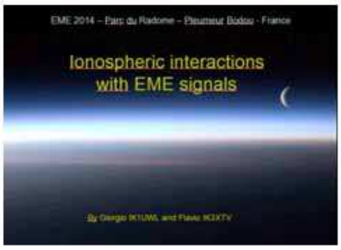
Ch. III - Limits of single polarity antennas in the VHF and UHF bands



Ch. I – 2014
QSB origins
2 m Faraday

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

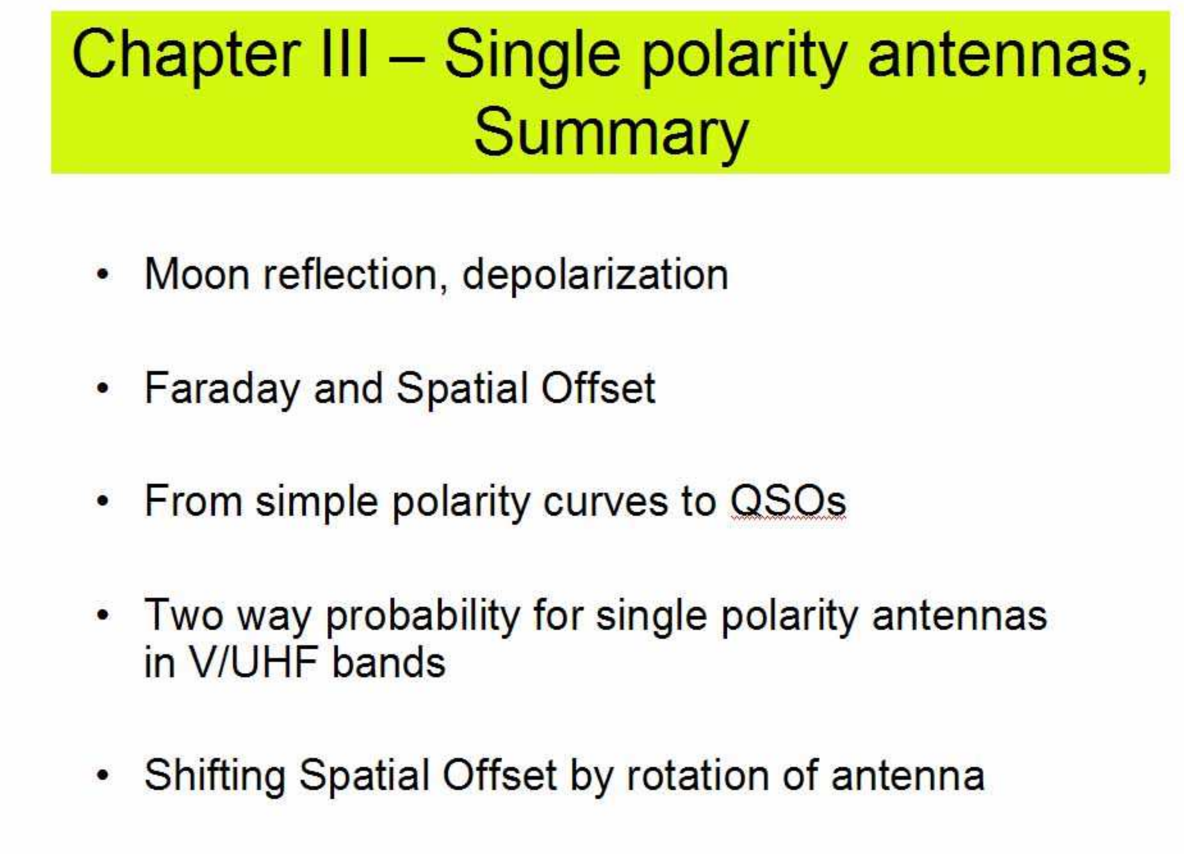
From studies by

Giorgio IK1UWL and Flavio IK3XTV

EME 2018 – The Netherlands

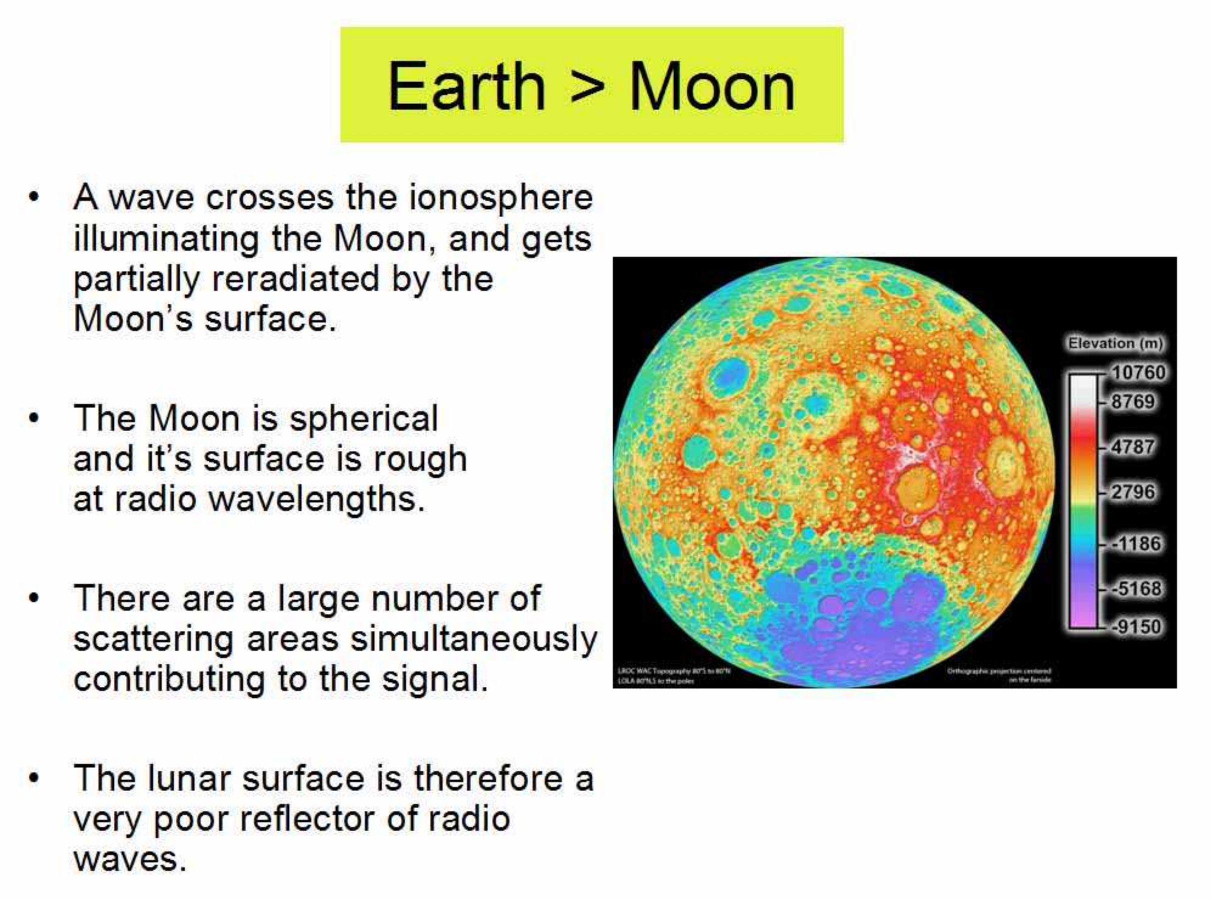
This is the third chapter of our analyses of the effects on EME signals of ionosphere transit We started with a research of QSB origins by researching ionospheric meteorology to understand causes of ionospheric turbulence which can affect signals going through it. At the same time we developed an Excel sheet capable to calculate Faraday effects for couples of stations during a full Moon pass. In Chapter I we limited results to the 2 m band. Since Faraday rotation is inversely proportional to the square of frequency, in Chapter II we analyzed what happens to the same couples of stations on different VHF and UHF bands. Chapter III intends to analyze qso probability in VHF and UHF bands for stations with linearly polarized antennas, and the effects of shifting Spatial Offset.
We added some info on Moon reflection.

Slide 2



We will start by analyzing Moon reflection, and its eventual effects on depolarization.
We will recall the main characteristics of the Faraday effect and of Spatial Offset.
We will show polarity curves for both ways so to be able to analyze a qso and the decode probability for single polarity antennas, including the effect of mechanical axial rotation of the antenna.

Slide 3



Part of the wave radiated towards the Moon illuminates it and gets partially reflected. The image shows the altimetry distribution of Moon's ground, from peaks 10 km high (white, red) to depths of -9 km (blue, pink).

There is not a single reflecting area, but a large number of scattering areas, all contributing to the reflected signal.

Slide 4

Radar studies of the Moon

Table by NASA – Feb. 1973

Wave-length, cm	ρ_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

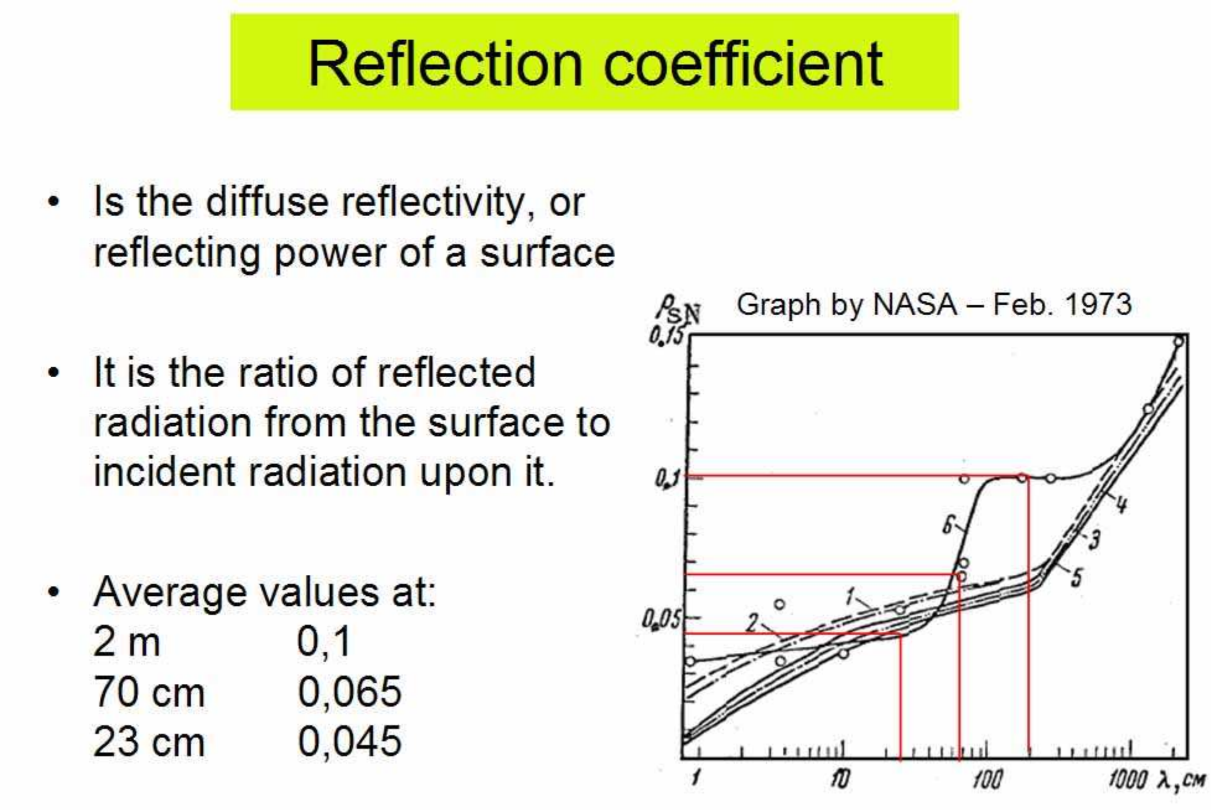
- 1960 on 1296 MHz
- 1964 on 144 MHz
- 1964 on 432 MHz
- 1970 on 2,3 GHz
- 1972 on 50 MHz
- 1987 on 3,4 GHz
- 1987 on 5,6 GHz
- 1988 on 10 GHz
- 2001 on 24 GHz
- 2005 on 47 GHz
- 2005 on 28 MHz
- 2009 on 70 MHz

Approximately in the sixties there was an interest in finding out if communication via the Moon as passive reflector, was possible. These researches were conducted on many different frequencies and the amount of energy reflected was also measured.

In the same years also amateurs started trying to exploit the Moon for world coverage on VHF and up.

The table on the right shows the year in which the first qso was made for which band.

Slide 5



This is a graph of reflection coefficients from the above radar experiments.
From which we gather that the amount reflected as a function of frequency is:

2 m 0,1

70 cm 0,065

23 cm 0,045

This percentage regards only the wave illuminating the Moon, not the total wave emitted.

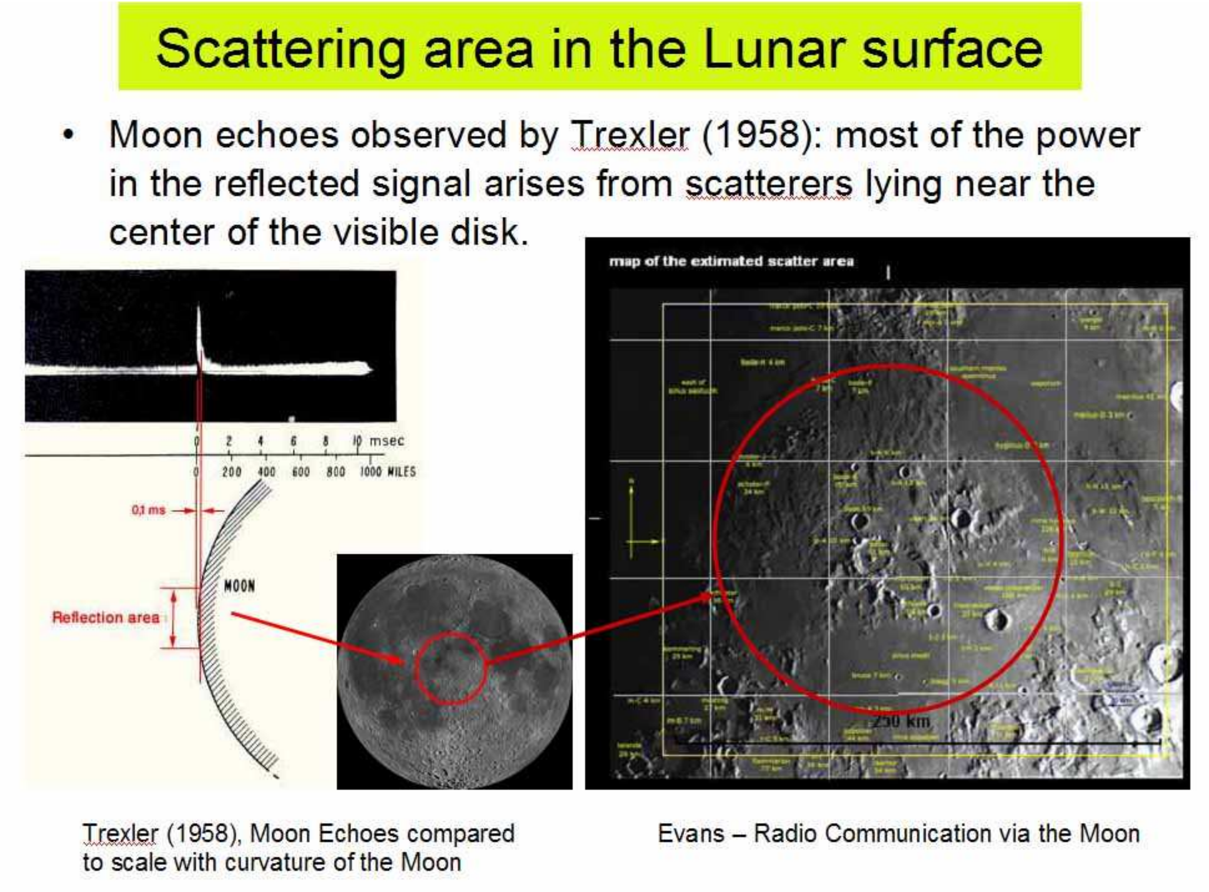
<u>For example</u>: lets consider an antenna with a beam width of 5°.

The Moon, seen by Earth, is 0°,5 wide

This means that only $(0,5/5)^2$ = 1% illuminates the Moon.

So, with 10% reflection of this 1%, only 1/1000 of the wave is reflected.

Slide 6



In the 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.

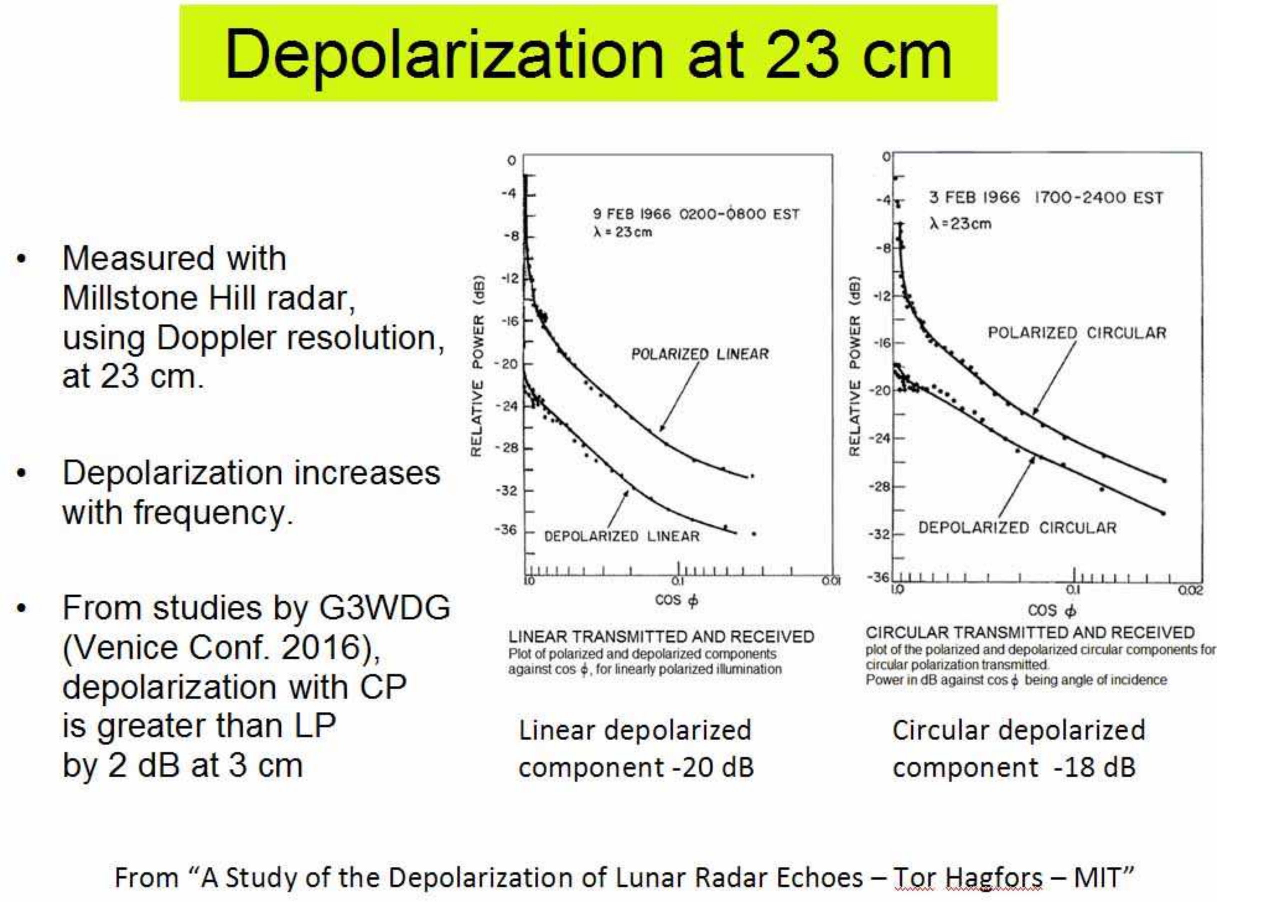
From the figure on the right you can see the type of surface from which the wave is scattered.

Slide 7

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.

Slide 8



From tests made with the Millstone Hills radar at 23 cm, the amount of depolarization was measured both for a linearly polarized wave and for a circularly polarized wave.

This depolarization is practically negligible in the VHF bands, but becomes increasingly higher in the microwave bands.

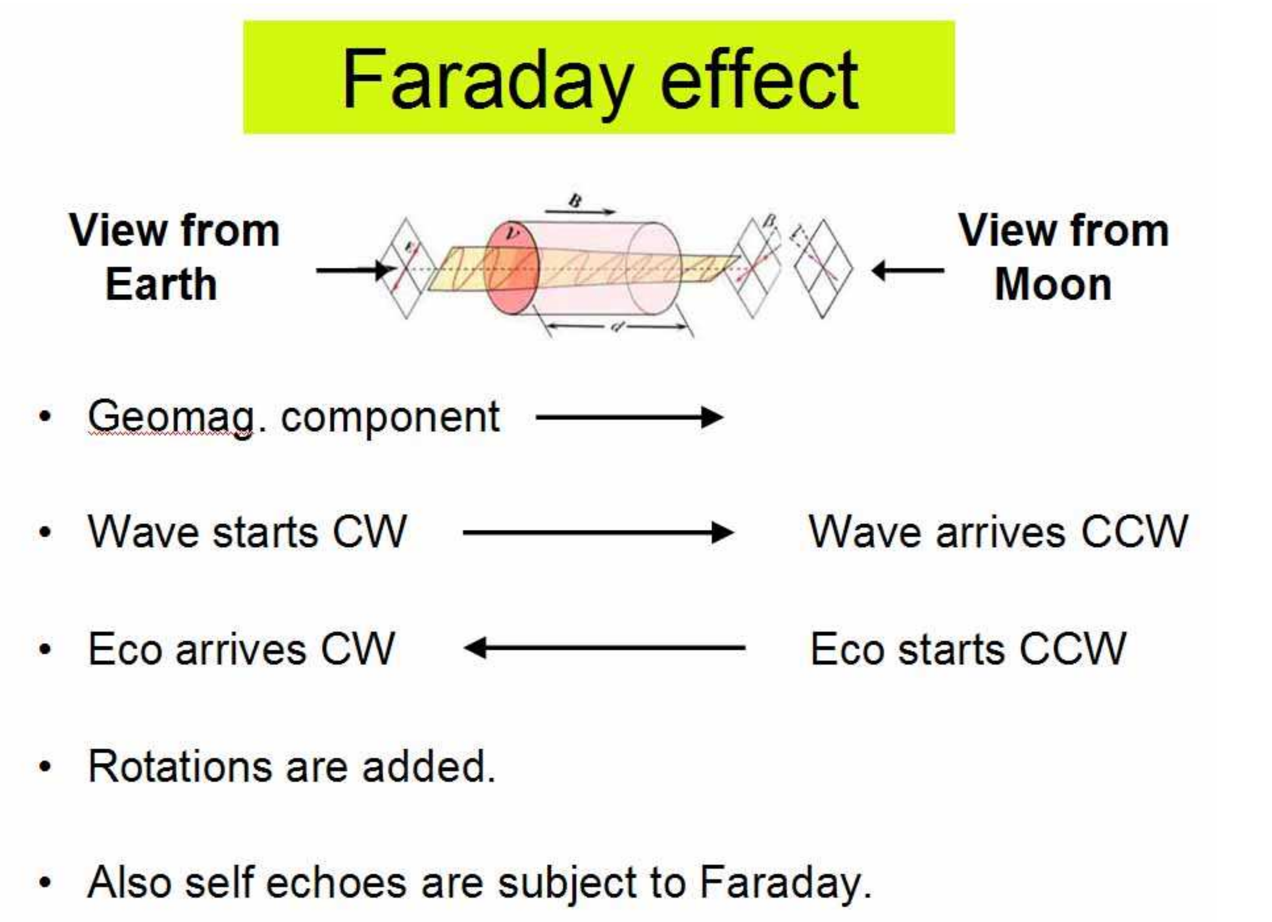
From studies by G3WDG (Venice Conf. 2016), depolarization with CP is greater than LP by 2 dB at 3 cm, same as shown by the above graphs.

Slide 9

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** and **Spatial Offset**

Slide 10



When a wave traverses a plasma which is also immersed in a magnetic field, the plane of polarization rotates. When the magnetic field component is in the same sense of the wave motion, the rotation, seen from the origin of the wave, is clockwise.

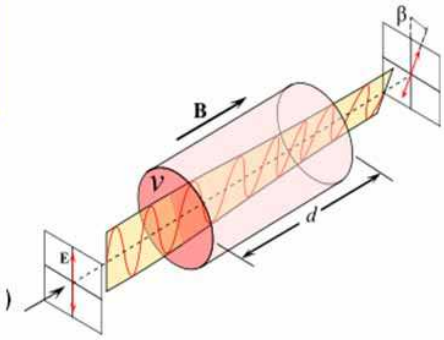
Seen from the point of arrival, the rotation is counterclockwise.

If the wave is now reflected and returns back in the opposite sense of the magnetic field component, it will be seen rotating counterclockwise from the reflection point, and will be seen rotating clockwise from the arrival point.

The above figure is a summary of these concepts.

Slide 11

Faraday rotation



Geomag. field — Electron content

$$\Delta\Phi = k/f^2 * F*\cos FM * k_s*VTEC$$

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

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

Faraday rotation is proportional to the magnetic field component and to the amount of plasma traversed. The formula gives the average rotation value, since the ionosphere is turbulent., which cause short term variations of plasma density.

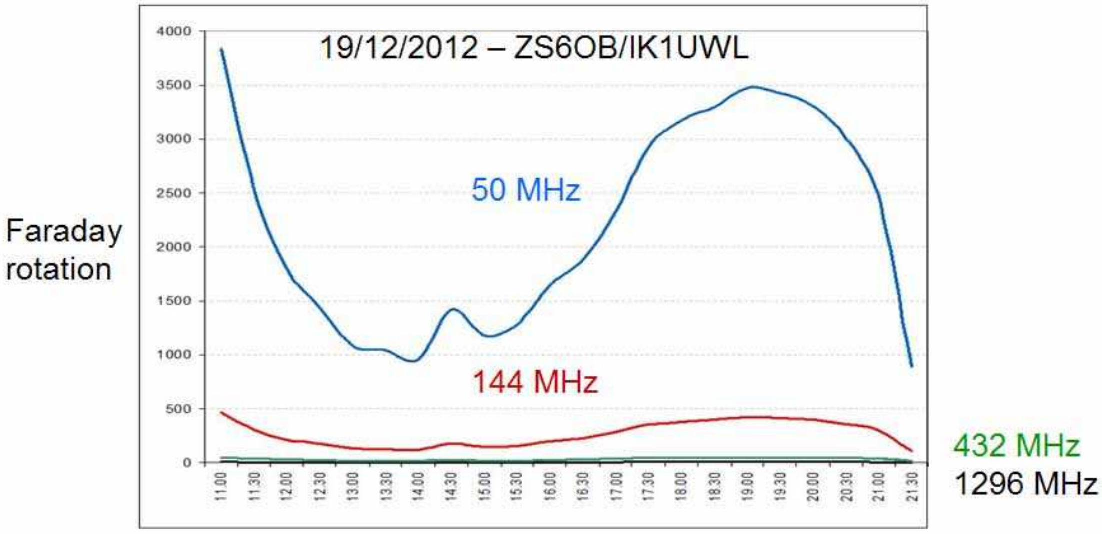
The turbulence is also the cause of short term QSB.

<u>The coefficient of the formula contains the inverse square of the frequency.</u>

So it decreases to about 1/9 for each successive band.

Slide 12

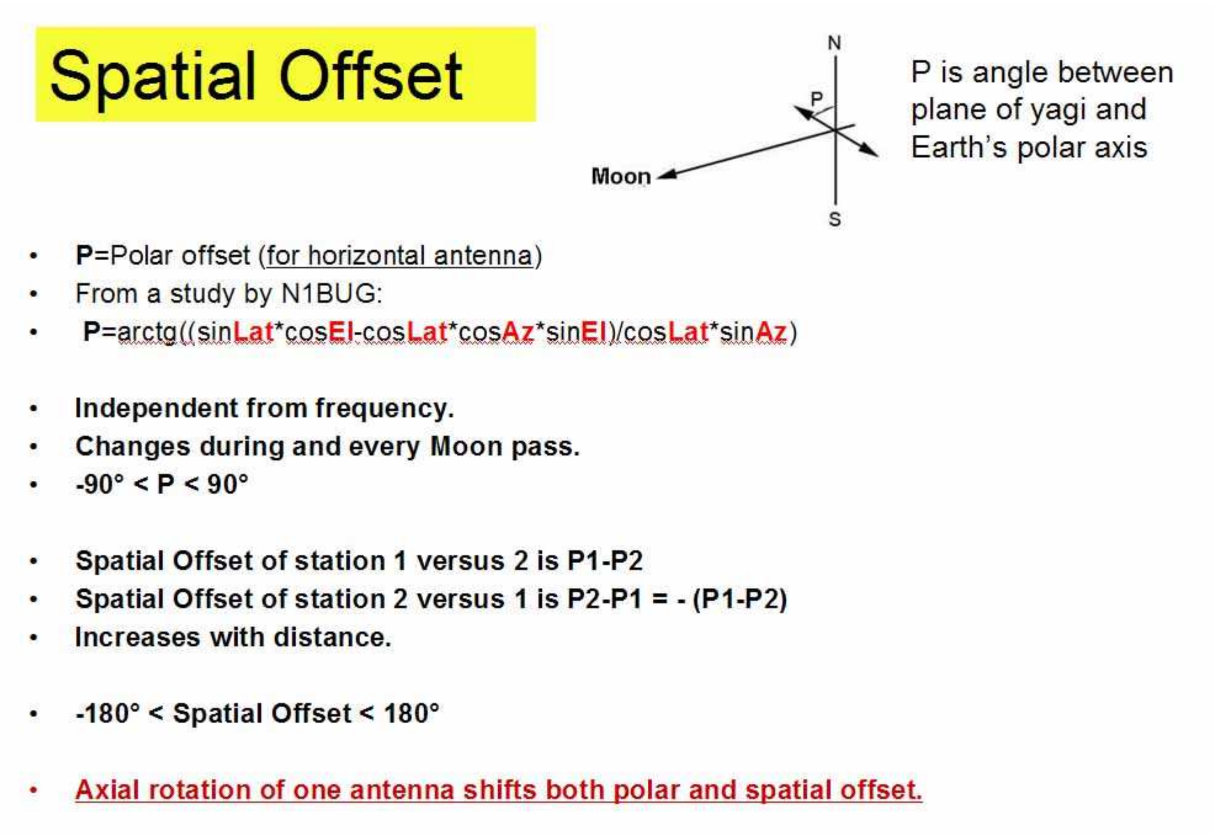
Faraday in VHF and UHF



- 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.

The example shown above is relative to a qso between ZS6OB and IK1UWL in the V/UHF bands.

Slide 13



<u>Polar Offset</u> is the angle that the plane of the antenna makes with Earth's axis.

The formula for Polar Offset (of horizontal antennas) is:

Polar Offset = arctg((sin**Lat***cos**El** - cos**Lat***cos**Az***sin**El**)/cos**Lat***sin**Az**)

Independent from frequency.

It varies during the Moon's pass; changes every Moon's pass, and with Moon's declination.

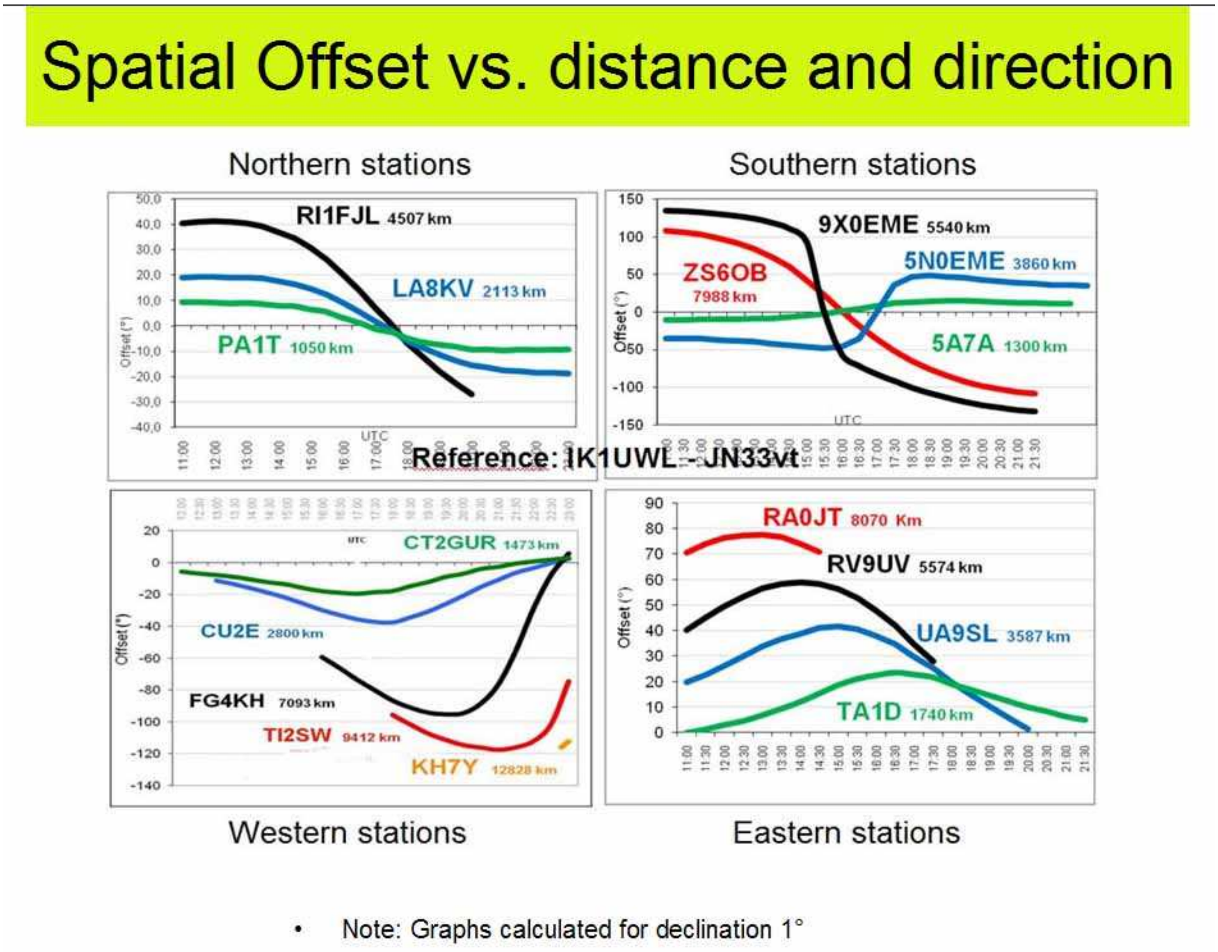
<u>Spatial Offset</u> is the angle between the planes of two antennas, so is the difference P1-P2 of the two polar offsets It represents the polarization difference when receiving directly a wave from the other station.

Spatial Offset of the second station respect the first has the same value but opposite sign.

Max value of Spatial Offset increases with increasing distance between stations.

Axial rotation of one antenna adds a constant to both polar and spatial offsets, shifting them by the rotation amount.

Slide 14



This is an overview of how Spatial Offset behaves, as a function of distance and direction.

All graphs are for declination +1°, same date.

These graphs comes from our preceding presentations.

They show that maximum values increase with distance between the stations.

As a very rough rule of thumb, max offset is in the order of 1% of the distance

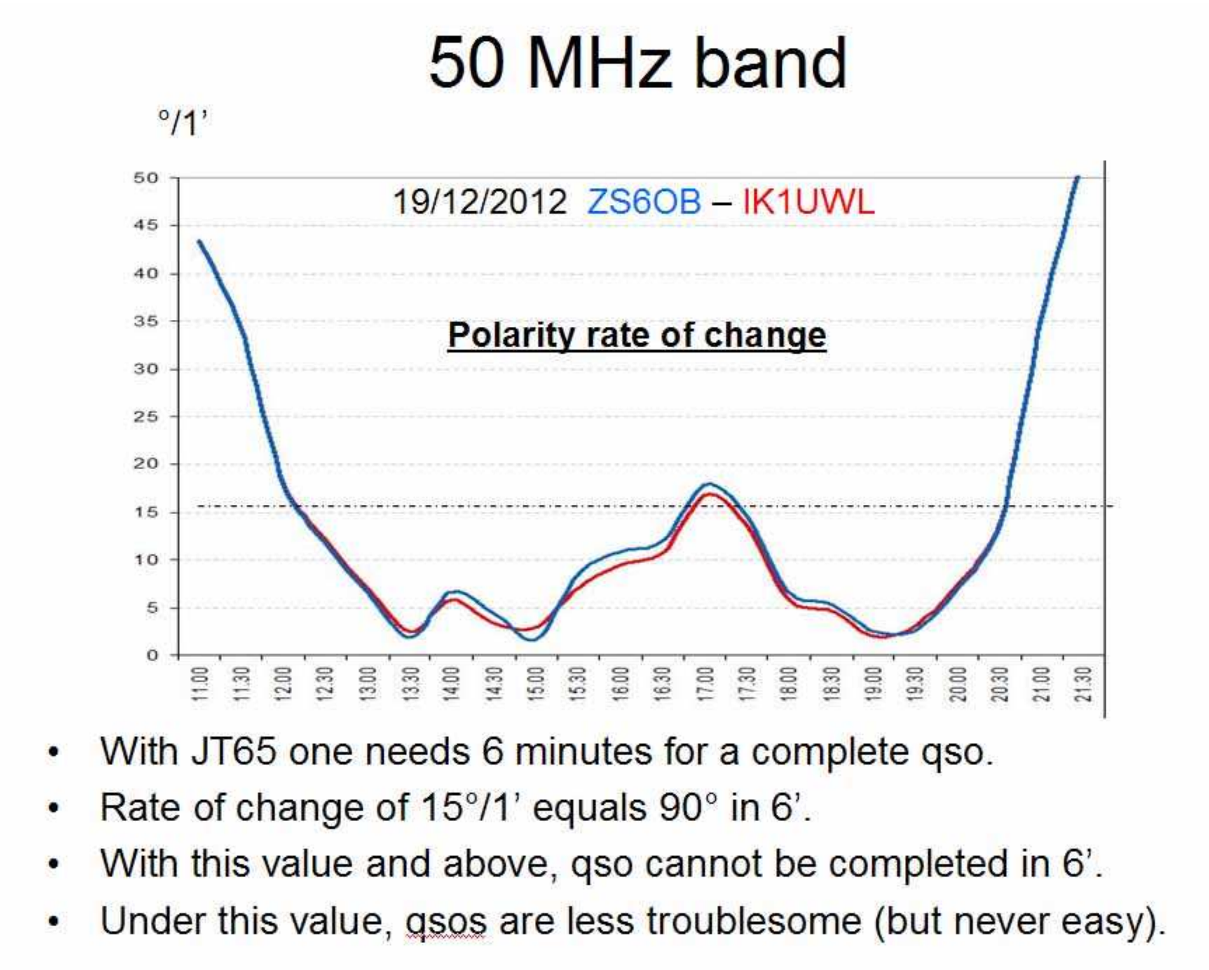
Offset changes slowly during the Moon pass.

Slide 15

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.

Slide 16



The 6 m "magic band" is peculiar in many ways. Positive aspects are Es multihop events every summer, and in meteor scatter you see pings several seconds long.

In EME, there is a negative aspect.

Faraday rotates so quickly that polarity can pass from H to V in minutes.

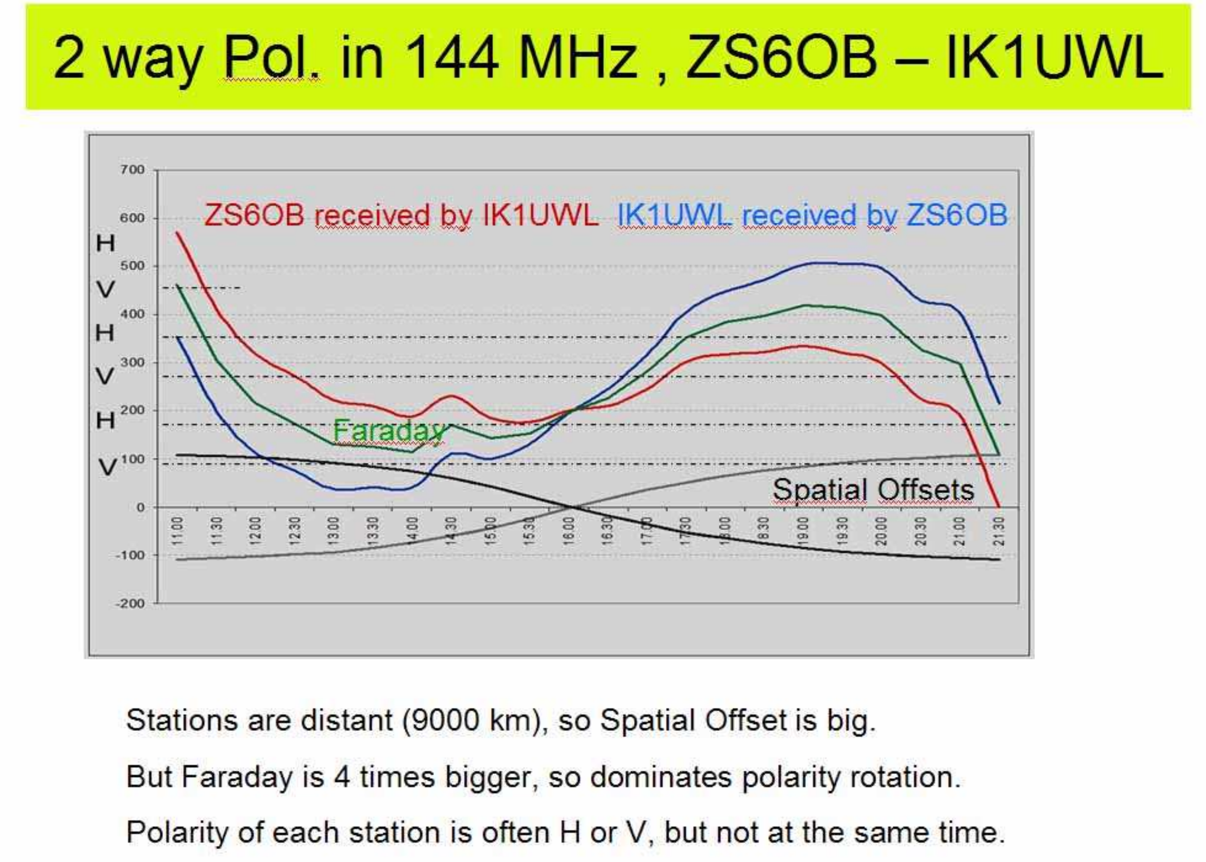
The above graph represents the rate of change of polarity during a Moon's pass.

15 degrees per minute mean 90° in 6 minutes; the time for a normal digital qso.

At this level, and above, there will be discontinuities in the decodes, and qsos will be longer than normal.

Also under this level there is a high probability of V pol. happening during a single qso.

Slide 17



We here show what happens both ways.

Graph easy to build with small additions to the excel sheet.

Faraday is the same for both station.

Spatial Offset just reverses sign when calculated for the second station.

Black curve refers to offset of ZS6OB respect IK1UWL,

Gray curve is vice versa the offset of IK1UWL respect ZS6OB.

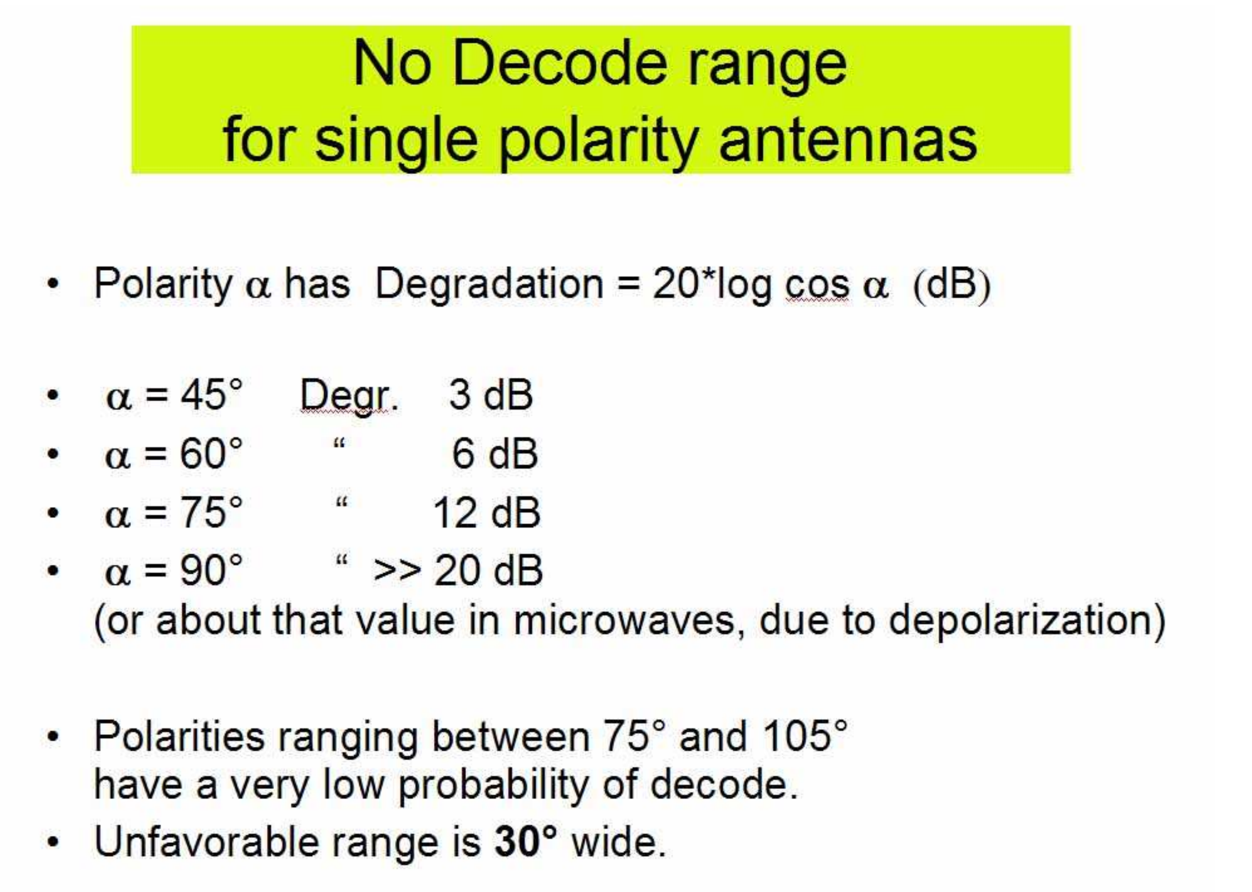
So polarity of the received signal is the sum of the common Faraday curve and of the respective Spatial Offset.

What can we get from this graph?

First thing to notice is that signals are H or V at different times, so we need to define a criterion for decodability.

Let’s examine the conditions in which signals are probably not decodable.

Slide 18



For <u>single polarity antennas</u>, degradation of a signal , received rotated respect the antenna’s plane, is 20*log cos α (dB). See some cases above.

Note: at α = 90° degradation should be infinite, but some depolarization gets into play in general, so, practically, it is usually very high but not infinite.

In digital qsos between average stations, when polarity is favorable, typical signal levels are around -16,-20 dB.

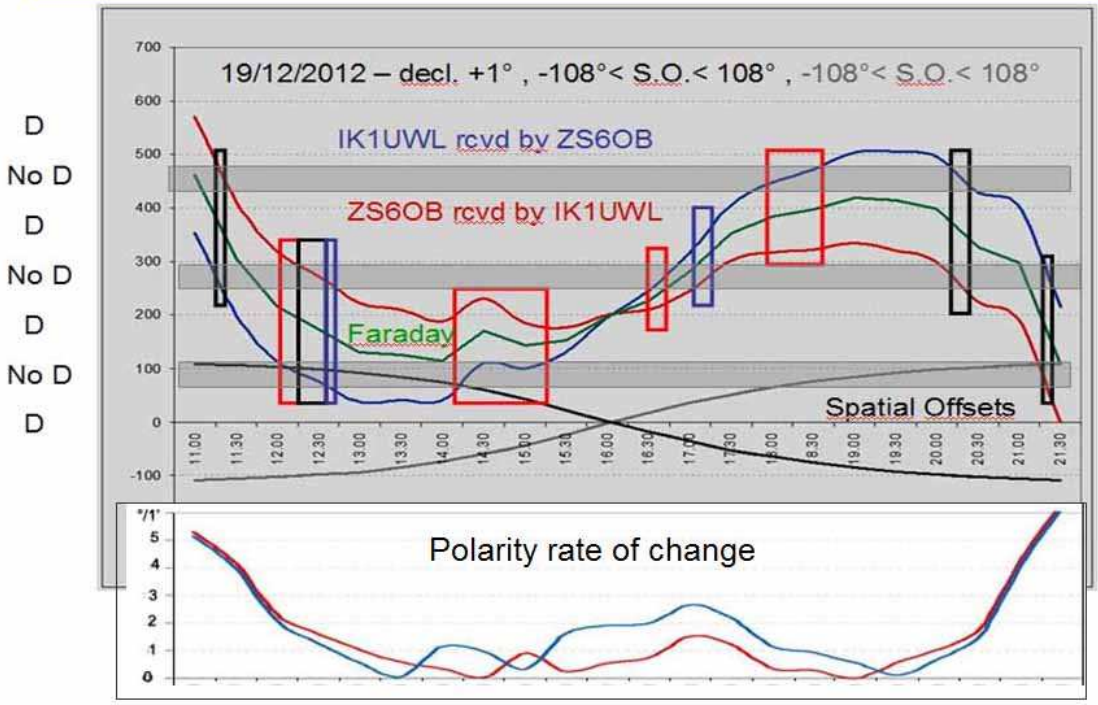
In these cases a degradation of 12 dB would shit these levels to -28 to -32 dB, and becomes the start of a no-decode situation.

So lets consider the polarity range of 75° - 105° (30° wide) as NO DECODE due to 12 dB degradation.

Every 180 degrees the situation repeats, so also 255° - 285° etc. are no-decode ranges.

Slide 19

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

Instead of lines for H and V, lets insert bands 30° wide at the V positions.

When only one of the stations falls in these bands there are 1 way conditions.

When both stations fall in these bands we have No Decode (black rectangles).

In one way cases, the color of the rectangle indicates which station is decodable.

Under the polarity graph we have added another graph: Rate of Change (in °/1')

When RoC is around 5°/1', the 30° band is traversed in 6 minutes.

With RoC about 2°/1' we have longer negative periods, around 15 minutes.

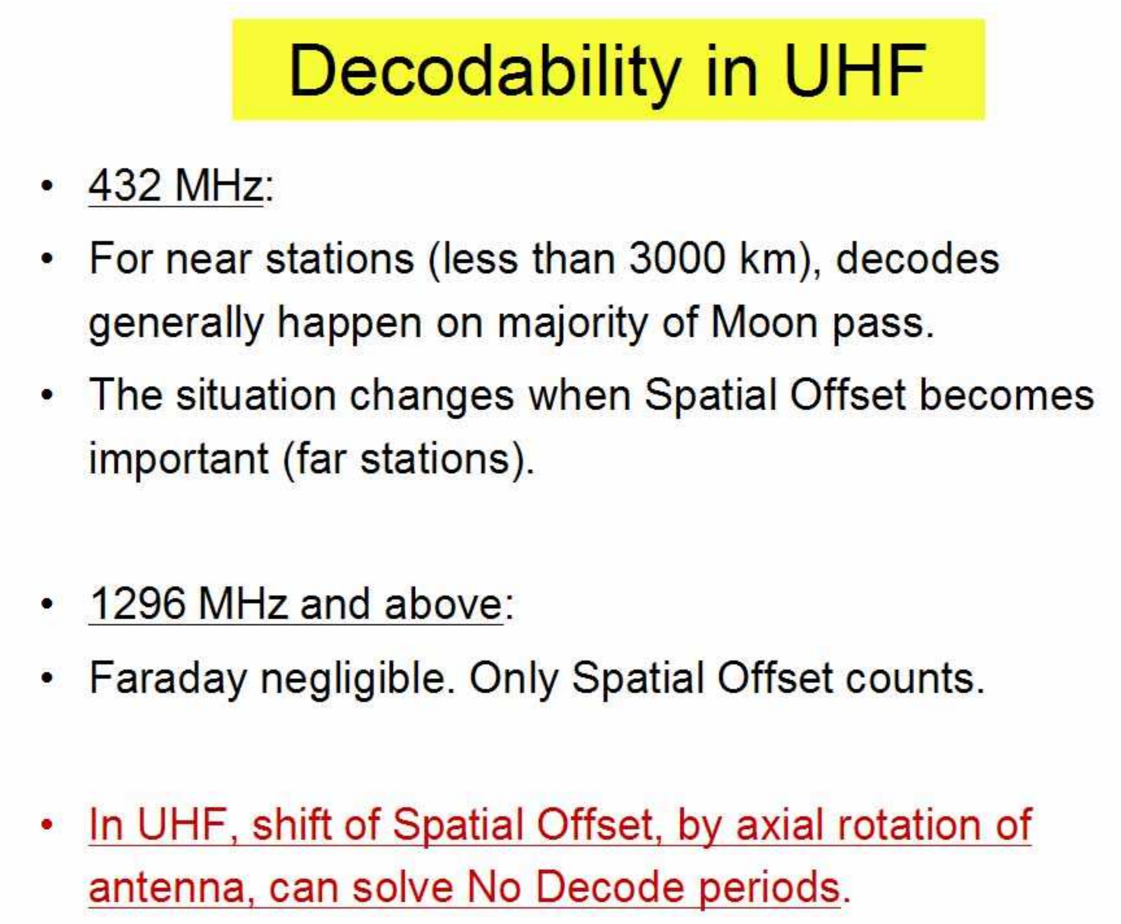
And we see a 1 hour one way when RoC of ZS6OB remains very low.

<u>This Moon pass is typical for 2 m: many short 1W or No D periods.</u>

Overall two way decodability exists for about 67% of the Moon pass.

Lets now move to the UHF bands..

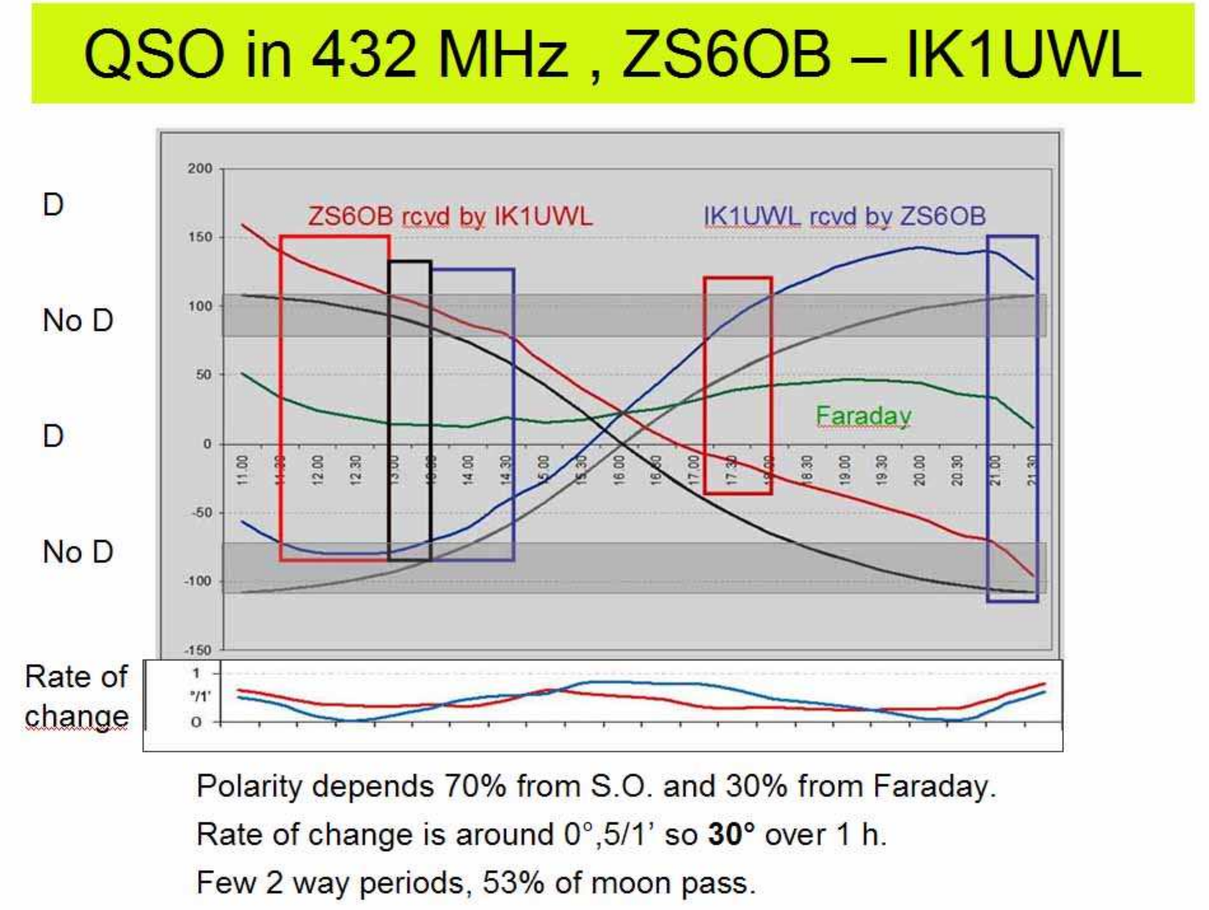
Slide 20



On 432 MHz Faraday can push polarities into No-Decode range, also with low values of Spatial Offset (near stations).
For far stations S.O. generally causes no decodes for part of the Moon pass.
On 1296 MHz Faraday is very low, and coupled with low Spatial Offset leaves polarity always in Decode range for near stations. Not so for far stations.
Rotation of one of the sources (yagi or feed) can shift Spatial Offset and therefore polarity out of No-Decode range (see examples later).

Lets examine a case of distant station: ZS6OB is about 8000 km away from IK1UWL.

Slide 21



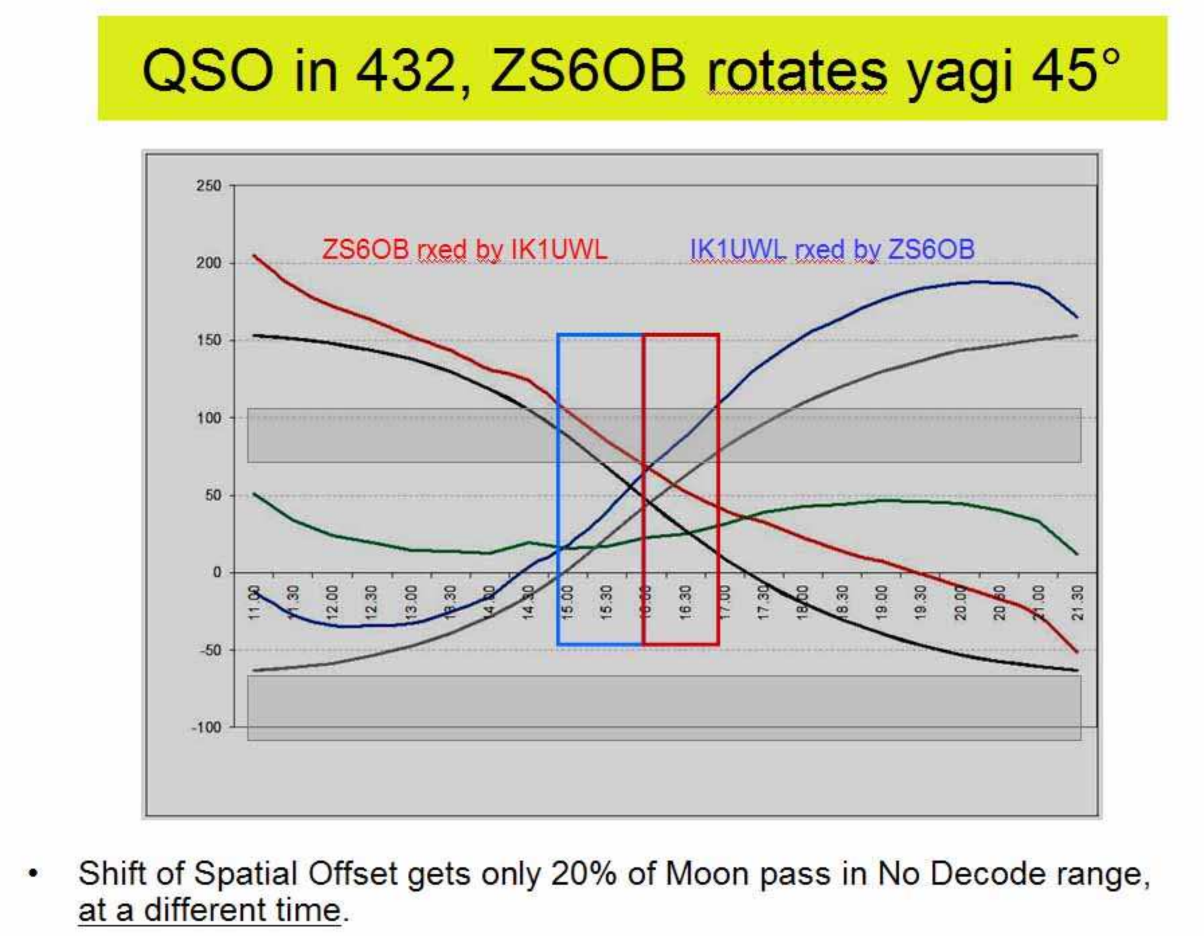
On 70 cm Faraday is generally many tens of degrees.

So, if the distance between stations is greater than 4000/5000 km approx., Spatial Offset surely pushes the rx polarity in the no-decode ranges. Spatial Offset varies very slowly, and from the graph of RoC we see rates from 0°.5/1' to 1°/1', which means long One Way or No D periods, between 30' and 1 hour.

These can happen one after the other, so in this case we have one 3 hour negative period.

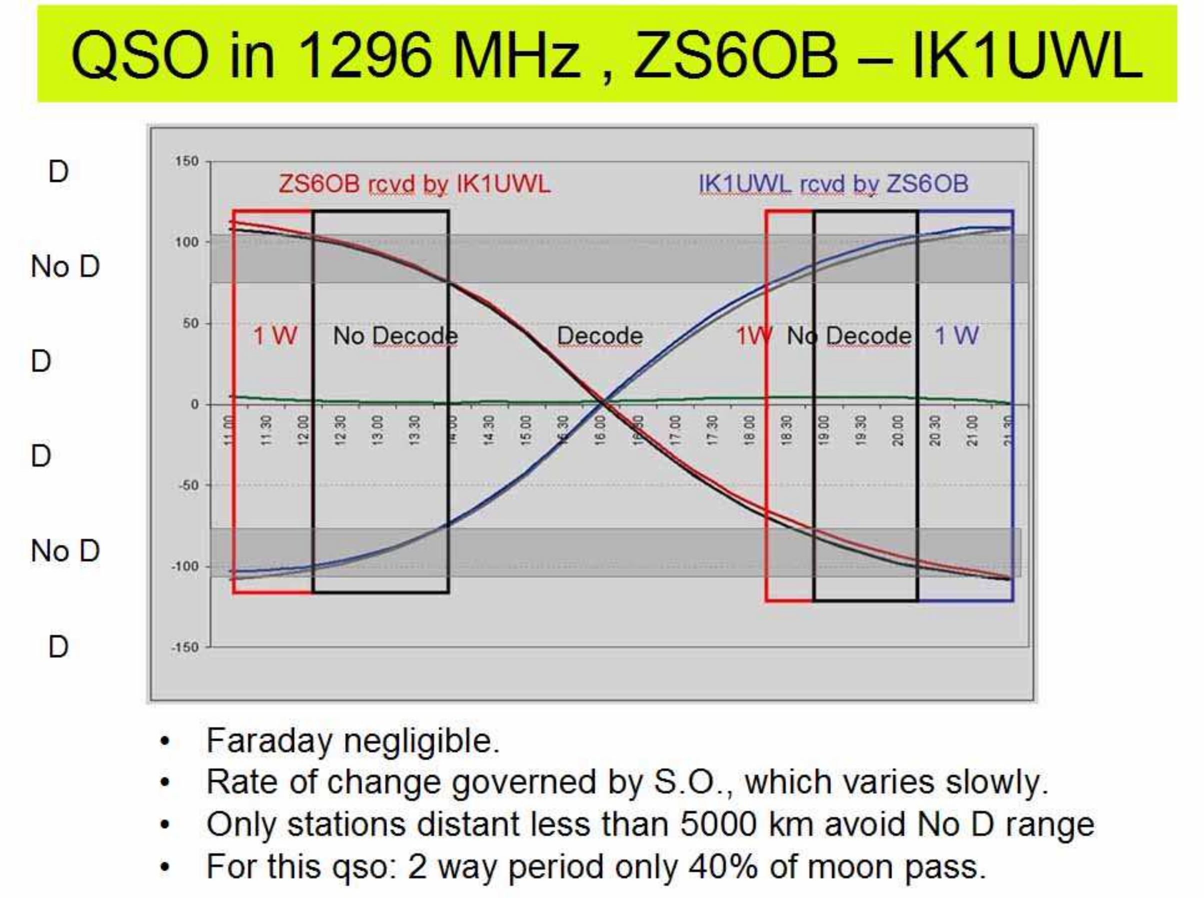
Overall two way decodability exists for 53% of the Moon pass.

Slide 22



If one of the stations rotates the antenna (or the dish feed) along its axis. the Spatial Offsets between the stations shifts by the same amount of the mechanical rotation. And the time period in which polarity is in the No Decode range changes completely. The timely use of this method during the Moon pass allows 100% decodability.

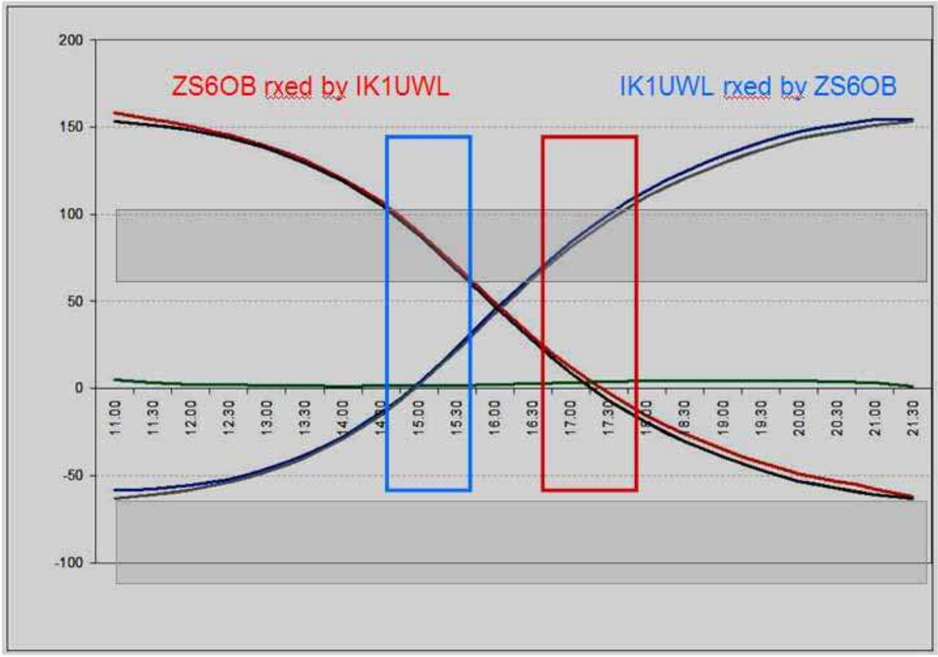
Slide 23



With Faraday rotation in the order of some degrees, rx polarity is defined practically only by the Spatial Offset. And with distance between stations giving maximum Spatial Offset greater than 75°., this offset pushes polarity in the no-decode range for 60% of pass.
2 way decodability happens only in 40% of Moon’s pass.
With distances between stations decreasing towards 4000-5000 km, the time period in which Spatial Offset gets polarities in the no-decode range gradually decreases.
Near stations have Spatial Offsets that do not reach the No Decode bands, so they have 100% decodability during the Moon pass.

Slide 24

QSO in 1296, ZS6OB rotates yagi 45°



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

As shown for the 432 MHz band, rotation of source polarity of one of the stations gives the desired shift of Spatial Offsets.

So the time period in which polarity is in the No Decode range changes completely.

The timely use of this method allows 100% decodability over the Moon pass, also to distant stations.

Slide 25 - Resumee

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 50-70 % of Moon pass.
  Shift of Spatial Offset by source rotation gives important changes.
- **1296** and up: 99% Spatial Offset, Faraday insignificant.
  Polarity changes very slowly.
  Shift of Spatial Offset by source rotation is very effective.
  2 way on 40-50% of Moon pass for distant stations becoming gradually 100% for near stations.