Coordinate Inaccuracy Impacts and Solutions

Panel Discussion

May 13, 2014

Survey Accuracy Codes

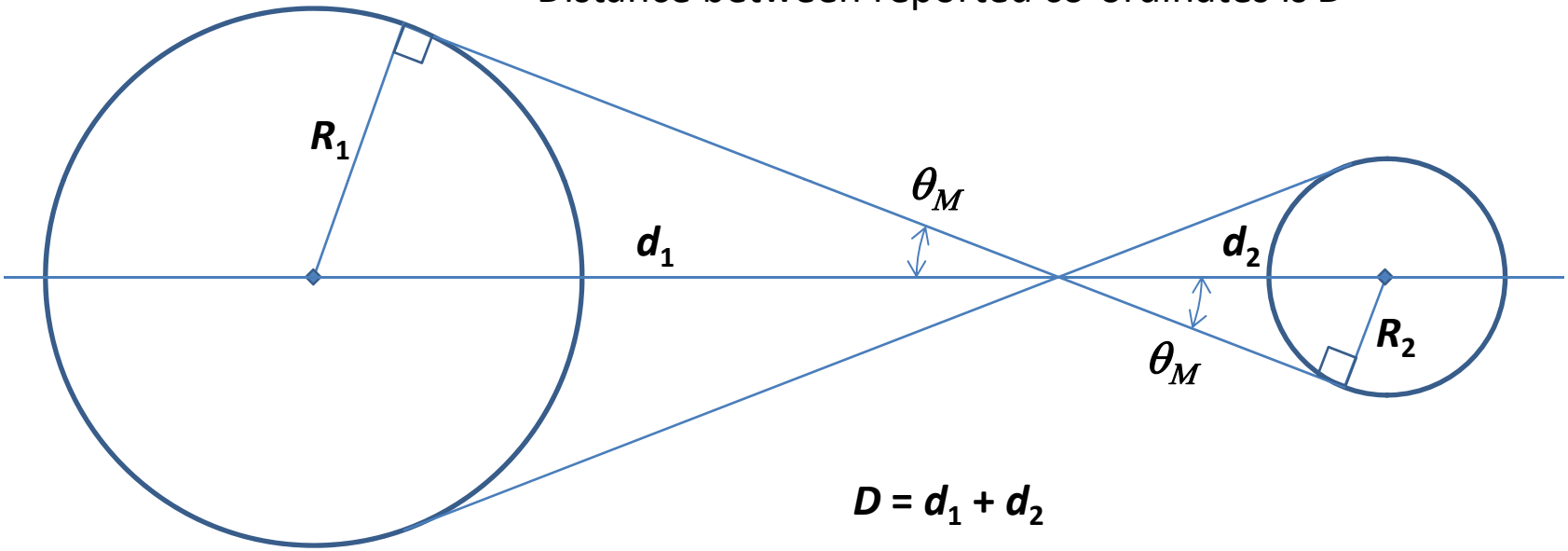
FAA Order 8260.19E Appendix C

HORIZONTAL			VERTICAL		
Code	Tolerance		Code	Tolerance	
1	20 ft	6 m	A	3 ft	1 m
2	50 ft	15 m	B	10 ft	3 m
3	100 ft	30 m	C	20 ft	6 m
4	250 ft	75 m	D	50 ft	15 m
5	500 ft	150 m	E	125 ft	38 m
6	1,000 ft	300 m	F	250 ft	75 m
7	1/2 NM	900 m	G	500 ft	150 m
8	1 NM	1800 m	H	1,000 ft	300 m
9	Unknown		I	Unknown	

Maximum Possible Azimuth Error

Site 1 is within distance R_1 of its reported co-ordinates
Site 2 is within distance R_2 of its reported co-ordinates

Distance between reported co-ordinates is D



$$D = d_1 + d_2$$

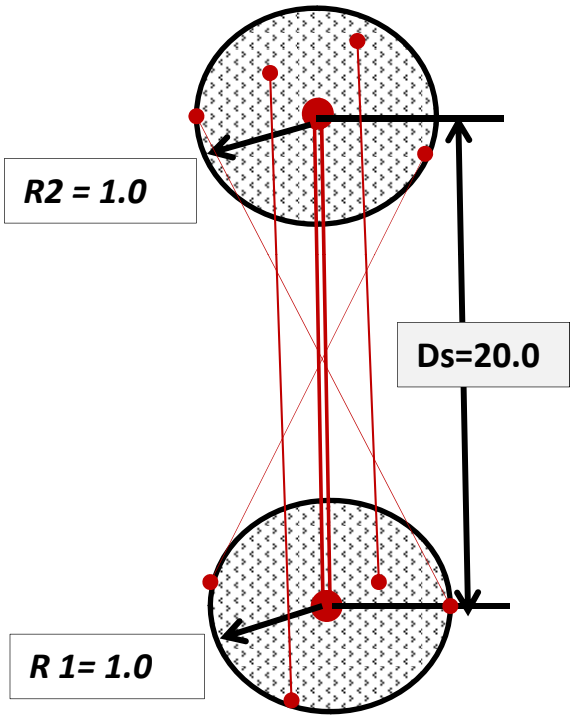
$$\sin\theta_M = \frac{R_1}{d_1} = \frac{R_2}{d_2} = \frac{R_1 + R_2}{D} \qquad \theta_M = \sin^{-1}\left(\frac{R_1 + R_2}{D}\right)$$

Robert Ferguson Simulation Results

Example Path: Ds/R = 20.0 Uniform and Weighted Probability Within Site Uncertainty Areas

Tabulate Cumulative Percentages of Azimuths Offsets from Central Path

Same Size Uncertainty Areas



Uniform Probability or Weighted Probability of Potential Sites w/i Areas

(578 Pts/Area – 334K "Links")

(Accuracy is "OK" with much fewer Pts)

Ds = 20.0	R1=1.0 R2=1.0	Wt =1.0/1.0 and Wt=0.1/0.1 at Edge				
Angle	Line Count w/I 0.25 Degree		Cumulative % > Angle			
(Degrees)	Non-Weighted	Weighted	Non-Wted		Weighted	
0.00	30364	5143.2	100.000	%	100.000	%
0.25	29671	5037.8	90.911	%	89.093	%
0.50	28877	4893.7	82.030	%	78.410	%
0.75	27547	4622.9	73.386	%	68.032	%
1.00	26162	4321.7	65.141	%	58.228	%
1.25	24578	3956.9	57.310	%	49.064	%
1.50	23002	3562.7	49.953	%	40.672	%
1.75	21124	3139.4	43.068	%	33.117	%
2.00	19360	2707.8	36.745	%	26.459	%
2.25	17538	2298.7	30.950	%	20.717	%
2.50	15756	1902.2	25.700	%	15.842	%
2.75	14045	1544.3	20.984	%	11.809	%
3.00	12313	1208.4	16.780	%	8.534	%
3.25	10511	920.0	13.095	%	5.971	%
3.50	8789	673.9	9.948	%	4.020	%
3.75	7269	479.4	7.318	%	2.591	%
4.00	5664	319.1	5.142	%	1.574	%
4.25	4338	201.4	3.446	%	0.897	%
4.50	3137	120.4	2.148	%	0.470	%
4.75	2067	61.4	1.209	%	0.215	%
5.00	1240	28.9	0.590	%	0.085	%
5.25	558	9.2	0.219	%	0.024	%
5.50	174	2.1	0.052	%	0.004	%

Note:

1. Max Angle from Center Line = 5.735 Deg (vs. 5.739 Geometry)

2. Cumulative Percentages include both Positive/Negative offsets

3. Weighted Taper: Linear Decrease 1.0 (Center) to 0.1 (Edge)

Ds/R = 20.0 For Example: Ds/R = 200 Ft/10 Ft, 500 Ft/25 Ft, 1000 Ft /50 Ft , 2000 Ft/100 Ft …

Robert Ferguson Simulation vs Analytic Results

$D/R_1 = 5$		$\eta = 0.1$	θ_{max}	$D/R_1 = 10$		$\eta = 0.1$	θ_{max}	$D/R_1 = 40$		$\eta = 0.1$	θ_{max}
θ	Simulation		12.71	θ	Simulation		6.32	θ	Simulation		1.58
Deg	Ferguson	Willis	Theory	Deg	Ferguson	Willis	Theory	Deg	Ferguson	Willis	Theory
0	100.00%	100.00%	100.00%	0.0	100.00%	100.00%	100.00%	0.000	100.00%	100.00%	100.00%
1	89.62%	88.982%	88.917%	0.5	88.89%	88.981%	88.916%	0.125	88.88%	88.982%	88.916%
2	79.25%	78.046%	77.923%	1.0	77.70%	78.040%	77.919%	0.250	77.70%	78.038%	77.918%
3	68.86%	67.268%	67.107%	1.5	67.03%	67.268%	67.097%	0.375	67.05%	67.266%	67.093%
4	58.61%	56.716%	56.566%	2.0	56.50%	56.702%	56.541%	0.500	56.54%	56.696%	56.533%
5	48.62%	46.489%	46.399%	2.5	46.25%	46.446%	46.352%	0.625	46.24%	46.432%	46.337%
6	39.05%	36.728%	36.717%	3.0	36.60%	36.650%	36.639%	0.750	36.57%	36.627%	36.615%
7	29.98%	27.604%	27.647%	3.5	27.46%	27.466%	27.532%	0.875	27.41%	27.422%	27.496%
8	21.58%	19.291%	19.340%	4.0	19.14%	19.098%	19.185%	1.000	19.05%	19.035%	19.137%
9	14.05%	11.966%	11.997%	4.5	11.77%	11.759%	11.804%	1.125	11.70%	11.698%	11.745%
10	7.62%	5.940%	5.910%	5.0	5.69%	5.746%	5.704%	1.250	5.63%	5.684%	5.639%
11	2.77%	1.793%	1.738%	5.5	1.67%	1.676%	1.597%	1.375	1.61%	1.642%	1.553%
12	0.40%	0.148%	0.137%	6.0	0.16%	0.128%	0.103%	1.500	0.14%	0.126%	0.093%
13		0.000%	0.000%	6.5		0.000%	0.000%	1.625		0.000%	0.000%

$$\eta = R_2 / R_1 = 0.1$$

Wide Area Augmentation System (WAAS) Equipped GPS

(See www.wikipedia.com - GPS WAAS)

WAAS GPS designed to meet 7.6 meter accuracy 95% of the time

Assuming errors follow a two dimensional Normal distribution

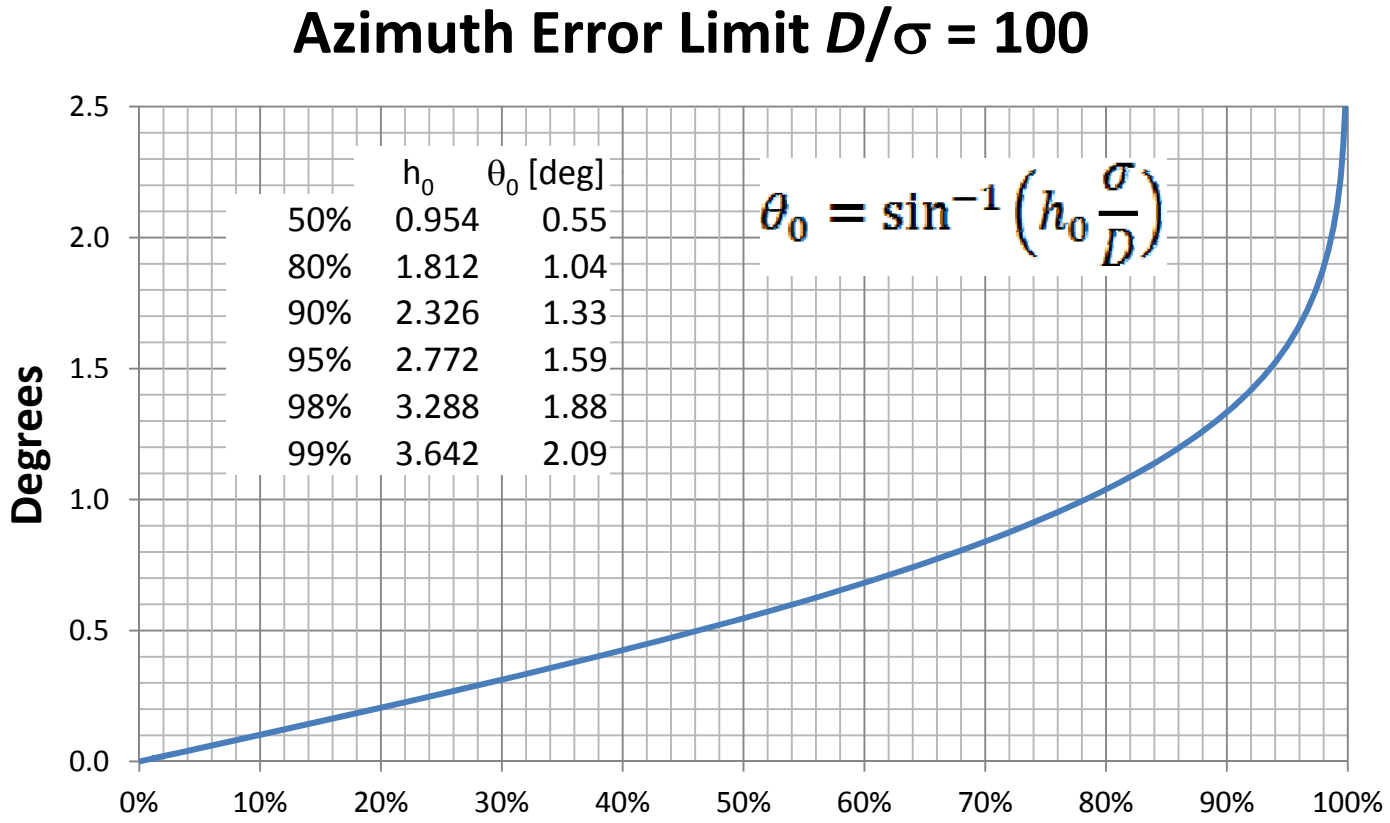
$$P(x,y) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2}$$

Implies the standard deviation is

$$\sigma = z/\sqrt{-2\ln(1-p)} = 7.6\text{m}/\sqrt{-2\ln(1-0.95)} = 3.1\text{m}$$

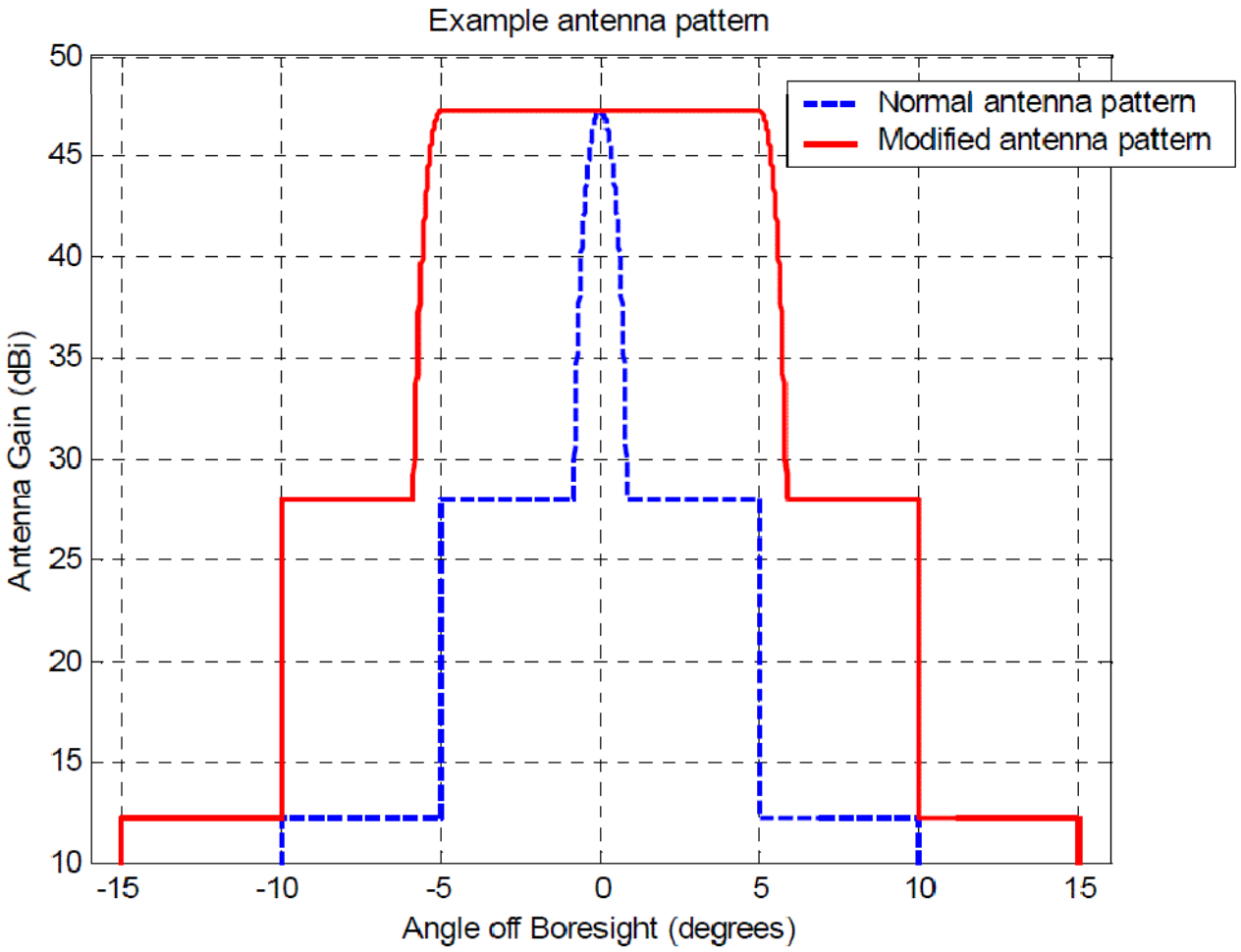
Example Azimuth Error Calculation

For a 310 m path with 3.1 m standard deviation $D/\sigma = 100$



WCAI Document WCA-PCG-7080-1

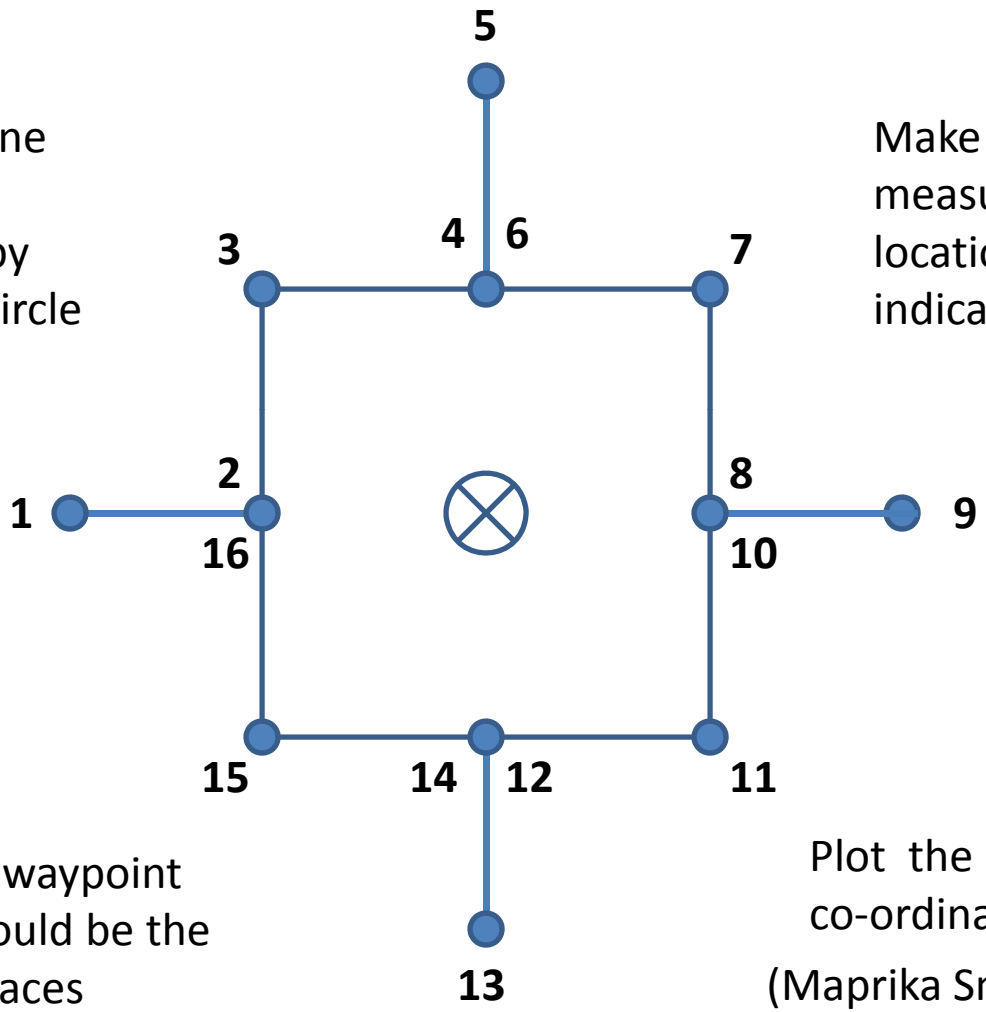
Path Coordination Guide for the 71-76 and 81-86 GHz Millimeter Wave Bands



Antenna pattern modified by pointing offset

Guerlain Hand Held GPS Siting Method

Task is to determine co-ordinates of location marked by the X within the circle



Make GPS waypoint measurements at locations and order indicated in diagram

Distance between waypoint measurements should be the same number of paces

Plot the 16 waypoint co-ordinates on a map

(Maprika Smart Phone Ap)

Guerlain Hand Held GPS Siting Method