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Comments on position measurements used in draft AECS-02-02-r7

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Position Error Measurements

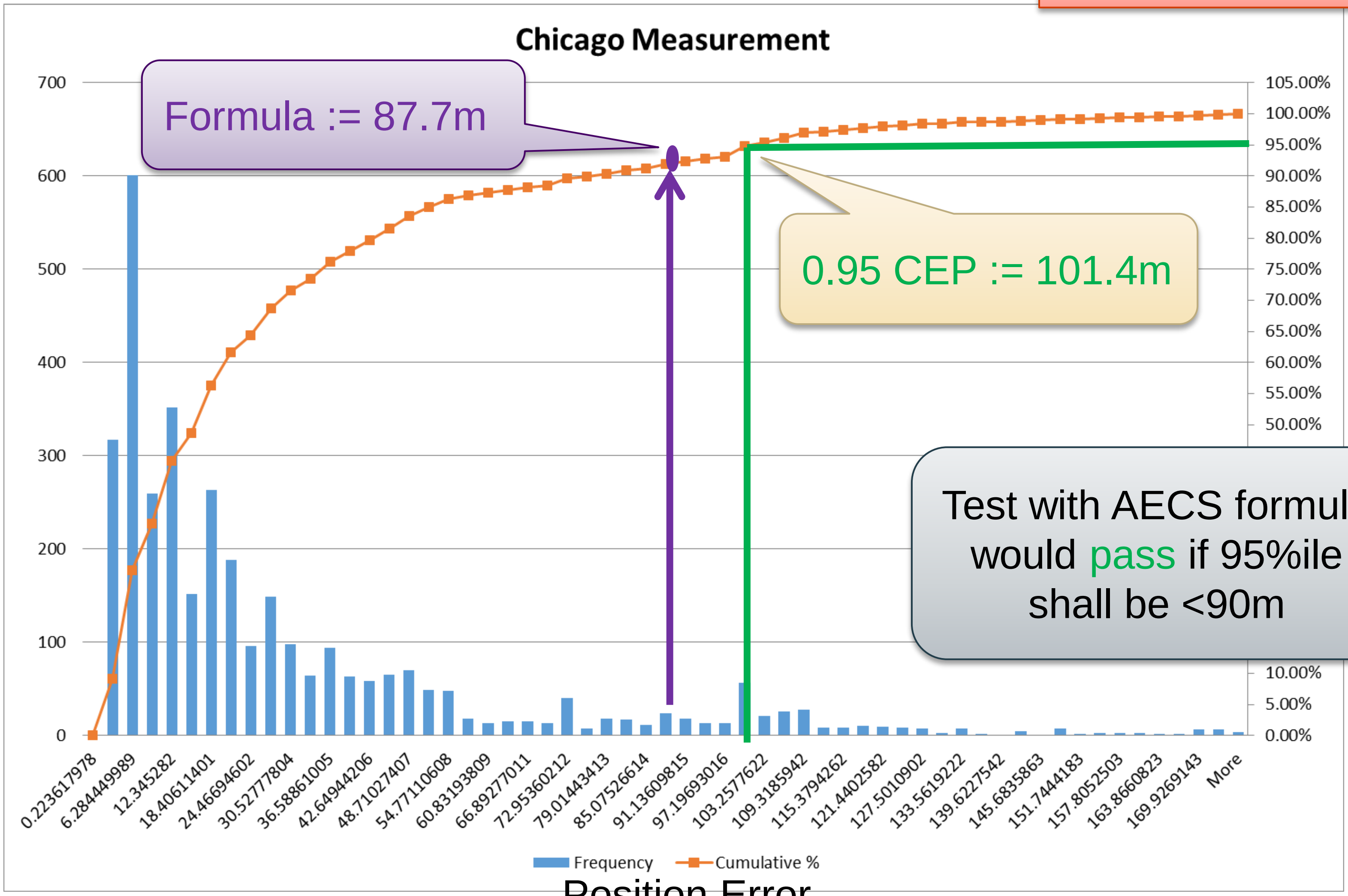
- The formula currently suggested in the AECS draft (Annex 8, Section 3.2.10) to calculate the error probability is assuming a Gaussian distribution of the error, which is not a reasonable assumption
  - The position error distribution depends on the available GNSS constellations, the date of the testing as well as on the environmental conditions around the test area leading to different multipath reflections and shadowing of the GNSS signals
  - Depending on the actual distribution there will be a difference between the currently suggested AECS formula and the desired confidence of 95% percentile
  - The threshold derived from the current AECS formula does not guarantee that 95% of points will be in that error bound.

- Circular Error Probability (CEP) is a well established metric to measure the position error at a given error bound, e.g. CEP is used in mobile communication standards
  - 3GPP TS37.571-1
  - 3GPP2 C.S0036

Example: Chicago Measurements

samples = 3460

PDF



CDF

Position Error

Example:
Uniform distribution of x/y error [-12.5,12.5]m

samples = 300

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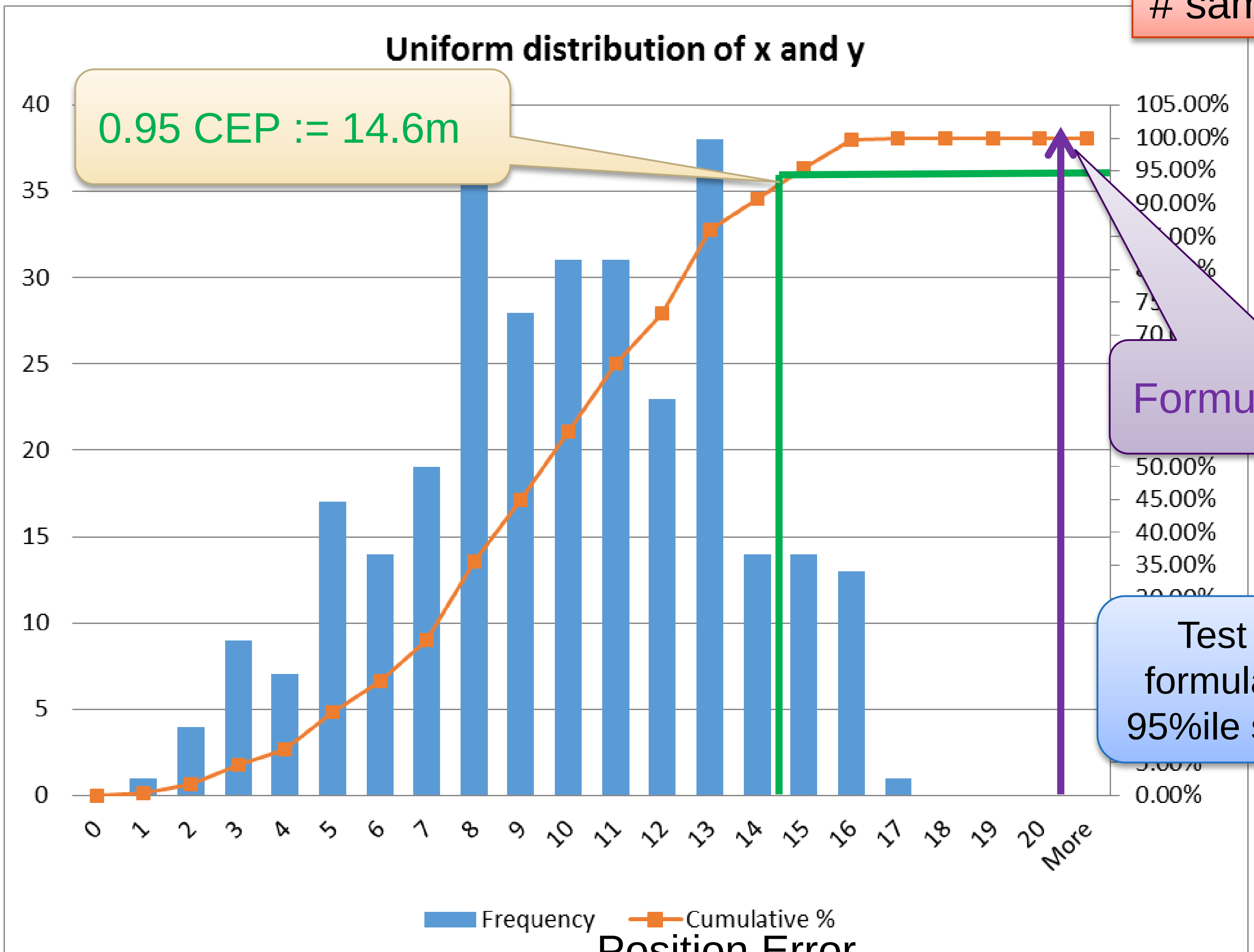
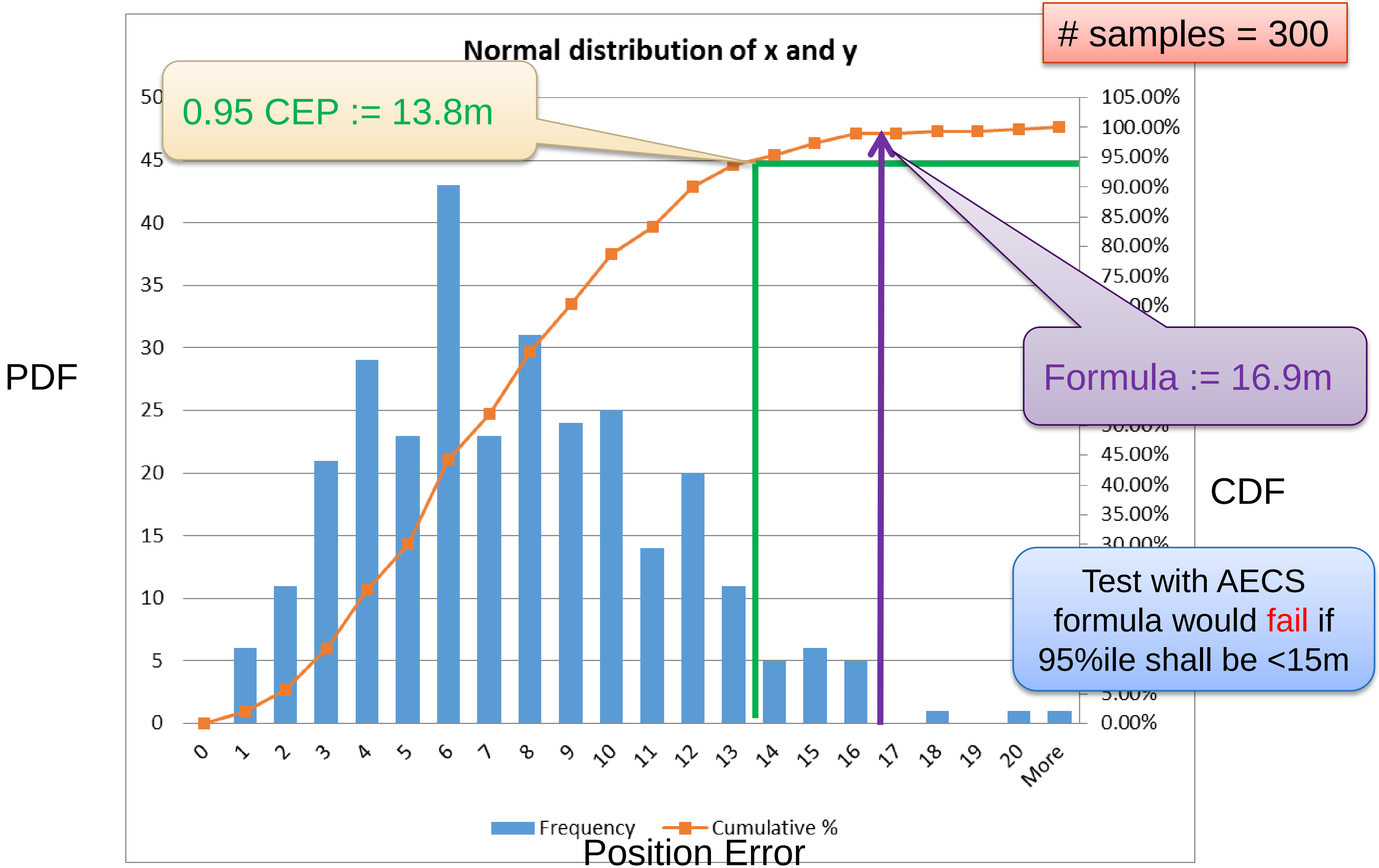


CDF

Test with AECS formula would fail if 95%ile shall be <15m

Position Error

Example:
Normal distribution of x/y error N(0,5.6)



Calculation of Confidence Boundaries

- The confidence boundaries of the CEP estimate are only dependent on the number of measurement samples and can be obtained by employing the “Clopper-Pearson Method“ (see e.g. http://www.sigmazone.com/binomial_confidence_interval.htm)

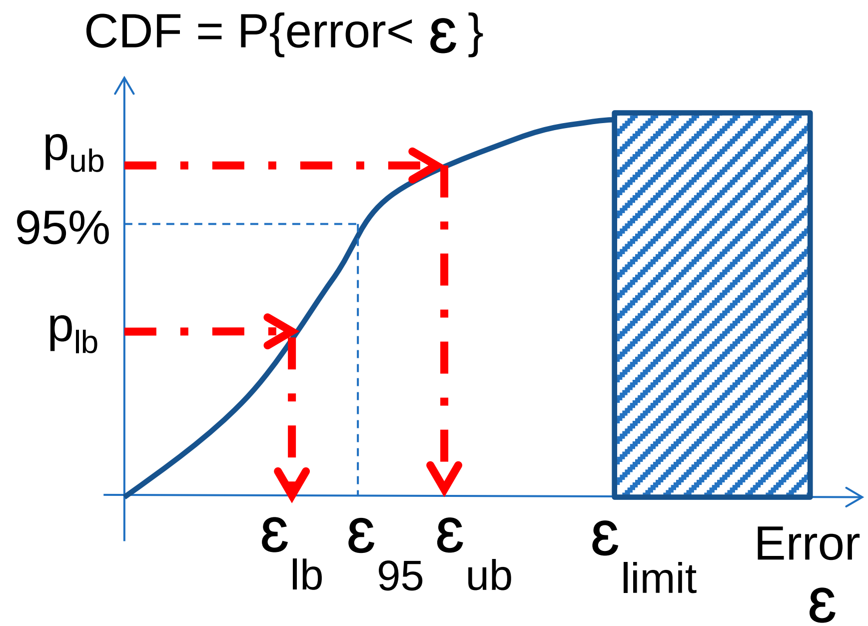
$$p_{ub} = 1 - \mathrm{BetaInv}\left(\frac{\alpha}{2}, n-k, k+1\right)$$

$$p_{lb} = 1 - \mathrm{BetaInv}\left(1-\frac{\alpha}{2}, n-k+1, k\right)$$

- where
  - p_{lb} is the confidence interval lower bound
  - p_{ub} is the confidence interval upper bound
  - n is the number of trials
  - k is the number of successes in n trials, i.e. # errors that are < error limit (e.g. 15m)
  - α is the percent chance of a wrong estimate, 1-α is the confidence level (e.g. 0.95)
  - BetaInv is the inverse of the beta cumulative distribution function

Recommended test procedure

Goal: 95%ile of the position errors ε are below the error limit ε_{limit} with 95% confidence



1. Calculate the cumulative distribution function (CDF) of the measured position errors with sufficient granularity
2. Obtain the error ε_{lb} @ p_{lb} through linear interpolation based on the desired lower bound for a confidence level 1-α=0.95 considering the number of measurement samples n (see e.g. table).
3. Test pass if $\varepsilon_{lb} \leq \varepsilon_{limit}$

Test time	# samples n	p_{lb} [%]	p_{ub} [%]
1h	3600	94.2	95.7
2h	7200	94.4	95.5
4h	14400	94.6	95.3

Conclusion

- The currently suggested formula to calculate the 95%ile position error boundary assumes Gaussian distribution of the position errors
- This may lead to cases where the device under test (DUT)
  1. passes the test even though its not fulfilling the 95%ile position error requirement
  2. fails the test even though it is fulfilling the 95%ile position error requirement
- To avoid wrong test conclusions, it is recommended to apply the following modifications to the current AECS draft AECS-02-02-r7
  - Removal of Sections 3.2.7, 3.2.8 and 3.2.9
  - Replace content of Section 3.2.10 by the following text

"Calculate horizontal coordinates error between position estimate and ground truth at circular error probability (CEP) with 0.95 confidence level."

Thank You !

Questions?

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