This monograph was originally presented at a seminar hosted by IRWA's Southern California Inland Empire Chapter 57 in April 1998.

The Death of Right of Way Corridors

Understanding Wireless Technologies for Cell Site Leasing

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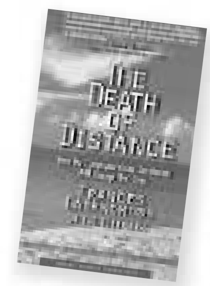


A recent book entitled *The Death of Distance* explains how the revolution in wireless telecommunications is effecting our society. Wireless communications technologies not only eliminate stationary communications, but also result in the figurative death of the need for right-of-way corridors. The need for a continuous land corridor for telephone transmission lines is eliminated under wireless technology.

Wireless communications technologies can serve mobile users where conventional wired systems can only serve stationary sites. Such new technologies eventually offer to be cheaper than conventional communications technologies partly because of the avoidance of right-of-way costs. Base station antenna sites and mobile switching station sites represent the real estate component of the new wireless technologies.

The world economy and government is being affected by the telecommunications revolution. The business opportunities are huge. Despite the non-necessity for right-of-way corridors, the opportunities for public agencies to lease land for telecommunications sites is limited only by their capacity to respond. The challenge for public agencies is to move fast or be excluded from the growth of the new wireless telecommunications infrastructure.

It is estimated that cellular communications carriers will need 15,000 new cell sites by the year 2005. One hundred thousand sites will be needed for PCS (Personal Communications Systems) sites. The demand for Enhanced Specialized Mobile Radio (ESMR) sites mainly by Nextel has been unexpected, but is estimated to equal the number of cell sites.

Many of the cellular, PCS and SMR sites will require appropriate line-of-sight microwave links to connect them with the switched hard-wired telephone network. With the growth of these newer wireless technologies, the demand for antenna sites is also changing from mountaintop sites to lower elevation sites such as foothills, tall buildings, water tanks and church steeples.

The aim of this article is to provide public agency personnel and consultants with a brief non-technical introduction to wireless cellular communications technologies to facilitate site leasing and valuation.

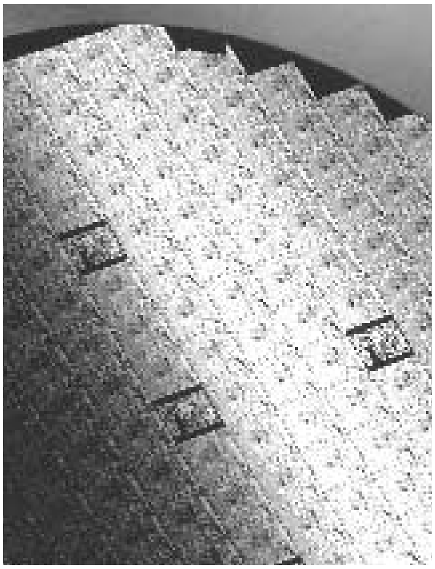
■ Radio Basics

To understand cellular technologies for cell site leasing it is imperative to know some radio basics first.

The recorded origin of the technology of untethered communications across large distances beyond the range of the human voice can be traced back over 3,500 years. The Greeks used two large screens hiding five torches and a code in which the Greek alphabet was divided into five groups to communicate across long distances. The torches would be raised to indicate a pair of numbers.

In the play *Agamemnon,* the Greek playwright Aeschylus describes how news of the fall of the city of Troy in Asia Minor was communicated over a distance of 600 kilometers to Agamemnon's palace in Greece by way of this system in approximately 1200 BC.

Wireless communications are defined as the ability to communicate without the use of wires, the links between communicators in the conventional telephone network. Wires are the conduits for voice transmission much like two tin cans and a string, only powered by electricity and conveyed in copper wires to carry longer distances.



The main wireless technologies can be divided into analog and digital technologies. In analog technology the media (air) is made to transmit the amplitude (vibration), frequency, or phase (time) of the human voice. Amplitude modulation is similar to what we know as AM radio. Frequency modulation is similar to FM radio. In digital technology human speech is first converted to a series of coded pulses. Digitized pulses can communicate with computers.

A typical analog system can add 20 to 32 customers to the system for each available voice/radio channel. If an analog cell site has 50 radio channels installed, it can serve 1,000 customers. New digital technologies can multiply this by a factor of three to 20 times. If a 50-channel analog cell site was converted to digital it could serve 3,000 to 20,000 customers.

All signals are modulated (modified) to transmit through the atmosphere. Modulated signals are transmitted through the handset antenna in a cell phone through the atmosphere to the base station antenna. The transmitter variable is power output. Higher-power output increases the distance traveled by the signal but it also increases the probability of interference.

The radio frequency (RF) waves are part of the electromagnetic spectrum that includes visible light, ultraviolet light, infrared, microwaves and x-rays. The relevant range of electromagnetic waves for wireless telecommunications services is 800 MHz band for cellular and 1,900 MHz band for PCS. The higher the speed or frequency of a wave is expressed in hertz. Hertz is a measure of the number of times a wave oscillates or swings back and forth in a second of time. Thousands of cycles per second is expressed as kilohertz (kHz), millions of cycles in megahertz (MHz), and billions in gigahertz (GHz). Human speech is transmitted in the kilohertz range, radio, TV and cellular telephone in the megahertz range, and microwave in the gigahertz range.

Propagation loss is the diminution in signal strength when it traverses across space. Propagation loss increases with distance and frequency. Hence, propagation losses are higher for PCS bands at 1,900 MHz than for cellular bands at 800 MHz.

■ Cellular System Basics

Prior to the concept of a cellular system, mobile communications services were provided similar to radio and television stations. Huge transmitters were set up at the highest point in a given population area. High-power transmissions were sent resulting in a large coverage area. The problem with this was this system is that it had a capacity problem and consumed large amounts of power. If 25 channels were available for voice transmission in a metropolitan area, only 25 calls could simultaneously be made on the system.

One solution to this problem was to reduce the size of the coverage area into cells. The other solution was to re-use the radio channels while making sure that adjacent cells did not have the same radio frequency. Cell frequency re-use must be at least two cells away from each other.

A simple table lamp analogy can be used to best explain how a cell system works. If you had a table lamp with a lampshade on it at the height of the ceiling in the middle of a dark room, the single lamp would illuminate the entire room. Hypothetically, if this one large cell can serve 25 cars the capacity of the system would be limited. However, if you put 15 lamps only on the floor of the dark room instead of the ceiling they would only illuminate a small area or cell. If each cell could accommodate 25 cars the capacity of the same service area is increased to 375.

In our table lamp analogy each lamp must not have the same color of light as the adjacent lamp. Therefore, white, red, green, blue, and orange bulbs are used in the lamps to make sure there is no overlap. Moreover, the power of each light bulb can be reduced from say 200 amps to 25 amps.

■ Types of Technologies

Cellular Technology. Cellular systems operate on the principle of radio frequency reuse. Areas of coverage are divided up into small honeycomb (hexagonal) cells that overlap at the outer boundaries. The greater the number of users, the closer spaced the transmitters. In rural areas, the cells are much further apart. Cell sites typically transmit and receive in the 800-megahertz (MHz) range. The average cell is three to five miles across; two to 10 miles are possible. The separate cell clusters create minimum radio frequency interference, since cells must be at least two cells apart from each other.

The four main hardware components of a cellular network are:

- Cell site (AKA base station)
- Mobile Telephone Switching Office (MTSO)
- Public Switched Telephone Network (landline network)
- Cellular (mobile) handset

The cell site is generally comprised of a radio equipment building constructed of concrete block, a back-up generator for uninterruptible power supply, a propane fuel tank, antenna tower or pole, and cable tray between the building and the antenna tower. If there are no telephone land lines available for linkage to the hard-wired telephone system, there must be an appurtenant microwave antenna to send the batched wireless messages to a remote mobile telephone switching office. Typical cell site costs are as shown in Exhibit A.

Cell site antennas are normally placed on monopoles that can be masked to blend in with the visual landscape. A "mono-palm" or "mono-pine" is an antenna disguised to appear like a palm or pine tree. Some communities are requiring cell sites be housed in rustic windmill structures. Design requirements are a form of what economists call "rent extraction" and represent a struggle between municipalities and public and private landowners over rent.

When a cell site is chosen, there is a 50 percent chance that it cannot be acquired. The "Quarter Radius Rule" of radio frequency engineering states that an antenna location can be found within one quarter of the size of the cell (R/4). If a cell is 8 miles in diameter, the alternate site can be located within a two-mile radius; if a two-mile cell, within a half-mile radius. This rule applies only on flat terrain.

Many cell sites may have a technological monopoly in the rental market. For example, if a six panel cellular antenna array is co-located on a 110-foot high microwave tower in a community where there are no natural promontories, tall buildings, or other permitted towers, the site has a monopoly advantage in the market. The replacement of such a unique co-located cell site may entail the erection of four smaller freestanding monopole sites at an enormous cost relative to the rent paid for the single co-located site.

The rental value of sites that offer a unique advantage of cost savings, radio frequency coverage, or are the only antenna sites permitted in a certain locale cannot be fully appraised for their fair market rental value because they reflect a monopoly value. The rent for such sites must be negotiated. An appraisal can facilitate such negotiations, but is limited in valuing sites that are unique or have a monopoly advantage.

Exhibit A - TYPICAL CELL SITE COSTS

ITEM	COST (IN $1,000)
Radio Tower	$70
Building	$40
Land	$100
Install communication line	$5
Construction	$50
Backup power supply	$10
Total	$285

Exhibit B - COMPARISON OF TECHNOLOGIES

CELLULAR	PCS
High antenna/large sites	Smaller footprint
Few sites (32 Km cell size)	More sites (500 m cell size)
More expensive radio equipment	Less expensive radio equipment
Higher output (3-15 watts)	Lower output (0.1-0.5 watts)
Higher consumer cost	Lower consumer cost
Right-of-way advantage	Right-of-way & base station advantage

PCS Technology. PCS (Personal Communications Systems) is a broad range of individualized telecommunications services beyond voice communications than enable people or devices to communicate independent of location. PCS is a misnomer because even a conventional telephone call is considered personal. It is perceived that PCS is a combination of universal communications services (i.e., cellular, data transmission, paging, e-mail, etc.) in one common appliance. PCS promises an array of services at a potentially cheaper price. PCS employs a frequency re-use technology like cellular does, but at lower power frequencies in the 1,900 MHz range. Long-distance carriers hope to reduce the $21 billion they pay each year to regional Bell companies for access by looking to PCS as a way to sidestep such charges.

Because there are existing FCC (Federal Communications Commis-sion) licensed users in the same radio spectrum authorized for PCS service operators, the government requires the existing users (mainly microwave) to relocate to a different frequency over time. The new users must pay the radio frequency relocation costs. Typical relocation costs are reported to be $225,000 per link. A comparison of PCS with cellular technology is shown in Exhibit B.

SMR Technology. SMR and ESMR stands for Specialized Mobile Radio and Enhanced Specialized Mobile Radio. SMR is for closed user groups (dispatching taxis, delivery vehicles, warehouse crews, public safety, etc.). SMR has been adapted for telephone use. Most users are businesses. SMR technology can be used for conference calling "anywhere, anytime, with anyone." By alliances with common telephone carriers, SMR networks can connect with public switched telephone and cellular networks competing directly with cellular and PCS providers. Nextel is the larger

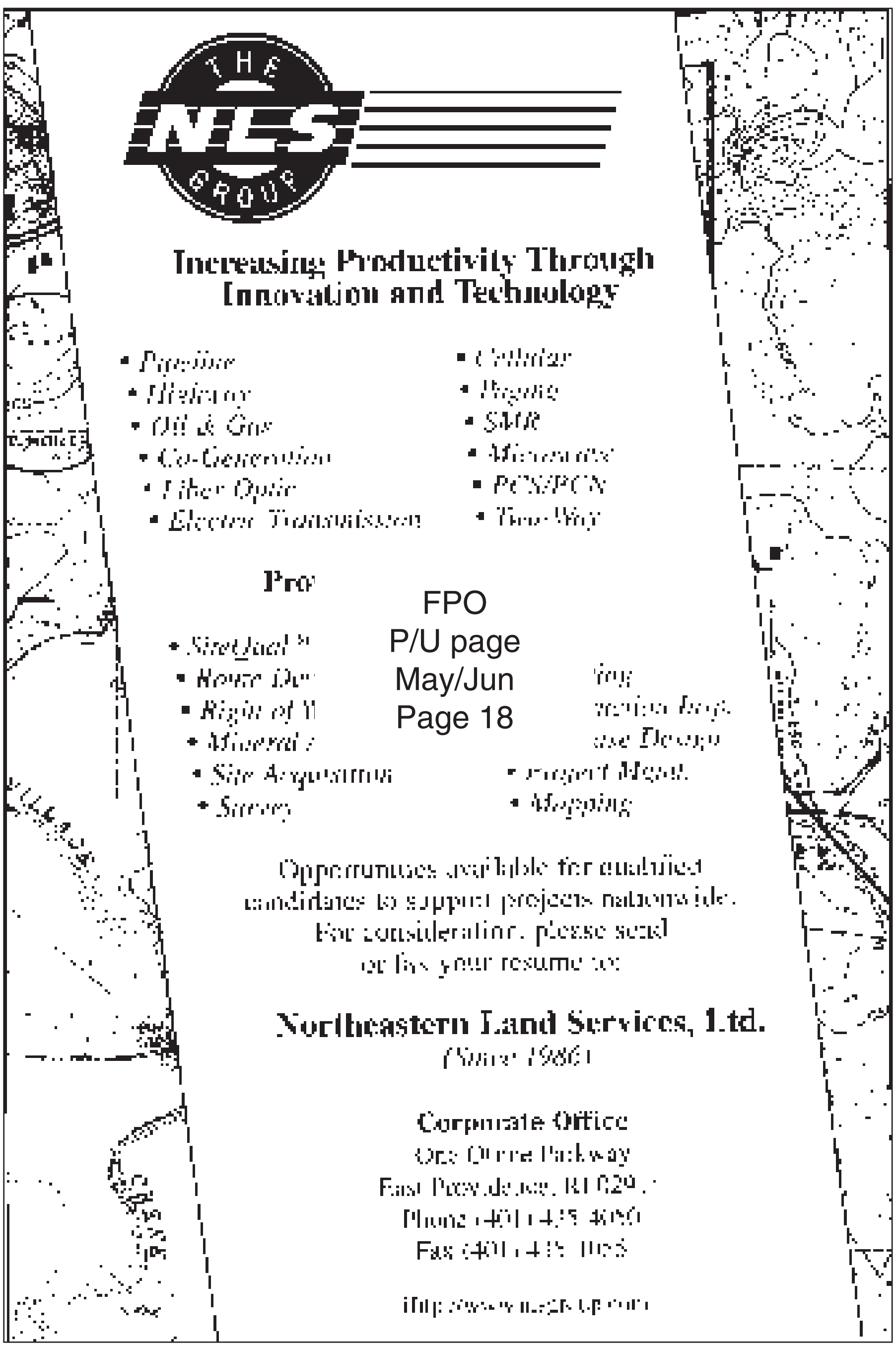
SMR provider in the United States.

SMR antenna sites are classified into "in-building sites" and "outside sites." As the SMR network is put into place and the number of subscribers grows, the initial radio coverage areas are being filled with additional "capacity sites" to remediate busy signals and waiting cues.

Wireless Local Loop (WLL). Historically, homes were connected into the hard-wired telephone network using copper cable. This is called a local loop because it connects homes or businesses to the telephone switching office.

Using wireless instead of copper lines is less expensive in terms of rights of way and construction, reduces the up front capital costs, and avoids lengthy delays in awaiting Internet connection services.

Wireless Local Loop operates in the gigahertz range of the radio frequency spectrum (typically 2.4 GHz), which is the same as microwave.



Because of the necessary delays in rewiring the entire United States with fiber optic lines that can provide broadband Internet connections, Wireless Local Loop technology offers low cost and rapid connection to the information highway. WLL is sometimes also called Residential Broadband or Wireless Access Systems (WACS). Actually, WLL is not a new technology as much as an access technology that overcomes the "last mile" constraints of current technologies.

WLL technology works through roof-mounted directional antennas at the subscriber's premises, pointing toward the base station and providing a large gain in signal strength compared to using a conventional cellular phone.

Unlike cellular, WLL provides wireless services only to stationary sites. WLL is most suitable to home subscribers who do not need or want to pay for the added costs of the high data transmission rate technologies required for businesses.

WLL technology competes with copper and fiber optic cable. WLL out performs cable where market penetration and subscriber rates are low, and is less competitive where the penetration rate exceeds 25 percent of the population.

Because WLL depends on a line-of-sight (LOS) signal, it is limited by geographical obstructions and the possibility of new buildings obstructing the radio path. The optimum sites for WLL base stations will be those centrally located in residential areas with elevation above surrounding terrain that offers unobstructed linear pathways to homes within an approximate three kilometer distance of the base station.

The accounting firm of Price Waterhouse has predicted that WLL will replace wired telephone access as the predominant connection modality in the next five to 10 years.

Other market analysts project 10 percent of all lines installed will use WLL by the year 2000.Communications companies offering WLL technology are

Iowave, SkyLink, and others.

Microwave Link. Microwave technology serves as a link from cellular, PCS, and SMR systems to hard wire telephone systems in remote or rural areas. Unlike cellular, PCS, and SMR technologies, microwave is a line-of-sight (point-to-point) technology. The advantage of microwave is the ability to get around physical obstructions.

A microwave system consists of:

- Transmitter
- Receiver
- Antenna (horn or parabolic shaped)
- Towers
- Path way (line of sight through the air)

Microwave antennas are large horn-shaped pieces of equipment that are typically mounted on towers in contrast with monopoles. Typically, microwave systems require two antennas vertically separated for transmission and reception. The greater the distance between microwave hops the larger the vertical spread required between the two microwave antennas on a tower. It is not possible to screen a microwave antenna like a cellular, PCS, or SMR antenna. The typical microwave distances before repeaters are necessary is shown in Exhibit C.

The advantages of a microwave system are:

- the ability to span long distances
- the ability to overcome obstacles (valleys, mountains) in a transmission path
- high bandwidth capacities
- no right-of-way requirement
- high return on investment (quick payoff)

The disadvantages of a microwave system include:

- FCC licensing
- path and frequency coordination
- purchase or rental of real estate for towers and shelters
- power for remote systems
- disruption of path by new construction
- time required to get service (typically 2 years)

As communications carriers install

Exhibit C - TYPICAL MICROWAVE DISTANCES

Frequency	Approximate distance
2-6 GHz	30 miles
10-12 GHz	20 miles
18 GHz	7 miles
23 GHz	5 miles

Exhibit D - COMPARISON OF MACROCELL SITES

ANTENNA ARRAY	CAPACITY/COVERAGE
Omni-directional (pole antenna)	Minimum traffic capacity/360-degree coverage
Single-Sector	Directionally focused area/45-90 degree coverage
Three-Sector	Typically 9 panels (3 x 3); 3 directions/360-degree
Six-Sector	Typically 18 panels (3 x 6), 6 directions-360-degree

fiber optic cable, the use of microwave systems will diminish or be relegated to a back-up system in the event of failure of the fiber optic system.

Microwave is done wherever it is cheaper than the leased-line costs from major telephone carriers. The typical cost for leasing a 24-channel leased line between cell sites in the United States is reported at $750 per month in the year 1992. New companies like Windstar and Advanced Radio Technology (ARTS) are offering to "leap-frog" land lines with microwave on building tops to tie into telephone/internet services. So-called "cyber-buildings" with microwave links are an emerging tier of the telecom market until such time as fiber optic cable is extended.

An important piece of technical information to know regarding microwave systems is that they can carry a large volume of telephone traffic over long distances.

Telephone companies that equest a cell site together with an accompanying microwave link in emote areas may be patching together a long-distance telephone network now that the deregulation of the telecommunications companies allows local telephone carriers to become long-distance carriers as well.

A lease for a cell site with an accompanying microwave link can, in essence, become a part of a long-distance telephone network handling a high volume of telephone traffic across the continent. Typical cell site rents may not be applicable to such dual use facilities.

■ Types of Cellular Sites

A communication site is a physical location suitable for radio equipment to transmit and receive signals to a geographic area. There is almost an infinite number of communications site configurations.

There are mountaintop sites that typically have multiple users all sharing common facilities and a tower. There are single-user cell sites that can either have a direct hard-wire telephone link or be tethered to an accompanying microwave system to accomplish a "wireless link to the hard-wire telephone system. The most common types of single user or cellular sites are:

- Macrocell sites (cellular)
- Microcell sites (PCS)
- Picocell sites (SMR in-building sites, etc.)

Macrocell Sites. Macrocell sites can be further classified by the type of antennas on the site. The intensity of use of a communications site can approximately be gauged by the type of antenna on the site. Omni-directional antennas serve the least number of users and have the appearance of a 10-foot pole. A single-sector antenna is focused to serve only a single direction such as a hard to cover mountain pass.

It has a small coverage area but can have a large volume of traffic depending on location. A Three-Sector Site has an antenna panel array shaped in a triangular fashion and faces in all directions. A Six-Sector Site has a hexagonal shaped antenna array and reflects the maximum number of antenna panels at one location. See Exhibit D.

Rents for cell sites should be based on the capacity of the antenna on the site. The greater the intensity of uses the higher the rent and vice versa. Whether the cell site is an "initial site" or a "capacity site" that merely adds capacity during peak usage times should also be considered.

Microcell Sites. Microcell sites are becoming more prevalent as carriers strive to achieve more frequency re-use. Types of microcells include:

- T1 fed cell — fed by a copper hard wire telephone link
- Fiber-fed cell — fed by a fiber-optic cable link
- Re-radiator cell (repeaters) that add capacity but not coverage

Microcell sites are typically observed on street light poles and on the side of buildings. The antenna panels are typically much smaller than those used on macrocell sites.

Metricom and Ardis are two data communications companies that offer mobile Internet, e-mail data connections. Metricom uses spread spectrum radio technology with what they call a Richochet modem that scrambles the radio signal to prevent security breaches.

Picocell Sites. The word "pico" mean beak or point in Spanish. Picocell sites are designed to serve small, focused areas such as in-building applications, parking garages, college campuses, large petroleum plants, etc. Picocell antennas are typically small and made to visually blend into the surrounding environment.

Micro-LOS Sites. Micro LOS sites are base stations for Wireless Local Loop technologies described above. The micro-LOS site consists of a base station with a central transceiver unit (CTRU) that links subscribers by an air interface with the hard-wired local telephone exchange. Micro LOS sites must have unobstructed linear pathways to subscribers homes.

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■ The "Death" of Wireless?

In the near future low orbiting satellites and unmanned spacecraft may compete with or eliminate the need for some cellular antenna sites.

However, base station microwave sites will continue to be needed to beam signals up to the satellites because a hand-held cell phone does not have sufficient power to send a signal to a satellite. Low-orbiting satellite technology may also have a half-life once fiber optic cable becomes more universally available across the United States. Even with satellites, terrestrial base stations will be needed at a minimum for back-up systems in case of satellite malfunction.

Supplied with the above information, right-of-way personnel can better understand the technical aspects of cellular telecommunications for site leasing and valuation. ■

Sources

Frances Cairncross, *The Death of Distance: How The Communications Revolution Will Change Our Lives* (Boston, Massachusetts: Harvard Business School), 1997.

Annabel Z. Dodd, *The Essential Guide To Telecommunications* (Upper Saddle River, New Jersey), 1998.

Ira Brodsky, *Wireless: The Revolution in Personal Telecommunications* (Boston: Arctech House), 1995.

Ron Schneiderman, *Future Talk: The Changing Wireless Game* (New York: IEEE Press), 1997.

John E. Evans, "New Satellites for Personal Telecommunications," *Scientific American* (April 1988): 70-77.

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JOB BANK

IRWA has a new free service for right-of-way employers and for those seeking employment. The **Job Bank**, which includes job postings of prospective employers and resumes of job seekers, has had very positive response during its trial period. Anyone can access and update information on the Job Bank through the IRWA web page at HYPERLINK http:// www.irwa.com.

As of December 31, 1997, the voice recorded Job Hotline was discontinued. For questions about these employment services, contact Tamera at International Headquarters, (310) 538-0233, ext. 131.