Chapter I
Ionospheric interactions with EME signals

EME 2016 – Venice - Italy

Chapter II

Signal polarity in V/UHF bands

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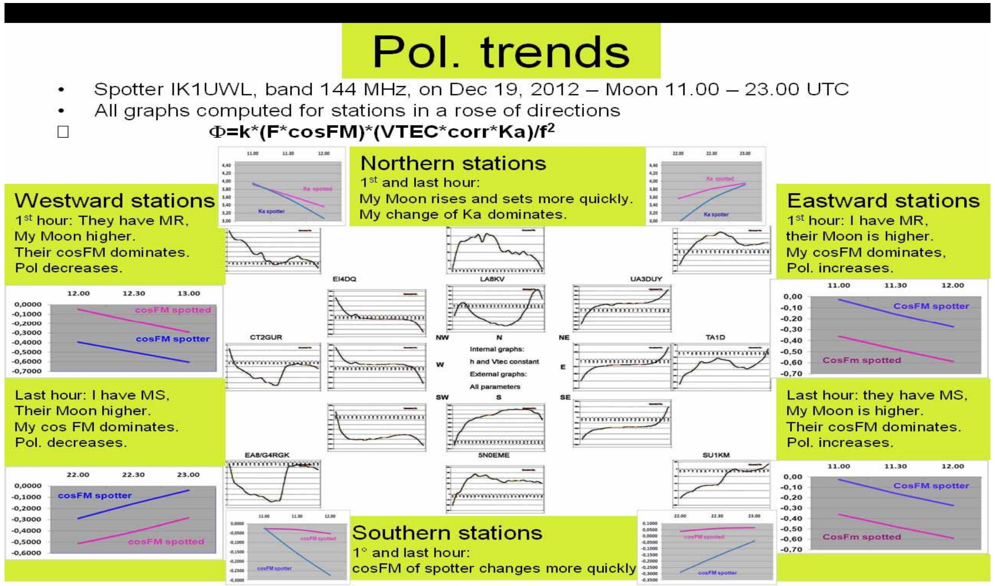
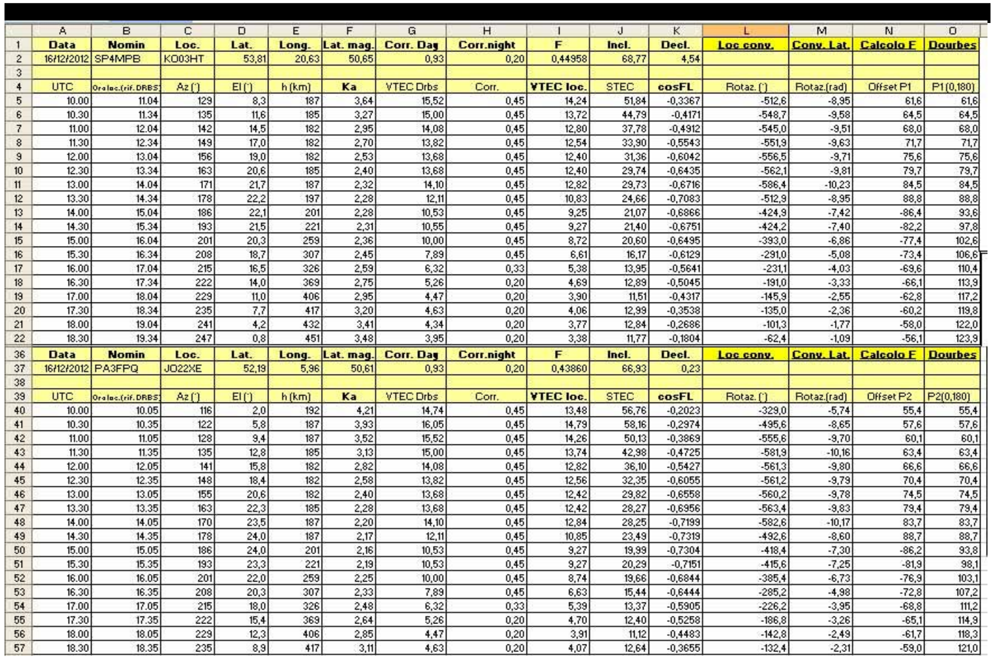
Background

- **Chapter I**
- In 2014, in France, we showed you, besides QSB origins, Faraday's behavior on 2 m.



- All computations and graphs were made with an Excel sheet, complete with the relevant formulas.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	Data	Nomin	Loc.	Lat.	Long.	Lat. mag.	Corr. Day	Corr.night	F	Incl.	Decl.	Loc conv.	Conv. Lat.	Calcolo F	Dourbes
2	16/12/2012	SP4MPB	KO03HT	53,81	20,63	50,65	0,93	0,20	0,44958	68,77	4,54				
3															
4	UTC	Ora loc.(rif. DRBS)	Az (°)	El (°)	h (km)	Ka	VTEC Drbs	Corr.	VTEC loc.	STEC	cosFL	Rotaz. (°)	Rotaz.(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	Data	Nomin	Loc.	Lat.	Long.	Lat. mag.	Corr. Day	Corr.night	F	Incl.	Decl.	Loc conv.	Conv. Lat.	Calcolo F	Dourbes
37	16/12/2012	PA3FPQ	JO22XE	52,19	5,96	50,61	0,93	0,20	0,43860	66,93	0,23				
38															
39	UTC	Ora loc.(rif. DRBS)	Az (°)	El (°)	h (km)	Ka	VTEC Drbs	Corr.	VTEC loc.	STEC	cosFL	Rotaz. (°)	Rotaz.(rad)	Offset P2	P2(0,180)
40	10.00	10.05	116	2,0	192	4,21	14,74	0,45	13,48	56,76	-0,2023	-329,0	-5,74	55,4	55,4
41	10.30	10.35	122	5,8	187	3,93	16,05	0,45	14,79	58,16	-0,2974	-495,6	-8,65	57,6	57,6
42	11.00	11.05	128	9,4	187	3,52	15,52	0,45	14,26	50,13	-0,3869	-555,6	-9,70	60,1	60,1
43	11.30	11.35	135	12,8	185	3,13	15,00	0,45	13,74	42,98	-0,4725	-581,9	-10,16	63,4	63,4
44	12.00	12.05	141	15,8	182	2,82	14,08	0,45	12,82	36,10	-0,5427	-561,3	-9,80	66,6	66,6
45	12.30	12.35	148	18,4	182	2,58	13,82	0,45	12,56	32,35	-0,6055	-561,2	-9,79	70,4	70,4
46	13.00	13.05	155	20,6	182	2,40	13,68	0,45	12,42	29,82	-0,6558	-560,2	-9,78	74,5	74,5
47	13.30	13.35	163	22,3	185	2,28	13,68	0,45	12,42	28,27	-0,6956	-563,4	-9,83	79,4	79,4
48	14.00	14.05	170	23,5	187	2,20	14,10	0,45	12,84	28,25	-0,7199	-582,6	-10,17	83,7	83,7
49	14.30	14.35	178	24,0	187	2,17	12,11	0,45	10,85	23,49	-0,7319	-492,6	-8,60	88,7	88,7
50	15.00	15.05	186	24,0	201	2,16	10,53	0,45	9,27	19,99	-0,7304	-418,4	-7,30	-86,2	93,8
51	15.30	15.35	193	23,3	221	2,19	10,53	0,45	9,27	20,29	-0,7151	-415,6	-7,25	-81,9	98,1
52	16.00	16.05	201	22,0	259	2,25	10,00	0,45	8,74	19,66	-0,6844	-385,4	-6,73	-76,9	103,1
53	16.30	16.35	208	20,3	307	2,33	7,89	0,45	6,63	15,44	-0,6444	-285,2	-4,98	-72,8	107,2
54	17.00	17.05	215	18,0	326	2,48	6,32	0,33	5,39	13,37	-0,5905	-226,2	-3,95	-68,8	111,2
55	17.30	17.35	222	15,4	369	2,64	5,26	0,20	4,70	12,40	-0,5258	-186,8	-3,26	-65,1	114,9
56	18.00	18.05	229	12,3	406	2,85	4,47	0,20	3,91	11,12	-0,4483	-142,8	-2,49	-61,7	118,3
57	18.30	18.35	235	8,9	417	3,11	4,63	0,20	4,07	12,64	-0,3655	-132,4	-2,31	-59,0	121,0

- Results were checked for congruence with real decodes.

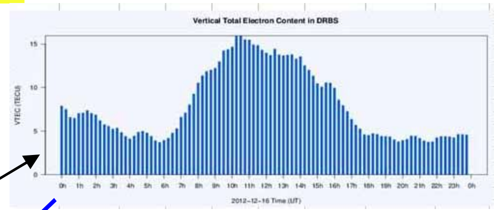
- We have a big library of stations pairs

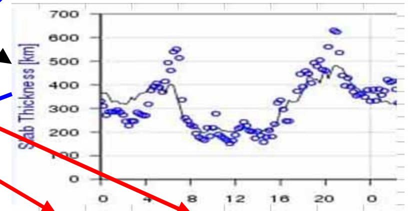
Our Excel sheet

Steps: 1 2 3

Moon Sked

L	M	N	O
Loc conv.	**Conv. Lat**	**Calcolo F**	**Dourbes**





	A	B	C	D	E	F	G	H	I	J	K
1	**Data**	**Nomin**	**Loc.**	**Lat.**	**Long.**	**Lat. mag**	**Corr. Day**	**Corr.night**	**F**	**Incl.**	**Decl.**
2	16/12/2012	SP4MPB	KO03HT	53,81	20,63	50,65	0,63	0,20	0,44958	68,77	4,54
3											
4	UTC	Ora loc.(rif. DRBS)	Az (°)	El (°)	h (km)	**Ka**	VTEC Drbs	Corr.	**VTEC loc.**	STEC	**cosFL**
5	10.00	11.04	129	8,3	187	3,64	15,52	0,45	14,24	51,84	-0,3367
6	10.30	11.34	135	11,6	185	3,27	15,00	0,45	13,72	44,79	-0,4171
7	11.00	12.04	142	14,5	182	2,95	14,08	0,45	12,80	37,78	-0,4912
8	11.30	12.34	149	17,0	182	2,70	13,82	0,45	12,54	33,90	-0,5543
9	12.00	13.04	156	19,0	182	2,53	13,68	0,45	12,40	31,36	-0,6042
10	12.30	13.34	163	20,6	185	2,40	13,68	0,45	12,40	29,74	-0,6435
11	13.00	14.04	171	21,7	187	2,32	14,10	0,45	12,82	29,73	-0,6716
12	13.30	14.34	178	22,2	197	2,28	12,11	0,45	10,83	24,66	-0,7083
13	14.00	15.04	186	22,1	201	2,28	10,53	0,45	9,25	21,07	-0,6866
14	14.30	15.34	193	21,5	221	2,31	10,55	0,45	9,27	21,40	-0,6751
15	15.00	16.04	201	20,3	259	2,36	10,00	0,45	8,72	20,60	-0,6495
16	15.30	16.34	208	18,7	307	2,45	7,89	0,45	6,61	16,17	-0,6129
17	16.00	17.04	215	16,5	326	2,59	6,32	0,33	5,38	13,95	-0,5641
18	16.30	17.34	222	14,0	369	2,75	5,26	0,20	4,69	12,89	-0,5045
19	17.00	18.04	229	11,0	406	2,95	4,47	0,20	3,90	11,51	-0,4317
20	17.30	18.34	235	7,7	417	3,20	4,63	0,20	4,06	12,99	-0,3538
21	18.00	19.04	241	4,2	432	3,41	4,34	0,20	3,77	12,84	-0,2686
22	18.30	19.34	247	0,8	451	3,48	3,95	0,20	3,38	11,77	-0,1804

Results for each station

SP4MPB (tx)

Rotaz. (°)	Rotaz.(rad)	Offset P1
-512,6	-8,95	61,6
-548,7	-9,58	64,5
-545,0	-9,51	68,0
-551,9	-9,63	71,7
-556,5	-9,71	75,6
-562,1	-9,81	79,7
-586,4	-10,23	84,5
-512,9	-8,95	88,8
-424,9	-7,42	-86,4
-424,2	-7,40	-82,2
-393,0	-6,86	-77,4
-291,0	-5,08	-73,4
-231,1	-4,03	-69,6
-191,0	-3,33	-66,1
-145,9	-2,55	-62,8
-135,0	-2,36	-60,2
-101,3	-1,77	-58,0
-62,4	-1,09	-56,1

Wave going up

PA3FPQ (rx)

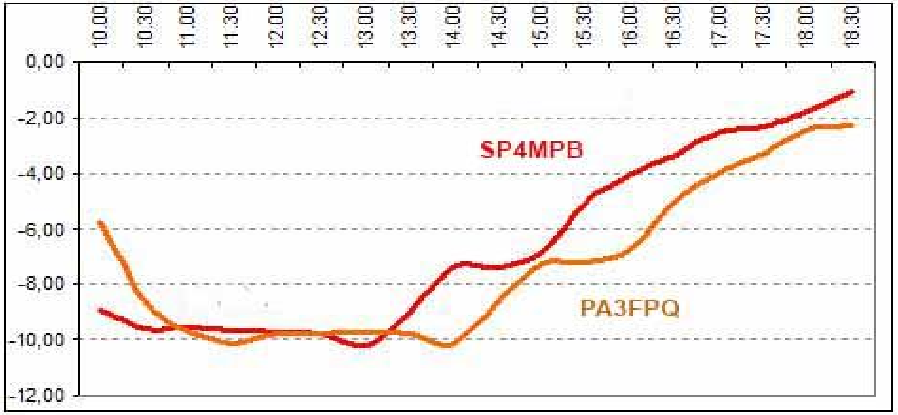
Rotaz. (°)	Rotaz.(rad)	Offset P2	P2(0,180)
-329,0	-5,74	55,4	55,4
-495,6	-8,65	57,6	57,6
-555,6	-9,70	60,1	60,1
-581,9	-10,16	63,4	63,4
-561,3	-9,80	66,6	66,6
-561,2	-9,79	70,4	70,4
-560,2	-9,78	74,5	74,5
-563,4	-9,83	79,4	79,4
-582,6	-10,17	83,7	83,7
-492,6	-8,60	88,7	88,7
-418,4	-7,30	-86,2	93,8
-415,6	-7,25	-81,9	98,1
-385,4	-6,73	-76,9	103,1
-285,2	-4,98	-72,8	107,2
-226,2	-3,95	-68,8	111,2
-186,8	-3,26	-65,1	114,9
-142,8	-2,49	-61,7	118,3
-132,4	-2,31	-59,0	121,0

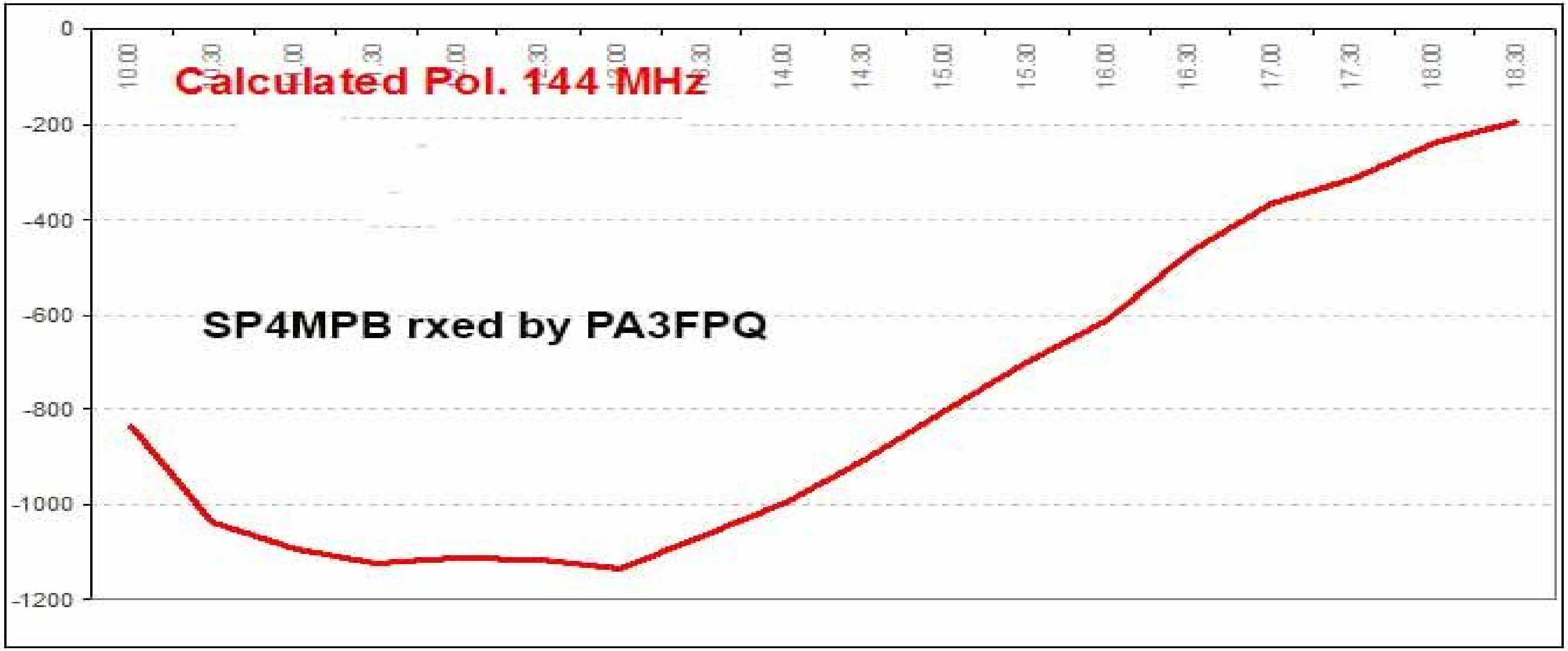
Wave coming back

Final results in 2 m

- Differences in evolution of Ka and of cosFM give different evolution to Faraday rotation of each station.

- Final polarity is algebraic sum of individual rotations and offsets.





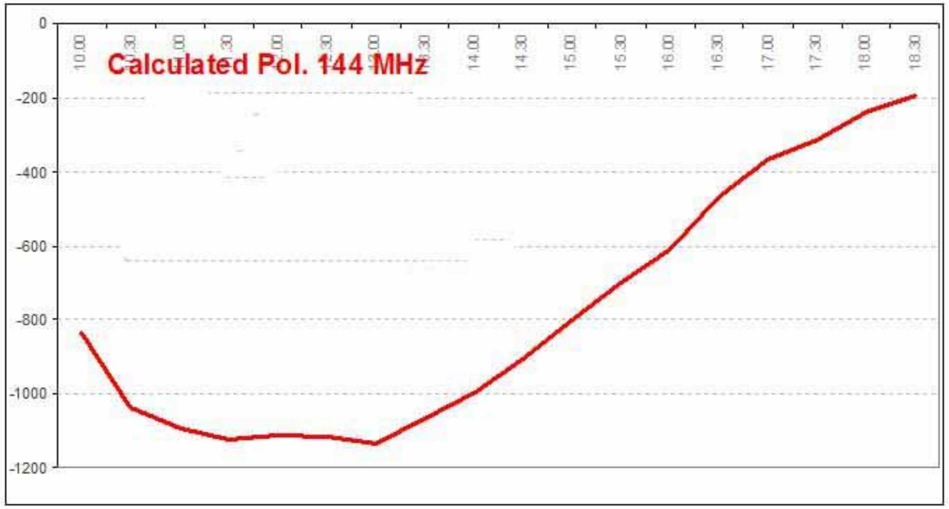
Chapter II

- Using this Excel sheet library, we intend to expand on the polarity issue for the four V/UHF bands.
- Polarity of an incoming signal is the sum of Spatial Offset and Faraday rotation.
- Spatial Offset is dependent only on the relative location of the stations.
- Faraday is dependent on frequency, ionosphere’s density, and on Moon’s position.

From our library: Spatial Offsets

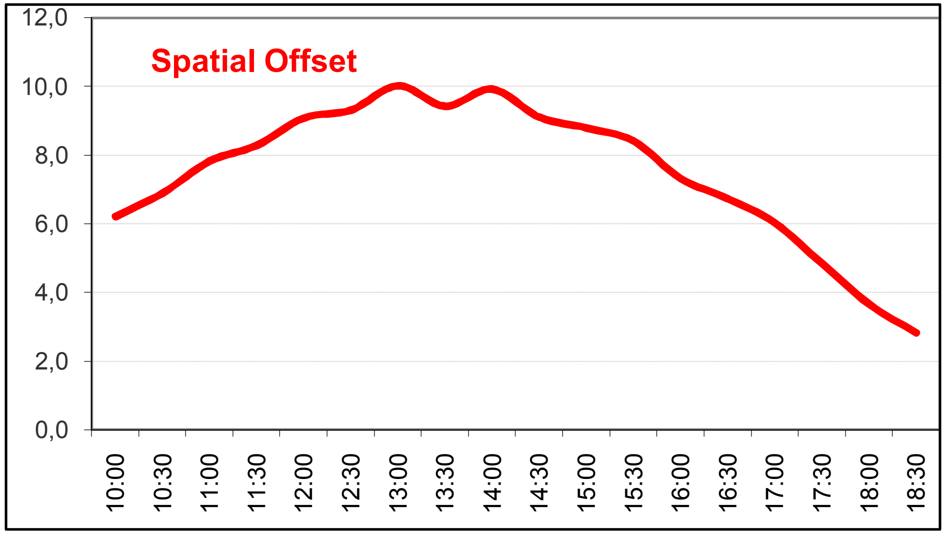
- **SP4MPB rxed by PA3FPQ on 2 m: Calculated Polarity**

UTC	Somma rot.(°)	P1-P2 (°)	Pol. Calc.
10.00	-842	6,2	-835,4
10.30	-1044	6,9	-1037,3
11.00	-1101	7,8	-1092,8
11.30	-1134	8,3	-1125,5
12.00	-1118	9,1	-1108,7
12.30	-1123	9,3	-1114,0
13.00	-1147	10,0	-1136,6
13.30	-1076	9,4	-1066,9
14.00	-1007	9,9	-997,6
14.30	-917	9,1	-907,7
15.00	-811	8,8	-802,6
15.30	-707	8,4	-698,2
16.00	-617	7,3	-609,2
16.30	-476	6,7	-469,5
17.00	-372	6,0	-366,1
17.30	-322	4,8	-316,9
18.00	-244	3,7	-240,4
18.30	-195	2,8	-191,9

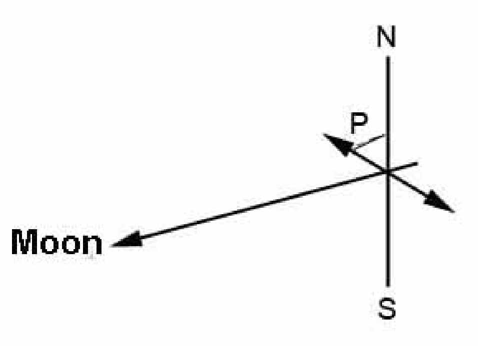


- **With a simple shift: Spatial Offset between SP4MPB and PA3FPQ**

UTC	Somma rot.(°)	P1-P2 (°)	Pol. Calc.
10.00	-842	6,2	-835,4
10.30	-1044	6,9	-1037,3
11.00	-1101	7,8	-1092,8
11.30	-1134	8,3	-1125,5
12.00	-1118	9,1	-1108,7
12.30	-1123	9,3	-1114,0
13.00	-1147	10,0	-1136,6
13.30	-1076	9,4	-1066,9
14.00	-1007	9,9	-997,6
14.30	-917	9,1	-907,7
15.00	-811	8,8	-802,6
15.30	-707	8,4	-698,2
16.00	-617	7,3	-609,2
16.30	-476	6,7	-469,5
17.00	-372	6,0	-366,1
17.30	-322	4,8	-316,9
18.00	-244	3,7	-240,4
18.30	-195	2,8	-191,9

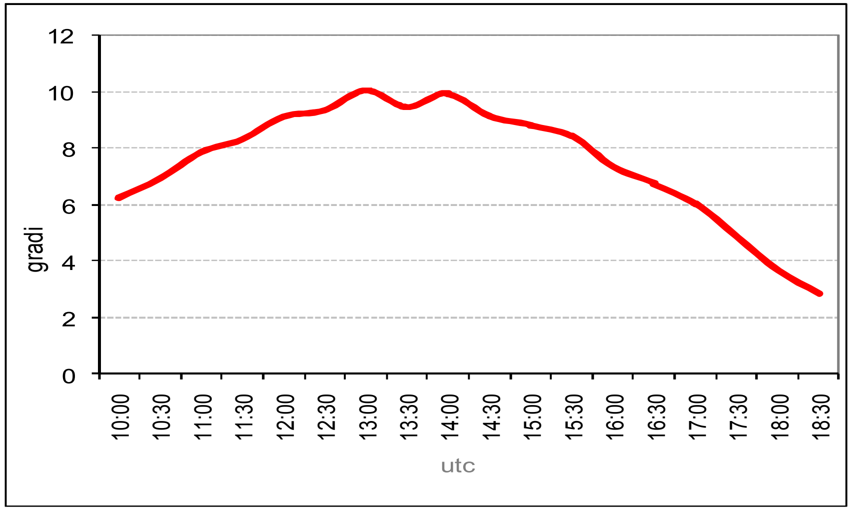


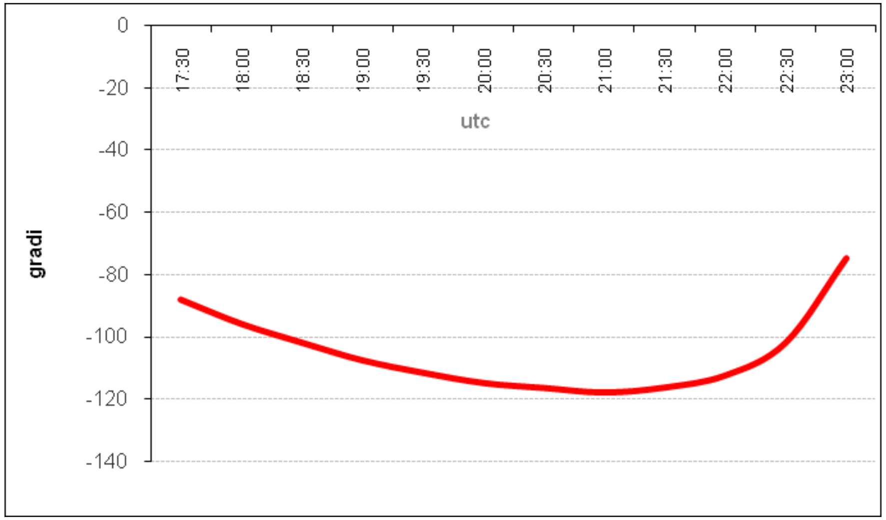
Spatial Offset



Angle between earth's axis and polarization vector

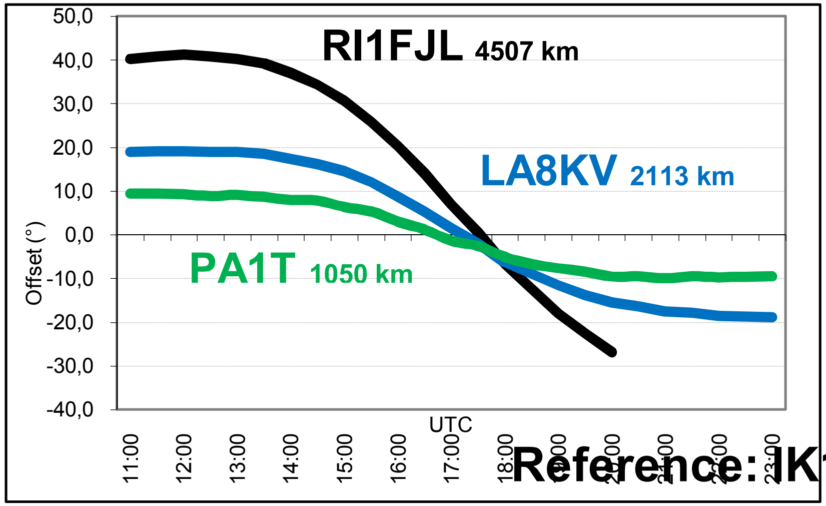
- **P**=Polar offset
- From a paper of N1BUG:
- **P**=arctg((sin**Lat***cos**El**-cos**Lat***cos**Az***sin**El**)/cos**Lat***sin**Az**)
- **Spatial Offset** = P1 – P2
- <u>Same for all bands, variables are Lat, Az, El</u>
- <u>Spatial Offset increases with distance</u>
- SP4MPB 1000 km east of PA3FPQ TI2SW 9000 km west of IKUWL
- from 2°,8 to 10° from 74°,8 to 117°,7



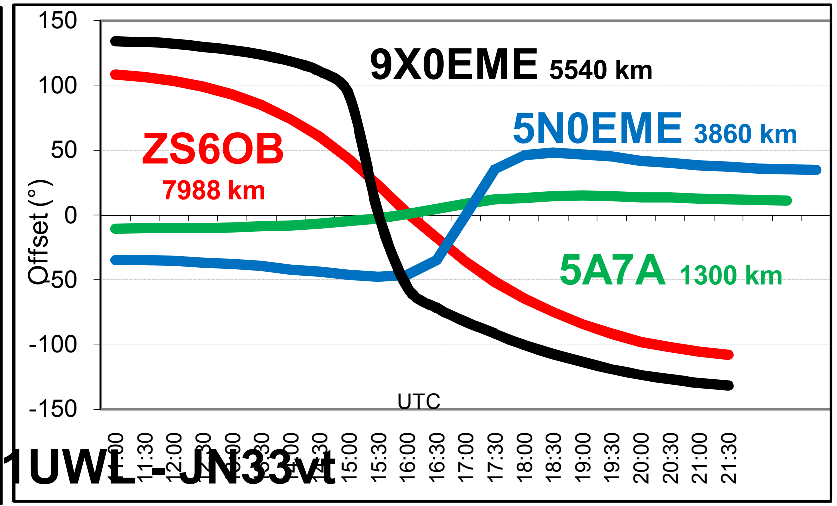


Offset: change with distance and direction

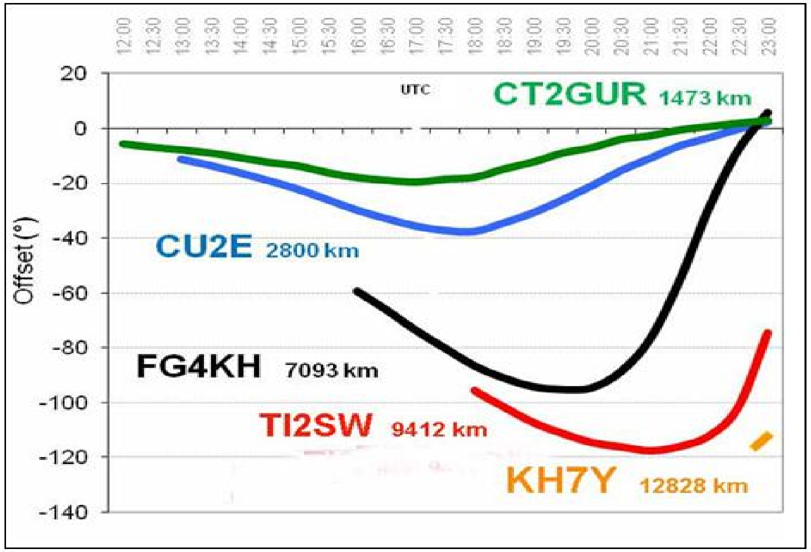
Northern stations

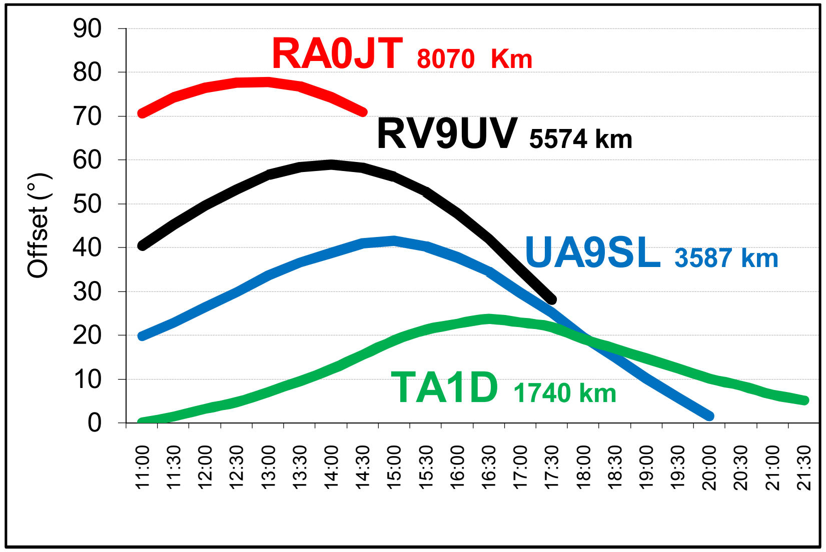


Southern stations



Reference: IK1UWL - JN33vt





Western stations

Eastern stations

From our library: Conversion to other bands

- In our sheet, column L (Rotaz. °) calculates the Faraday rotation: **1,14*F*cosFM*STEC**
- **1,14 is k/f² for 144 MHz** (with k=2,36*10^{16})
- One needs only to substitute 1,14 with the coefficient for another band:

6m	2m	70 cm	23 cm
9,46	**1,14**	**0,127**	**0,0123**

- Our library gets quadrupled.

=1,14*I2*K5*J5*57,3

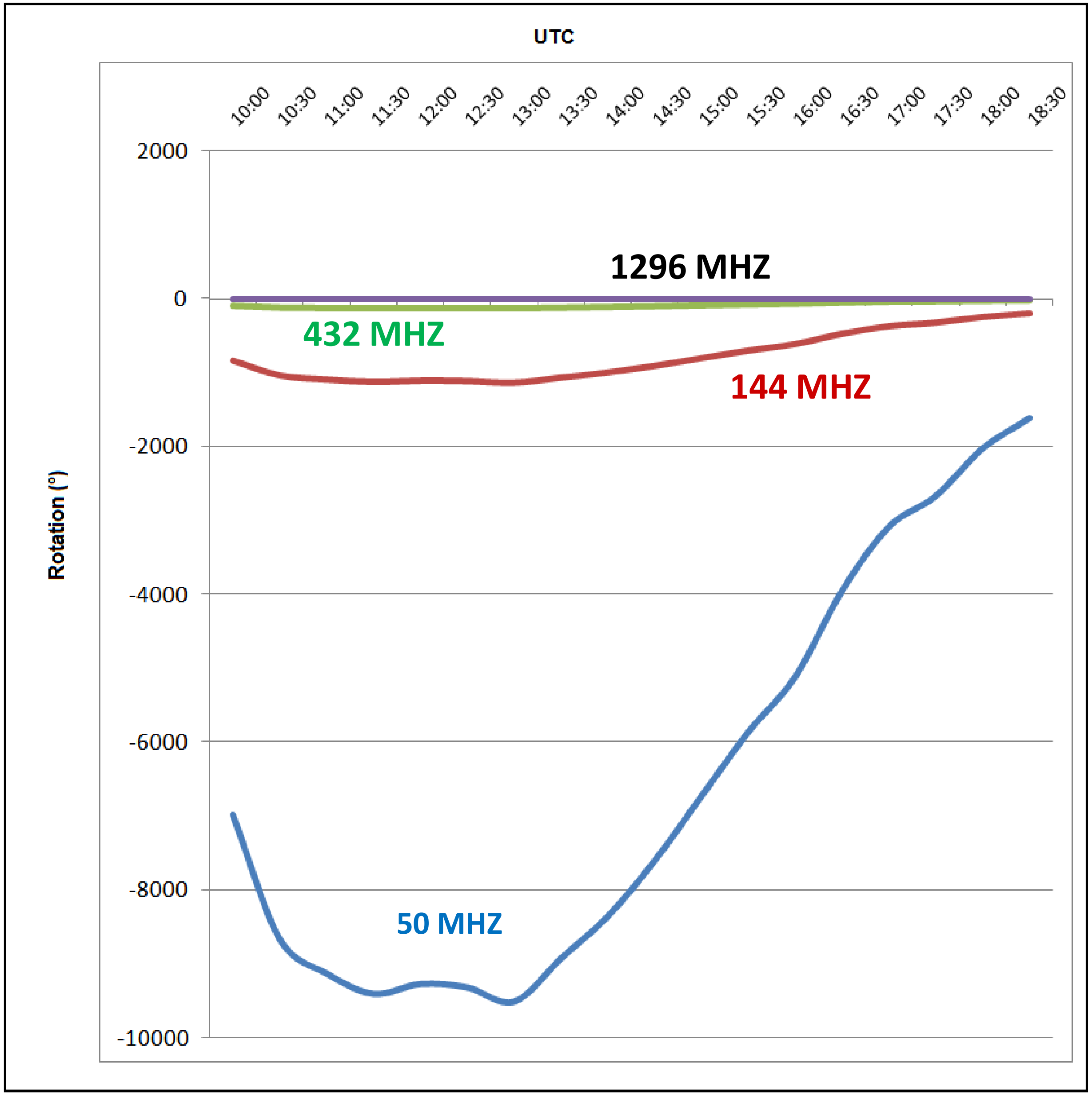
B	C	D	E	F	G	H	I	J	K	L
omin	**Loc.**	**Lat.**	**Long.**	**Lat. mag.**	**Corr. Day**	**Corr.night**	**F**	**Incl.**	**Decl.**	**Loc conv.**
MPB	KO03HT	53,81	20,63	50,65	0,93	0,20	0,44958	68,77	4,54	
:.(rif. DRBS)	Az (°)	El (°)	h (km)	**Ka**	VTEC Drbs	Corr.	**VTEC loc.**	STEC	**cosFL**	Rotaz. (°)
11.04	129	8,3	187	3,64	15,52	0,45	14,24	51,84	-0,3367	-512,6

4 bands (6 m, 2 m, 70 cm, 23 cm)

Total rotation (**Faraday + Spatial Offset**) for SP4MPB received by PA3FPQ on four bands.

Big polarity changes only in the VHF bands.

Note: curves refer to an unperturbed ionosphere

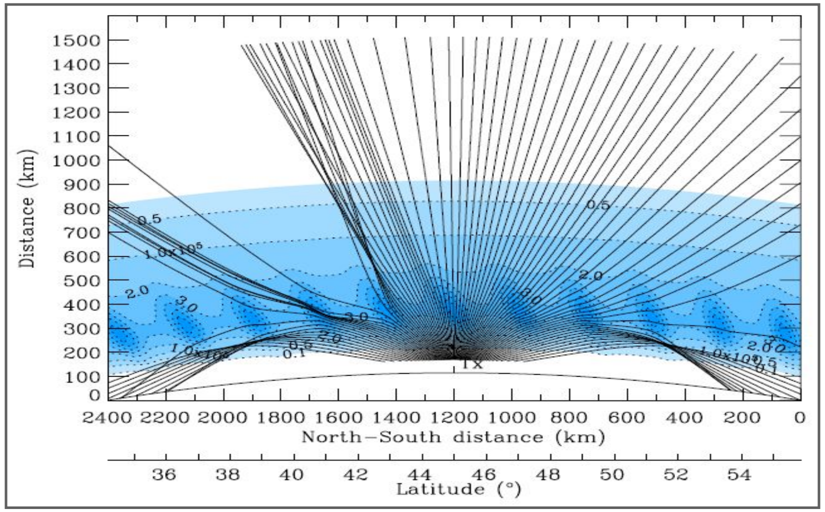


VHF bands, unperturbed ionosphere

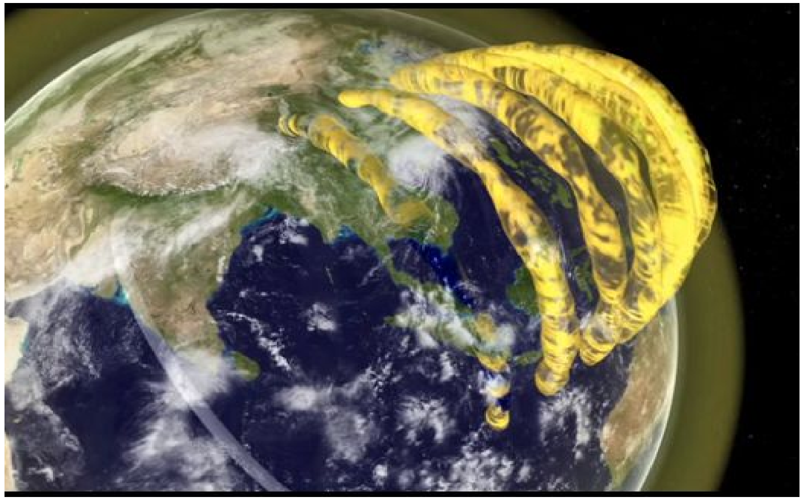
- In VHF, polarity is determined mainly by Faraday rotation which is much bigger than Spatial Offset .
- $\Phi = (k/f^2) * (F*\cos FM) * (k_a*VTEC)$
- Factors influencing Faraday
- Band (rotation inversely proportional to **f^2**)
- During the Moon Pass (for an unperturbed ionosphere):
- 0 < cos**FM** < 1   since 90°> **FM** > 0°
- $1 < k_a < 3{,}7$
- 4 < Vertical **T**otal **E**lectron **C**ontent < 40 TECU (10^{16} electrons/m^2)

VHF bands, turbulent ionosphere

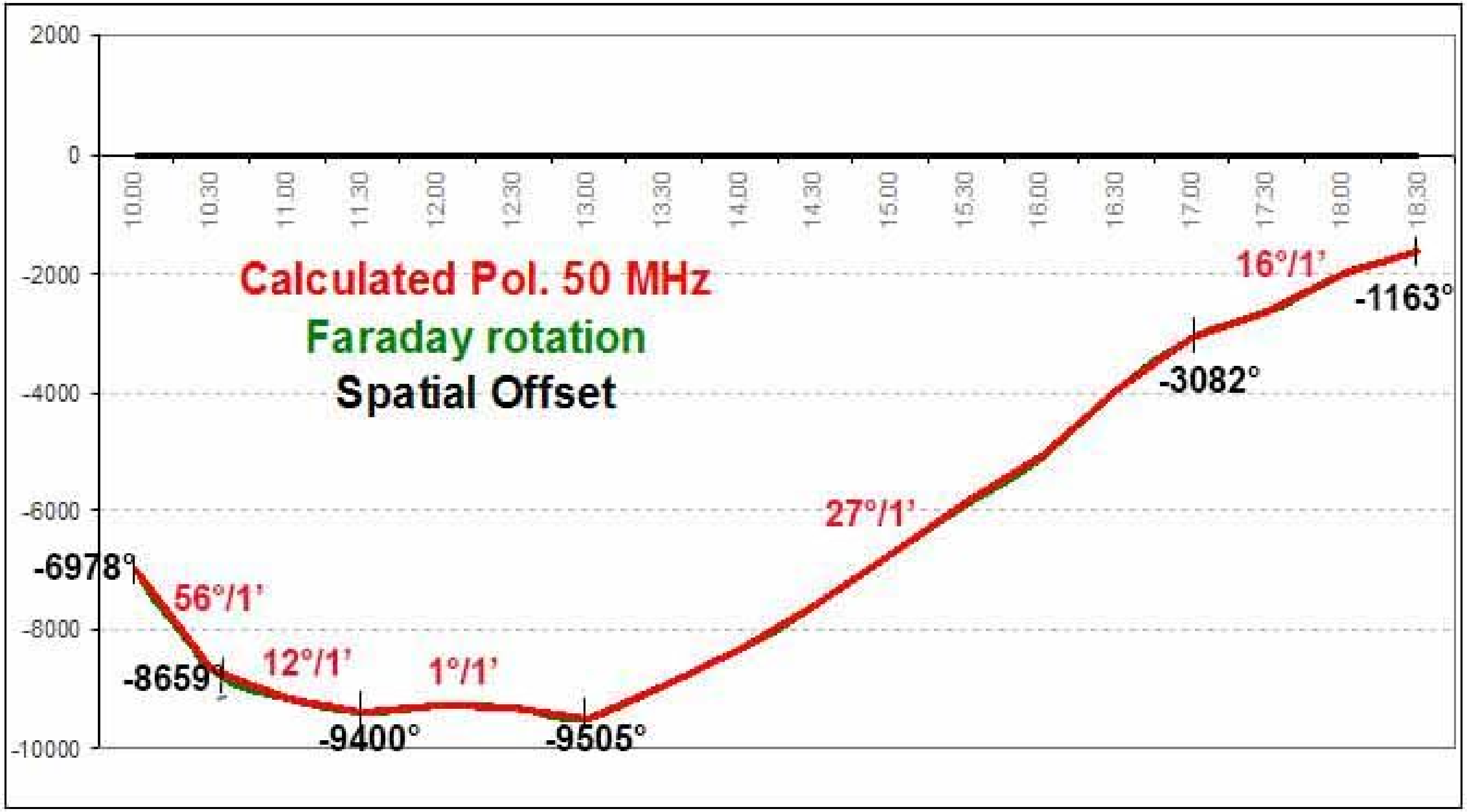
- Superimposed on the average evolution of Faraday rotation during a Moon pass, there can be a more quicker fluctuation due to the effect of ionospheric winds and plasma tubes.
- Winds cause undulations and waves (TIDs), so free electron density varies in space and time, causing rotation fluctuations.
- Australian scientist of the University of Sydney , Cleo Loi, has made the very interesting discovery of plasma tubes in Earth's magnetosphere. These structures are important because they cause signal distortions that could affect trans-ionospheric communication



Recent discovery of Plasma tubes



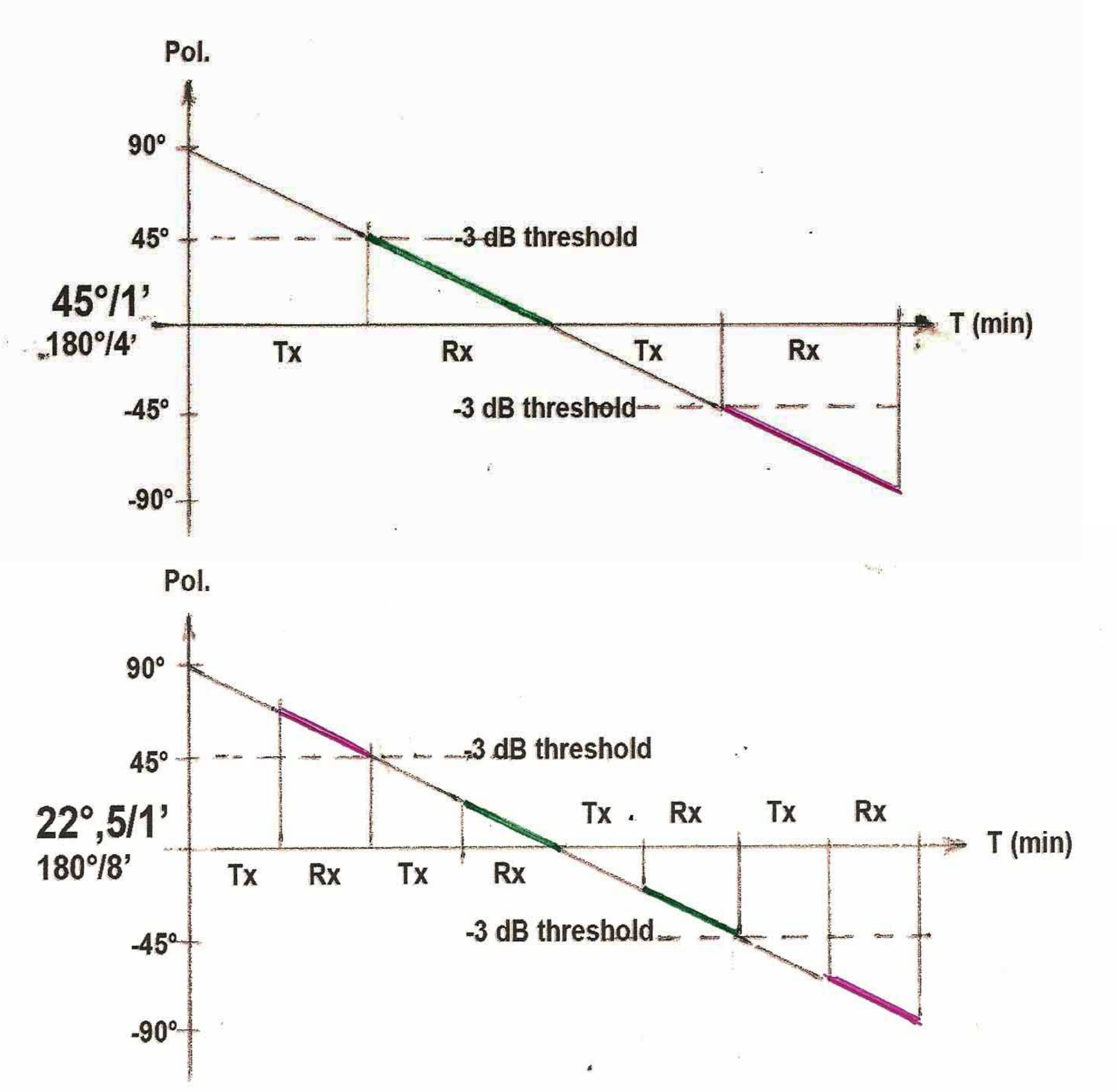
VHF, 50 MHz band Ts 3600 °K



- Faraday rotates thousands of degrees, so spatial offset is negligible

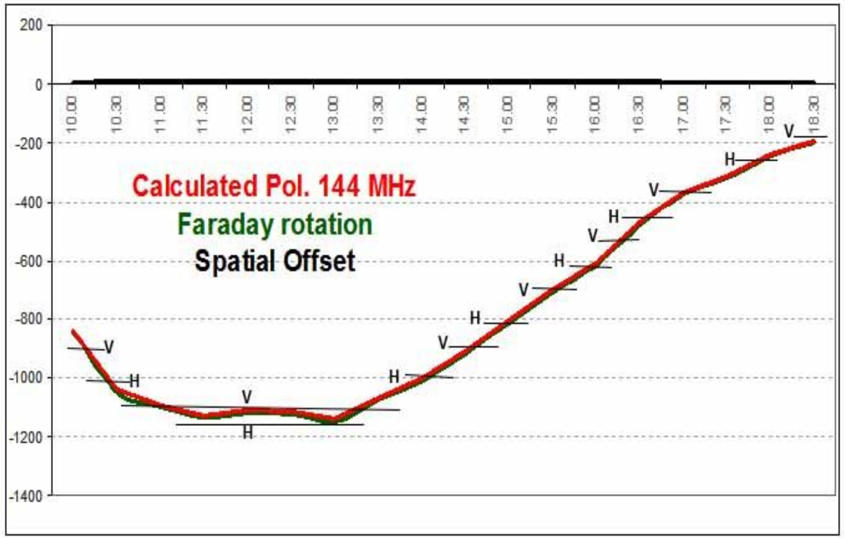
Effect of rotation speed on a JT65 qso

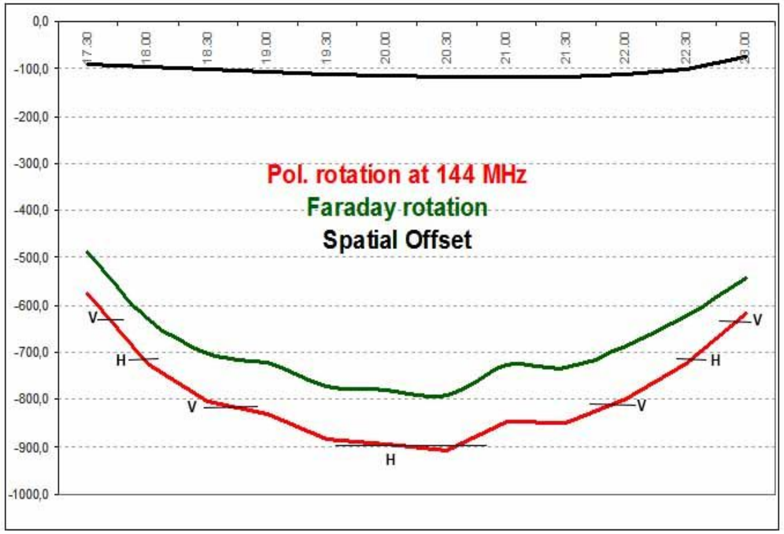
- Hypothesis: signal level 3 dB above minimum decodable when polarity 0°
- With polarity 90° decode not possible
- With polarity 45° degradation is 3 dB
- So only when polarity is between 45° and -45° decode is possible.
- How many 1' periods occur in 180° of rotation?



VHF, 144 MHz band   Ts 300 °K

- Near station (1000 km) — Far station (9000 km)
- SP4MPB – PA3FPQ — TI2SW – IK1UWL

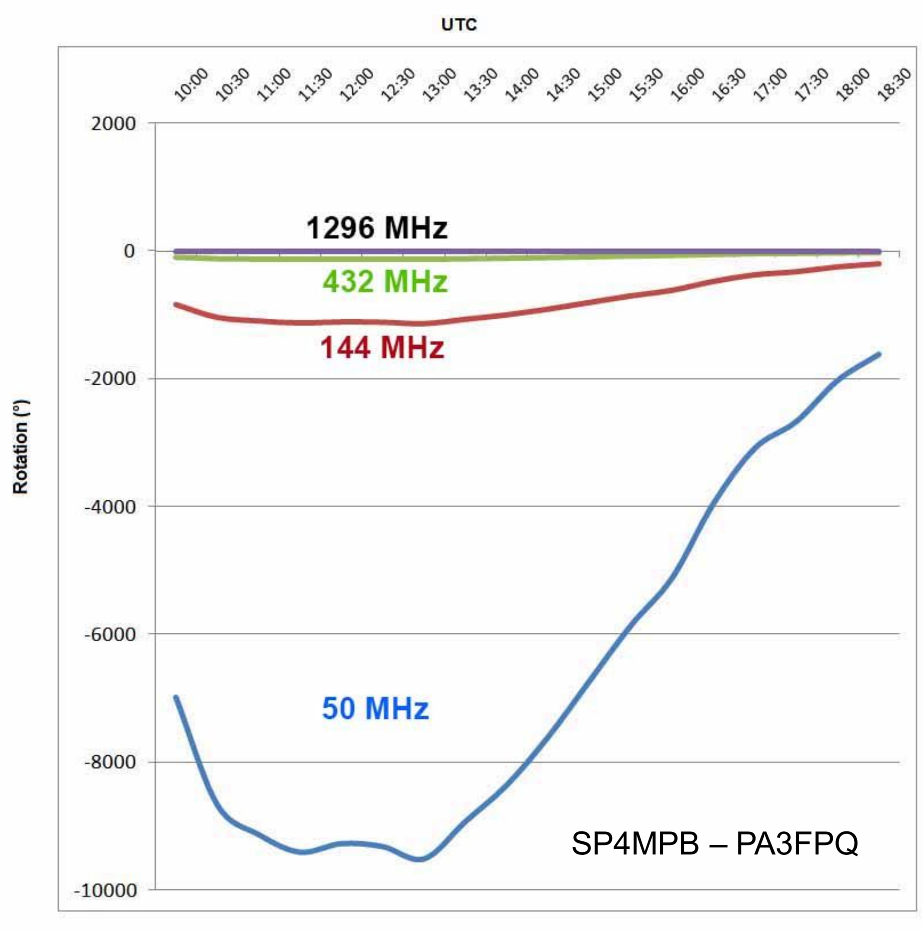




- Faraday rotates hundreds of degrees, so overrides spatial offset also when it is big due to distance.
- V-H-V transitions with typically a 30 to 60 minute period.

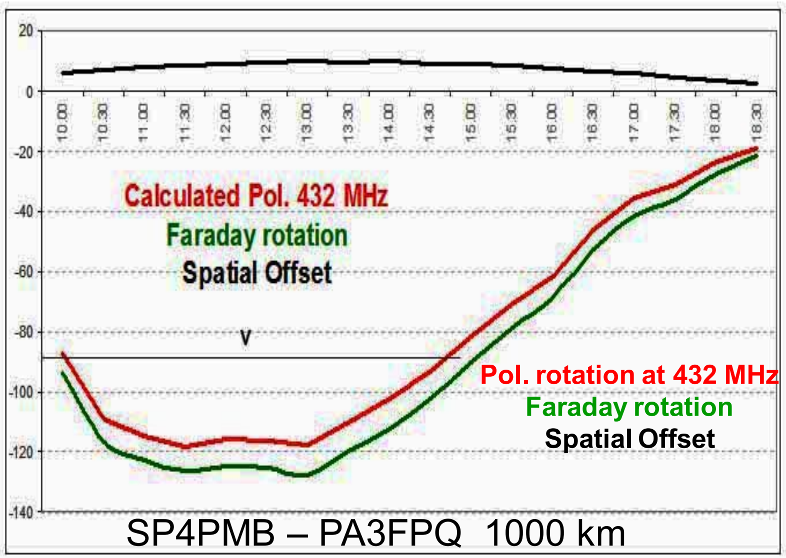
UHF bands

- In the UHF bands the dominant factor becomes spatial offset, which can reach and pass half turn (in which case the supplement counts since phase does not count) .
- Distance between stations has the biggest influence.

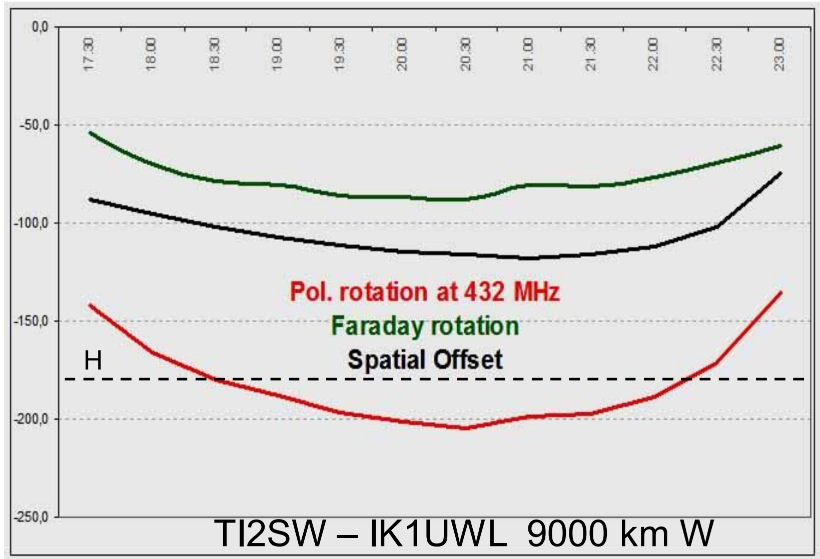


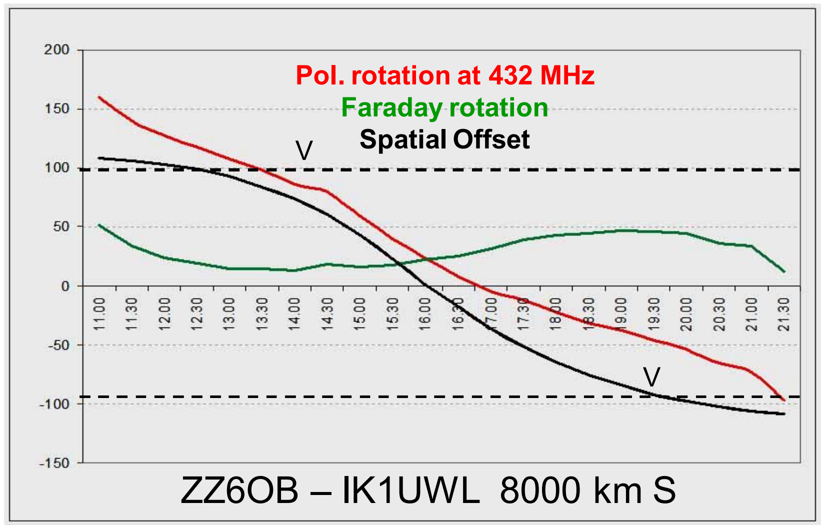
UHF, 432 MHz band   Ts 85 °K

Near station



Far station

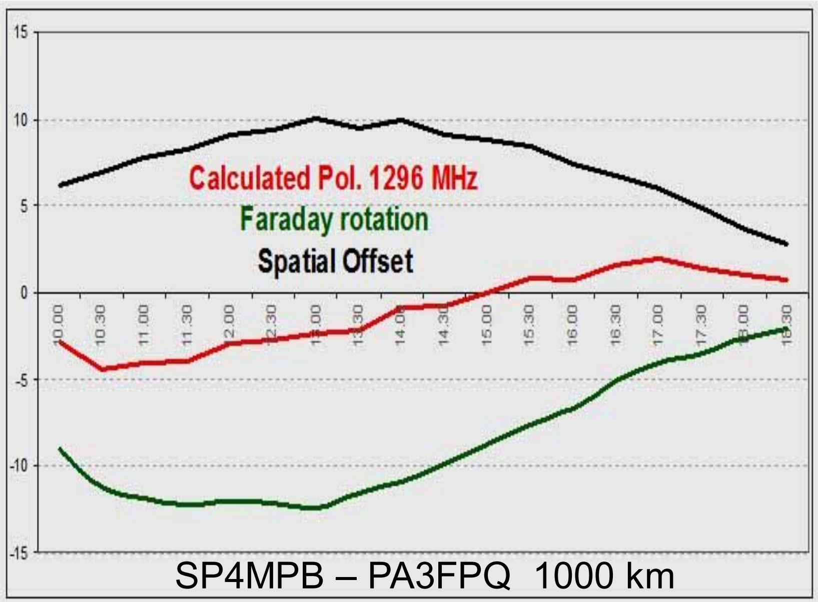




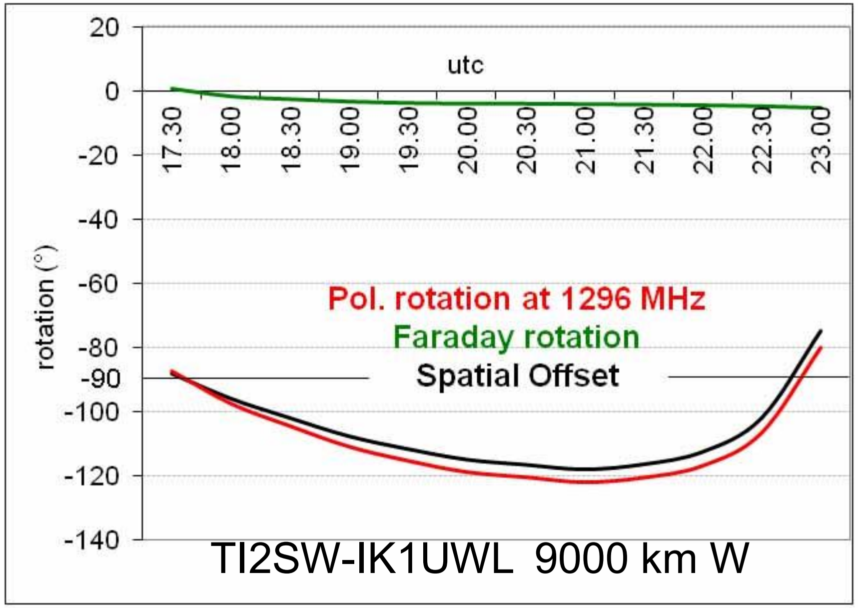
- <u>Faraday rotates only tens of degrees</u>, and is comparable to spatial offset.
- <u>Spatial offset is the biggest factor for far stations.</u>
- V-H-V transitions are few and far apart.

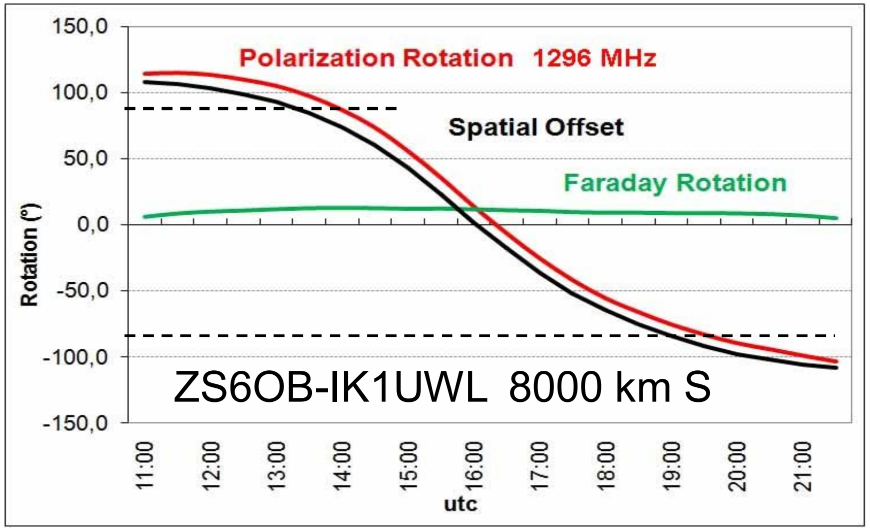
UHF, 1296 MHz band   Ts 68 °K

Near station



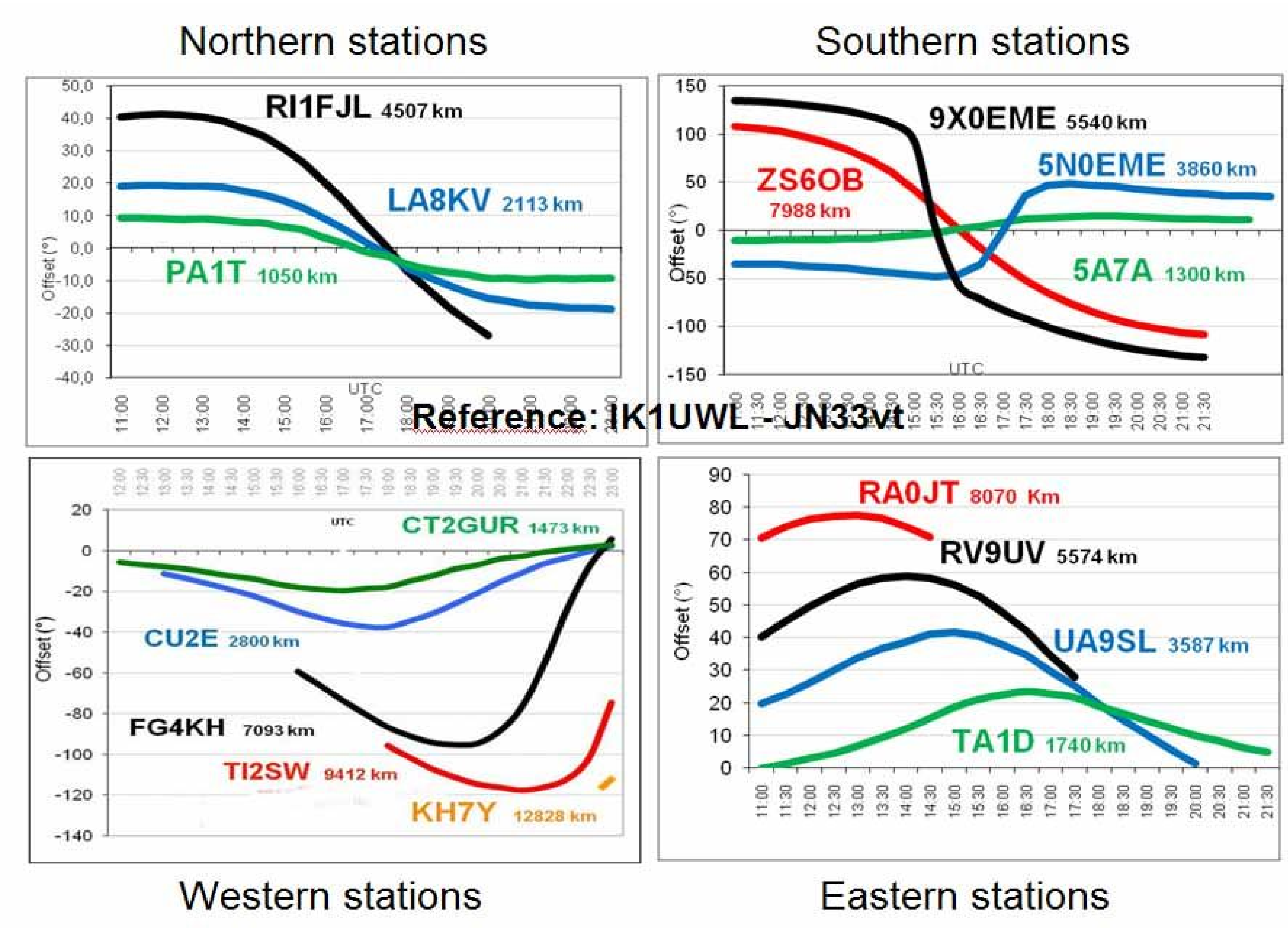
Far station





- Faraday rotates only some degrees.
- Spatial offset becomes the dominant factor.
- If circular pol. is not used, some control of polarization is useful.

UHF, 1296 MHz band Ts 68 °K



VHF/UHF bands overview

- VHF bands are dominated by Faraday, UHF bands are dominated by Spatial Offset
- Going from 6 m to 23 cm, polarity changes with decreasing speed.
- From peaks in the order of 1200°/h on 6m (because of Faraday), we tend towards 10°-20°/h on 23 cm (due to Spatial Offset).
- So when single polarity of the receiving antenna is in use, favorable and unfavorable periods increase in length and decrease in number.
- <u>Our Excel sheet has allowed us to give numbers and orders of magnitude to characteristics qualitatively known of these bands for single polarity antennas.</u>

Chapter II - 2016

Chapter I - 2014

- Thanks for the attention.
- We are glad meeting you all again.