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Effect of Google Earth and Angle of Arrival Inaccuracies on E911 Location

Wireless E911 location is typically accomplished with a combination of Time Difference on Arrival (TDOA) and Angle of Arrival (AoA) techniques. This is especially true for location of older "Feature Phones" which do not have GPS and cannot upload their location via a data connection.

In February 2015 the Federal Communications Commission issued a Fourth Report and Order for "Wireless E911 Location Accuracy Requirements" as considered in PS Docket No. 07-114. The rulemaking was part of an ongoing effort by the FCC to impose requirements that wireless carriers must adapt to shifting public safety needs in the face of wireless technology evolution. The FCC's E911 rules (47 C.F.R.§20.18 [2, 3]) require CMRS providers to make location information available to PSAPs based on either a "dispatchable location" or a 2D horizontal accuracy of 50 meters for 40% of calls within two years, increasing to 80% of calls within six years.

Concurrent with the 3rd NPRM and prior to the 4th R&O, Sunsight Instruments LLC published the white paper "E911 Location Accuracy" which discussed in detail the effect of inaccuracies of recorded latitude/longitude of antennas in the base station almanac on TDOA, and the effect of azimuthal inaccuracies in sector antenna alignment on AoA. Sunsight filed this white paper in response to the 3rd NPRM, and the FCC referenced the white paper in their 4th R&O.

This document expands on the white paper analysis and shows how inaccuracy in the recorded latitude/longitude of sector antennas in the base station almanac can increase the inaccuracy of AoA. Specifically, it addresses the case where Google Earth™ is used to estimate sector antenna location.

To begin with, and this is a key point: Google's official policy on Google Earth's accuracy is that it's NOT accurate. Previous End User License Agreement (EULA) for Google Earth stated "Google makes no claims as to the accuracy of the coordinates in Google Earth. These are provided for entertainment only and should not be used for any navigational or other purpose requiring any accuracy whatsoever." They now (as of February 2016) state "When you use Google Maps/Google Earth's map data, traffic, directions, and other Content, you may find that actual conditions differ from the map results and Content, so exercise your independent judgment and use Google Maps/Google Earth at your own risk. You're responsible at all times for your conduct and its consequences."

Disclaimers aside; how accurate are Google Maps and Google Earth? There are several studies on this. The two most well recognized are:

National Institutes of Health (NIH) + Oakridge National Labs (2008)
Potere, NCBI
Citation: Journal List > Sensors (Basel) > v.8(12); 2008 Dec > PMC3791001
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3791001/

Columbia University (2013)
Ubukawa, Taro - Center for International Earth Science Information Network (CIESIN), The Earth Institute at Columbia University
http://www.ciesin.columbia.edu/confluence/download/attachments/19726351/Ubukawa_PositionalAccuracy_march2013.pdf?version=1&modificationDate=1363795265000

Potere's 2008 study is often-cited in other derivative works. Ubukawa's work is particularly interesting because it attempts to address the effect of elevation in shifting a mapped point – this is of particular relevance to antenna work since we're typically dealing with elevated sites on towers, buildings, etc. Ubukawa's calculations for elevation shift are derived from the ASTER GDEM global elevation model (created by Japan's Ministry of Economy, Trade, and Industry - and NASA), and the EGM96 global geoid model. (Refer to Figure 1)

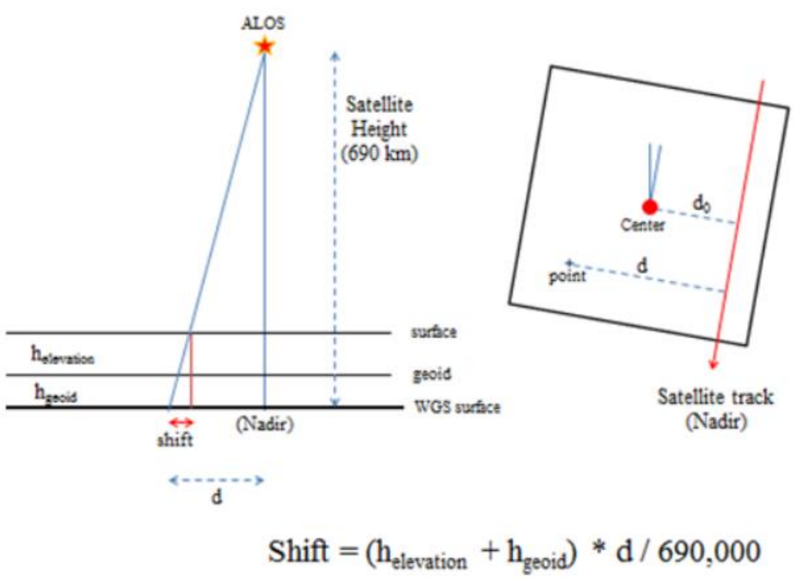

Figure 1 : Model for calculating Elevation Shift (from Ubukawa, 2013)

Potere's 2008 study found that Google Earth has a Root Mean Square Error (RMSE) of 22.6 meters in the United States, Canada, Australia, New Zealand, and Japan. This was based on 64 sample control points, in 16 sample cities. Errors ranged from 0.9 m to 53.0 m, with a standard deviation of 12.3 m.

Ubukawa's 2013 study found that Google Earth has an RSME of 8.2 meters across the sample set. 140 sample control points, which were not regionally grouped like Potere's work. Errors ranged from 0.5 m to 20.1 m, with a standard deviation of 4.2 m. This decrease in the RSME (increased accuracy) is likely due to Google's use of better technology in the five years between Potere's 2008 study and Ubukawa's 2013 study. However, it still shows that Google Maps / Google Earth have notable inaccuracy. It should also be noted that the RSME error from Ubukawa 2013 does NOT take into account shifting from man-made structure elevation.

The question then becomes; how does that inaccuracy affect the accuracy of E911 location techniques?

Consider an Angle of Arrival scenario where a single site has a 3° azimuthal error on the alignment of the sector antenna being used for the location estimate. The distance error caused by that angle error is estimated from standard trigonometry as follows:

$$Error[feet] = 2 * 5280 * distance[miles] * \tan\left(\frac{AngleError[radians]}{2}\right)$$

For the case of a 3° azimuthal error, the error at 1 mile is approximately 277 feet and at two miles is approx. 553 feet. If the location of the antenna is determined using Google Maps / Google Earth, and we use the RSME from Ubukawa perpendicular to the vector between the antenna and the target, then the potential location error becomes 277 ± 26.9 feet (at 1 mile) and 553 ± 26.9 feet (at 2 miles).

Now let's consider the case where two sites each have 3° azimuthal error of their sector antennae used for the location estimate. The error vectors intersecting will define a four-sided polygon, which we'll call the Area of Error. While not perfectly square, we can estimate the Area of Error by the following equation:

$$AreaError[sq\ feet] = Error[feet]^2$$

The Area of Error will be minimized when the angle between the two sites in 90°. Using the previous distances we find that the Area of Error is 76,729 sq-feet (over 1.75 acres) at 1 mile and 305,809 sq feet (over 7 acres) at 2 miles from the antenna. (Refer to Figure 2)

If to this azimuthal inaccuracy we then add on the RSME from Ubukawa, the equation becomes:

$$AreaError[sq\ feet] = (Error[feet] + RSME[feet])^2$$

This increases the Area of Error to 92,355 sq feet (an increase of 20%) at 1 mile, and 336,284 sq feet at 2 miles. (Refer to Figure 2)

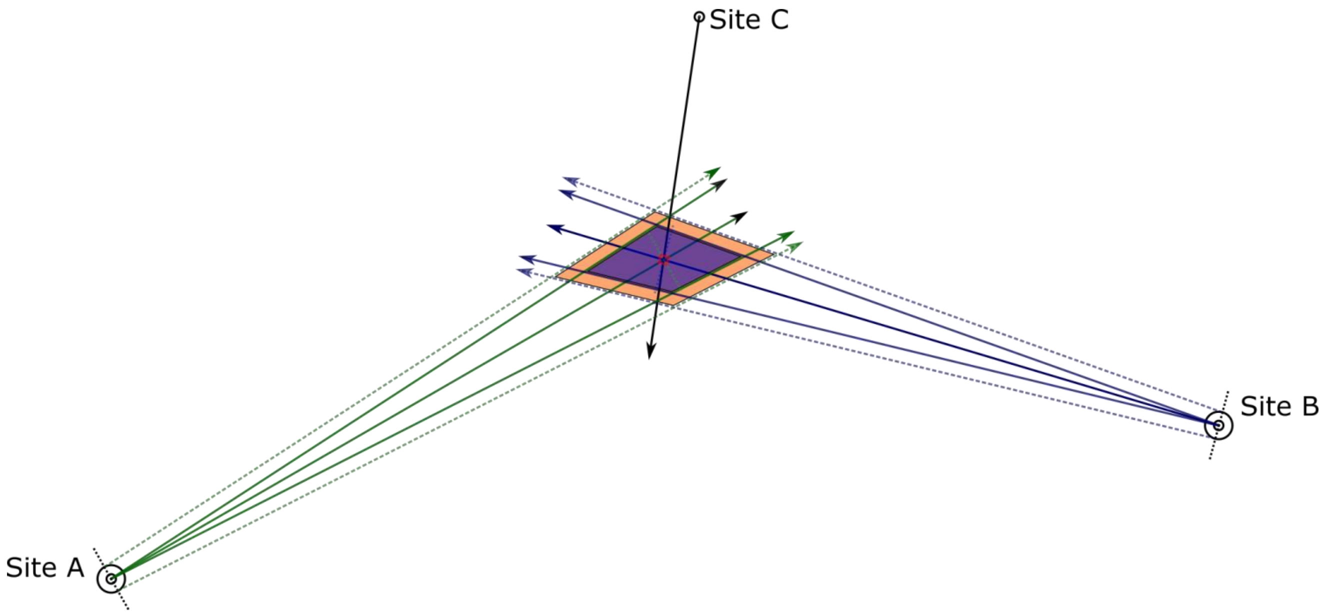

Figure 2 : Area of Error for two sites with 3° azimuthal error and additive RSME per Ubukawa 2013

Again; it's important to remember that these Areas of Error are based on the ground level RSME and do NOT account for the shifting caused by the elevation effect.

Conclusion: While the major contributor to location error is azimuthal inaccuracy, it's clear that Google Maps / Google Earth are inaccurate enough for their 2D errors to become noticeable in the calculation of E911 location error. Add to this the error caused by trying to determine latitude/longitude by setting 2D placemarks on 3D structures (buildings, towers, etc.) and we conclude that only actual measured location and azimuth alignment using calibrated test instruments can provide the accuracy needed to meet the FCC's 2015 mandate for Wireless E911 location.

About the Author

David Witkowski is the founder and Principal Consultant of Oku Solutions, a firm specializing in market-entry and business development for the wireless industry. Over a career spanning 30 years David has held positions of leadership and responsibility in the wireless and telecommunications industry at companies ranging in size from Fortune 500 multi-nationals to early stage startups.

David serves as President of the non-profit Wireless Communications Alliance, as an advisor to the Carnegie Institute of Technology Dean's Council at Carnegie Mellon University, and as a member of the Wireless Communications Initiative committee for Joint Venture Silicon Valley. David is a Senior Member in the Radio Club of America, and a Senior Member in the IEEE. He obtained his BSEE from University of California with a study emphasis on modulation theory and RF/wireless design.