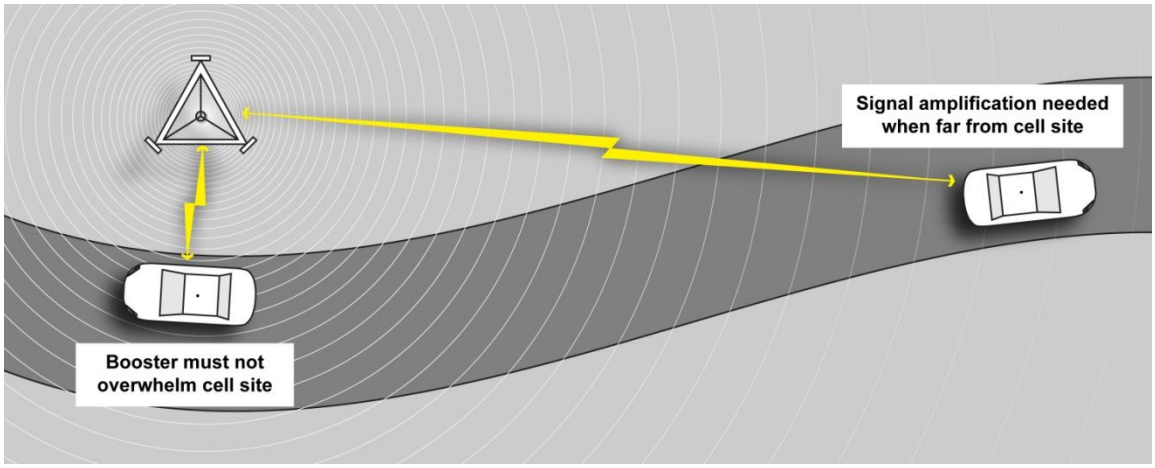
The problems that had to be solved included:

- Avoiding oscillation due to feedback. If the external antenna is placed too close to the in-car cradle (which has its own internal antenna), oscillation due to feedback could occur. You may have experienced similar feedback when a microphone is placed too close to the speaker of a public address system and a howling whine comes out of the speakers. In a cell phone booster, feedback oscillation causes the system to generate noise. This noise signal can interfere with nearby cell sites' ability to receive signals from other cell phones, causing disruption of service to other users, and could actually degrade the performance of the phone inside the vehicle. Thus it is essential to prevent feedback oscillation.

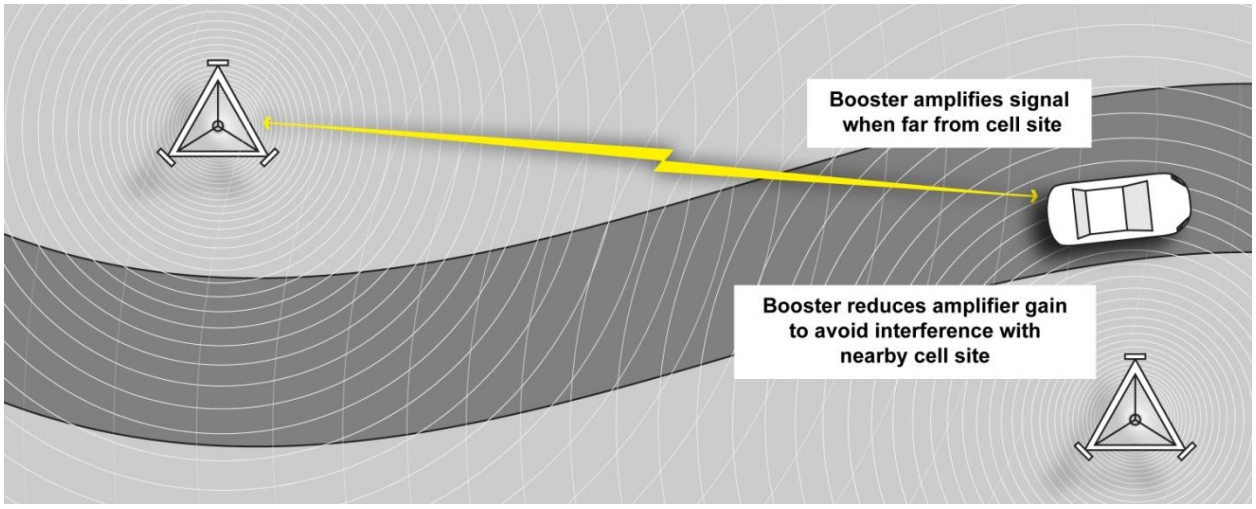


- Preventing overload of the cell site with which the phone is communicating. When you are far from the nearest cell site, the booster needs to transmit at the maximum allowable power. If

you then drive close to the cell site, it must appropriately adjust itself so as not to overwhelm the cell site, disrupting service to other users (and, of course, if you are close to the cell site, signal amplification is not needed). This prevents any type of network overload or potential interference.



- Avoiding interference to adjacent cell sites. A more subtle variation of the above occurs when your cell phone is communicating with a distant cell site, but there is another cell site (operated by a different service provider) close by. There is a possibility that the booster could cause interference to the other network operators' cell site. If the booster transmits a strong signal in order to reach the distant site, it could potentially interfere with the nearby cell site.



Thus a booster must be designed to avoid transmitting broadband noise that would cause a problem to nearby cell sites.

These issues lead us to two overarching design principles for cellular telephone boosters:

1. Do no harm to the network. The booster must be designed so that under no circumstances will it overload or interfere with any existing wireless network. Network operators are appropriately concerned about the types of devices that can access their networks and the potential for those devices to cause interference. There have been situations where devices not properly designed have caused network interference. These incidents affected not only the customers using the equipment but also those who were sharing the same cell site. Also, the booster must not interfere with other nearby networks that may operate on different frequencies or with different network technologies than those of the customer.

2. Be invisible to the network. Beyond not harming the network, a well-designed booster will essentially be invisible to the network. That is, the cellular phone communicating through the booster should always look exactly like a phone that is near the cell site. The purpose of a mobile booster is to increase the range and reliability of a customer's phone in a vehicle. At the same time, the booster must be aware of the cellular network and operate in such a way as to preclude it from overloading or interfering with the network.

To our knowledge, Wilson Electronics is the only company producing cell phone boosters that adhere to these design principles.

Wilson Electronics' Design

The cell phone boosters produced by Wilson Electronics have three key features that address the issues described above.

Avoiding Oscillation Due to Feedback

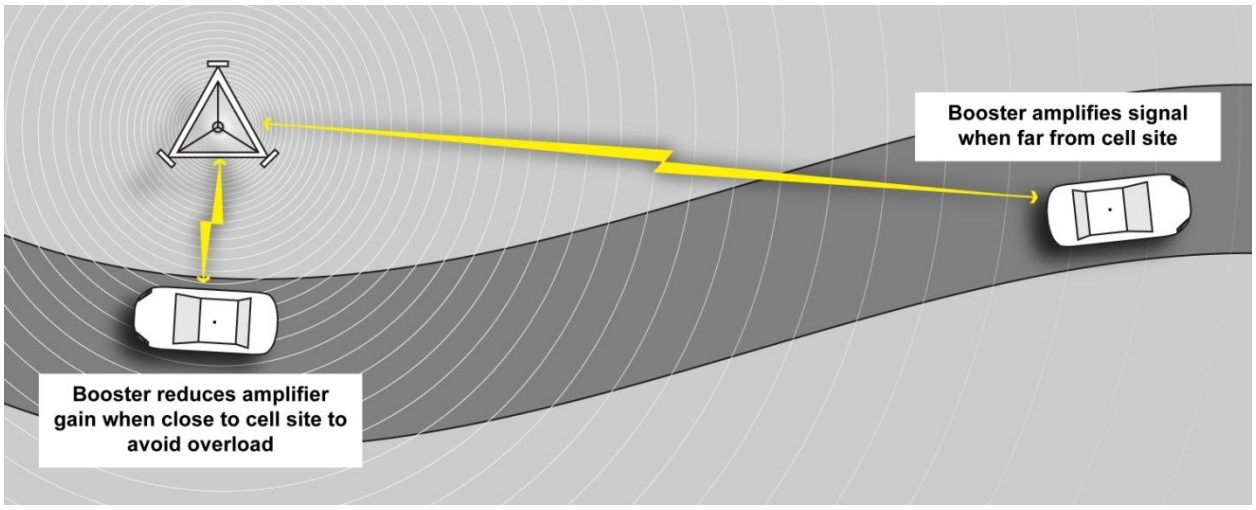
Oscillation protection avoids the problem of feedback. Since in-car boosters are consumer installed, it is possible that the antenna might be placed too close to the internal booster. No matter how well written the installation instructions, some consumers may install the antenna near the booster. Or even if the initial installation is correct, the antenna might be later moved, perhaps thrown in the back seat when the vehicle is taken through a car wash.

If this happens, oscillation will occur the next time the booster is powered on. If left unchecked, it will cause the system to broadcast noise, interfering with the cellular network. On the Wilson booster, there is an indicator light that turns red when an oscillation has occurred, informing the user that the antenna needs to be repositioned. But more importantly, the booster protects the network by detecting any oscillation. Within 10 milliseconds (1/100th of a second), the booster reduces gain (amplification) or shuts down if needed to prevent network interference. By designing a booster that provides both a

visual indication and a failsafe way of preventing oscillation from generating unwanted noise on the network, Wilson eliminates the feedback problem.

Preventing Cell Site Overload

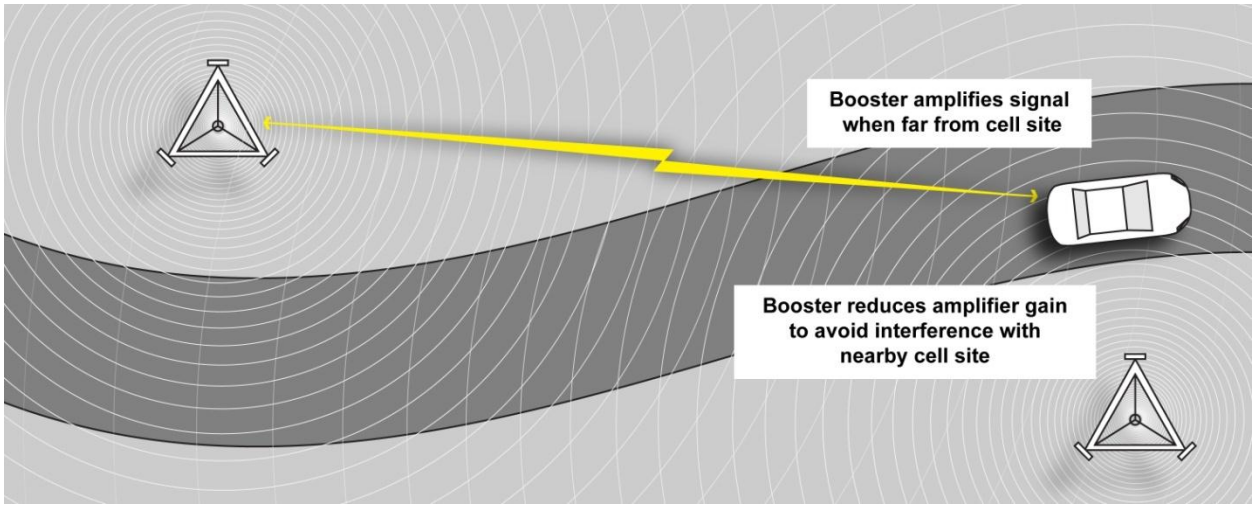
As described above, it is critical to avoid overloading a nearby cell site by broadcasting too strong a signal. When your phone is connected to the cellular network, the cell site constantly communicates with the phone, telling it to adjust the transmit power as it moves closer to or farther from the tower. This happens hundreds of times each second. The Wilson cell phone booster measures both the transmit signal strength from the phone and the incoming signal strength from the cell site. It uses these measurements to determine how close the phone is to the cell site, and adjusts its operation accordingly.



As you approach the cell site, less and less boost of your phone's signal is required. In this situation, the amplifier reduces the gain, or if necessary, shuts off completely. Thus at no time is the cell site overloaded with too strong a signal. Then, as you move away from the site and signal amplification is required, the booster comes back on (if it shut down) and continually varies its gain for optimal performance.

Avoiding Interference with Nearby Cell Sites

When any broadband amplifier boosts a signal, depending on its gain, it also can generate detectable background noise. In a case where the cell site with which your phone is communicating is far away, the booster will amplify the phone's transmit signal to reach that distant site. If another network operator's site is nearby, it is essential that the booster not generate background noise that could interfere with that nearby site.



By continuously monitoring the signal strength of nearby cell sites, the Wilson cell phone booster adjusts the transmitting signal gain (amplification) to avoid the possibility of interference with the nearby cell site, even though that site may use different frequencies or technologies. As you move away from the nearby cell site, the booster can increase signal amplification to give you the best possible connection to your distant cell site without ever interfering with the nearby cell site.

Other Design Features

Beyond the three key features described above, Wilson cell phone boosters have other design features to protect the cellular networks.

It is important to ensure that the cell phone booster does not interfere with adjacent wireless channels when transmitting. Thus the Wilson transmitting amplifier is designed to have adequate dynamic range. This means that the amplifier is not straining when operating at or near full power. It ensures that the amplifier maintains a linear response to the signal from the cellular phone, and it minimizes the likelihood of the outgoing signal “bleeding” onto adjacent channels.

In addition, the booster must have amplification correctly balanced between the forward link (cell site to cell phone) and the reverse link (cell phone to cell site). Well-balanced amplification is essential to preserve the correct relative power balance in the network. If this is not done, the phone could have problems establishing a call, even though it shows “more bars” from the boosted incoming signal. Some existing products in the market in fact boost only the incoming signal to the cell phone and do nothing to amplify the outgoing signal from the phone to the cell site. These products can actually worsen communications in areas of marginal coverage.

More than Design

All of this technology is designed to give the customer the maximum benefit of the booster while at the same time ensuring that both the customer's and other networks are fully protected and that the booster will not cause interference to any of the systems. But a great design is worthless if not well manufactured.

Wilson cell phone boosters are manufactured in the United States in its southwestern Utah facility. Each unit is tested before being shipped. The testing is monitored in real time, and if a problem is discovered, the engineering team is immediately notified. Wilson's advantage in this area is that the engineering team is located adjacent to the manufacturing line, not 6,000 miles away, as is the case for products manufactured abroad. Thus the engineers are immediately available to troubleshoot and correct any problems before the boosters are packaged and shipped.

Experience in Canada

Wilson's experience in Canada with TELUS, one of the largest wireless service providers in the country, is an example of the cooperation that can exist with network operators. Wilson has sold nearly 50,000 signal boosting devices in Canada, which TELUS actively markets in the best interest of the citizens of Canada. TELUS cooperated with Wilson on the design and testing of the Wilson 801209 dual-band wireless booster to ensure its use would not cause interference with the TELUS network.

Most of Canada is rural and cell towers are understandably sparse. Wilson's signal boosters have worked well to provide service where it was not previously possible, or reliable, without any significant system interference. In those circumstances, TELUS cooperated with Wilson in order to better serve its customers. TELUS' engineers worked closely with Wilson engineers to design and build a product that would not interfere with its CDMA system.

In addition, TELUS developed its own standards for cellular boosters and had Wilson products tested against these standards by independent laboratories. Based on Wilson's experience working with TELUS and going through all of the rigorous testing, Wilson had a similar experience with another of Canada's largest cell phone service providers, Bell Mobility. Bell understands that it is very difficult to cover every part of the country and that Wilson signal boosters can provide an effective tool to help customers stay connected in weak signal areas. Bell Mobility has approved and marketed multiple Wilson amplifiers over the past several years.

A Call for Dialog

Wilson Electronics looks forward to working with the wireless network operators, the CTIA, and the FCC to demonstrate that cell phone boosters are a needed product for many customers, and that they can be safely used without causing interference to the cellular networks.

Existing booster products that do not have the protections described in this white paper are known to cause interference with cellular networks. Surprisingly, such products can be legally sold in the United States, as they in fact comply with the current FCC certification requirements. This is why Wilson believes that the FCC should amend its certification of cell phone boosters to ensure that all cellular networks are protected. All cell phone boosters should be required to incorporate the following features:

1. Oscillation (feedback) must be detected and responded to immediately. The booster must either shut down or reduce amplifier gain to the point where the oscillation feedback is eliminated. This will prevent interference with nearby cell sites.

2. Nearby cell sites must be detected and responded to immediately. The booster must either shut down or reduce amplifier gain to the point where the output does not exceed established standards. This will prevent the booster's transmissions from overloading the nearby cell site.

3. The booster must support bi-directional signal amplification of the signal from the cell site to the mobile phone, and from the mobile phone to the cell site. Lack of bi-directional amplification can affect the balance of the cellular network.

The FCC certification should document tests that will ensure that any device receiving certification successfully operates as described above. Wilson also believes that the FCC should require that all existing cell phone boosters be re-certified to the new tests within one year of the rule adoption. Wilson is prepared to work with the network operators, the CTIA, and the FCC to develop such tests.

We believe that such a course of action will maximize cellular phone customer satisfaction while ensuring that all cellular networks are free from interference from poorly designed boosters.

Conclusion

Many cell phone users experience dropped calls and slow data rates when using their phones in their cars. While there are a number of booster products in the market today, the Wilson booster is the only one that provides visual confirmation to the customer that it is installed correctly as well as protection against interfering with cell sites, even cell sites from other networks.

In-car or mobile cellular phone signal boosters:

- Are important products that can improve the satisfaction of cellular phone customers when they are using their phones while in their cars by virtually eliminating dropped calls and boosting data download speed.
- Can be designed and built in such a way that they do not interfere with the operation of cellular networks.
- Should be certified by the FCC, using amended rules to ensure only well-designed boosters achieve that certification.

- Wilson Electronics wants to work with the FCC, CTIA, and network operators to make this happen.

Inferior in-car or mobile cellular signal boosters that do not meet the features described are already on the market today, and people are buying them. We believe that as consumers become more aware of them, network interference problems will only increase. The best solution, therefore, is to ensure that only products demonstrated as non-interfering should be certified for use.

It is interesting that in Canada, TELUS has not only endorsed the Wilson in-car boosters but is actively selling them to its customers. Yet in the United States, there is presently a hot debate on this topic and many comments have been filed with the FCC. Unfortunately, there are many in-car boosters that can be purchased over the Internet. Most of them do not protect the cellular operators or the user from interference, and they often have other problems that have been discussed in this paper.

Another issue that has developed during this debate is that none of the U.S. network operators nor their approved test labs have any established guidelines for testing these devices to measure both their effectiveness and their ability to protect all cellular networks from interference. Yet the FCC has certified not only the Wilson in-car boosters but others as well. This means that the boosters have passed the FCC's emission tests. It does not mean they have passed more rigorous testing to ensure that they will do no harm to the network with which they are communicating or to any other nearby network.

What is needed is for the industry to come together and determine how to best devise a set of tests that will ensure that these boosters work as advertised and that they do not cause any interference. People are buying them and those who have tried the Wilson units have nothing but praise for their operation. In fact, some employees of several networks have these devices installed in their vehicles and have stated that they have fewer dropped calls and can use their own network in places where it was not previously possible. However, the FCC, the CTIA, and many of the network operators have not been able to reach an agreement about how best to go about testing and certifying these devices. Some of the network operators have even petitioned to eliminate boosters from the marketplace.

Some of the network operators with whom we have discussed these devices feel that endorsing or certifying the in-car boosters would be an admission that their own network is not as robust as they would like their customers to believe. The reality is that regardless of how many cell sites are built, and regardless of how much detail is placed on network coverage and performance, there will be places where users experience dropped calls and/or reduced data rates as they drive around. Approving and certifying in-car boosters is not an admission of their failure to provide adequate coverage, but rather it is helping their customers have a better overall experience, have fewer dropped calls, and better access to broadband services at faster data rates.

It also seems strange to us that while network operators are spending both time and money to enhance their in-building coverage by use of femtocells, bi-directional amplifiers, and distributed antenna systems, they have not addressed the mobility coverage issues in the same fashion, especially when there are solutions available today that work and at the same time protect both the network they are

operating on and other networks. It seems as though the solution would be to open a dialogue with the CTIA taking the lead and working with companies such as Wilson that want to provide a solution that both works and is non-interfering.

There is no such thing as a perfect network and there never will be. Radio waves bounce around and are absorbed by vegetation and buildings, and cell sites are shadowed by new buildings or terrain. Unfortunately, it takes a number of years to locate, design, and build new cell sites that will solve known coverage issues. It makes sense that until such time as the networks are bulletproof (never) that another tool to enhance customer satisfaction makes sense, as long as network operators are able to pre-determine which boosters have been designed to maximize their customers' experience while not creating any problems with any of the networks.

Working together, the FCC, CTIA, cellular network operators and Wilson Electronics can deliver in-car cellular signal boosters that will improve customer satisfaction while protecting the cellular networks.

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