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This Document written by R L Knight in February 2005.

PCS Wireless Cellular Site Isolation Protection

(Self Contained on a Monopole or Tower)

by Richard Knight Sr.

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Abstract

Competition in today's market place demand Personal Communication System (PCS) cellular tower sites that have reliable telecommunication facilities. Currently, ninety eight percent of all telecommunication facilities supporting these sites, in the US today, are wire-line copper facilities, and with rare exception, not properly engineered to provide reliable service.

New technology has continued to support high speed circuits over these copper pairs to meet the current needs of the cell site. Because of the higher speeds, these circuits are more critical than ever as they carry many simultaneous calls. Even more than before, their reliability is paramount. Without very reliable service the cellular provider will lose customers in today's competitive market place and subsequent call generated revenue.

Recently, huge investments have been made in building larger cell coverage areas in TDMA technologies along with equipment conversions and migration to Global Standard for Mobile communications (GSM) technologies. The commitment of these monies was with the promise of growth from an increased customer base. However, moving to new technologies without ensuring the reliability of the wire-line facilities supporting them will be monies ill spent, and growth not realized.

PCS Cell Sites with Low Connectivity Hurt Revenue

If customer calls cannot get through or are being dropped, the provided cellular service is lacking and your customers will go elsewhere. To grow a customer base, normal day to day cellular service demands highly reliable trouble free service.

Providing wireless E911 emergency cellular service, as mandated by the FCC, demand reliable telecommunications. Fines and required subsequent reports to the FCC, for the failure of providing consistently reliable E 911 wireless services, hurt revenue and the growth of customer base.

What Causes Equipment Damage and Low Connectivity?

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Time Division Multiple Access (TDMA) and GSM technologies are very vulnerable to extraneous energy sources such as power surges, lightning, ground potential rise, magnetic fields, electric fields, etc. Lightning events for example will cause momentary interruption in high speed circuits to the wireless cell site that in turn would cause an interruption in a conversation or possibly even a dropped call.

A direct or nearby lightning strike may cause major equipment damage and can damage the cable serving the site with the high speed circuits. The typical resulting downtime is usually three to five days and in some cases the total reconditioning of the site may take several months. Generator damage can take even more time to get the cellular site back up.

Duckworth states that the typical equipment damage from a single lightning strike, to an improperly engineered wireless cell site averages $35K. This does not include loss in revenue or maintenance dollars and productivity. He also states that lightning damage to wireless PCS sites is approximately a quarter of a billion dollars annually in the US.

What do we do about it? We have to ask if the site equipment is installed correctly. Does the total installation meet the standards and requirements set by the manufacturer? Is the warranty still in effect? If so, then we have to assume that at least the manufacturer feels that the installation meets design specification and has also taken the environment of the site into consideration.

We now have to ask if cellular equipment is being damaged. If so, then is the protection for that equipment at fault and is not adequate!

Are the Wire-Line Services Properly Protected? Do We Have the Correct Protection Devices Installed?

A Site investigation answers **NO** to both questions. Therefore, standard circuit protection is the culprit and additional circuit protection is necessary. Well, let's just improve on that hardware and/or on the installation that was completed at this site. Won't that take care of the problem?

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No, It Can Not!

The problem is caused by a phenomenon known as Ground Potential Rise (GPR). GPR is defined by I.E.E.E. Standard 487 as *"The product of a ground electrode impedance, referenced to remote earth, and the current that flows through that electrode impedance."*

What is remote earth? What current? Where does this current come from? Where is this current trying to go? What does that mean?

Remote earth is generally defined as a location on the earth that is distant from or "remote" from the event at the near location. The current, also referred to as surge current, results from a GPR and occurs when a ground plane is energized and a potential results between two remote locations. This results in two separate locations having different potentials in which current will now flow to neutralize this potential difference.

This phenomenon is known as Ground Potential Rise (GPR) and basically means that if two different locations are at different potentials current will flow between then on any metallic facilities. To prevent damage on wire-line telecommunication services between these two locations require equipment that will isolate these services. Standard circuit protection used in the industry shorts energy to ground, thus it does not isolate and will not prevent damage to telecommunication facilities during a GPR.

How does this GPR relate to the Cell site?

The wireless cell site equipment and the associated tower combine to create a small area ground electrode or grounded field (small grid of buried wires and/or a grouping of bonded and grounded objects that together create a grounded mass) of finite impedance to remote earth. During a GPR related event, this small ground electrodes' impedance (resistance) allows a difference in potential to develop between the sites grounded grid or field and the telephone cable pairs and the cable shield that originates at the C.O. or equivalent.

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The grounding impedance of the site and the impedance to remote earth of the cable pairs electrically create a voltage divider between the earth at the site and the remote earth through these same cable pairs. The C.O. ground impedance is much lower than the cell site ground. When lightning is the source of the energy directly striking the tower or related equipment, the site becomes elevated and the energy sees the cable pair as the least path of impedance to drain off most of this energy. That is how the GPR is created from either lightning or a transmission line power fault. The rest of the energy drains off through the sites' ground field over a very short period of time.

The amount of this voltage (GPR) could be several thousand volts, possibly as high as 40,000 volts. This potential will then drain off to equalize this site through any means possible. Usually this means the cable pairs and cable shield are now energized and carrying a large amount of energy and are draining this energy through the cable to the C.O. ground or other locations that are remote to the elevated site. This large energy flow may cause equipment damage and possible personnel injury if not engineering for a GPR.

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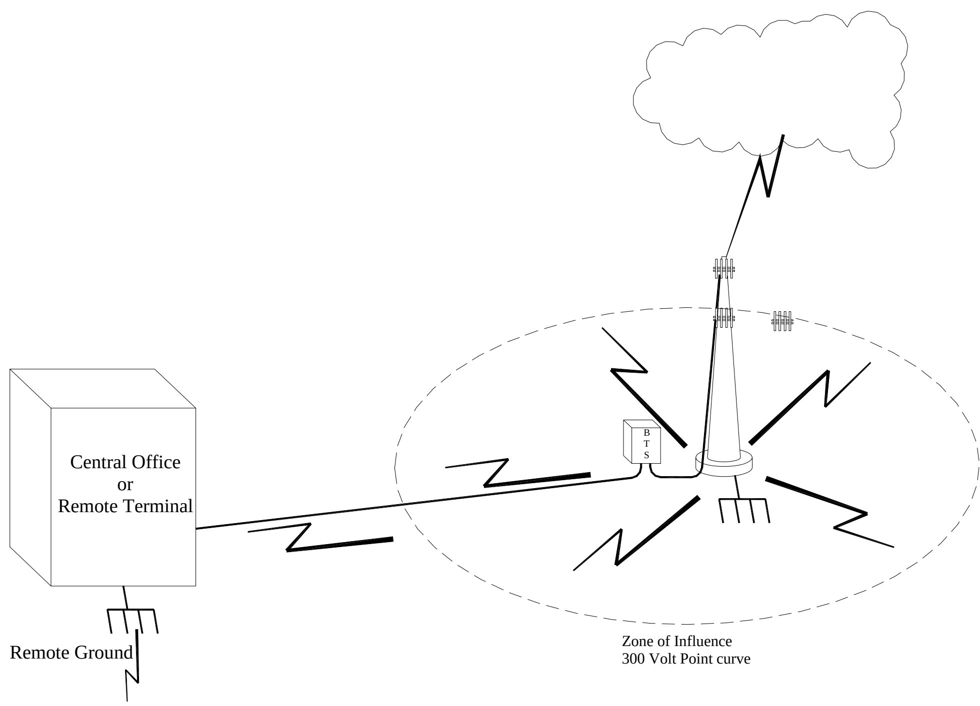

Figure 1
This shows the typical energy flow during a Lightning caused GPR event to the tower, surrounding earth and related equipment. Damage to equipment occurs while the energy is draining off through the remote or C.O. connection to ground. Since there is energy flow, safety issues are extremely compromised.

Standard protection methods of shunting (drainage) technology do not work on circuits that are subjected to GPR. This is because with a GPR potential the ground is the source of the energy, not a location to drain energy off. Standard protection (drainage) equipment would directly connect the electrical potential of the GPR onto the circuit. In effect, the energy flows from the ground or the equipment at the site onto the circuit. This energy at the very least causes damage to equipment with the possibility of a fatality or injury being the foremost issue of concern.

So we need to secure the existing services while economically providing for future communication needs with a minimum of change to current methodologies

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or functions. At the same time we must provide safe and reliable communications to any site where Ground Potential Rise (GPR) may be an issue.

These ideas look really great. How do we do that?

Improve the Grounding of the Wireless Cellular Site?

SAFETY ITEM:
If the equipment and/or structures at the site are not properly bonded to each other and subsequently grounded, there is a potential of energy flow between equipment, the tower and earth. This is an important safety item and MUST be corrected.

It sounds like the protective grounding of the site is the culprit. If we correct that, that will solve the problem, right?

Well, maybe it will, but are we sure that will solve it? Can we afford the cost of an extensive grounding rework project? How much engineering time do we have to utilize and who would implement the system? Would it do the job when it is complete? Are we sure?

Improving the ground at a site may be a priority, but there are practical limitations. The cost of lowering the impedance to earth of the equipment can be quite high. Do we have enough real-estate at the site to accomplish this? What do I need real-estate for? The act of lowering grounding impedance requires that the earth contact area for a grounding system be augmented by chemical means or increased in geographic area. That brings up another question. How low would the impedance have to be to solve the problem? Since we are dealing with energy, what is this energy level we are trying to protect against?

Since we are talking about a voltage developed across an impedance, how low does that impedance have to be to solve this issue? Also, at what potential level does this GPR energy have to be at to be considered dangerous from the possibility of causing a fire? I.E.E.E. Standard 487 sets a GPR value of 1000

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Volts-Peak as the upper limit and above which we must utilize special protection techniques to maintain telecommunications service.

Determining the impedance value to be met that will control a GPR event will require an engineering evaluation and subsequent decision. Lightning is one of the possible sources for this energy. Since there is such a variable in energy from lightning strike(s), how do you determine what energy level or impedance value to design or build for?

In most cases the cost of lowering the impedance to eliminate the problem exceeds the cost of other more sure ways of solving the problem. And in the case of a lightning event, there is a total guess as to what the energy value of the strike will be.

As you can see there are more questions unanswered than those that have been answered. So it appears that improving the grounding is not the primary way to solve this issue. So, what does work?

Introduction of Isolation Methodology

Solution

With standard protection technologies (drainage equipment) incapable of protecting these sites the only thing left to do is to install affordable High Voltage Isolation (HVI) equipment on the existing telecommunication circuits while providing for future growth or changes. This isolation equipment would replace the standard drainage protection equipment as the primary protection for the site.

Overview of Isolation Technology

The isolation process allows the electrical potential of the GPR affected site to change as the GPR voltage occurs from the event. All of the equipment at the site is then elevated in potential with reference to a remote earth location (a location that is not influenced by the GPR event). This elevated potential is then greater than 300 Volts. This would electrically look like the bird on the power

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line. The bird is unaffected by the voltage on the line because he is at the same potential as the line. As long as he does not touch a differing potential (one of the other wires or a grounded object) he will be just fine.

At the same time the part of the circuit that resides on the Central Office side of the isolation equipment remains at the stable Central Office potential (whatever the working circuit voltage is, from a range of -24 to -190 VDC). With the station side at the higher voltage from the GPR and the CO side at the lower voltage (working circuit voltage level) the differing potentials across the isolation equipment are not seen by the total circuit, only that energy on each half of the circuit. Since each side of the circuit is now like a bird on the wire, there is no energy transfer from one side (station) to the other side (CO). At the same time the circuit performs through the isolation equipment providing all circuit functions, oblivious to the GPR event. The result is an equipment installation that provides safe reliable communication.

Motivation and Benefits

Why should this equipment be engineered into a wireless cell site? The answer is to:

- Provide a safe means for personnel to communicate.
- Provide reliable communication circuits between the Cell site and the serving telephone switch. This will keep calls up and allow the customer to talk longer (more minutes of revenue, maybe, or at least happy with the service!).
- With no call interruption, the customer base should grow and not shrink.
- Provide desired communication for information services needed for proper site or services management. This could be Equipment Alarms, Site Intrusion Alarms, Battery Plant Status, the list could go on.

What is the real benefit?

If these services are secured, then the site can operate and provide the customer with the services for which it was designed. This would of course increase and maintain revenues at or above the expected level!

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Of course at the same time the safety of personnel working at the site doing installs or any equipment maintenance would not be exposed to hazardous voltages.

Therefore, it is indeed realistic to know that a design can be implemented that is easy to work with and will provide for safe working conditions, stable and secure existing circuits, and future circuits can be installed and maintained with little if any changes to the isolation/protection equipment.

Cell Site Application of Isolation Technology

The concept of isolation protection in lieu of drainage protection for a cell site is in concert with I.E.E.E. Standard 487-2000. The methods and equipment for an isolation installation are referenced and explained in this standard. The isolation equipment on the market today, (Teleline Isolator being of the highest quality) can provide economic isolation to many different circuit types by deploying differing circuit cards and mounting methods from individual modules to multiple position shelves and circuits cards. A multiple position shelf utilizes a small footprint of space on the mounting wall to accommodate many circuits with a high voltage level of isolation. Teleline Isolator can protect wire-line facilities up to a voltage level of 50,000 Volts rms.

This deployment will provide a minimum of an IEEE Service Performance Objective (SPO) Class 'B' circuit. With additional equipment a Class 'A' SPO can be established on some circuit types. The following SPO Classifications are quoted from IEEE 487:
"A) Class A. Non-interruptible service performance (should function before, during, and after the power fault condition)
B) Class B. Self-restoring interruptible service performance (should function before and after the power fault condition)"

This SPO of a Class 'B' circuit relates to a circuit serving the cell site with a very high degree of reliability. A circuit interruption would occur only if induction into the telephone cable pair exceeds the operating level of the cable protectors located in the Central Office or elsewhere in the C.O. Side of the circuit. These same protectors would then reset and restore service immediately after the event

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concludes or the voltage level on the circuit is reduced to below the operating point of the protectors. The circuit would be interrupted for only milliseconds in time in comparison to hours or perhaps days when major equipment damage is incurred from the usage of drainage devices.

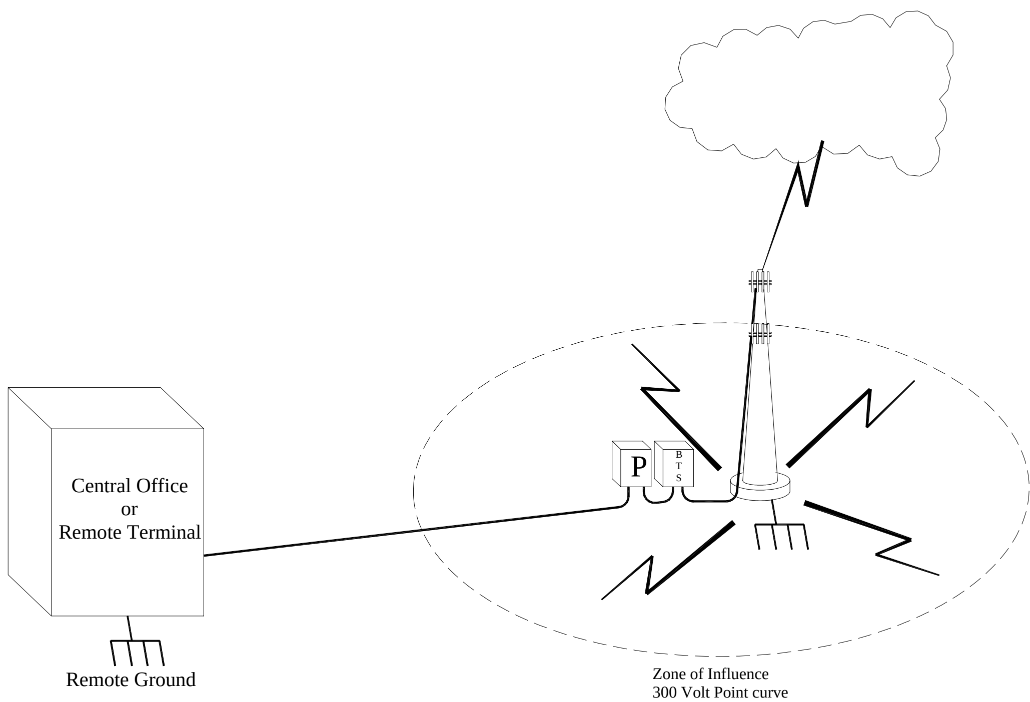

Figure 2
This shows how the addition of isolation equipment (cabinet indicated by the Positron 'P') blocks the energy flow of a Lightning caused GPR event to the tower, surrounding earth and related equipment. Damage to equipment is prevented since there is no energy drain through the equipment to remote ground. Since there is no energy flow, safety is insured.

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Conclusion

The wireless service equipment and network is ever expanding. It is a simple fact that because of this increase in coverage area, the equipment at any one site and the total network is becoming more and more exposed to lightning, power line ground faults and other events that can cause a cellular site GPR. We now know that standard wire-line drainage protection does not work against GPR. As previously identified, surge or drainage technology only makes it worse by directly connecting the ground of the site to the circuit. The resulting energy flow or drain occurs at the remote end of the circuit. This current flow, resulting from a GPR, may cause personnel as well as equipment damage. Utilization of isolation technology provides the needed isolation and therefore protection against GPR events, thereby solidifying service and revenue streams.

Further Reading

"Guide for Protection of Equipment and Personnel from Lightning", by Ernest M. Duckworth Jr., P.E. in the Journal of Performance of Constructed Facilities, Vol. 16, No. 3, August 1, 2002. This paper can be ordered at:

http://scitation.aip.org/vsearch/servlet/VerityServlet?KEY=ASCERL&smode=strresults&maxdisp=25&possible1=Duckworth+Jr.%2C+Ernest+M.&possible1zone=author&OUTLOG=NO&aqs=true&key=DISPLAY&docID=1&page=0&chapter=0&aqs=true

There are three IEEE Standards that pertain to the essence of protecting a site subjected to GPR. They are available from the IEEE at 445 Hoes Lane, P.O. Box 1331, Piscataway, New Jersey 08855-1331, on the Internet at www/ieee.org, or can be ordered via telephone at 800-678-4333.

Indirectly these IEEE Standards (protection items) apply to a cell site:

- 487-2000 – Recommended Practice for the Protection of Wireline Communication Facilities Serving Electric Supply Locations (The current version is 487-2000 which is currently up for revision by the IEEE Power Systems Communications Committee working group) (2007 has since been published)

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- 367-1996 – Recommended Practice for Determining the Electric Power Station Ground Potential Rise and Induced Voltage From a Power Fault (Revised

- 1590-2003 – Recommended Practice for the Electrical Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Location

The document titles do not indicate that they do apply to a cell site. Not having read the documents, one might assume that the title alone identifies that the document deals only with an Electric Supply Location and would not in any way apply to a Cell or PCS site. However, the reason they do apply is that they are the only documents that identify and tell you how to treat the GPR issue regardless of the source of the energy. They go into great lengths to describe the phenomena and give very detailed recommendations as to what it is, how to calculate for it, what equipment can be used, how to wire it and what level of service (SPO already identified) to design to or expect from the installation. Since there isn't anything else out there that deals with the problem, these are the only standards that apply to the site and the issue of GPR.

Additional Standards:

There are at least two additional standards that apply to service to or equipment at the Cell site. Those standards are:

National Electric Safety Code: (2002 is the Current issue) Published by the I.E.E.E.
This document deals with the communication cable and power facilities serving the site. These may be aerial or buried installations.

National Electrical Code: (2005 is the Current Issue) Published by the National Fire Protection Association, Inc. NFPA.
This document deals with the electrical wiring of the cellular equipment itself. That is the BTS, battery plant, AC power service connecting to equipment, equipment electrical bonding, etc.