Drillstring Magnetic Interference

ISCWSA MWD Error Model Terms

Harry Wilson ISCWSA 38, New Orleans, 3 October 2013



MWD Magnetic Azimuth

- Dominant error sources:
 - Uncertainty associated with nominal declination angle
 - Z axis disturbance field from magnetised BHA components
- Both quantified in the MWD (basic) error model

ISCWSA MWD Error Model

1	ISCV	VSA MWD, Rev. 2	2 (Sta	ndaro	d) De	tails				-	X
	Term	Value (1 sig	D	I	A	Description	Depth weighting function	Inclination weighting function	Azimuth weighting function	Prop. Meth	Correcti
	ABX	0.004 m/s ²	1	1	1	x-accelerometer bias	0	- cosI*sina/Gt	[tanq*(cosI*sinAm*sina - cosAm*cosa) + cotI*cosa]/Gt	Systematic	Standard
	ABY	0.004 m/s ²	1	1	1	y-accelerometer bias	0	- cosI*cosa/Gt	[tanq*(cosI*sinAm*cosa + cosAm*sina) - cotI*sina]/Gt	Systematic	Standard
	ABZ	0.004 m/s ²	1	1	1	z-accelerometer bias	0	- sinI/Gt	tanq*sinI*sinAm/Gt	Systematic	Standard
l	AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm	Systematic	Standard
	AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180	Systematic	Standard
	ASX	0.0005 fract	1	1	1	x-accelerometer scale factor	0	sinI*cosI*sin2a	- [tanq*sinI*(cosI*sinAm*sina - cosAm*cosa) + cosI*cosa]*sina	Systematic	Standard
	ASY	0.0005 fract	1	1	1	y-accelerometer scale factor	0	sinI*cosI*cos2a	- [tanq*sinI*(cosI*sinAm*cosa + cosAm*sina) - cosI*sina]*cosa	Systematic	Standard
	ASZ	0.0005 fract	1	1	1	z-accelerometer scale factor	0	- sinI*cosI	tanq*sinI*cosI*sinAm	Systematic	Standard
	AZ	0.36 °	1	1	1	Magnetic declination uncertainty	0	0	p/180	Global	Standard
	DBH	5000 deg-nT	1	1	1	Magnetic declination uncertainty	0	0	p/180/(B*cosq)	Global	Standard
	DREF	0.35 m	1	1	1	Depth reference, random	1	0	0	Random	Standard
	DSF	0.00056 fract	1	1	1	Depth scale factor, systematic	D	0	0	Systematic	Standard
	DST	2.5e-007 1/m	1	1	1	Depth stretch/temperature, global	D*V	0	0	Global	Standard
	MBX	70 nT	1	1	1	x-magnetometer bias	0	0	(cosAm*cosa - cosI*sinAm*sina)/(B*cosq)	Systematic	Standard
	MBY	70 nT	1	1	1	y-magnetometer bias	0	0	- (cosAm*sina + cosI*sinAm*cosa)/(B*cosq)	Systematic	Standard
	MBZ	70 nT	1	1	1	z-magnetometer bias	0	0	- sinI*sinAm/(B*cosq)	Systematic	Standard
	MSX	0.0016 fract	1	1	1	x-magnetometer scale factor	0	0	(cosI*cosAm*sina - tanq*sinI*sina + sinAm*cosa)*(cosAm*cosa	Systematic	Standard
	MSY	0.0016 fract	1	1	1	y-magnetometer scale factor	0	0	(- cosI*cosAm*cosa + tanq*sinI*cosa + sinAm*sina)*(cosAm*sin	Systematic	Standard
	MSZ	0.0016 fract	1	1	1	z-magnetometer scale factor	0	0	- sinI*sinAm*(sinI*cosAm + tanq*cosI)	Systematic	Standard
	MXY	0.06 °	1	1	1	xy tool misalignment, systematic	0	p/180*[1 + FIw*(sinI - 1)]	0	Systematic	Standard
ł	MXY	0.06 °	1	1	1	xy tool misalignment, systematic	0	0	- p/180*[1 + FIw*(sinI - 1)]/sinI	Systematic	Standard
	MXY	0.06 °	1	1	1	xy tool misalignment, systematic	0	p/180*FIw* cosI *cosAt	- p/180*FIw* cosI *sinAt/sinI	Systematic	Standard
	MXY	0.06 °	1	1	1	xy tool misalignment, systematic	0	p/180*FIw* cosI *sinAt	p/180*FIw* cosI *cosAt/sinI	Systematic	Standard
	SAG	0.2 °	1	1	1	BHA sag	0	p/180*sinI	0	Systematic	Standard



Axial Drillstring Interference

- Cause
- Effect

Axial Drillstring Interference

- Induced magnetisation
 - Not included in the ISCWSA model
- Remnant/Permanent magnetisation
 - Included in ISCWSA model

ISCWSA Error Terms

1	sigma							
AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

- Why SinISinA?
- Why AMIF?

ISCWSA Error Terms

I	sigina							
AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

Total DSI = sqrt(AMID² + AMIF²)

- 0.25° at vertical or north/south
 - But zero positional effect at vertical
- 0.65° at horizontal, east/west
- Need for fixed term may be questioned
- Values are arbitrary

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ISCWSA Model Bias Option

1	CIO	mo
	510	110
	<u> </u>	
	<u> </u>	

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

- AMID
 - Treated as biased error displacing mean towards equator by 0.33°
 - Uncertainty reduced to 0.5°
- Now not recommended by ISCWSA

BHA Conformance with Model's Assumption

• Pre-job

- Test BHA spacing for compliance with model's assumption

• While drilling

- Dip and Bt QC tests include DSI uncertainty per error model

- Geomag location matters
 - Azimuth "signal" is B_H
 - BHA Interference-Field_H is a competing signal
 - Resultant azimuth signal is the vector sum of the two

Example Location: Offshore, Louisiana

Location: Offshore, Louisiana

Well Profile Geomagnetic Values Inclination 90.00 deg Mag Azimuth 90.00 deg Use Mag Ref Dip Uncert. 0.19 deg B total Uncert.	45744 nT 130 nT
Setup Results XY scale (expert use only)	
Error Model Used in Well Planning O INTEQ O ISCWSA O BP Tool Type DAS B total Uncert.	76 nT
BHA Configuration No intermediate steel	
Length 40.0 45.0 75.0	Î ft
Tool 8"motor Info	8'' collar 🗨
Pole Enable Input Fields NOTE: pole strengths must be specified at 1 sigma, i.e. 68.3% probability Strength 240	370 uWb

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• Result (90Inc/90Az)

- Uncorrected Option-				
	This BHA	Max Allowed		
Azimuth Uncert.	0.88	1.95	deg	PASS
Bz Uncert.	388	857	nT	

- "Max Allowed" is error model assumption scaled to 3 sigma
- "This BHA" also scaled to 3 sigma

Location: Offshore, Louisiana

Well Profile			- Geomagnetic Val	ues	 				
Inclination	30.00	deg		Dip	56.61	deg	B total	45744	nT
Mag Azimuth	60.00	deg	Use Mag Ref	Dip Uncert.	0.19	deg	B total Uncert.	130	nT

Location: Offshore, Louisiana

• 30Inc/60Az

Г	-Uncorrected Option-				
		This BHA	Max Allowed		
	Azimuth Uncert.	0.38	1.08	deg	PASS
	Bz Uncert.	388	1098	nT	

Location: Offshore, Louisiana

• 30Inc/60Az



Max Allowed Bz Uncert feeds into QC test limit values

• 30/60



Location: North Slope, Alaska

-Well Profile		magnetic Values					
weinnome		magnetic values	0.0 4 7				_
Inclination 9	0.00 deg	— Dip	80.17	deg	B total	57463	nT
		se Mag Ref					_
Mag Azimuth 9	0.00 deg 🗀	Dip Uncert.	0.19	deg	B total Uncert.	143	nT
Mag Azimuth 9	0.00 deg	se Mag Ref Dip Uncert.	0.17	aeg deg	B total B total Uncert.	143	ni nT

Pre-Job QC of BHA – Example - Alaska

30/60

Γ	Uncorrected Option—	This BHA	Max Allowed		
	Azimuth Uncert.	0.98	1.08	deg	PASS
	Bz Uncert.	388	428	nT	
	90/90				
Г	Uncorrected Option—				
Γ	Uncorrected Option—	This BHA	Max Allowed		
	Uncorrected Option Azimuth Uncert.	This BHA 2.27	Max Allowed	deg	FAIL
Γ	Uncorrected Option Azimuth Uncert. Bz Uncert.	This BHA 2.27 388	Max Allowed 1.95 334	deg nT	FAIL

Must increase non-mag spacing

Why did it fail?

- Geomag location matters
 - Azimuth "signal" is B_H
 - Dip sensitive
 - BHA Interference-Field_H
 - Inc/Az sensitive

QC at Low Inclination or N/S

• 0/0, 90/0, 90/180

	Uncorrected Option —				
		This BHA	Max Allowed		
	Azimuth Uncert.	0.00	0.75	deg	PASS
	Bz Uncert.	388		nT	
	• 10/10				
ſ	– Uncorrected Option —				
		This BHA	Max Allowed		
	Azimuth Uncert.	This BHA 0.07	Max Allowed 0.75	deg	PASS
	Azimuth Uncert. Bz Uncert.	This BHA 0.07 388	Max Allowed 0.75 4269	deg nT	PASS
	Azimuth Uncert. Bz Uncert.	This BHA 0.07 388	Max Allowed 0.75 4269	deg nT	PASS
	Azimuth Uncert. Bz Uncert.	This BHA 0.07 388	Max Allowed 0.75 4269	deg nT	PASS
	Azimuth Uncert. Bz Uncert.	This BHA 0.07 388	Max Allowed 0.75 4269	deg nT	PASS
	Azimuth Uncert. Bz Uncert.	This BHA 0.07 388	Max Allowed 0.75 4269	deg nT	PASS

- Values are arbitrary
 - Therefore BHA must conform
- Weighting function models attitude sensitivity
- Biased option not recommended
- Uncertainty is not location dependent
 - Therefore spacing requirement is location dependent
- QC tests insensitive at low Inc and N/S

Alternative Quantification

ISCWSA Standard

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

Alternative Quantification

ISCWSA Standard

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

Alternative to AMID

AMIBZ 150 nT 1 1 1 Axial magnetic interference, Bz bias 0 0 - sinI*sinAm/(B*cosq)

- Bz bias effect, not azimuth
- Value still arbitrary
- Geomag location dependent via B*CosDip weighting
- AMIF (AZ) optional

Alternative Quantification

ISCWSA Standard

AMID	0.6 °	1	1	1	Axial magnetic interference, systematic	0	0	p/180*sinI*sinAm
AMIF	0.25 °	1	1	1	Axial magnetic interference, fixed	0	0	p/180

Alternative to AMID

AMIBZ 150 nT 1 1 1 Axial magnetic interference, Bz bias 0 0 - sinI*sinAm/(B*cosq)

Adopted by ISCWSA Operator Wellbore Survey Group (AMIL)

Pre-Job QC of BHA – Alternative Error Term

 Location: Offshore, Louisiana 	Error Model Used in Well Planning INTER O ISCWSA O BP				
• 30/60	Non-mag. Spacing Standard				
This PUA May A	llowed				
Azimuth Uncert. 0.38 Bz Uncert. 388	0.44 deg 450 nT PASS				
• 90/90					
- Uncorrected Option					
This BHAMax AlleAzimuth Uncert.0.88Bz Uncert.388	owed 1.02 deg 450 nT PASS				

Pre-Job QC of BHA – Alternative Error Term

- Location: North Slope, Alaska
- 30/60

- Uncorrected Option- Azimuth Uncert. Bz Uncert.	This BHA 0.98 388	Max Allowed 1.14 450	deg nT	PASS
• 90/90				
- Uncorrected Uption				
	This BHA	Max Allowed		
Azimuth Uncert.	2.27	2.63	deg	
Bz Uncert.	388	450	nT	PASS

Pre-Job QC of BHA - Comparison

Location: Offshore, Louisiana, 90/90

Standard



Pre-Job QC of BHA - Comparison

Location: North Slope, Alaska, 90/90

Standard



QC at Low Inclination or N/S

10/10 • Standard				
- Uncorrected Option Azimuth Uncert. Bz Uncert.	This BHA 0.07 388	Max Allowed 0.75 4269	deg nT	PASS
 Alternative 				
- Uncorrected Option Azimuth Uncert. Bz Uncert.	This BHA 0.07 388	Max Allowed 0.08 450	deg nT	PASS

Error Model Variants - Spacing Options

 Single non-mag spacing option may be too restrictive

Error Model Used in Well Planning							
● INTEQ ○ I	SCWSA	O BP					
Non-mag. Spacing	Standard 💌						
	Standard						
BHA Configuration	Short	e steel					
	Long						

Tool type	OnTrak
Model name	OnTrak (Long spacing)
Comment	
Standard Cu	stom Cone of uncertainty
Author wils	harf
Corrections Depth SAG Magnetic Dual Inc	c
Applications Drill pipe Single sl Floater Logging Bent sub	speed
	Long spacing (Long magnetic spacing) Short spacing (Short magnetic spacing)

- Error terms model permanent magnetisation
- Fixed value term contributes uncertainty even at north/south
- Arbitrary term values
 - Therefore BHA must be evaluated for compliance with model
- Weighting function models attitude sensitivity



ISCWSA terms

- Uncertainty is not location dependent
- Therefore spacing requirement is location dependent

Alternative term

- Uncertainty is location dependent
- Therefore spacing requirement is not location dependent
- Compliance more likely?
- Single spacing option is restrictive



- Survey QC tests should include model's DSI contribution
- ISCWSA terms result in QC tests that catch out-of-spec Az, but not out-of-spec condition
- ISCWSA terms reduce QC sensitivity at low inc and N/S
- QC tests derived from alternative term catch out-of-spec condition, but can trip with insignificant Az error

