
Understanding How Interference Can Impact Your 1900-MHz Cell Sites

A White Paper

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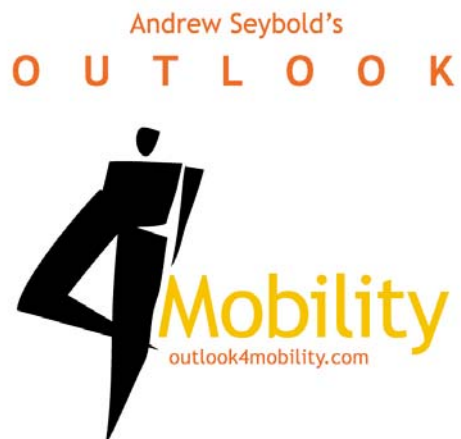
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PREFACE

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WIRELESS COMMUNICATIONS SYSTEMS

Wireless communications or cellular phone systems have been in use in the United States since 1983. Over time, these systems have been upgraded from analog to digital technology in order to provide additional capacity and clarity, as well as to add functions such as short messaging and wireless data access for subscribers.

Commercial wireless systems are some of the most complex wireless networks in the world. Each system is comprised of multiple "cell sites" and each cell site employs multiple channels. In addition, many cell sites are "sectorized," which means that channels are connected to antennas that are pointed in a specific direction or at a specific sector. Typically, cell sites are divided into two or three sectors in order to provide coverage in all directions from the tower site.

With the CDMA digital technology, the same channels are reused at each cell site. With TDMA and GSM, different channels are used at adjacent cell sites and are reused at sites that are beyond the coverage of the first site.

It is of paramount importance that each cell site be equipped with receivers that can "hear" wireless handsets within their coverage area. Ideally, cell sites are constructed so that their transmitters and receivers are balanced — the transmitter and receiver both cover the same geographic area. However, making improvements that will help the cell site receiver "hear" better is beneficial in terms of reducing dropped calls and increasing actual data rates.

For maximum "hearing" ability, the cell site must be optimized and the receivers must be designed to provide maximum sensitivity (see page X for a discussion of receiver sensitivity). However, in the real world, sensitivity can be diminished by a number of factors. Most wireless service providers spend huge amounts of time and effort to optimize each cell site. It is of utmost importance to ensuring that each site is performing as well as possible since the process of adding cell sites is difficult at best due to zoning constraints, availability of suitable sites, and the expense of adding sites.

Other radio transmitters co-located at the same site or in close proximity can generate noise in and around the receiver's tuned frequency. The site itself, which consists of computers and other control equipment, can also generate noise that will affect receiver sensitivity. Add to this that there is a general noise level (referred to as a noise floor) that can impact the receiver's ability to hear weak signals. (SC to insert info on General noise floor here)

Even if there is no detectable noise at a cell site that could impact a receiver's ability to hear, that does not mean that the site will be immune from interference in the future. The receivers at the site could lose some of their ability to capture signals as new equipment is added, changes are made to advance existing technology (e.g., AMR for GSM), other operators build new sites nearby, or as the noise floor increases. Therefore, it is not only necessary to monitor the site when it is first constructed, the site must be monitored over its lifetime. If changes to the level of interference are detected, there are remedies available to help correct the problem.

Interference problems have been popping up since the first cellular band (850 MHz) was opened up to commercial operation. At first, cell sites were constructed by individual wireless network operators. It was not uncommon to see three or four cell towers within a few miles of each other. Today, because it is more difficult to obtain permits to erect new cell sites, many of these network operators are working together to share space at the same site. Moreover, since the first 850-MHz towers were built, the industry has switched from analog to digital technologies, which can and do generate more noise in and around their allocated channels.

There has also been an increase in the use of 800-MHz and 900-MHz channels both above and below the cellular slice of spectrum. One of the most troublesome problems facing existing 850-MHz wireless operators is the co-location of Nextel and Motient (a nationwide data-only service provider), public safety agencies, and private radio systems in the 860-865-MHz band. When cellular was first deployed, Nextel's system consisted of large, high-powered sites that were sparsely deployed. As Nextel's system morphed into a cellular-like system, the company began building towers in the same locations as the rest of the cellular community. Other systems operating in this band also make use of high-level sites. Since their channels lie just outside of the receive channels used by cellular operators, the addition of these sites added to interference levels at many of the true cellular network operators' sites.

As wireless network operators have increased the number of sites in order to provide additional capacity and coverage, the issue of interference from other radio systems has increased.

As a result, many cellular operators are finding it necessary to take more extreme measures to protect their site receivers from interference. This is being accomplished in a variety of ways. Several wireless network operators are using tower-mounted pre-amplifiers to increase the sensitivity of their receivers, but increasing the sensitivity in this way also increases the noise that the receiver hears. Without filters to limit

the bandwidth of the pre-amplifier, the receiver will hear noise generated on adjacent channels as well as on the main channel.

One of the most reliable ways to enhance a base station is to use a combination of pre-amplifiers and filters to narrow the range of the spectrum that a receiver "hears" while amplifying the signals of the selected channel. This combination has solved problems at many sites by reducing interference. It has also resulted in fewer dropped calls, increased coverage per site, and, in some cases, increased data speeds since noise can adversely affect the reception of data and require the handheld or laptop to re-transmit many packets of data, thereby slowing the average throughput of the system.

LESSONS LEARNED AND APPLICABLE TO THE 1900-MHZ SPECTRUM

All of the lessons that have been learned in the 850-MHz wireless band are also applicable to the newer 1900-MHz PCS (Personal Communications System) spectrum that is being used exclusively by Sprint PCS, Cingular Wireless, T-Mobile and some regional players, and for expansion of capacity and coverage by AT&T Wireless, Cingular Wireless, Verizon Wireless, and some regional wireless operators.

The 1900-MHz band is made up of 120 MHz of spectrum from 1850 MHz to 1910 MHz and from 1930 MHz to 1990 MHz. In between these allocations is 20 MHz of spectrum available for both fixed and mobile unlicensed use. While this spectrum has not yet been put into service, there is the potential that it will be. Since this portion of the spectrum is for unlicensed use, the type of technology that can be deployed in this 20 MHz of spectrum is not defined by the FCC and there is no guarantee that such use will not interfere with the operations of licensed PCS spectrum holders. Potentially, any number of RF systems could occupy this slice of spectrum: Wi-Fi or 802.11 spread spectrum, TD-SCDMA, OFDM, or other modulation schemes. Any and all could be deployed and potentially cause problems for wireless operators both above and below this unlicensed segment of the PCS band.

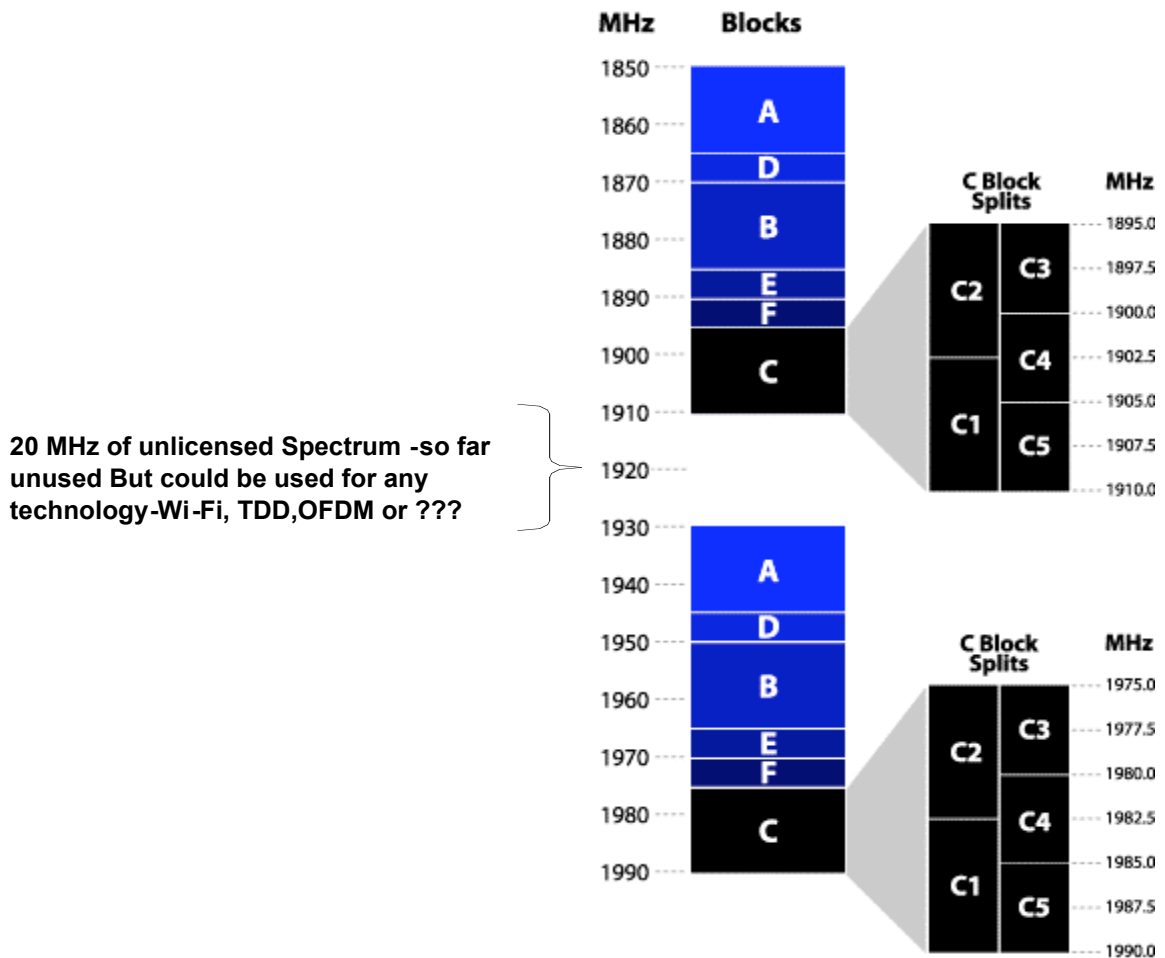


Figure 1. PCS Spectrum Allocations

THE PCS BAND AND ITS NEIGHBORS

The PCS band was first divided into six different segments (A-F) in each region of the country. Recently, the FCC decided to sub-divide the C block in some areas adding the potential for up to four additional systems, increasing the potential number of wireless systems making use of the PCS spectrum to a total of eight in each of many regions of the United States. This presents yet another case for potential interference.

The spectrum just below the current PCS allocations (1850-1990 MHz) is presently allocated for use by the Federal Government and is designated for both fixed and mobile services. The FCC recently re-allocated 1710 MHz to 1755 MHz for 3G wireless services (along with 2110-2155 MHz). At present, it is not known when this spectrum will be made available and whether those now using it will be re-located to 1755-1850 MHz, which is just below the existing PCS band.

The spectrum just above the PCS band (1990 MHz to 2025 MHz) is presently allocated for use by both the Federal Government and earth-to-space stations for satellite communications. However, this spectrum could be added to that already allocated for the PCS band if the President's Spectrum Management Task Force so recommends.

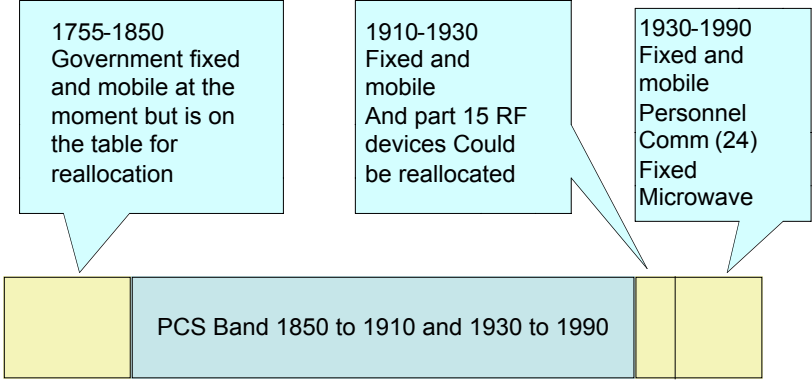


Figure 2. Spectrum Above and Below PCS

The potential for RF interference increases in the noise floor are as great or greater in the PCS spectrum as it is in the 850-MHz band. All of the wireless systems operating in the PCS band make use of digital technologies. Today, GSM/GPRS/EDGE and CDMA2000 1X are the technologies of choice. However, it is possible that GSM operators will migrate to WCDMA. WCDMA, unlike CDMA2000 1X (which uses a 1.25-MHz channel) requires a full 5 MHz of spectrum on both the receive and transmit sides of the systems. In other parts of the world, spectrum that is allocated for WCDMA (known as UMTS in Europe) includes "guard bands" on either side of the allocation in order to reduce interference. In the United States, our PCS allocations are split into 5, 10, 15, 20, and 30-MHz slices. A wireless network operator deploying WCDMA might choose to use two 5-MHz channels in a 10-MHz allocation, posing problems for themselves as well as adjacent operators.

Another pending issue is the spectrum licensed to NextWave that is not presently in use. Most of this spectrum is in the F band (5-MHz allocations). If NextWave follows through with its claims that it will be building out a nationwide broadband data system making use of TD-SCDMA or OFDM, which use the same portion of the spectrum for transmitting and receiving data, there could be severe consequences for GSM or CDMA 1X systems operating adjunct to this spectrum.

OTHER FACTORS AFFECTING PERFORMANCE

Other factors that can and will affect the amount of RF noise pollution in this portion of the spectrum include:

- Urban RF congestion. Since there could possibly be from six to ten wireless licenses in each urban area, there is a potential for interference from/to systems using adjacent spectrum blocks. Because cell sites are being built closer together to increase capacity and to provide better in-building coverage, the potential for interference is heightened. (It already requires approximately three times the number of cell sites in the PCS band to cover the same geographic area as in the 850-MHz “cellular band.”)
- There is possible interference from the 20 MHz of unlicensed spectrum between the two PCS bands.
- Co-location of multiple PCS systems at the same site increases the potential for interference and increased RF noise floor levels. Many local municipalities are requiring cell site tower sharing because of perceived tower and health-related issues.
- Spectrum above and below the PCS allocations are in a state of flux. Today the spectrum just below the PCS band is allocated for fixed and mobile use by the Federal Government. However, it has been included in spectrum that the FCC is considering making available for third-generation wireless systems. The spectrum above the PCS band is presently allocated for mobile satellite systems (earth to space), thus the terrestrial transmitters for these systems are located adjacent to the PCS spectrum.
- The Federal Communications Commission (FCC), the President’s Spectrum Management Task Force, and the NTIA are all in the process of reviewing current spectrum allocations and making recommendations for new methods of allocating spectrum that still permits new technologies to enter the market. Any and all of these recommendations could affect interference in this band.

The FCC is presently asking for comments on a new way to measure receiver interference. This methodology is referred to as “Interference Temperature” and could dramatically change the permitted levels of interference that must be tolerated by a licensed station.

The FCC is also asking for comments on the use of Software-Defined Radios (SDR). These proceedings could have an impact on future interference/noise floor increases. Proponents of this technology claim that spectrum allocations and shared-use spectrum plans could become

viable due to the nature of SDR products and their supposed ability to differentiate between “real radio signals” and noise. Mixing SDR and current-day technology poses a potential for increased interference.

The FCC is investigating the transmission of high-speed data over mid-level power lines. There are two proposals in play. The first calls for such systems to make use of spectrum in the 2-80-MHz range, which would have no impact on the PCS spectrum. However, the second proposal is based on another technology that would use the 2000-MHz and above spectrum, creating a potential for interference and an increased noise floor.

DEALING WITH THE UNKNOWN

An additional area of concern is the stability of the spectrum allocation plan. For example, two satellite radio companies have received permission and have deployed terrestrial repeaters (XM and Sirius). While these two companies operate in the 2300-MHz band and the potential for interference to the PCS band is minimal, the fact that the FCC has granted these two companies the right to use high-powered terrestrial repeaters in spectrum reserved for satellite systems is an indication that many changes to our RF environment are possible over the next few years.

Because of the increase in the number of wireless subscribers in the United States and the rest of the world, and the demand for both increased geographic and in-building coverage, wireless providers are rethinking their cell site designs and spending more time and money optimizing existing sites prior to building out new sites.

Common “best practice” engineering when installing cell site radios and antenna systems is no longer sufficient to ensure maximum performance from a site. In today’s harsh RF environment, sites need to be engineered differently. Filters, pre-amps and filters, and other devices that can minimize interference while maximizing receiver sensitivity are now a must.

Fortunately, there are a number of remedies available today. Devices can be retrofitted into existing sites to help with existing interference issues, prevent new problems, and optimize the return link thereby minimizing dropped calls while increasing data throughput. There is an abundance of evidence as to the benefit of these types of devices including empirical data on the reduction of dropped calls and the increase in data throughput.

These remedies should also be considered a “must have” when planning new sites, especially in harsh RF environments such as urban areas. Experience has shown that optimizing sites will reduce dropped calls and fill in “dead spots.” In some cases the result will be better overall coverage with fewer than anticipated sites. Today’s harsh RF environment requires that “best practices” now include more protection for these sites than ever before.

RECEIVER SENSITIVITY

How well a receiver can “hear” is dependant on a variety of factors. First is the receiver sensitivity – how well a receiver can “hear.” One way to understand receiver sensitivity is to start with a single grain of sand. If you place this grain of sand between your thumb and finger you might not even feel it. However, if you put the grain of sand in your eye it would feel like a huge boulder.

Your eye is more sensitive than your thumb so it feels the grain of sand better than your thumb. The same applies to a wireless receiver: The better its sensitivity, the better it hears.

12/30/03

FCC Releases Notice of Proposed Rulemaking on Smart Radios Proceeding.

NPRM: [Word](#) | [Acrobat](#)

News Release (12/17/03): [Word](#) | [Acrobat](#)

Powell Statement: [Word](#) | [Acrobat](#)

Copps Statement: [Word](#) | [Acrobat](#)

Martin Statement: [Word](#) | [Acrobat](#)

Adelstein Statement: [Word](#) | [Acrobat](#)

T11/28/03

FCC Releases Notice of Proposed Rulemaking Regarding "Interference Temperature" Approach for Interference Management.

NPRM: [Word](#) | [Acrobat](#)

News Release (11/13/03): [Word](#) | [Acrobat](#)

Powell Statement: [Word](#) | [Acrobat](#)

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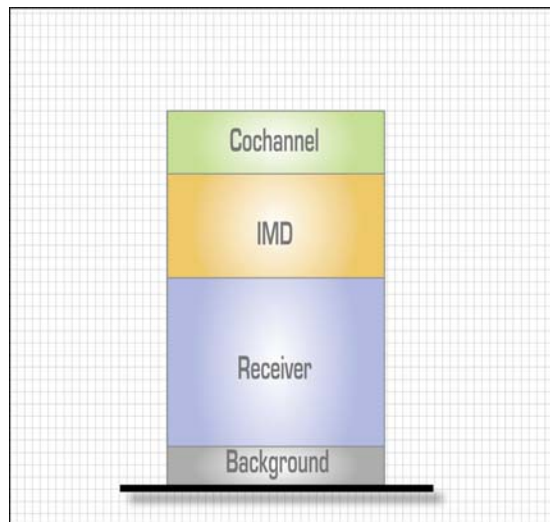
APPENDIX -NOISE IN RECEIVERS

The degradation of a signal as it passes through multiple receiver components is described by the **noise factor of the receiver**. For most receiver designs the noise factor is dominated by the RF front-end. The conventional noise factor can be calculated for an entire receive chain, F_{Rec} , using the following equation:

$$F_{Rec} = F_1 + \frac{F_2 - 1}{G_1} + \frac{F_3 - 1}{G_2 G_3} + \dots,$$

where F_x and G_x are the noise factor and gain factor for each component in the chain. They are represented as linear ratios rather than logarithmic dB (i.e.).

The most important metric for mobile performance is **signal-to-noise ratio** at the base-station receiver. In addition to the usual (thermal) noise, "noise" now includes **intermodulation distortion (IMD) noise** and **cochannel interference** from other users on the same frequency. IMD noise is generated in the non-linear receiver elements as mixing products of signals not necessarily in the user frequency band.



• Figure 3. Total receiver noise.

The total noise factor, or generalized noise factor (GNF) of the receiver is given by:

$$GNF = F_{Rec} + \frac{N_{IMD}}{N_{in}},$$

where N_{in} is the background noise power and N_{IMD} is the IMD noise power referenced to the input of the receiver at a given frequency. Since GNF is a characterization of the receiver, cochannel interference is not included. However, both the GNF and cochannel interference are needed when determining the effects of noise and interference on critical performance metrics, such as coverage, capacity utilization and quality of service.

Reductions in the GNF lead directly to increased coverage (including in-building), increased capacity utilization, and better quality of service.