

Radio Propagation - VHF and higher

(Without the Mathematics)

Presented by

Dr John Worsnop G4BAO

RSGB Propagation Studies Committee

RadCom "GHz bands" Columnist

With a little help from

<http://www.mike-willis.com/Tutorial/propagation.html>



VHF and above – the big myth

Foundation Exam Syllabus, 6.a.5, states:

“Recall that, at VHF/UHF, range decreases as frequency increases, and that in general, VHF/UHF waves have a range not much beyond line of sight”

So Range on VHF and up is “in general” line of sight plus a bit eh?

Oh Dear!!..... “in general” is an understatement..!!

That sounds really boring.....no DX... so why bother?

.....and why are there over 220 current 50MHz DXCC holders?

.....and I’ve worked 66 DXCCs myself by not being very active?

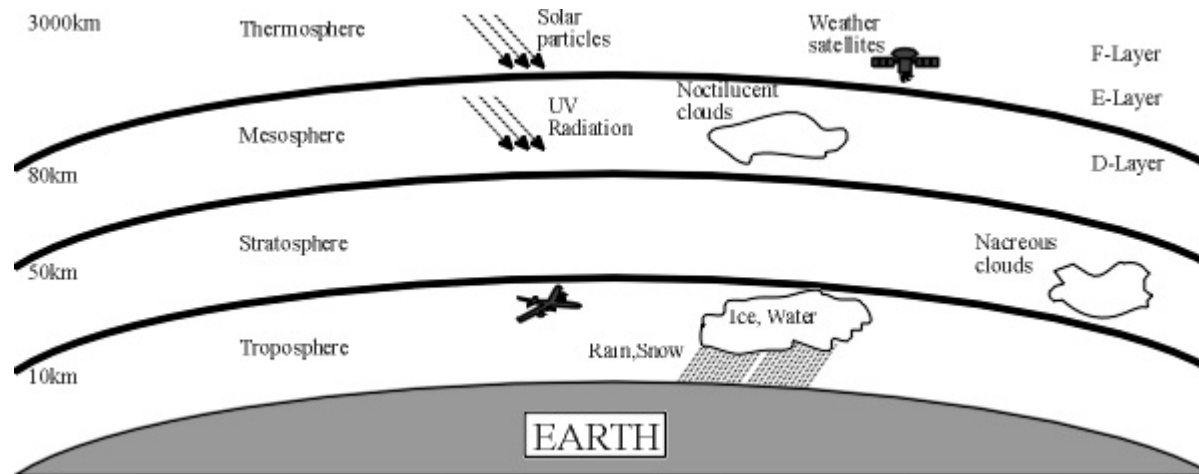
.....and I’ve worked 20 DXCC entities on 1.3GHz

.....and 36 on 70MHz?

It’s frankly misleading and must put people off VHF



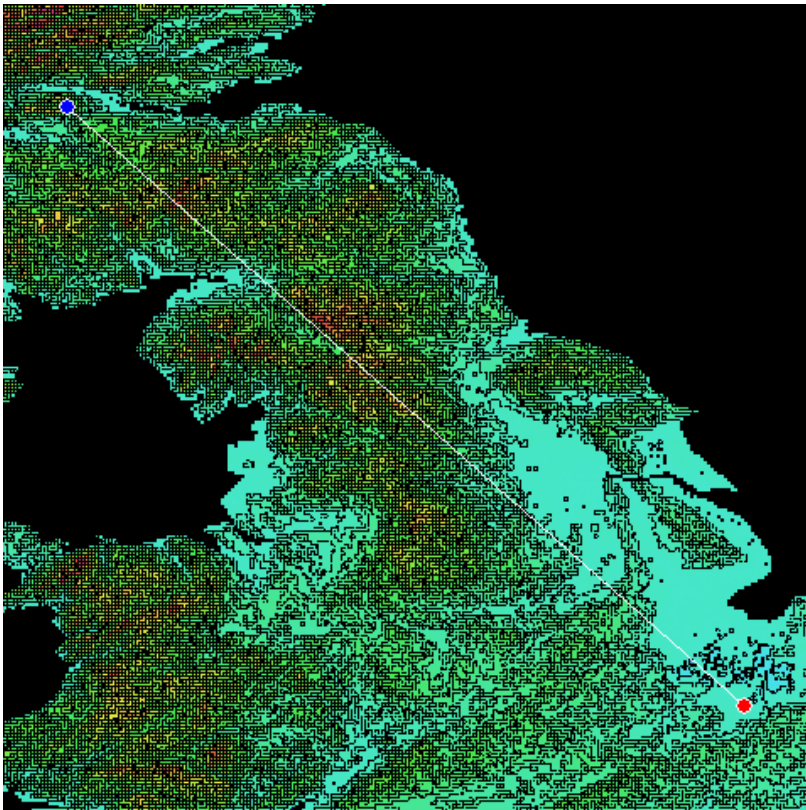
The environment for VHF propagation



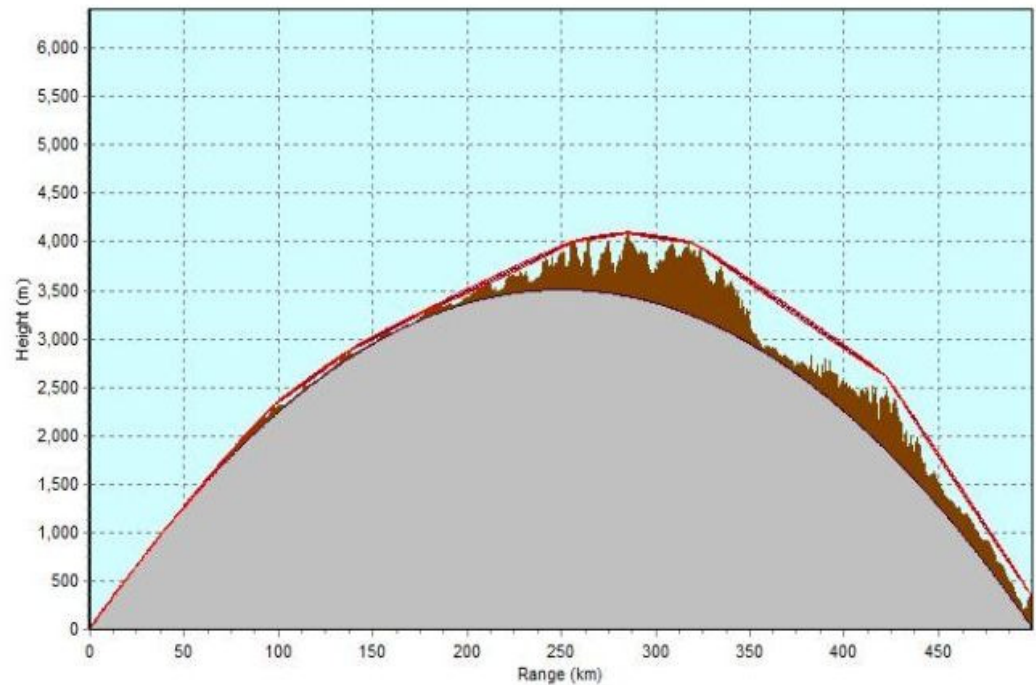
Most VHF propagation goes on in the troposphere
- with some notable exceptions

The environment for VHF propagation

Terrain map G4BAO -> GM0USI/P



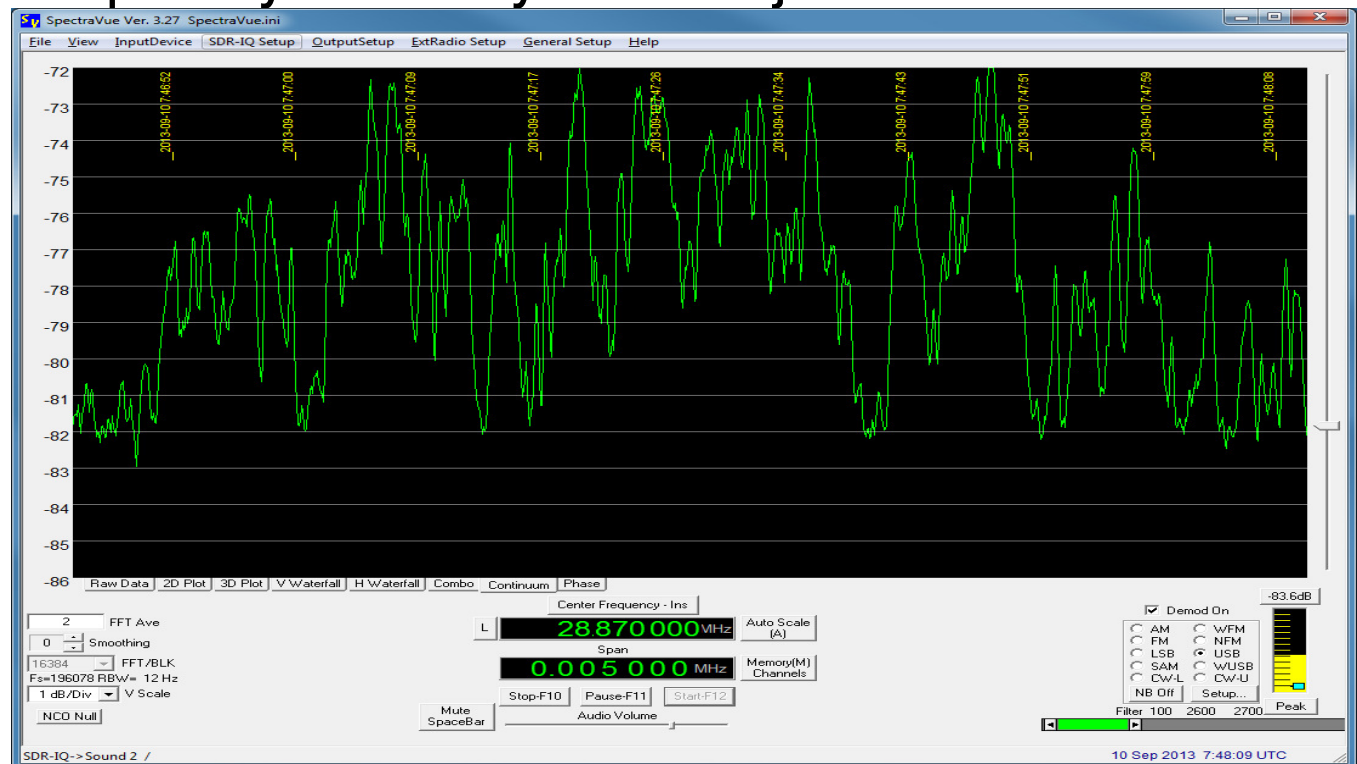
Path profile



A bit of physics

- Radio waves are the same as light waves, they are just lower in frequency. So they are subject to:

-
- Refraction
- Reflection
- Diffraction
- Scattering

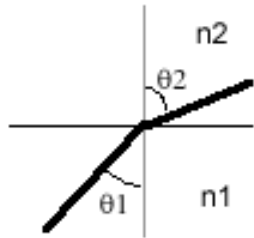


- Most VHF propagation is a combination of all of the above. That makes it INTERESTING
- Even line of sight signals fade due to multipath

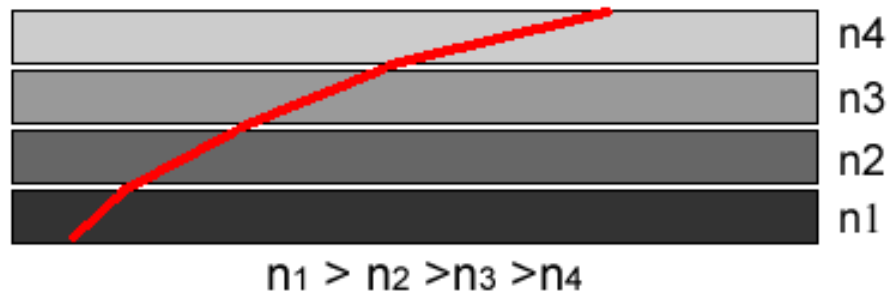
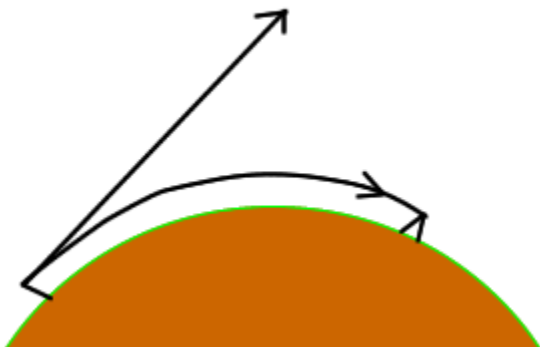
A bit of physics

- Refraction
- Reflection
- Diffraction
- Scattering

Snell's Law



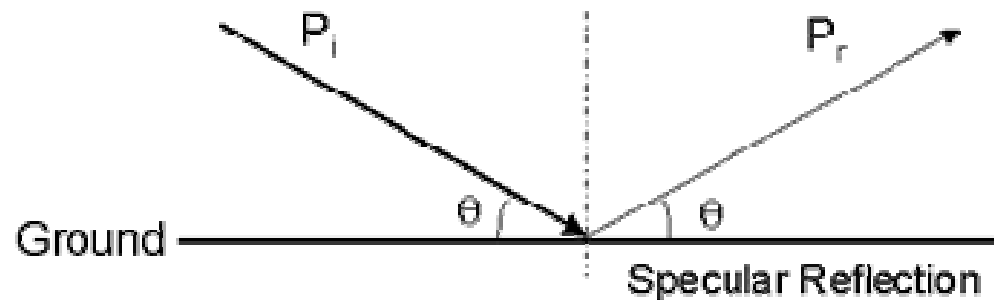
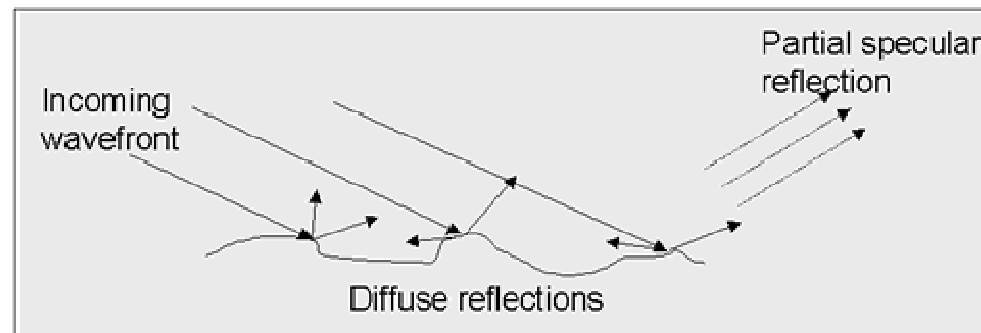
$$\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1}$$



Typically, the refractive index in the troposphere falls slowly with height and the resulting refraction causes the radio horizon to appear to be 1.33 times further away than the geometric horizon.

A bit of physics

- Refraction
- Reflection
- Diffraction
- Scattering

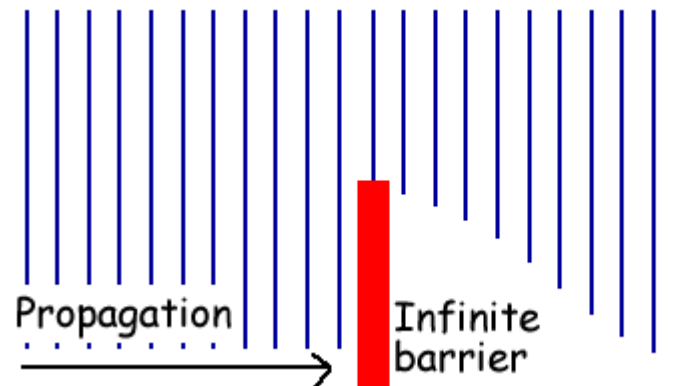


Reflections from the Ground

The reflection co-efficient for ground reflections depends principally on the dielectric constant ϵ and the conductivity σ . It is different for vertical and horizontal polarization.

A bit of physics

- Refraction
- Reflection
- Diffraction
- Scattering



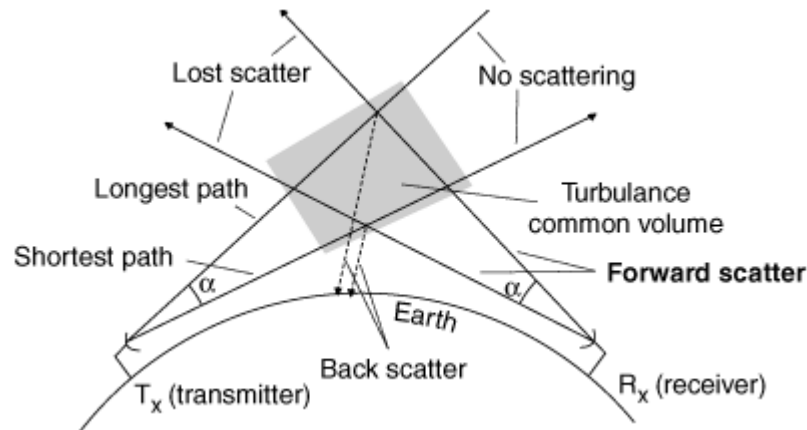
The Huygens principle of wavelets can be used to explain this –

“Each point on a wavefront acts as a source of secondary wavelets. The combination of these secondary wavelets produces the new wavefront in the direction of propagation”

A bit of physics

Tropospheric scatter is the scattering of RF energy from regions of the troposphere with slightly different refractive index

- Refraction
- Reflection
- Diffraction
- Scattering



Rayleigh Scattering

Rayleigh scattering is normal scattering of radiation by particles whose size is 0.1 or less than that of the radiant wavelength. Scattering increases with the fourth power of the frequency.

(Which incidentally is why the sky is blue.)

Physics in action

Propagation modes beyond line of sight

- Extended Tropospheric - A combination of refraction and diffraction
- Tropospheric Ducting
- Tropospheric Scatter
- Rain Scatter
- Meteor Scatter
- Aircraft Reflection
- Sporadic E (Es) Ionospheric refraction/reflection
- Ionospheric Scatter
- Auroral Backscatter

Physics in action

Propagation modes beyond line of sight

- **Extended Tropo**

- Tropospheric Ducting
- Tropospheric Scatter
- Rain Scatter
- Meteor Scatter
- Aircraft Reflection
- Sporadic E (Es)
- Ionospheric Scatter
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- All bands above 50MHz
- “Flat band”
- 150 -200km depends on equipment & site
- Always present
- Caused by normal refraction and diffraction
- “4/3 earth” effect

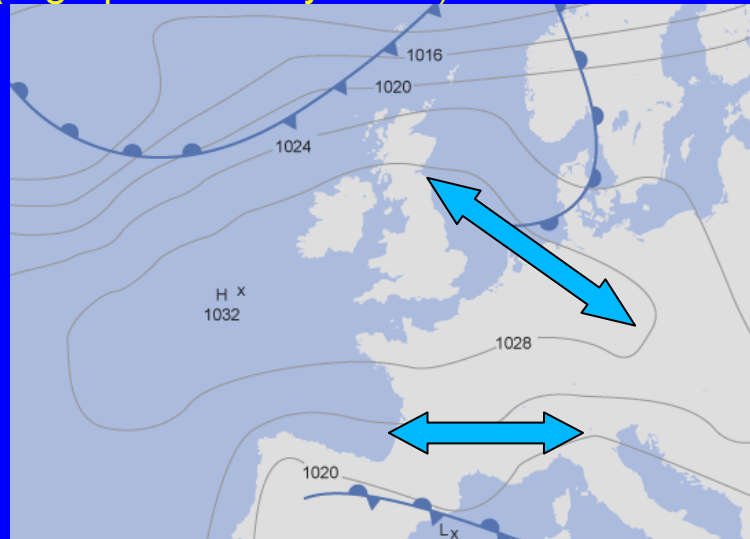


Physics in action

Propagation modes beyond line of sight

- Extended Tropo
- **Tropo Ducting**
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- Best at 144MHz and above
- 1000 -1500km typical (SP,DL,SM,OZ,EA,HB9)
- “Bitterverlifton” ☺
- Weather-dependent
 - “Temperature inversion” layers
 - Paths often along the edge of anticyclones (High pressure systems)



A tropo sea duct off the Spanish coast, August 2013

See the trapped pollution layer?

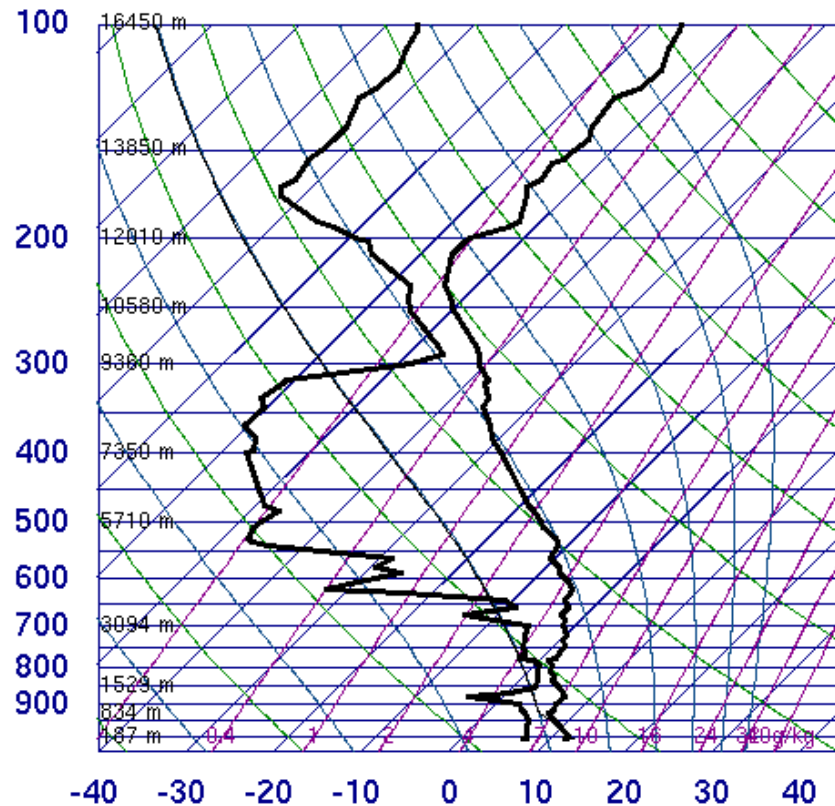


Physics in action

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- Inversion layers
- Refractivity profile - flat band



SLAT	53.00
SLON	-1.25
SELV	117.0
SHOW	8.44
LIFT	11.36
LFTV	11.25
SWET	146.9
KINX	19.20
CTOT	18.20
VTOT	20.70
TOTL	38.90
CAPE	0.00
CAPV	0.00
CINS	0.00
CINV	0.00
EQLV	-9999
EQTV	-9999
LFCT	-9999
LFCV	-9999
BRCH	0.00
BRCV	0.00
LCLT	278.7
LCPL	922.5
MLTH	285.2
MLMR	6.22
THCK	552.3
PWAT	18.22

00Z 11 Sep 2013

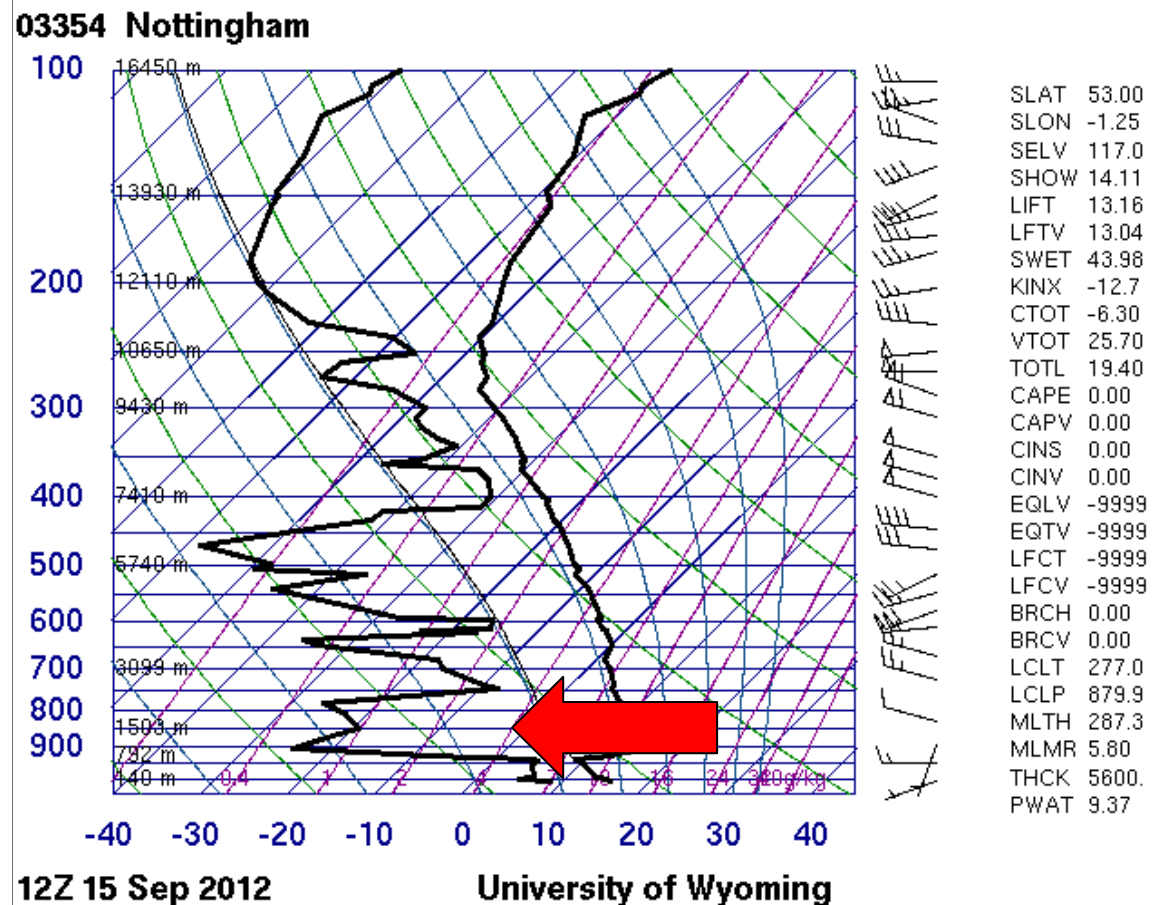
University of Wyoming

Physics in action

Propagation modes beyond line of sight

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- **Refractivity profile during ducting**
- The day of the 10GHz UK record 1429km QSO between GM0USI/P and F2CT/P

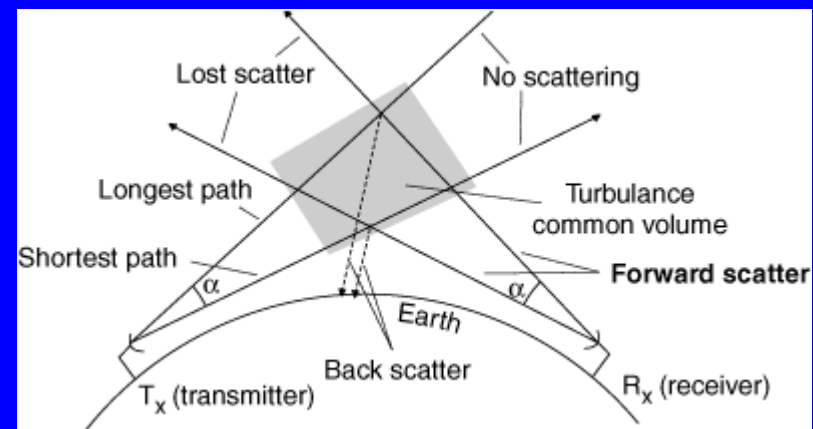


Physics in action

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- 144MHz to 5GHz bands
- 1000km depending on equipment
- Usually requires QRO and big antennas
- Always present
 - Used by professional fixed broadband links



Physics in action

Propagation modes beyond line of sight

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- **Rain Scatter**
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- Bands above 1296MHz
- Weather dependent (obviously)
- 150-400km depending on equipment
- Scattering from rain droplets
- Depends on drop size and intensity

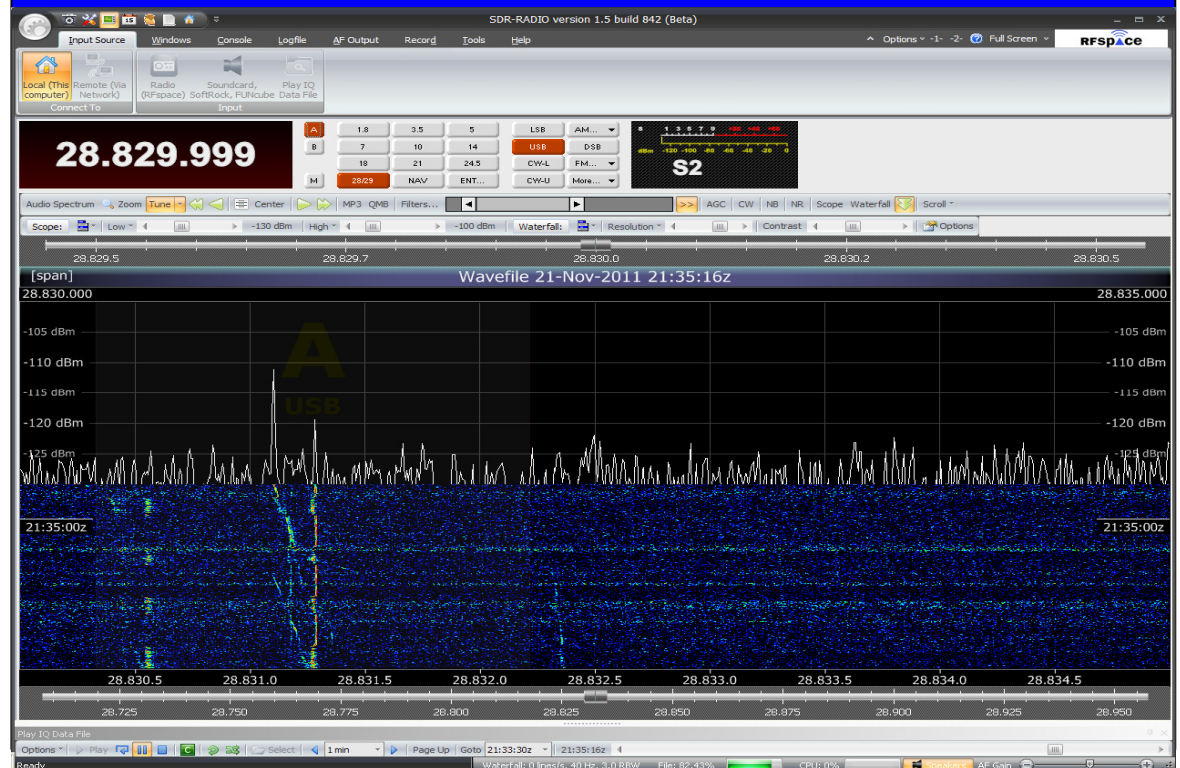


Physics in action

Propagation modes beyond line of sight

- Extended Tropospheric
- Tropospheric Ducting
- Tropospheric Scatter
- Rain Scatter
- Meteor Scatter
- **Aircraft Reflection**
- Sporadic E (Es)
- Ionospheric Scatter
- Auroral Backscatter

- 144MHz to 10GHz
- Up to 800km depending on equipment
- Aircraft must be approximately at the mid point of the path



Physics in action

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- 50MHz to 144MHz
- Up to 2500km depending on equipment
- Specular reflection from ionised trails of shower and random meteors
- Path loss proportional to freq^3
- JT modes used and timed periods.
 - JT6M and ISCAT-B on 50MHz
 - FSK441 on 70 and 144MHz
- Minimum Equipment
 - 50W and a dipole for 50MHz
 - 50W and small beam for 70MHz
 - 100W and a 9 element for 144MHz

Physics in action

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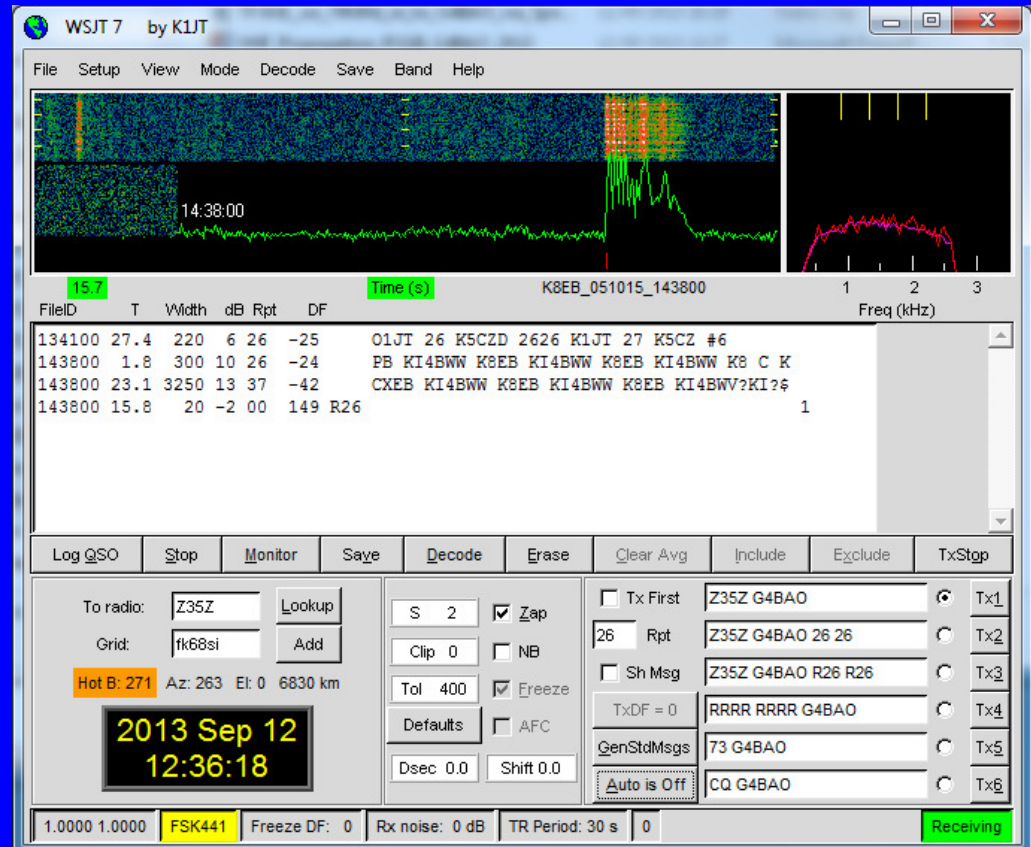
Some examples



JT6M



FSK441



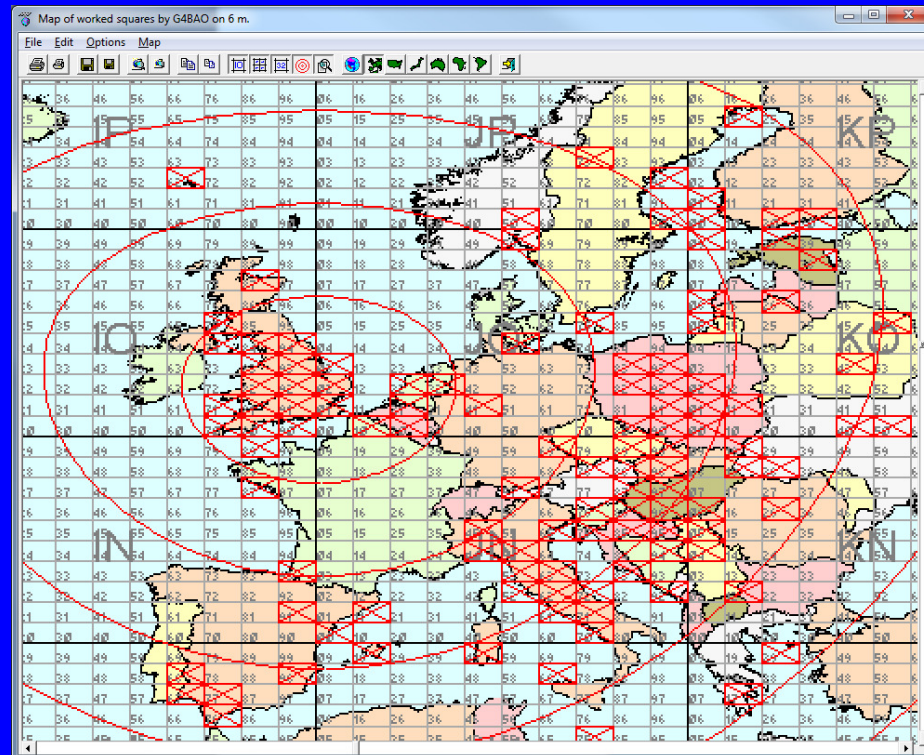
Physics in action

Propagation modes beyond line of sight

- Extended Tropospheric
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- **Sporadic E (Es)**
- Ionospheric Scatter
- Auroral Backscatter



- 50MHz to 144MHz bands (432MHz rarely)
- 1000 -5000km+. Single and double hop.
- Characterised by huge signals and deep fading.
- Mainly a summer phenomenon (April-Sept)



Physics in action

Propagation modes beyond line of sight

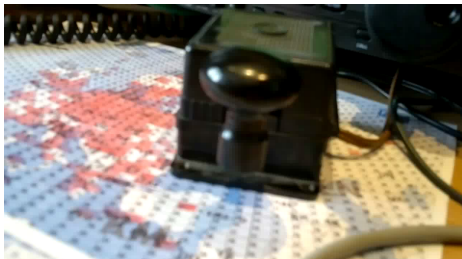
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- Tropospheric Ducting
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- Sporadic E (Es)
- **Ionospheric Scatter**
- Auroral Backscatter

- Mainly 50 and 70MHz or 144MHz
- Usually requires QRO and big antennas
- D and E layer Forward Scatter
- 1000 -2500km.
- Optimum time between 10am and 2pm, local time, when the sun is highest and D layer ionization is greatest.
- Marked daily variation in the intensity of ionosscatter
- Some days will be completely unusable.

Physics in action

Propagation modes beyond line of sight

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- Rain Scatter
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- Sporadic E (Es)
- Ionospheric Scatter
- **Auroral Backscatter**



- 50MHz to 432MHz bands
 - lower bands better
- Caused by solar flares
 - Energetic particles spiral down the earth's field lines and ionise the polar E layer
- Backscatter mode
 - everyone beams North(ish)



Putting it all together

- Not just line of sight plus a bit!
- Lower VHF bands can give good results with Es even with a “poor” site.
- 50 watts to a vertical on “six” and you’ll work summer Es DX
- High pressure systems are generally good for VHF
- High K and A indices are good for the low VHF bands as they can result in Auroras
- Monitoring weather maps, the University of Wyoming upper air soundings, and the K index will give you an indication of what bands you should concentrate on.
- Summer good for rain scatter due to prevalence of thunderstorms
- Spring/Autumn are good for tropospheric ducting and extended tropo
- Coastal sites are very good for sea ducting on the GHz bands
- QTH is not everything, system design is.