EME 2014 – Parc du Radome – Pleumeur Bodou - France

Ionospheric interactions with EME signals

By Giorgio IK1UWL and Flavio IK3XTV

The beginning of this research: a pile-up on 2m band decoded with MAP65

Date: 2012-aug-03 - Station IK1UWL - Band 144 MHz

DT Pol ORG DF dB UTC 144.143 -129 0 -2 0 1.7 63 4 -22 0008 CQ OX3LX HP15 144.143 -138 3 -1 0 1.7 64 3 -20 0010 CQ OX3LX HP15 144.143 -144 0 -2 -1 1.7 48 3 -22 0012 CQ OX3LX HP15 144.143 -153 0 -2 -1 1.9 43 5 -22 0014 CQ OX3LX HP15 144.143 -161 1 -1 0 1.5 31 1 -21 0016 CQ OX3LX HP15 144.143 -170 0 -1 0 1.7 15 2 -21 0018 F6HVK OX3LX HP15 OOO 1 0 5 144.143 -176 0 0 0 3.6 0 4 -18 0020 RRR 144.143 -185 1 0 0 1.7 18 5 -20 0022 RK3FG OX3LX HP15 OOO 1 0 17 144.143 -191 0 0 0 1.0 0 4 -19 0026 RRR 144.143 -199 1 -1 0 1.7 10 4 -19 0028 CQ OX3LX HP15 144.143 -205 0 -2 0 1.5 4 4 -18 0030 I3MEK OX3LX HP15 OOO 144.143 - 214 0 0 0 3.6 0 3 - 18 0032 RRR 144.143 - 217 - 1 0 - 1 2.1 0 4 -18 0034 IZ3KGJ OX3LX HP15 OOO 144.143 -226 0 0 0 1.0 0 4 -23 0038 RRR 144.143 -229 -1 -1 -1 1.6 -4 4 -19 0040 CQ OX3LX HP15 144.143 -232 -2 -1 -1 1.8 -7 5 -20 0042 CQ OX3LX HP15 144.143 -238 0 -1 -1 1.8 -9 4 -18 0044 CQ OX3LX HP15 144.143 -243 3 -1 1 1.8 -13 3 -20 0046 K1UWL OX3LX HP15 OOO 1 0 7 144.143 -246 0 0 0 1.0 0 4 -18 0048 RRR

MAP65 can be a research tool. Besides decodes for ham activity, it measures also levels and polarity.

With this tool we started to research what happens in the ionosphere.



The ionosphere, space weather

Partially ionized gas layer between ~50 and ~1000 km
 height and permeated by Earth's magnetic field is a
 turbulent ocean, roughened by high speed winds.







zonal currents in the stratosphere with seasonal inversion



Courtesy: Istituto di Scienze dell'Atmosfera e del Clima - CNR, Italia.

The ionosphere, space weather



Ionospheric Waves

Ionospheric effects: Attenuation, Deviation, Rotation of the wave
 Winds cause undulations and waves (TIDs), so free electron density varies in space and time.

□ These fluctuations of electron density have a lens effect on our signals, focusing or defocusing them.

- Moon is wide 0.5 degrees
- our beam is wide many degrees
- change of width changes gain

The Travelling Ionospheric Disturbances (TIDs)

Class	Horizontal wavelenght	Periods	Horizontal phase velocities
LSTIDs Large scale	>1000 Km	0,53 h	3001000 m/s
MSTIDs Medium scale	1001000 Km	12 min1h	100300 m/s
SSTIDs Small Scale	<100 Km	A few minutes	<200 m/s

Source: INGV Istituto Nazionale di Geofisica e Vulcanologia - Italy



Image source:Research and Technology Organisation. North Atlantic Treaty Organisation. Characterising the Ionosphere. Author: G. Wyman (January 2009)

Focusing/Defocusing effects

Fast scintillations caused
 by lunar libration
 and ionospheric turbulence
 (ssTIDs, periods of minutes)



Slower fluctuations from msTIDs
 (observed at mid latitudes every day)
 (300 km wavelength, wind 100 m/s
 = 360 km/h, period 50 minutes)



QSB

Band dependence (ionospheric refraction is proportional to 1/f²)



Courtesy: Radio Science, Volume 13, Number 1, pages 167-187, January-February 1978 AGU American Geophysical Union

• Regions dominating the effect



Collecting on-the-air data

- Results must be checked with real situations, from different sources.
- We chose **LiveCQ** as a source.
- René PE1L accepted to store all decodes from MAP65 spotters (all 2m band) in a file.
- We made an Excel sheet, with data sorted by date, spotter and spotted.
- Example: 18/08/2012 DG0OPK PE1L, data, pol and level graphs
- Note: MAP65 rotation is sum of spatial offset and up going and return Faraday rotation



Static ionosphere absorption



Source:Radio Wave Propagation by Lucien Boithias, published by North Oxford Academic

Dynamic ionosphere: signal level fluctuations

In 2 m JT65B decodes we see fluctuation of the levels, showing both medium term (4'-8') ripple (2-3 dB) and long term (1-2 h) undulations (4-5 dB).



Cannot be attributed to variation of attenuation. Most logical explanation is <u>focusing or defocusing</u> in curved layers of ionospheric waves.

Dynamic ionosphere: signal level fluctuations

In 2 m JT65B decodes we see fluctuation of the levels, showing both medium term (4'-8') ripple (2-3 dB) and long term (1-2 h) undulations (4-5 dB).



Cannot be attributed to variation of attenuation. Most logical explanation is <u>focusing or defocusing</u> in curved layers of ionospheric waves.

Rotation: Faraday effect

• In 1845 Faraday discovered that the plane of polarization of linearly polarized light, traversing a medium, can be rotated by the application of an external magnetic field aligned in the direction in which the light is moving.



An electromagnetic wave, crossing the ionosphere, will rotate by:

 $\Phi = \mathbf{k} * \mathbf{B} * \mathbf{TEC} / \mathbf{f}^2$ (rad), with:

B = Geomagnetic field component in Moon's direction

TEC = **T**otal **E**lectron **C**ontent of the path

f = wave frequency

$\Phi = \mathbf{k} * \mathbf{B} * \mathbf{TEC} / \mathbf{f^2}$

- **Band dependence**, with same B and TEC:
- 50 MHz 90° 360° 2.25 turns
- 144 MHz
 10°
 40°
 90°
 432 MHz
 1°,1
 4°,5
 10°
- 1296 MHz 0°,1 0°,5 1°,1
- Evidently, Faraday is a concern mainly in VHF
- Microwavers are concerned only by Spatial Offset
- Polar polarization is the angle between an antenna and earth's polar axis.
- **Spatial offset** between two stations is simply the difference between the polar polarizations of the two stations.
- For solving the algorithm we need sources for B and TEC

$\Phi = \mathbf{k} * \mathbf{B} * \mathbf{TEC} / \mathbf{f}^2$

East

- From the web site of the British Geological Survey, introducing Lat&Long of station, Median Height of the ionosphere, and Date, one obtains:
- Total field F (nTesla
- Inclination I (°)
- Declination **D** (°)
- Magnetic latitude





We need **B**, Geomagnetic field component in Moon's direction.

North

Ζ

Down

Vector F is defined by *—Inclination* and *Declination*. Vector Moon's direction is defined by *Azimuth* and *Elevation*. For projecting Field F on the Moon's direction we need the angle FM between these two vectors. Formula:

cosFM=cosI*cosD*cosEL*cosAz+cosI*sinD*cosEI*sinAz-sinI*sinEI



$\Phi = \mathbf{k} * \mathbf{B} * \mathbf{TEC} / \mathbf{f}^2$

- TEC (Total Electron Content) is measured in TECU (TEC Units) = 10¹⁶ electrons/m²
- The number of TECUs represent the total number of electrons present in a cylinder of 1 m² of section, crossing the ionosphere in the wave's direction.
- We used data from the **Royal Observatory of Belgium (ROB),** in **Dourbes**, which publishes VTEC histograms with values every 15', and archives each day of the year.

The ionosphere cannot be defined by a number, since its density varies with altitude.

A useful schematization is representing it by a slab of uniform density.

This slab represent the transformation of the real ionosphere in an equivalent ionosphere

With two numbers we can represent an equivalent ionosphere.

The ROB (Dourbes) site gives both VTEC and Slab Thickness



TEC: From Dourbes to other places

• **TEC Longitudinal variation:** Global trend quite regular and correlated to the local solar time

• TEC Latitudinal variation

The TEC value, varies non-linearly from the poles to the equator (geomagnetic) With the algorithm representing this curve, introducing the Mag. Lat. of the station, we find the correction of Dourbes VTEC.

•Slant TEC

Crossing the slab obliquely there are more electrons. Instead of Vertical TEC we must use Slant TEC.

TEC = STEC = Ka*VTEC

With Earth radius=6367 km, Ionosphere beginning at 100 km height, and h=Slab Thickness Ka =(SQR((6467+h)²-(6367*cosEl)²)-SQR(6467²-(6367*cosEl)²))/h



Institute of Communication and Navigation, German Aerospace Center (DLR)



TECU variation = 0,02*LAT²-2,5*LAT+95



Φ=k*(F*cosFM)*(VTEC*corr*Ka)/f²

- We now have the data for the complete formula. For 144 MHz, k/f²=1,14 with F in Gauss.
- Wave plane rotation is controlled by these variables:



N hemisphere: cosFM ranges from 0 to -1 S hemisphere: cosFM ranges from 0 to 1



□ TEC (constant or changing slowly, 100% to 30%)

□ Moon elevation (slant passage Ka from 3.7 towards 1)

First check, amount of rotation

• We made an Excel sheet, and we got good congruence in the majority of cases analyzed. Example:

3	Spotted	locator	6		lat	t long		Corr ¥T		EC a	Inclination(*) 77,51 ¥TEC-DRBS		F (Genze) *** 0,48387 ¥TEC (TECU)		
4	OX3LX	HP15E0			65,6	;	-37,625		0,2						
5	Date	UTC	Local	time	ne Decir		AZ (')	Z ()							
6	August 3, 2012	0.08	21:1	9	21,3	2		134		7		14,3	1	9,8	
7		0.46	21:5	7	21,9	5		143		9		13,65		9,2	
				6	. Latituda	Dee	clination(')	Gale	Banline	Cans	Latitude	Dour	bes		
					70,13	14. 1	-22.991	WWLO		Kp=	3 quiet				
				h	(Km)	Ű.	Ka	A	(4B)	F	(Geurs)	θ (')	P()	
					300	×	3,49	0	,070	0,	48387	-10	08,78	72,44	
	×			8	300		3,30	0	,067	0,	48387	-16	30,75	75,35	
17	Spotter	locator		1	lat		long		Corr ¥TI		Inclinatio	on() Fr		Gaurs) ***	
18	IK1UWL	JN33VT			43,84		7,79	7,79 0			59,45		-0,41456		
19	Date	UTC	Local	time	Decin	nal	AZ (')	El spatt		HO YTEC-DI		RBS VTE		(TECU)	
20	August 3, 2012	0.08	0:2	0	24,3	5		179		36		12,35	1	13,8	
21		0.46	0:58		24,98			190 3		36,00		11,7	1	13,2	
3.00				G	Latitude	De	clination(')								
				1	40,46		0,953								
				h	(Km)		Ka	A	(4B)	F	(6+wr)	θ (9	P()	
				Ĩ	300	1	1,59	(),082	-0	,41456	50	08,63	89,27	
			1	6	300	8	1,59	0,079		-0,41456		482,63		-82,70	
								Re	sumee		1			1	
								sta	ge	UTC	Dalta (*)	Diff	.cale.	Real	
								Tst	nterval	0.08	-51,97		77.97	-76	
										0.46	-26,00				

Common-moon pol. total trend

- Having now confidence in the basic correctness of formula and correction coefficients, we proceeded to build a new <u>Excel sheet</u>, covering the <u>entire common-moon period</u>.
- Partial checks were possible using the LiveCQ decoded periods.
- Example: SP4MPB spotted by PA3FPQ, total pass:

1	Date	Call	Loc.	Lat.	Long.	Lat. mag.	Corr. Day	Corr.night	F	Incl.	Decl.	Loc conv.	Conv. Lat.	Calc. E	Dourbes
2	16/12/2012	SP4MPB	KO03HT	53,81	20,63	50,65	0,93	0,20	0,44958	68,77	4,54	. = .			
3		Second Second													
4	UTC	caltime.(ref.DRB	Az (')	EI()	h(km)	Ka	VTEC Drbs	Corr.	VTEC loc.	STEC	cosFM	Bot. (*)	Rot.(rad)	Offset P1	P1 (0,180)
5	10,00	11.04	129	8,3	187	3,64	15,52	0,45	14,24	51,84	-0,3367	-512,6	-8,95	61,6	61,6
6	10.30	11.34	135	11,6	185	3,27	15,00	0,45	13,72	44,79	-0,4171	-548,7	-9,58	64,5	64,5
7	11.00	12.04	142	14,5	182	2,95	14,08	0,45	12,80	37,78	-0,4912	-545,0	-9,51	68,0	68,0
8	11.30	12.34	149	17,0	182	2,70	13,82	0,45	12,54	33,90	-0,5543	-551,9	-9,63	71,7	71,7
9	12.00	13.04	156	19,0	182	2,53	13,68	0,45	12,40	31,36	-0,6042	-556,5	-9,71	75,6	75,6
10	12.30	13.34	163	20,6	185	2,40	13,68	0,45	12,40	29,74	-0,6435	-562,1	-9,81	79,7	79,7
11	13.00	14.04	171	21,7	187	2,32	14,10	0,45	12,82	29,73	-0,6716	-586,4	-10,23	84,5	84,5
12	13.30	14.34	178	22,2	197	2,28	12,11	0,45	10,83	24,66	-0,7083	-512,9	-8,95	88,8	88,8
13	14,00	15.04	186	22,1	201	2,28	10,53	0,45	9,25	21,07	-0,6866	-424,9	-7,42	-86,4	93,6
14	14.30	15.34	193	21,5	221	2,31	10,55	0,45	9,27	21,40	-0,6751	-424,2	-7,40	-82,2	97,8
15	15.00	16.04	201	20,3	259	2,36	10,00	0,45	8,72	20,60	-0,6495	-393,0	-6,86	-77,4	102,6
16	15.30	16.34	208	18,7	307	2,45	7,89	0,45	6,61	16,17	-0,6129	-291,0	-5,08	-73,4	106,6
17	16.00	17.04	215	16,5	326	2,59	6,32	0,33	5,38	13,95	-0,5641	-231,1	-4,03	-69,6	110,4
18	16.30	17.34	222	14,0	369	2,75	5,26	0,20	4,69	12,89	-0,5045	-191,0	-3,33	-66,1	113,9
19	17.00	18.04	229	11,0	406	2,95	4,47	0,20	3,90	11,51	-0,4317	-145,9	-2,55	-62,8	117,2
20	17.30	18.34	235	7,7	417	3,20	4,63	0,20	4,06	12,99	-0,3538	-135,0	-2,36	-60,2	119,8
21	18,00	19.04	241	4,2	432	3,41	4,34	0,20	3,77	12,84	-0,2686	-101,3	-1,77	-58,0	122,0
22	18.30	19.34	247	0,8	451	3,48	3,95	0,20	3,38	11,77	-0,1804	-62,4	-1,09	-56,1	123,9
36	Date	Nomin	Loc	Lat	Long	lat man	Corr Dag	Corr night	F	Incl	Decl	Loc conv	Conv Lat	Cale F	Dourbes
36	Date 16/12/2012	Nomin PA3EPQ	Loc.	Lat.	Long.	Lat. mag. 50.61	Corr. Day	Corr.night	F -0.43860	Incl. 66.93	Decl.	Loc conv.	Conv. Lat.	Calc. E	Dourbes
36 37 38	Date 16/12/2012	Nomin PA3FPQ	Loc. JO22XE	Lat. 52,19	Long. 5,96	Lat. mag. 50,61	Corr. Dag 0,93	Corr.night 0,20	F -0,43860	Incl. 66,93	Decl. 0,23	Loc conv.	Conv. Lat.	Calc. E	Dourbes
36 37 38 39	Date 16/12/2012 UTC	Nomin PA3FPQ	Loc. JO22XE Az (1)	Lat. 52,19 El (1)	Long. 5,96	Lat. mag. 50,61 Ka	Corr. Day 0,93 VTEC Drbs	Corr.night 0,20 Corr.	F -0,43860 YTEC loc.	Incl. 66,93 STEC	Decl. 0,23 cosFM	Loc cony. Bot.(1)	Conv. Lat.	Calc. F	Dourbes
36 37 38 39 40	Date 16/12/2012 UTC 10.00	Nomin PA3FPQ scal time (ref. DRB: 10.05	Loc. JO22XE Az() 116	Lat. 52,19 El() 2,0	Long. 5,96 h (km) 192	Lat. mag. 50,61 Ka 4,21	Corr. Dag 0,93 VTEC Drbs 14,74	Corr.night 0,20 Corr. 0,45	F -0,43860 VTEC loc. 13,48	Incl. 66,93 STEC 56,76	Decl. 0,23 cosFM -0,2023	Loc conv. Rot.() 329.0	Conv. Lat. Rot.(rad) 5,74	Calc. F Offset P2 55,4	Dourbes P2(0,180) 55,4
36 37 38 39 40 41	Date 16/12/2012 UTC 10.00 10.30	Nomin PA3FPQ peol time (ref. DRB: 10.05 10.35	Loc. JO22XE Az (') 116 122	Lat. 52,19 El() 2,0 5,8	Long. 5,96 h (km) 192 187	Lat. mag. 50,61 Ka 4,21 3,93	Corr. Dag 0,93 VTEC Drbs 14,74 16,05	Corr.night 0,20 Corr. 0,45 0,45	F -0,43860 ¥TEC loc. 13,48 14,79	Incl. 66,93 STEC 56,76 58,16	Decl. 0,23 cosFM -0,2023 -0,2974	Loc conv. Rot. (1) 329,0 495,6	Conv. Lat. Rot.(rad) 5,74 8,65	Calc. F Offset P2 55,4 57,6	Dourbes P2(0,180) 55,4 57,6
36 37 38 39 40 41 42	Date 16/12/2012 UTC 10.00 10.30 11.00	Nomin PA3FPQ scaltime(ref.DRB: 10.05 10.35 11.05	Loc. JO22XE Az (') 116 122 128	Lat. 52,19 El() 2,0 5,8 9,4	Long. 5,96 h (km) 192 187 187	Lat. mag. 50,61 Ka 4,21 3,93 3,52	Corr. Dag 0,93 VTEC Drbs 14,74 16,05 15,52	Corr.night 0,20 Corr. 0,45 0,45 0,45	F -0,43860 ¥TEC loc. 13,48 14,79 14,26	Incl. 66,93 STEC 56,76 58,16 50,13	Decl. 0,23 cosFM -0,2023 -0,2974 -0,3869	Loc conv. Rot.(') 329,0 495,6 555,6	Conv. Lat. Rot.(rad) 5,74 8,65 9,70	Calc. F Offset P2 55,4 57,6 60,1	P2(0,180) 55,4 57,6 60,1
36 37 38 39 40 41 42 43	Date 16/12/2012 UTC 10.00 10.30 11.00 11.30	Nomin PA3FPQ acaltime(ref.DRB: 10.05 10.35 11.05 11.35	Loc. JO22XE Az () 116 122 128 135	Lat. 52,19 El() 2,0 5,8 9,4 12,8	Long. 5,96 h (km) 192 187 187 187	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13	Corr. Day 0,93 VTEC Drbs 14,74 16,05 15,52 15,00	Corr.night 0,20 Corr. 0,45 0,45 0,45 0,45	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74	Incl. 66,93 STEC 56,76 58,16 50,13 42,98	Decl. 0,23 cosFM -0,2023 -0,2974 -0,3869 -0,4725	Loc conv. Rot.(') 329,0 495,6 555,6 581,9	Conv. Lat. Rot.(rad) 5,74 8,65 9,70 10,16	Calc. F Offset P2 55,4 57,6 60,1 63,4	P2(0,180) P2(0,180) 55,4 57,6 60,1 63,4
36 37 38 39 40 41 42 43 44	Date 16/12/2012 UTC 10.00 10.30 11.00 11.30 12.00	Nomin PA3FPQ 2014time(ref.DRB: 10.05 10.35 11.05 11.35 12.05	Loc. JO22XE Az() 116 122 128 135 141	Lat. 52,19 El () 2,0 5,8 9,4 12,8 15,8	Long. 5,96 h (km) 192 187 187 185 182	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82	Corr. Day 0,93 VTEC Drbs 14,74 16,05 15,52 15,00 14,08	Corr.night 0,20 Corr. 0,45 0,45 0,45 0,45 0,45	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74 12,82	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10	Decl. 0,23 cosFM -0,2023 -0,2974 -0,3869 -0,4725 -0,5427	Los conv. Rot. () 329,0 495,6 555,8 581,9 561,3	Conv. Lat. Rot.(rad) 5,74 8,65 9,70 10,16 9,80	Calc. F Offset P2 55,4 57,6 60,1 63,4 66,6	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6
36 37 38 39 40 41 42 43 44 45	Date 16/12/2012 UTC 10.00 10.30 11.00 11.30 11.30 12.00 12.30	Nomin PA3FPQ 10.05 10.35 11.05 11.35 11.35 12.05 12.35	Loc. JO22XE Az() 116 122 128 135 141 148	Lat. 52,19 El () 5,8 9,4 12,8 15,8 15,8 18,4	Long. 5,96 h (km) 192 187 187 187 185 182 182	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58	Corr. Day 0,93 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82	Corr.night 0,20 Corr. 0,45 0,45 0,45 0,45 0,45 0,45 0,45	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74 12,82 12,56	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35	Decl. 0,23 cosFM -0,2023 -0,2974 -0,3869 -0,4725 -0,5427 -0,6055	Loc conv. Bot. () 329,0 495,6 555,6 581,9 561,3 561,2	Conv. Lat. Rot.(rad) 5,74 8,65 9,70 10,16 9,80 9,80 9,79	Calc. F Offset P2 55,4 57,6 60,1 63,4 86,6 70,4	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 70,4
36 37 38 39 40 41 41 42 43 44 45 46	Date 16/12/2012 UTC 10.00 10.30 11.00 11.30 12.00 12.30 13.00	Nomin PA3FPQ 10.05 10.35 11.05 11.35 12.05 12.35 13.05	Loc. JO22XE Az() 116 122 128 135 141 149 155	Lat. 52,19 El () 5,8 9,4 12,8 15,8 15,8 18,4 20,6	Long. 5,36 h (km) 192 187 187 187 185 182 182 182 182	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58 2,40	Corr. Day 0,93 VTEC Drbs 14,74 16,05 15,52 15,50 14,08 13,82 13,68	Corr.night 0,20 0,25 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 VTEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82	Decl. 0,23 0,2023 -0,2023 -0,2974 -0,3869 -0,4725 -0,5427 -0,6055 -0,6558	Loc conv. Rot. (1) 323,0 435,6 555,6 551,9 561,2 561,2 560,2	Conv. Lat. Rot.(rad) 5.74 8.85 9.70 10,16 9,80 9,79 9,78	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 70,4 74,5
36 37 38 39 40 41 42 43 44 45 46 46 47	Date 16/12/2012 UTC 10.00 10.30 11.00 11.00 12.00 12.30 13.00 13.30	Nomin PA3EPQ 10.05 10.35 11.05 11.35 12.05 12.35 13.05 13.35	Loc. JO22XE Az() 116 122 128 135 141 148 155 163	Lat. 52,19 El (') 2,0 5,8 9,4 12,8 15,8 15,8 18,4 20,6 22,3	Long. 5,96 h(km) 192 187 187 185 182 182 182 182	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58 2,40 2,28	Corr. Day 0,93 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82 13,68 13,68	Corr.night 0,20 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 VTEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 28,27	Deci. 0,23 0,202 0,2023 -0,2074 -0,3869 -0,4725 -0,5427 -0,6055 -0,6558 -0,6558 -0,6956	Rot. (1) 329,0 495,6 555,6 581,9 581,9 581,3 561,3 561,2 560,2 560,2 560,2 563,4	Conv. Lat. Rot(rad) 5,74 8,65 9,70 10,16 9,80 9,79 9,78 9,83	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4
36 37 38 39 40 41 42 43 44 45 46 47 48	Date 16/12/2012 UTC 10.00 10.30 11.00 11.30 12.00 12.30 13.00 13.00 13.00 14.00	Nomin PA3FPQ 10.05 10.35 11.05 11.35 12.05 12.35 13.05 13.05 13.35 14.05	Loc. JO22XE Az() 116 122 128 135 141 148 155 163 170	Lat. 52,19 El() 2,0 5,8 9,4 12,8 15,8 15,8 18,4 20,6 22,3 23,5	Long. 5,96 h(km) 192 187 187 185 182 182 182 182 185 187	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58 2,40 2,28 2,20	Corr. Day 0,93 VTEC Drbs 14,74 16,05 15,52 15,50 14,08 13,82 13,88 13,88 13,88	Corr.night 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74 12,82 12,82 12,42 12,42 12,84	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 28,27 28,25	Decl. 0,23 0,2023 -0,2974 -0,3869 -0,4725 -0,5427 -0,6055 -0,6558 -0,6558 -0,6956 -0,7199	Los conv. Rot. [1] 329,0 495,6 555,6 581,9 561,3 561,3 561,2 563,4 583,4 583,4 582,6	Conv. Lat. Rot.(rad) 5,74 8,65 9,70 10,16 9,80 9,78 9,78 9,78 9,83 10,17	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 86,6 70,4 74,5 74,5 73,4 83,7
36 37 38 39 40 41 42 43 44 45 46 45 46 47 48 49	Date 16/12/2012 UTC 10.00 10.30 11.00 11.30 12.30 13.30 13.30 14.00 14.30	Nomin PA3FPQ sedtime(ref.DRB: 10.05 10.35 11.05 11.35 12.05 12.35 13.05 14.05 14.35	Loc. JO22XE Az() 116 122 128 135 141 148 155 163 163 170 178	Lat. 52,19 2,0 5,8 9,4 12,8 15,8 15,8 18,4 20,6 22,3 23,5 24,0	Long. 5,96 h (km) 192 187 187 187 185 182 182 182 182 182 187 187	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58 2,40 2,28 2,20 2,17	Corr. Day 0,93 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,88 13,68 13,68 14,10 12,11	Corr.night 0,20 Corr. 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,45	F -0,43860 VTEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42 12,42 12,44 12,84 10,85	Incl. 66,93 STEC 56,76 50,13 42,98 36,10 32,35 29,82 28,27 28,27 28,25 23,49	Decl. 0,23 0,2023 -0,2974 -0,3869 -0,4725 -0,5427 -0,6555 -0,6555 -0,6556 -0,7199 -0,7319	Loc conv. Rot. (1) 329,0 495,6 555,6 581,9 561,2 561,2 560,2 563,4 552,6 492,6 492,6	Conv. Lat. Rot.(rad) 5,74 8,65 9,70 10,16 9,80 9,79 9,78 9,83 10,17 8,60	Calc. F Offset P2 55,4 55,6 80,1 63,4 66,6 70,4 74,5 79,4 83,7 88,7	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 86,6 70,4 74,5 79,4 83,7 88,7
36 37 38 39 40 41 41 42 43 44 45 46 47 48 49 50	Date 16/12/2012 UTC 10.00 10.30 11.00 11.30 12.00 12.30 13.30 13.30 14.00 14.30 14.30 15.00	Nomin PA3FPQ 10.05 10.35 11.05 11.35 12.05 12.05 12.35 13.05 13.35 14.05 14.35 14.35 14.35	Loc. J022XE Az() 116 122 128 135 141 148 155 163 170 178 186	Lat. 52,19 2,0 5,8 9,4 12,8 15,8 15,8 15,8 18,4 20,6 22,3 23,5 24,0 24,0 24,0	Long. 5,96 h (km) 192 187 187 185 182 182 182 182 185 187 187 201	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58 2,40 2,28 2,20 2,217 2,16	Corr. Day 0,33 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82 13,88 13,88 13,88 13,88 13,88 14,10 12,111 10,53	Corr.night 0,20 Corr. 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,45	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42 12,42 12,42 12,42 12,42 12,85 9,27	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 29,82 28,27 28,25 23,49 19,99	Decl. 0,23 0,2974 -0,2023 -0,2974 -0,3869 -0,4725 -0,6555 -0,6558 -0,6558 -0,6558 -0,6558 -0,7199 -0,7319 -0,7314	Loc conv. Rot. () 329,0 495,6 555,8 561,3 561,3 561,2 560,2 563,4 582,6 492,6 418,4	Conv. Lat. Rot.(rad) 5.74 8.65 9.70 10,16 9.80 9.79 9.78 9.83 10,17 8.60 7.30	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7 88,7 -86,2	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 70,4 74,5 73,4 83,7 83,7 83,7 83,8
36 37 38 39 40 41 41 42 43 44 45 46 47 48 49 50 51	Date 16/12/2012 UTC 10.00 10.30 11.30 11.30 12.30 12.30 13.30 13.30 14.00 14.30 15.00 15.30	Nomin PA3EPQ 10.05 10.35 11.05 11.35 12.05 12.35 12.35 13.35 13.35 14.05 14.35 15.05 15.05	Loc. JO22XE A2(1) 1116 122 128 135 141 148 155 163 170 178 186 183	Lat: 52,19 2,00 5,8 3,4 12,8 15,8 18,4 4 20,6 22,3 23,5 24,0 24,0 24,0 24,0 23,3	Long. 5,36 h (km) 132 187 187 185 182 182 182 182 182 182 185 187 187 201 221	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58 2,40 2,28 2,20 2,17 2,16 2,19	Corr. Day 0,33 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82 13,68 13,68 13,68 14,10 12,11 10,53 10,53	Corr.night 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 VTEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42 12,42 12,42 12,84 10,85 9,27 9,27	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 28,27 28,25 23,49 19,99 20,29	Decl. 0,23 0,2974 -0,2023 -0,2974 -0,3869 -0,4725 -0,6055 -0,6558 -0,6956 -0,7199 -0,7304 -0,7304 -0,7151	Loc conv. Rot. (1) 323,0 435,6 555,6 561,3 561,2 560,2 562,2 563,4 582,6 432,6 432,6 448,4 415,6	Conv. Lat. Rot(rad) 5,74 8,65 9,70 10,16 9,80 9,73 9,83 10,17 8,60 7,30 7,25	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7 88,7 - 88,7 - - 88,2 - - 81,9	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7 88,7 88,7 93,8 93,8
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52	Date 16/12/2012 UTC 10.00 10.30 11.30 11.30 12.30 12.30 13.30 13.30 14.00 15.30 15.30 16.00	Nomin PA3EPQ 10.05 10.35 11.05 11.35 12.05 12.35 13.35 13.35 14.05 14.35 15.05 15.35 16.05	Loc. JO22XE Az () 116 122 128 135 141 141 148 155 163 170 178 186 193 201	Lat. 52,19 2,0 5,8 9,4 12,8 15,8 15,8 15,8 15,8 15,8 15,8 15,8 15	Long. 5,36 h (km) 132 187 187 185 182 182 182 182 182 182 185 212 212 201 221 259	Lat. mag. 50,61 Ka 4,21 3,93 3,52 2,58 2,40 2,28 2,40 2,28 2,20 2,20 2,17 2,16 2,19 2,25	Corr. Day 0,33 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82 13,68 13,68 14,10 12,11 10,53 10,53 10,00	Corr.night 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 VTEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42 12,42 12,42 12,42 12,42 12,42 12,42 12,42 12,84 10,85 9,27 9,27 8,74	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 28,27 28,25 23,49 19,99 20,29 19,99 20,29	Decl. 0,23 cosFM -0,2023 -0,2974 -0,3869 -0,4725 -0,6427 -0,64558 -0,6558 -0,6558 -0,6558 -0,6356 -0,7199 -0,7304 -0,7304 -0,7151 -0,6844	Loc conv. Rot. (1) 323,0 445,6 555,6 561,3 561,3 561,3 561,2 560,2 563,4 582,6 442,6 442,6 442,6 448,4 445,6 385,4	Conv. Lat. Rot(rad) 5,74 8,65 9,70 10,16 9,80 9,79 9,78 9,83 10,17 8,60 7,30 7,25 6,73	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5 73,4 83,7 -86,2 -81,9 -76,9	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 86,6 70,4 74,5 79,4 83,7 83,7 83,7 93,8 93,8 103,1
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53	Date 16/12/2012 UTC 10.00 10.30 11.00 12.00 12.30 13.00 13.30 14.00 14.30 15.30 15.30 16.00 16.30	Nomin PA3FPQ sedtime(ref.DRB: 10.05 10.05 11.05 11.05 12.05 12.05 12.05 13.05 14.05 14.05 14.05 15.05 16.05 16.05	Loc. JO22XE A2 (1) 1166 122 128 135 1411 148 155 163 1700 178 186 193 201 208	Lat: 52,19 El () 2,0 5,8 9,4 12,8 15,8 18,4 20,6 22,3 23,5 24,0 24,0 24,0 24,0 24,0 24,0 22,0 3 22,0 0 20,3	Long, 5,36 h (km) 192 187 187 182 182 182 182 182 182 187 289 299 307	Lat. mag. 50,61 Ka 4,21 3,93 3,52 3,13 2,82 2,58 2,40 2,28 2,20 2,17 2,16 2,19 2,25 2,33	Corr. Day 0,93 VTEC Drbs 14.74 16,05 15,52 15,00 14,08 13,88 13,68 13,68 14,10 12,11 10,53 10,53 10,53 10,53	Corr.night 0,20 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74 12,86 12,42 12,56 12,42 12,56 12,42 12,84 10,85 9,27 9,27 9,27 9,27 9,27 9,27	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 28,27 28,27 28,25 23,49 19,99 20,29 19,66 15,44	Decl. 0,23 0,2974 0,2974 0,3868 0,4725 0,6427 0,6055 0,6558 0,6558 0,6558 0,7199 0,7304 0,7304 0,7304 0,7304 0,7304	Loc conv. Rot. (1) 329,0 435,6 555,6 581,9 561,2 560,2 560,2 562,6 432,6 432,6 4415,6 385,4 285,2	Conv. Lat. Rot(rad) 5,74 8,65 9,70 10,16 9,80 9,79 9,78 9,83 10,17 8,60 7,30 7,25 6,73 4,98	Calc. F Offset P2 55,4 55,4 55,6 80,1 63,4 66,6 70,4 74,5 79,4 83,7 88,7 -86,2 -81,9 -76,9 -72,8	Dourbes P2(0,180) 55,4 55,6 60,1 63,4 86,6 70,4 74,5 73,4 88,7 88,7 93,8 98,1 103,1 107,2
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54	Date 16/12/2012 UTC 10.00 10.30 11.00 12.00 12.00 12.30 13.00 13.30 14.00 14.30 14.30 15.00 15.30 16.00 16.30 17.00	Nomin PA3FPQ 10.05 10.05 11.05 11.05 11.05 12.05 12.05 12.05 12.05 13.05 13.05 13.05 14.05 14.05 14.35 15.05 15.35 16.05 16.35 16.35	Loc. JO22XE Az (1) (16) (122) (12)) (122)	Lat: 52,19 El () 5,8 9,4 12,8 15,8 15,8 15,8 15,8 15,8 22,0 24,0 24,0 24,0 23,3 22,0 24,0 24,0 23,3 22,0 20,3 3 18,0	Long. 5,36 h(km) 187 187 182 182 182 182 182 182 182 182 182 182	Lat. mag. 50,61 Ka 4,21 3,93 3,52 2,58 2,40 2,28 2,20 2,17 2,16 2,19 2,25 2,33 2,48	Corr. Day 0,33 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82 13,88 13,68 14,10 12,11 10,53 10,53 10,53 10,00 7,89 6,32	Corr.night 0,20 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 VTEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42 12,42 12,42 12,42 12,42 12,42 12,86 9,27 9,27 9,27 9,27 8,74 8,63 5,39	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 28,27 28,25 23,49 19,39 20,29 19,86 15,44 13,37	Decl. 0,23 0,2974 0,2974 0,3869 0,4725 0,5427 0,6055 0,6558 0,6558 0,6558 0,6558 0,6558 0,7199 0,7319 0,7319 0,7304 -0,7151 0,6844 0,68444 -0,5905	Loc cons. Rot. () 329,0 495,6 555,6 561,3 561,2 560,2 563,4 582,6 492,6 418,4 415,6 385,4 285,2 226,2 226,2	Conv. Lat. Rot.(rad) 5,74 8,65 9,70 10,16 9,80 9,79 9,78 9,83 10,17 8,60 7,30 7,25 6,73 4,98 3,95	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7 88,7 -86,2 -81,9 -76,9 9 -72,8 -68,8 -68,8	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7 83,7 93,8 98,1 103,1 107,2 111,2
36 37 38 39 40 41 42 43 44 45 46 47 48 90 51 52 53 54 55	Date 16/12/2012 UTC 10.00 10.30 11.30 12.00 12.30 13.30 13.30 14.00 14.30 15.30 16.30 16.30 16.30 17.30	Nomin PA3EPQ 10.05 10.05 11.05 11.05 11.35 12.05 12.05 12.35 13.05 12.35 13.05 14.35 15.55 14.35 15.55 15.35 16.35 16.35 16.35 17.35	Loc. JO22XE A2(1) 1112 1122 128 135 141 148 155 163 163 170 178 186 193 201 208 205 222	Lat: 52,19 2,0 5,8 9,4 12,8 15,8 18,4 4 20,6 22,3 23,5 24,0 24,0 23,3 22,0 24,0 23,3 22,0 3 24,0 23,3 18,0 0 20,3 18,0 0 20,3 18,0 0 20,3 18,0 20,0 20,0 20,0 20,0 20,0 20,0 20,0 2	Long. 5,36 h (km) 132 187 187 185 182 182 182 182 182 182 182 182 182 182	Lat. mag. 50,61 Ka 4,21 3,93 3,52 2,58 2,40 2,28 2,20 2,17 2,16 2,19 2,25 2,33 2,48 2,48 2,48	Corr. Day 0,33 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 14,10 12,111 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,53 10,55 10,5	Corr.night 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42 12,42 12,42 12,42 12,42 12,42 12,42 12,42 12,42 12,42 12,42 12,85 9,27 9,27 9,27 8,74 6,63 5,39 4,70	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 36,10 32,35 29,82 29,82 28,27 28,27 28,25 23,49 19,99 20,29 19,96 15,44 13,37 12,40	Decl. 0,23 0,2974 -0,2023 -0,2974 -0,3869 -0,4725 -0,6558 -0,6558 -0,6558 -0,6558 -0,6558 -0,6956 -0,7199 -0,7304 -0,7151 -0,68444 -0,5905 -0,5258	Loc conv. Rot. (1) 329.0 495.6 555.6 581.9 561.2 560.2 563.4 582.6 4932.6 418.4 415.6 385.4 285.2 226.2 186.8	Conv. Lat. Rot.(rad) 5,74 8,65 9,70 10,16 9,80 9,79 9,83 10,17 8,60 7,30 7,25 6,73 4,98 3,95 3,26	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7 -86,2 -81,9 -72,8 -68,8 -68,8 -65,1	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 70,4 74,5 79,4 83,7 88,7 93,8 98,1 103,1 107,2 111,2 1114,9
36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56	Date 16/12/2012 UTC 10.00 10.30 11.30 11.30 12.30 13.30 13.30 14.00 15.30 15.00 15.30 16.00 16.30 17.00 17.30 18.00	Nomin PA3EPQ 10.05 10.35 11.05 11.35 12.05 12.35 13.35 13.35 14.05 14.35 15.05 15.55 15.55 15.55 16.35 16.05 16.35 17.05 17.35 18.05	Loc. JO22XE A2 (1) 116 122 128 135 141 148 155 163 170 178 186 193 201 208 215 222 229	Lat: 52,19 2,0 5,8 3,4 12,8 15,8 15,8 15,8 15,8 12,3 23,5 24,0 24,0 24,0 24,0 24,0 24,0 24,0 24,0	Long. 5,36 h [km] 192 187 187 185 182 182 182 182 182 182 182 182 182 182	Lat. mag. 50,61 Ka 4,21 3,93 3,52 2,58 2,40 2,28 2,20 2,17 2,16 2,19 2,25 2,33 2,48 2,40 2,25 2,33 2,48 2,64 2,85	Corr. Day 0,33 VTEC Drbs 14,74 16,05 15,52 15,00 14,08 13,82 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 13,68 14,10 12,11 10,53 10,53 10,53 10,00 7,89 6,32 5,26 4,47	Corr.night 0,20 0,45 0,45 0,45 0,45 0,45 0,45 0,45 0,4	F -0,43860 ¥TEC loc. 13,48 14,79 14,26 13,74 12,82 12,56 12,42 12,42 12,42 12,42 12,42 12,84 10,85 9,27 9,27 9,27 8,74 8,63 5,39 4,70 3,91	Incl. 66,93 STEC 56,76 58,16 50,13 42,98 32,35 29,82 28,27 28,25 23,49 19,99 20,29 19,86 15,44 13,37 12,40	Decl. 0,23 cosFM -0,2023 -0,2974 -0,3869 -0,4725 -0,6558 -0,6558 -0,6558 -0,6956 -0,7199 -0,7304 -0,7151 -0,6844 -0,6444 -0,6444 -0,5905 -0,5258 -0,4483	Loc conv. Rot. (1) 323,0 435,6 555,6 581,3 561,2 560,2 560,2 563,4 582,6 432,6 4432,6 448,4 415,6 385,4 226,2 226,2 226,2 226,2 186,8 142,8 1	Conv. Lat. Rot(rad) 5,74 8,65 9,70 10,16 9,80 9,79 9,78 9,83 10,17 8,60 7,30 7,25 6,73 4,98 3,95 3,26 3,26 2,49	Calc. E Offset P2 55,4 57,6 60,1 63,4 66,6 70,4 79,4 79,4 79,4 79,4 79,4 79,4 79,4 79	Dourbes P2(0,180) 55,4 57,6 60,1 63,4 66,6 66,6 66,6 70,4 74,5 79,4 83,7 88,7 93,8 93,8 93,8 93,8 103,1 103,1 107,2 111,2 114,9 118,3

POL trend: SP4MPB spotted by PA3FPQ 16-12-2012 – 1000 km ENE of spotter



- SP4MPB was active from 13.58 to 14.42 utc (near sunset)
- In this phase, TEC had a quick decrease.
- Followed by a brief increase pre sunset, then decreasing from sunset to night.
- Calculated and real trend are coherent.

Pol trend: I2FAK spotted by PA3FPQ

1/12/2012 - Contest ARRL - 828 km SSE of spotter



Pol. trends as function of direction

- Spotter IK1UWL (Band 144 MHz Dec 19, 2012 Moon 11.00 23.00 UTC)
- All graphs computed for stations in a rose of directions Φ=k*(F*cosFM)*(VTEC*corr*Ka)/f²



Pol. trends as function of direction

- Spotter IK1UWL (Band 144 MHz Dec 19, 2012 Moon 11.00 23.00 UTC)
- All graphs computed for stations in a rose of directions Φ=k*(F*cosFM)*(VTEC*corr*Ka)/f²



Pol. trends as function of direction

- Spotter IK1UWL, (Band 144 MHz Dec 19, 2012 Moon 11.00 23.00 UTC)
- All graphs computed for stations in a rose of directions

Φ=k*(F*cosFM)*(VTEC*corr*Ka)/f²



Conclusions

• QSB of JT65 decodes:

Is caused by focusing or defocusing of our beam going through the waves of the windy ionosphere.

• Faraday rotation:

There are three phases in a Moon pass:

1 - In the first hours after Moon rise the rate of change of polarization is high. Causes:

a) – change of angle FM between Moon direction and magnetic field

b) – change in length of ionospheric crossing (slant coeff. Ka)

2 – In the central part of Moon pass changes in angle FM and coeff. Ka balance each other, so polarization changes depend mainly from ionospheric evolution (of Total Electron Content)

3 – In the last hours before Moon set the rate of change of polarization is high for the same causes of phase 1

References

- Aspects of Weather and Space Weather in the Earth's Upper Atmosphere: The Role of Internal Atmospheric Waves by Michael C. Kelly.
- - INGV istituto nazionale di Geofisica e Vulcanologia.
- TOTAL ELECTRON CONTENT STUDIES OF THE IONOSPHERE John A. Klobuchar,, e t al Air Force Cambridge Research Laboratories L. G. Hanscom Field, Massachusetts.
- The Potential of Broadband L-Band SAR Systems for Small Scale Ionospheric TEC Mapping
- (Remote Sensing Technology Institute, German Aerospace Center (DLR) Oberpfaffenhofen, D – 82234 Wessling, Germany
- - Institute of Communication and Navigation, German Aerospace Center)
- GEOMAGNETISM TUTORIAL Whitham D. Reeve Reeve Observatory Anchorage, Alaska USA
- - Frederick University, 7 Y. Frederickou St., Palouriotisa, Nicosia 1036, Cyprus
- Electron density measurements of the plasmasphere experimental observations and modeling studies
- Cooperative Research Centre for Satellite Systems Department of Physics, La Trobe University Bundoora, Australia
- - Propagation Factors In Space Communications (NATO)
- Seasonal variations of storm-time TEC at European middle latitudes Royal Meteorological Institute (RMI), Belgium
- - Radio Wave Propagation by Lucien Boithias, published by North Oxford Academic