Proposed Municipal or Fire Code For Public Safety Indoor Wireless Coverage[1]

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1.0 Background

Public safety agencies across the U.S. face poor indoor radio coverage, especially in the 800 MHz band. Poor coverage is caused by both building losses and interference from intentional and unintentional radiators. There are several technical solutions to this problem, including the traditional bidirectional amplifier, either with radiating cable (e.g., Radiax™) or discrete antennas fed by coaxial cable. Fortunately for the public safety community, the growth of cellular radio has created a market for modern, sophisticated distributed antenna systems. These modern systems generally employ fiber optic cable and in some cases, CAT-5 twisted-pair cable. They are available in the 800 MHz band from a variety of vendors, including TX-RX, Kaval, LGC Wireless, Mikom Wireless, Allgon, EMS Wireless, ADC, and Mobile Access. This list is not all-inclusive. It is a crowded field. At least one company (ADC) sells an all-digital solution. More traditional coaxial cable-based systems are still available in the 150 MHz and 450 MHz bands from TX-RX, Kaval, and others.

Most public safety agencies believe it is fair and reasonable to make a building owner responsible for assuring the existence of a viable public safety radio signal throughout his or her property. This is particularly true where the development itself greatly attenuates the public safety radio signal or activities at the development increase the need for public safety response to the site. The alternative is to place the burden for major improvements to the public safety radio system upon the community as a whole, or to settle for situations where public safety communication is not reliable. When these factors come together at a public site, the responsibility to address the reliability of public safety communications is as important as assuring there are adequate fire escapes or sprinkler heads.

Municipalities have implemented building or fire codes to address this problem in the past, but results have been poor because the code was not written in a language that was measurable or enforceable. Measuring radio signals indoors involves an understanding of the complex propagation environment and the application of sophisticated techniques and statistical methods. These techniques and methods are just now attracting the attention of industry standards committees, and their use is not yet widespread.

Our firm, Pericle Communications Company, recently helped the City of Bloomington, Minnesota develop a municipal code to address indoor public safety radio performance. One of the motivations for this code was poor radio coverage inside the Mall of America, despite a

radio coverage clause in the real estate development agreement. Although it looked good on paper, the clause proved unenforceable in practice.

Other cities that have similar ordinances include:

Broward County, Florida
Boston, Massachusetts
Scottsdale, Arizona
Burbank, California
Roseville, California

In the next section, we propose some code language that is measurable and enforceable. The suggested measurement techniques are backed by good engineering practice and are based in part on EIA TSB-88A.

2.0 Proposed Code[2]

1.0 Definitions.

Carrier-to-Interference Ratio. The *carrier-to-interference ratio* (*C/I*) is the ratio of the received power of the radio system control channel (or a continuously keyed traffic channel) to the received power of an interference reference (usually an idle traffic channel). If the carrier-to-noise ratio (*C/N*) is less than the measured *C/I*, substitute *C/N* for *C/I*.

Coverage Requirement. The *C/I* shall exceed 20 dB at 95% or more of the locations measured. Equivalently, the *service area reliability* shall be 95% or greater.

Radio Frequency Control Plan. The Radio Frequency Control Plan is a written document published and distributed by the building owner for the purpose of protecting the public safety radio system from harmful interference generated on the property or otherwise under the control of the owner. It shall include the following minimal provisions:

- Restrict the use of any electronic systems known to degrade the effectiveness of public safety radio communications.

- Notice of initial use and implementation of any wireless communication device.

- Site access during reasonable business hours when necessary to assess the source of interference to public safety radio communications.

- Authority to order an immediate abatement or discontinuance of any device suspected to be a source of degradation to public safety radio communications.

[2]Much of this language was contributed by Ron Whitehead, formerly Deputy Chief of Police, Bloomington, Minnesota.

Distributed Antenna System (DAS). The DAS is a network of amplifiers, fiber optic cable, coaxial cable, and radiating cable and/or discrete antennas installed on or inside the property to enhance indoor radio communications, including offices, retail space, warehouse space, enclosed courtyards, parking garages, tunnels, and underground areas.

Measurement. A *measurement* is a linear average of subsamples applied to the center of a grid cell.

2.0 Requirements.

2.1 Main Requirement. The developer and the subsequent owner shall meet the Coverage Requirement for the City's public safety radio system within any structure. The coverage requirement shall be verified using the procedures specified by the Acceptance Test, described below.

2.2 New Construction. At the time of building occupancy, the owner shall verify that the coverage requirement is met by performing measurements in accordance with the Acceptance Test.

2.3 Distributed Antenna System Requirements. Buildings and structures which do not support the required level of radio coverage as defined above and verified by the Acceptance Test shall be equipped with an FCC-approved DAS that amplifies the City's public safety radio signals to provide adequate radio coverage throughout the building or structure. If any part of the installed system contains an electrically powered component, the system shall be capable of operating on an independent battery and/or generator system for a period of at least twelve (12) hours without commercial power.

2.4 Acceptance Test. Measurement locations shall be uniformly distributed to the extent practical. There shall be at least one measurement per 3,000 square feet of gross building square footage, but no two measurement points shall be within 40 feet of each other. Adequate radio coverage shall be determined for the structure and for parking areas separately. Execute the following steps:

a. Using a test receiver with sensitivity equal to or better than the public safety radio, measure idle channel power (i.e., interference power) for each public safety radio channel, excluding the trunking control channel (if applicable). Select the channel with the highest level of average interference as the idle channel for acceptance testing. Ask the public safety agency to take this channel out of service for the duration of the test.

b. Create a uniform grid over each floor with 50 foot centers.

c. At each accessible grid location, take at least 50 equally spaced subsamples of the control channel and the idle channel over a distance of 29λ to 50λ (40λ preferred), where λ is

the radio carrier wavelength (λ is approximately one foot at 850 MHz).

d. Average these subsamples linearly, convert each linear average to dBm, compute the *C/I*, and apply this ratio to the grid point. Note that the test receiver should have a thermal noise floor lower than the public safety receiver. For any measurements of the interference channel that are less than the thermal noise floor of the public safety receiver, substitute the public safety receiver thermal noise floor (e.g., -123 dBm) for the interference value before computing the *C/I*. The public safety agency, their maintenance contractor, or equipment vendor should be able to furnish the value of thermal noise floor.

e. Repeat Steps c-d for each grid point.

f. Calculate the service area reliability:

$$\text{Service Area Reliability (\%)} = \frac{T_p}{T_t}\ 100\%$$

where T_p is the total number of grid points passed (i.e., *C/I* > 20 dB)
T_t is the total number of grid points measured

If the building fails to achieve the coverage requirement of 95% service area reliability, or if any single floor of the building fails to meet a 95% service area reliability, the building owner shall install a DAS and conduct a new Acceptance Test. Figure 1 illustrates the measurement methodology with dimensions applicable to an 800 MHz system.

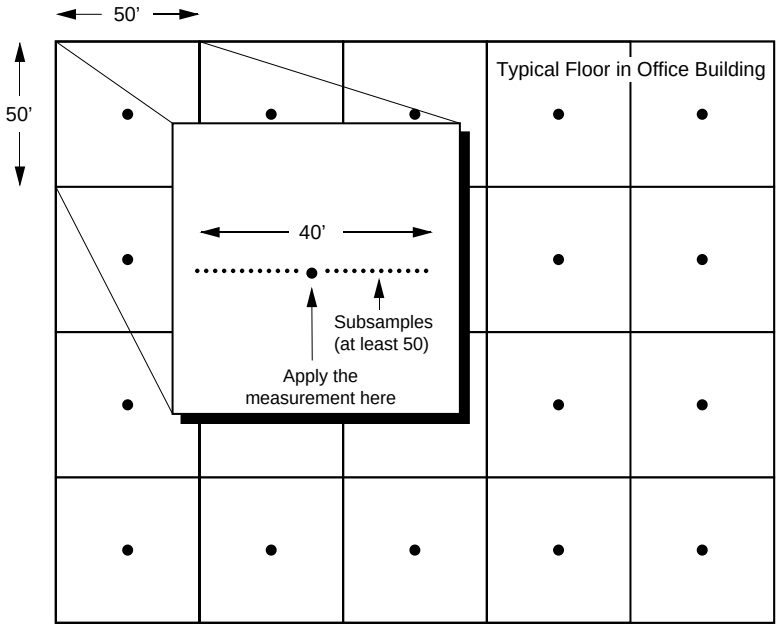

Figure 1 - Measurement Example Applicable to 800 MHz Radio Systems

Measurements shall be taken with calibrated radio receivers by personnel with appropriate knowledge and training. Test results shall be certified by a licensed professional engineer or approved by a designated City official, at the City's option.

2.5 Radio Frequency Control Plan. Irrespective of whether adequate radio communications exists in any building or structure, a property owner shall develop and maintain a radio frequency control plan which deals with the use of licensed and unlicensed wireless communication devices by tenants and other occupants. The radio control plan shall be incorporated into the lease of every tenant.

2.6 Testing of DAS.

2.6.1 Annual testing. When a DAS is required, it shall be the building owner's responsibility to have all active components of the system, such as amplifiers, power supplies and backup batteries, tested once every twelve (12) months. Alternatively, the DAS may be continuously monitored electronically with remote fault alarms. Amplifiers shall be tested or monitored to ensure that the gain has not degraded from the installed value. Backup batteries and power supplies shall be tested under load for a period of at least one hour to verify that they will properly operate during an actual power outage.

2.6.2 Five-year testing. In addition to annual testing, the building owner or operator shall perform a radio coverage test in accordance with the Acceptance Test procedure described above to ensure the system provides adequate radio coverage at least once every five (5) years.

2.7 Infrastructure Requirement. Irrespective of whether adequate radio communication exists in any building or structure, a two (2) inch raceway or conduit into which cable or conduit could be laid shall be provided in every building or structure which is constructed within the City. Such raceway or conduit shall include an opening in the roof which shall allow for placement of an exterior antenna and centralized access to each floor of the building or structure. It shall be reserved for public safety DAS use and no other purpose.

3.0 Discussion

Although we believe the code language proposed herein is the best practical way to protect public safety radio communications indoors, it is not without controversy. Although the language is vendor-independent, some vendors will object if they see a competitive disadvantage. For example, the requirement for periodic testing or monitoring (which is cheaper) will favor those vendors with remote monitoring capability.

The public safety agency will also encounter resistance from the real estate development community if for no other reason than the added cost of indoor wireless systems (if needed). At the very least, the building owner must pay for an initial Acceptance Test to verify that adequate coverage exists. This objection can be mitigated somewhat by applying the rules to a subset of all buildings. Perhaps buildings over a certain size or buildings that fall within a certain zoning category must comply, but others do not.

Some will argue that the public safety agency has overstepped its bounds by controlling the airwaves, a authority that rests solely with the FCC. However, building owners and antenna site owners frequently impose interference rules more stringent than the FCC's for the mutual benefit of all radio tenants and to make the venture commercially viable. The FCC rules are not adequate when transmit and receive antennas are closely spaced as they are on a rooftop. Furthermore, unlicensed radio systems, such as 900 MHz alarm systems, that interfere with licensed public safety radio systems would ultimately be shut down by the FCC anyway. By applying the suggested code language, the building owner prevents this type of interference from occurring in the first place.

There are some implementation issues. For example, is the owner required to submit the acceptance test results to the public safety agency for approval? Or does the building department approve the test results? The annual test of the amplifier could be submitted to the fire marshal or to the police. It would simply be a certification that the system works and that the battery back-up is operational. Perhaps procedures similar to certification of fire suppression systems can be applied to minimize new bureaucracy.

Also, for medium and small buildings, does the language require enough measurements for statistical significance? This is a tough problem because taking more measurements means the measurements will be too close spatially and therefore correlated, which is undesirable. As a practical matter, smaller buildings with less than 20 measurements can only pass the 95% requirement if *all* measurements meet or exceed the *C/I* requirement.

How does one prevent the building owner from skewing the results so that hard-to-cover areas such as basements fall in the 5% that does not require coverage? We have included language that requires that each individual floor also meet the 95% service reliability, but perhaps other language is needed to close all "loopholes". The City of Bloomington has a more elaborate set of requirements to address this problem.

How involved should the public safety agency be in the selection and installation of the DAS? Most DAS amplifiers are wideband, so there is some danger that an improperly or inadequately filtered system will pass other radio signals and create harmful interference on either the uplink or the downlink. For example, uplink signals originating from rooftop donor antennas will see multiple public safety repeater sites and cellular radio cell sites, potentially causing harmful uplink interference. Should the end-to-end system be certified, and not just the indoor coverage? At the very least, the public safety agency must have a

record of all BDAs in the city so interference problems can be investigated efficiently.

Building owners generally do not have radio interference expertise. Should the public safety agency furnish a sample Radio Frequency Control Plan to all owners at the time they apply for a building permit?

Certificate of occupancy issue — is the certificate contingent on passing the Acceptance Test? If so, is the Building Department trained to ask for and evaluate the test results? Some procedures are needed to ensure the radio coverage requirement does not slip through the crack.

What is the penalty for non-compliance? Is the building owner strictly liable for radio coverage? Are civil fines imposed? If found in default, does the owner have a specified period to cure? Are fines applied administratively, or must the city sue for compliance in every case (an expensive task)?

4.0 Point of Contact

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