College Station, Texas
UDO Engineering Review

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Table of Contents

Columbia Telecommunications Corporation (CTC) was asked by the City of College Station to comment on proposed amendments to its tower zoning ordinance to determine the impact of the ordinance on the number of towers needed to provide cellular service, and the potential impact of the amendments on Cellular, PCS, microwave, wireless Internet service providers.

Many communities have struggled with the proliferation of towers, as cellular phone service requires locating many antennas sites in a community to provide the desired service. One method of managing this proliferation is to make changes to local zoning regulations, which limit or require conditions on the construction of new towers. Often, the changes impact all towers regardless of their purpose and it becomes difficult to clearly craft a single ordinance to address all situations.

Task 1. The Effects of Height Relative to Cellular, PCS, and Wireless Internet Service Providers Coverage Service in College Station.

Generally, the higher the antennas are above the ground, the greater an area their service can cover. Conversely, the lower the antennas are above ground level (AGL), the smaller the coverage area. Of course, this depends on the type of service and nature of the transmissions, which vary with the type of antenna, power, foliage, and terrain.

For cellular phone and PCS service, given the limited band of frequencies licensed to it by the Federal Communications Commission (FCC), operators reuse frequencies that are assigned to them from cell to cell. Consequently, the provider must limit the area served by each individual cell to prevent interfering with the closest other cell reusing the same frequencies. This necessitates a relatively large number of cells serving the College Station area compared to other services such as commercial broadcast services, where just a single site may be all that is needed to serve an entire community. For example, an AM, FM, or TV station will normally have only one transmission facility.

Typically, we see cell phone towers just under 200 feet or lower, which is due to several factors. One is the structural design of the tower, and another is Federal Aviation Authority (FAA) requirements related to tower height. The FAA requires all towers over 200 feet to be lit for aviation navigation safety reasons, and the bright lights on those towers often disturb residents in the community. However, there are target heights that carriers require to efficiently maximize the coverage from each location.

In order to attain the proper height for antennas and their resultant coverage, there are a number of different factors that are considered. Carriers try to achieve a certain signal strength across the cell area to assure reliable coverage as their customers travel through the cell, and as the customers' calls are "handed-off" from one cell to another as they travel through the City.

The terrain, and height of the antennas are also critical to this coverage. Thus, if there are shorter antenna heights serving an area, there may be a need for more antennas to provide the seamless coverage service required as cell phone users drive through an area.

Figure 1 illustrates a gap in service coverage. The dark blue area indicates the -85 dBm signal strength target typically desired by the industry across the service area at least 95 percent of the time. At service levels less than that, calls may be heard at only one end of the "line", or the connection may be lost. As shown, the target roadway has that level of service fairly consistently across the service area except for a large gap in the area to the left in the illustration. The proposed cell site, shown in red, is intended to fill in the gap. In Figure 2, the cell is "turned on" and the expected coverage of -85 dBm is shown to continue along the roadway as desired. Additional engineering information about radio coverage is provided in Appendix A, under "Interpreting the RF Documentation".

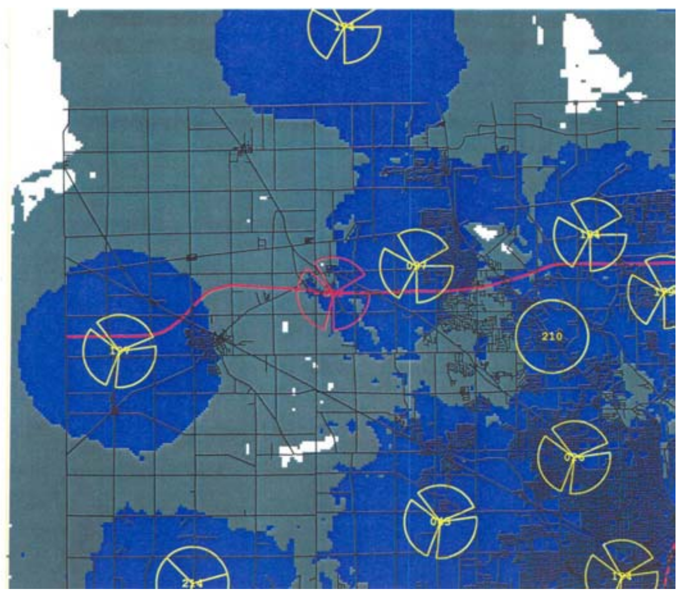

Figure 1: RF propagation without new site (in red)

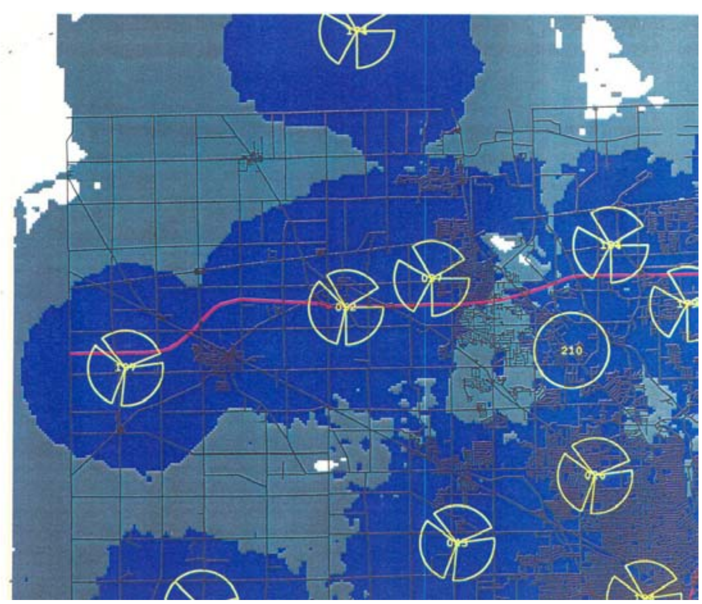

Figure 2: RF propagation with new site

Figure 3 shows the signal coverage from two alternative structure heights: one at 150 feet AGL (shaded in dark green), and another at 100 feet AGL (shaded in blue). As shown, antennas at 150 feet fill the underserved area. In our illustration, antennas at 100 feet only partially serve the area and may leave gaps in coverage. If coverage is not complete with sufficient signal strength across the underserved area, calls may be lost as the caller travels from cell to cell.

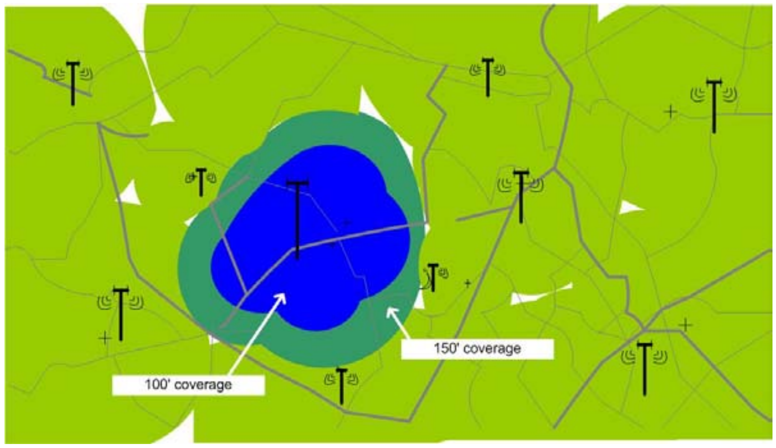

Figure 3: Illustrated Coverage from Antennas at 150' or from Antennas at 100'

Alternatively, as illustrated in Figure 4, two shorter towers may be needed to provide the equivalent coverage possible from one taller tower.

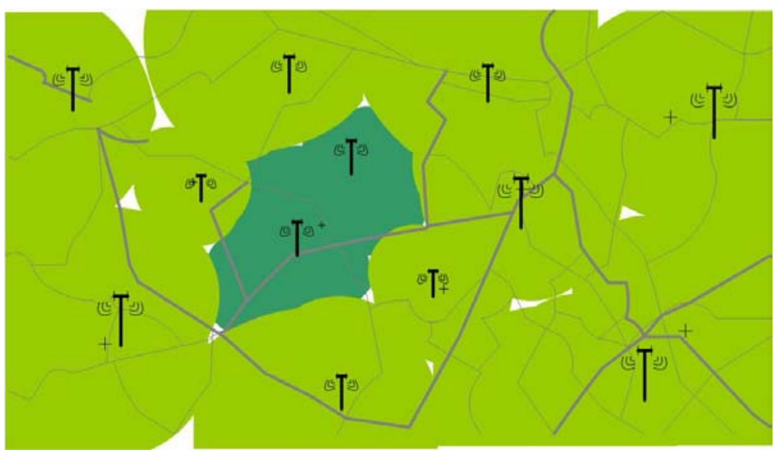

Figure 4: Use of Two Shorter Towers to Provide Coverage to Underserved Area

To give a different sense of the cell coverage area, Figure 5 shows the theoretical signal strength for the area covered by antennas at 100 feet AGL and 150 feet AGL.

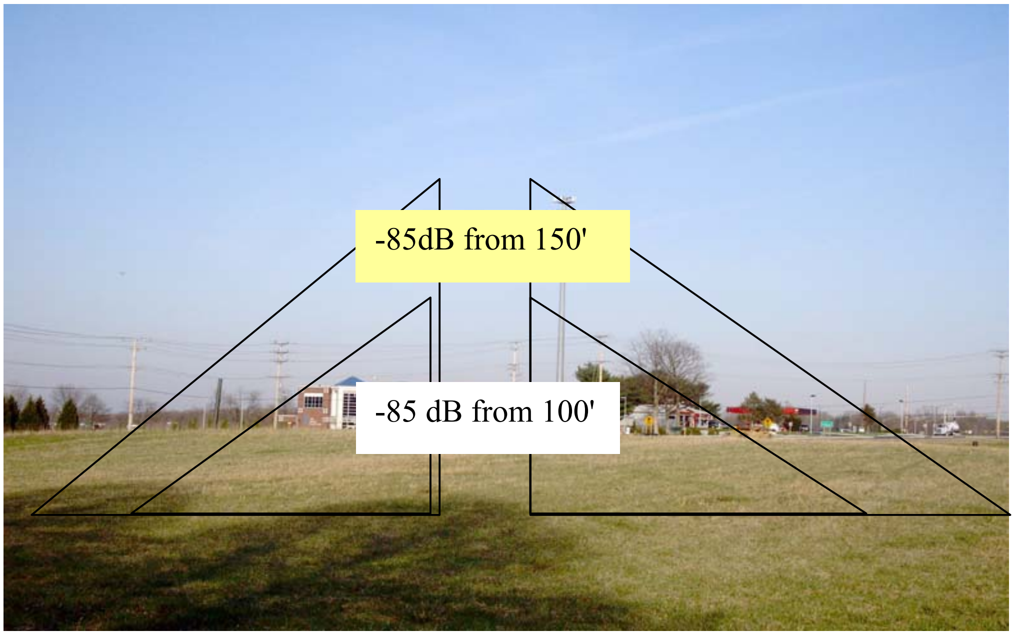

Figure 5: Signal Strength for 800 MHz service from 100' and 150' Tower

The results shown are based on the calculations provided in Table 1. Table 1 shows the expected cell size with –85 dBm signal strength based on engineering modeling formula. The calculations are derived from a standard mathematical model used to calculate expected coverage for typical 800 MHz and 1900 MHz-type cellular service, given certain parameters. The parameters include path loss (signals diminish over distances), environmental factors (for rural, urban, or suburban areas), a link loss budget (the difference between the low power of the cell phone and the great power of the cell base station), and the type of antenna used (omni-directional, directional, size signal pattern, etc). Detailed engineering information about the basis for these calculations may be found in Appendix B.

Using this simple model, Table 1 shows the differences in coverage area for towers at 100 feet and 150 feet calculated at a signal strength of -85 dBm. For signals at 1900 MHz, the overall coverage area diameter is roughly 328 feet smaller using a 100-foot monopole rather than a 150-foot monopole. For signals in the 800 MHz frequency range, which by their nature may extend farther than at 1900 MHz, the difference is approximately 656 feet smaller at -85 dBm.

Table 1: Coverage at -85 dBm

Antenna Height Above Ground	Predicted coverage for 1900 MHz systems	Predicted coverage for 800 MHz systems
150 feet	3,018 feet	6,562 feet
100 feet	2,690 feet	5,906 feet
Difference	328 feet	656 feet

The actual models used by cellular system engineers when designing and evaluating a proposed site are more detailed then our model. The calculations are more site-specific and also include factors related to the terrain and multi-path fading, among others. These additional factors will have a significant impact when dealing with shorter facilities. For example, multi-path fading reflects the impact of signals bouncing off of buildings and hills, which diminish signal coverage. This is more significant at lower elevations. The carrier's calculations also take into consideration other aspects of the specific carrier's service parameters and existing network. In addition, terrain differences across the cell also have an impact on the coverage and signal strength.

Another important consideration when determining placement of cell sites is the signal strength differences between the phone and the cell transmitters. A strong signal received at the cell phone will enable the caller to clearly hear the other party on the call. A strong signal received at the antenna will determine how well the caller on the other end of the line will hear the person using the cell phone. The power of the transmitter at the cell site is much more powerful than the transmitter in the small hand-held cell phone. The combination of these two devices is a factor in determining how well the system works. Engineers address this matter in the link budget calculations during the RF network design process. This also explains why, as cell phone users move through a service area, they can sometimes hear differences in the clarity of voice quality during a conversation. Figures 6 and 7 are examples of signals from a cell tower using more powerful, larger antennas compared to the signal coverage from a cell phone with less powerful smaller, antennas. In these illustrations, large gaps (indicated in blue) show reception gaps at the cell from the lower power of the cell phone's transmitter.

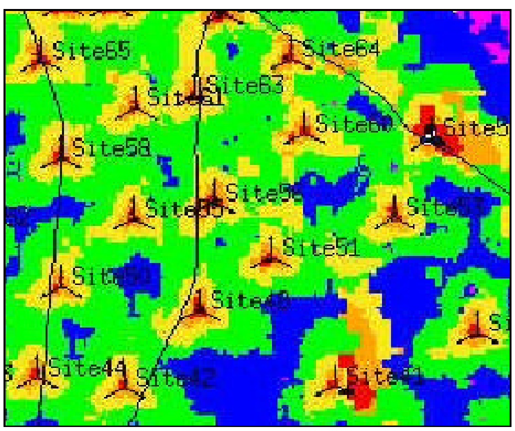

Figure 6: Cell Receiver Propagation Plots

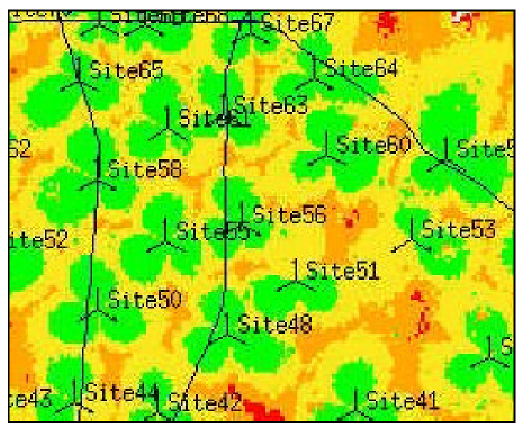

Figure 7: Cell Transmitter Propagation Plots

If the signal from the cell phone cannot reach the cell site, there can be no reception from the phone. In the illustration, the area is fully covered by the cell antennas but the signals from the cell phone are weaker and do not link with the cell sites.

Another factor to consider in reducing the height of new towers is that it can make the structure a less attractive option for collocating additional antennas. The first carrier's antennas attached to a new tower are usually at the top of the tower. But subsequent carriers will have to be at lower levels due to vertical separation requirements to avoid interference with antennas transmitting in frequency ranges close to one another. Today, we typically see attachments with vertical separations of about ten feet. This means that the second carrier's antennas could be located at about 80' to 90', and a third carrier's antennas could be at 60' to 80 feet above the ground. This, of course, depends on the size and type of antenna, and the frequencies involved. When antennas are limited to the lower elevations, there are consequences in coverage and efficiency of the system. At elevations of 100 feet or below, the antennas are probably close to the height of many buildings in College Station, which adds to service problems because of the effects of multi-path fading and/or obstructions due to terrain or foliage. Figure 8 illustrates the effects of terrain changes that create gaps in coverage, which an increase in antenna height can sometimes resolve. Antennas at greater heights can transmit signals over obstructions and can therefore cover areas blocked when antennas are at lower elevations. Also note that the signals fade as the distance increases from the antennas. The darker shaded areas indicate that areas where signals are blocked by hills are minimized because the antennas are higher. For antennas at the lower elevation, the areas blocked (indicated by the lighter shaded areas) are greater.

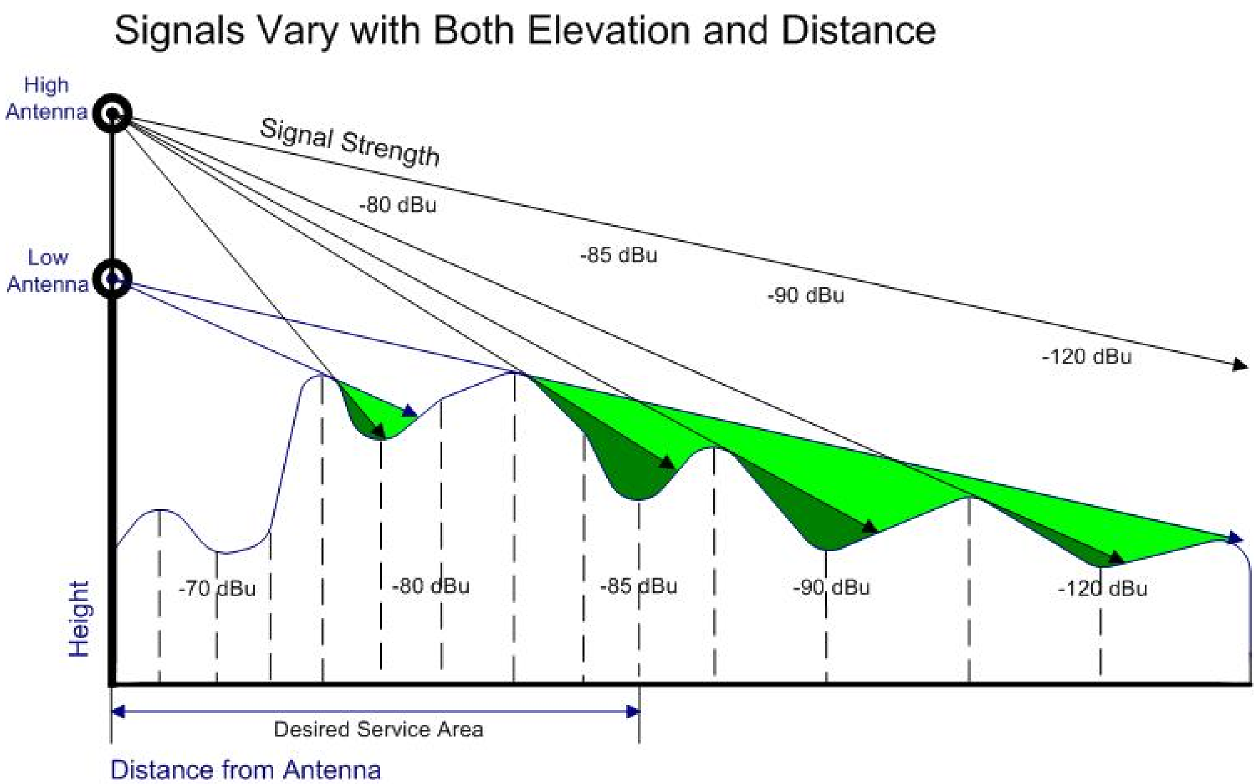

Figure 8

So, reducing the height of towers for cellular service providers' antennas may reduce the coverage area for new sites in the future, and may result in the need for more cell sites and perhaps more towers. However, the need for more cells does not necessarily imply that carriers will need a new tower for each new cell. This is because antennas can be attached to many types of structures that already exist within a service area. Carriers can attach their antennas to the rooftops of commercial buildings, water tanks, electric power company transmission line facilities, and even within the enclosures of church steeples. However, there will most likely be a need for some new cell towers in the future, because capacity or coverage needs may arise in areas where there are no existing structures of the appropriate height suitable for antenna placement to obtain the desired coverage objectives.

The opportunity to collocate antennas on an existing tower minimizes requests for additional new towers by others. This is important because of the number of other antennas that will undoubtedly be deployed across the City in the future as more services are offered and market demand for them increases. Based on just a cursory review of the FCC's database, we find that there are over 600 transmitters already licensed within two miles of the center of College Station. Additional new antennas may be able to collocate on existing structures, but at some point, new towers will be needed, especially for some of the line-of-sight services.

Wireless Internet and other infrared or microwave technologies, and other emerging point-to-point wireless technologies, require a clear line-of-sight from transmitter to receive antenna to operate. A line-of-sight is necessary because the infrared beam travels in a straight line.

For line-of-sight services, higher elevations are important because it minimizes obstructions between antennas. A typical wireless Internet design consists of equipment installed at the customer's premises (usually on the roof of the building), and equipment for the service provider installed at a strategic tower location from which they can reach multiple subscribers. If a clear line-of-sight cannot be obtained, it is difficult to provide service to those customers.

Wireless Internet service providers also use a central base station where land-based facilities are available to link to its Internet Service Provider (ISP). This is usually a location where they can mount antennas high enough to receive signals from many surrounding individual subscriber locations. If there is no land-based facility near the base station central to their customers, signals are sometimes relayed, via another line-of-sight microwave, to another site where connections can be made to link the subscriber to its ISP.

The economic impact of additional sites could be considerable. Typically, a 120-150 foot monopole might cost in the range of $195,000 to $250,000. A 250-300 foot self-supporting lattice towers might cost as much as $300,000. But much of the cost of a new facility is in the additional sets of antenna, ground equipment, cables, and equipment shelters that are associated with additional cell sites. Therefore, regardless of whether a new tower is also required, there are fixed electronic equipment costs incurred with each additional antenna location. If a new tower is needed, however, once constructed it can provide a source of revenue for the tower owner in the form of rental fees from other service providers leasing space on the tower. This can sometimes offset the costs of the tower.

Task 2. Comment on Current Testimony Regarding the Legislative Changes and Discussions with Interested Parties

Based on our review of the written testimony, and from our discussions with the two parties we were requested to contact, Chet Fry of Texas Communications and Jeff Collins of Cybercom, it appears that the focus of their concern is that the UDO includes many kinds of services in the height limitations that, by their nature, require higher antenna elevations. They make a case that there should be exemptions for those services because the nature of their business requires that antennas be placed at higher locations. These include business radio, land transportation radio services for railroad, taxicab, and motor carriers, and industrial communications systems. Many of these kinds of businesses, such as two-way business radio and wireless Internet service, require a single higher transmitting facility to cover a large geographic area, as opposed to a cellular tower, which can be shorter because of the nature of that service. So, unless specifically excluded from the regulation, they would be forced to go through a special exception review process in order to obtain a permit. Some of the businesses to which we refer typically use towers at heights of 250-400 feet AGL. They argue, and we agree, that for their purposes, those antennas do need to be higher than the limits set in the legislation.

Earlier in this report we mentioned that we found over 600 licensed transmitters already within two miles of the center of College Station. Most of the 600 transmitters are for these kinds of services. On the other hand, what appears to be excluded from regulation, for example, is a tall tower typically found at a cable television system headend, should one be located within the city limits of College Station. Often, these could be 100-200 foot towers with off-air television reception antennas or small dishes less than 2-meters in diameter. So, even though we agree with the respondents claims of needing taller facilities, and though there are apparently provisions for exceptions that may be approved, this could be problematic for the City in administering these regulations. We want to bring this to the City's attention, because there may be many different types of services impacted by the UDO.

Task 3. Suggestions for City Review of Applications to Construct Towers in the Community

To evaluate the requirement for a particular tower location, at a minimum, a basic application should contain the following information:

- The zoning category identifying what type of facility is permitted in what zone;
- An explanation of the extent to which the applicant considered existing collocation opportunities such as existing buildings, towers, and other structures;
- A description of the system parameters including transmit and receive frequencies, specifications for the antennas proposed for attachment to the tower, effective radiated power, FCC license information, etc.;
- A description of the coverage objectives of the site selection indicating supporting radio frequency analysis and documentation supporting how the new facility addresses gaps in existing coverage;
- Vicinity maps and site plans showing the location of the facility within the community and on the property;
- A description of the tower and ground space to accommodate additional carriers' antennas and ground equipment;
- A statement about the surrounding topography if it impacts the sites selection, facility height, and service quality;
- RF propagation contour maps showing the area (with adjacent sites, existing and future) with and without the coverage from the proposed site, illustrated in color with signal strength contours plus and minus 5 dB from the desired signal coverage objective;
- Information about the selection of the proposed site and what existing alternatives were ruled out with an explanation of why they cannot work in lieu of a new tower; and,
- Any additional supporting documentation, including drive test results or balloon tests, that the carrier may have performed.

Upon receipt of this information, the City can then evaluate the need for the coverage and how the proposed site meets that need. The City should conduct a site visit and survey the area around the site to see if there are any existing structures that could be used to attach the carrier's antennas and possibly still meet the coverage objectives. Photos should be taken of any potential alternative sites showing what facilities may already be attached to the existing structure. If additional information from the carrier is needed to rule out any possible reasonable alternative location not previously considered by the carrier, a request for additional information should be sent to the carrier to address the alternative in question. A staff report can then be prepared which includes the conclusions about the proposed site and its potential impact on the community and the carrier's needs.

In the interest of including the items noted above, we have redlined the application section of the UDO amendment, and provided a supporting explanation about the suggested changes in Section 4.

Task 4. Recommendations Pertaining to the Wording of a Final Tower Zoning Ordinance Based on the Engineering Study

Without knowing the carrier's current network within College Station, the location of current and proposed antenna sites and respective RF coverage patterns, and if there are any suitable tall existing structures at those proposed locations, we cannot determine the extent to which these changes in the UBO may hinder future deployment of antennas or the extent to which additional towers may be needed. We can generally say that a case could be made that some 100-foot towers will be too low for the effective deployment of some services.

In reviewing this legislation, we see a couple of pitfalls in the way it is presently constructed. First of all, we note that there are a number of types of antennas for services that are exempt from this regulation. In reviewing that list, we also note that there are a number of other services that do not appear to be covered at all.

For example, business radios and unlicensed services or experimental services such as satellite radio, and some aspects of the wireless Internet service providers, which can transmit high power signals (not considered by definition as a "WTF") and can also necessitate antenna heights of 280-400 feet AGL. Defining WTF as "low powered" facilities appears to us to be problematic. The FCC refers to low power for FM services as being 100 watts or less. For some two-way radio services, 10 watts is considered low power. For a typical low power television station, the powering is 10 Kilowatts or less. The maximum effective radiated power from a cellular base station is limited to 500 watts, which, in our opinion, is not low power. If, for example, the wireless Internet Providers are deemed low power services and subject to the height limitations, there will be problems for new providers that may require the higher tower needs of line-of-sight services as described above. Therefore, we believe including low power in the definition for WTF is confusing.

Presumably, towers taller than the limits in the UDO or less than the separation requirements from other towers can be considered case-by-case by the City based on the justification of need relative to the services the applicant plans to deliver. An AM radio "antenna", as a case in point, requires a number of tall towers (200 feet to 400 feet) to provide service. Furthermore, the placement and number of towers impact the coverage area. In addition, some broadcast radio services have service coverage requirements that are part of the FCC's license requirements. In those cases, the carrier would be required to make their case based on the type of service and its inherent needs. The City would then have a basis for a decision for granting a permit and setting any special conditions about those taller towers.

In the end, an alternative to changing height limits would be to not change the current height limitation of 150 feet. Based on the information we have been provided, it appears that with the current 150-foot limitation, there has not been any significant outcry of adverse impact on services. In the information we were provided, there were no comments expressed that the present ordinance has stifled growth and deployment of new services. So, it may be more productive for the City to focus its attention on encouraging collocation and assuring that the carriers have done all they can in that regard before seeking permission for a new tower. This can be accomplished by some of our suggested changes to the City's review process, as discussed below.

Redlined UDO Amendment

H. APPLICATION PROCEDURES

1. Site Plan Requirements
   An application for administrative approval or a Conditional Use Permit for a WTF shall include the following items (in addition to the site plan and other information required for a standard CUP application):

a. An inventory of the applicant's existing and future towers that are either within the City, the City's ETJ, or within at least 1 mile of the City's boundary where the ETJ does not extend that far. The inventory shall include specific information about the location, design, and height of each tower. The owner must have on file with the development department a master list of all existing tower structures owned or controlled by the owner. Such list must specify the name, address and telephone number of the owner of record, the tower locations by address and legal description, tower height, the number of antenna arrays on the tower, and the names, addresses, and telephone numbers of all other users of the tower structures. The zoning administrator may share such information with other applicants or organizations seeking to locate antennas within the City.

b. Site plan and elevation profile of the tower, drawn to scale and clearly indicating the location, height, and design of the proposed tower and antennas, location of the equipment cabinets for the applicants equipment and space for at least two additional equipment sheds or cabinets for future collocator's equipment, ~~transmission buildings and other accessory uses,~~ access, parking, fences, and landscap~~ed~~ing planned for the areas.

c. The linear separation distance from other transmission towers within a one-mile radius of the proposed tower site. The linear separation distance from all residentially zoned properties, residential structures, and applicable thoroughfares (Section D.2) within 500 feet of the proposed tower.

d. A visual impact analysis, presented as color photo simulations, showing the proposed site of the WTF. At least four views shall be submitted looking toward the site (typically north, south, east and west) including views from the closest residential property and from adjacent roadways. The photo-realistic representation shall depict a "skyline" view showing the entire height of the proposed tower or WTF, to scale, and the structures, trees, and any other objects contributing to the skyline profile. If a balloon test has been conducted, provide photos of the balloon on the horizon from at least four different directions from which the balloon is visible.

e. Plans for the antenna and the antenna tower shall be prepared and signed by a licensed professional engineer and designed to withstand sustained winds of at least 80 miles per hour.

f. All telecommunication facilities must meet or exceed the current standards and regulations of the FAA, the FCC, and any other agency of the Federal Government with the authority to regulate telecommunication facilities. An applicant for a permit shall submit an affidavit confirming compliance with applicable regulations.

g. ~~Grid plan (propagation map) of the service area for existing and future structures for a period of not less than 5 years. The submission should include a maps showing the "search ring" that was required for siting the proposed facility.~~ A map showing all existing and planned antenna locations, including possible search ring areas for a service area providing service within a one-mile perimeter around the City.

2. Collocation Requirements
No new tower shall be built, constructed, or erected in the City unless the tower is capable of supporting at least two additional wireless telecommunication facilities. ~~The applicant must submit a letter addressed to the City declaring an intent and willingness to construct a proposed tower that would allow additional service providers to locate on the new tower.~~

3. Documentation of Need and Alternatives
No new communications tower shall be permitted unless the applicant demonstrates to the reasonable satisfaction of the approving authority that no existing tower, building, structure, ~~or alternative technology~~ can accommodate the applicant's proposed antenna. The applicant shall submit information related to the availability of suitable existing towers, other structures ~~or alternative technology~~ that can accommodate the applicant's proposed antenna. The zoning official or approving authority may request information necessary to demonstrate that reasonable alternatives do not exist. The applicant must submit:

~~a. The names, addressees, and telephone numbers of all owners or other towers or usable antenna support structures within one-half mile radius of the proposed new tower site, including City owned property.~~ A listing of possible existing structures or towers that were considered but ruled out for attachment of the proposed antennas. If they were ruled our for

RF coverage reasons, provide the RF contour maps showing that the alternative did not meet coverage objectives. If the alternative was ruled out for non-RF reasons, explain the nature of the reason for rejecting the alternative.

~~b. A sworn affidavit attesting to the fact that the applicant made diligent, but unsuccessful, efforts to obtain permission to install or collocate the new facility on existing towers or antenna support structures located within one-half mile radius of the proposed tower site. The affidavit shall spell out the efforts taken by the applicant.~~

~~c. A description of the design plan proposed by the applicant in the City. The applicant must demonstrate the need for towers and why technological design alternatives, such as the use of microcell, cannot be utilized to accomplish the provision of the applicant's telecommunications services.~~

b. RF propagation contour maps showing the site and all adjacent existing and planned antennas illustrating, in color, coverage with and without the site, using plus and minus 5dB gradients. Include a description of the desired coverage objectives in terms of signal strength and geographic service area.

§D (5): As a point of information, we have seen some "stealth" facilities, those disguised as trees and flagpoles built to be 120 to 140 feet tall. These types of monopoles, although disguised, can still be quite noticeable in the community. For example, a 120-foot monopole disguised as a flagpole in a residential neighborhood may appear out of place to some, as it is a flagpole of a size more appropriate for a large municipal facility or shopping center. Additionally, monopoles designed as trees, if there are no other tall trees around the site, may appear obtrusive to some as well, especially if the monopole is not fully "grown", with "branches" concealing the antenna array only at the topmost portion of the monopole. The City may wish to consider use of wording that would condition new stealth towers to the same height limitations for non-stealth towers, or provide some other limit that may be agreeable to the community. A photo of a monopole approximately 100-120 feet high disguised as a flagpole at a high school football field is attached as Appendix C for your reference.

We also note that there is no Section F in the version of the amendment that we were provided.

Explanation of CTC's redlined edits to the UDO §H Application Procedures:

1 (b): This change is to include the elevation profile of the tower showing where the applicant will attach its antennas on the structure. This will also ensure that the tower is not being constructed taller than needed for the applicant's antennas. To make the tower more marketable to possible collocators, a tower builder, for speculative purposes, may wish to make the tower higher than may be necessary for the antennas for which the tower is being built. At the same time, in the interest of providing collocation opportunities, that tower will be able to accommodate additional carriers and perhaps preclude the need for another tower. So, we also suggest a requirement for the ground space to be large enough for other equipment, so that when the tower is constructed there will already be space available for potential collocator's equipment.

1 (d): The carriers will often conduct a balloon "test" to show how high the top of the tower will be once constructed. (See Appendix A for a description of a balloon test). If the carrier has already performed this work, it should be provided to the City to verify the photo simulations and to give a sense of where the top of the tower will be on the horizon.

1(g): This should suffice to illustrate the carrier's planned coverage for the area, and will enable City staff to see how a new tower may fit in with what is already on the ground and what may be needed in the future. This can also serve to assist City staff in coordinating future collocation among the carriers. The carriers usually consider this information proprietary, so the City may want to consider a provision for making this information available for review by the City while still keeping the network coverage and marketing information confidential. Also, a plan five years out is an extremely long time for these industries. The market is usually more near-term than that, and we suggest that simply asking the carrier to let the City know of what it has presently activated, what is currently being constructed or activated, and what is planned but not presently pursued, should cover all of the bases.

§2: We suggest that space should be made for a minimum of two additional carriers to attach to the new tower and to install their equipment on the ground.

§3 (a): A carrier will usually first determine if there are any existing buildings or towers to which they can attach their antennas to save the time and expense of constructing a new tower. It appears that the intent of this section is to assure that they have done so. We have found that asking what alternatives they considered and why they ruled them out satisfactorily addresses that concern. It also answers why an obvious existing structure was not used, and provides additional supporting documentation leading to the request for the new tower. Usually a site survey conducted by City staff around the area proposed for a new tower will reveal any obvious alternatives. If the carrier did not consider any obvious alternatives, then a request for additional information can be sent to the carrier asking why the alternative in question wasn't considered. We suggest that this approach may be more useful than the wording in the draft ordinance. This should also take care of §3 (b) as well.

New §3 (b): We suggest a new section requiring submission of the RF contour maps with the application (refer to our explanation of the RF maps in Appendix A). This is typically one of the primary tools used by the carriers to select a search ring and determine the likelihood that the proposed new facility can provide the desired coverage. These maps are often considered proprietary by the carriers because it illustrates their network coverage, which they keep confidential from their competitors. The City may want to consider a provision to enable the City to review this information but keep it confidential.

Appendix A

The design of a wireless cellular system, including the determination of the spacing of the cells and siting of antennas, depends upon a number of factors including the frequency spectrum, geography and topographical features, and subscription and usage rates. Additional transmission facilities are constructed to meet demand from new subscribers and to eliminate holes in existing coverage areas.

Service providers must weigh these considerations in selecting sites for their antennas to provide the service to their customers. Computer models are used to examine the radio frequency (RF) aspects of the site selection process. Given a certain set of parameters, the model can generally predict what the RF coverage, or propagation, may be for a certain site and show the results on a map. The result of the modeling process is an RF contour or propagation map, which is a visual representation of the coverage based on different alternatives loaded into the computer. The objective in using the model is to select the antenna placement which most consistently provides the desired signal strength across the desired service area. The selection of a site is, in part, determined from what the model projects. It is a computer model and is not based on empirical data.

RF Propagation Maps

Very simply explained, the RF propagation modeling process is based on:

- The terrain of the surrounding area to be served - a topographical survey of the surrounding area loaded in the computer program. The program factors the elevation contours into the model to reflect changes in signal strength due to terrain. For example, where changes in elevation present a barrier to the signals, weaker signal strength will be indicated. Where the obstruction is so severe that it would be expected to block signals entirely, no signals are indicated; and,

- The signal strength, elevation, direction and angle of the antennas, and the operating characteristics of the antennas to be used. Each antenna has certain electromagnetic emission characteristics and power ratings. Depending on the technical specifications of antennas the carrier uses for its network, different emission patterns will be transmitted. The model, using a mathematical algorithm, depicts a theoretical pattern of expected service coverage across the terrain. Appendix A is a more detailed description of two such models as an example for reference. The model, given a different direction setting across the terrain, a different angle toward the ground, or a different transmission power, will generate different results. For different elevations of the antennas above the ground, the model will project differing service coverage for some sectors of the service area. Factors such as signal fade, reflection, co-channel interference, multipath reception, Doppler effects, signal delay, and building or vehicle penetration are all other factors which come into consideration as well in building the model.

RF propagation maps are computer-generated illustrations of the expected coverage provided by a proposed antenna. RF maps typically illustrate the coverage around the proposed site with and without the proposed antennas at the new location. The RF coverage is overlaid on a map with major roadways shown for reference. By using colors, letters, or other similar methods, the maps indicate the expected signal strength of transmissions from the existing adjacent cell facilities and the proposed antenna placement. From the RF maps, one can see where there are gaps in coverage or where there are areas of reduced coverage within the service area. The maps illustrate how the proposed antenna siting improves coverage to meet the service standards established by the carrier for its customers. This information is, in part, used to select a single site among alternative sites being considered.

The computer programs typically do not provide for additional effects from seasonal changes in vegetation or other existing structures which may also impact the signal quality. Some sites may work fine in the winter, but in the months when trees are in full foliage, the reception can be quite different. Tall buildings also diminish signal quality and cause other kinds of distortions (in the form of reflections and partial blockages) which affect the signal quality. A carrier will usually prepare a propagation loss "budget" to determine the maximum loss or limiting factor in cell coverage radius. This process considers the transmit power, antenna gain, receive sensitivity, and losses as signals pass through equipment such as duplexers, filters combiners and even the cables which connect the equipment to the antennas.

Site Selection

Based on the information from the model, a "search ring" is then defined and the carrier's staff conducts an analysis of the general vicinity within the ring to determine if any existing structures may be used to attach the antennas. The search ring is based on the geographical center of the "ideal" RF model which illustrated the best coverage of the gap in service. The carrier then dispatches a site acquisition team to search the area within a certain defined radius from the center of the projected coverage. Some use an area within a mile of the center point. Others use more like a quarter of a mile. When buildings, existing towers, water tanks, or other existing structures are found, the model is run again using the information about each different structure for the potential antenna height, directional placement, and strength of the transmissions. Through this process a list of alternatives is generated. From the list, a site will targeted and then the carrier determines if that site can be leased, antennas successfully attached to the structure if one exists, or, if there is no existing structure, can raw land be leased and a building permit be obtained to construct a new tower or monopole.

In conducting a review of an application for a new tower, the permitting authority can address coverage issues by reviewing the RF propagation maps submitted by the applicant. These maps are illustrations of an RF signal level analysis generated by computer models showing predicted signal level gradients. In other words, the map shows what signal levels one would expect to see across the terrain of the desired service area from new antennas attached to a structure at the proposed elevation.

In addition to the RF maps, which only represent theoretical coverage, carriers often perform "drive tests." Drive tests are simulations conducted by carriers to determine signal strength around a proposed site more reliably than the RF models and resultant propagation maps. To conduct a drive test, carriers raise a temporary transmitter antenna at the proposed location, typically by use of a crane, and drive the roads in the general vicinity of the proposed antennas to sample signal strength along the route by use of electronic devices within the vehicle. The results of the drive tests are also plotted on maps, typically using different colors to indicate different signal levels received by the vehicle as it roams the service area.

Carriers can also conduct a "balloon test". To do this, the carrier raises a balloon to the approximate elevation of the proposed monopole or tower. The balloon location may then be observed by interested parties in the surrounding general vicinity to determine the extent to which the structure will be noticeable to the community. The balloon test provides a sense of adverse visual effects of a proposed monopole or tower. Balloon tests are usually documented with photographs from various strategic locations where the top of the structure may be visible.

Interpreting the RF Documentation

The burden of proof is on the applicant to demonstrate that existing antennas do not provide the desired signal level to the area the applicant identifies as lacking service. The industry has generally established that an adequate signal level is at least –85 dB or better, say –75 dB. RF engineers generally accept the type of service proposed by the applicant as the desirable minimum signal level to ensure reliable continuous conversation as a cell phone user travels through the service area from cell to cell. This is illustrated in Figure 1.

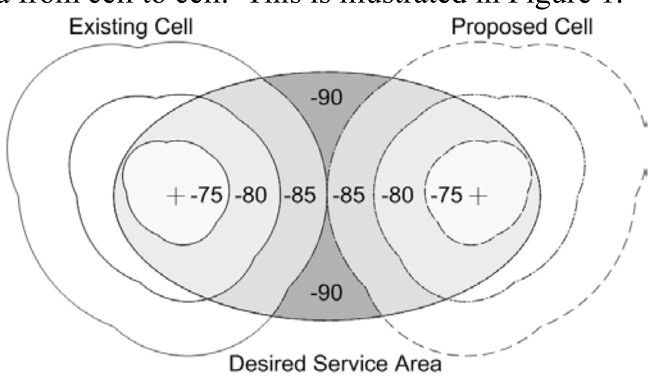

Figure 1: Adequate Signal Coverage
+ = Cell antenna site

In Figure 2, we illustrate a case when the – 85 dB signal gradient is not continuous, creating certain consequences in service. In the white coverage gap area, there is a very high likelihood that there will be places where calls will be disconnected, voice quality will be poor or intermittent, or one party will not hear the other.

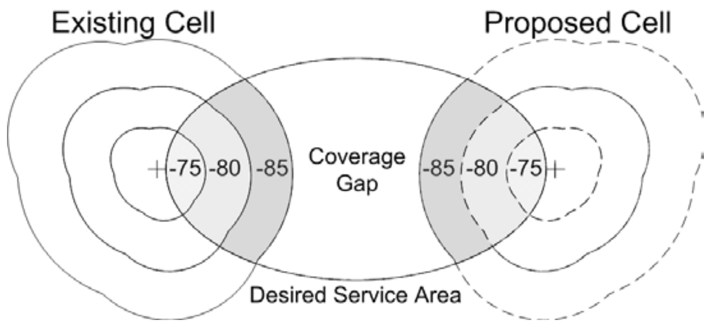

Figure 2: Inadequate Signal Coverage

In conducting a review of the RF documentation and the site area, one can see the extent to which the need for a new tower has been demonstrated by the applicant. One should look to see that there are no existing antennas which provide that signal level, and the extent to which the proposed antenna site provides the desired signal level. If there are existing structures in the area to which the applicant could attach its antennas and provide the desired signal level, there may be no need for a new tower. A survey of the area around the proposed new tower can sometimes reveal existing structures the carrier may not have considered. If it is believed that there are other viable alternatives to a new facility, the carrier can be asked to perform additional analysis based on the alternatives to validate whether or not the alternative will work to provide the desired coverage.

The types of construction and the surrounding geography can affect the transmission characteristics of an antenna, and therefore must be taken into the design consideration. In addition, there are some methods of making these towers less offensive to residents through screening, disguises, and using existing facilities such as church steeples, flag poles, or other less visually offensive systems. These are often referred to as "stealth" facilities.

Appendix B

Explanation of Engineering Calculations and Results

There are many factors that affect Radio Frequency (RF) performance and coverage for Cellular and PCS systems. In performing the required engineering calculations, several assumptions were made to best represent the different technologies, engineering parameters, and equipment used by the carriers. It is important to note that different results would be obtained depending on many factors such as transmit frequency, differences in technology (i.e. GSM, IS-136, IS-95), base station equipment capabilities, and environmental influences such as fading or shadowing effects. There are numerous technical challenges in RF capacity and coverage planning that a carrier needs to deal with in delivering the optimum coverage to subscribers from each site.

The engineering calculations included in this review are mainly based on the Okumura-Hata and COST-231-Hata model predictions for systems in the 800 MHz and 1900 MHz range. A link budget calculation is also included to show the relevant assumptions for the 800 MHz and 1900 MHz systems. In performing the calculations, an environmental-correction factor of –10 dB was used for suburban areas, which is consistent with industry practices.

Table 1 shows the relationship between cell radius and four antenna heights. The result represents RF coverage of at least –85 dBm.

Table 1: Summary of results from most reliable -85 dBm coverage radius calculation

Antenna Height	Predicted Cell Radius for 1900 MHz systems (feet)	Predicted Cell Radius for 800 MHz systems (feet)
35 ft*	984	1,968
75 ft	1,213	2,625
100 ft	1,345	2,953
150 ft	1,509	3,281

The following assumptions were made in performing the engineering calculations:

- Base Station transmit power = 8 Watts for 1900 MHz system, 16 Watts for 800 MHz system
- Antenna Gain = 18 dB
- Base Station transmit feeder loss = 3 dB
- Base Station transmit combiner loss = 3 dB
- Receive antenna gain = 2 dB downlink, 18 dB uplink
- Body Loss = 3 dB
- Outdoor margin = 8.6 dB[1]
- Environmental-Correction Factor = -10 dB for suburban areas

[1] Calculation based on single server probability with path loss slope of 44.9 dB/decade and standard deviation of 8 dB

Formulas:

Okumura-Hata (800-MHz band)
A (dB) = 69.55 + 26.16 log (F) – 13.82 log (H) + [44.9 – 6.55 log (H)] x log (D) + C

COST-231-Hata (1800/1900-MHz band)
A (dB) = 46.3 + 33.9 log (F) –13.82 log (H) + [44.9 – 6.55 log (H)] x log (D) + C

A = Path loss, dB
F = Frequency, MHz
D = Distance between base station and mobile station, km
H = Effective height of base station antenna, meters
C = Environmental-correction Factor, dB

Table 2: Industry Target of –85 dBm based on Okumura-Hata and COST-231-Hata models

	Tower Height 35ft	Tower Height 75 ft	Tower Height 100 ft	Tower Height 150 ft
Frequency	800 MHz	800 MHz	800 MHz	800 MHz
Distance between base station and MS	0.60 km	0.80 km	0.90 km	1.00 km
Effective height of base station antenna	10.67 m	22.86 m	30.48 m	45.72 m
Environmental correction factor	-10 dB	-10 dB	-10 dB	-10 dB
Okumura-Hata, Path Loss (dB)	113 dB	113 dB	113 dB	113 dB
Frequency	1900 MHz	1900 MHz	1900 MHz	1900 MHz
Distance between base station and MS	0.30 km	0.37 km	0.41 km	0.46 km
Effective height of base station antenna	10.67 m	22.86 m	30.48 m	45.72 m
Environmental correction factor	-10 dB	-10 dB	-10 dB	-10 dB
COST-231-Hata, Path Loss (dB) =	113 dB	113 dB	113 dB	113 dB

Table 3: Link Budget Calculation

	1900 MHz Suburban downlink	1900 MHz Suburban uplink	800 MHz Suburban downlink	800 MHz Suburban uplink
Transmit power (Watts)	8	1	16	1
Transmit power (dBm)	39	30	42	30
TX antenna gain (dBi)	18	2	18	2
Body Loss (dB)	0	3	0	3
TX feeder loss (dB)	3	0	3	0
TX combiner loss (dB)	3	0	3	0
Isotropic transmit EIRP (dB)	51	29	54	29
Isotropic transmit EIRP (Watts)	126	0.8	251	0.8
Receiver sensitivity level (dB)	-102	-104	-113	-104
Receive antenna gain (dBi)	2	18	2	18
Diversity gain (dB)	0	4	0	4
Receive system loss (dB)	0	0	0	0
Body loss (dB)	3	0	3	0
Isotropic effective receive sensitivity level (dBm)	-101	-122	-112	-122
Isotropic maximum free-space path loss (dB)	155	155	155	155
Outdoor margin	8.6	8.6	8.6	8.6

Appendix C

Photo of +/- 120' "Flagpole" Monopole at High School Football Field