The coordinate system

Normally, the Horizontal coordinate system is used for such systems in EMIGMA.



Horizontal Coordinate System

_direction of unit vectors change with profile direction
\$\hat{X}\$ and \$\hat{Y}\$ are horizontal and \$\hat{Z}\$ is up.
\$\hat{X}\$ is directed parallel to the tangent of the profile at each station.
\$\hat{Y}\$ is perpendicular to the tangent at each station
\$\hat{tangent}\$ the station locations are your normal GPS or grid values

Transmitters and Receivers



System Components •_the transmitter and receiver are both wound coils • a current is injected into the transmitter coil and this produces a magnetic moment. • the magnetic field caused by the transmitter and the ground running through the receiver coil produces a voltage which is output • the voltage output can be converted to a value of magnetic field coupling with the coil if desired • the measured magnetic field is aligned with the moment of the receiver coil • mathematically the source and receiver are defined as point electric dipoles – this is satisfactory as the coils are small with respect to the tx-rx separations

Data Processing



_ **↑**Imag

output voltage (w) or (f)

Re complex plane

Normalization



Instrument Aspects

 \circ a square wave current of a certain frequency is injected into the transmitter

the fundamental harmonic of this boxcar is extracted in the receiver which produces a real part and an imaginary part
the real part is inphase with the current in the transmitter
the imaginary part is out of phase with the current

Inphase – a common name for the real part of the output Quadrature – a common name for the imaginary part of the output

Normalization

the strongest field is that directly from the transmitter which contains no part of the ground response
this direct (primary) field is inphase and can be computed if the coil strength and the current are known
this primary field is removed from the output voltage either by computation or by the use of a bucking coil (e.g. airborne systems)
the remaining voltage is the ground response
the remaining or secondary voltage is then divided by the primary voltage which was previously subtracted
the resulting voltage output is then dimensionless
depending upon the manufacturer the resulting voltage can be adjusted to different units



Additional Comments

• in an airborne system, the tx and rx and housed in a bird which is flexible during flight and thus normally a bucking coil is used to reduce and normalize to the primary response

 \circ in the PROMIS system, 3 components of the secondary field are measured simultaneously and so the coil orientation of tx and rx should be made accurately

 \circ in the older MaxMin system, one can measure Hx as well as Hz but the orientation of the receiver coils in both cases must be made accurately

Data Units

<u>Data Units</u> • the raw response is always calculated according to the formula below • this ratio, however, can be expressed in various units as below

Response (Re, Im) = { Measured Voltage (Re,Im) – Primary Field }

Primary Field

InPhase Units – Percent (%), PPT, PPM Quadrature Units – Percent (%), PPT, PPM, apparent conductivity

Data Units Apparent Conductivity

it should be noted that the word "apparent" is extremely important for understanding these units
this does mean actual conductivity, but rather the ratio expressed in terms of an approximate formula
which represents an equivalent halfspace for the ground and not the actual ground conductivity
the formula assumes a halfspace for the ground and then only one (1) term in the accurate representation
from physical principles of such a system

Data Units – apparent conductivity

Data Units Apparent Conductivity

 \circ it should be noted that the word "apparent" is extremely important for understanding these units \circ this does mean actual conductivity, but rather the ration expressed in terms of an approximate formula which represents an equivalent halfspace for the ground and not the actual ground conductivity \circ the formula assumes a halfspace for the ground and then only one (1) term in accurate representation of such a system from physical principles \circ in the formula below "s" is the distance between transmitter and receiver. This formula assumes no effect from the (1/s) term in the response \circ if indeed the ground is a halfspace then the expression is most accurate when the induction number, $[\sigma \omega v_0 s^2]$ is small

$$\sigma_{app} = \frac{4}{\omega v_0} \frac{(H)_{quadrature}}{H_{primary}}$$

Tx-Rx separations in EMIGMA



Tx-Rx separations in EMIGMA

Some Examples

standard horizontal coplanar inline system configuration (HCP): Tx - Mz ; Rx - Hz; separation (dx, 0, 0) [EM38 - (1,0,0), EM31 - (3.66,0,0)
standard horizontal coplanar crossline system configuration (HCP): Tx - Mz ; Rx - Hz; separation (0, dy, 0)
standard vertical coplanar in line system configuration (VCP): Tx - My ; Rx - Hy; separation (dx, 0, 0)
standard vertical coplanar crossline system configuration (broadside VCP): Tx - Mx ; Rx - Hx; separation (0, dy, 0)

Configuration Page Example in EMIGMA – EM38

Tx-Rx			X	
System Name	 System	Type Moving Tx, Moving Rx		
1. System Mode EM/IP/Resistivity Coord.System:	Horizontal: X horizontal along profile, Z vertica 💌	Separation(s) (moving system) i	nput>	
C Fixed C Moving 2. Transmitter Type 1. TX-DIPOLE C Coil C current Dipole Loop Pole Dipole Moment (Amp*m^2) 1	Mz My Mx	SEP-REF-POINT AT CENTER # X Y 1. 1.0000e+000 0.0000e+000 0.0000e 2. 0.000e+000 1.000e+000 0.000e	Z ++000 ++000	
Tx/Rx Replacement Mode Receiver Add Replace Multiple Tx Generator Coord System: 3. Receiver Type Coord System: Coil Voltage Dipole Loop Pole Receiver Input> Receiver Input>	Horizontal: X horizontal along profile, Z vertice Hx Hy Hz	Tx Rx 1 3 2 2 1 3 3 1	Create Comp Sep 1 1 2 R	1. Mz, Hz, (1,0,0) 2. My, Hy, (1,0,0)
Ip/Res System Wizard				3. Mz, Hz, (0,1,0) 4. Mx, Hx, (0,1,0)
	< B)	ack Next > Cancel	Help	

System Configurations

○ 1: *standard HCP*

0 2: standard VCP

o 3: standard HCP crossline

0 4: standard VCP crossline, broadside

Opening a database





10

1		 Em34 Em31/Em38 EM31-R Max-Min Fugro AeroQuest Unknown EM31-R System Name 	Import Select & For other s and give it	ting Da System systems sele t a name	ata – 2 ect Unknown
	2	Input Filename File View Select on Import Data file Look in: coll_head.xyz File name: File name: Files of type: XYZ Files (*.xyz) EMIG	re line as the header	Brows Set header line Apply first Multiplier Apply first Separation Separation M C C C C C C C C C C C C C C C C C C	Browse for XYZ columnar datafile

outs. I	mport Wizard	l Step 1.					
loc	ut Filonomo	E:\intern\EDE	M demo datal	hase\rawdata\ch1_l	head xuz		Prowee
	achiename				iouu.iye		DIOWSE
File	View		Selec	t one line as the hea	ader		
			CP1990051			9	Set header line
L	NE1		CH300031				
55	3262.654311	4180924.072563	97.750000	15.900000 154.2	50000 20.478	Ap	oly first Multiplier
55	3262.654004	4180924.072665	94 500000	15.880000 159.0 15.90000 159.2	000000 20.47		
	0202.0003402	4100324.072040	34.300000	15.000000 153.2		App	ly first Separation
				Concelier	<u>ت</u>		
	Frequen	icy Tx- Tv	- Rx Orientation B	v Multipler	ן ארי	「x - Rx Sepa dY	ration dZ
	9800		- Z	- -	1 1	0	
	0000						
I v	9800				2	U	
☑	9800	Z	• Z	- 1	3.66	0	0
	N					0	
	<u>k</u>	_ !					
	0		7	▼ 1	0	0	0

If your file does not contain a Header line with our specific annotation then use 'Set Header line' to set the header. Use the provided example file for assistance.

	• I=	nort Minore	I Chap 1									
JUC	s. III	iipurt w izart	гэтер									
	Inpu	ıt Filename	E:\ir	nterp\FDE	M_der	no_datal	base\raw	/data\cb1_h	ead.xyz	-	Brow	se
			1									
	File	View				Selec	t one line	e as the hea	der			1
	77	UTM_X_UTN	4_Y CP	Q9800S1	CPI9	B00S1	CPQ980	DS2 CP1980)0S2 CPQ98(<mark>-</mark>	1.	Set head	ler line
	LIN 553	IE1 3262 654311	418092	4 072563	97	750000	15 900	100 154 25	0000 20 478	1		
	553	3262.654004	418092	4.072665	101	1.000000	15.88	0000 159.0	00000 20.47		Apply first f	Multiplier
	553	3262.653462	418092	4.072846	94.	500000	15.860	00 159.25	0000 20.478	1	Applu first S	enaration
				_				Correction	<u> </u>			oparation
		Frequer	юу	Tx · Tx	Rx Or	ientation R	×	Multipler	ъ	Tx - Rx	Separation dY	ďZ
	☑	9800		Z	•	Z	•	1	1	0	0	
	◄	9800		Z	•	Z	-	1	2	0	0	
	☑	9800	_	Z	-	Z	-	1	3.66	0	0	
					v		-	1	0	Ι	(
		jo l			-		~	1	0	0	í	

Note 1: Dipole orientations may be X,Y, or Z. These are in reference to the 'Horizontal" co-ordinate system (Manual). For example, Z-Z is horizontal co-planar and Y-Y or X-X or vertical coplanar. Y is perpendicular to line and X is tangential to the line.

Note 2: Separations may be dX, dY or dZ. dX is along line while dY is across line. For example, a dipole configuration with X-X and a separation of (0,dy,0) is vertical coplanar 'broadside'.

Format. Import Wizard Step 2.

File Header View: // UTM_X_UTM_Y_CPQ980 LINE1 553262.654311 4180924.07 553262.654004 4180924.07 553262.653462 4180924.07	Select the suitab 0051 CPI980051 0 2563 97.750000 0 2665 101.000000 0 2846 94.500000 0	le line to define data format CPQ9800S2 CP19800S2 Cf 15.900000 154.250000 24 0 15.880000 159.000000 3 15.860000 159.250000 24 15.850000 159.250000 24	Construction and the start of a new profile Construction and the
Location (column#, name)			
	Frequency F-1, Inphase F-1, Quadra.	Column#, Frequency 4 CPI9800S • 9800 3 CPQ98005 •	Column#, name _F.equency
□ Z □ dZ: alt bird	🔽 F-2, Inphase 🖅 r-2, Quadra.	S CP19800S • 9800 5 CP09800(•	F-7, Inphase F-7, Quadra.
.45ierault Unit meter feet	✓ F-3, Inphase✓ F-3, Quadra.	8 CPI9800S 9800 7 CPQ9800(9800	F-8, Inphase F-8, Quadra.
GPSZ	 F-4, Inphase F-4, Quadra. 		F-9, Inphase P
Fiducial	F-5, Inphase F-5, Quadra.		F-10, Inphase F-10, Quadra. F-10, Quadra.
Units (Inphase) O Percent O PPT	© PPM	Units (Quadrature)	PPT C PPM © mS/m
4		< Back	Next > Cancel Help

☑ Check that the import has recognized the columns correctly.

Set the height of the instrument.

Check the data units.

Note:

mS/m is not an actual data unit. The data has been converted by the instrument manufacturer through an approximation to this unit. EMIGMA converts it back to the original data units. You may later display in these approximate units.

Profiles and Local	ions		
Profile LINE1	# Locations 417	Total Number of Profiles:	14
LINE2 LINE3 LINE4 LINE5 LINE6 LINE6 LINE7 LINE8 LINE9	557 606 604 557 531 130 420 616	Total Number of Locations: Modify Profile	5980
LINETU LINET1 LINET2 LINET3 LINET4	628 261 202 233 218	Profile: Delete every 2	Apply
Shift Value	28	Shift Coordinate Values (e.g. f	or resolution)
× Coor	Sample Value Sh dinate 553262.625 -6	ift Value Shift X 0 50000 Shift Y 0	Reset
	0K Canc	el Average Precision (m)	Apply

You may choose not to import all profiles or decimate the data.

In addition, if you require sub-metre accuracy in your data positioning you may /wish to strip off the leading numbers of the UTM positions

port Wizard Step 3.	
	your data is probably
System Parameters	positioned at a common Tx
Survey Type: Moving Tx Moving Rx 💌	reference point. This is
Coordinate Systems: Horizontal	because the data is collected
Separation Reference Point:	because the data is conected
Normalization Type:	from a common Tx antennae
Normalization Divisor:	
Normalization Convention:	Note: The centre point of the
	3 Ry-Ty data are not the
	J IX-1X uata are not the
Project Name Give Me a name	same.
Import to the Database Messages:	
Bun Import	Der Levererte
systemoreating	Run Import:
locationscreating	
Processing Completed	

If using an EM31-R, then

Importing Data - Final



Calculating Apparent Resistivity

Select Algorithm			
Helicopter Data:			
Homogeneous	half-space apparent resistivity	model	
C Pseudo-layer h	alf-space model + Centroid dej	pth algorithm	
C Export Resistiv	ities to the PEX-file		
0	ancel Select	-	
		_	
	Homogeneous half-sp	ace apparent resistivit	_ []
	Start Resistivity:	Target Type:	
	100	C Amplitude C Innhase	
	Fit Tolerance:	 Quadrature 	
	<u>[0.01</u>		
		PRO	CESS
		Ca	ncel
EMIGMA		×	
Do you	want to store resistivity data in a	a new Data Set?	
	Yes No		
		L EN	41G



Calculate the best fitting half-space app rho for any dipole-dipole frequency EM data airborne or ground

> Calculate the best fitting half-space app rho choose which data elements to use e.g. for EM34 then Quadrature is default

> > Store to new dataset or attach to original data

х

Plotting Data - 1 (V90_tutorial .pdf for more details)



For apparent conductivity: Settings -> Custom -> App Cond EMIGMA FDEM Tutorial

Plotting Data - 2

Channel	Selec	ction		
_ Indicate	e Char	nnels		Selections for Plot 1
Plot #	-	Frequency	- Field	Abscissa
	1	6400 🔹		C Depth C Pos # O Distance
	0	_	?	C Fiducia
	0		?	Data Kind:
	0		?	Data
	0	,	?	App Resistivity
	0	· · · · · · · · · · · · · · · · · · ·	?	
	0	, 	?	U HZ
	0		?	🗖 Chargeability
	0		?	Derivative
	0		?	Clear All Selections
	0		7	
	0		?	General Information
	0		?	Reference Point At
	0		?	O Tx O Center O Rx
	0		?	
				OK Cancel

app rho display

use calculated best fit apparent resistivity

for apparent conductivity Settings -> Custom -> App Cond EMIGMA FDEM Tutorial

Gridding data - 1

<u>ی</u>

###

Interpolate to Grid

interpolate to regular grid

🔶 3D interpolation		? ×		
Gridding Data Number: 279 Min X: Profile Number: 11 Max X:	Data 8468.72 Min Y: 88741.6 Min Z 8954.61 Max Y: 89190.3 Max Z	sel	ect Compon	ents
Select Data for Interpolation: Select Data Data App Resistivity 2.1 Method: 4.1	Intercolation ct Components for Interpolation: I All Com (x[Dipole My] Rx[Dipole Hy] Separ[10.00 0.00 0.00 (x[Dipole M2] Rx[Dipole H2] Separ[10 (x[Dipole M2] Rx[Dipole Hy] Separ[21 (x[Dipole M2] Rx[Dipole H2] Separ[21 (x[Dipole M2] Rx[Dipole M2] Separ[21] Sepa	oonent wer		<u>?</u> X
Natural Neighbour Max Iteration: Max Iteration: Proprior Resolution 1000 State Derivative Information © Set to zero © Estimate	Current Profi	e: Current Position: X: 4295. Click+Drag red line to resize or use Output	.46, Y: 51698.01 t Grid settings ✓ Input Bounds × Min: 3660.7 × Max: 4421.4 Angle: -70 T	e Show Labels Show Locations 7047 Y Min: 49806.339 4438 Y Max 51224.519 otal locations: 258
	Load Grid 50757_	v v	Dutput Grid Infe U Min: 709 U Max: 709 dU: 111.0 nU: 130 To Input Bou	imation 1.504 V Min: 496 V Max: 200 dV: 50.00 nV: 9 Apply
Set Grid Settings	49780 36 Average dista	0 3896 4181 nce between locations: 22.2427 Average of	H For FFI Show Grid Angle: -70 Center X: 404 Center Y: 500 distance between lines: 93.9999 H	

Gridding data - 2

(*) 3D interpolation	Internalate to Crid
Data Data	
Data Number: 279 Min X: 8468.72 Min Y: 88741.6 Min Z: 10.2 Profile Number: 11 Max X: 8954.61 Max Y: 89190.3 Max Z: 0.2	
Interpolation Interpolation: Select Data for Interpolation: Select Components for Interpolation: Data 1. Tx(Dipole My) Rx(Dipole Hy) Separ(10.00 0.00 0.00) App Resistivity 2. Tx(Dipole M2) Rx(Dipole Hz) Separ(10.00 0.00 0.00) Method: 1. Tx(Dipole Mz) Rx(Dipole Hz) Separ(20.00 0.00 0.00) Natural Neighbour Image: Component of the component of	Model Has Related Grid(s) View Grids
Max Iteration: 0 Channel Interpolation Progress: Factor: 1000 Status: Derivative Information Grid Remove Extrapolated Points Set to zero Grid Setting Z - level: Status: Grid Setting Z - level: Use Input 0.2 Use Split Technique dX dY dZ	Grid Information ? × Grid Data Set(s) Grid Data Set Information NatNeighbour_23 Orthogonal local dimensions: Data Type: NatNeighbour_23,30 NatNeighbour_23,31 Not register in the set of
View Grid Characteristics	Data Created 10/7/2003 11:35:10 Grid Data Set NotNeighbour_29_32 NotNeighbour_29_32 Change Name D: 32 Delate Grid Project EM34 Oct 2003 Survey EM34 Data Set 1 1 6400.000 2 1600.000 3curvey EM34 Data Set Measured Domain Type: Frequency
	Export to Geosoft (grd) Export to System Exit Remove Extrapolated Points Difference of grids Help

Viewing Gridded Data - 1



Grid Presentation



Viewing Gridded Data - 2









automatic save to database

contents of *.mod file point by point information

Single line depth contour available only for single line inversions

Save to database after completion



le View												X	10	Inversion
File Name:]:\interp\	ICT\data	abase\ict_	databas	se_25_2	.pex							, fin	al model
\ x LINE0 8475.14	y d1 89032-89	k1 n nnnn	rho1 d n nnnnn	2 k2 124.6	rho2 -2 6670	d3 0.00000	k3 98.9	rho3 -5 334	d4 k4	rho4	d5 -8 0010	kt 📤		17
8474.61 8474.18 8473.99	89022.76 89012.75 89002.82	0.0000 0.0000 0.0000	0.00000 0.00000 0.00000	139.2 117.6 103.4	-2.6670 -2.6670 -2.6670	0.00000 0.00000 0.00000	92.7 85.9 89.0	-5.334 -5.334 -5.334	0.00000 0.00000 0.00000) 78.0) 75.3) 84.9	-8.0010 -8.0010 -8.0010	0. 1 0. 1 0.	6	le+011
8473.62 8473.22 8472.95	88992.83 88982.80 88972.77	0.0000 0.0000 0.0000	0.00000 0.00000 0.00000	112.6 101.2 87.9	-2.6670 -2.6670 -2.6670	0.00000 0.00000 0.00000	90.0 95.4 97.5	-5.334 -5.334 -5.3340	0.00000 0.00000 0.00000) 82.5) 96.8 109.6	-8.0010 -8.0010 -8.0010	i 0. i 0. i 0.		le+008
8472.55 8472.25 8471.86	88962.87 88952.88 88942.53	0.0000	0.00000 0.00000 0.00000	87.7 · 77.9 · 75.0 ·	2.6670 2.6670 2.6670	0.00000 0.00000 0.00000	92.2 84.6 84.7	-5.3340 -5.3340 -5.3340	0.00000	97.8 93.1 97.3	-8.0010 -8.0010 -8.0010	0.0 0.0 0.0	Para	
8471.33 8471.14 8470.65	88932.58 88922.53 88912.55	0.0000	0.00000	115.7 119.8 82.1	-2.6670 -2.6670	0.00000	115.7 119.8 96.8	7 -5.334 3 -5.334 -5 3340		0 115. 0 119. 117.7	7 -8.001 8 -8.001			4.316020+008
8470.31 8469.80	88902.55 88892.58	0.0000	0.00000	88.3 108.9	2.6670	0.00000	108.1	-5.334	0.00000) 141.4 0 177.9	9 -8.001	0 (4.31602e+008
8469.48 8468.99 8468.72	88872.71 88862.79	0.0000	0.00000 0.00000 0.00000	148.0 137.3	-2.6670 -2.6670 -2.6670	0.00000	216.3 207.4	+ -5.334 3 -5.334 4 -5.334	0 0.0000 0 0.0000 0 0.0000	0 283.3 0 366.3 0 375.3	9 -8.001 2 -8.001 8 -8.001	0 (0 (0 (4.31602e+008
LINE1 8504.96 8504.92	89024.79 89014.77	0.0000 0.0000	0.00000 0.00000	123.7 116.3	-2.6670 -2.6670	0.00000 0.00000	137.0 130.3) -5.334 3 -5.334	0 0.0000 0 0.0000	0 153. 0 147.9	4 -8.001 9 -8.001	0 (0 (₊₁	d D	ata Files
1	0000E 10	<u></u>	0 00000	75 0	2 0070	0.00000	100 7	5.004		[OK			View Convert to GPSZ

inversion results saved to database contains synthetic data under the model with the model attached – (*.pex)



The *.pex file is a columnar ASCII file inside your database directory

Use CDI Viewer for viewing models



CDI Viewer



