TROPOSCATTER OVER THE ALPS

VHF Propagation studies with JT65 digital mode

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Introduction

The multiple knife edge model for terrain diffraction is related in this document, after several experiments. There is the possibility to overpass the Alps in vhf communication, even with low power do not exceed 2 watts. Many tropospheric irregularities added with signals diffraction over the Alps peaks, which are capable of supporting the propagation with a quite good regularity , even during poor conditions. This is propagation for multiple diffraction can carry out the signal beyond the shadow zone. Further, radio waves, thanks to this form of diffraction, following the earths' curvature for several hundreds of km. through the troposphere. I used WSJT because the software is well suited for propagation studies. You can work with very weak signals but especially you can see the signal and viewing time and spectrum frequency of received signal in the real time.

Troposcatter

This type of tropospheric propagation is supported by turbulence located in the upper limit of the troposphere, the scatter is due to multiple refractions agglomerations of air of different density, to give a better idea, the scatter (scatter radiation = diffuse) consists of simultaneous refraction by many small objects like air bubbles. This mechanism, when the wave passing through the troposphere meets a turbulence, it makes an abrupt change in velocity. This causes a small rate of the energy to be scattered in a forward direction and returned back to Earth at distances beyond the horizon. Tropo-scatter links are possible at any time although they require very sensitive equipment and high gain antennas system because the attenuation caused by these repeated "bounce" and scattered, are much higher than normal tropospheric propagation. Air is not uniform, there are eddies, thermals, turbulence etc. where the air has slightly different pressure and hence a different refractive index. The eddies have outer scales ~100m and inner scales of ~ 1mm. Energy that is fed into a turbulent system goes primarily into the larger eddies and from these, smaller eddies are shed. This process continues until the scale of the turbulence is small enough for viscous action to become important and dissipation as heat to occur.The maximum distance reached is highly dependent on equipment (tx output power) and antenna system. Troposcatter signals are characterized by a strong fading, caused by the continuous changing conditions of microcells of diffusion and random paths that may make reflected signals reaching the receiver out of phase (distortion).

Diffraction

Diffraction is a physical phenomenon associated with the deviation of trajectory of the waves. Refraction and diffraction involving both a withdrawal of some waves from their direction of origin, the main difference is that refraction occurs as a result of some change the characteristics of the medium through which the waves should pass, while the diffraction takes place when the wave passes over the board which is an obstruction in its path. It can also possible that radio waves are bent slightly (and thus diffracted) also above the rounded edges, and on medium wave and long has the same curvature of the earth to behave in this way. Finally, radio waves can also be diffracted when they lapping (to overcome) the edges or corners of any type of Obstruction. What is known as a knife edge diffraction (Knife-edge diffraction), which occurs mainly on VHF, UHF and in addition, shall scatter the signal even in what would be the shadow zone beyond the obstacle.

Ground diffraction

Terrain diffraction plays an important role in Tran horizon communication. It can even dominate the propagation process. Diffraction is most important when there is a common edge (such as mountain peak) at the horizon, located at very small angle to both the transmitter and receiver. Under the right conditions, it is possible that diffraction from several consecutive edges can dominate. Further, during times with unusually high refractive index variation, the radio horizon can be altereted to a high degree so as to lower angles with any distance edges. The alps path is expected to be significantly affected by this phenomena. The angles with the horizon are not large and even during super refractivity conditions, the waves must diffract around several edges. It diffraction occurs there would be an increase of the power at the lowest height viewed by the system. The Doppler shift associated with that power would also very small.

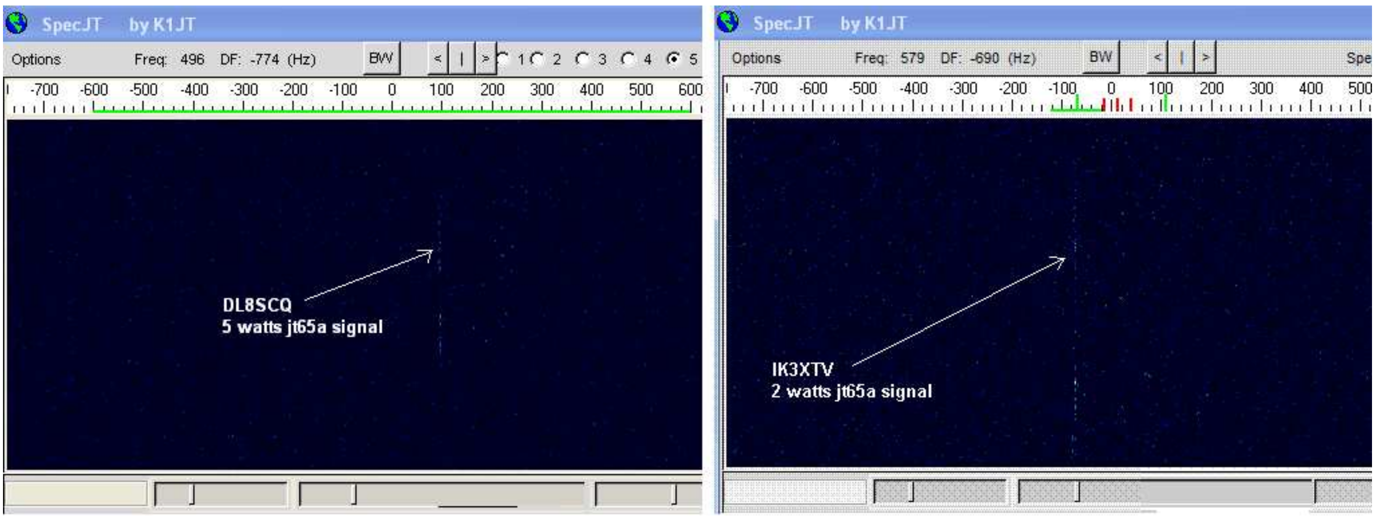


Fig.1 jt65A signal trasmetted by IK3XTV with tx out power of 2 watts (right spect) and DL8SCQ's signal of 5 watts (left spect). Distance 387 km.

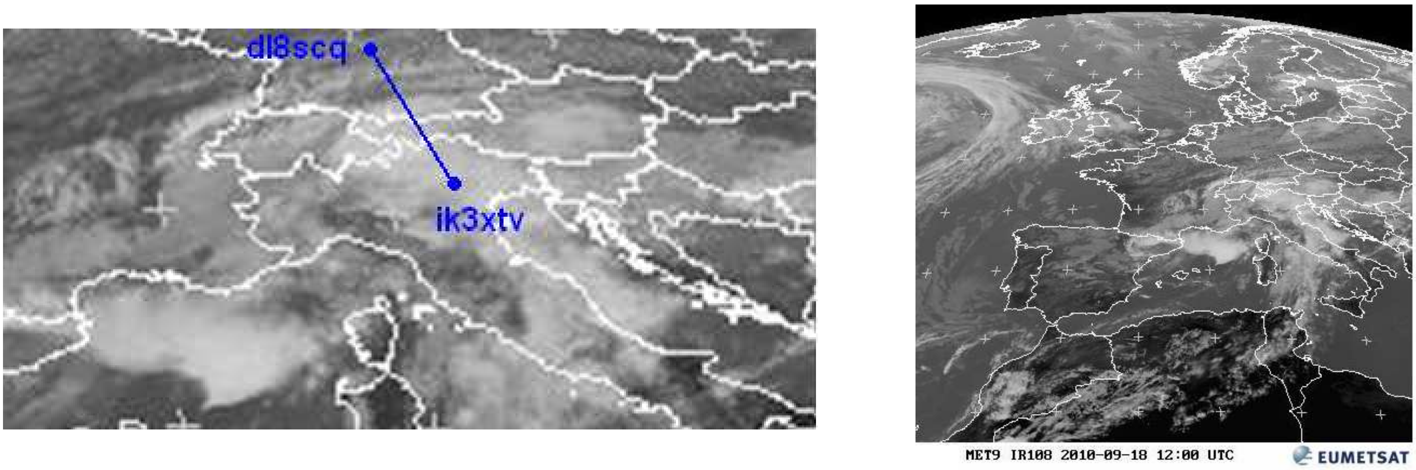


Fig.2: Satellite photo with the weather situation during low power experiment. The weather in the souther part of the Alps was overcast and rainy and rain, while was high pressure with clear sky and sunny in the northern sector.

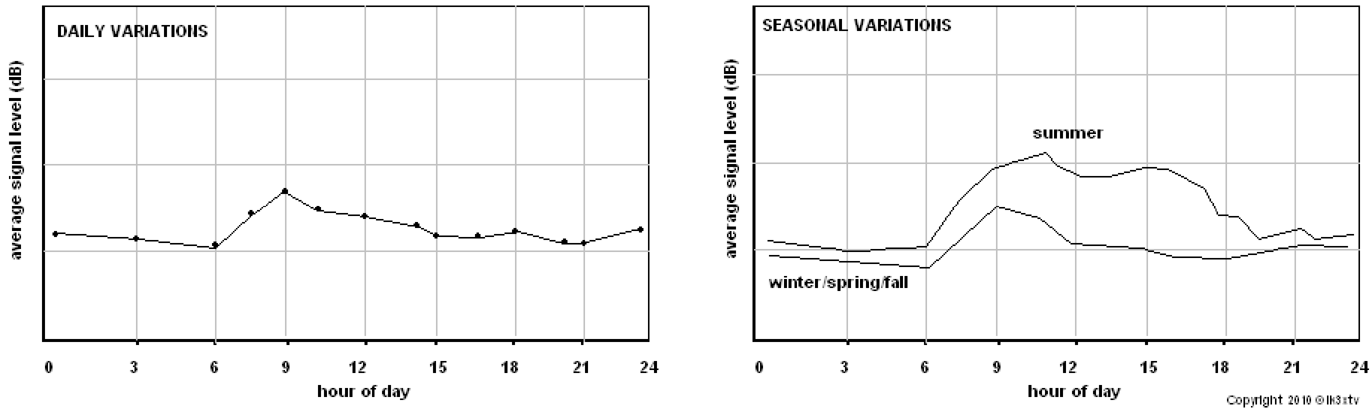


Fig.3 The graphs show the summary result of troposcatter research and reported the average signal level during the course of a day and during the year. The graphs derive from the interpretation of many data of QSO on VHF and mediated in order to graph the level of troposcatter propagation. The difference between the hours of day and night are due to the considerable air temperature variations.

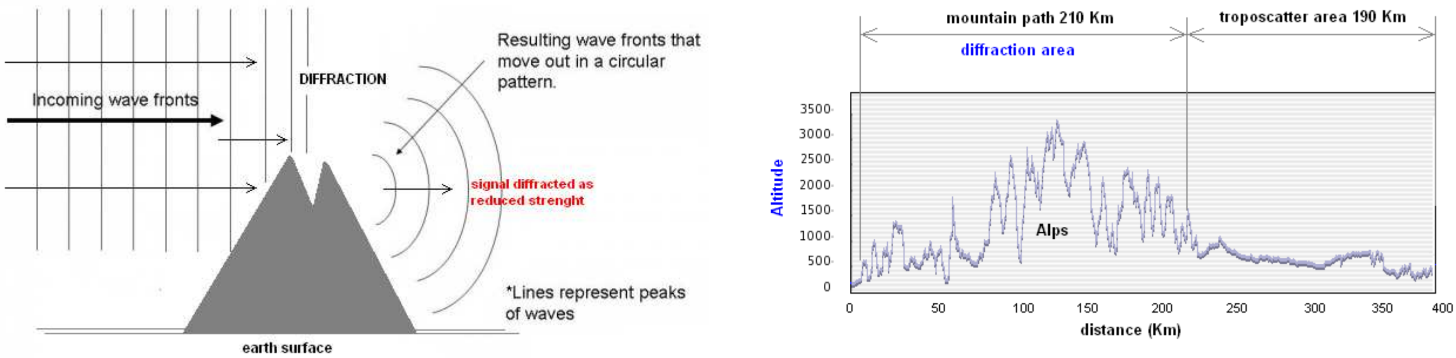
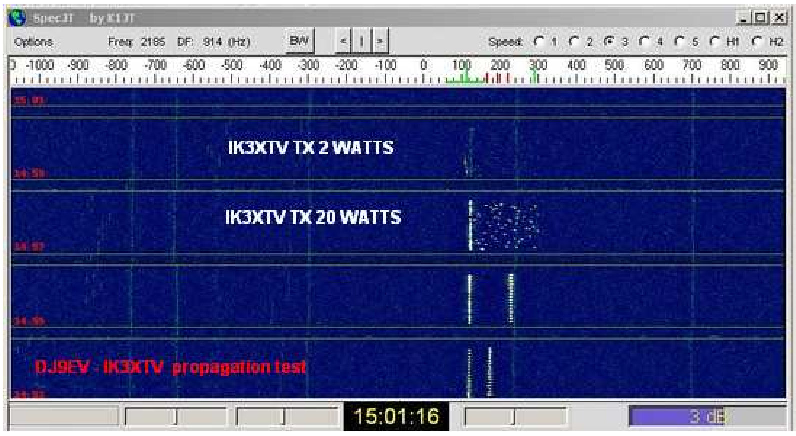


Fig.4: left: The figure shows the basic principle of electromagnetic wave diffraction : "knife-edge diffraction. For multiple diffraction, and that 'what happens in reality, there a series of many individual diffraction. Right: propagation path with diffraction and troposcatter area.
The longest trans-Alps qso has made with DF2ZC. In this case, using EME power the path has been of 618 Km, with about 200 km of diffraction section and more of 400 km of troposcatter enhancements path.

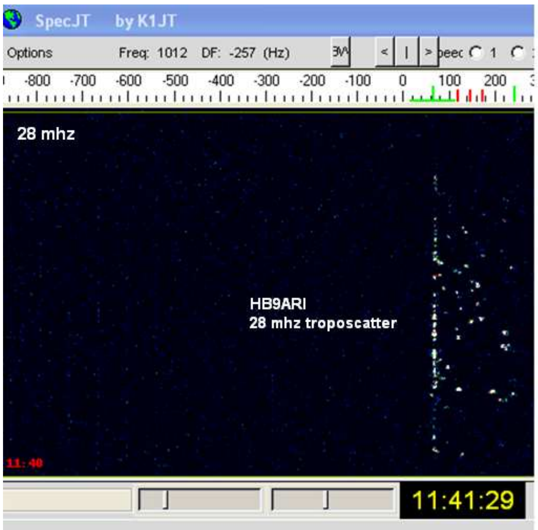
Propagation improvement from snowy terrain

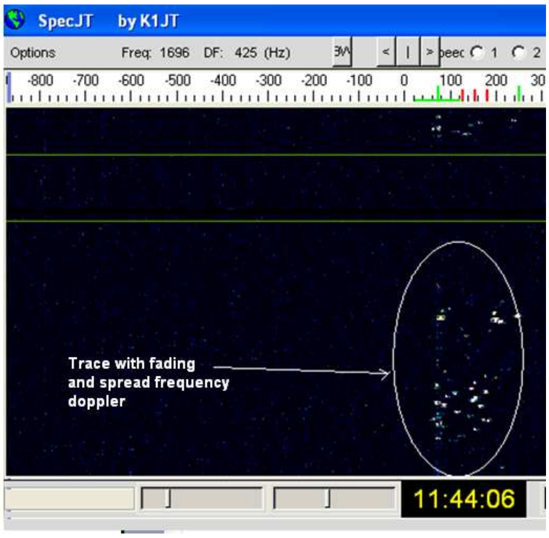
Some experiments seems to show a possible propagation improvement when the Alps path is covering of snow.
This could be due because the diffraction is more efficient and the diffraction losses are lower (the diffraction coefficient is better). Signals appears to be less afflicted by rapid and even slow fading compare with normal terrain.



10 meters band troposcatter experiment

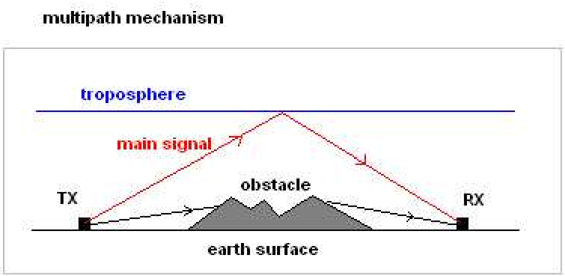
Always with WSJT I also made some tests in tropospheric propagation in the 10 meters Ham radio band. This experiments have confirmed that the Troposcatter over the Alps can be possible even in this frequency. You need more power, because the antennas have a significantly lower gain, but also because the air bubbles in the spreading of signal have an amplitude too small to support the refraction on wavelengths of 10 meters and the diffraction over the mountains obstacle absorbs more energy. Signal is affected by fast fading. (test with HB9ARI)





interference Causes Reflection and Diffraction

The terrain around an antenna plays an important part in its signal quality. If there are any obstructions around an antenna the waves emitted will bounce off them much like light reflecting, in that there is an angle of incident and an angle of reflection. In the picture shown below we have an example of the tropospheric path from a transmitter, Tx, to a receiver, Rx, (red line) and two reflection paths (black line) with also a diffraction over an obstacle. In reality there are countless reflections but we'll look at two for now



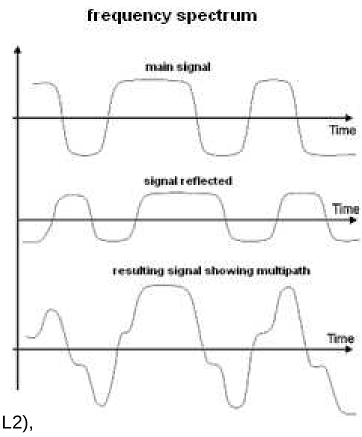
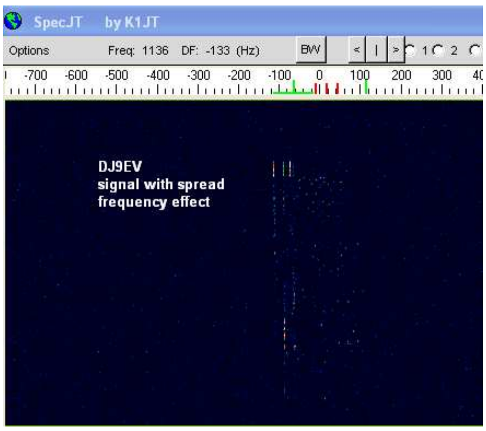


Fig.5 multipath mechanism: the received signals and the combined received signal (L1 and L2),



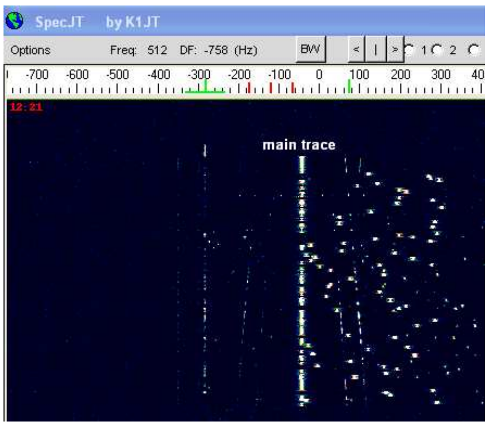


Fig.6. Left: very weak signal over the alps affected by frequency spread. Right: strong local signal with multipath propagation effects , with a main trace and other secondary traces coming up from difference path reflections (multipath) with frequency drfit.

Reflections
Also shown in the Figure 5, where are the received signals and the combined received signal. To understand how these are represented we must understand its propagation a little more. The first thing you may notice about the received signals is their phase shift; this can easily be explained. The EM waves emitted are traveling at the same speed, about the speed of light or 3x10^8 m/s, but their distance traveled from Tx to Rx is different. First, we let the corresponding distances for Line 1, Line 2, be d1, d2. Then we know their corresponding delays would be t1 = d1/c, t2 = d2/c, where c is the speed of light. Now we know when they get there but you may also notice there is a difference in amplitudes between the multipath received signals. In Wave Basics, it is shown that signal strength diminishes over distance but that is not the case here because the difference in distance is not large enough to be the cause. Instead, the physics behind the reflection is needed. When an EM wave reflects off an object some energy is transmitted to the material of the object and the rest is reflected. The reflection coefficient depends on the material. Apart from reflections, diffraction can also be a cause of reduced signal strength. For instance of diffraction due to a peak or ridge. A peak or ridge like the one depicted greatly reduces the signal strength to the area below the line-of-sight but because it is a form of radiation and diffracts, connection may still be possible but at a very low level of power.

Frequency Selective Fading

In any radio transmission, the channel spectral response is not flat. It has dips or fades in the response due to reflections causing cancellation of certain frequencies at the receiver. Reflections off near-by objects (e.g. ground, buildings, trees, etc) can lead to multipath signals of similar signal power as the direct signal. This can result in deep nulls in the received signal power due to destructive interference. For narrow bandwidth transmissions if the null in the frequency response occurs at the transmission frequency then the entire signal can be lost.The original signal is spread over a wide bandwidth and so nulls in the spectrum are likely to only affect a small number of carriers rather than the entire signal. The information in the lost carriers can be recovered by using forward error correction techniques. Often the signals are afflicted by an enlargement of the frequency spectrum and scintillation (frequency spread) this is explained very well by applying a theory formulated by Rumsey (University of California - San Diego). It explains how this scintillation depends on a fluctuating space-time refractive index of the medium located between the source (transmitter) and the observer (Receiver).It is enough just a small variation to produce the phenomenon, especially when you have a change of the refractive index in the space of a wavelength.

Delay Spread

The received radio signal from a transmitter consists of typically a direct signal, plus reflections off objects such as buildings, mountings, and other structures. The reflected signals arrive at a later time then the direct signal because of the extra path length, giving rise to a slightly different arrival times, spreading the received energy in time. Delay spread is the time spread between the arrival of the first and last significant multipath signal seen by the receiver. In a digital system, the delay spread can lead to inter-symbol interference. This is due to the delayed multipath signal overlapping with the following symbols. As well as, in jt65 digital protocol there is a robust error correction scheme that is able to overcome this problem.

hypothesis
In the table below there is the free space path loss calculation of 2 watts signal at 144 mhz, about the very weak signal experiment with German Station DL8SCQ, using theoretical equation.
The received signal power level is expected at 0,08 micro Volts. I cannot calculate the resulting power level after several diffraction and troposcatter effects. The resulting received power level is certainly much lower. Think of the enormous energy absorbed during these processes. The resulting would be extremely weak. I guess , despite the excellent ability of WSJT software to extract weak signals from noise, if the resulting signal is too low to reach the receiver. Although I realize that could be very abnormal and unorthodox, there may be a kind of auto amplification into tropospheric / atmosphere propagation process as well as a focussing effect or lens effect over signals. You have to think that visible light is always an electromagnetic radiation that involves the movement of photons / electrons in the medium.

Free space path loss calculation

Distance to Transmitter : 387.00 kilometers
Transmitter Frequency : 144.0000 MHz (0.1440 GHz)
Transmitter Power : 2.00 Watts (33.01 dBm)
Transmitter Antenna Gain : 17.15 dBi (15.00 dBd)
Receiver Antenna Gain : 17.15 dBi (15.00 dBd)

Received Power Level : -128.66 dBm (0.08 μVolts)
Free Space Attenuation : 127.37 dB

References:
CSIRO
Wikipedia
ARRL usa
Articoli vari di Marino Miceli, I2SN (RR)
RSGB Propagation studies section.

Important notes: This research is still in progress. Any further contribution is really appreciated.
Please contact ik3xtv : Ik3xtv@gmail.com

Tanks for testing:
DL8SCQ, HB9ARI,HB9CAT,DJ9EV,OE3FVU,DF2ZC,DG6MAN,DL8GAP,OE8HBQ,OE3WMA,OK1MDK,DF2ZC