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VIA US MAIL AND E-MAIL

April 17, 2009

Amanda Lee
Senior Planner
City of San Diego - Development Services Department
1222 First Avenue, MS 501
San Diego, CA 92101-4155

Subject: Draft San Diego Municipal Code revisions regarding amateur radio antenna support structure

Dear Amanda:

In reviewing the City's second draft of the Municipal Code revisions for amateur radio antenna support structures released on or about February 12, 2009 (the "Draft"), as later amended at the Community Planners Committee meeting on February 24, 2009 (lowering the height of such structures to 45 feet for a solely ministerial review process), my client, the San Diego DX Club, still has significant concerns regarding the legality of the City's position. In order to find a reasonable compromise between the parties, my client has authorized the preparation of the attached model set of Municipal Code revisions (see Addendum #1) which comply with federal and state preemption requirements (the "Model").

The Model has been annotated with comments in the right hand portion of the screen to clarify the legal points sought to be covered by both parties; namely, the City's legitimate interests under its police power as they are limited by federal and state requirements to use the minimum practicable regulations necessary to provide reasonable accommodation of an amateur radio operator's effective communications.

While the annotations shown in the Model are fairly clear on their face, several of the points made warrant further elucidation, as follows:

1. <u>The separateness of an antenna and an amateur radio antenna support structure</u>. An amateur radio antenna support structure should be kept as a discrete object, separate from an antenna for the following reasons:

a) from a drafting viewpoint, the existing definition of an *antenna* in SDMC §113.0103 specifically excludes its support structure, thus any inclusion of the antenna in the support structure could lead to confusion and illogical results;

b) an amateur radio service antenna may be a standalone device, not needing a support structure. As you and I discussed previously, a non-permanent installation such as a wire antenna hung between two points on a lot or a HF, VHF or UHF antenna which is not permanently attached to a *structure* would not need a building permit. But under the Draft, there is currently no such differentiation between permanent and non-permanent structures;

c) an amateur radio antenna may be moved, replaced, added or removed from an amateur radio antenna structure by its owner, in order to improve and/or experiment with communications. These operations should not require any additional review or permitting by the City as doing so would hinder the amateur radio operator's effective communications and ability to experiment (both are protected aspects of the amateur's use pursuant to PRB-1). By including the antenna in the amateur radio antenna structure definition and regulating the structure, the City would potentially have that ability to hinder the operator – this would be an unreasonable burden on its face and would fail a challenge; *and*

d) an antenna placed on an urban lot is fairly likely to encroach into the setback given the narrow widths of many such lots (e.g. 25'-75'). Because the Draft includes the antenna in the amateur radio antenna support structure's definition any part of it encroaching into the setbacks trigger a Process Two (Neighborhood Use Permit – NUP) review. Given the likely nature of such an encroachment, to impose anything more than a ministerial process for just the antenna is tantamount to an unreasonable burden and thus, on its face, fails to reasonably accommodate effective communications with minimum practicable regulation. Therefore, we propose that the setbacks be enforced for the permanent amateur radio antenna support structure pursuant to the terms of the Model, but not the antenna itself, due to the physical limitations of many standard City lots. The zoning code does not impose setback limitations on other non-permanent structures or non-fixed personal property – it should be no different for antennas.

2. <u>Utilizing a modified building permit review process for amateur radio antenna support structure 82 feet or less</u>. As stated in my previous letter letter to Deputy City Attorney Jana Garmo, dated January 1, 2009, a height of 82 feet should be the floor in triggering anything more than a ministerial review. Failing this, the City stands a fair chance of being in contravention of federal and state requirements to reasonably accommodate effective communications with minimum practicable regulations.

To clarify the point, it is worthwhile to review the use of both the 20M (14 MHz) and 40M (7 MHz) bands. These bands represent the "bread and butter" range in the spectrum for much of amateur radio communications worldwide owing to their effectiveness during daytime and nighttime operation, respectively, even in unfavorable conditions. The importance of these bands, especially during emergency circumstances, cannot be overstated. A half wavelength dipole antenna (a standard antenna) or yagi (beam) antenna on the 20M band requires a full wavelength above electrical ground for effective communications, at distances typically sought on this band. At 20M, a full wavelength is approximately 70 feet. (the free-space resonant length of a full wavelength at 20 meters is calculated by dividing 984 by the frequency of 14 MHz equalling 70.29 feet.). This height also constitutes a one-half wavelength on the 40M band, which, while less effective than a full wavelength above electrical ground, does allow for at least some low-angle radiation for medium- to longer-distance communication on this band, with good performance in the range of 400-500 miles, to potentially reach important targets, such as Sacramento. The importance of being able to communicate effectively with the State's capitol, during the course of an emergency, needs no additional discussion.

Further, the general ground conditions in the San Diego area alter the effective electrical ground position under the amateur radio antenna support structure, requiring the 70 feet 20M wavelength and 40M half wavelength height to be increased by an average of 12 ft to achieve the same antenna advantage as over more normal ground condition soils. The sum of the 70.29 feet required for a full wavelength at 20M, and a half-wavelength at 40M, plus the 12 feet necessary to compensate for regional electrical ground effects dictates an amateur radio antenna support structure height of 82 feet in total. The calculations attached as Addendum #2 prove up the need for 5 to 49 feet of additional height in the San Diego region in order to make reasonable accommodations for effective communications. Since this range is rather large, it was determined that adding 12 feet to the 70 foot baseline height, for 82 feet total, would be sufficient for the average expected local applicant.

From a legal perspective, the City cannot simply "balance" its interests in aesthetics against amateur radio operators' right to effective communications. Both the FCC and the courts have concurred that this balancing test has been concluded by PRB-1 to require that amateurs radio operator be able to *effectively communicate*, notwithstanding legitimate local interests. (See *Order RM-8763*, 15 F.C.C.R. P22151 (2000) at Paragraph 7; see also *Pentel v. City of Mendota*, 13 F.3d 1261 (8th Cir. 1994)*; Marchand v. Town of Hudson.* 788 A.2d 250 (2001); *Palmer v. City of Saratoga Springs*, 180 F. Supp. 2d 379 (N.D. N.Y. 2001)*; Snook v. City of Missouri City, TX* (2003 U.S. Dist. LEXIS 27256); overturning the "balancing test" described in *Evans v. Bd. of County Comm'rs*, 994 F.2d 755, 762 (10th Cir. 1993)).

Because, from the City's point of view, there is no quantifiable resultant difference between the installation of a 45 feet and 82 feet amateur radio antenna support structure (both heights are over the City's coastal height limits), but there is a vast improvement in communications capabilities, there is no logical reason for a more onerous review on taller structures. That is, excepting the possibility that the City actively wishes to squelch the installation of such structures – in complete contravention of both PRB-1 and CA Government Code Section 65850.3.

To further illustrate the point, the Draft's current language would require a $5,000 initial deposit for an NUP review, which will ultimately limit the number of amateur radio operators to those few who have the means to make such an application. Besides failing to meet the minimum practicable regulation necessary to reasonably accommodate effective communication, this requirement will chill the 1st Amendment rights of amateur radio operators by means of a prior restraint on communications (see generally *New York Times Co. v. United States* (1971) 403 U.S. 713). The effect of unreasonably limiting the pool of amateur radio operators in a way unrelated to time, place and manner (but rather, by the expense of being permitted to communicate) is not only unconstitutional, it may ultimately affect the City in a more immediate fashion.

Effective emergency communications depend greatly upon the physical constraints of the structures supporting amateur radio antennas. The City's apparent goal to limit amateur radio antenna support structures heights below effective communications levels may ultimately forestall, or altogether deny, the construction of such a structure. Any such disallowed or delayed amateur radio antenna support structure may well be the very one which would have saved lives and property in a disaster (whether, local, regional, national or global). The usefulness of amateur radio operators during emergencies has been borne out time and again (e.g. the 2003 and 2007 San Diego wildfires saw amateur radio operators assisting private individuals and City and County emergency staff, averting an even greater disaster, all at no cost to the City). It would be shortsighted, on the City's part, to think amateur radio operators would not be needed again.

Addendum #3, attached to this letter, illustrates the tremendous increase in communications effectiveness when comparing 45 feet high antennas to 75 feet (before ground-quality adjustment) high antennas in a variety of locations in the San Diego region. Note that this increase in communication effectiveness is greater than that seen going from 75 feet to 120 feet, lending even more credence to the importance of an 82 foot (after ground-quality adjustment) baseline for a minimal review process on amateur radio antenna support structures. The critical importance of these greater heights on VHF-UHF antennas used by local EMCOMMs (emergency communication amateur radio operators) during emergencies cannot be overstated. Due to the variability of San Diego's terrain (i.e. hills and canyons spread throughout the region), the height of these VHF-UHF antennas using line-of-sight frequencies is paramount in completing the propagation path – this is especially true in instances where repeater stations are knocked out due to catastrophic events, which was the case in San Diego during the last string of wildfires in the area.

Finally, it is worth noting that in reviewing the comments delivered to the City (pursuant to a California Public Records Request made on February 19, 2009), on its initial draft of the Municipal Code revisions relating to amateur radio antenna support structures, it is fairly clear that only one commentor found 45 feet to be a feasible height owing to his location and communications needs. This is no way justifies the City to extrapolate that this same height will be effective for communications for the average amateur radio operator. Rather, the majority of the commentors demanded greater heights or no limits whatsoever.

3. All amateur radio antenna support structures should be assessed under a modified Process One review. The Model, as prepared, does away with the need for a Process Two review altogether, owing to the inherent initiation costs and burdensome processing. Reviewing an application for an amateur radio antenna support structure is a basically ministerial process, rather than a discretionary one, since there is no final, legal position the City may take which would completely disallow the construction of such a tower, pursuant to the limits placed on local agencies by both PRB-1 and CA Gov't Code Section 65850.3.

Rather, the Model proposes a set of standards by which either the staff or the Development Services Director can make a final determination of the location and conditions under which the applicant can be reasonably accommodated so that he or she can effectively communicate with other authorized amateur radio operators. Those standards describe the minimum regulation necessary to make such an accommodation without unduly burdening an amateur radio operator, while still giving the City right to pursue its own legitimate interests, within reason.

If there are any questions relating to the Model, please do not hesitate to contact me at 619-236-1201 or fmt@lfap.com. Upon completion of your review of the materials presented, I request to be provided with further details on how the City proposes to accommodate San Diego amateur radio operators' communications needs so that my client can plan its course of legal action accordingly.

Sincerely,
LOUNSBERY FERGUSON ALTONA & PEAK

Felix M. Tinkov, Esq.

cc: Jana Garmo, Deputy City Attorney

Addendum #1

Model San Diego Municipal Code Revisions

§113.0103 Definitions

…

Antenna means a device or system used for the transmission or reception of radio frequency signals for wireless communications. It may include an Omni-directional (whip or vertical), directional (panel or yagi [beam]), dish, wire or GPS *antenna*. It does not include the support structure.

…

Amateur radio antenna support structures means the support *structure* for an *antenna* used for purposes of transmitting and receiving radio signals pursuant to 47 C.F.R. Part 97, which use shall be considered an *accessory use*.

§129.0203 Exemptions from a Building Permit

…

(a)(13) *Antennas* supported, attached or otherwise affixed in, on or to a tree, wire, cord, or other non-permanent *structure* or the roof or wall of a previously permitted *structure* on the *lot* or not permanently affixed to any *structure*.

§141.0421 Amateur radio antenna support structures

(a) The City of San Diego recognizes the underlying purposes of the federal amateur radio service are to provide a reliable emergency communication system, to foster international goodwill and to encourage individual experimentation by authorized amateur radio operators pursuant to 47 C.F.R. Part 97. The purpose of this Section is to ensure that *amateur radio antenna support structures* are designed and located in a way that avoids hazards to public health and safety and minimizes adverse aesthetic effects, while promoting and reasonably accommodating effective amateur radio communications.

(b) An *amateur radio antenna support structure* is an attached or detached *accessory structure*, located on a *lot*, that supports an antenna which allows authorized parties to effectively communicate with similarly authorized parties, both locally and globally, on

Comment [FMT1]: Note that the antenna definition already found in §113.0103 expressly excludes the support structure, justifying our position that the support structure definition not include the antenna.

Comment [FMT2]: The reference to 47 C.F.R. Part 97 provides the basis for Federal description of amateur radio service so that it does not need to be repeated in full in the SDMC.

Comment [FMT3]: Given the nature of the support structure as an ancillary one to the main structure on a lot, the description of its use as an accessory matches well with the City of San Diego's "accessory use" definition in §113.0103. Additionally, LA County Code at 22.52.1420 defines support structure similarly. See http://municipalcodes.lexisnexis.com/codes/lacounty/_DATA/TITLE22/index.html

Comment [FMT4]: The current language exempts antennas from a building permit solely if they are supported on a roof. This fails to account for a number of other potential scenarios used by amateur radio operators which might otherwise be permissible pursuant to §129.0203(a)(24) and just spells them out for clarity's sake.

Comment [FMT5]: These three goals are the underpinning for the FCC and the mandatory State protection of amateur radio service – see 47 CFR Part 97.1(a),(b) & (e), PRB-1 (101 FCC 2d 952 (1985)) Sec. 24, and CA Gov't Code Sec. 65850.3.

Comment [FMT6]: A description of the legitimate interests of the local agency per PRB-1 (101 FCC 2d 952 (1985)) Sec. 25.

Comment [FMT8]: Mandatorily required under state law at CA Gov't Code Sec. 65850.3.

Comment [FMT7]: Description of the federal interest under PRB-1 (101 FCC 2d 952 (1985)) Sec. 22 and 24.

Comment [FMT9]: The FCC recognizes that communications may be regional, national and/or international in nature, depending upon the individual radio operator's desires – See PRB-1 (101 FCC 2d 952 (1985)) Sec. 24 and 25.

those federally designated frequencies set aside for such purpose, for so long as such communications are not used for commercial purposes.

(c) *Amateur radio antenna support structures* may be permitted as a limited use in accordance with Process One, and the process described below, in the zones indicated with an "L" in the Use Regulations Tables in Chapter 13, Article 1 (Base Zones) subject to the following regulations:

(1) An applicant must obtain an amateur radio operator license from the Federal Communication Commission, or a foreign amateur radio operator license granting similar rights within the United States pursuant to a federally subscribed treaty, prior to applying for a *building permit* to install an *amateur radio antenna support structure*.

(2) The maximum *structure height* for an *amateur radio antenna support structure* shall be 82 feet above grade, unless a waiver or modification is granted pursuant to subdivision (d) of this Section below.

(3) The *amateur radio antenna support structure* shall be located on the *lot* in a manner which will minimize the extent to which the structure is visible to nearby residents and members of the general public so long as doing so does not limit the effective communications of the amateur radio operator. Antenna structures shall be considered to satisfy this criterion if the *amateur radio antenna support structure* is located within the *building envelope*, except as permitted under subdivisions (d), (f) and (g) of this Section below.

(4) The *amateur radio antenna support structure* shall be installed and maintained in compliance with applicable building standards and in good condition.

(5) A ground-mounted *amateur radio antenna support structure* shall be permanently installed.

(6) In lieu of the standard Building Permit/Process One procedures described in §129.0201 et. seq., an applicant for an *amateur radio antenna support structure* shall only be required to submit an application, on a form supplied by the Development Services Department, accompanied by the following information, maps, plans and fees:

Comment [FMT10]: This is a reiteration of the City's earlier amateur radio ordinance drafts.

Comment [FMT11]: No rights to construct an amateur radio antenna support structure until the operator has obtained an FCC license, or an equivalent, reciprocal foreign license – the FCC permits foreign license holders to communicate within the US in reciprocity for other countries granting similar rights to US amateur radio operators.

Comment [FMT12]: 20M and 40M are amongst the most widely used communications bands owing to their usefulness for daytime and nighttime operations, respectively, even in unfavorable propagation conditions – this is vital during emergency communications. The physics of waveform transmission for a yagi [beam] antenna over ground minimally require a height of 70 ft. An additional 9 to 23 ft of height is required to counteract the general ground effects in the San Diego region, as shown in the attached addendum, though our analysis shows that 12 ft. would be sufficient for the majority of users. Further, all classes of amateur radio operators are permitted by the FCC to operate in these bands. For more about the 20M band see http://en.wikipedia.org/wiki/20_meters. For more about the 40M band see http://en.wikipedia.org/wiki/40_meters.

Comment [FMT13]: The City's legitimate interest in aesthetics is limited against the requirement for effective communications. See PRB-1 (101 FCC 2d 952 (1985)) Sec. 24 and 25; *Order RM-8763, 15 F.C.C.R. P22151 (2000)* at p. 3; and *Pentel v. City of Mendota, 13 F.3d 1261, 1264* –"*PRB-1, 101 F.C.C.2d 952* specifically requires the city to accommodate reasonably amateur communications. This distinction is important, because a standard that requires a city to accommodate amateur communications in a reasonable fashion is certainly more rigorous than one that simply requires a city to balance local and federal interest when deciding whether to permit a radio antenna.."

Comment [FMT14]: Matches the requirements of LA County Code at Sec. 22.52.1430(E).

Comment [FMT15]: Because of the unique nature of amateur radio antenna support structures, it makes sense to develop specific requirements which differentiate these structures from others. The process described here matches most closely to LA County's Code at Sec. 22.52.1440.

(A) Site plans drawn to scale and dimensioned, showing the proposed location of the antenna structure;

(B) Manufacturer's specifications of the *amateur radio antenna support structure* evidencing the *certification* of the structural calculations by a registered professional engineer. Special welding certificates and/or inspections will not be required for *amateur radio antenna support structure* certified by a registered professional engineer;

(C) Details of footings, guys, and braces, if any;

(D) Elevations drawn to scale and dimensions so as to fully describe the proposed structure; and

(E) An application fee sufficient to cover the cost of processing by the City but not to exceed that imposed for the plan check of an cellular/mobile phone *antenna* as an *accessory structure*. Notwithstanding this provision, in no case shall the application fee be greater than the total cost of the applicant's *amateur radio antenna support structure*, *antenna* and mast, as evidenced by receipts or similar proof.

(d) Upon an applicant's request, the development standards in Section 141.0421 shall be waived or modified by the Development Services Director in order to reasonably accommodate site specific needs for effective communication if:

(1) The applicant submits a statement, signed under penalty of perjury, detailing the reasons why strict conformance with the development standards specified in Section 141.0421(c) will:

Comment [FMT16]: DSD Info Bulletin 501 – March 2006 – lists the plan check fee for such antenna structures as $645 on page 12 of 43. While the fees should likely be lower for an amateur structure when compared to a commercial structure, the fee described is likely reasonable and should not go up significantly. These fees are also in line with those required by LA County. See LA County Code Sec. 22.52.1440 and 22.60.100 which currently require a $953 plan check fee for antenna structures.

Comment [FMT17]: In order to ensure that plan check fees are not unreasonably burdensome and therefore in contravention of the requirement for reasonable accommodation (see *Pentel* at 1264, PRB-1 (101 FCC 2d 952 (1985) Sec. 25 and CA Gov't Code Sec. 65850.3.

Comment [FMT18]: In an instance where an amateur radio operator's needs cannot be accomplished within the regulations above, a simplified "appeal" process to the Director of Development Services provides the "minimum practicable regulation" required under both PRB-1 (see Sec. 25) and CA Gov't Code Sec. 65850.3. The City's currently proposed alternative process requires an NUP, placing an undue burden on the applicant which chills communication because: (1) a $5K initial deposit is required before starting the application, which amount is greater than most applicants will spend on their amateur hobby, or possibly even have available for deposit; (2) a presentation must be made to the community planning group which will ultimately have no effect on the necessity of the deviation and which will require more time and money than is minimally practicable; and (3) require additional materials to be submitted by the applicant pursuant to the standard NUP guidelines which are unnecessary for review and therefore not minimally practicable. Further, this process is in line with LA County's process which recognizes the importance of minimizing cost and burden to the applicant – see LA County Code Sec. 22.52.1440(A)(7) and 22.52.1450

Comment [FMT19]: This is in conformance with LA County's process – see Code Sec. 22.52.1440(A)(7).

(A) unreasonably interfere with the operator's ability to receive or transmit signals. Unreasonable interference shall be found if communication effectiveness falls below a level of 75% at any signal arrival angles used by the operator; or

(B) impose unreasonable costs on the operator. Costs shall be deemed unreasonable if they are 120% percent of the total cost of amateur radio antenna support structure, antenna and mast, as evidenced by receipt or similar proof of price and in no case may exceed $2,500; or

(C) not be necessary to achieve the goals and objectives of this part.

(2) The applicant supplies evidence which reasonably demonstrates the veracity of the operator's statement, including, but not limited to, computer models, mathematical analyses, expert testimony, receipts or invoices.

(e) In granting the waiver or modification described in Section 141.021(d) above, the Development Services Director may impose conditions reasonably necessary to accomplish the purposes of this Section, provided those conditions do not unreasonably interfere with the ability of the applicant to effectively communicate, or impose unreasonable costs on the amateur radio operator when viewed in the light of the cost of the equipment.

(f) An applicant may appeal a decision of the Development Services Director to the Planning Commission pursuant to Section 112.0504.

(g) Any amateur radio wire *antenna* or vertical HF, VHF, and/or UHF antenna affixed to an existing permitted *structure*, a tree, or non-permanent *structure* on the *lot*, or not otherwise permanently installed, shall not require a building permit.

(h) An *antenna* may encroach into the setback on the *lot*.

(i) *Amateur radio antenna support structures*, antennas and masts in existence as of the effective date of the ordinance codified in this Section may continue to be used without complying with the provisions of this Section and shall be considered a legal nonconforming use. Existing *amateur radio antenna support structures* may be enlarged, expanded or relocated only if brought into compliance with this Section.

Comment [FMT20]: This "effective communications" standard is the minimum prescribed by the *Snook* court. See *Snook v. City of Missouri City, TX* (*2003 U.S. Dist. LEXIS 27256)* at p. 5- 6 (Finding of Fact #9 states "To conduct effective emergency operations, Snook must be able to achieve at least a 75 to 90 percent successful signal under the changing variables that impact emergency or other amateur radio communications."

Comment [FMT21]: In order to ensure that there is no undue burden in applying for an amateur radio antenna support structure, the costs must be minimized accordingly. The FCC agrees with this position as evidenced *RM 8763 (2000), on Petition of the ARRL and Barry Gorodetzer* which states, in Sec. 7, in pertinent part, "an amateur operator may apprise a zoning authority that a permit fee is too high, and therefore unreasonable, or that a condition is more than minimum regulation." Again, this is also recognized by LA County at Code Section 22.52.1440(A)(7) and 22.52..1450.

Comment [FMT22]: This is in congruence with LA County Code Sec. 22.52.1450.

Comment [FMT23]: This appeal process would be required under the reasonable accommodation standard to ensure that the applicant and the City be allowed to negotiate a compromise which satisfies each party's requirements. See *Pentel* at p. 1264 and *Snook* at p. 47.

Comment [FMT24]: The antennae described in this section refer to non-permanent structures which do not need an amateur antenna support structure and therefore do not need a building permit. The SDMC exempts antenna generally from building permit requirements at Sec. 129.0203(a)(13).

Comment [FMT25]: Since the antenna itself is not a permanent structure, its encroachment into the setback, like any other non-permanent structure under the SDMC, should not be restricted. Moreover, because of the narrow width of much of the City's private lots, failing to affirmatively exempt antennas from setback requirements would not be a reasonable accommodation, because most antennas will invariably pierce setbacks in a small lot. As an example, a common halfwave 20M dipole antenna (34' in length) would necessarily encroach into setbacks on a smaller urban lot.

Addendum #2

Effects of Real Ground On Amateur Radio Antenna Support Structure Height Requirements in San Diego

Prepared by
Members of the San Diego DX Club

Executive Summary

Calculations of height requirements for high frequency antenna support structures are normally made using ideal isotropic ground conditions. However, San Diego's real world ground conditions of relatively low soils conductivity, low dielectric constants and low humidity require compensating adjustments to ideal radio wave propagation models. Calculations based on three ground mechanisms, the Soils Conductivity Effect, the Skin Effect and the Proximity Effect, that are predominant in San Diego, minimally require 5'-49' be added to amateur radio antenna support structure heights over ideal ground conditions.

Contributors

In preparing this paper, members of the San Diego DX Club worked with known experts in the field of radio wave propagation including:

W. Ross Stone, PhD
Editor-in-Chief, IEEE Antennas and Propagation Magazine

Professor Ray Vincent MSEE
Naval Post Graduate School and Principal Investigator with Stanford Research Institute US Military HF Over the Horizon Radar Systems

Richard LeMassena BSEE
Antenna Design Expert with 50 years experience including the design of the Voyager Deep Space Satellite Antennas

1. Introduction

In layman's terms, the ground beneath an amateur radio antenna support structure is important because significant portions of a radio signal either (1) reflect off of the ground to produce a sky wave for long distance communication, (2) conduct through the ground as a ground wave for local communication, or (3) are absorbed by the ground producing waste heat (in turn, reducing communications ability). Ground conditions play such a vital role in radio communications that the Federal Communications Commission publishes a map of ground conductivity at http://www.fcc.gov/mb/audio/m3/index.html,[1] the American Radio Relay League (ARRL)

Antenna Handbook[2] devotes an entire chapter just to considerations of ground effects and the US Department of Defense[3] has numerous publications on antenna ground considerations.

Despite the importance of ground conditions, many amateur radio operators fail to observe the importance of these effects in their amateur radio antenna support structure height requirement determinations. Instead assumptions are made that these structures will be constructed over perfect isotropic ground, reflecting 100% of sky wave energy incident upon it, conducting 100% of ground wave energy and losing no radio energy as heat. Unfortunately, these assumptions lead to improper calculations and potentially ineffective communications capabilities.

In order to transform ideal isotropic calculations to reflect real world conditions in San Diego it is necessary to revise amateur radio antenna support structure height calculations based on three ground mechanisms, (1) the Soils Conductivity Effect, (2) the Skin Depth Effect and (3) the Proximity Effect – all of which have considerable consequences in the region.

2. How Ground Acts on Radio Waves

The ground around and under an amateur radio antenna support structure must be a consideration in determining the actual environment in which an antenna must operate. Ideal condition amateur radio antenna support structure calculations deal mainly with theoretical antennas in free space completely discounting the influence of nearby ground. A more accurate model analyzes ground interactions relative to two areas, the *reactive near field* and the *radiating far field*.

The reactive near field only exists very close to the amateur radio antenna support structure itself. In this region, the antenna acts as though it is a large lumped-constant inductor or capacitor, where energy is stored and very little of it is actually radiated. The interaction with the ground and structures in this area creates mutual impedances between the antenna and its environment and these interactions not only modify the feed-point impedance of an antenna, but also often increase losses. This is known as the "Proximity Effect".

In the radiating far field, the presence of ground profoundly influences the radiation pattern of a real antenna. The interaction depends on the antenna's polarization with respect to the ground. For horizontally polarized antennas, the *shape* of the radiated pattern in the elevation plane depends primarily on the antenna's height above ground. The electrical properties of the ground may diminish far-field performance below "perfect-ground" conditions.

2.1 Reflections, in General

First, consider the case of flat ground. Over flat ground, either horizontally or vertically polarized down trending waves launched from an antenna into the far field strike the surface and are reflected by a process very similar to that by which light waves are reflected from a mirror. As is the case with light waves, the angle of reflection is the same as the angle of incidence, so a wave striking the surface at an angle of, say, 15° is reflected upward from the surface at 15°. The reflected waves combine with direct waves (those radiated at angles above the horizon) in various ways. Some of the factors that influence this combining process are the height of the antenna, its length, the electrical characteristics of the ground, and as mentioned above, the polarization of the wave. At some elevation angles above the horizon the direct and reflected waves are exactly in phase—that is, the maximum field strengths of both waves are reached at the same time at the same point in space, and the directions of the fields are the same. In such a case, the resultant field strength for that angle is simply the sum of the direct and reflected fields. (This represents a theoretical increase in field strength of 6 dB over the free-space pattern at these angles.)

At other elevation angles the two waves are completely out of phase—that is, the field intensities are equal at the same instant and the directions are opposite. At such angles, the fields cancel each other. At still other angles, the resultant field will have intermediate values. Thus, the effect of the ground is to increase radiation intensity at some elevation angles and to decrease it at others. When plotted, the results of an elevation pattern will show *lobes* and *nulls*.

The concept of an *image antenna* is often useful to show the effect of reflection. The reflected ray has the same path length that it would if it originated at a virtual second antenna with the same characteristics as the real antenna, but situated below the ground just as far as the actual antenna is above it. Now, if we look at the antenna and its image over perfect ground from a remote point on the surface of the ground, we will see that the currents in a horizontally polarized antenna and its image are flowing in opposite directions, or in other words, are 180° out of phase. But the currents in a vertically polarized antenna and its image are flowing in the *same* direction—they are *in* phase. This 180° phase difference between vertically and horizontally polarized reflections, off of ground, is what makes their combination with direct waves behave in a very different manner from non-reflected or direct waves.

3. <u>Soils Conductivity Effect</u>

An amateur radio antenna support structure placed over salt water (close to an ideal conductor @ over 5,000 mSiemens/m) will produce ideal results for a specific location. Yet, if that same structure is moved only a few hundred feet away over dry, poorly conductive earth, the resultant communications effectiveness will be significantly reduced.

According to FCC Data, the majority of San Diego ground exhibits conductivity ranging from 1-4 mSiemens/m. This compares with 5,000 mSiemens/m of Sea Water and 1-30 mSiemens/m typically found elsewhere in the USA. Table 1 below presents typical data.

Table 1 - Conductivities and Dielectric Constants for Common Types of Earth			
SURFACE TYPE	Dielectric Constant	Conductivity (mSiemens/m)	Relative Quality
Fresh water	80	1	Very Poor
Salt water	81	5000	Perfect
Pastoral, low hills, rich soil, typ Dallas, TX, to Lincoln, NE areas	20	30	Very good
Pastoral, low hills, rich soil typ OH and IL	14	10	Average
Flat country, marshy, densely wooded, typ LA near Mississippi River	12	7.5	Average
Pastoral, medium hills and forestation, typ MD, PA, NY, (exclusive of mountains and coastline)	13	6	Average
Pastoral, medium hills and forestation, heavy clay soil, typ central VA	13	5	Average
Rocky soil, steep hills, typ mountainous (San Diego)	12-14	2	Poor
Sandy, dry, flat, coastal (San Diego)	10	2	Poor
Cities, industrial areas (San Diego)	5	1	Very Poor
Cities, heavy industrial areas, high buildings (San Diego)	3	1	Very Poor

However soils conductivity is also greatly affected by the relative humidity of the soils. In San Diego, due to its dry, desert-like conditions, soils conductivity realistically approaches only 1 mSiemens/m and a dielectric constant of 3.[4]

The High Frequency Terrain Analysis (HFTA) Program permits the inclusion of both Soils Conductivity and Dielectric Constants as computational variable factors. In order to determine the absolute effect of the low conductivity, low dielectric constant, low humidity San Diego Soils, an analysis was conducted based on 7.2 MHz and 14.2 MHz antennas, as follows:

1. Using Sea Water as an Ideal Ground (5000 mSiemens/m, Dielectric Constant 80) HFTA was used to calculate a figure of merit, in dBi, for a 75' antenna at various locations in San Diego. On 40 M, this yields a figure of merit range of 1.1 to 3.7 dBi and on 20M a range of 7.1 to 8.6 dBi to a European Azimuth depending on location.

2. Using San Diego Ground (1 mSiemens/m, Dielectric Constant 3), HFTA was used to calculate a figure of merit, in dBi, for a 75' antenna. On 40 M, this yields a figure of merit range of 1.1 to 3.5 dBi and on 20M a range of 7.1 to 8.6dBi to a European Azimuth depending on location.

3. Since the figure of merit from #2 was lower than #1, HFTA was iterated at various heights using San Diego Ground until the figure of merit matched that of #1.

4. The difference in height between #1 and #3 is the additional height required in San Diego to compensate for poor ground conditions. These calculations yield approximately 4' – 6' in additional required height for the San Diego region.

[Modelling for alternative locales including Asia, Africa and South America would produce generally similar final results.]

4. Skin Depth Effect

In ideal conditions, 100% of sky wave energy that hits the ground is reflected back to the sky. In real world conditions, a significant portion of the sky wave energy penetrates the earth and is dissipated as heat. What determines how much energy is lost to heat is the depth to which the radio signal penetrates the earth. The soil characteristics predominately control the penetration depth and, in turn, the amount of energy consumed in heating the earth.[5,6]

4.1 Depth Of RF Current Penetration

When considering ground characteristics, the depth of RF current penetration can be calculated based upon the frequency of the wave, the soil and rock dielectric constants, and the respective conductivities of soil and rock layers being penetrated. The following equation can be used to calculate the current density at any depth:

$$e^{-pd} = \frac{\text{Current Density at Depth d}}{\text{Current Density at Surface}}$$

where

d = depth of penetration in cm

e = natural logarithm base (2.718)

$$p = \left(\frac{X \times B}{2} \times \left(\sqrt{1 + \frac{G^2 \times 10^{-4}}{B^2}} - 1 \right) \right)^{1/2}$$

$X = 0.008 \times \pi^2 \times f$

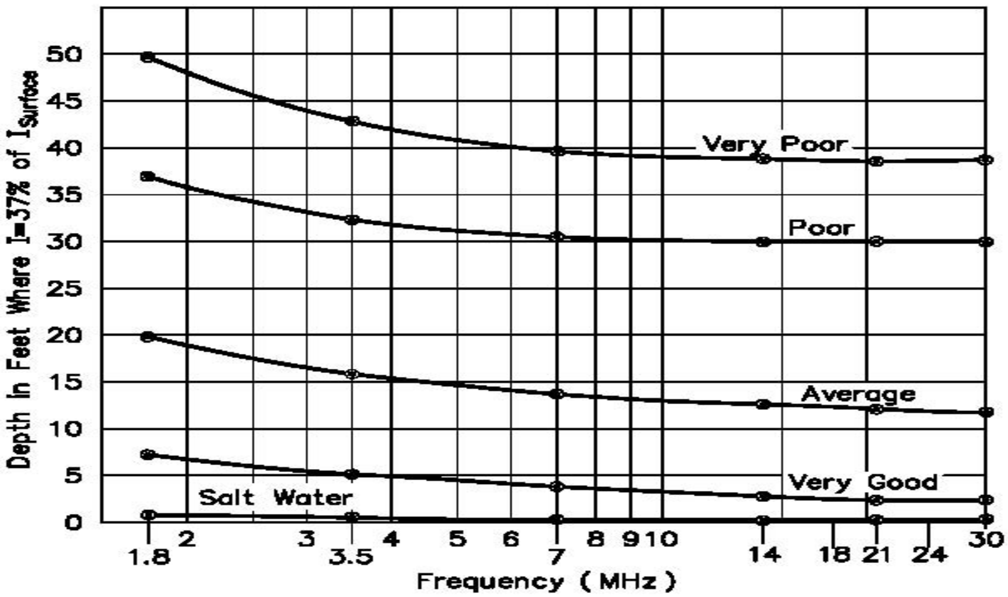
$B = 5.56 \times 10^{-7} \times k \times f$

k = dielectric constant of earth

f = frequency in MHz

G = conductivity of earth in S/m

Applying this formula yields this chart below



For San Diego soil conditions, this yields 30’ to 40’ skin depth penetration.

The following formula calculate skin depth losses:

$$Loss = (k_1 \cdot \sqrt{f} + k_2 \cdot f) \cdot l$$

Where k_1 *and* k_2 are *constants*, f is *frequency* and l *is skin depth*

The loss is directly proportional to the skin depth. In a worst case scenario, where 100% of a sky wave incident upon the ground (which is 50% of the total power) is lost due to heating, this would represent a loss of 3 dBi in a figure of merit calculation. When applying the loss formula to San Diego soils (a skin depth of 30’ to 40’), and more comprehensive calculations from available literature, San Diego soils contribute a loss of 0.2 to 1.1 dBi due to the skin effect.

Table 2 - Estimated Skin Effect Loss

	20M - 7.2MHz (dBi)	40M - 14.2MHz (dBi)
SCRIPPS RANCH	**0.5**	**0.9**
SOUTH BAY	**0.2**	**0.4**
MIRA MESA	**0.6**	**1.1**
LA JOLLA	**0.3**	**0.5**
MISSION GORGE	**0.4**	**0.8**
NORTH PARK	**0.3**	**0.6**
PACIFIC BEACH	**0.2**	**0.4**

In order to determine the absolute effect of the skin effect losses due to San Diego soil characteristics, an analysis was conducted based on 7.2 MHz and 14.2 MHz antennas, as follows:

1. HFTA was used to calculate a figure of merit, in dBi, for a 75' antenna at various locations in San Diego. On 40 M, this yields a figure of merit range of 1.1 to 3.7 dBi and on 20M a range of 7.1 to 8.6dBi to a European Azimuth depending on location..

2. The figure of merit, in dBi, from #1 was reduced by Table 2 to compensate for the energy losses due to the Skin Effect.

3. As the figure of merit from #2 was lower than #1, HFTA was iterated at various heights using San Diego Ground until the figure of merit matched that of #1.

4. The difference in height between #1 and #3 is the additional height required in San Diego to compensate for Skin Effect losses. These calculations typically yield 4 – 15 ft in additional required height for San Diego. [Modelling for alternative locales including Asia, Antarctica Africa and South America would produce generally similar final results.]

5. Additional Height Calculation Considerations

Real world conditions, unlike ideal conditions, interact with one another to create different and/or cumulative effects. As a result, terrain must be considered in concert with the above calculations to determine the interaction of these effects simultaneously.

In order to determine the absolute effect of the combined Soils Conductivity and Skin Effect losses due to San Diego ground conditions, an analysis was conducted based on 7.2 MHz and 14.2 MHz antennas, as follows:

1. HFTA was used to calculate a figure of merit, in dBi, for a 75' antenna at various locations in San Diego based on Perfect Soils with zero Skin Effect Depth. On 40 M, this yields a figure of merit range of 1.1 to 3.7 dBi and on 20M a range of 7.1 to 8.6 dBi to a European Azimuth depending on location.

2. HFTA was used to calculate a figure of merit, in dBi, for a 75' antenna at various locations in San Diego based on San Diego ground with zero Skin Effect Depth. On 40 M, this yields a figure of merit range of 1.1 to 3.5 dBi and on 20M a range of 7.1 to 8.6 dBi to a European Azimuth depending on location.

3. The Ideal Soils Figure of Merit, in dBi, from #1 was adjusted by Table 2 to compensate for energy losses due to the Skin Effect to produce a Target Figure of Merit. On 40 M this yields a figure of merit range of 1.7 to 3.9 dBi and on 20M a range of 6.8 to 9.0 dBi to a European Azimuth depending on location.

4. As the figure of merit from #2 was lower than Target Figure of Merit #3, HFTA #2 was iterated at various heights using San Diego ground until the figure of merit matched that of #3.

5. The difference in height between #2 and #4 is the additional height required in San Diego to compensate for Skin Effect losses. This yields a required height range of 79' to 93' on 20M and 78' to 119' on 40M with the major variable being the location of the local amateur radio antenna support structure.

Appendices A and B show the results for this combined height analysis for 7.2MHz and 14.2 MHz, respectively.

6. Proximity Effect

Any structure located within ½ wavelength of an antenna feed point will have a direct impact on the reactive near field of the antenna and will significantly impact impedance and radiation resistance. Such structures will also significantly impact the far field radiation patterns of the antenna.[7]

Due to the fact that such structures are entirely location and structure specific there is no generalized formula which may be used to determine their direct impact on antenna height requirements. Nevertheless, the proximity effect has been studied and useful rules of thumb have been developed to compensate for losses due to structures.[8]

Generally, if a building feature, such as a roof, is within ½ wavelength of the antenna feed point, the height of this feature acts as the effective ground level for amateur radio antenna support structure height calculations. In such circumstances, the feature's height should be added to the total amateur radio antenna support structure height when performing HFTA calculations.

7. Conclusions

The San Diego region has generally poor soil/ground conditions for radio wave propagation. In order to counteract these conditions, at least 5' to 49' must be added to theoretical ideal world amateur radio antenna support structure height calculations for compensation purposes. It is possible that additional height might be necessary for reasonably effective communications to more distant locales, including Asia, Antarctica, South America and Africa.

Appendix A - Additional Height Analysis for 7.2MHz

Assumptions - 40 Meters 7.2 MHz

1. Dipole Antenna
2. Antenna Heights @ 75'
3. San Diego Soils - Low Soil Conductivity (1mS/M), Low Dielectric Constant

Direction Europe - Terrain Azimuth 30 Degrees

Address	Perfect Soil	San Diego Soils	Skin Effect Loss	Net Ground Loss Target	Required Total Height	Additional Height needed over 70' baseline
	dBi	dBi	dBi	dBi	Ft	Ft
FLAT TERRAIN	1.7	1.5	0	1.7	79	9
SCRIPPS RANCH	1.1	1.1	0.5	1.6	93	23
SOUTH BAY	2.6	2.5	0.2	2.8	79	9
MIRA MESA	1.3	1.1	0.6	1.9	87	17
LA JOLLA	1.3	1.2	0.3	1.6	90	20
MISSION GORGE	2.0	1.8	0.4	2.4	85	15
NORTH PARK	1.4	1.2	0.3	1.7	82	12
PACIFIC BEACH	3.7	3.5	0.2	3.9	85	15

Appendix B Additional Height Analysis for 14.2MHz

Assumptions - 20 Meters 14.2 MHz

1. 2 Element Yagi Antenna
2. Antenna Heights @ 75'
3. San Diego Soils - Low Soil Conductivity (1mS/M), Low Dielectric Constant

Direction Europe - Terrain Azimuth 30 Degrees

Address	Perfect Soil	San Diego Soils	Skin Effect Loss	Net Ground Loss Target	Required Total Height	Additional Height needed over 70' baseline
	dBi	dBi	dBi	dBi	Ft	Ft
FLAT TERRAIN	8.3	8.3	0	8.3	75	5
SCRIPPS RANCH	5.9	5.8	0.9	6.8	78	8
SOUTH BAY	8.6	8.6	0.4	9.0	83	13
MIRA MESA	7.5	7.4	1.1	8.6	88	18
LA JOLLA	7.1	7.1	0.5	7.6	88	18
MISSION GORGE	8.2	8.1	0.8	9.0	119	49
NORTH PARK	8.1	8.1	0.6	8.7	86	16
PACIFIC BEACH	7.3	7.3	0.4	7.7	83	13

References

[1] See http://www.fcc.gov/mb/audio/m3/index.html.

[2] American Radio Relay League Antenna Handbook, 21st Edition, Chapter #3.

[3] "Design Handbook for High Frequency Radio Communications," US Department of Defense, MIL-HDBK-413 28-MAR-86.

[4] "Accurate Evaluation of Magnetic- and Electric-Field Losses in Ground Systems," Dorado, L.A.; Trainotti, V.; IEEE Antennas and Propagation Magazine, Volume 49, Issue 6, Dec. 2007 Pages: 58 – 70.

[5] "Simplified calculation of ground losses in low- and medium-frequency antenna systems," Dorado, L.A.; Trainotti, V.; IEEE Antennas and Propagation Magazine, Volume 48, Issue 6, Dec. 2006 Pages: 70 – 81.

[6] "Ground Constants and their Impact on Vertical Monopole Performance," Christman, V; National Contest Journal, Volume 37, Number 2, March/April 2009 Pages: 4-7.

[7] "Height radius effect on MF AM transmitting monopole antenna," Trainotti, V.; IEEE Transactions on Broadcasting Volume 36, Issue 1, March 1990 Pages: 82 – 88.

[8] See #3 above.

Addendum #3

Analysis of Increase in Effective Communications by Increased Amateur Radio Antenna Support Structure Height

COUNTRY	CALL	AZMUTH FROM SD	AZMUTH MODEL
NORTH AMERICA			**70**
CANADA	VE3	**45**	
	VE7	**345**	
USA	K1	**60**	
	K4	**80**	
	K6	**325**	**325**
MEXICO	XE	**125**	
EUROPE			**30**
RUSSIA	UA	**15**	
UK	G	**35**	
FRANCE	F	**35**	
GERMANY	DL	**30**	
SOUTH AMERICA			**125**
BRAZIL	PY	**120**	
ARGENTINA	LU	**135**	
AFRICA			**90**
SOUTH AFRICA	ZS	**90**	
OCEANA			**260**
AUSTRALIA	VK	**260**	
HAWAII	KH6	**265**	
ASIA			**310**
CHINA	BY	**320**	
JAPAN	JA	**305**	

Assumptions - 20 Meters 14.2 MHz

1. 2 Element Yagi Antenna
2. Antenna Heights @ 45', 75', 120'
3. San Diego Soils - Low Soil Conductivity (1mS/M), Low Dielectric Constant

Direction: Europe - Terrain Azimuth 30 Degrees

Address	45' dBi	75' dBi	Gain %	120' dBi	Gain %
FLAT TERRAIN	5.2	8.3	**204%**	9.3	**126%**
SCRIPPS RANCH	2	5.8	**240%**	9.7	**245%**
SOUTH BAY	5.5	8.6	**204%**	9.7	**129%**
MIRA MESA	4.5	7.4	**195%**	9.7	**170%**
LA JOLLA	3.2	7.1	**245%**	8.8	**148%**
MISSION GORGE	4.2	8.1	**245%**	8.7	**115%**
NORTH PARK	4.8	8.1	**214%**	9.4	**135%**
PACIFIC BEACH	5.9	7.3	**138%**	9.5	**166%**
	Average Improvement		**211%**		**154%**

Direction: Asia - Terrain Azimuth 310 Degrees

Address	45' dBi	75' dBi	Gain %	120' dBi	Gain %
FLAT TERRAIN	5.4	8.2	**191%**	8.8	**115%**
SCRIPPS RANCH	8	5.9	**62%**	2.9	**50%**
SOUTH BAY	5.6	8.4	**191%**	8.9	**112%**
MIRA MESA	2.9	7.5	**288%**	8.9	**138%**
LA JOLLA	6.5	9.1	**182%**	9.5	**110%**
MISSION GORGE	6.8	7.9	**129%**	7.3	**87%**
NORTH PARK	5.5	8.1	**182%**	8.6	**112%**
PACIFIC BEACH	5.9	8.2	**170%**	8.7	**112%**
	Average Improvement		**174%**		**105%**

Direction: Africa - Terrain Azimuth 90 Degrees

Address	45' dBi	75' dBi	Gain %	120' dBi	Gain %
FLAT TERRAIN	2.4	6.1	**234%**	8.5	**174%**
SCRIPPS RANCH	3.3	7.3	**251%**	8.1	**120%**
SOUTH BAY	4.7	7.5	**191%**	9.4	**155%**
MIRA MESA	5	7.1	**162%**	9.2	**162%**
LA JOLLA	-8.4	-5.8	**182%**	-2.5	**214%**
MISSION GORGE	3.9	5.5	**145%**	4.1	**72%**
NORTH PARK	3.3	6.7	**219%**	8.7	**158%**
PACIFIC BEACH	4.1	6.5	**174%**	8.9	**174%**
	Average Improvement		**195%**		**154%**

Direction: South America - Terrain Azimuth 125 Degrees

Address	45' dBi	75' dBi	Gain %	120' dBi	Gain %
FLAT TERRAIN	6.2	8.6	**174%**	9	**110%**

SCRIPPS RANCH	7.9	10.5	**182%**	10.1	**91%**
SOUTH BAY	6.2	8.6	**174%**	8.9	**107%**
MIRA MESA	6.5	10.3	**240%**	11.5	**132%**
LA JOLLA	5.5	6.1	**115%**	4.6	**71%**
MISSION GORGE	7.5	9.7	**166%**	7.8	**65%**
NORTH PARK	6.8	8.9	**162%**	9.4	**112%**
PACIFIC BEACH	6.5	8.9	**174%**	9.1	**105%**
		Average Improvement	**173%**		**99%**

Assumptions - 40 Meters 7.2 MHz

1. Dipole Antenna
2. Antenna Heights @ 45', 75', 120'
3. San Diego Soils - Low Soil Conductivity (1mS/M), Low Dielectric Constant

Direction: Europe   - Terrain Azimuth 30 Degrees

Community	45'	75'	Gain %	120'	Gain %
	dBi	dBi		dBi	
FLAT TERRAIN	-2.5	1.5	**251%**	4.3	**191%**
SCRIPPS RANCH	-2.9	1.1	**251%**	3.5	**174%**
SOUTH BAY	0.2	2.5	**170%**	4.5	**158%**
MIRA MESA	-2.4	1.1	**224%**	3.6	**178%**
LA JOLLA	-0.7	1.2	**65%**	3.8	**182%**
MISSION GORGE	-1.2	1.8	**200%**	3.9	**162%**
NORTH PARK	-3.0	1.2	**263%**	4.1	**195%**
PACIFIC BEACH	1.5	3.5	**158%**	5.2	**148%**
	Average Improvement		**198%**		**173%**

Direction: Asia   - Terrain Azimuth 310 Degrees

Address	45'	75'	Gain %	120'	Gain %
	dBi	dBi		dBi	
FLAT TERRAIN	-3.2	1.0	**263%**	4.2	**209%**
SCRIPPS RANCH	-2.7	0.2	**195%**	1.2	**126%**
SOUTH BAY	-3.0	1.2	**263%**	4.3	**204%**
MIRA MESA	-5.1	0.5	**363%**	4.1	**229%**
LA JOLLA	-1.8	2.4	**263%**	5.0	**182%**
MISSION GORGE	-1.6	2.0	**229%**	4.7	**186%**
NORTH PARK	-3.3	1.3	**288%**	4.6	**214%**
PACIFIC BEACH	-2.7	1.0	**234%**	4.0	**200%**
	Average Improvement		**262%**		**194%**

Direction: Africa   - Terrain Azimuth 90 Degrees

Address	45'	75'	Gain %	120'	Gain %
	dBi	dBi		dBi	
FLAT TERRAIN	-13.6	-9	**288%**	-5	**251%**
SCRIPPS RANCH	-5.5	-4.9	**115%**	-3.7	**132%**
SOUTH BAY	-2.8	-3.3	**89%**	1	**269%**
MIRA MESA	-3.4	5.3	**741%**	2	**47%**
LA JOLLA	-23.2	-21.5	**148%**	-21	**112%**
MISSION GORGE	-12.3	-8.6	**234%**	-10.1	**71%**
NORTH PARK	-5.1	-3.8	**135%**	-1.3	**178%**
PACIFIC BEACH	-4.7	-1.1	**229%**	-1.1	**100%**
	Average Improvement		**247%**		**145%**

Direction: South America   - Terrain Azimuth 125 Degrees

Address	45'	75'	Gain %	120'	Gain %
	dBi	dBi		dBi	
FLAT TERRAIN	-2.6	1.3	**245%**	1.6	**107%**

SCRIPPS RANCH	4.7	5.3	**115%**	7.2	**155%**
SOUTH BAY	-2.6	1.6	**263%**	4.6	**200%**
MIRA MESA	0	4.2	**263%**	5.4	**132%**
LA JOLLA	0.9	2	**129%**	1.1	**81%**
MISSION GORGE	0.5	0.9	**110%**	5	**257%**
NORTH PARK	0.7	3.6	**195%**	6.3	**186%**
PACIFIC BEACH	-1.9	2	**245%**	4.9	**195%**
	Average Improvement		**196%**		**164%**