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July 23, 2001

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FEDERAL COMMUNICATIONS COMMISSION
OFFICE OF THE SECRETARY

Ms. Magalie Roman Salas
Secretary
Federal Communications Commission
445 12th Street, S.W.
12th Street Lobby, TW-A325
Washington, DC 20554

Re: Revision of the Commission's Rules to Ensure Compatibility with Enhanced 911 Emergency Calling Systems, CC Docket No. 94-102

Dear Ms. Salas:

On behalf of TruePosition, Inc., enclosed please find an "Analysis of the Performance and Viability of the Mobile-Assisted Network Location System (MNLS)." This report is being submitted in response to recent meetings representatives of TruePosition held with members of the Wireless Telecommunications Bureau. We anticipate that TruePosition's research, as well as the conclusions presented herein, will be helpful in the Commission's deliberations concerning the recent Phase II waiver requests.

In accordance with the Commission's rules, I am submitting two copies of this letter.

Sincerely,

David M. Don

cc: Thomas Sugrue
James Schlichting
Kris Monteith
Blaise Scinto
Patrick Forster
Dan Grosh
Marty Liebman
Joel Taubenblatt

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Analysis of the Performance and Viability of the Mobile-Assisted Network Location System (MNLS)

1 Introduction

TruePosition, Inc. ("TruePosition") submits these *ex parte* comments for the purpose of assisting the Commission in its evaluation of the Mobile-Assisted Network Location System (MNLS). TruePosition's comments are intended to clarify issues related to MNLS performance and its ability to satisfy the needs of wireless 911 callers and public safety personnel for accurate position information in TDMA networks.

2 Overview of Key Issues

Over the past nine years TruePosition has evaluated the use of relative power measurements for locating mobile phones. Based on the results of extensive theoretical and applied analysis, TruePosition has concluded that mobile phones cannot be located accurately and reliably using relative power measurements and location pattern matching techniques for use in E911 and many other commercial location applications. TruePosition provides an overview of the key issues that drive this conclusion in order to assist the Commission with its evaluation of the MNLS.

In general, TruePosition concurs with the MNLS analysis provided by SigmaOne, which focuses primarily on the macroscopic propagation effects caused by buildings and terrain. Additional variations in relative power also result from the environment very close to the mobile unit, such as use in a vehicle, use in a building, the subscriber, and the orientation of the antenna on the handset. This is the focus of TruePosition's analysis and simulation.

Furthermore, TruePosition believes that the best MNLS performance will be achieved through the use of relative power measurements, as opposed to absolute power measurements. For this reason, TruePosition conducted all experiments and simulations using relative power measurements, while SigmaOne focused its analysis on absolute power measurements.

2.1 Significant Variations in Relative Power Measurements Induced by the Local Environment Cannot be Predicted and/or Calibrated

TruePosition recently conducted an experiment to measure the effect that small changes in the RF propagation environment immediately surrounding a mobile phone have on the forward channel relative power measurements made by the TDMA mobile phone. The tests were conducted in several suburban and rural areas using commercially available TDMA mobile phones and cellular test sets. In each of the test areas, power measurements were made inside a car, outside a car, and inside a building from several locations within a 10-meter by 10-meter area. At each location, power measurements were made with the TDMA mobile phone oriented in several realistic calling positions

with the antenna pointing forward, back, left, right, up, down and next to the caller's ear. In each test, the received power level measurements for the surrounding sites as reported by the mobile phone were collected and logged. Each of the received power measurements was averaged over 5 seconds (which is the standard interval for a TDMA mobile phone).

Since relative power measurements provide less variation than absolute power measurements, the power of the strongest site was subtracted from the other sites to provide relative measurements for each site. **The relative power measurements collected in this experiment were found to have a standard deviation of 6 dB in each of the 10-meter by 10-meter test areas.**

It is important to note that this 6 dB variation in relative power measurements caused by the local RF propagation environment is fundamental and cannot be overcome. The possible permutations of mobile phone orientation and local environment are so numerous that it is practically impossible to predict or measure all of them. Even if all of the permutations of mobile phone orientation and local environment were characterized perfectly there would be numerous ambiguities between different calibration points making it virtually impossible to achieve reasonable accuracies using the most advanced pattern matching techniques. Thus, the MNLS cannot realistically overcome the effects of the local RF propagation environment even with the use of the most advanced system modeling tools, advanced interpolating techniques, extensive drive testing, and advanced pattern matching techniques.

In addition, this fundamental 6 dB variation in relative power measurements caused by local effects will dominate the unique RF propagation signature created by the other more well behaved aspects of the environment (e.g. buildings, terrain, etc.) in all but the densest urban environments. This means that advanced pattern matching techniques will not achieve results better than well-known propagation models in all but the densest urban environments.

2.2 Location Accuracy Degrades Significantly as Cell Site Spacing Increases

Statistically, propagation loss increases by approximately 10 dB each time the distance from the transmitter to the receiver doubles. This means, for example, that a TDMA mobile phone will measure a 10 dB decrease in received power when it moves from a distance of one half the radius of the serving cell site's coverage area to the edge of the serving cell site's coverage area.

In a dense urban environment with 1 kilometer cell site spacing, a TDMA mobile phone can move a distance of 250 meters while measuring a 10 dB decrease in received power. In a suburban environment with 7 kilometers cell site spacing a TDMA mobile phone can move 1,750 meters while measuring a 10 dB decrease in received power. In a rural environment with 15 kilometers cell site spacing a TDMA mobile phone can move 3,750 meters while measuring a 10 dB decrease in received power. Viewed another way, the location error in a rural environment is 15 times more sensitive to power measurement errors than in the dense urban scenario. Likewise, the location error in the suburban environment is 7 times more sensitive to power measurement errors than in the dense

urban scenario.

2.3 Expected Location Accuracy of the MNLS

To demonstrate the effect of the fundamental 6 dB variation in the relative power measurements caused by the local RF propagation environment, TruePosition simulated the location accuracy of the MNLS using cell site data from real deployments. A perfectly calibrated theoretical propagation law was used. A random error with a 6 dB standard deviation was added to the ideal power measurements for each site prior to computing the location. The location error was computed for many trials at many different points in the coverage area. The simulation was repeated over several coverage areas including suburban and rural environments. Table 2-1 below shows the accuracy as a function of cell site spacing.

Cell Site Spacing (km)	Accuracy of 67% of Calls (m)
2	340
5	850
10	1,700
15	2,550

Table 2-1 Expected Accuracy of the MNLS

When actually implemented, the accuracy performance results achieved by the MNLS in these environments will generally fare worse due to additional sources of error such as imperfect calibration of the propagation environment, imperfect calibration of the base station transmit path including the antennas, and measurement errors by the phone not accounted for by the simulation. Stated differently, in order to achieve even these results, each market will first have to be perfectly calibrated.

It is clear to see from these results that the accuracy performance achieved by the MNLS will be inadequate to meet the needs of wireless 911 callers and public safety personnel, and does not approach the performance demonstrated by network-based location technologies that utilize TDOA and AOA. These results also fail to approach the FCC's wireless E911 accuracy requirements.

2.4 Limited Test Results Published To Date Do Not Address Key Issues

TruePosition has attempted to review all of the MNLS test results published to date. These test results do not address the fundamental 6 dB variance in relative power measurements caused by the local RF propagation environment, nor do they address the negative impact of increased cell site spacing.

It appears from the limited test results published to date that the MNLS has been tested in only very small areas with dense cell site spacing. The confusion surrounding the limited

testing of MNLS is further compounded when GSM test results are improperly combined with TDMA test results. This is a significant issue as GSM networks (especially European GSM networks) typically have much more dense cell site spacing than TDMA networks in the U.S.

It is quite possible to draw inaccurate conclusions from such limited tests. For example, if the database of predicted and/or measured propagation loss is constrained to an unrealistically small area, for instance covering just a highway where testing is to be conducted but not the surrounding area, the probability of test calls resulting in unambiguous database matches is unrealistically high. In another example, if the same equipment configuration (e.g. TDMA mobile phone with an external antenna attached to the roof of a van in a particular orientation) is first driven down the test route to generate the calibration database and then later driven down the same test route to make the actual test calls, the probability of test calls resulting in very strong database matches is unrealistically high.

Extensive and comprehensive testing needs to be performed in order to get an accurate characterization of the performance of the MNLS. This testing needs to be performed in a large area covering urban, suburban and rural environments with cell site spacing ranging between 1 kilometer and 15 kilometers. Test points should be distributed throughout the entire coverage area and should not overlap with calibration points. Test calls should be placed using different TDMA mobile phones than those used for calibration. Test calls should be placed in vehicles, outdoors and in buildings with the mobile in different orientations in both stationary and moving scenarios.

2.5 Five Second Averaging Can Lead to Increased Errors

TDMA mobile phones typically average their MAHO power measurements over a 5 second interval. The description of MNLS includes this fact, stating that a measurement is made every 1.28 seconds and 4 measurements are averaged over 5 seconds. In 5 seconds, a vehicle traveling 60 miles per hours will move 134 meters. MNLS proponents predict that a 50 meter grid of radio signatures will be required to produce the best MNLS location results. If so, moving vehicles will pass through multiple grid points during the average call, causing erroneous location calculations.

3 Comments on U.S. Wireless Corporation's *Ex Parte* Filing Regarding MNLS

On July 11, 2001 U.S. Wireless Corporation (USWC) submitted *ex parte* comments[1] to "clarify issues related to MNLS performance and the role MNLS technology can play in meeting the E-911 Phase II mandate." TruePosition has reviewed these comments and below sets forth its analysis:

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1 *Ex Parte* Comments Of U.S. Wireless Corporation On Performance, Viability, and Application of the Mobile-Assisted Network Location System (MNLS), CC Docket No. 94-102 (filed July 11, 2001).

- The USWC system should perform relatively better compared to the MNLS. USWC is making uplink measurements using a 6-element antenna array. The diversity provided by the array assists in overcoming path phenomena, such as fading and multipath. The MNLS involves the mobile making downlink measurements. Mobile phones, however, do not have antenna diversity. USWC's "straightforward technique combined the 6 antenna power measurements into a single combined power measurement" and, according to USWC, "performed relatively poorly." USWC had to use a "power signature" based upon 36 separate antenna measurements over 6 collection sites to achieve accuracies that were still significantly worse than the 250 meters forecast by some proponents of the MNLS.
- USWC data results for October 19-20, 2000 are not representative of typical cell site configurations. USWC had 6 collection sites in a 2 square mile suburban area. Therefore, each collection site covered an area of 2/6 (or 1/3) of a square mile. This implies an average "collection site" radius of about 1/3 of a mile (or 537 meters). If USWC had simply used the closest collection site's lat/long as the estimate of the call location, the average error should have been 537/2 meters = 268 meters in such a dense deployment. In contrast, average cell site spacing in most suburban systems is 2 to 6 miles.
- USWC claims that the MNLS and USWC Power Calibration are "closely related." If so the Power Calibration results appear worse than the 250 meters accuracy predicted by the MNLS proponents. Most of USWC's paper discusses a large combination of techniques actually used in the Radio Camera system, including time and angle based measurements, and covariance matrices created by the use of 6 antenna elements per receive site. USWC also noted that proper Data Pre-processing is required to build the calibration database (i.e. eliminating noisy data that is corrupted based on distortion in the propagation channel, etc.). USWC uses proprietary techniques to detect and eliminate samples that have been corrupted. Further, USWC claims to use a "fairly sophisticated optimization approach to transform the measured signal data into an RF signature which is then compared with a stored database in order to find the closest signature." Again, USWC has an advantage of 6 antennas per site while the MNLS has 1 antenna in the phone. Further, USWC uses Data Post-processing such as Kalman filtering and motion dynamics to smooth its data. It thus seems difficult to conclude from the discussion that MNLS and USWC are closely related.
- USWC's experience is that "comprehensive empirical modeling is required in order to achieve the desired performance goals." If a calibration database with 50 meter grid points is required, a major market that is about 30 miles by 30 miles in size would require approximately 921,000 separate grid points. If a technician were to drive every grid point to collect data, the technician would be required to drive over 28,000 miles. At an average speed of 25 miles per hour, over 1,100 hours would be required to drive the entire system just once. This would take 1 person about 6 months, not counting any time to process the data. Using USWC data for the top 400 urbanized markets, and counting 100% of the major and secondary roads, there are 678,750 miles of road. At 25 miles per hour, this would require 27,150 man-hours to drive it only once. This still leaves uncalibrated a significant amount off-road area.

Similar extensive efforts required to calibrate a typical major market will significantly impact the MNLS deployment timeframes and recurring operating costs.

- USWC references its published patents, which describe the creation of "signal signatures from a subspace of array covariance matrix." An examination of the patents describes a large number of measurements and criteria that are used in creating and interpreting the signal signatures. Further, the creation of the array covariance matrix is dependent upon having a multitude of antennas at each cell site. The MNLS is a far simpler approach, using only one antenna in the mobile phone, and only 1 criteria – power. Therefore, it is not equivalent for USWC to state that the MNLS can operate similar to USWC, and in particular that "an MNLS technique that has been properly designed and trained through drive test calibration can similarly benefit by exploiting" the "presence of fading, shadowing, and scattering phenomena." If a one-antenna power measurement system could achieve the same results as USWC's system, it seems unlikely that anyone would have developed a more complex system as the one described in USWC's patents.
- Finally, the USWC filing is contradictory. On the one hand, USWC states that empirical testing is required to calibrate the system and that predictive models are not sufficiently accurate. On the other hand, USWC states that the calibration process does not require data to be collected at all points within the coverage area and that modeling techniques can "fill-in" or predict missing calibration data. USWC goes on to predict that the MNLS will require only driving 10% of the roadways in a given market. This is in stark contrast to the data pre-processing and optimization arguments made earlier in the paper. USWC at once would have one believe that it took 5 years of development, including 2 years for Power Calibration, to achieve the demonstrated results in a 6 site, 2 square mile area – and at the same time, describe a fairly simple power measurement process requiring the driving of only 10% of the road with no recalibration to account for seasonal effects, cell site power, neighbor lists, or frequency plans that are changed.

4 Conclusion

Over the past nine years TruePosition has evaluated the use of relative power measurements for locating mobile phones. Based on the results of extensive theoretical and applied analysis TruePosition has concluded that mobile phones cannot be located accurately and reliably using relative power measurements and location pattern matching techniques to meet the needs of mobile 911 callers and public safety personnel. If the MNLS were to be deployed in typical TDMA networks, accuracy in the range of 850 meters to 2550 meters for 67% of all calls should be expected in the significant majority of areas. The record does not offer any evidence that the MNLS can overcome the fundamental 6 dB variation in relative power measurements caused by the local RF propagation environment even with the use of the most advanced system modeling tools, advanced interpolating techniques, extensive drive testing, and advanced pattern matching techniques.

The MNLS test results published to date do not address the fundamental 6 dB variance in relative power measurements caused by the local RF propagation environment, nor do

they address the negative impact of increased cell site spacing. It appears that the MNLS has only been tested in very small areas with dense cell site spacing. Given the limited testing performed to date there exists significant potential for grossly inaccurate conclusions. More extensive and comprehensive testing needs to be performed in order to get an accurate characterization of the performance of the MNLS.

The *ex parte* comments filed by U.S. Wireless Corporation in support of the MNLS erroneously apply capabilities such as a six-element receive antenna array and diversity averaging that are not applicable to the MNLS. In addition, USWC does not adequately address the fundamental 6 dB variance in relative power measurements caused by the local RF propagation environment, nor do they address the negative impact of increased cell site spacing. As a result, their comments fail to adequately and accurately characterize the expected performance of the MNLS in typical TDMA networks.