February 7, 2003
Mr. Patrick Forster
Wireless Telecommunications Bureau
Federal Communications Commission
445 12 Street, S.W.
Washington, D.C. 20554

EX PARTE
In the matter of CC Docket No. 94-102
Comments of LOCUS Corporation in Japan on Performance, Viability and Application of the Advanced Maximum-Likelihood Estimation for TDMA and GSM mobile systems.

Dear Mr. Forster:

LOCUS Corporation in Japan ("LOCUS") hereby submits the following *ex parte* comments on the Advanced Maximum-Likelihood Estimation ("AME") for TDMA and GSM mobile systems.

LOCUS previously submitted comments to the FCC on September 13, 2001, entitled "Comments of LOCUS Corporation in Japan on Performance, Viability and Application of the Mobile-Assisted Network Location System of AT&T Wireless". In those comments, LOCUS indicated that AME would comply with the mandate of E-911, based on the data taken in Japan.

In October 2002, LOCUS conducted a trial in Orlando, Florida by using the TDMA infrastructure of AT&T Wireless ("AWS") and succeeded in verifying compliance with the mandate of E-911 for the network-based solution. Since AME works on a Mobile Assisted Hand Off ("MAHO") basis, legacy handsets are also served and the infrastructure of wireless carriers need not be modified. Therefore, we believe that not only mobile carriers but also their subscribers can enjoy these benefits. AME is applicable to GSM and GPRS as well.

Recently, LOCUS concluded a business contract with Mitsubishi Corporation (Mitsubishi-shoji) in order to promote the technology of AME for E-911 in the US. Furthermore, in the near future, LOCUS and Mitsubishi-shoji will incorporate the entity LOCUS America (tentative name) in the US so that we can support our clientele more easily. LOCUS and Mitsubishi-shoji are planning to propose our AME service to AT&T Wireless, Cingular Wireless and other TDMA/GSM carriers.

We believe LOCUS and Mitsubishi-shoji will contribute to improving the accuracy of positioning for TDMA and GSM with the economical solutions as mentioned above.

Sincerely,

Hiroaki Koshima
President
LOCUS Corporation
Muraki Bldg., 1-16-20
Minami-senba, Chuo-ku,
Osaka 542-0081, Japan

Email address: koshima@ff.iij4u.or.jp
Phone: +81+6+6265+9061
Fax: +81+6+6265+9060

BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WAHINGTON, D.C. 20554

In the Matter of	**)**	
	)	
Wireless E9-1-1 Phase II Automatic	**)**	**CC Docket No. 94-102**
Location Identification Requirements	**)**	
	)	
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To the Commission:
EX PARTE COMMENTS OF LOCUS CORPORATION
On Performance, Viability and Application
of
the Advanced Maximum-Likelihood Estimation Location System (AME)

1. INTRODUCTION

LOCUS Corporation in Japan ("LOCUS") submits these *ex parte* comments to the Commission for the purpose of proposing the approval for mobile carriers to adopt the Advanced Maximum-Likelihood Estimation ("AME") to TDMA and GSM for complying with the mandate of E-911.

LOCUS previously submitted comments to the FCC on September 13, 2001, entitled "Comments of LOCUS Corporation in Japan on Performance, Viability and Application of the Mobile-Assisted Network Location System of AT&T Wireless". In those comments, LOCUS indicated that AME would comply with the mandate of E-911, based on the data taken in Japan.

In October 2002, LOCUS conducted a trial test in Orlando, Florida by using the TDMA infrastructure of AT&T Wireless ("AWS") and succeeded in verifying compliance with the mandate of E-911 for the network-based solution. Since AME works on Mobile Assisted Hand Off ("MAHO") basis, legacy handsets are also served and the infrastructure of wireless carriers need not be modified. Therefore, we believe that not only mobile carriers but also their subscribers can enjoy E-911's benefits. AME is applicable to GSM and GPRS as well.

Recently, LOCUS concluded a business contract with Mitsubishi Corporation

(Mitsubishi-shoji) in order to promote the technology of AME for E-911 in the US. Furthermore, in the near future, LOCUS and Mitsubishi-shoji will incorporate the entity LOCUS America (tentative name) in the US so that we can support our clientele more easily. LOCUS and Mitsubishi-shoji are planning to propose our AME service to AT&T Wireless, Cingular Wireless and other TDMA/GSM carriers.

AME takes advantage of the sophisticated probability theory. Fluctuations of signal strength affected by reflection, shadowing and diffraction caused by terrain, clutter, vehicles and human bodies are well compensated for errors by AME.

This report summarizes the field trial conducted by LOCUS last October in a TDMA network, and verifies AME can comply with E-911 mandate of network based solutions. Section 2 describes theoretical background on AME. Section 3 explains how the measurements were taken in this trial and Section 4 describes the database entry process. Section 5 presents the result of verification accuracy of the Orlando field trial. Conclusions are provided in Section 6.

2. Theoretical Background

Traditional Signal Strength ("SS") methods and Enhanced Signal Strength ("ESS") method by LOCUS [1] for commercial Location Based Services ("LBS") have been used successfully in Japan for the past several years, most notably with Personal Handy-Phone Systems ("PHS"). These methods are especially suitable for PHS since it uses micro-cells, but insufficient for TDMA and GSM/GPRS to comply with the E-911 mandate because of their larger cell sizes.

AME is a technique based on the maximum-likelihood probability theory. The fundamental idea is that AME estimates location of a mobile station by using signal strength from each base station. Database of profile with observation data at each grid is created in advance. The concept of AME is applicable to TDOA and even A-GPS, as well. The algorithm of this theory was introduced in [2].

2.1 An Outline of Algorithm

To simplify it, description of the maximum-likelihood estimation is carried out in two dimensions. We assume the model as following;

- The model based on received signal strength.
- A mobile station receives signals from *n* base stations.
- The short-term median of received signal strength follows decibel normal distribution.
- Received signal strength from each base station is independent of each other.

Position of a mobile station is $\underline{x_s} = (x_s, y_s)$ and short-term median $\Gamma = (\Gamma_1, \Gamma_2, \Gamma_3, \cdots, \Gamma_n)$. Fluctuation occurred under the influence of surrounding moving objects is supposed that it has a certain probability density function based on long-term median $\overline{\Gamma} = (\overline{\Gamma}_1, \overline{\Gamma}_2, \cdots, \overline{\Gamma}_n)$. Observation data that the position of a mobile station is independent to each base station can be expressed as

$$p(\Gamma) = p(\Gamma, \Sigma | \underline{x_s}) = p_1(\Gamma_1, \sigma_1 | \underline{x_s}) \cdot p_2(\Gamma_2, \sigma_2 | \underline{x_s}) \cdots p_n(\Gamma_n, \sigma_n | \underline{x_s}) \qquad (2.1)$$

It can be expressed with the following formula that the probability distributions of Γ_i follow the decibel normal distribution of standard deviation σ_i

$$p(\Gamma_i | \underline{x_s}) = \frac{1}{\sqrt{2\pi\sigma_i^{\ 2}}} \exp\left\{ -\frac{(\Gamma_i - \overline{\Gamma}_i)^2}{2\sigma_i^{\ 2}} \right\}, \qquad i = 1,2,3,\cdots,n \qquad (2.2)$$

Here, $p(\Gamma_i | \underline{x_s})$ is not a conditional probability but the probability when a parameter is set.

$\underline{x_s}$ is not a random variable but a presumed parameter.

The probability in which obtains $\Gamma + \Delta$ around Γ is defined and let it be the likelihood function. Δ is a permission deviation within a range of acceptable bias caused by observation position or apparatus.

$$l(\Gamma_1, \Gamma_2, \cdots, \Gamma_n | \underline{x_s}) = \int_{\Gamma=\Gamma_1}^{\Gamma_1+\Delta} p_1(\Gamma, \sigma_1) d\Gamma \int_{\Gamma=\Gamma_2}^{\Gamma_2+\Delta} p_2(\Gamma, \sigma_2) d\Gamma \cdots \int_{\Gamma=\Gamma_n}^{\Gamma_n+\Delta} p_n(\Gamma, \sigma_n) d\Gamma \qquad (2.3)$$

It is referred to as logarithm likelihood function $J(\Gamma; \underline{x_s})$ as

$$J(\Gamma; \underline{x_s}) \equiv \ln L(\Gamma; \underline{x_s}) \qquad (2.4)$$

When probability density can be set to very small Δ as it is fixed, logarithm likelihood function is carried out from formula (2.2) as follows

$$J(\Gamma; \underline{x_s}) = -\frac{1}{2} \sum_{i=1}^{n} \ln(2\pi\sigma_i^2) - \sum_{i=1}^{n} \left\{ \frac{(\Gamma_i - \overline{\Gamma}_i)^2}{2\sigma_i^2} \right\} + n \cdot \ln(\Delta) \qquad (2.5)$$

The maximum-likelihood position of $\underline{x_s}$ is corresponding to maximize logarithm likelihood function $J(\Gamma; \underline{x_s})$. The position to be estimated $\hat{x}_s$ is given by

$$\hat{x}_s = \arg\left\{ \max_{\underline{x_s}} J(\Gamma; \underline{x_s}) \right\} \qquad (2.6)$$

3. Measurements for Database and Verification of AME

LOCUS conducted the field trial in downtown Orlando, Florida in October 2002. The environment in multi offices and buildings create various multi-path which makes it more difficult to pinpoint a position. LOCUS sent several crews to Orlando to collect data and perform the verification test. Pedestrian measurements were carried out in some areas though most of the measurements were performed by vehicle.

3.1 Measurement Conditions

3.1.1 Downtown Orlando, Florida.

The region of downtown Orlando, a range of 1.6km north and south, and 3.2km east and west was covered as shown in Figure 1.

Figure 1

3.1.2 Equipment

During the measurements, both measuring receivers and mobile stations were used. An Agilent E6450B RF receiver with built-in GPS was used to measure signal strength and channel numbers from surrounding base stations. Latitude and longitude obtained by the internal GPS receiver was correlated with the signal strength and other information recorded at positions of observation. Nokia 5615 AT&T Digital PCS phones were used to measure signal strength and channel information for database creation. Agilent E6474A was used as control software for data received by the mobile station and the receiver.

3.1.3 Obtaining Latitude/Longitude

To determine each measurement position, a RF receiver with built-in GPS in which latitude and longitude are coordinated with the signal strength at the measured position was used.

3.2 Measurements for Database

Pedestrian measurements were performed in early stage of database measurement for the initial verification of AME performance. Then, the measurements for the database creation were executed via vehicle. There are no significant differences in the AME accuracy, either by pedestrian or vehicle measurement. Signal strength was collected in the range of 1.6km north and south, and 3.2km east and west including the area covered throughout the pedestrian measurement (see Figure 2). Equipments such as gyros and GPS with dead reckoning available for vehicle measurement were not used in this trial. Instead, in some places, accurate genuine positions were obtained after the compensation made by proprietary methods.

Figure 2

3.3 Verification Measurements

One thousand sets of latitude and longitude were selected at random within the range of the coverage area. The position of these sample locations was referred by GPS positioning, street name and building. The signal strength received from mobile stations was recorded at the observation position. Verification measurements were made on the streets inside stationary vehicles and vehicles at certain speed.

4. Database

The database stores profiles of data statistically processed at grid points in the coverage area. The profile includes average value of signal strength and standard deviation for the grid points. This information is then used to determine the position of the mobile station. However, in case that the GPS provides extremely poor accuracy, data sets were excluded from database entry. A typical grid size is approximately 10 to 20 meters.

5. Trial Results

The FCC E911 mandate for the network-based solution requires 67% and 95% of the calls to be located within 100 and 300 meters accuracy, respectively. The results of the trial indicated accuracy errors of 51 meters at 67% and 276 meters at 95%. According to FCC guidelines, order statistics may be used as a way by which a verification test is determined whether it satisfies the FCC standard or not. The confidence interval of the FCC accuracy standard is determined based on 90% of reliability and the number of samples [3]. The results of the AME verification in this trial are presented in Table 1. At the sample size of 1,000 locations selected at random, calculated errors at the 90% confidence level were 63 meters and 291 meters for 67% and 95%, respectively. The cumulative error distribution is provided in Figure 3.

Table 1 Verification Results

	Cumulative	90% Confidence
FCC 67%	51 meters	63 meters
FCC 95%	276 meters	291 meters

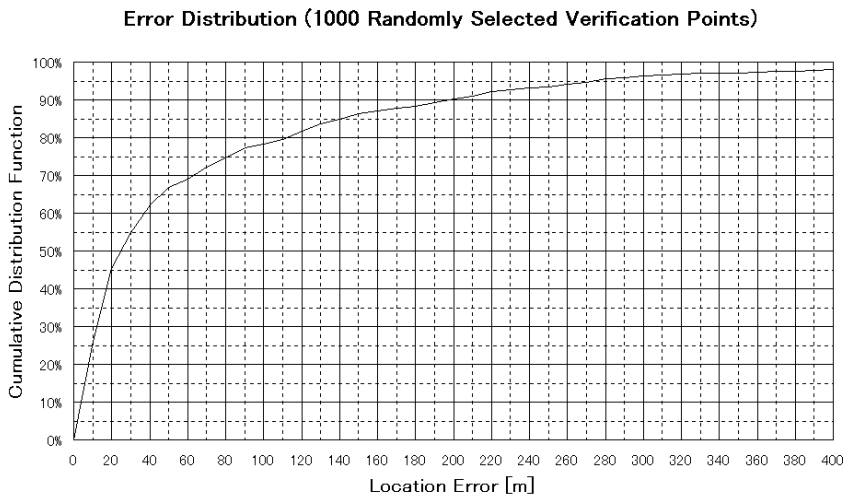

Figure 3 Cumulative Error Distributions

6. Conclusion

In general, achieving accurate location in urban areas is a challenge because of the influences of multi-path and shielding objects. AME takes advantage of probability theory, so the deviation of signal caused by terrain and clutter is taken into account. As a result, the positioning accuracy was considerably improved by AME comparing with conventional triangulation methods and probability methods with signal strength.

In the October field trial in Orlando, the AME accuracy resulted in the cumulative errors of 51 meters at 67% and 276 meters at 95%. At the 90% confidence level, the result of calculated errors was 63 meters at 67% and 291 meters at 95%. Hence, LOCUS concludes that the trial with AME in Orlando, Florida has clearly met the FCC Phase II mandate.

References

[1] H. Koshima and J.H. Hoshen, *"Personal Locator Services Emerge"* IEEE SPECTRUM February 2000, pp. 41~48

[2] M. Aso, M. Kawabata, and T. Hattori, *"A New Location Estimation Method Based on Maximum Likelihood Function in Cellular Systems"* IEEE Vehicular Technology Conference, VTC2001, October 2000

[3] *Guidelines for Testing and Verifying the Accuracy of Wireless E911 Location System*, OET BULLETIN No.71, released April 12, 2000

Respectfully submitted,

Hiroaki Koshima
President
LOCUS Corporation
Muraki Bldg., 1-16-20
Minami-senba, Chuo-ku,
Osaka 542-0081, Japan

Email address: koshima@ff.iij4u.or.jp
Phone: +81+6+6265+9061
Fax: +81+6+6265+9060

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