Developing Specifications for Cellular-Telephone Base Stations

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Abstract: The emergence and continued growth of the cellular-telephone and related telecommunications industry has been phenomenal. The cellular industry has the potential of evolving into a "100-year industry," as did wire telephone, radio, and television. New systems (networks) continue to be built, and there is a continuous need to expand existing systems (networks). A cell is the basic building block of a cellular-telephone system (network). Each cell contains a base station (cell site), which provides transmitting and receiving facilities. This paper discusses various factors that are unique to the development of specifications for sites, buildings, and building improvements used for cellular-telephone base stations (cell sites). The discussion is limited to the equipment shelter or building, applicable site work, the tower or antenna mounts, and the alternating-current electrical system with a possible generator backup system. The objective of this paper is to provide insight relevant to the special considerations required in the development of specifications for cellular-telephone base stations (cell sites).

Introduction and Objective

A base station (cell site) is the basic building block of and key link in a cellular-telephone system (or network). This paper provides a commentary on various factors that are unique to the development of specifications used for base stations (cell sites).

This commentary is based on the writer's professional observations. In 1984, the writer was project manager for the contractor who built the original 22 GTE Mobilnet base stations (cell sites) in Northern California. In 1985, the writer founded Woolery Associates, Berkeley, Calif., and has been continuously involved with the cellular telecommunication industry both with the construction of base stations (cell sites) for Cellular One and GTE Mobilnet in Northern California and with the development of plans and specifications for GTE Mobilnet at the national level.

The objective of this paper is to assist designers, owners, and contractors by providing insight relevant to special considerations required in the development of specifications for cellular-telephone base stations (cell sites).

History and Background

An article in *GTE Lenkurt Demodulator* provides an excellent description of cellular-radio technology ("Cellular Radio" 1982). Two key background articles on the subject were written by MacDonald (1979) and Young (1979).

License applications for cellular services were first accepted by the Federal Communications Commission in June 1982.

The first cellular system in Northern California, consisting of 22 base stations (cell sites), was built by GTE Mobilnet in 1984. Initially, the system was used by both Cellular One and GTE Mobilnet. As of May 1992, the

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GTE Mobilnet system in California has grown to more than 200 base stations (cell sites), and Cellular One has built and operates a separate system.

The change in cellular technology and cellular-telephone equipment seems to keep pace with or even surpass the change in personal-computers technology. During the writer's 10 years of experience in the industry, three generations of Motorola and currently a fourth generation of AT&T cellular-telephone equipment have been installed in GTE Mobilnet's system in California.

New uses for cellular technology continue to develop. For example, Hall (1992) reports that the computer age is about to go cellular. "Four cellular telephone companies are joining forces to construct what is being billed as the first nationwide network for sending computer data over cellular telephones."

Keller (1991) reports that cellular-phone sales have risen steadily from just under 500,000 units per year in 1987 to more than 2,500,000 units per year in 1991, and that new service subscribers have risen from less than 500,000 per year in 1987 to more than 1,500,000 per year in 1991. Keller also reports that despite the recession of 1991, the cellular business remains one of the world's strong performers by any index. Eckhouse (1993) reports the Cellular Telecommunications Industry Association estimates that the number of U.S. cellular-telephone customers exceeded 10,000,000 as of January 1, 1993.

The cellular industry has the potential of evolving into a "100-year industry," as did wire telephone, radio, and television.

BASE STATIONS (CELL SITES)

A cell is the basic building block of a cellular-telephone system. Each cell contains a base station (or cell site) that provides transmitting and receiving facilities. Fig. 1 shows a typical facility.

A base station (or cell site) is comprised of certain typical components. These components may be divided into two groups: the first group includes the equipment shelter or building, applicable site work, the tower or antenna mounts, and the alternating-current (AC) electrical system with a possible generator backup system; the second group includes the cellular-telephone or telecommunication equipment, the transmit and receive antennas, a microwave or T1 telephone link to a central switch, and the direct-current (DC) electrical system including batteries. (A T1 line is a special telephone line suitable for the transmission of computer or telecommunication data.)

Base stations (or cell sites) commonly use one of three categories of building construction: freestanding buildings, prefabricated buildings, and tenant-improved spaces in an existing building. Fig. 2 depicts an elevation of a freestanding or prefabricated building and Fig. 3 depicts a section of a tenant-improved space. A typical freestanding building or tenant improved space is approximately 7 by 10 m (20 by 30 ft) or 70 m^2 (600 sq ft), and a typical prefabricated building is 4 by 10 m (12 by 30 ft) or 40 m^2 (360 sq ft). Typical building construction costs are between $100,000 and $250,000. A building or space could be thought of as a "computer room" used to house cellular-telephone equipment.

The location of a base station (cell site) is usually dictated by the basic principles of radio engineering. In other words, a cell site must be constructed at a specific location—for example, on a certain mountaintop or along a specific section of freeway.

The antennas for a base station (cell site) can be mounted either on a

FIG. 1. Typical Base Station (Cell Site)

tower (monopole) or on an existing structure such as a building or water tower. The antennae need to be as close to the radio equipment as possible, say less than 60 m (200 ft). Longer runs are undesirable because of loss of signal quality.

COMMENTARY

The following commentary discusses various factors that are unique to the development of specifications for the first group of base-station (cell-site) components (building, site work, tower or antenna mounts, and AC electrical system). Table 1 shows relevant Construction Specification Institute (CSI) specification sections in matrix form with types of building construction to which these sections usually apply.

General Requirements

General requirements should be kept as simple and streamlined as possible. In some instances they may not be needed. A goal should be to build a base station (cell site) in four to six weeks with a very minimum of paperwork and its related expense.

Site Work

The reader should beware of asbestos or other environmental problems in tenant improvement work. Chain-link fences need to be grounded to the

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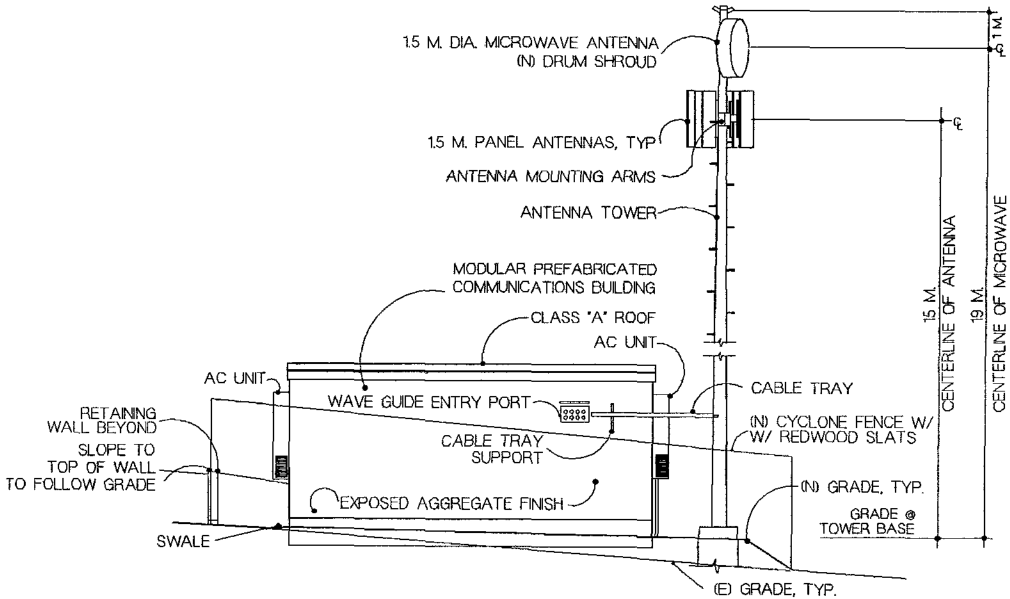

FIG. 2. West Elevation of Freestanding or Prefabricated Building, (Courtesy William Savidge & Associates, Berkeley, Calif.)

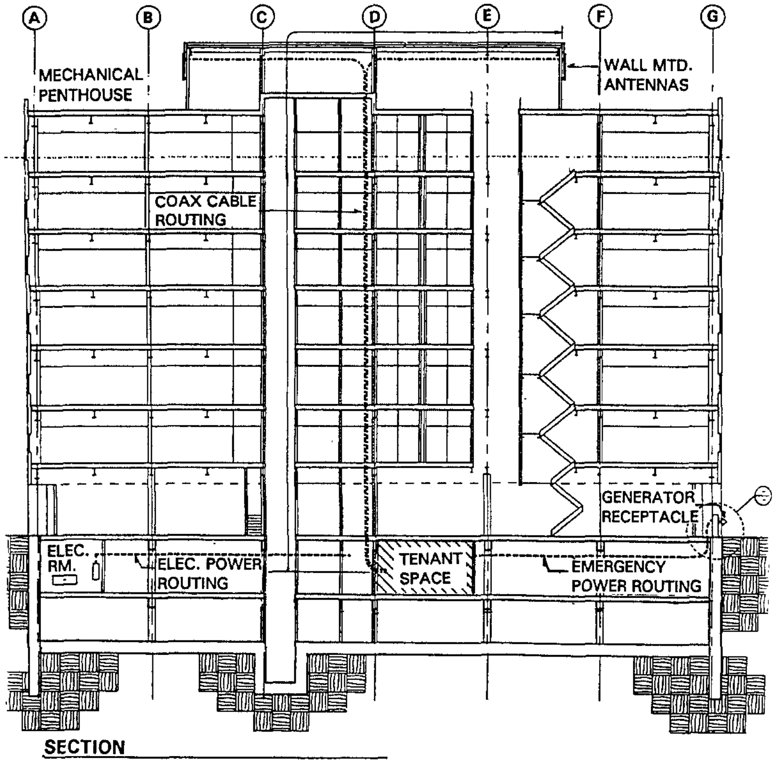

FIG. 3. Section of Tenant-Improved Space (Courtesy William Savidge & Associates, Berkeley, Calif.)

central grounding system. Towers need to be fenced not only to provide security and safety but also to prevent an unwanted legal liability caused by an "attractive nuisance". Ordinarily, geotechnical reports are only necessary for sites with tower foundations. Unpaved mountainous access roads normally require a grading plan. It is usually necessary to pave access roads with slopes greater than 30%.

Concrete

Sometimes there is a logistical problem in getting concrete to a mountaintop site, particularly with a travel time of less than 1 h from the batch plant. Use of a four-wheel-drive concrete truck with a heavy piece of equipment to assist is sometimes required. A helicopter and bucket is sometimes used, but this method is quite expensive. When travel time is a problem, the designer should consider using a special concrete mix that contains a retarder. Another solution is to haul the cement and aggregate in the truck dry and add the water at the job site. When a prefabricated building needs to be set as quickly as possible, it is a good idea to eliminate stub-ups in the concrete slab and make conduit penetrations through the walls.

Masonry

Freestanding buildings are normally built of reinforced unit masonry (grouted concrete block with reinforcement steel). The designer should

TABLE 1. Specification Sections

CSI Section (1)		New building (2)	Prefabricated (3)	Tenant improvement (4)
		Building Type		
01000	Schedules, controls, and submittals	Yes	Yes	Yes
02050	Demolition	No	No	Yes
02110	Site clearing	Yes	Yes	No
02200	Earthwork	Yes	Yes	No
02444	Chain-link fencing	Yes	Yes	No
02513	Asphalt-concrete paving	Yes	Yes	No
03010	Concrete work	Yes	Yes	No
04230	Reinforced unit masonry	Yes	No	No
05500	Metal fabrications	Yes	Yes	Yes
06100	Rough carpentry	Yes	Yes	Yes
07110	Waterproofing	Yes	Yes	Yes
07530	Roofing systems	Yes	Yes	No
07600	Flashing and sheet metal	Yes	Yes	Yes
07900	Sealants	Yes	Yes	Yes
08100	Doors, frames, and hardware	Yes	Yes	Yes
09250	Gypsum drywall	No	No	Yes
09500	Acoustical ceiling	No	No	Yes
09680	Resilient flooring	Yes	Yes	Yes
09900	Painting	Yes	Yes	Yes
09970	Fiberglass-reinforced polyester	Yes	Yes	Yes
10200	Louvers and vents	Yes	Yes	Yes
10900	Waveguide port	Yes	Yes	Yes
13000	Antenna installation	Yes	Yes	Yes
13100	Tower or monopole	Yes	Yes	Yes
15500	Halon fire-suppression system	Yes	Yes	Yes
15800	HVAC	Yes	Yes	Yes
16000	Electrical work	Yes	Yes	Yes

specify whether step CMU construction or full-height concrete-masonry-unit (CMU) construction with pour holes is required. Concrete-block construction offers better security against break-ins than wood-frame construction. Telecommunication buildings in remote locations are occasionally used as targets by irresponsible people with firearms. The cost of having a bullet penetrate a building and damaging equipment (it is assumed that these are unmanned sites) would be high compared to the extra cost of using masonry construction. The same arguments may be made for building prefabricated buildings out of concrete.

Metal

To support the cables, wires, and other parts that connect the various equipment racks with one another, base stations (cell sites) have either a suspended metal ceiling grid, such as Unistrut, Wayne, Mich., or a series of cable trays and ladders. A cable-tray and ladder system is the most economical but does not allow for future modifications and growth. A suspended metal ceiling grid over the entire floor area does permit changes as required for modifications of or additions to the cellular-telephone equipment.

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In seismically active areas, such as California, special earthquake bracing for the equipment should be considered.

Thermal and Moisture Protection

The cost of moisture protection compared to the cost of the cellular-telephone equipment is minimal. The equipment is highly susceptible to water damage. Therefore it makes sense to specify the best waterproofing, roof system, and flashing.

Tenant-improvement work normally involves running coax and electrical conduit through an existing structure. For example, three 100-mm (4-in.) conduits may be run from the basement to the penthouse of a 10-story office building. Core drilling is usually required at various floors and walls. After the conduit is installed, it is often necessary to fill the annular space between the drilled hole and conduit with a fire-rated material (such as Fire Stop from Dow Corning Corp., Midland, Mich.) to restore the fire rating of the floor or wall. This is an expensive process and research is needed on how to improve the procedure. It is important for the cellular telephone equipment room to be properly sealed to ensure proper operation of the Halon fire-suppression system and mechanical system.

Finishes

Gypsum drywall systems tend to slow down a job. A typical system involves fire taping, two coats of topping compound, an application of drywall sealer, and finally at least two coats of paint. A much faster and more efficient interior finish system is fiberglass-reinforced polyester (FRP) panels. Their use can save approximately one week of construction time.

Many building departments require a 1–4-h envelope for a cellular-telephone equipment room. It would be advantageous to have a 1–4-h rated acoustic ceiling system. The writer believes that such a system does not currently exist. Some acoustic ceiling systems, however, appear to be rated on one side but not the other.

Vinyl composition tile (VCT) is normally used. Cellular-telephone equipment contains numerous microelectronic cards and modules that can be damaged by static electricity. Certain specialty floor tiles such as Conductile from Vinyl Plastics Inc., Sheboygan, Wis., are available that contain copper and, when properly installed, provide a conductive floor. This type of floor can eliminate static electricity and provide electromagnetic-interference/radio-frequency–interference (EMI/RFI) shielding. Another solution to the problem of static electricity is the use of static mats installed in front of the equipment. Static mats are expensive and do require continued cleaning and maintenance to work properly.

Where there is an EMI or RFI problem, walls and ceilings are sometimes painted with special copper paint. It is easier to apply copper paint before the cellular-telephone equipment is installed. One drop or splatter of the highly conductive copper paint onto an equipment rack can cause catastrophic damage. Therefore EMI and RFI testing before the equipment is installed is recommended at base-station (cell-site) locations where there might be a problem.

Specialties

What is a wave guide port? This is a question often asked by contractors new to telecommunication construction. A wave guide port consists of one to two metal or fiberglass plates, approximately 60 by 60 cm (2 by 2 ft), with a series of holes, probably eight, and is installed in a windowlike opening. The coax cable to the transmit and receive antennas and the wave guide (cable) to the microwave antennas pass through these holes. There are special boots installed at the holes for weatherproofing.

Special Construction

Towers basically fall into three categories: monopoles, self-supported towers, and guyed towers. Typical towers used for base stations (cell sites) range from 15 to 30 m (50 to 100 ft). A typical maximum height is 50 m (150 ft). Monopoles are the most expensive but are often considered to be the least environmentally intrusive. Next in order of expense would be a freestanding tower. The least costly tower is a guyed tower, which has the disadvantage of requiring a larger site area to accommodate the anchorages for the guy wires. Both the designer and contractor need to be knowledgeable of and follow Federal Aviation Administration rules and regulations for towers.

Where antennas can be placed on an existing structure, such as a building or water tower, antenna mounts are normally used. Antenna mounts are generally fabricated out of angles, channels, and pipes, and are not commercially available. It is usually cost-effective for the owner to have several hundred made at one time and provide them to the contractor as an owner-furnished item. Since they are ordinarily exposed to the weather, hot-dipped galvanizing should be specified. Designed properly an installed mount should take the weight of a worker plus the weight of the antenna.

Mechanical

Most base stations (cell sites) contain a Halon fire-suppression system. Recently, however, there has been a trend to eliminate Halon systems because of environmental concerns with chloroflurocarbons. Halon gas may be nontoxic; the writer questions whether the chemical properties of Halon gas change when the gas is subjected to the heat of a fire. Halon gas combined with other products of combustion is most likely toxic. For a Halon system to be effective, an equipment room needs to be well sealed. Fire inspectors will often require a Halon dump test and measure the concentration of Halon gas 10–15 min after a dump.

Ideally a cellular-telephone equipment room would contain no louvers or vents in order to provide a closed system. There are several reasons that louvers and exhaust systems are used. Many fire departments require that a special Halon gas-exhaust system be installed to be used by the fire department in the event of a Halon dump. Even if not required by the local fire department, the designer should still consider including a Halon exhaust system. Cellular-telephone equipment operates from batteries. The question of what happens if a battery goes bad and produces a vapor problem needs to be addressed. The writer has noticed that, in recent years, battery manufacturers have started to put warning labels on their batteries and warnings in their literature that some kind of ventilation may be necessary. Another reason for a ventilation system is to allow operation or prolong operation during a time of power failure when a base station (cell site) is operating on batteries with no backup electrical system.

Cellular-telephone equipment generates large amounts of heat. In most cases air-conditioning is required. Most equipment is designed to shut down if the environment gets too hot. It has many similarities to a mainframe computer in that it is temperature-sensitive. Equipment typically has an

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ideal operating range of between 18° and 24°C (65° and 75°F). Redundancy of heating–ventilation–air-conditioning (HVAC)-systems—the use of two separate HVAC systems—is recommended. For optimal equipment operation, the HVAC diffusers should be located so that cold air blows down the rows of equipment—not into only one or two equipment racks.

Electrical

A key component of a base station (cell site) is the electrical system. The grounding system and surge arrester are somewhat unique.

A typical grounding system consists of a building ground ring, fence grounding, a tower ground ring, equipment grounding, and a halo ground ring. Designs for grounding systems are usually proprietary. A grounding system serves three general purposes: to protect human life, to protect equipment, and to ensure optimal equipment performance. Normally a grounding system is tested periodically (for example, once a year). Typical industry standards would be 3–5 Ω or less of resistance. At most sites a series of 3-m (10-ft) copper ground rods placed into the soil will meet this standard. Grounding at some sites is a problem because of the soil conditions. For example, at a rocky site with low conductivity, special grounding wells may be required.

A surge arrester is a "black box" attached to the electrical system that protects personnel and equipment from either lightning strikes or surges in an electrical power source (most likely the electrical service from the power company). There are some surge arresters on the market that reportedly do not work or have been known to fail. A surge arrester should be thought of as a fuse and not a circuit breaker. Once it does its job, it should be replaced and sent back to the manufacturer for repair.

Most base stations (cell sites) have a backup electrical system. A generator may be either portable, operating on diesel fuel, or permanent, operating on diesel fuel or liquid propane gas (LPG). There are environmental problems with storing diesel fuel underground. The most practicable diesel storage is an aboveground Underwriters Laboratory–rated double-wall tank. LPG tanks require special construction for fire safety and a site area large enough to locate the tank the appropriate distance from buildings and sources of combustion. When designing a generator system, two items have to be checked. Certain manual transfer switches are reputed to have design problems and in certain situations fuse open or shut in one position. The designer needs to verify that the switch has a reputation for operating properly. Control wiring from an automatic transfer switch should be run in a separate conduit. When control wiring is run in the same conduit as power wiring, there can be a problem with damage to electronic control cards that are used in many of today's generators.

SUMMARY AND CONCLUSIONS

A major goal in the design, construction, and operation of a base station (or cell site) is reliability and signal quality. The public expects the reliability and signal quality to equal that of a wire telephone system. Government agencies, such as police and fire departments, want the system to function in times of emergency. The development and refinement of proper specifications for base stations (or cell sites) will help ensure that this goal is met.

New cellular systems continue to be built in all parts of the world. Cellular technology is based on the principle that new base stations (cell sites) will be continuously added to an existing system to expand its capacity. There exists a continuous and growing need to build new base stations (cell sites). The industry needs base stations (cell sites) of proper reliability and quality that can be built quickly and economically.

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