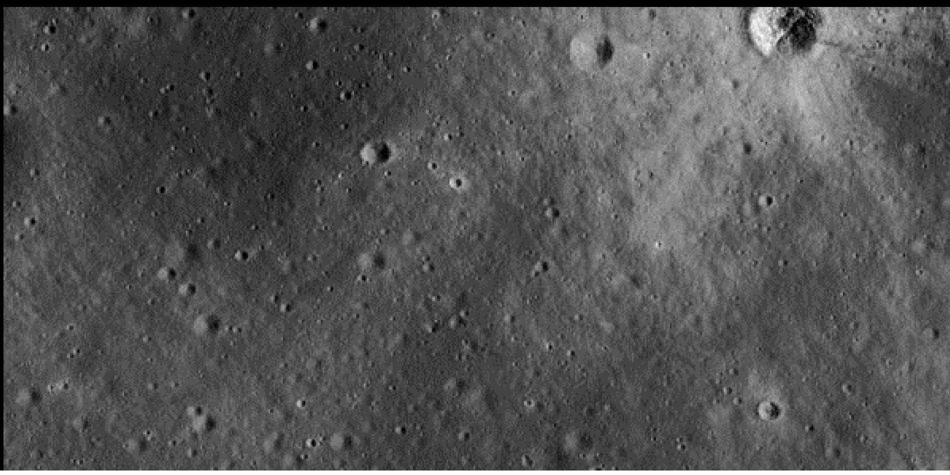
INTERACTION EFFECTS OF THE IONOSPHERE IN EME



EME 2014 World Conference

IONOSPHERIC INTERACTIONS WITH EME SIGNALS

I K 1 U W L - I K 3 X T V

Abstract
Hundredths of kilometers above us there is a stormy sea: the ionosphere, through which our EME signals have to go trough twice. The interactions are of various types: there are significant effects on signal amplitude (QSB), and wave polarization rotations (Faraday effect). Starting from data obtained from MAP65 decodes, we have made an analysis of QSB showing its dependence not on attenuation but on focusing or defocusing effects due to ionospheric waves. Then we have defined the algorithms for calculating Faraday rotation over the total moon pass, and compared them to actual MAP 65 decodes. We have found also how Faraday typically behaves as a function of correspondent station orientation. All this analysis is focused mainly on 144 MHz EME (our experience), but a good part is applicable to all bands.

Note: this document contains the complete presentation, plus some additional detail information.

IONOSPHERIC INTERACTIONS WITH EME SIGNALS

Giorgio Marchi, IK1UWL – Flavio Egano, IK3XTV - EME 2014 Conference **Date: August 2014**

Study start

Ham EME communication through the ionosphere has evolved over the years, from CW to the first digital mode JT44, then the ubiquitous JT65, and today MAP65 (thanks Joe Taylor).

Latest software arrival for EME communication, for a station equipped with cross yagis and suitable hardware, MAP65 gives JT65 type message decodes over an 80 kHz wide band, adding info on level and polarization. But MAP65 is not only a communications method, it is also a scientific instrument which, besides message decodes, gives us two important data: signal level and polarization angle.

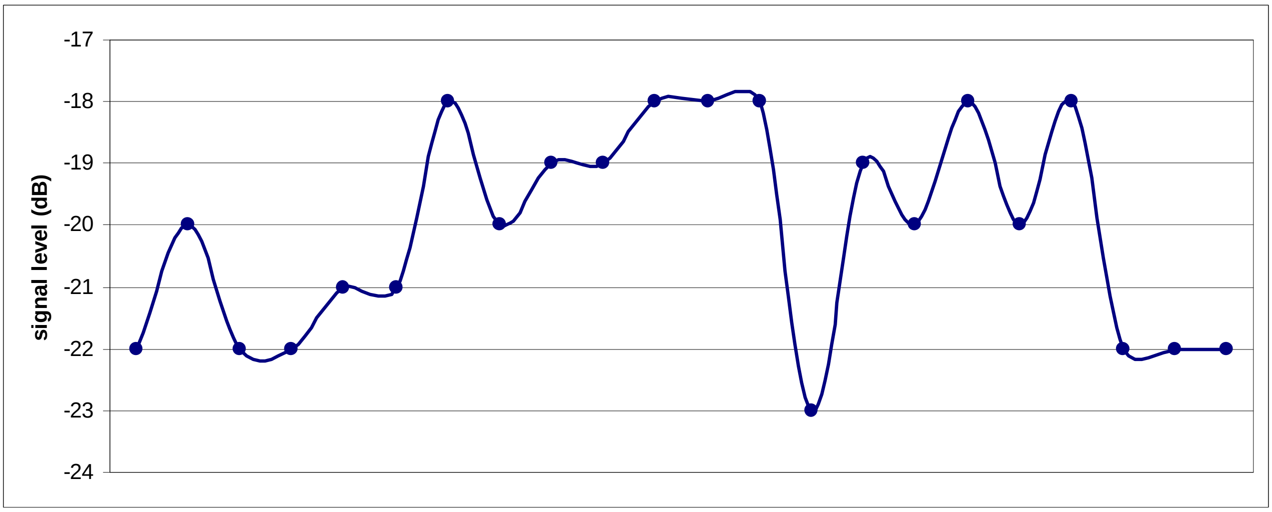
An EME pile-up

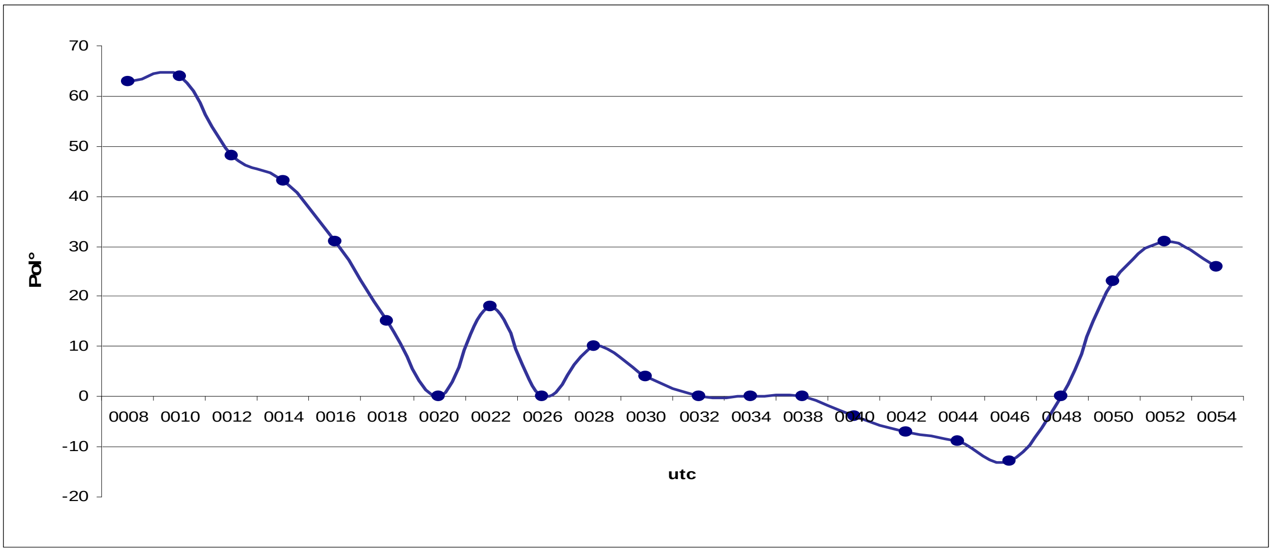
Our interest for these two additional parameters arose from the beginning. Giorgio IK1UWL had just installed MAP65 and used it to monitor OX3LX (and qso him). He saved 46’ of data

UTC Date: 2012-ago-03 00:00

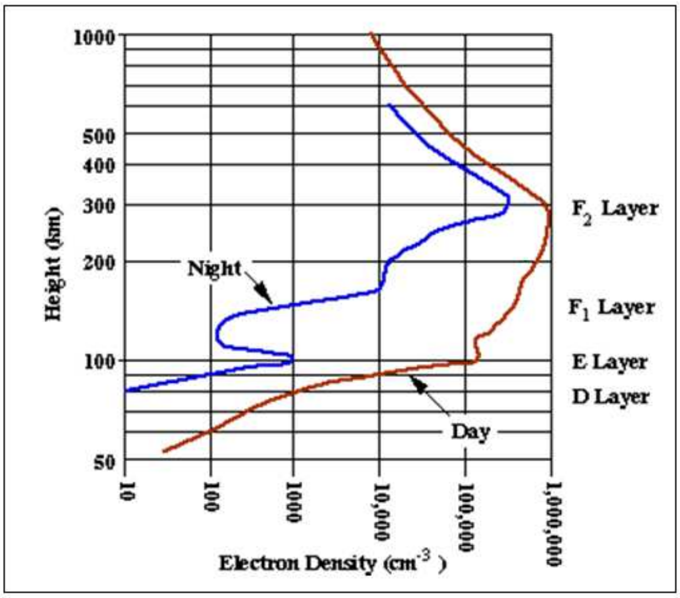
```
----------------------------------------------------------------------------
  QRG    DF         DT   Pol   dB  UTC
 144.143 -129  0 -2  0  1.7  63  4 -22 0008  CQ OX3LX HP15          1 10  8
 144.143 -138  3 -1  0  1.7  64  3 -20 0010  CQ OX3LX HP15          1 10 15
 144.143 -144  0 -2 -1  1.7  48  3 -22 0012  CQ OX3LX HP15          1 10  5
 144.143 -153  0 -2 -1  1.9  43  5 -22 0014  CQ OX3LX HP15          1 10  3
 144.143 -161  1 -1  0  1.5  31  1 -21 0016  CQ OX3LX HP15          1 10  4
 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                 0  0  0
 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                 0  0  0
 144.143 -199  1 -1  0  1.7  10  4 -19 0028  CQ OX3LX HP15          1 10  3
 144.143 -205  0 -2  0  1.5   4  4 -18 0030  I3MEK OX3LX HP15 OOO    1  0 16
 144.143 -214  0  0  0  3.6   0  3 -18 0032  RRR                 0  0  0
 144.143 -217 -1  0 -1  2.1   0  4 -18 0034  IZ3KGJ OX3LX HP15 OOO   1  0 18
 144.143 -226  0  0  0  1.0   0  4 -23 0038  RRR                 0  0  0
 144.143 -229 -1 -1 -1  1.6  -4  4 -19 0040  CQ OX3LX HP15          1 10 15
 144.143 -232 -2 -1 -1  1.8  -7  5 -20 0042  CQ OX3LX HP15          1 10 12
 144.143 -238  0 -1 -1  1.8  -9  4 -18 0044  CQ OX3LX HP15          1 10 10
 144.143 -243  3 -1  1  1.8 -13  3 -20 0046  IK1UWL OX3LX HP15 OOO   1  0  7
 144.143 -246  0  0  0  1.0   0  4 -18 0048  RRR                 0  0  0
 144.143 -252  1 -1  1  1.8  23  6 -22 0050  CQ OX3LX HP15          1 10  5
 144.143 -255 -1 -1 -1  1.8  31  5 -22 0052  CQ OX3LX HP15          1 10  4
 144.143 -261  2  0 -1  1.8  26  3 -22 0054  CQ OX3LX HP15          1 10  5
```

and put them in diagram





Besides being glad for the rare dx, the amount of variation of signal level and polarization angle in so short a time was surprising. Giorgio IK1UWL sent this data to Flavio IK3XTV, and we both decided to investigate on the causes of this.



The ionosphere

- 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.**
- Free electron density is variable in space and time.
- Their density (number per m3) determines various effects:

Slowdown, Attenuation, Deviation, Rotation

The ionosphere, space weather

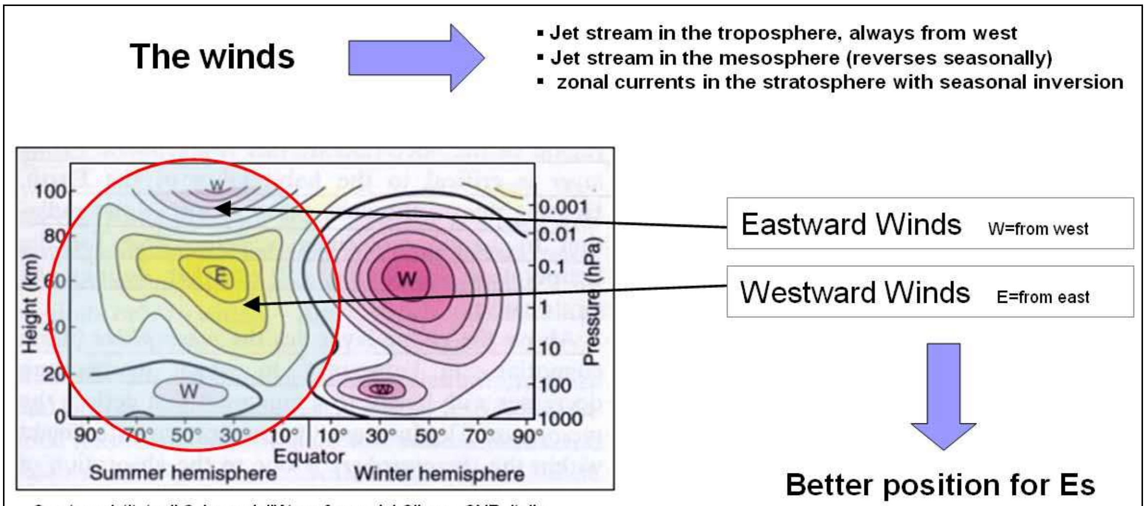
Weather near the surface involves winds that propagate like waves across the planet.

Weather in the upper atmosphere and in space is characterised by very strong winds, so has wavelike characteristics as well.

Space weather has two drivers: one is solar wind and radiation, the other is the dynamic atmosphere of Earth.

In the atmosphere travel waves very low in frequency (wavelength in the range of hundreds or thousands of kilometres) that carry energy and momentum also upwards (buoyancy waves).

Thermal effects cause tides with vertical movements and transfer of energy through shear winds. At the altitude at which sun radiation causes ionization there are winds with speed ranging in the hundreds of meters per second Being shear winds the ionosphere is roughened by shorter waves and vortices.



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

These winds, which are active most days for part of the day, cause Travelling Ionospheric Disturbancies (TIDs) which result in fluctuations of electron density and formation of amasses.

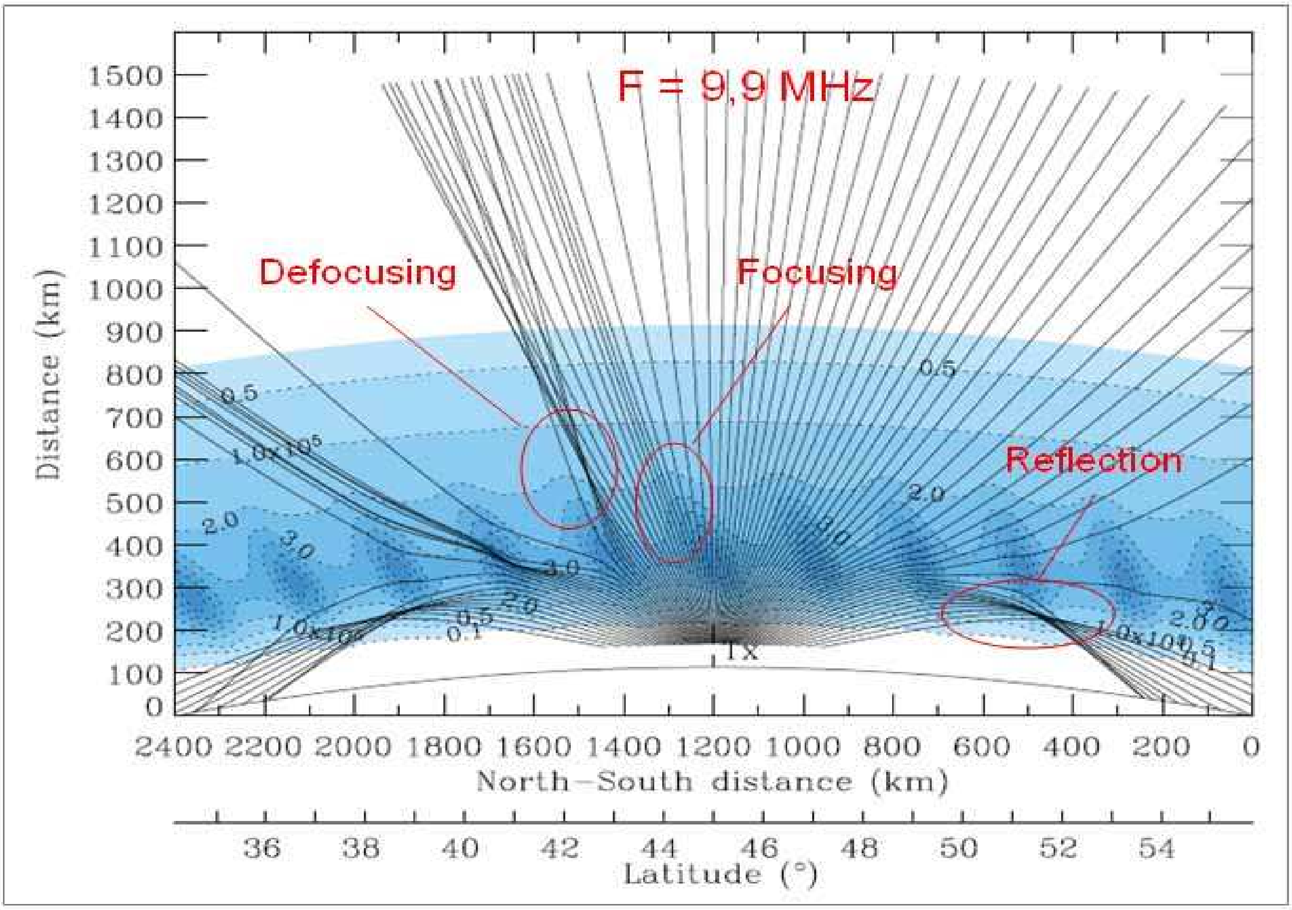
Ionospheric waves

The ionospheric winds cause continuous undulations and waves (Traveling Ionospheric Disturbances, TIDs) resulting in fluctuations of electron density.

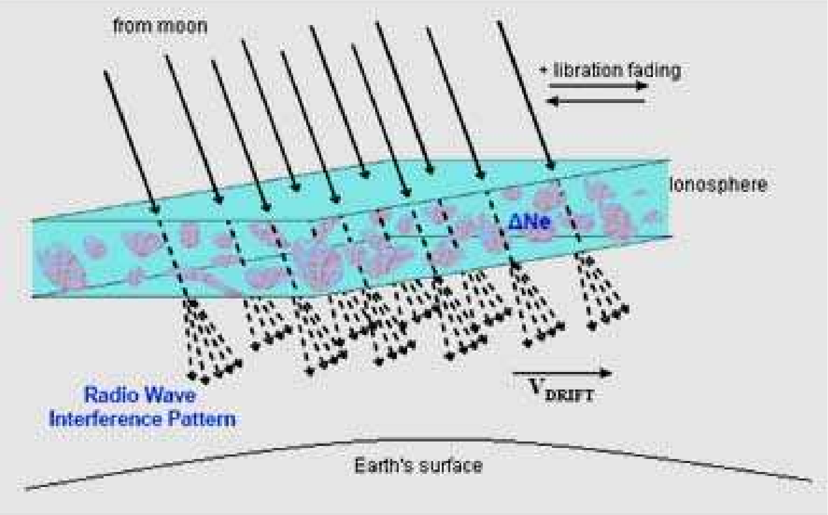
Class	Horizontal wavelenght	Periods	Horizontal phase velocities
LSTIDs Large scale	>1000 Km	0,5..3 h	300..1000 m/s
MSTIDs Medium scale	100..1000 Km	12 min...1h	100..300 m/s
SSTIDs Small Scale	<100 Km	A few minutes	<200 m/s

Source: INGV Istituto Nazionale di Geofisica e Vulcanologia - Italy

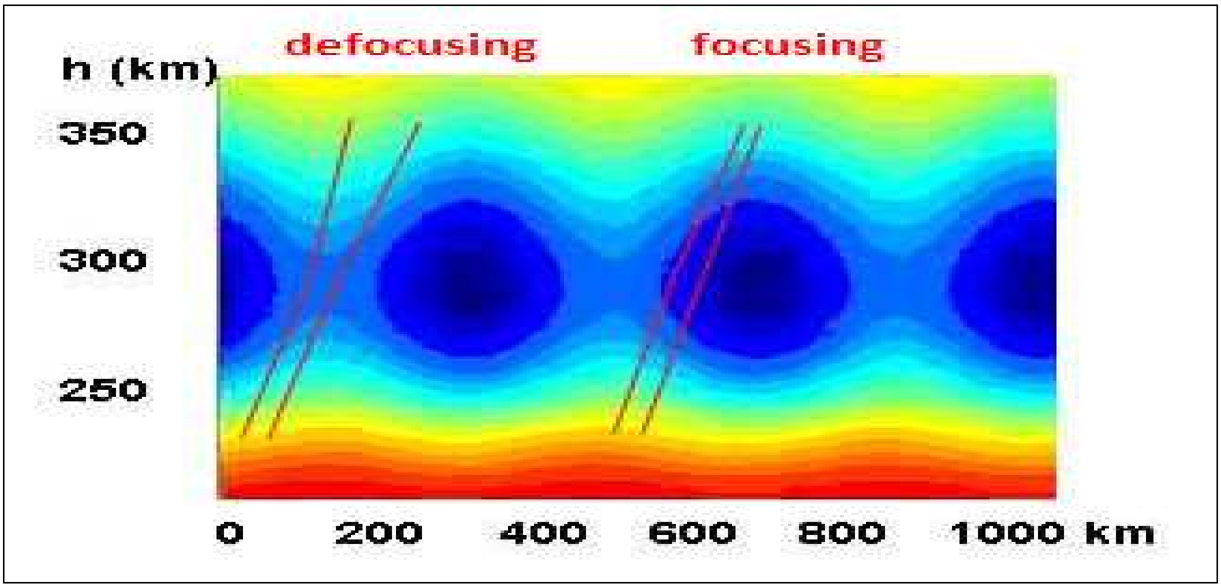
This turbulence and waves in the ionosphere have a lens effect on our signals, **focusing and defocusing** them.



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



Rapid scintillations caused by ionospheric irregularities (ssTIDs, periods of some minutes)



Slower scintillations due to msTIDs

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

QSB

QSB band dependence (ionospheric refraction is proportional to inverse square of frequency)

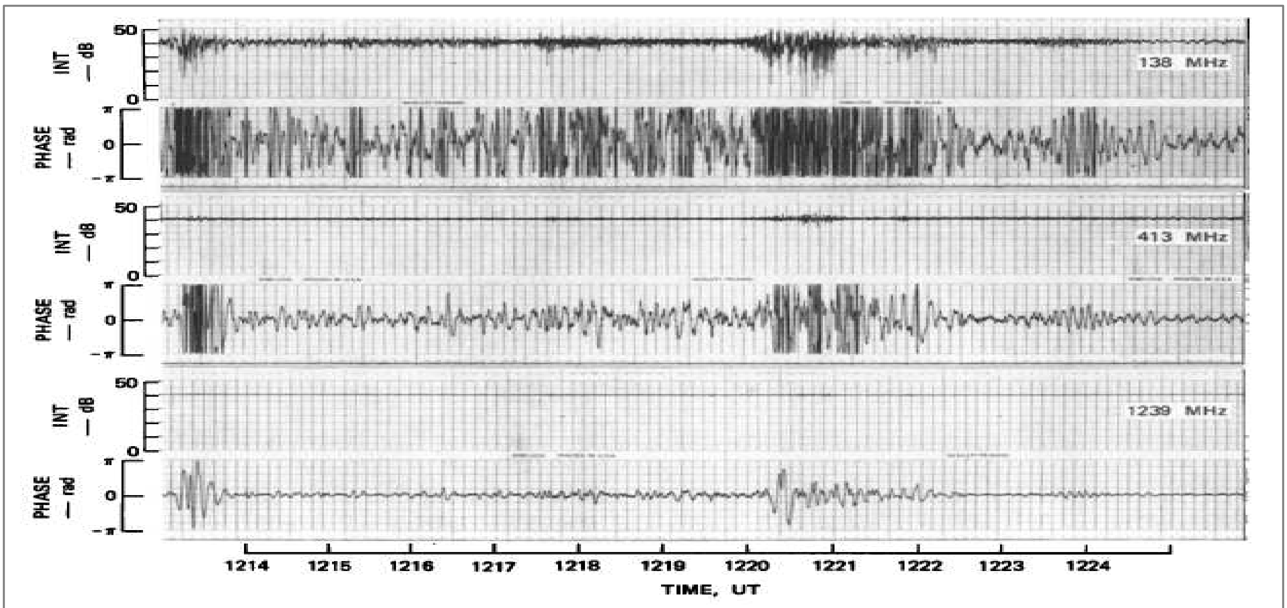
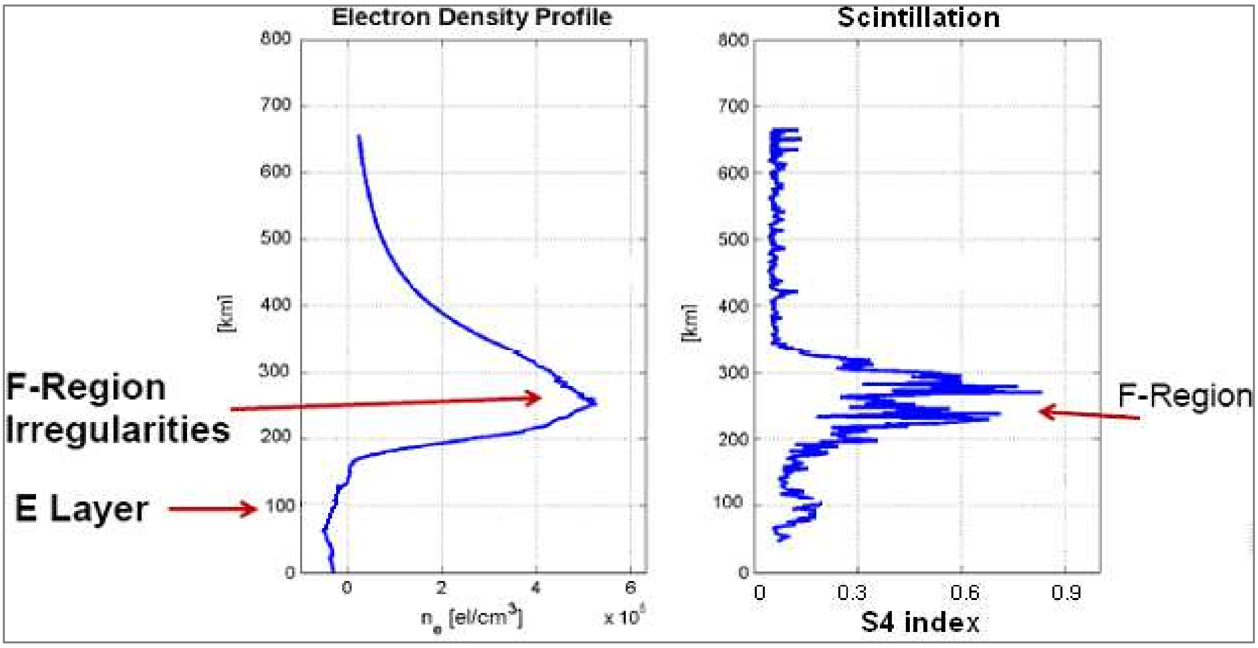


Fig. 8. Detrended VHF, UHF, and *L*-band strip charts from a pass recorded at Poker Flat on 29 May 1976.

Regions dominating effect



Signal level fluctuations

A – Static ionosphere

Among the first notions of ionospheric behaviour we got, was that absorption of signal energy was in the range of 0,1 to 0,5 dB at 144 MHz.

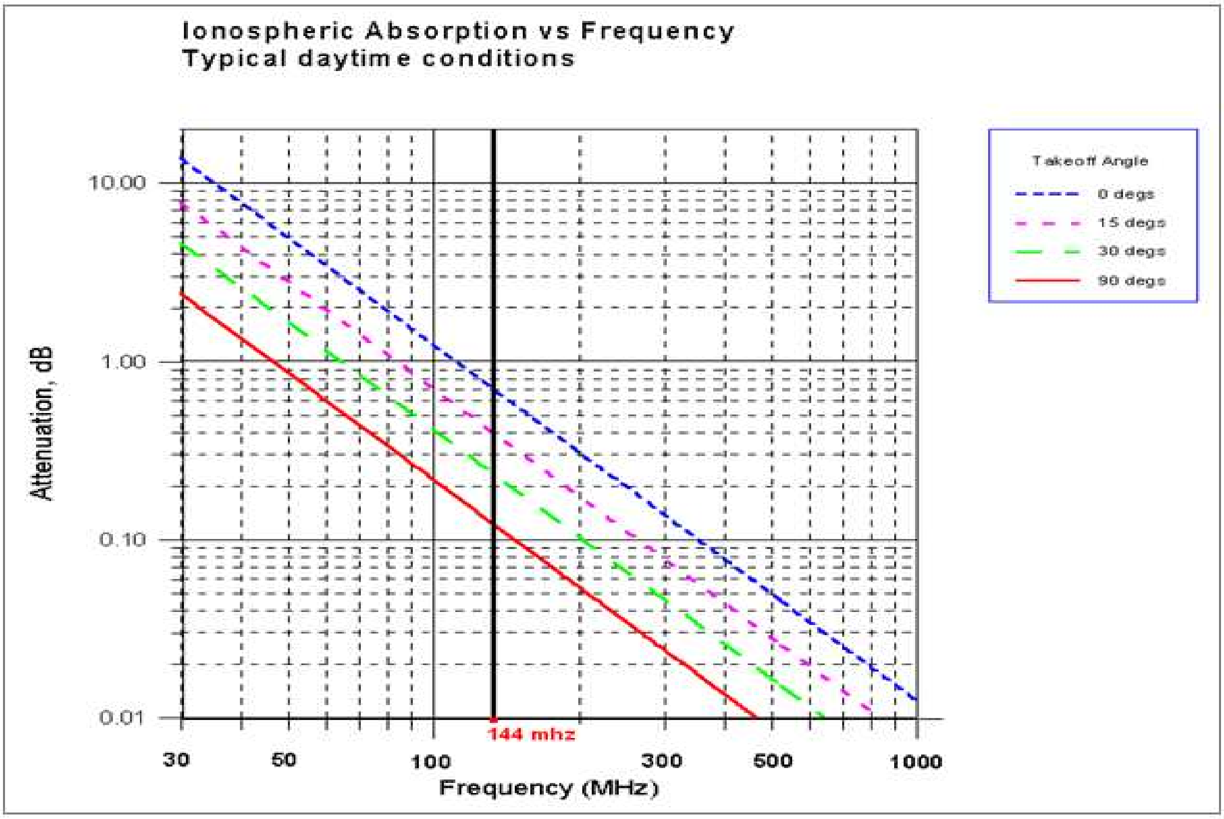
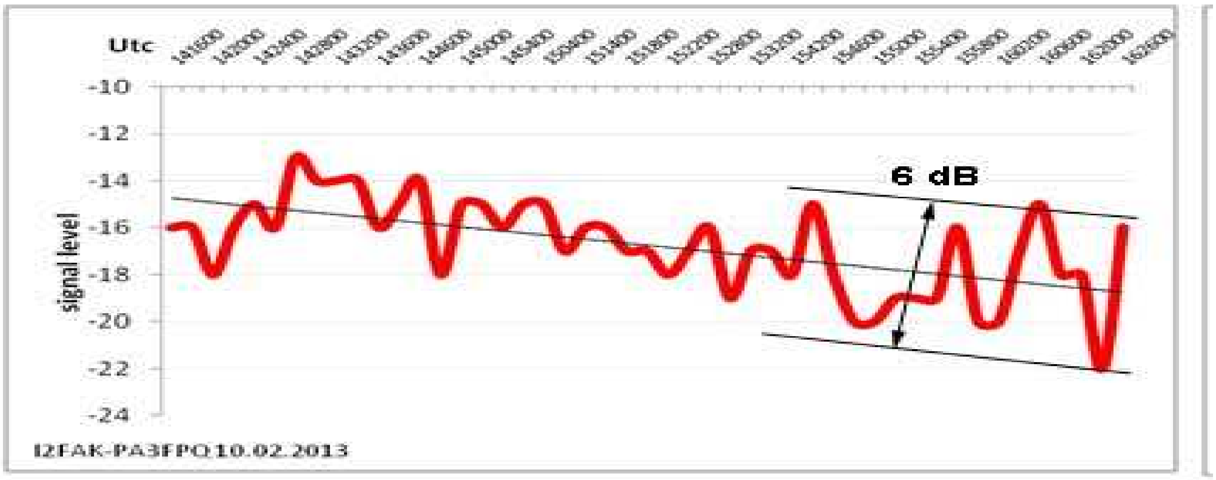


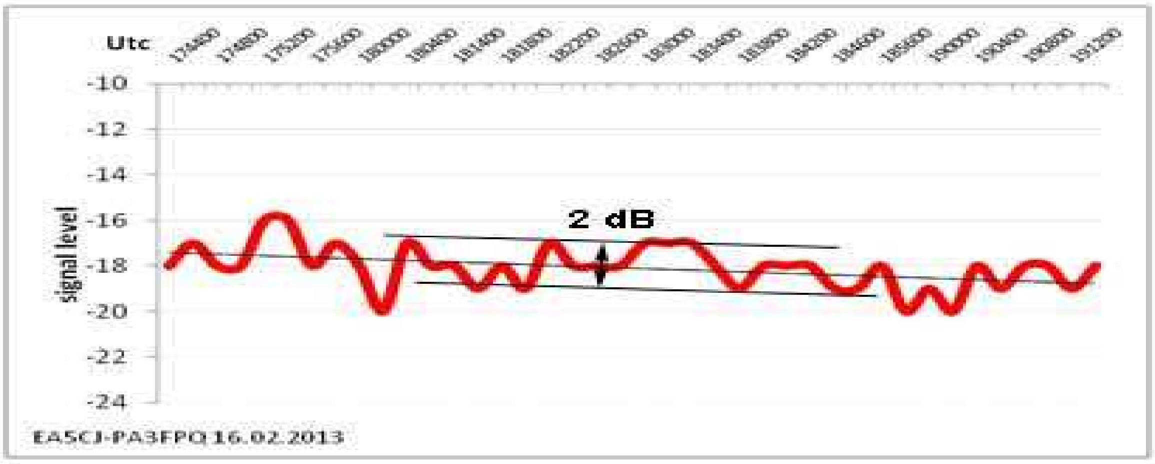
Image source: Darrel Emerson National Radio Astronomy Observatory - Tucson, AZ - USA

B – Dynamic ionosphere

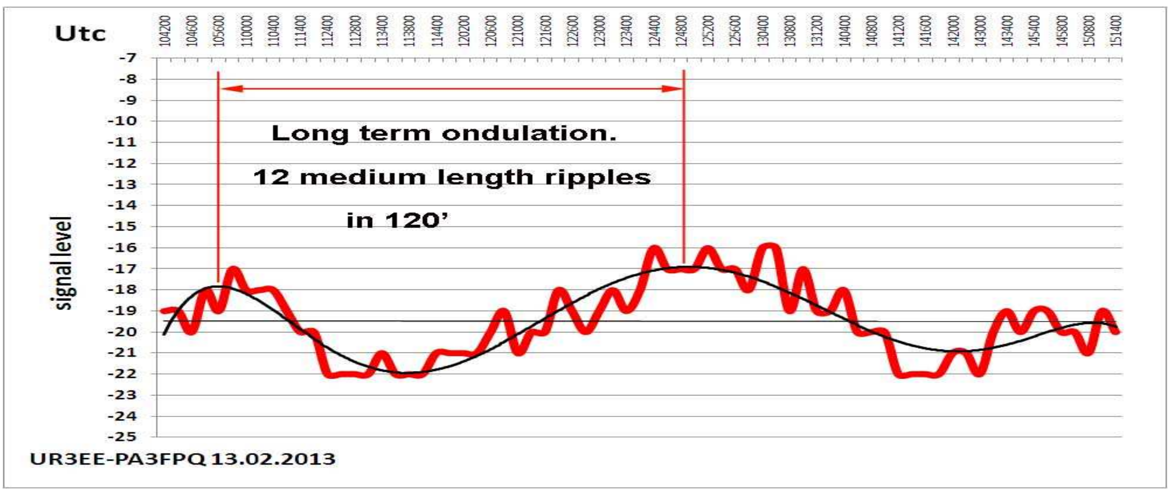
Whilst the observed medium period fluctuations of signal level are in the order of 3-6 dB in day conditions (attributable to ssTIDs)

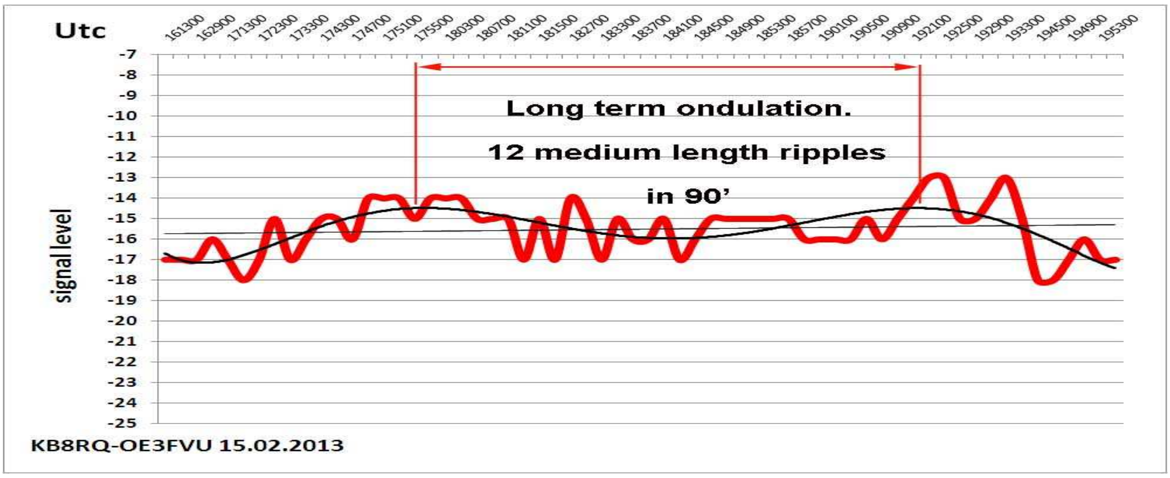


And of the order of 2 dB in night conditions



Additionally we noted long term fluctuations (attributable to msTIDs):





These cannot be attributed to absorption because a thirty-fold density change would be needed.

So we realized that turbulence and waves in the ionosphere have a

lens effect on our signals, focusing and defocusing them.

Faraday effect,

Faraday rotation is what happens to the polarization plane of a wave going through a ionized medium intersected by a magnetic field. The formula is very simple:

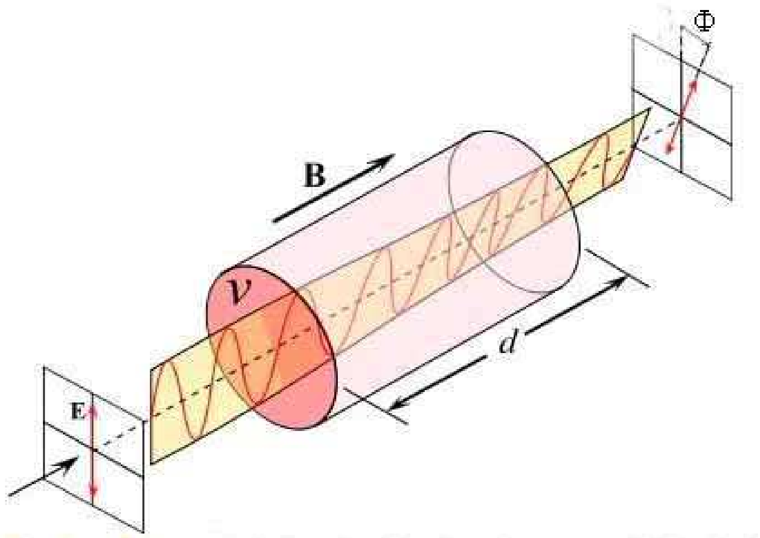
$\Phi = k * B * TEC / f^2$ (rad),

with

B = Geomagnetic field component in wave's direction of travel (i.e. towards or from the Moon)

TEC = Total Electron Content of the path

f = wave frequency



Effects tied to frequency

Angle of rotation is inversely proportional to the square of frequency.

Since our bands have frequencies increasing by a factor of three, the rotation becomes one ninth from a band to the next.

With the same conditions for B and TEC:

Band	Rotation (°)		
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.

Clarification on spatial offset:

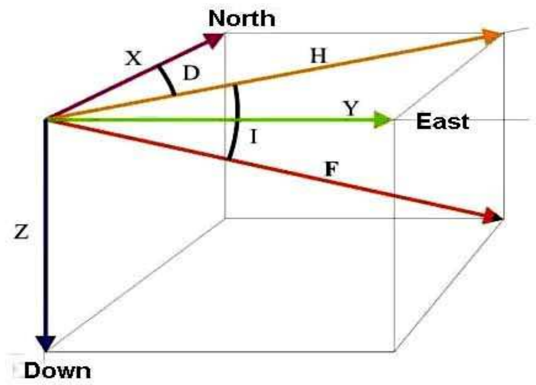
Polar polarization is the angle between an antenna and earth's polar axis.

Spatial offset between two stations is simply the difference between the polar polarizations of the two stations. This offset adds algebraically to Faraday rotation.

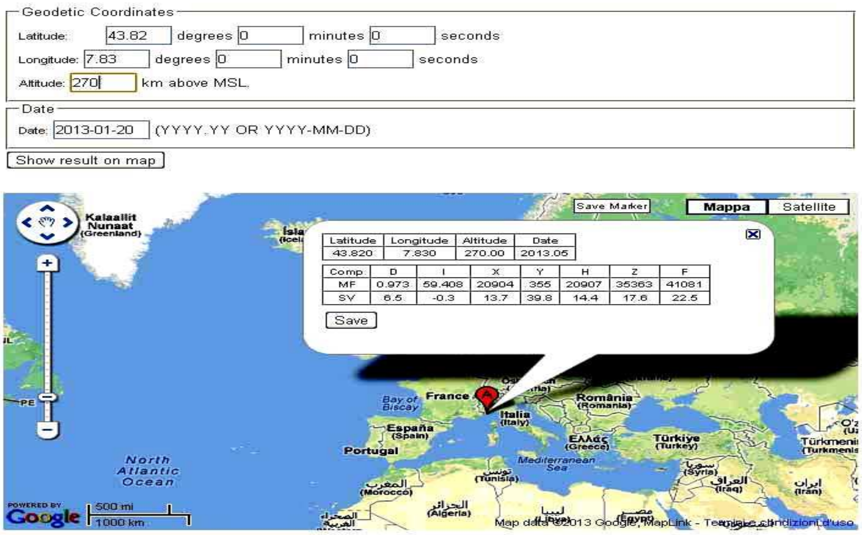
Geomagnetic field

We found a good source for F (total field) in the web site of the British Geological Survey.

Introducing Lat, Long, Median Height of the ionosphere, and Date, one obtains:



- Total field F (nTesla)
- Inclination I (°)
- Declination D (°)
- . Magnetic latitude



Latitude	Longitude	Altitude	Date
43.820	7.830	270.00	2013.05

Comp	D	I	X	Y	H	Z	F
MF	0.973	59.408	20904	355	20907	35363	41081
SV	6.5	-0.3	13.7	39.8	14.4	17.6	22.5

Legend

	D = Declination	I = Inclination	X = North Intensity	Y = East Intensity	H = Horizontal Intensity	Z = Vertical Intensity	F = Total Intensity
MF = Main Field	degrees east	degrees down	nT	nT	nT	nT down	nT
SV = Secular Variation	arcmin/year	arcmin/year	nT/year	nT/year	nT/year	nT/year	nT/year

Component B

In our formula we must introduce the Geomagnetic field component in Moon's direction.

Referred to a system of axis North, East, Up:

- The vector F is defined by I*nclination* and D*eclination*.
- Moon's direction is defined by Az*imuth* and El*evation*.

For projecting Field F on the Moon's direction we must calculate the angle FM between these two vectors.

The formula becomes:

cosFM=cosI*cosD*cosEL*cosAz+cosI*sinD*cosEl*sinAz-sinI*sinEl

from which **B = F * cosFM**

TEC (Total Electron Content)

TEC is a key parameter for describing Earth's ionosphere.

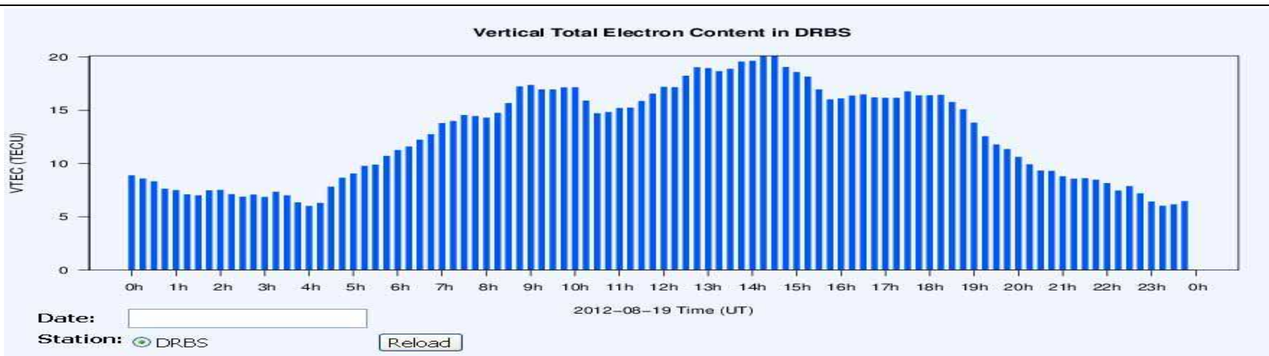
It is measured in TECU (TEC Units) = 10^{16} electrons/m^2

The number of TECUs represent the total number of electrons present in a cylinder of 1 m^2 of section, crossing the ionosphere in the wave's direction.

VTEC sources

Scientific Stations post VTEC (Vertical TEC) diagrams for each day. Among these we found the Royal Observatory of Belgium (ROB), that publishes VTEC histograms with values every 15', and keeps an archive for every day of the year. Measures are made by the observatory located in Dourbes (Belgium).

Typical summer VTEC diagram:



Typical winter VTEC diagram:

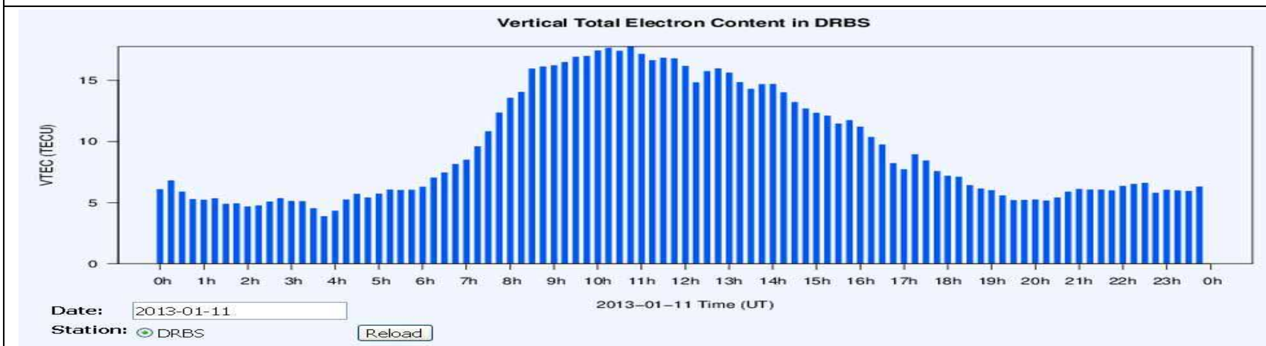
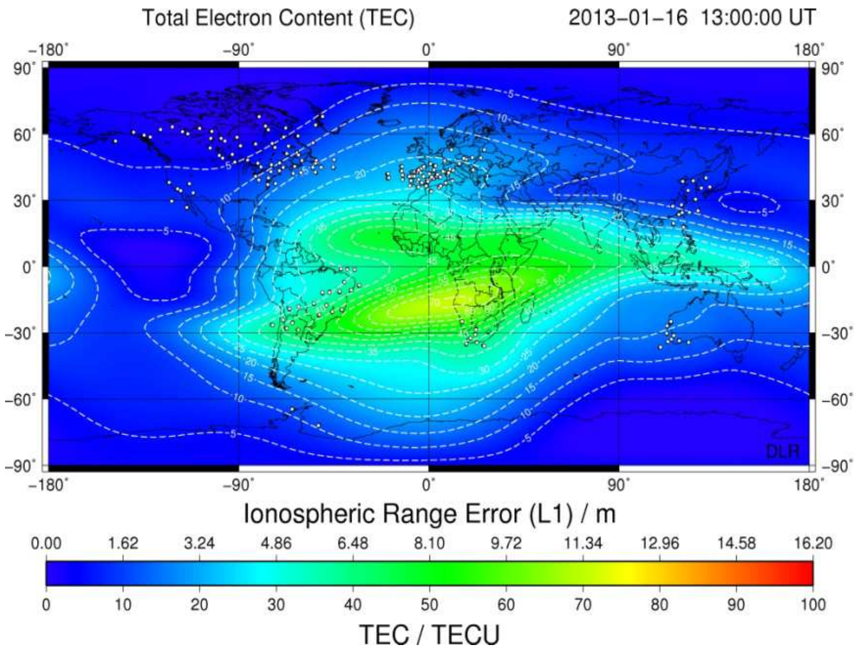


Image Source: ROB Royal Observatory Dourbes - Belgium

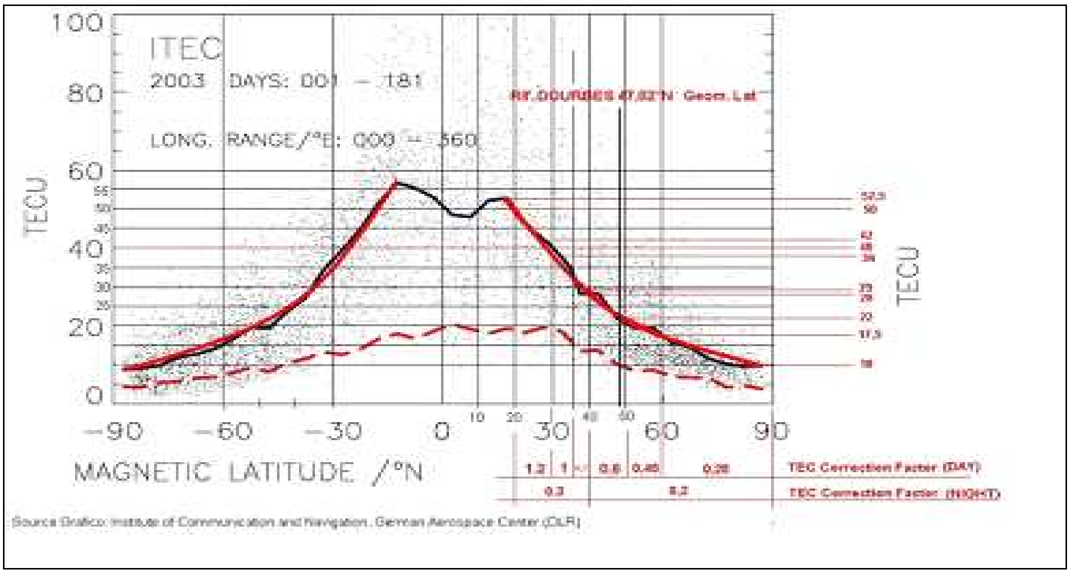
From Dourbes to other places

Spatial variation of TEC:

- Longitudinal variation: Global trend quite regular and correlated to the local solar time
- Latitudinal variation: The TEC value, varies non-linearly from the poles to the equator (geomagnetic)



This curve represents the latitudinal variation:



For our purposes we have simulated it with the algoritm:

TECU variation = 0,02*LAT^2-2,5*LAT+95

So for TEC value calculation:

1 – Dourbes VTEC at same time

2 – Magnetic latitude of station

3 – With algoritm representing the curve we find the correction to be applied to Dourbes VTEC

Slab thickness

Data on the Dourbes site give VTEC and slab thickness. These represent the transformation of the real ionosphere, with changing electron content with height and total thickness over 1000 km, in an equivalent ionosphere constituted by a uniform density layer with known TECU and thickness. Going through this slab gives the same effects as going trough the real ionosphere. The advantage is that two numbers define this ionosphere, without the need for integration of a complex graph.

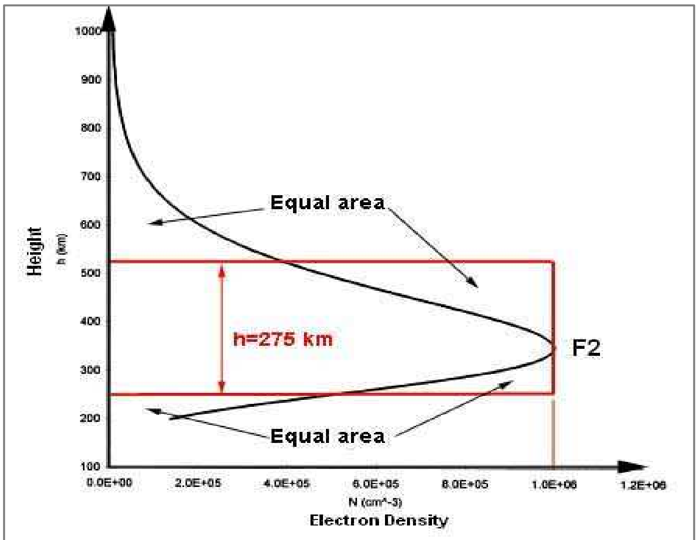


Fig. Schematic electron density height profile
Source: Journal of Atmospheric and Solar-Terrestrial Physics

Oblique passage (Slant TEC)

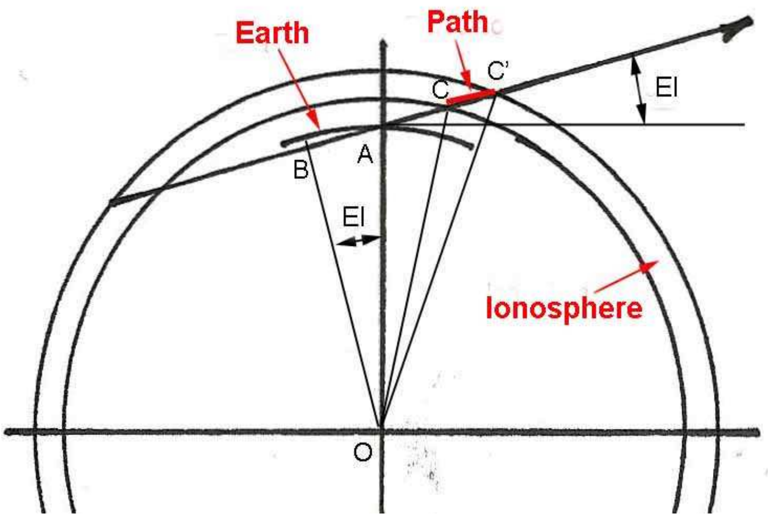
Ince the slab is crossed obliquely, the number of encountered electrons increases.

So TEC in our formula becomes TEC = STEC = Ka*VTEC, with Ka given by:

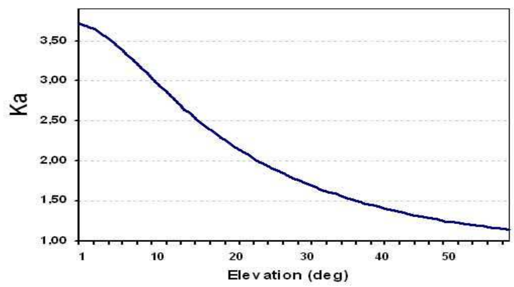
With Earth radius=6367 km, and Ionosphere beginning at 100 km height, with h=Slab Thickness

Ka =(SQR((64672+h)2-(6367*cosEl)2)-SQR(64672-(6367*cosEl)2))/h

This is easily found with Pitagora's theorem from



For h=350 km this is Ka as function of elevation



Final formula

We have now the data for the complete formula:

$$\Phi=k*(F*\cos FM)*(VTEC*corr*Ka)/f^2$$

For f=144 MHz, k/f^2=1,14 with F in Gauss.

Wave plane rotation is controlled by these variables:

- **Angle between Geomagnetic. field and Moon direction (cosFM ranges from 1 to -1)**
- **TEC (constant or changing slowly, 100% to 30%)**
- **Moon elevation (oblique passage Ka from 1 to 3,7)**

Collecting on-the-air data

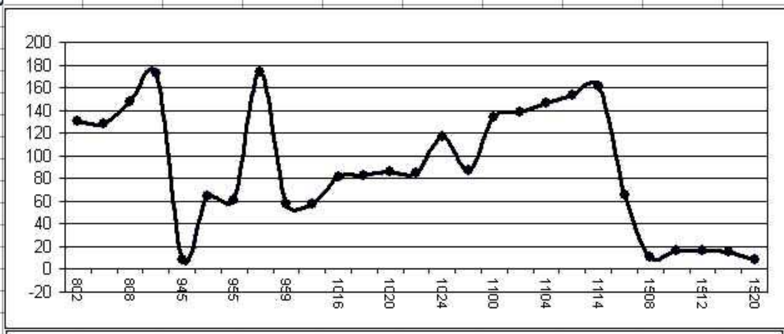
We needed many sources of data, geographically spread.

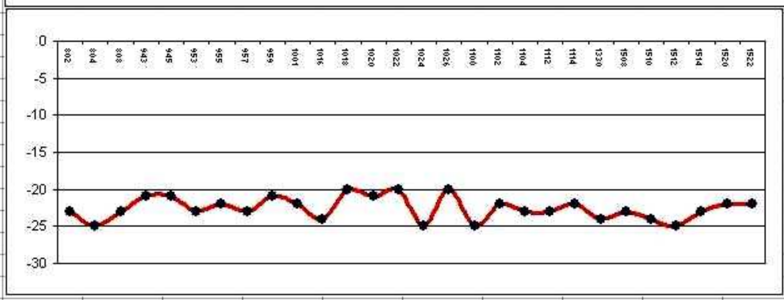
A big help came from René PE1L, who collected for us all the data published on line in LiveCQ in a file, accessible to us.

We sorted them in an Excel sheet by date, spotter and spotted.

Example: 18/08/2012 – DG0OPK – PE1L, data, pol and level graphs

2	date	utc	sig	pol	call	spotter
1927	18082012	802	-23	130	DG0OPK	PE1L
1929	18082012	804	-25	128	DG0OPK	PE1L
1937	18082012	808	-23	148	DG0OPK	PE1L
2036	18082012	943	-21	173	DG0OPK	PE1L
2039	18082012	945	-21	8	DG0OPK	PE1L
2045	18082012	953	-23	64	DG0OPK	PE1L
2050	18082012	955	-22	61	DG0OPK	PE1L
2055	18082012	957	-23	174	DG0OPK	PE1L
2057	18082012	959	-21	58	DG0OPK	PE1L
2060	18082012	1001	-22	58	DG0OPK	PE1L
2084	18082012	1016	-24	82	DG0OPK	PE1L
2086	18082012	1018	-20	83	DG0OPK	PE1L
2090	18082012	1020	-21	86	DG0OPK	PE1L
2094	18082012	1022	-20	85	DG0OPK	PE1L
2100	18082012	1024	-25	117	DG0OPK	PE1L
2105	18082012	1026	-20	87	DG0OPK	PE1L
2135	18082012	1100	-25	134	DG0OPK	PE1L
2137	18082012	1102	-22	138	DG0OPK	PE1L
2142	18082012	1104	-23	146	DG0OPK	PE1L
2145	18082012	1112	-23	153	DG0OPK	PE1L
2148	18082012	1114	-22	161	DG0OPK	PE1L
2251	18082012	1330	-24	66	DG0OPK	PE1L
2406	18082012	1508	-23	11	DG0OPK	PE1L
2412	18082012	1510	-24	17	DG0OPK	PE1L
2415	18082012	1512	-25	17	DG0OPK	PE1L
2421	18082012	1514	-23	15	DG0OPK	PE1L
2448	18082012	1520	-22	8	DG0OPK	PE1L
2456	18082012	1522	-22	4	DG0OPK	PE1L





So we could examine a great variety of cases, and start to identify tendencies.

Note: The polarization measured by MAP65 is the algebraic sum of spatial offset and of two ionospheric crossings: the Faraday rotation of the up going transmitted wave and that of the returning echo.

Amount of rotation in an interval

As a first check on our formulas, we compiled an Excel sheet for calculating what happens in a time interval, generally not greater of an hour. An example:

3	Spotted	locator		lat	long	Corr VTEC z	Inclination(°)	F (Gauss) ***
4	OX3LX	HP15EO		65,6	-37,625	0,2	77,51	0,48387
5	Date	UTC	Local time	Decimal	AZ (°)	El spotted (°)	VTEC-DRBS	VTEC (TECU)
6	August 3, 2012	0.08	21:19	21,32	134	7	14,3	9,8
7		0.46	21:57	21,95	143	9	13,65	9,2

Geom. Latitude	Declination(°)	Calc.Banline	Conv.Latitude	Dourbes	
70,13	-22.991	WWLOC converter	Kp=3 quiet		
h (Km)	Ka	A (dB)	F (Gauss)	θ (°)	P (°)
300	3,49	0,070	0,48387	-108,78	72,44
300	3,30	0,067	0,48387	-160,75	75,35

17	Spotter	locator		lat	long	Corr VTEC z	Inclination(°)	F (Gauss) ***
18	IK1UWL	JN33VT		43,84	7,79	0,2	59,45	-0,41456
19	Date	UTC	Local time	Decimal	AZ (°)	El spotted (°)	VTEC-DRBS	VTEC (TECU)
20	August 3, 2012	0.08	0:20	24,35	179	36	12,35	13,8
21		0.46	0:58	24,98	190	36,00	11,7	13,2

Geom. Latitude	Declination(°)				
40,46	0,953				
h (Km)	Ka	A (dB)	F (Gauss)	θ (°)	P (°)
300	1,59	0,082	-0,41456	508,63	89,27
300	1,59	0,079	-0,41456	482,63	-82,70

Resumee				
stage	UTC	Delta (°)	Diff.calc.	Real
1st interval	0.08	-51,97	-77,97	-76
	0.46	-26,00		

We checked many cases with good congruence between computed and observed rotations.

Global common moon trend

Having now confidence in the basic correctness of formula and correction coefficients, we proceeded to build a new Excel sheet, covering the entire common-moon period.

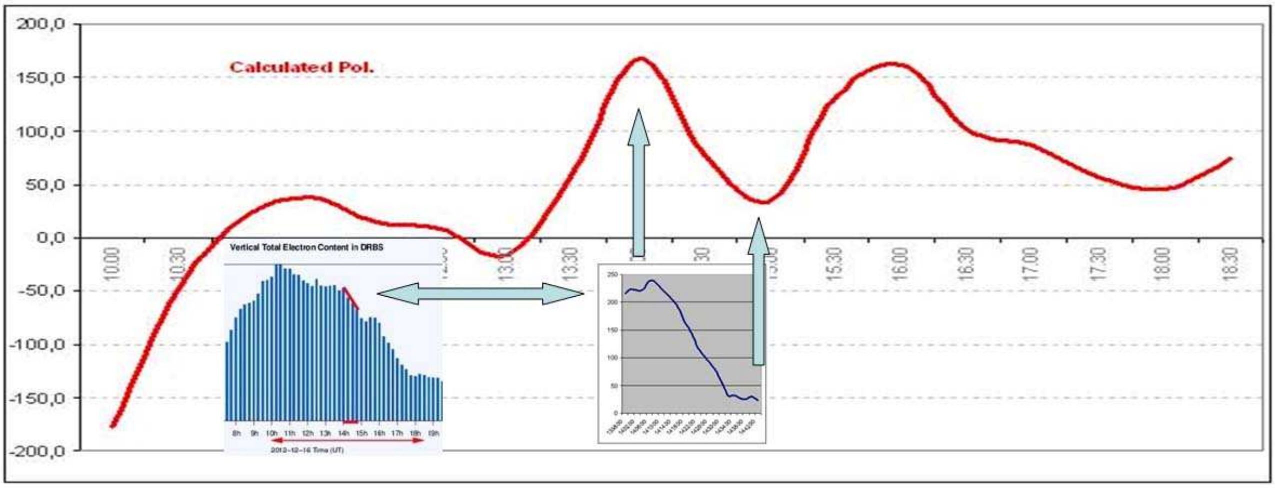
Our Excel sheet:

1	Date	Call	Loc.	Lat.	Long.	Lat. mag.	Corr. Day	Corr.night	F	Incl.	Decl.	Loc conv.	Conv. Lat.	Calc. 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	localtime.(ref.DRB	Az (°)	El (°)	h (km)	Ka	VTEC Drbs	Corr.	VTEC loc.	STEC	cosFM	Rot. (°)	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. mag.	Corr. Day	Corr.night	F	Incl.	Decl.	Loc conv.	Conv. Lat.	Calc. 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	localtime(ref.DRB:	Az (°)	El (°)	h (km)	Ka	VTEC Drbs	Corr.	VTEC loc.	STEC	cosFM	Rot. (°)	Rot.(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

Partial checks were possible using the LiveCQ decoded periods.

An example for SP4MPB spotted by PA3FPQ on 16/12/2012. All data were computed for 30’ intervals. The choice of these two stations depended on having a LiveCQ decode running continuously for 44’.

And the graphs we obtain from it (with superimposed the decoded graph):



SP4MPB was active from 13.58 to 14.42 utc.

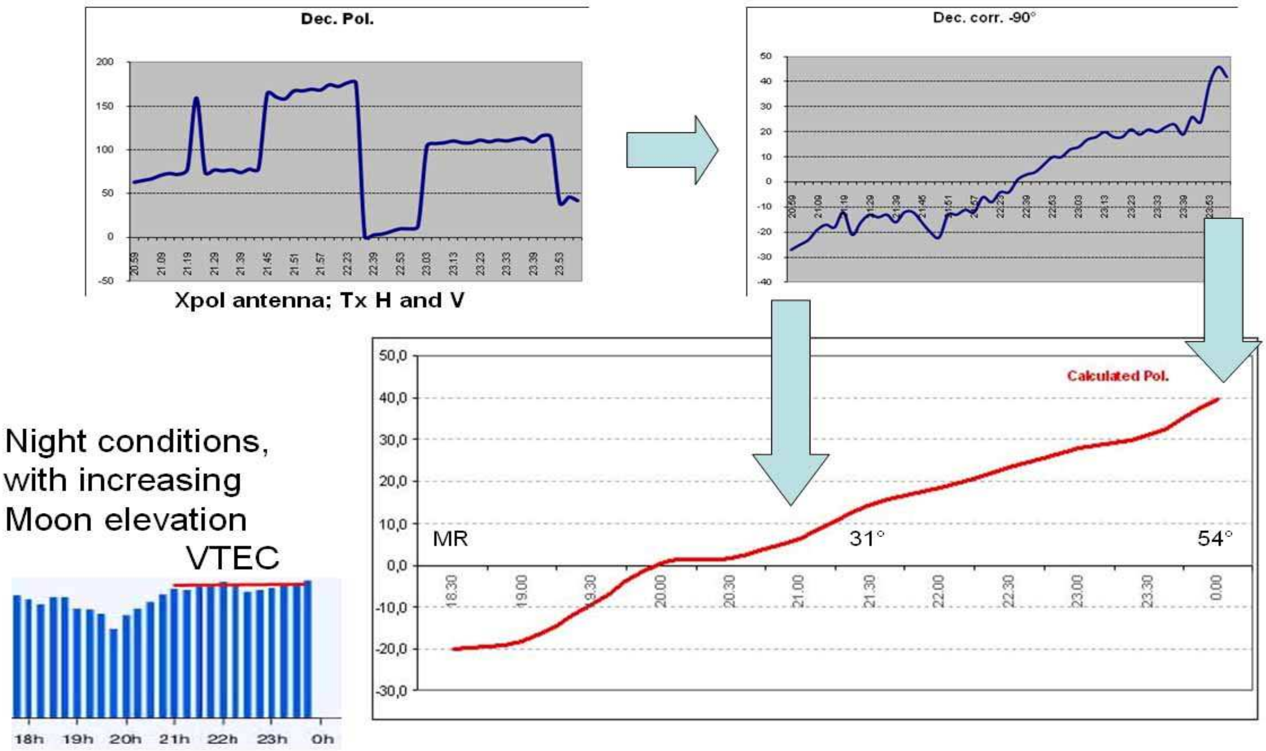
In this phase, TEC had a quick decrease, followed by a brief increase pre sunset, then decreasing from sunset to night. Calculated and real trend are coherent

A second example is I2FAK calling CQ in ARRL EME contest, on 1/12/2012.

Station is 828 SSE of spotter PA3FPQ.

Decoded pol showed 90° transitions when he changed tx form H to V.

Graph corrected for this is the right one.



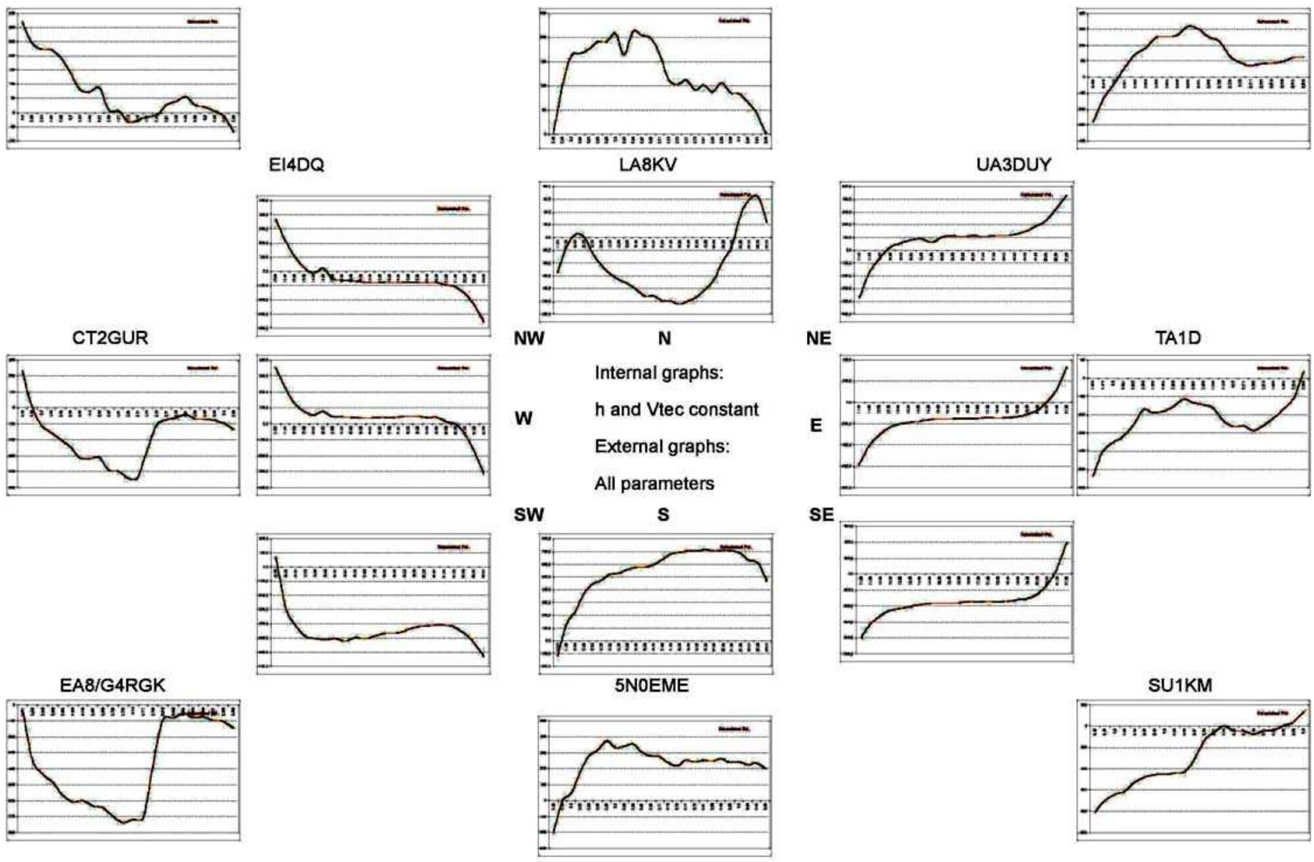
Night TEC was practically constant, so pol change derived mainly from increasing Moon elevation.

Polarization trends

When reception is difficult due to unfavorable Faraday rotation, one often wonders if this will change quickly. We decided to explore if tendencies could be found and used as a guide.

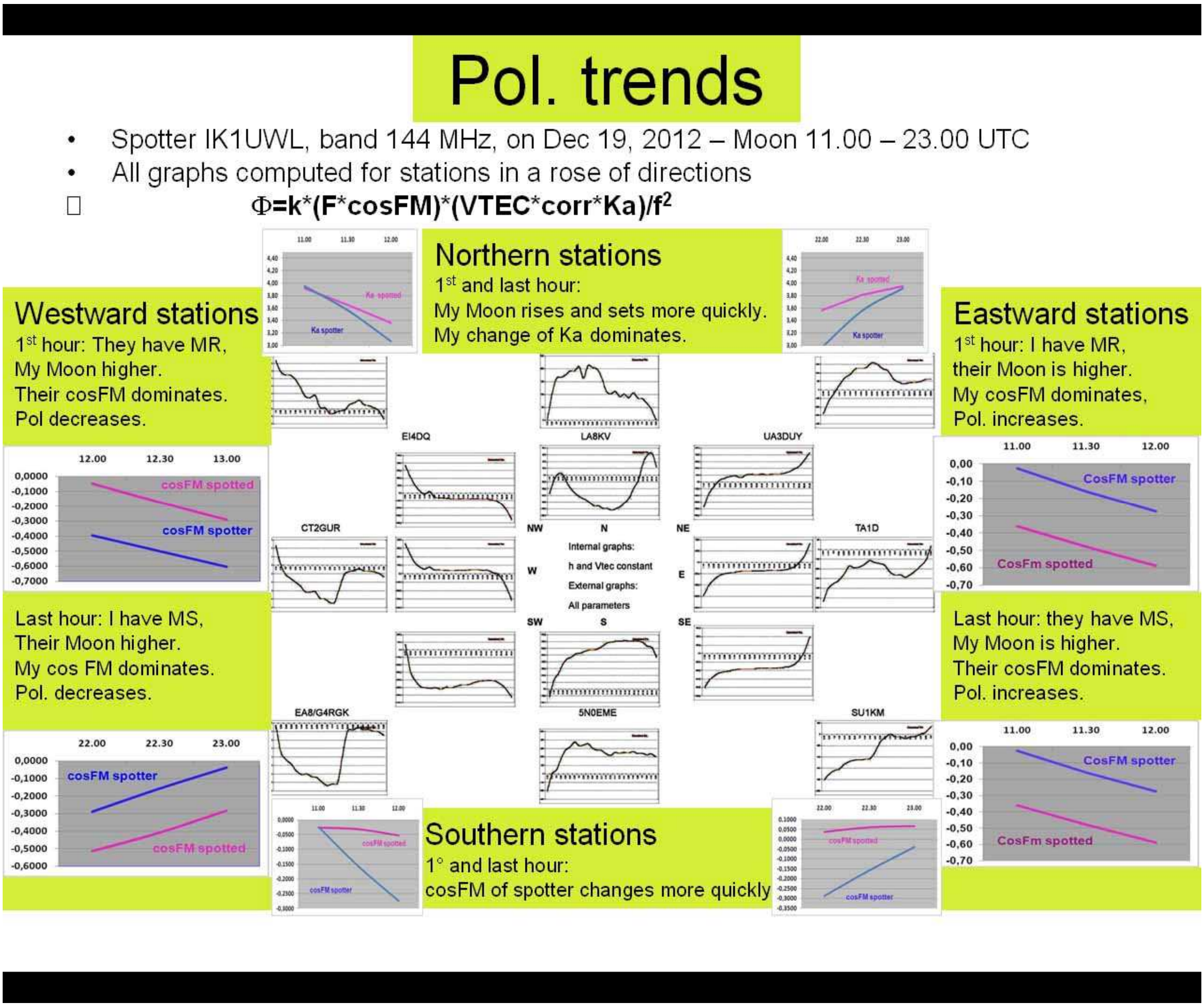
So we created a set of 8 computations for a full moon pass of IK1UWL station with stations in 8 different directions, N, NE, E, SE, S,SW, W, NW, all for the same moonpass, on Dec 19th 2012, in which the Moon was visible from 11.00 to 23.00 UTC. In this diagram the graphs are disposed in the outer ring.

Azimuth rose



In order to separate the eventual tendencies from changes in the ionosphere (which occur over a full moon pass, but are negligible in a short period), we computed also the rotations with constant VTEC and slab thickness, i.e. for an invariable ionosphere.

The relative graphs are disposed in the inner circle.



The first noticeable fact is the similarity at the beginning and at the end of the moon pass, whilst ionospheric changes give different evolutions in the central part of the moon pass.

Evidently, at moonrise and moonset the rapid change of inclination (which influences both cosFM and Ka) causes quick variations of rotation.

The overall shape of Eastward and Westward graphs is similar to a sinusoid, with slower variations in the central part. Specifically, at MR, cosFM variation of the station having MR, has a dominant effect, and is the cause, in the first hour approximately, of the pol rotation. The same effect can be seen at MS.

For Northern stations the factor Ka (change of Slant TEC) is the dominat factor at MR and MS.

For Southern stations the dominant effect, with IK1UWL spotting, is more tied to cosFM (angle between earth's Geomagnetic field and Moon direction) due to the field's condition above IK1UWL station, but also Ka show a similar effect.

Generalizing, during hours in which TEC changes little (during the day and during the night), Faraday rotation is affected mainly by angle changes (Moon elevation and Moon direction respect Geomagnetic field). Changes tied to TEC occur mainly during sunrise and sunset.

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

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