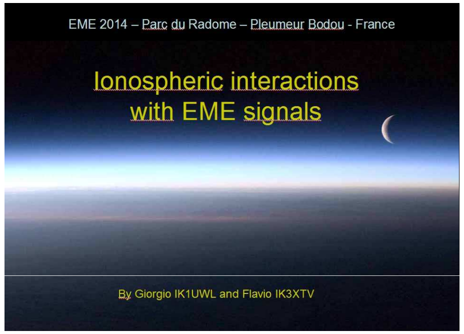
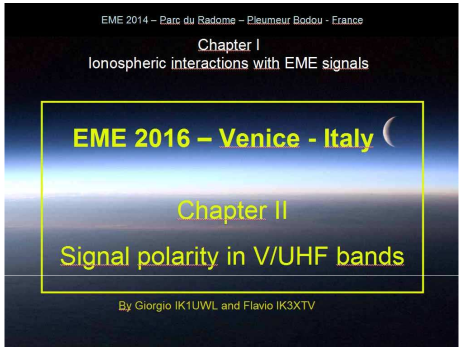
Ch. III - Limits
of single polarity antennas in the VHF and UHF bands



EME 2014 – Parc du Radome – Pleumeur Bodou - France

Ionospheric interactions
with EME signals

By Giorgio IK1UWL and Flavio IK3XTV



EME 2014 – Parc du Radome – Pleumeur Bodou - France

Chapter I
Ionospheric interactions with EME signals

EME 2016 – Venice - Italy

Chapter II

Signal polarity in V/UHF bands

By Giorgio IK1UWL and Flavio IK3XTV

Ch. I – 2014
QSB origins
2 m Faraday

Ch. II – 2016
Extension of Excel sheet to VHF and UHF bands

From studies by

Giorgio Marchi, IK1UWL and Flavio Egano, IK3XTV

EME 2018
The Netherlands

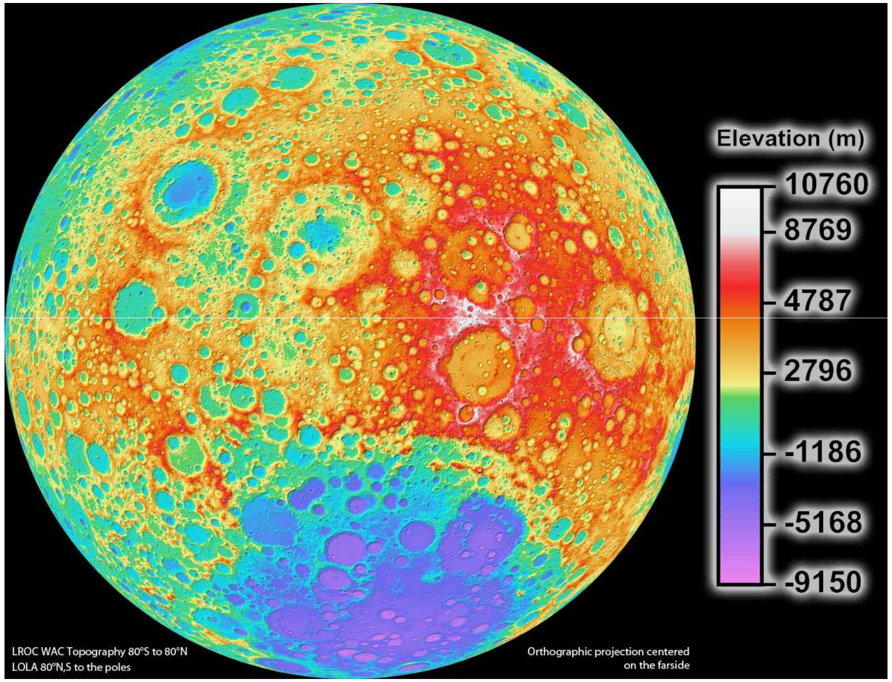
August 18, 2018

Chapter III – Single polarity antennas, Summary

- Moon reflection, depolarization
- Faraday and Spatial Offset
- QSO analysis over a Moon pass
- Two way probability for single polarity antennas in V/UHF bands
- Shifting Spatial Offset by axial rotation of antenna

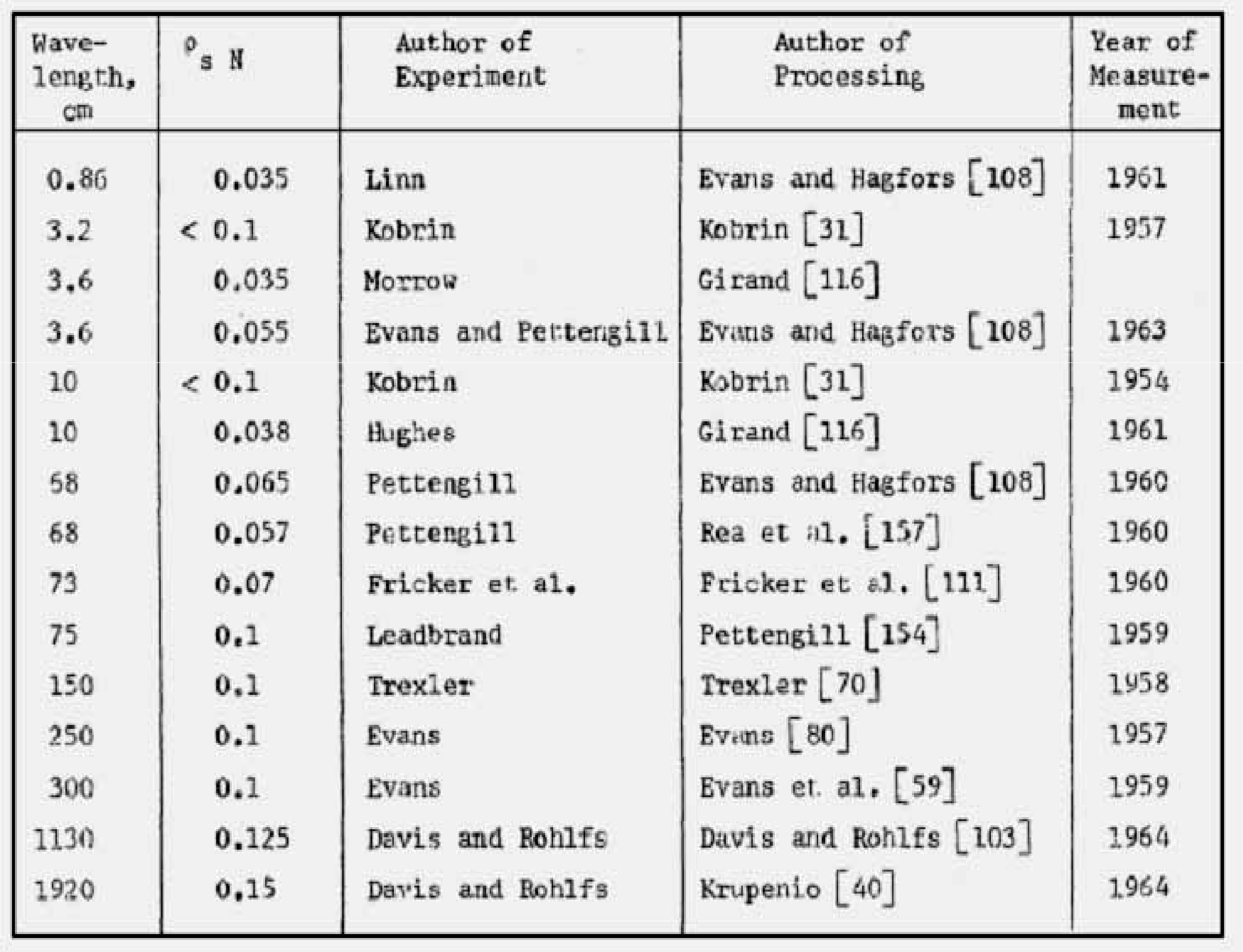
Earth > Moon

- A wave crosses the ionosphere illuminating the Moon, and gets partially reradiated by the Moon’s surface.
- The Moon is spherical and it’s surface is rough at radio wavelengths.
- There are a large number of scattering areas simultaneously contributing to the signal.
- The lunar surface is therefore a very poor reflector of radio waves.



Radar studies of the Moon

Table by NASA – Feb. 1973



Wave-length, cm	$\rho_s N$	Author of Experiment	Author of Processing	Year of Measure-ment
0.86	0.035	Linn	Evans and Hagfors [108]	1961
3.2	< 0.1	Kobrin	Kobrin [31]	1957
3.6	0.035	Morrow	Girand [116]	
3.6	0.055	Evans and Pettengill	Evans and Hagfors [108]	1963
10	< 0.1	Kobrin	Kobrin [31]	1954
10	0.038	Hughes	Girand [116]	1961
58	0.065	Pettengill	Evans and Hagfors [108]	1960
68	0.057	Pettengill	Rea et al. [157]	1960
73	0.07	Fricker et al.	Fricker et al. [111]	1960
75	0.1	Leadbrand	Pettengill [154]	1959
150	0.1	Trexler	Trexler [70]	1958
250	0.1	Evans	Evans [80]	1957
300	0.1	Evans	Evans et. al. [59]	1959
1130	0.125	Davis and Rohlfs	Davis and Rohlfs [103]	1964
1920	0.15	Davis and Rohlfs	Krupenio [40]	1964

1st EME

1960 on 1296 MHz
1964 on 144 MHz
1964 on 432 MHz
1970 on 2,3 GHz
1972 on 50 MHz
1987 on 3,4 GHz
1987 on 5,6 GHz
1988 on 10 GHz
2001 on 24 GHz
2005 on 47 GHz
2005 on 28 MHz
2009 on 70 MHz

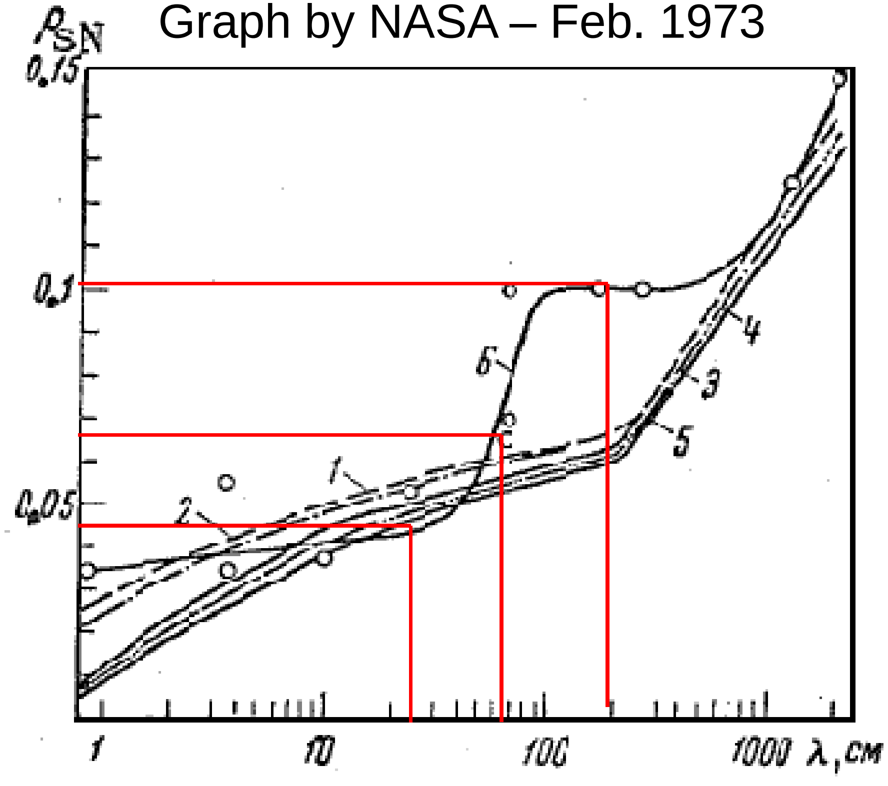
Reflection coefficient

- Is the diffuse reflectivity, or reflecting power of a surface

- It is the ratio of reflected radiation from the surface to incident radiation upon it.

- Average values at:

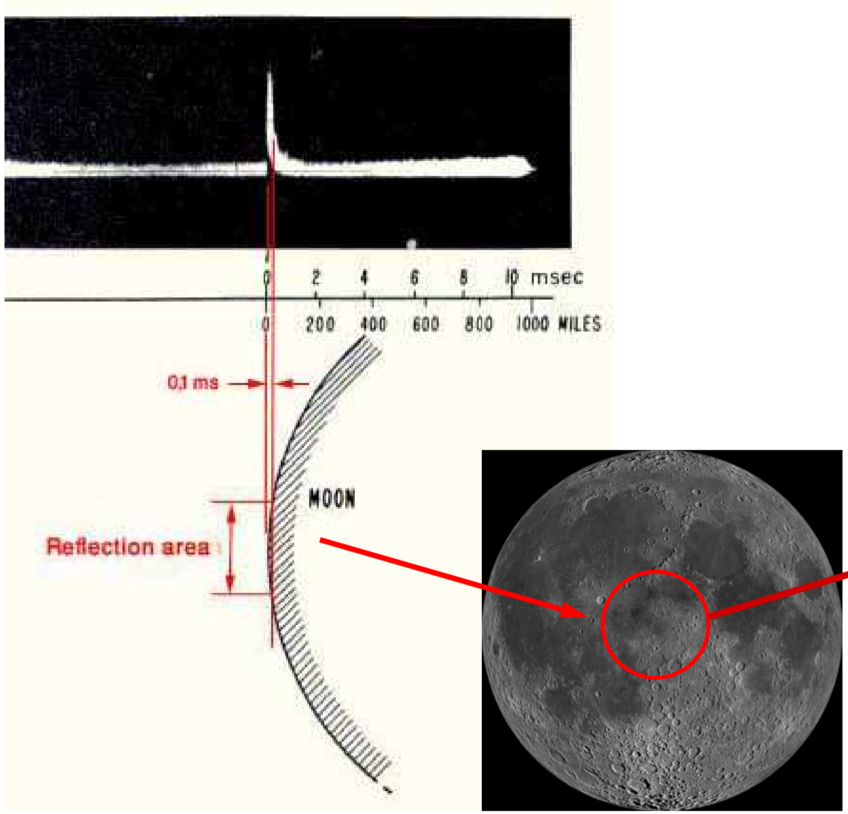
2 m	0,1
70 cm	0,065
23 cm	0,045



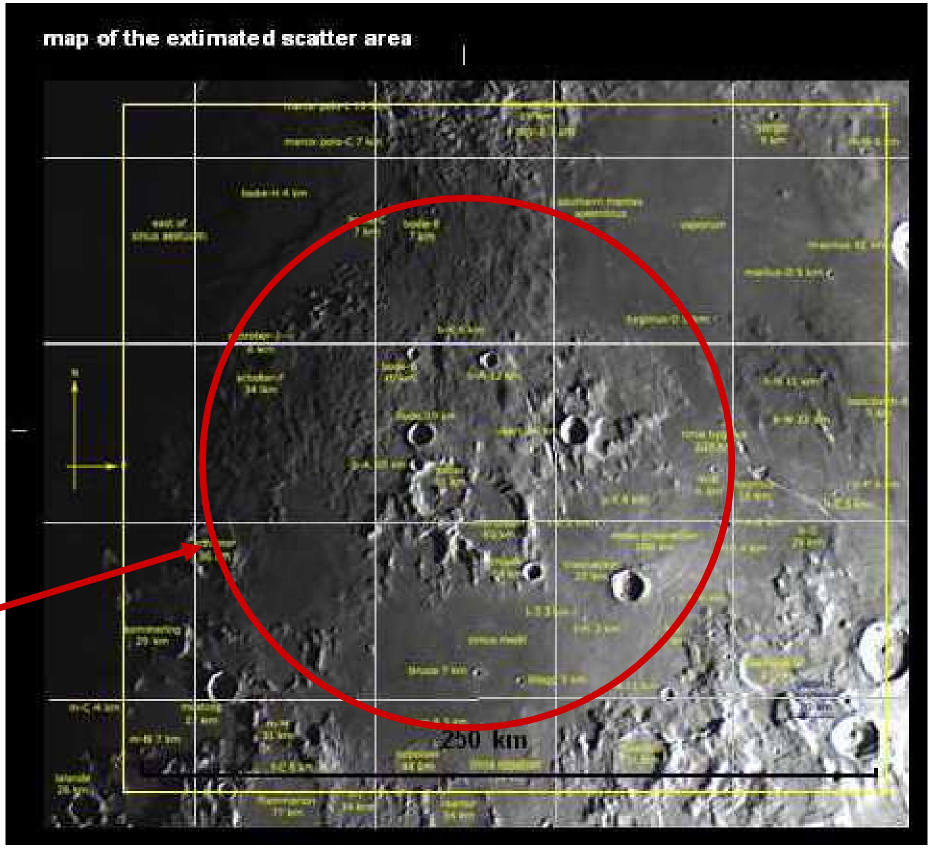
Graph by NASA – Feb. 1973

Scattering area in the Lunar surface

- Moon echoes observed by Trexler (1958): most of the power in the reflected signal arises from scatterers lying near the center of the visible disk.



Trexler (1958), Moon Echoes compared to scale with curvature of the Moon



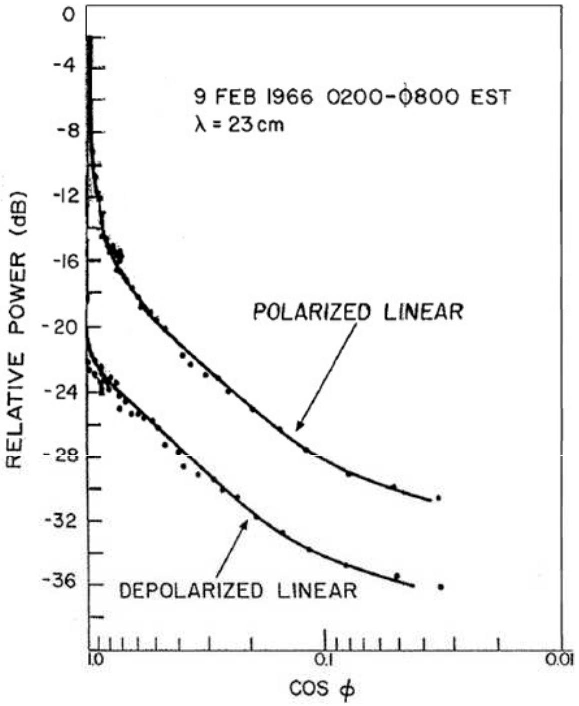
Evans – Radio Communication via the Moon

Moon’s surface

- Moon’ soil is porous, and is penetrated by an electromagnetic wave.
- This results in backscattering with different phases.
- Also mountains and craters generate backscattering.
- The specular portion of the backscatter represents a partially depolarized wave.
- The depolarization increases with frequency.

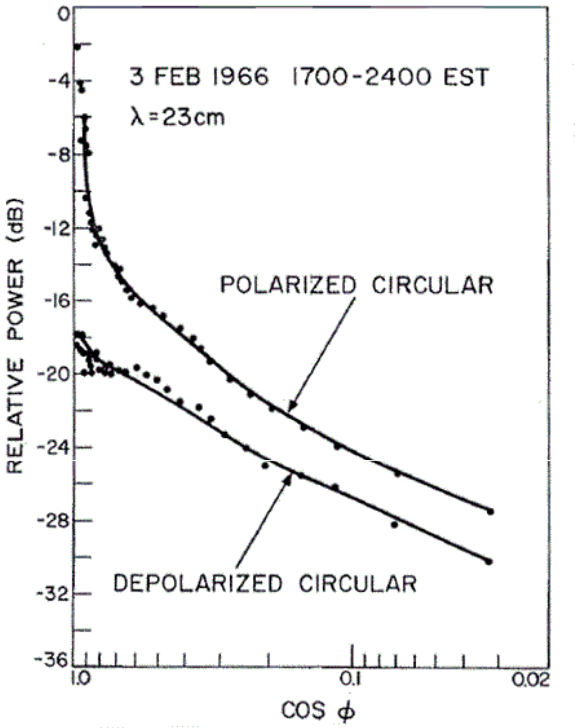
Depolarization at 23 cm

- Measured with Millstone Hill radar, using Doppler resolution, at 23 cm.
- Depolarization increases with frequency.
- From studies by G3WDG (Venice Conf. 2016), depolarization with CP is greater than LP by 2 dB at 3 cm



LINEAR TRANSMITTED AND RECEIVED
Plot of polarized and depolarized components against cos ϕ, for linearly polarized illumination

Linear depolarized component -20 dB



CIRCULAR TRANSMITTED AND RECEIVED
plot of the polarized and depolarized circular components for circular polarization transmitted.
Power in dB against cos ϕ being angle of incidence

Circular depolarized component -18 dB

From "A Study of the Depolarization of Lunar Radar Echoes – Tor Hagfors – MIT"

Moon > Earth

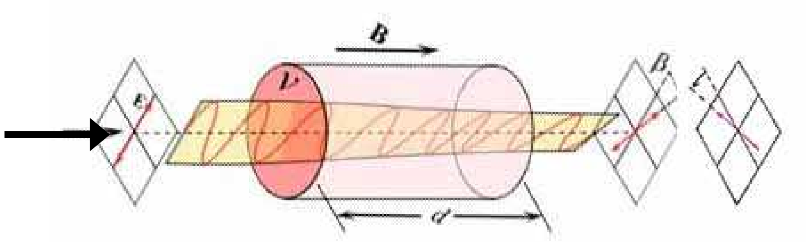
- The wave reradiated from the Moon, crosses again the ionosphere getting again rotated by the Faraday effect.

- And it is received by an antenna with different spatial orientation from the transmitting one (Spatial Offset).

- The echo is received with <u>polarity sum of two parameters</u>, **Faraday + Spatial Offset**

Faraday effect

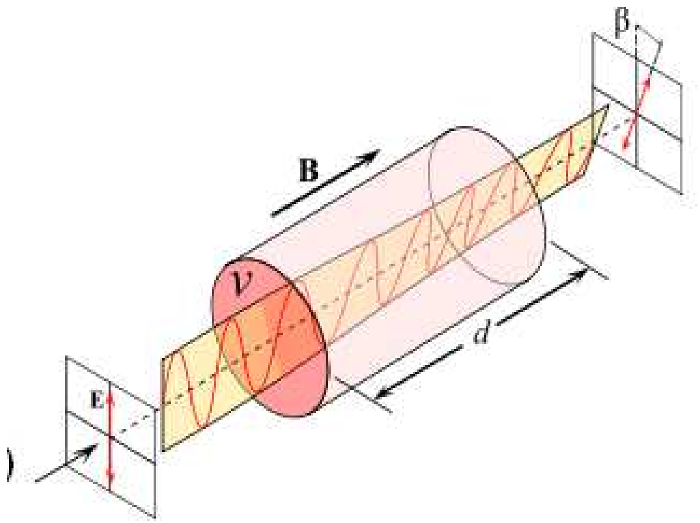
View from Earth →



← **View from Moon**

- Geomag. component →
- Wave starts CW → Wave arrives CCW
- Eco arrives CW ← Eco starts CCW
- Rotations are added.
- Also self echoes are subject to Faraday.

Faraday rotation



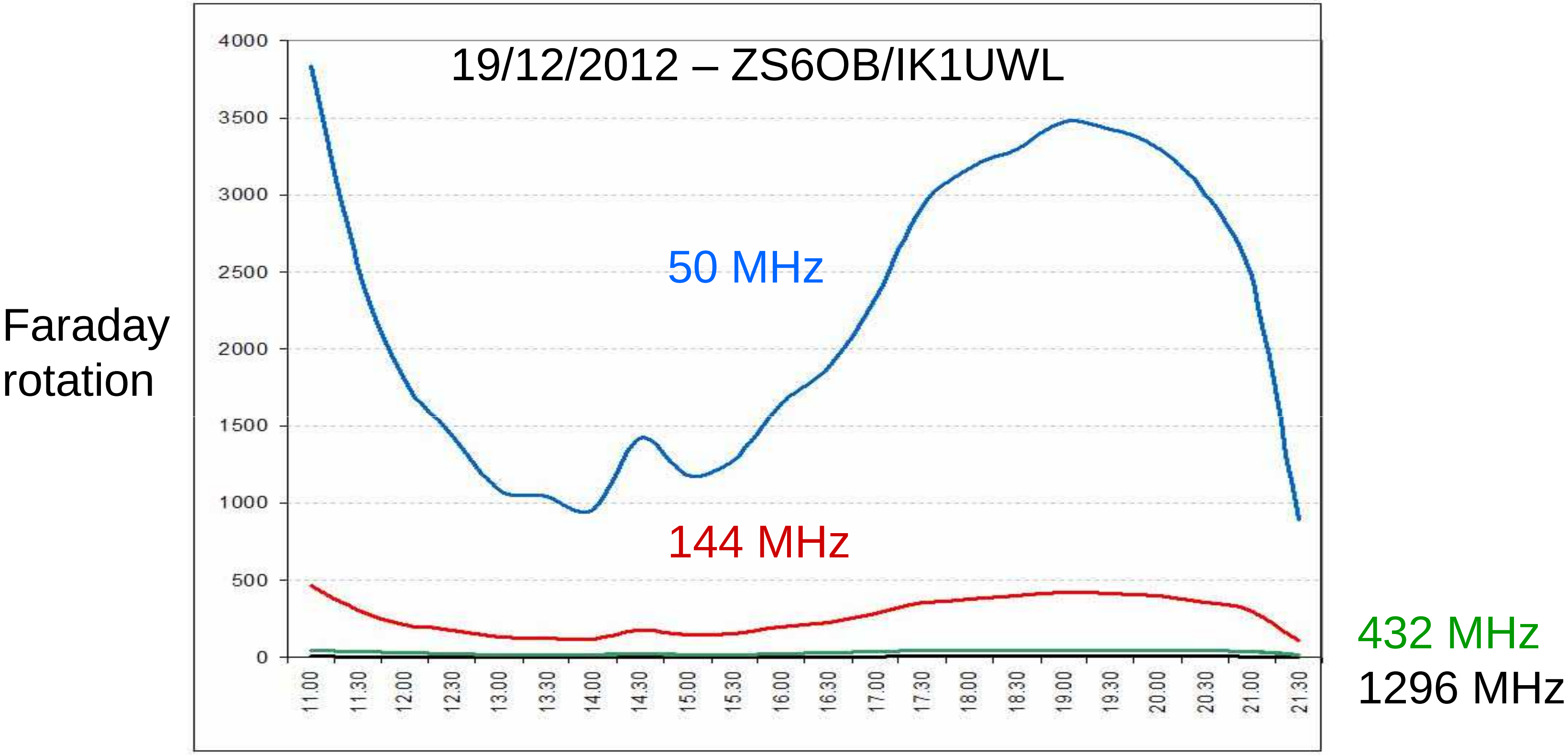
Geomag. field Electron content

$$\Phi = \boxed{k/f^2} * F*\cos FM * k_s*VTEC$$

- $k = 2,36*10^{16}$

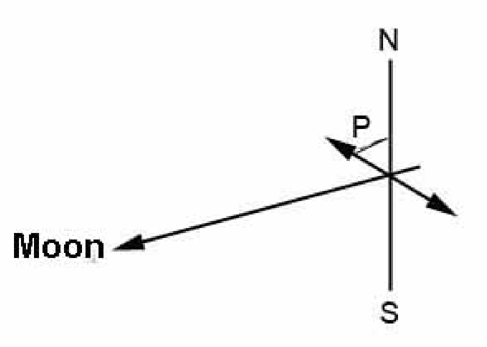
f =	50 MHz	144 MHz	432 MHz	1296 MHz
k/f^2 =	**9,46**	**1,14**	**0,127**	**0,012**

Faraday in VHF and UHF



- The k/f^2 coefficient determines rotations of thousands of degrees on 50 MHz; hundreds on 144, tens on 432, and is negligible on 1296 MHz and above.

Spatial Offset



P is angle between plane of yagi and Earth’s polar axis

- **P**=Polar offset (<u>for horizontal antenna</u>)
- From a study by N1BUG:
- **P**=arctg((sin**Lat***cos**El**-cos**Lat***cos**Az***sin**El**)/cos**Lat***sin**Az**)

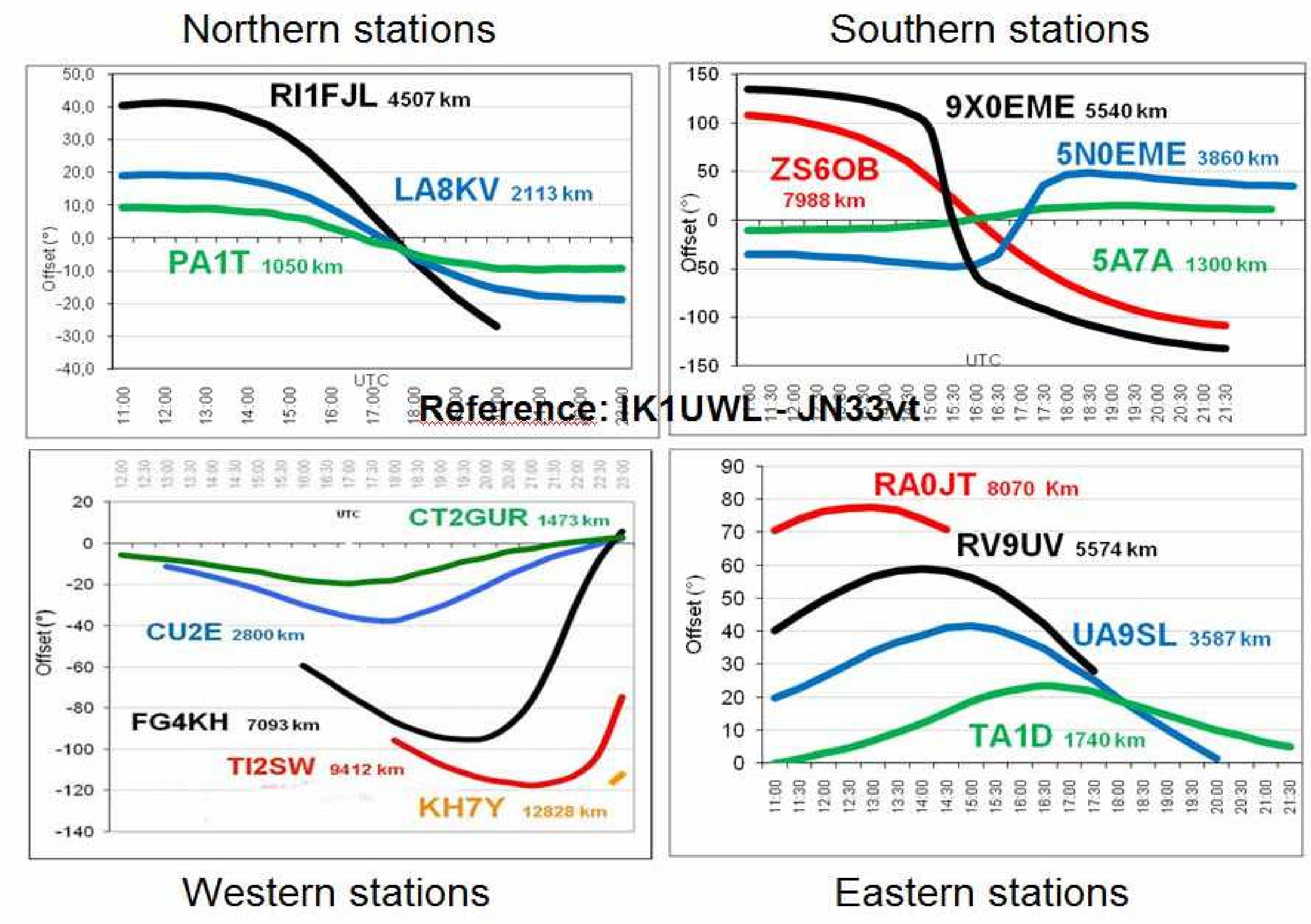
- **Independent from frequency.**
- **Changes during and every Moon pass.**
- **-90° < P < 90°**

- **Spatial Offset of station 1 versus 2 is P1-P2**
- **Spatial Offset of station 2 versus 1 is P2-P1 = - (P1-P2)**
- **Increases with distance.**

- **-180° < Spatial Offset < 180°**

- **<u>Axial rotation of one antenna shifts both polar and spatial offset.</u>**

Spatial Offset vs. distance and direction

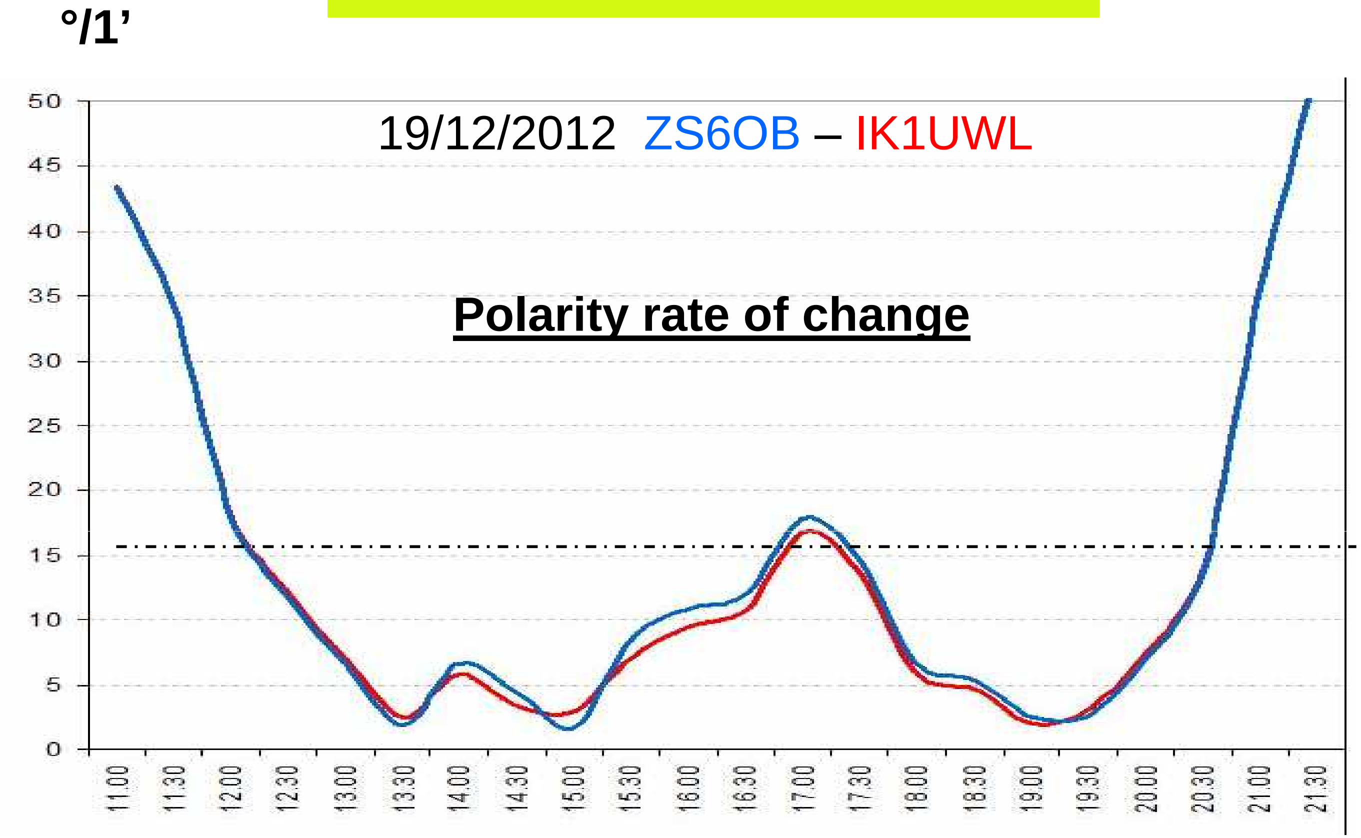


- Note: Graphs calculated for declination 1°

Decodability in VHF

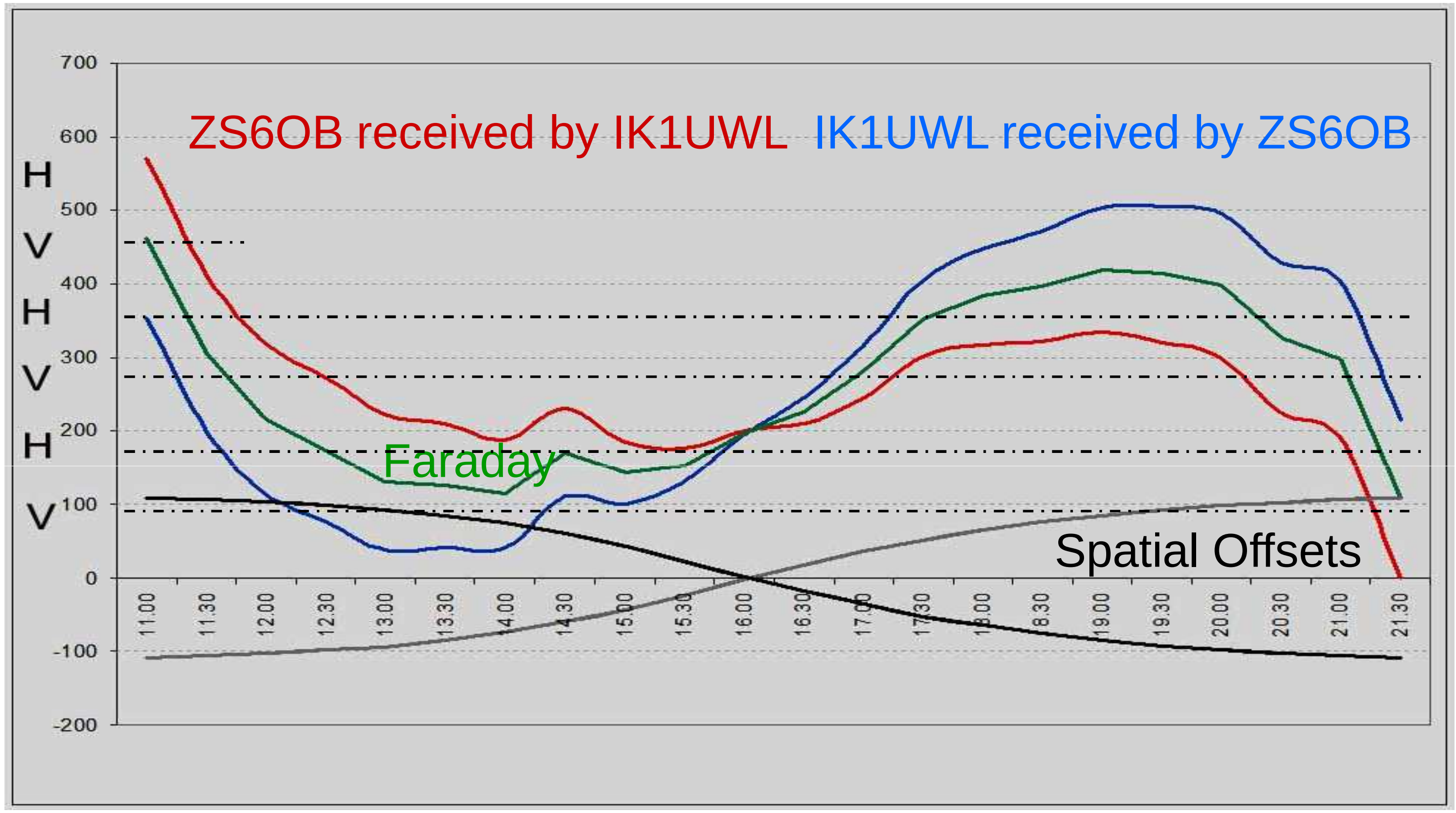
- Linearly polarized antennas cannot receive ortogonal signals.
- Faraday and Spatial Offset cause multiple turn rotation, so it happens many times during a Moon pass
- There are No Decode or One Way situations.
- Polarity Rate of Change determines duration of these negative situations.

50 MHz band



- With JT65 one needs 6 minutes for a complete qso.
- Rate of change of 15°/1' equals 90° in 6'.
- Above this value, qso cannot be completed in 6'.
- Under this value, qsos are less troublesome (but never easy).

2 way Pol. in 144 MHz , ZS6OB – IK1UWL



Stations are distant (8000 km), so Spatial Offset is big.

But Faraday is 4 times bigger, so dominates polarity rotation.

Polarity of each station is often H or V, but not at the same time.

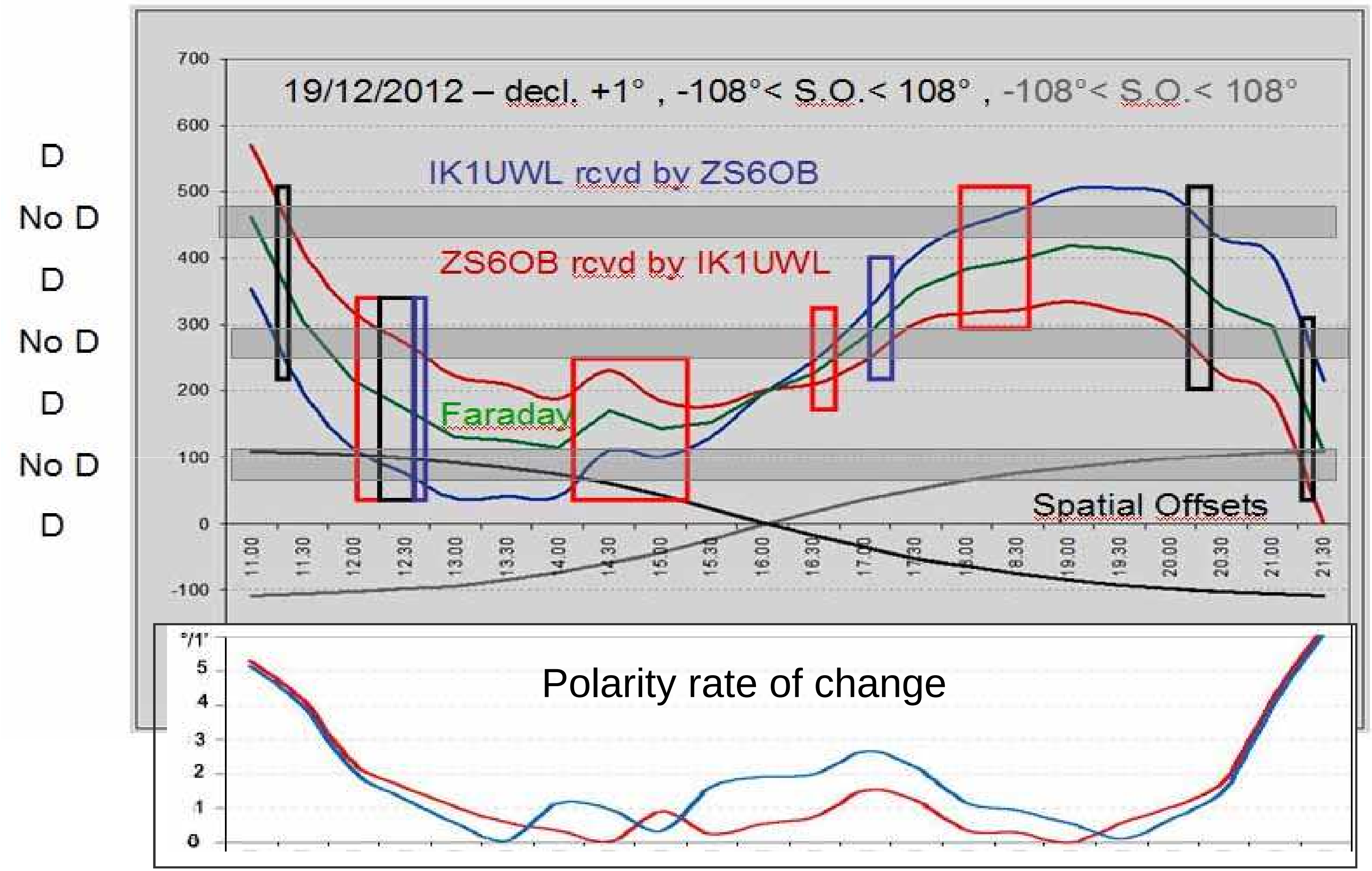
No Decode range for single polarity antennas

- Polarity α has Degradation = 20*log cos α (dB)

- $\alpha = 45^\circ$ Degr. 3 dB
- $\alpha = 60^\circ$ “ 6 dB
- $\alpha = 75^\circ$ “ 12 dB
- $\alpha = 90^\circ$ “ >> 20 dB
  (or about that value in microwaves, due to depolarization)

- Polarities ranging between 75° and 105°
  have a very low probability of decode.
- Unfavorable range is **30°** wide.

QSO in 144 MHz , ZS6OB – IK1UWL



- **30°** with 5°/1’ = 6’, with 2°/1’ = 15’, with 1°/1’ = 30’
- Frequent no D and 1 way.
- 2 way decodes 67% of moon pass

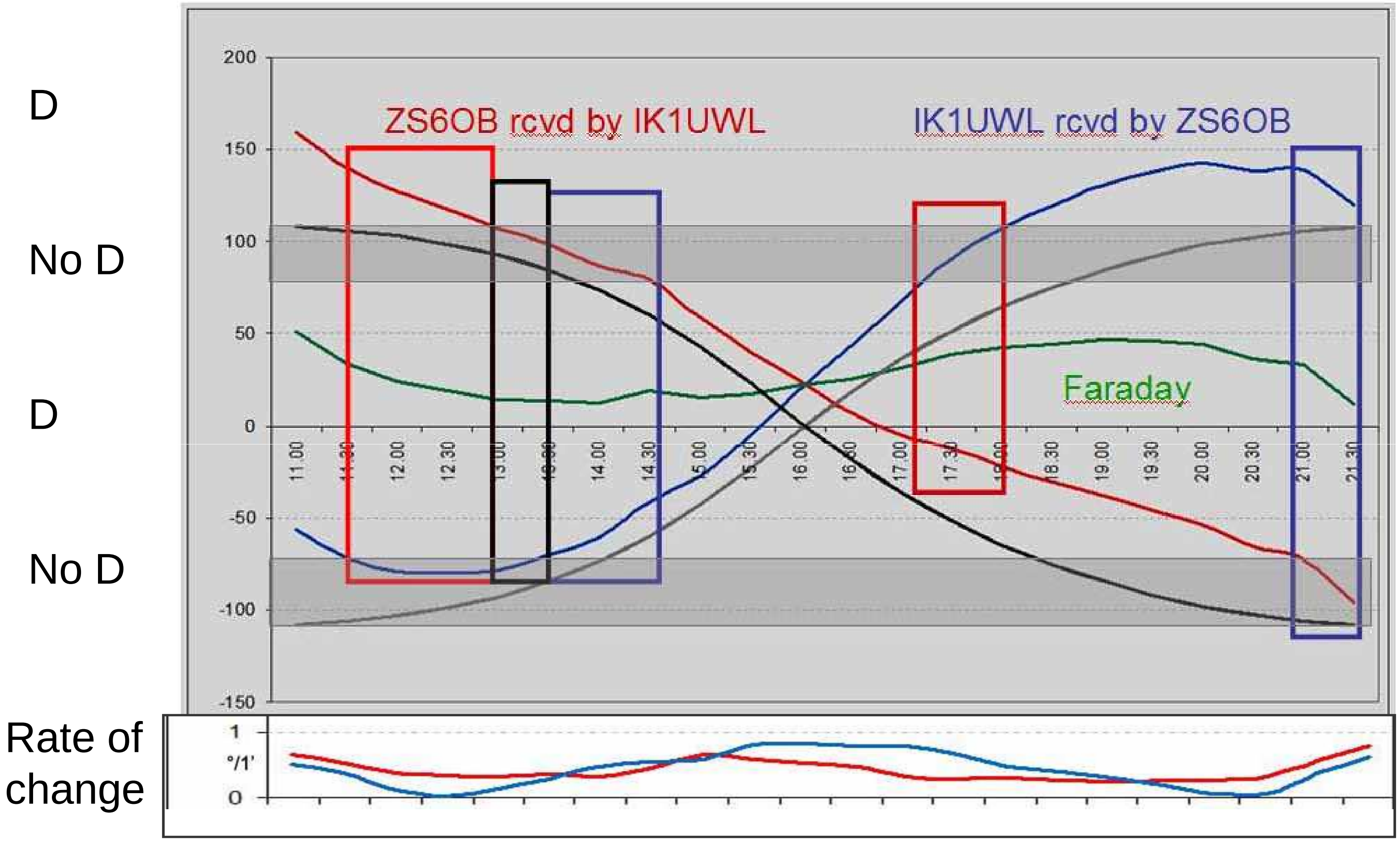
Decodability in UHF

- <u>432 MHz</u>:
- For near stations (less than 3000 km), decodes generally happen on majority of Moon pass.
- The situation changes when Spatial Offset becomes important (far stations).

- <u>1296 MHz and above</u>:
- Faraday negligible. Only Spatial Offset counts.

- <u>In UHF, shift of Spatial Offset, by axial rotation of antenna, can solve No Decode periods</u>.

QSO in 432 MHz , ZS6OB – IK1UWL

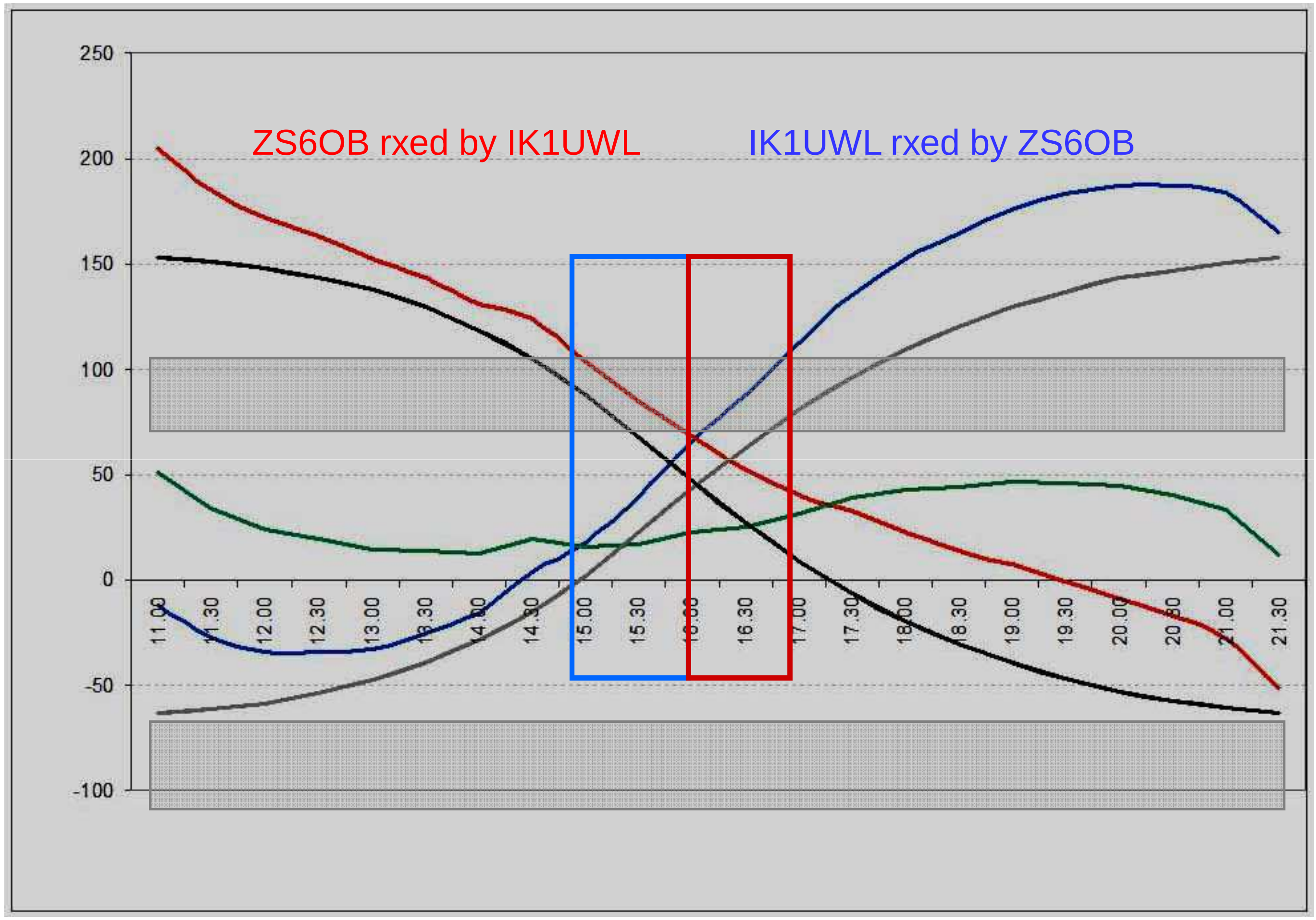


Polarity depends 70% from S.O. and 30% from Faraday.

Rate of change is around 0°,5/1’ so **30°** over 1 h.

Few 2 way periods, 53% of moon pass.

QSO in 432, ZS6OB rotates yagi 45°



- Shift of Spatial Offset gets only 20% of Moon pass in No Decode range, <u>at a different time</u>.

QSO in 1296 MHz , ZS6OB – IK1UWL

D

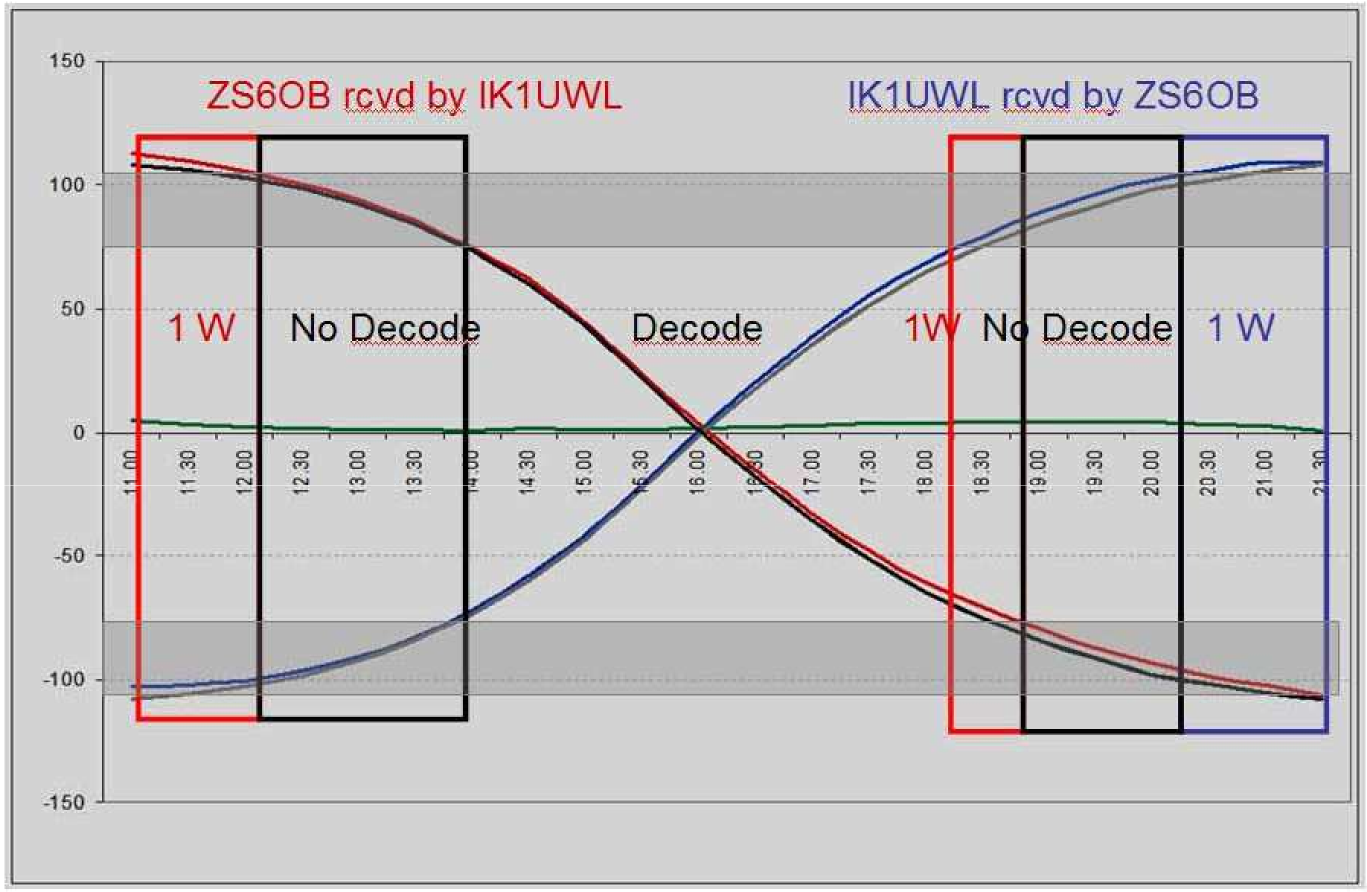
No D

D

D

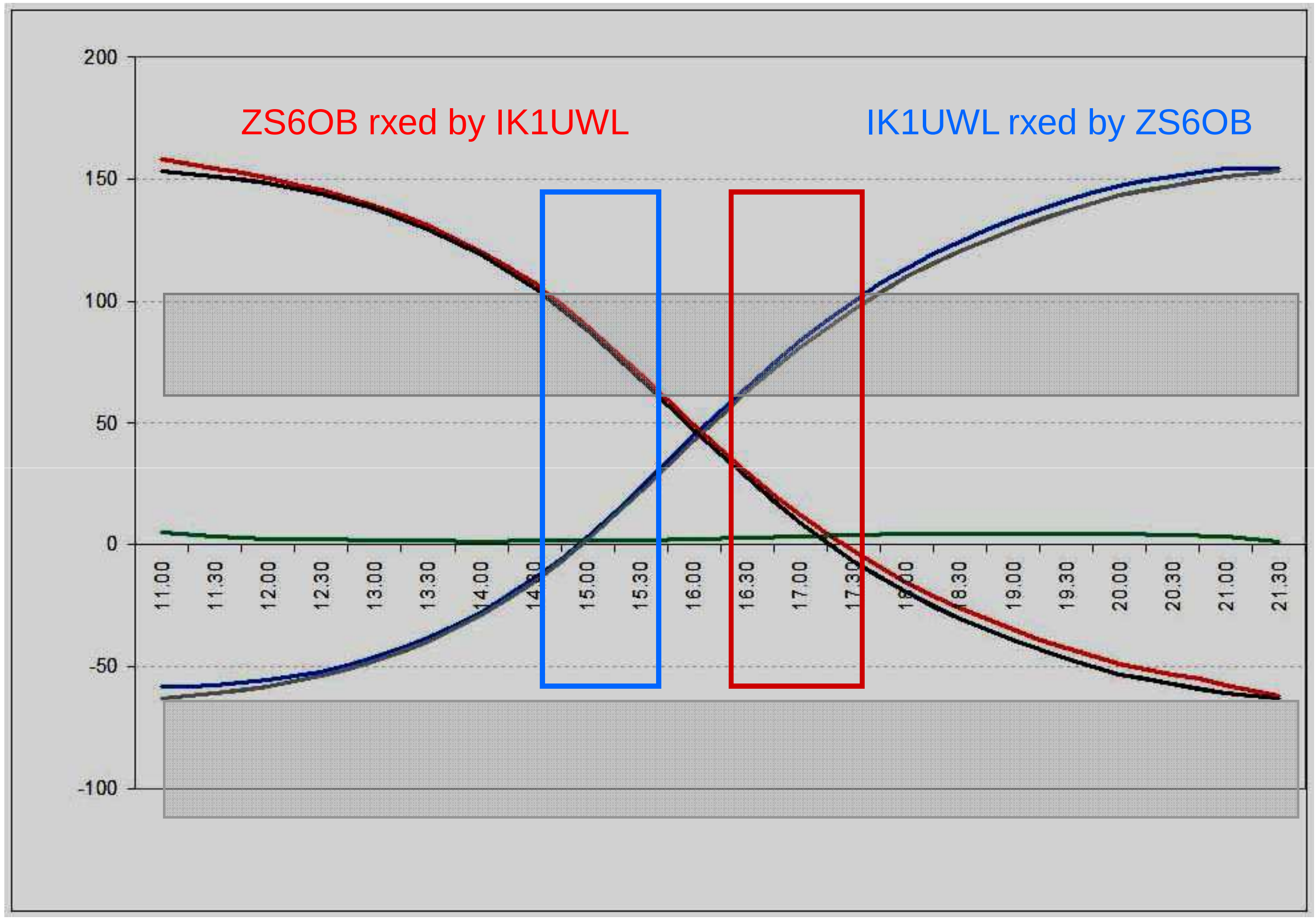
No D

D



- Faraday negligible.
- Rate of change governed by S.O., which varies slowly.
- Only stations distant less than 5000 km avoid No D range
- For this qso: 2 way period only 40% of moon pass.

QSO in 1296, ZS6OB rotates source 45°



- Change of Spatial Offset (rotating one yagi) changes radically time and duration of No Decode periods.

EME with single polarity antennas

- **50** : High polarity rate of change causes discontinuities during qso.

- **144** : Faraday dominates; polarity changes quickly.
  2 way on 70-80% of the Moon pass.

- **432** : 2/3 Spatial Offset 1/3 Faraday.
  Polarity changes more slowly.
  2 way on 30-70 % of Moon pass (depending on station distance).
  Shift of Spatial Offset by source rotation gives important changes.

- **1296** and up: 99% Spatial Offset, Faraday insignificant.
  Polarity changes very slowly.
  2 way on 40-50% of Moon pass for distant stations becoming gradually 100% for near stations.
  Shift of Spatial Offset by source rotation is very effective.

Thanks for the attention
from
Flavio and Giorgio

Venice 2016