Title:	UE Angle of arrival distribution
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1 INTRODUCTION

This contribution presents field data obtained from measurements of the Angle of Arrival (AOA) for the resolvable paths (rays) at the mobile (UE). The field data were collected in a suburban environment in Schaumburg, Illinois.

The mobile receive system was set up on a rooftop of a full-sized van. The UE antenna consisted of three-foot parabolic dish of 10 degrees beam width at –3 dB, equipped with a 2304 MHz feeder. The rotation speed of antenna was 360 degrees in 45 seconds and a sampling speed of 100 samples in 31 seconds, which allowed a sampling of data every 2.48 degrees. The resolvable rays were selected based on their relative power to total received power. The data were collected in 38 locations in a suburban environment in Schaumburg.

2 MEASUREMENT RESULTS

Figure 1 shows the power versus azimuth plot where the power is measured in relative dB units. In Figure 2 is presented the median power versus angle of arrival. As can be noticed, the distribution is not uniform with a peak in the line of sight direction (LOS), also there is a slight increase of the power for angles around 180 degrees, which correspond to the opposite direction of the LOS. Figure 3 and Figure 4 present the normal plot and the histogram plot for the RMS angle spread values. The RMS formula uses as reference the LOS. As can be observed, the RMS distribution can be approximated by a normal distribution having a mean of 71.8 degrees and a spread of 26 degrees. Few values, greater than 104 degrees (the uniform distribution), correspond to those cases when a strong signal is received from 180 degrees direction. Figure 5 and Figure 6 show the similar plot for the AOA RMS when a circular formula is applied. In this case, the reference is not fixed but is chosen to minimize the RMS value, which takes into consideration the circular aspect of data (-180 and 180 points are identical and not the extremes of the interval). As expected, the mean RMS value is reduced to 65 degrees and the spread to 20 degrees. In order to implement such “floating” reference direction a second statistics for the reference should be defined which would complicate the modeling task. Figure 7 presents a plot of the angle of arrival mean and spread as a function of the ray power. The AOA has the same average, no matter the ray’s power and the spread is inverse proportional with ray’s power. The actual spread of the angle of arrival at UE can be modeled as an exponential distribution as Equation 1:

$$\sigma = 104.12(1 - e^{-0.2175\ |P|}) \qquad (1)$$

Where σ is the angle spread and P is the ray power in dB. Figure 7 suggests that the rays could be generated from zero mean distributions with spreads related to the ray power as in Equation 1. Figure 8 shows the AOA RMS distribution at UE resulted from simulations using the Motorola rays based model [2], which is based on the field data measurements. The model, using 6 rays each one with an angular spread of 35 degrees, was able to reproduce quite well the measured AOA RMS for both normal and circular RMS formulas.

Four different locations were selected to investigate the polarization impact on the received signal. In each location, several measurements for successive displacements of the van were done for all polarization transmit-receive antenna combinations. The results are presented in the Figure 9 show the cross-polarization isolation as a function of the ray power. The reference signal was for vertical transmit to vertical receive antenna and was compared with the vertical transmit to horizontal receive signal (red stars) and with horizontal transmit to vertical receive signal (blue squares). Interesting observation is the linear dependence with the power of the cross polarization isolation i.e. a more powerful ray has more isolation than a less powerful ray. Similar behavior was found when the signal horizontal to horizontal was considered as reference. Figure 9 could be interpreted like this, for known vertical to vertical ray component, the cross-polarization isolation could be modeled as a normal distribution with an average (μ) linear dependent on the vertical-to-vertical transferred power and the spread (σ) power independent and equal to about 5 dB.

$$\mu = 0.34 \times [P_{VV}]_{dBr} - 7.2dB$$

As result of this observation, a general formula can be derived for the vertical and horizontal power components for each ray. The gains in terms of the envelope voltage γ_{ij} can be then generated as $\gamma_{ij} = 10^{Norm(\mu_{ij}, \sigma_{ij})/20}$.

$$\begin{bmatrix} h_H^R \\ h_V^R \end{bmatrix} = \begin{bmatrix} \gamma_{11} & \gamma_{12} \\ \gamma_{21} & \gamma_{22} \end{bmatrix} \times \begin{bmatrix} h_H^T \\ h_V^T \end{bmatrix}$$

Where $h_H^R, h_V^R, h_H^T, h_V^T, \gamma_{ij}$ are the receive horizontal, the receive vertical, the transmit horizontal, the transmit vertical voltage amplitudes, and respectively the correspondent gains. Additional multiplications have to be done on both sides with rotation matrices in order to obtain the horizontal and vertical components in the general case.

3 CONCLUSIONS

The paper presents the angle of arrival and the polarization data collected at the subscriber unit (UE) in Schaumburg, Illinois. Several data are shown in the support of non-uniform distribution of power versus angle of arrival. A model for the angle of arrival of rays at UE is proposed. The model already included in Motorola propagation models [1,2] suggests that each ray has a power drawn from a normal distribution with a mean line of sight and a variance based on the ray's power. Using a six ray model, where each ray has a fixed 35 degrees spread we were able to reproduce the measured data based on the above model. Base on the field data a simple polarization model was proposed.

References

[1] Motorola, "A Ray Based MIMO Propagation Model", 3GPP2 TSG-C Submission 20010820027, Portland, OR, August, 20-24,2001
[2] Motorola, "Correlated Spatial Channel Model", SCM-029, Conference Call, June 4 th 2002

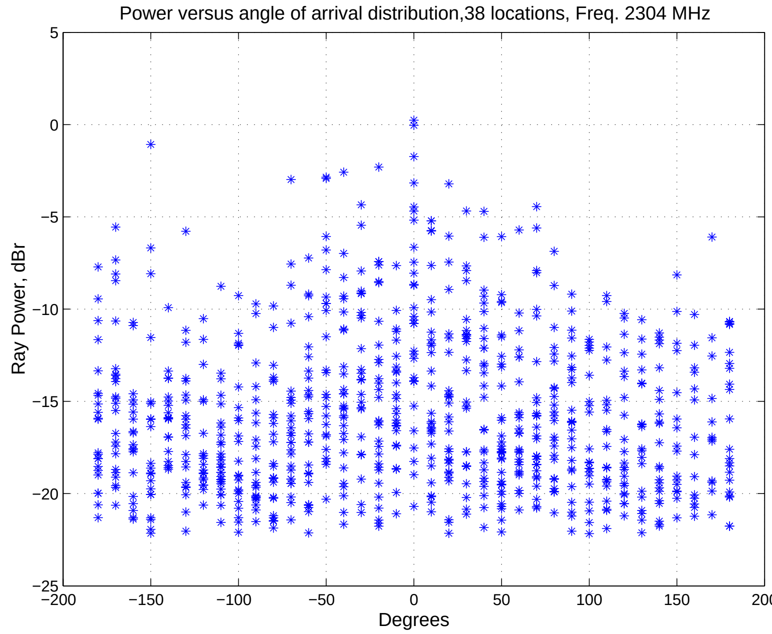


Figure 1

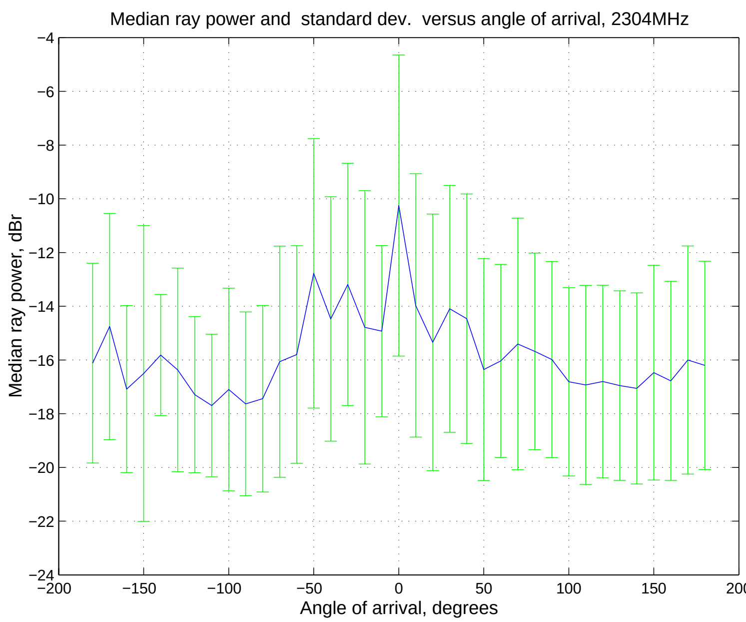


Figure 2

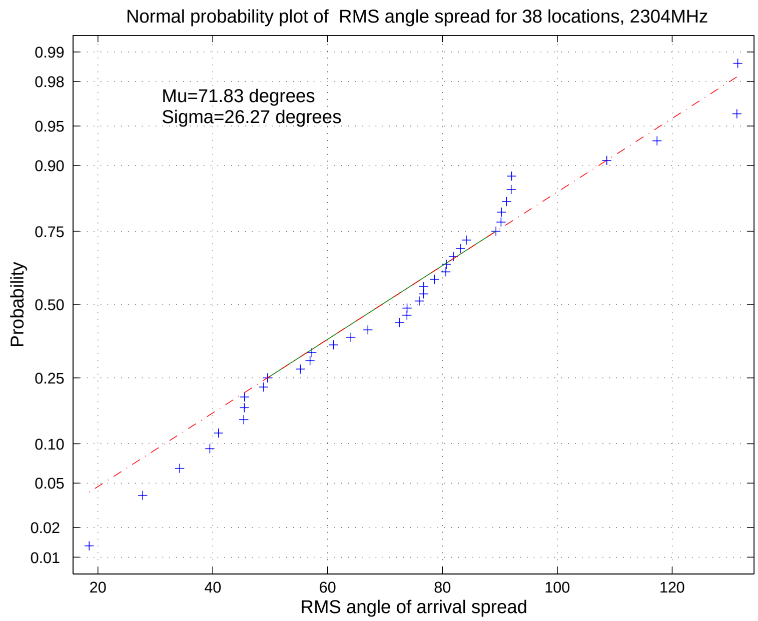
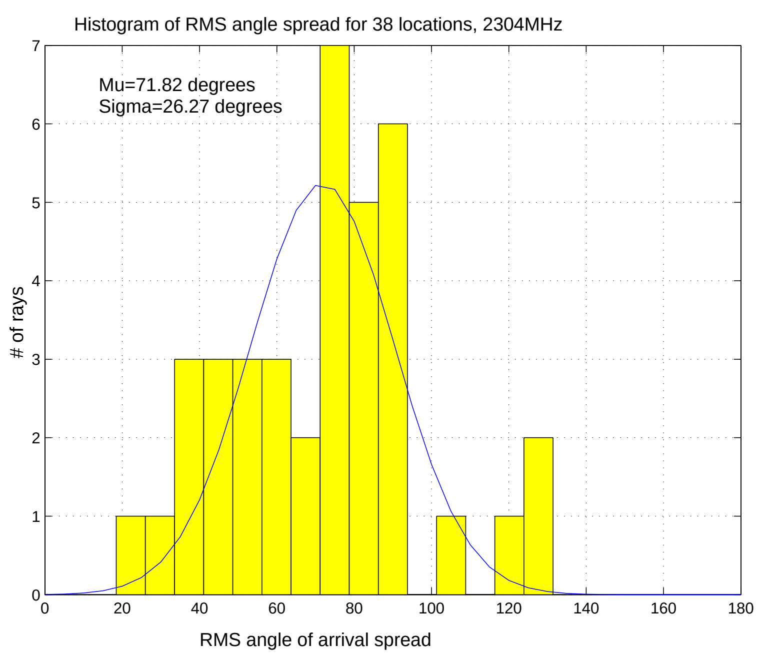


Figure 3



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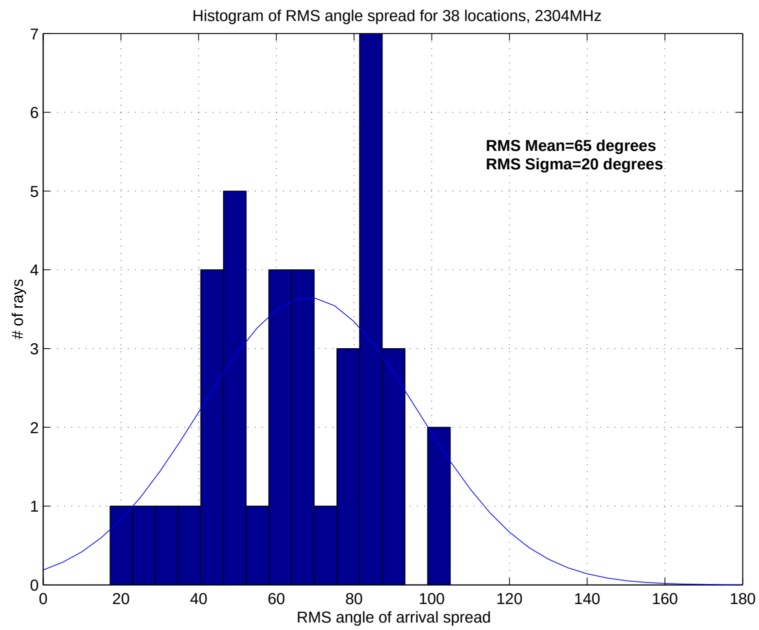


Figure 5

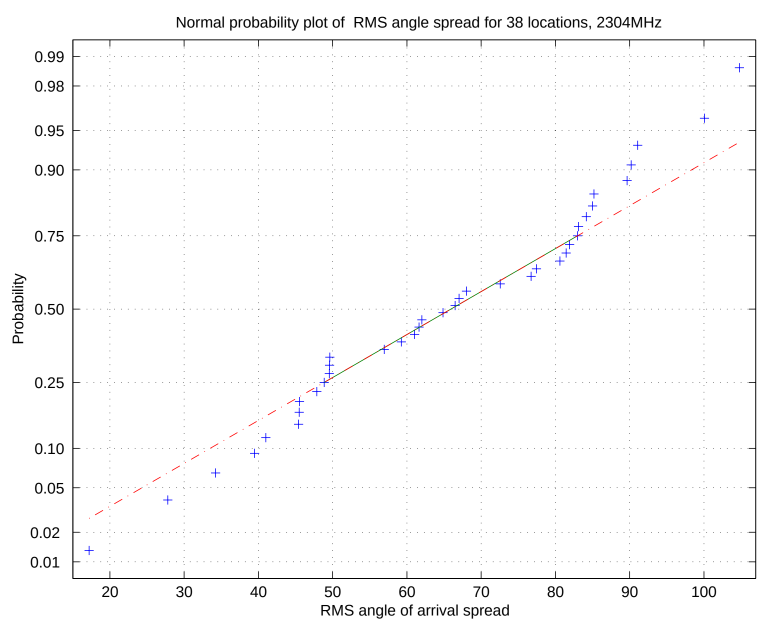


Figure 6

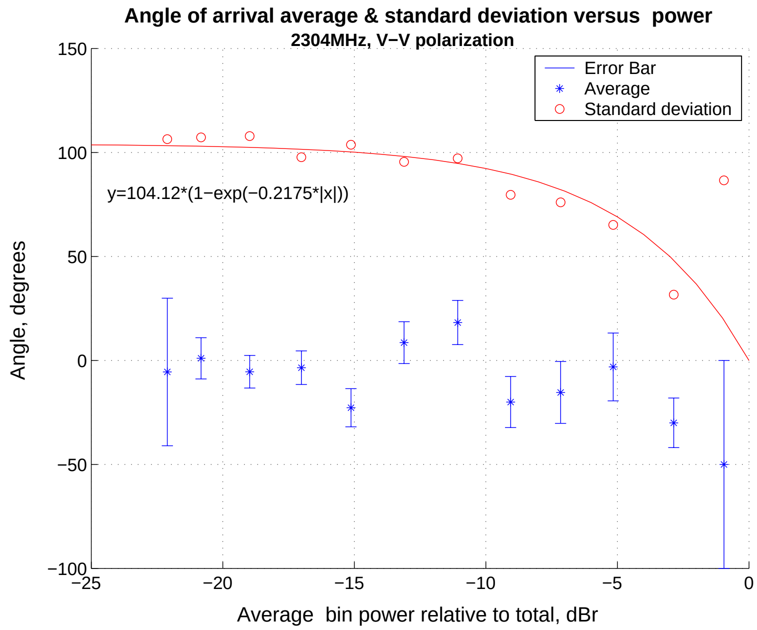


Figure 7

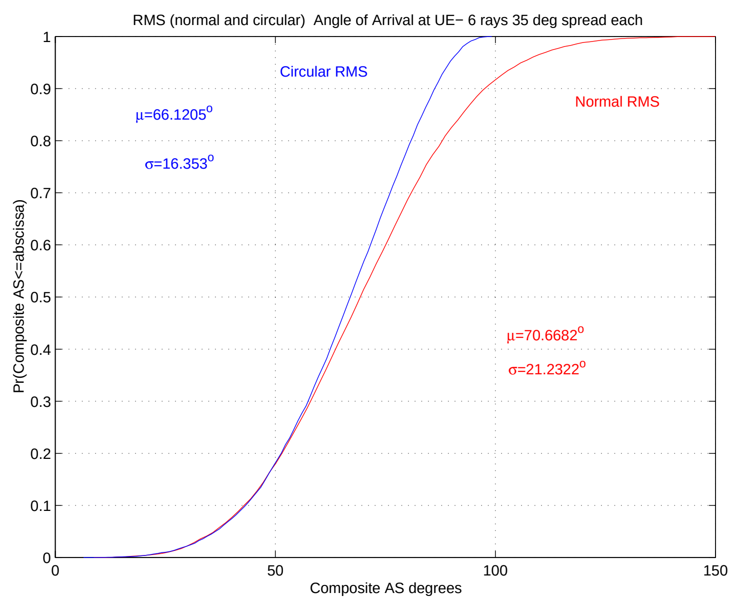
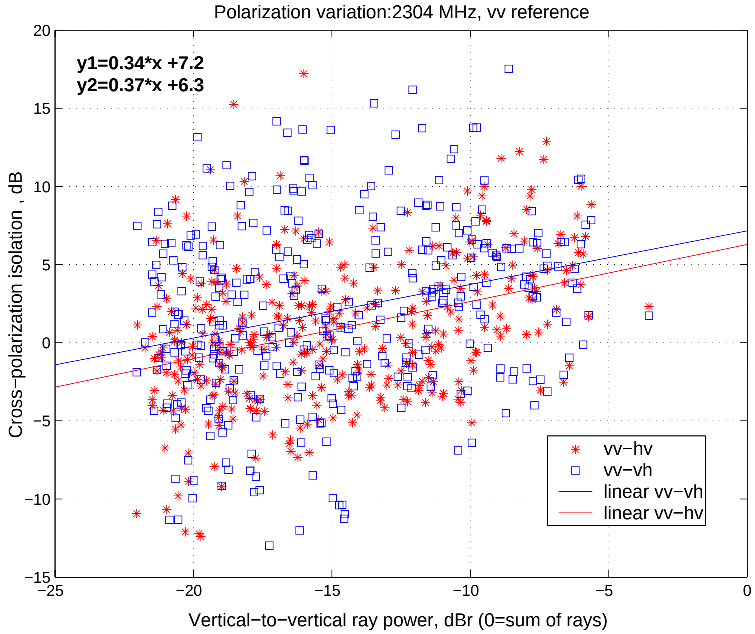


Figure 8


Polarization variation:2304 MHz, vv reference
y1=0.34*x +7.2
y2=0.37*x +6.3
vv−hv
vv−vh
linear vv−vh
linear vv−hv
Cross−polarization isolation , dB
Vertical−to−vertical ray power, dBr (0=sum of rays)
20
15
10
5
0
−5
−10
−15
−25
−20
−15
−10
−5
0

Equation 9