East-West Exclusion Zones: Why Do We Have Them and How Can We Eliminate Them?

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Wellbore Positioning Technical Section

The Industry Steering Committee on Wellbore Survey Accuracy (ISCWSA)

Speaker Information

- September 22, 2016

Why Exclusion Zones?

Problem With Drilling East/West

- Axial Magnetic Interference (AMI) is dominant error source (Az)
- 50% more error than Declination

Problems With the Corrections

- Multiple solutions
- Degraded accuracy

Available Corrections

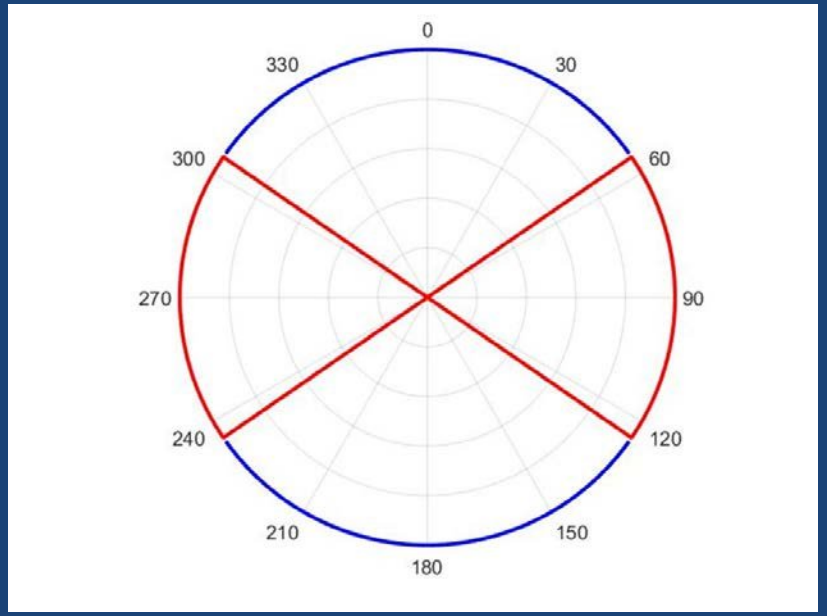
- Single Station Correction (SSC)
- Multi-Station Analysis (MSA)

Exclusion Zones for Horizontal Wells

Existing Standards (SPE 125677):

- BGGM
  - sin(Inc)*sin(Az) < 0.82
  - ±35° from East/West
- IFR1
  - sin(Inc)*sin(Az) < 0.91
  - ±25° from East/West

BGGM Exclusion Zone

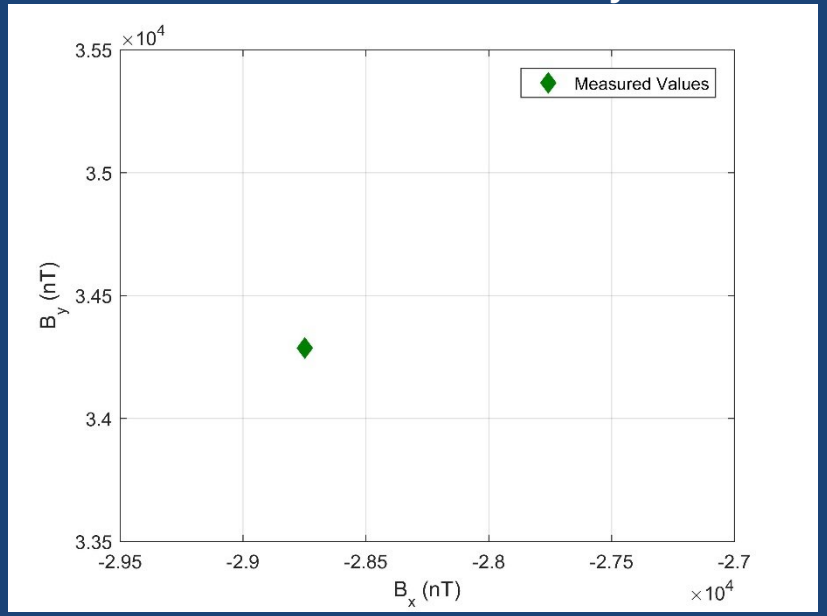


Multiple Solutions: SSC

Single Station Correction

- B_x and B_y are measured

Measured Value of (B_x, B_y)

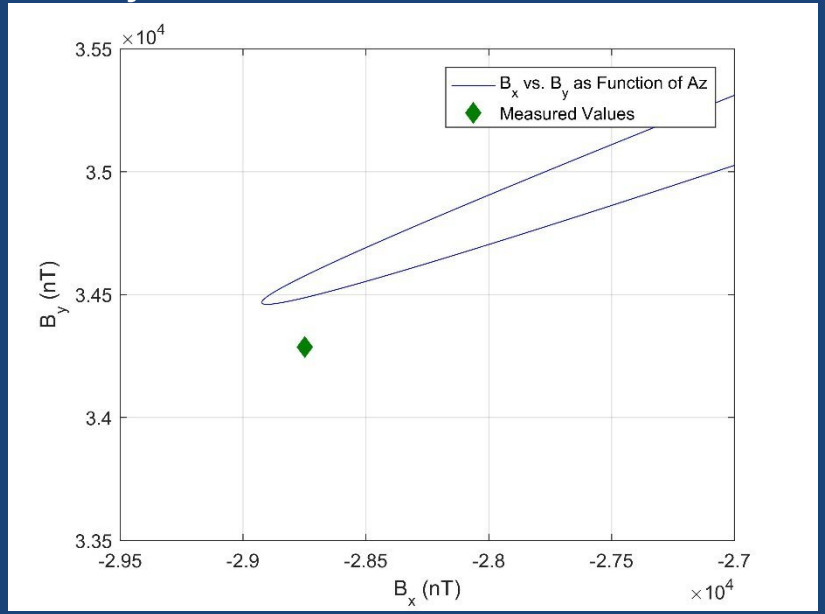


Multiple Solutions: SSC

Single Station Correction

- B_x and B_y are measured
- B_x and B_y are modeled as a function of Az using:
  - Reference Bt
  - Reference Dip
  - Measured Inc
  - Measured TF

(B_x, B_y) as a Function of Az

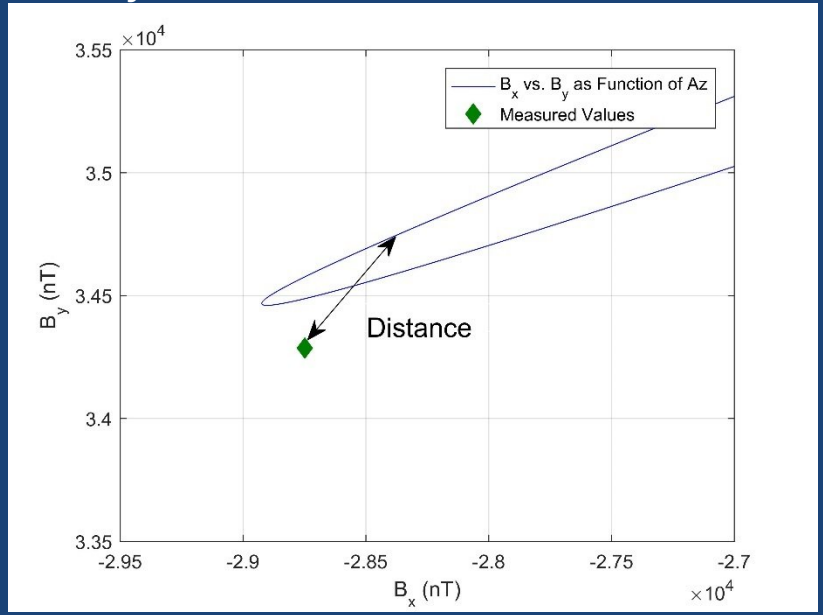


Multiple Solutions: SSC

Single Station Correction

- B_x and B_y are measured
- B_x and B_y are modeled as a function of Az
- Minimum distance between model and measurement is found

(B_x, B_y) as a Function of Az

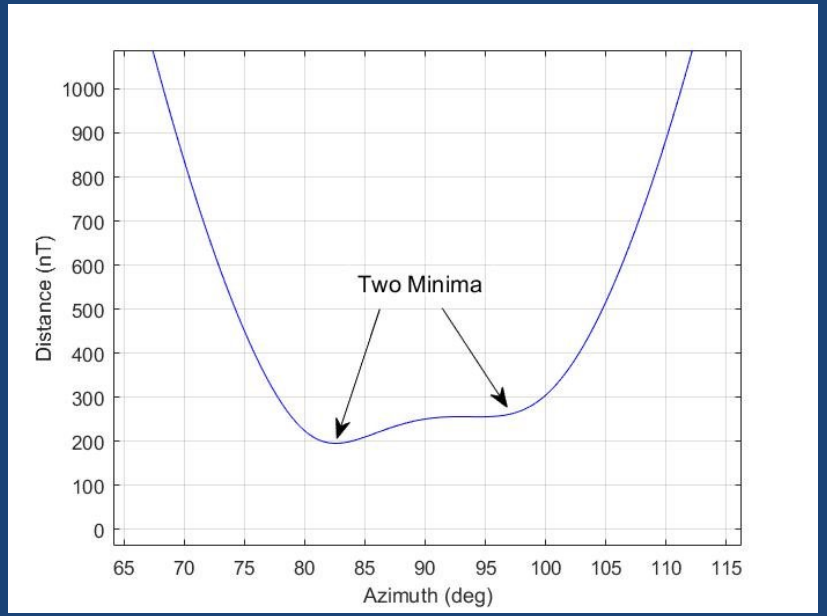


Multiple Solutions: SSC

Single Station Correction

- B_x and B_y are measured
- B_x and B_y are modeled as a function of Az
- Minimum distance between model and measurement is found

Distance from Meas. to Model

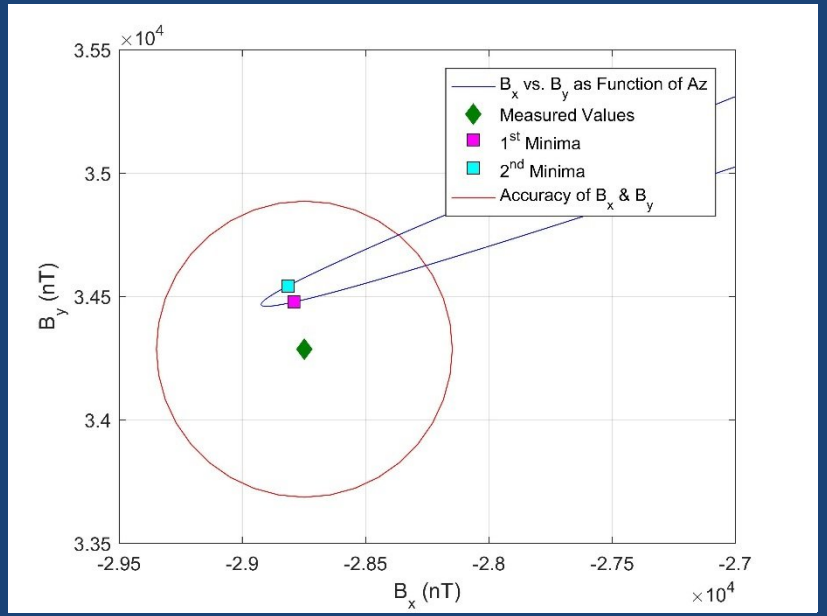


Multiple Solutions: SSC

What to Do?

- Consider uncertainty on
  - Reference Bt
  - Reference Dip
  - Measured Inc
  - Measured TF

Multiple Minima Inside 3σ Uncertainty

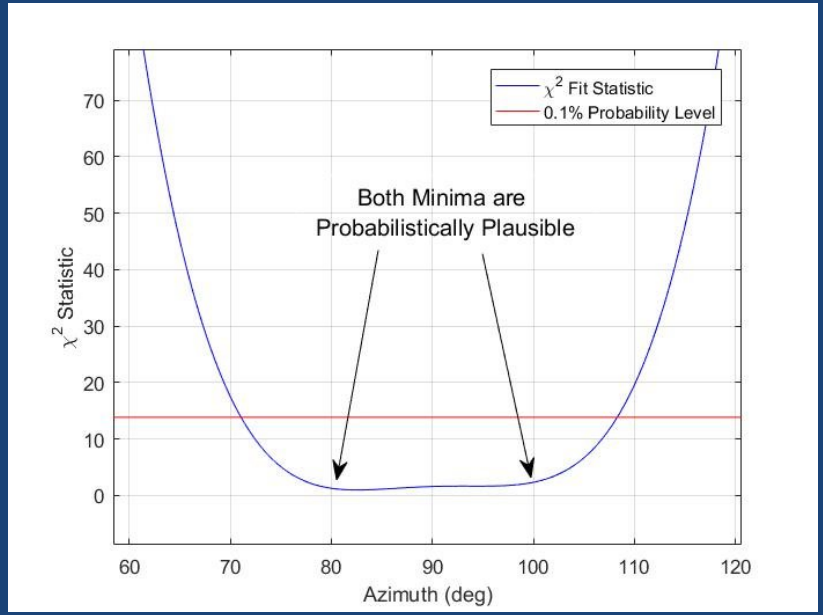


Multiple Solutions: SSC

What to Do?

- Consider uncertainty
- Map into χ^2 test
  - Reject minima w/ a probability of occurrence of < 0.1%
- If multiple minima remain, cannot trust solution

Distance as χ^2 Statistic

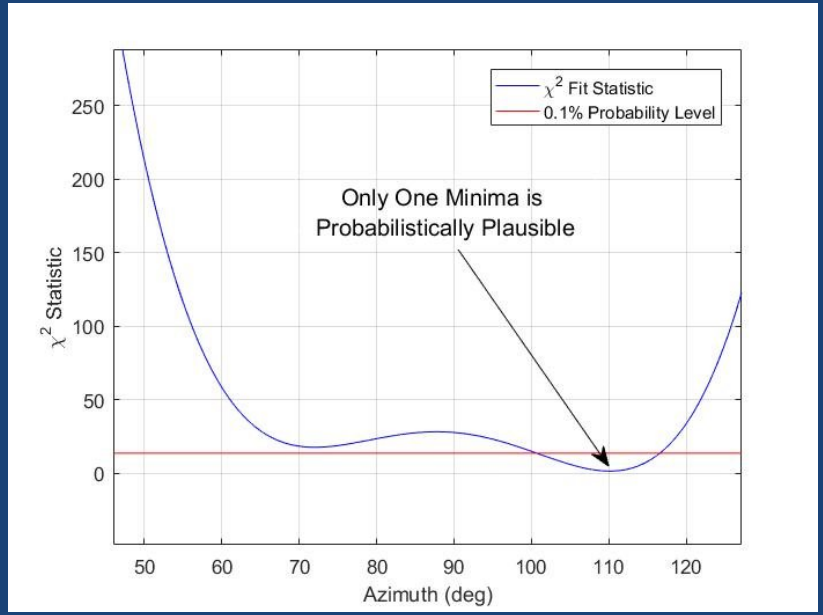


Multiple Solutions: SSC

Alternate Example

- Only 1 probabilistically plausible solution
- Ok to move forward with valid solution

Distance as χ^2 Statistic



Multiple Solutions: MSA

Similar to SSC

- Multiple solutions can exist
  - Not true that MSA can automatically replace SSC in an exclusion zone
  - Variation in wellbore direction can resolve
  - Required amount of variation is situation-dependent

Degraded Accuracy: SSC

Correction Not as Accurate as Standard MWD IPM near East/West

- Specific IPM derived to model accuracy of correction (‘+AX’)
- Accounts for effects of magnetic reference field errors

Degraded Accuracy: SSC

MWD+AX IPM

No	Code	Term Description	Wt.Fn.	Wt.Fn. Source	Type	Magnitude	Units	Prop.	P1	P2	P3	Wt.Fn. Comment
16	DECG	MWD: Declination - Global	AZ	SPE 67616	AziRef	0.36	deg	G	1	1	1	
17	DECR	MWD: Declination - Random	AZ	SPE 67616	AziRef	0.1	deg	R	0	0	0	
18	DBHG	MWD: BH-Dependent Declination - Global	DBH	SPE 67616	AziRef	5000	deg.nT	G	1	1	1	
19	DBHR	MWD: BH-Dependent Declination - Random	DBH	SPE 67616	AziRef	3000	deg.nT	R	0	0	0	
20	MDIG	MWD: Magnetic Dip with Z-Axis Corr - Global	MDI	SPE 67616 Table 1	Mgntcs	0.2	deg	G	1	1	1	
21	MDIR	MWD: Magnetic Dip with Z-Axis Corr - Random	MDI	SPE 67616 Table 1	Mgntcs	0.08	deg	R	0	0	0	
22	MFIG	MWD: Total Magnetic Field with Z-Axis Corr - Global	MFI	SPE 67616 Table 1	Mgntcs	130	nT	G	1	1	1	
23	MFIR	MWD: Total Magnetic Field with Z-Axis Corr - Random	MFI	SPE 67616 Table 1	Mgntcs	60	nT	R	0	0	0	
24	SAG	MWD: Sag	SAG	SPE 67616	Align	0.2	deg	S	1	0	0	
25	XYM1	Misalignment: XY Misalignment 1	XYM1	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	
26	XYM2	Misalignment: XY Misalignment 2	XYM2	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	
27	XYM3	Misalignment: XY Misalignment 3	XYM3	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	Singularity when vertical
28	XYM4	Misalignment: XY Misalignment 4	XYM4	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	Singularity when vertical

Degraded Accuracy: MSA

More Complicated Version of SSC

- 100+ different possible parameter combinations
  - Each solution will have a different accuracy
  - Would require 100+ different IPM's to model

Degraded Accuracy: MSA

MWD+IFR1+MS IPM

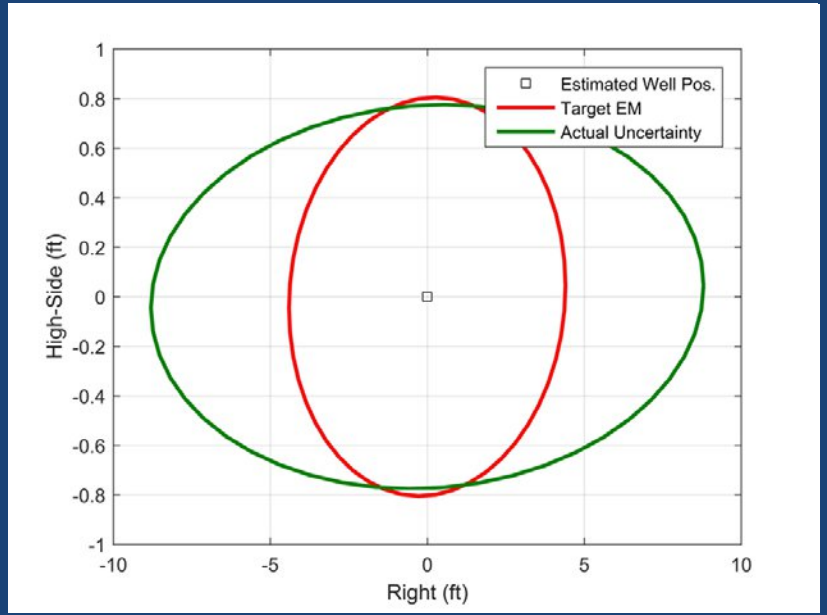
No	Code	Term Description	Wt.Fn.	Wt.Fn. Source	Type	Magnitude	Units	Prop.	P1	P2	P3	Wt.Fn. Comment
17	MSZ	MWD: Z-Magnetometer Scale Factor	MSZ	SPE 67616 Table 1	Sensor	0.0008	-	S	1	0	0	
18	DECG	MWD: Declination - Global	AZ	SPE 67616	AziRef	0.15	deg	G	1	1	1	
19	DECR	MWD: Declination - Random	AZ	SPE 67616	AziRef	0.1	deg	R	0	0	0	
20	DBHG	MWD: BH-Dependent Declination - Global	DBH	SPE 67616	AziRef	1500	deg.nT	G	1	1	1	
21	DBHR	MWD: BH-Dependent Declination - Random	DBH	SPE 67616	AziRef	3000	deg.nT	R	0	0	0	
22	AMIL	MWD: Axial Interference - [illegible]	AMIL	Halli[illegible]	Mgntcs	100	nT	S	1	0	0	
23	SAG	MWD: Sag	SAG	SPE 6761[illegible]	Align	0.2	deg	S	1	0	0	
24	XYM1	Misalignment: XY Misalignment 1	XYM1	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	
25	XYM2	Misalignment: XY Misalignment 2	XYM2	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	
26	XYM3	Misalignment: XY Misalignment 3	XYM3	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	Singularity when vertical
27	XYM4	Misalignment: XY Misalignment 4	XYM4	SPE 90408 Table 9 - Alt. 3	Align	0.1	deg	S	1	0	0	Singularity when vertical

Degraded Accuracy: MSA

What Can We Do?

- '+MS' error model does not model the accuracy of MSA corrections
- No published requirements exist to check for valid use
- Best option is to calculate accuracy directly for chosen solution

Solution EOU vs. '+MS' EOU

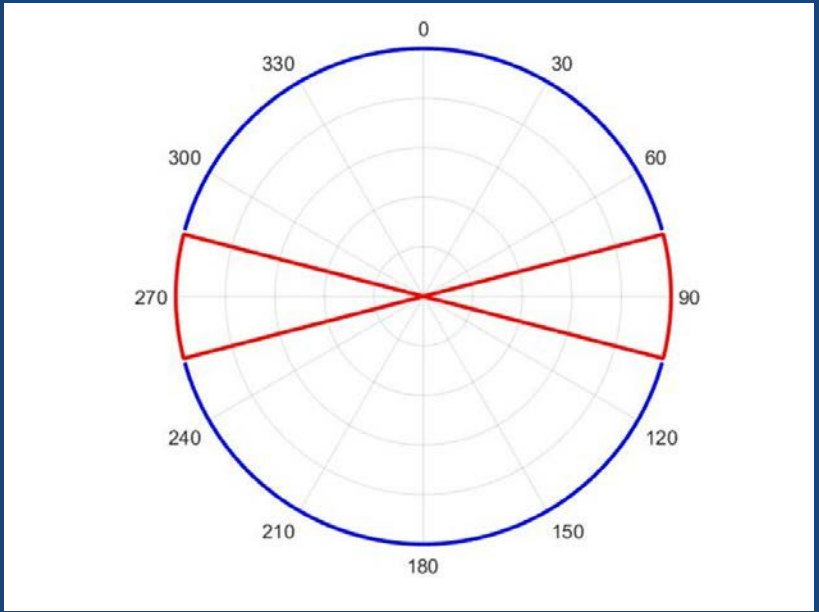


Drilling Safely East/West

If AMI corrections are required:

- Check for multiple solutions
- Ensure IPM assigned to corrected surveys does not overstate accuracy

MSA Exclusion Zone for Horizontal Wellbores: ±15°

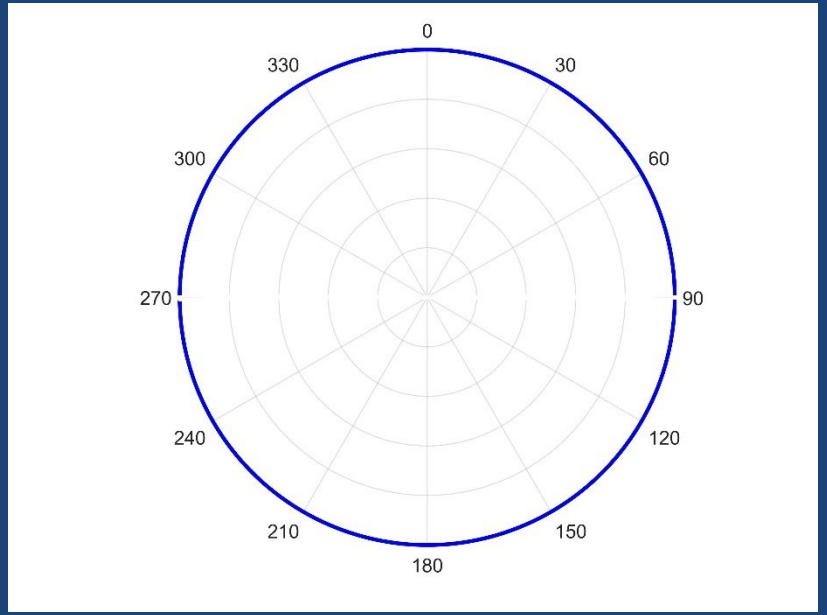


Eliminating the Exclusion Zone

Including Part of the Build in the Lateral:

- Start lateral at 80° Inclination
  - Exclusion Zone is ±5°
- Start lateral at 70° Inclination
  - Exclusion Zone is eliminated

MSA Exclusion Zone with Part of Build Included in Lateral



Conclusion

- Axial Magnetic Interference (AMI) maps into large Azimuth errors when drilling East/West
- SSC & MSA have problems
  - Multiple solutions
  - Degraded accuracy
- Can reduce ±35° exclusion zone by
  - Checking probabilistic plausibility of extra solutions
  - Validating target IPM against calculated accuracy of corrections (MSA)