Use of a DRM Modulation to study the ionosphere

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  - Ionosphere
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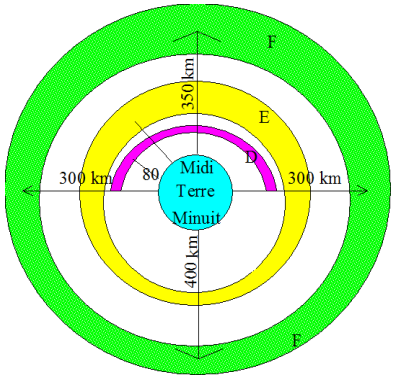
Introduction

Pleumeur Bodou Radio Observation

- Association (10 members)
- Main objectives
  - Promote and lead on the previous spatial telecommunication site, activities centered on the observation of radio frequency: radio astronomy, ionosphere, …, etc
  - Rehabilitation and retrofitting of one or more antennas on the site for radio astronomy
  - Installation of special equipment (Galileo, ...)
  - Teaching animation, training, research program, cooperation with institutional laboratory, ..., etc
- To know more about the association and its project: http://www.obsradio.asso.fr

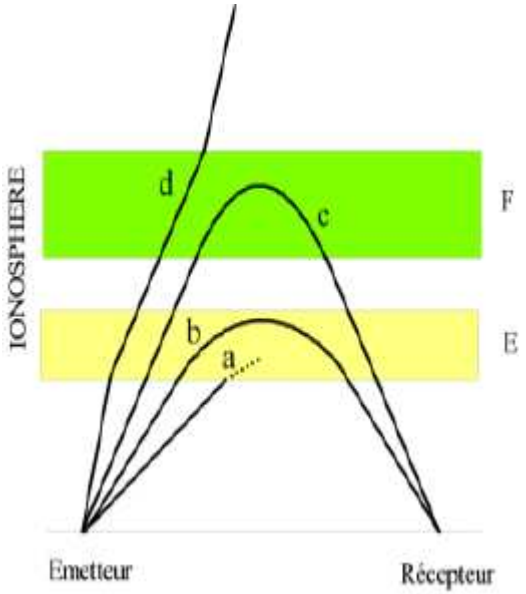
Ionosphere

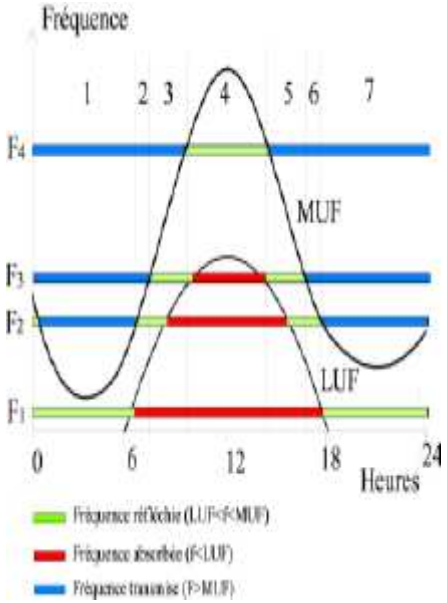


- Region of the upper atmosphere where charges (+, -) are present in quantities large enough to influence the trajectory of radiowaves
- Three layers
  - D layer (75-95 km) : absorption layer
  - E layer (95-150 km) : reflective layer
    - Normal E layer (E layer)
    - Sporadic E layer (Es layer)
  - F layer (> 150 km): reflective layer
    - F1 layer (150-210 km) : present during daytime
    - F2 layer (> 150 km): the highest and the most ionised reflective layer

Ionosphere

- Communications by ionospheric reflexion
  - $L_{owest}U_{seful}F_{requency}$<frequency<$M_{aximum}U_{seful}F_{requency}$
  - MUF
    - Maximum density
      - Local hour
      - Season
      - Geographical site
      - Solar activity
    - Input angle inside the ionosphere
      - Hop distance
      - Reflexion height
  - LUF
    - Ionospheric absorption
      - Path duration in the ionosphere
      - Crossed layers
    - Power emitted by the tranmitter





Ionosphere

- Forecasting the radiowaves propagation conditions
  - Objectives (for a given link)
    - Plan and select antennas
    - Plan adequate frequencies
    - Plan exploitation schedules

Ionosphere

- Investigation methods
  - Bottomside sounding (vertical or oblique)
    - Critical frequencies of the different layers
    - Reflexion Virtual heighs
  - Vertical topside sounding
    - F2 layer critical frequency (foF2)
  - Backscatter sounding
    - Over the horizon detection
    - Determination of wave height over the ocean
  - Incoherent scatter sounding
    - Electronic density
    - Ion and electronic temperature
    - Ions speed along the magnetic field
  - …
  - Use of a DRM modulation on an ionospheric link
    - Determination the weak frequency variations of the received signal
      - In narrow band (2Hz)
      - In wide band (10Khz)
    - Object of the present communication

Experiment

The experiment

- The studied ionospheric link
  - Emitter
    - Ismaning (Germany): near Munich
      - 11°04’47’’ E
      - 48°13’11’’ N
    - BR5akt
      - 6085 kHz
      - 50 kW
  - Receiver
    - Keranstrou- Ploumilliau (France): near Lannion
      - 03°32’06’’ E
      - 48°42’18’’ N
  - Distance Emitter-Receiver: 1120 km

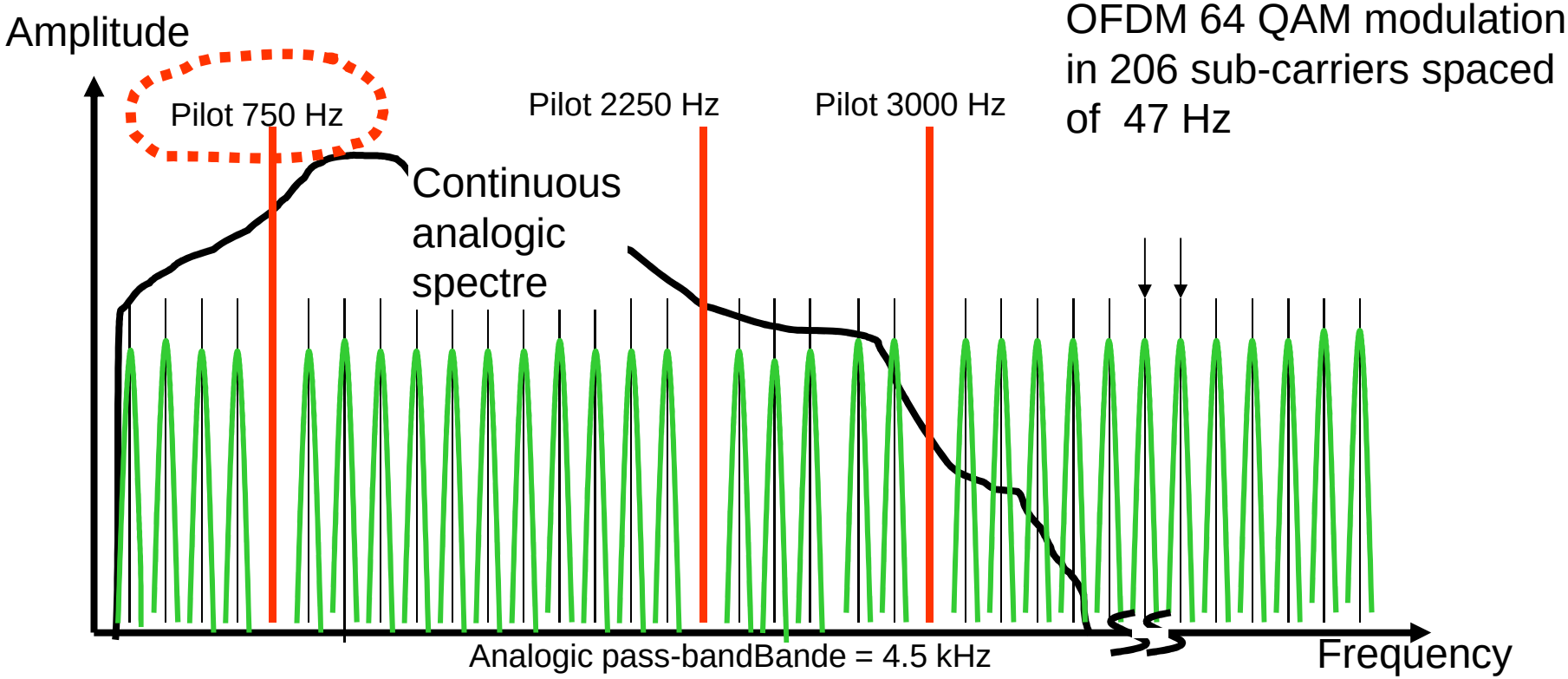
The experiment

- Digital Radio Mondiale (DRM)
  - Open worlwide digital broadcasting standard (F<30MHz)
  - Allow a large coverage (thousands of km)
  - Advantage / analogical broadcasting
    - Sound quality improvement
    - Received stations identification
    - Weaker emit power
  - Receiver
    - simple et light
    - Bandwidth : 10 KHz
    - Data rates : 8-20 kbits/s even 72 kbits/s when using several channels

The experiment

- DRM (continuation)
  - Transmission
    - Used Modulation: QAM (Quadrature Amplitude Modulation) constellation
    - Code : OFDM (Orthogonal Frequency Division Multiplexing)
      - Allow a very good robustness of the signal to the propagation destructive echoes
    - Use of an error corrector code
      - In case of hole in the pass-band,
      - In case of signal confusion due to multi paths,
      - In case of frequency shift due to doppler effects
    - Principle:
      - Obtain a uniform spectral density by dividing the numerical signal total flux on numerous subcarriers modulated individually in QAM modulation
      - The sub-carriers pheses are orthogonal to reinforce the diversity of the signal in comparison with the propagation echoes

Comparison between analogical and DRM transmitted spectres



Equivalent pass-band of the DRM = 12 kHz
Bits rate: 17kbits / second

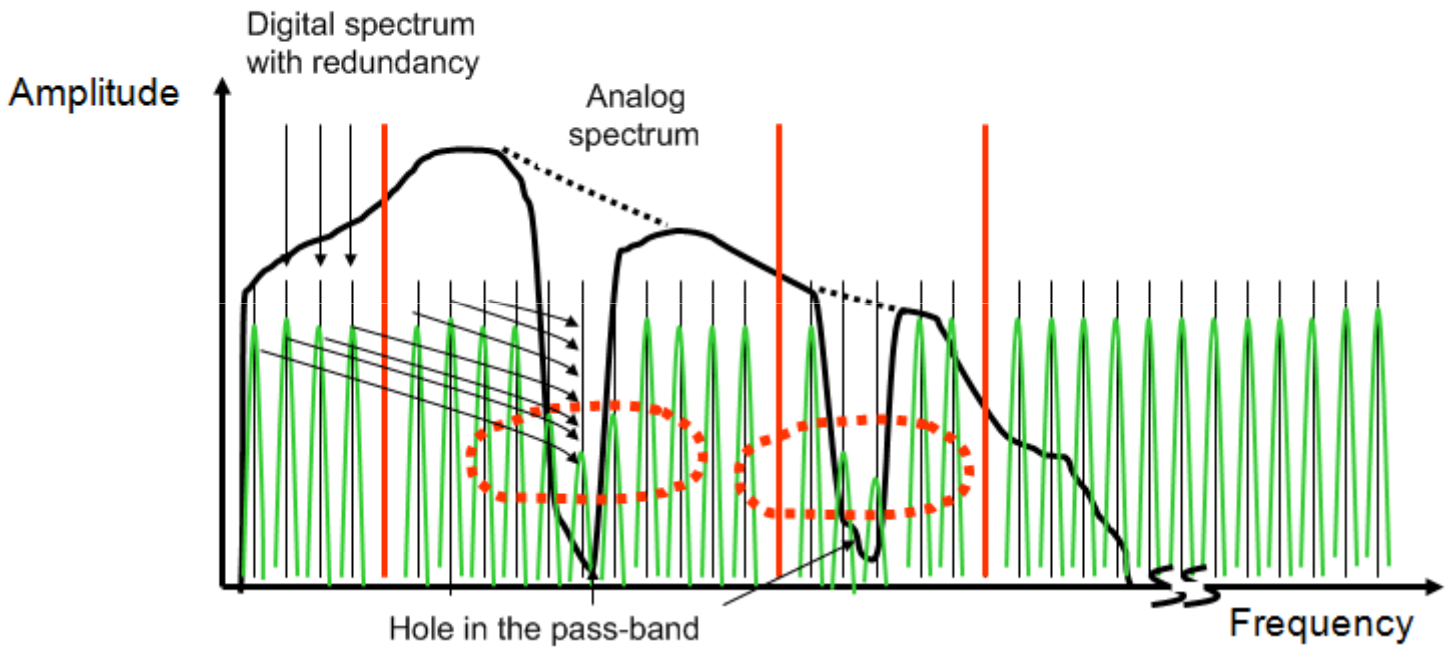
Legend :

•The pilot signal at **750 Hz**, 2250 Hz and 3000 Hz are **very stable references**. Their amplitude have a higher level and are **not amplitude modulated**. The pilot signals are used as input signal by the sound card. The phase information of frequency pilots are used by the **DREAM** sotfware to decode the DRM signal. Measurements of their perturbations are used as measurement to see **the movements and the modification of the ionosphere** through the **Spectrumlab** software

• OFDM = Orthogonal Frequency division Multiplexing

• 64QAM = Quadature Amplitude Modulation : Phase and amplitude modulation with a 64 positions constellation

Selective fading effect in analog and digital communications



In analogic transmission; a hole in the spectrum results in a sound degradation

In DRM the signal is transmitted with redundancy on all sub-carriers and with an error corrective code in order to be able to correct it in case of hole of the pass-band filter resulting from negative interference or frequency shift due to Doppler effect

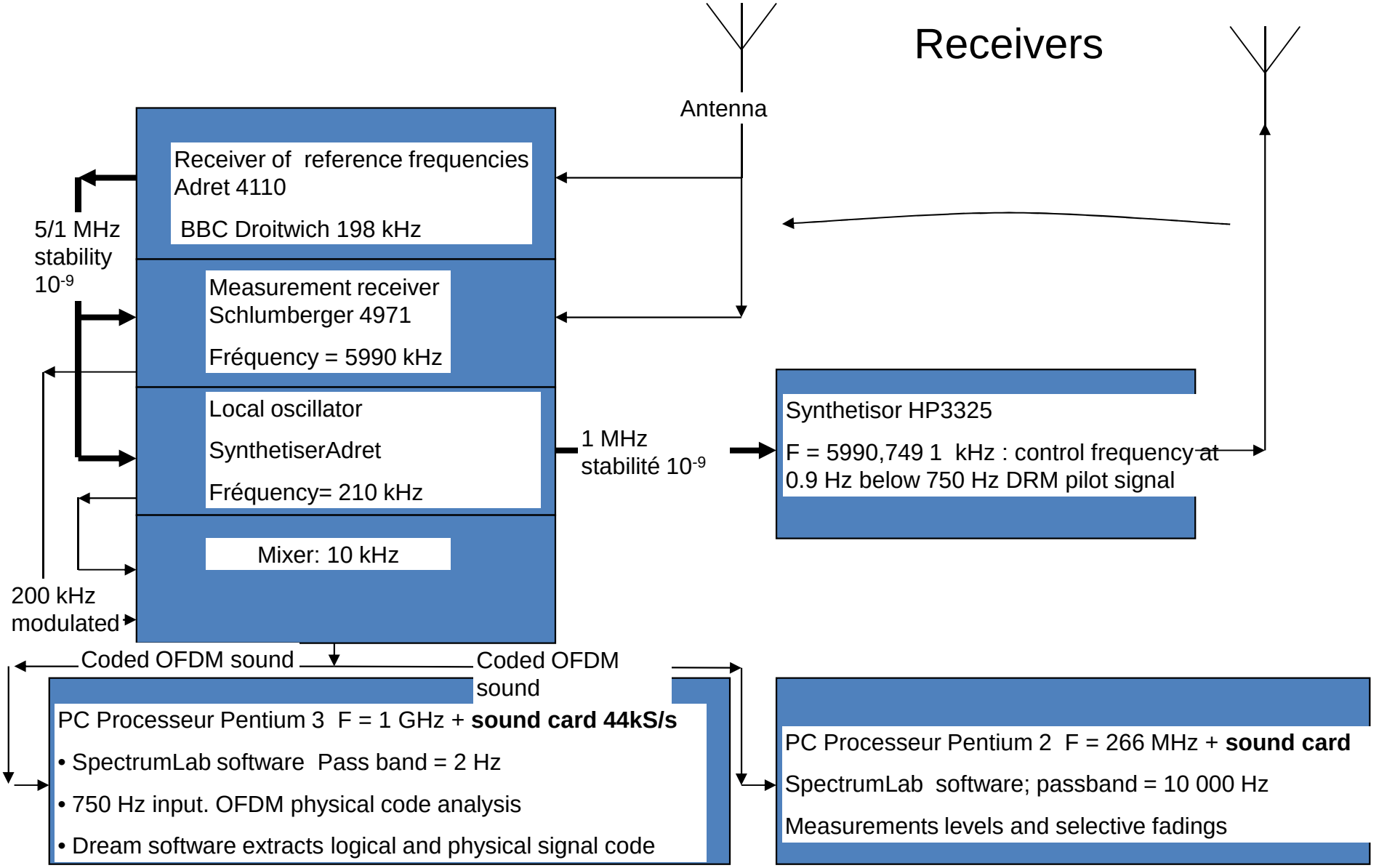
The experiment

- The used softwares
  - DREAM (open source)
    - Extract the principal characteristic from the DRM signal:
      - Station determination
      - Physical and logical code
  - SPECTRUMLAB
    - A spectral analyser device (FFT)
      - Input signal: numerical signal digitalized by the sound card inside the PC computer
    - Output Graphic (signal level, frequency, time)
      - The level of the signal in the frequency domain in fonction of the time

The experimentation

- The OFDM coded Signals are used as sounder to study the ionospheric variations
- The receiver consists of 2 parts:
  - A narrow band system (2 Hz)
    - Measurements of the perturbations of the 750 Hz pilot DRM signal
  - A wide band system (10 kHz)
    - Measurements of selective fading level

Receivers



Narrow band receiver : measurement s of the DRM pilot signal disturbances (750 Hz)

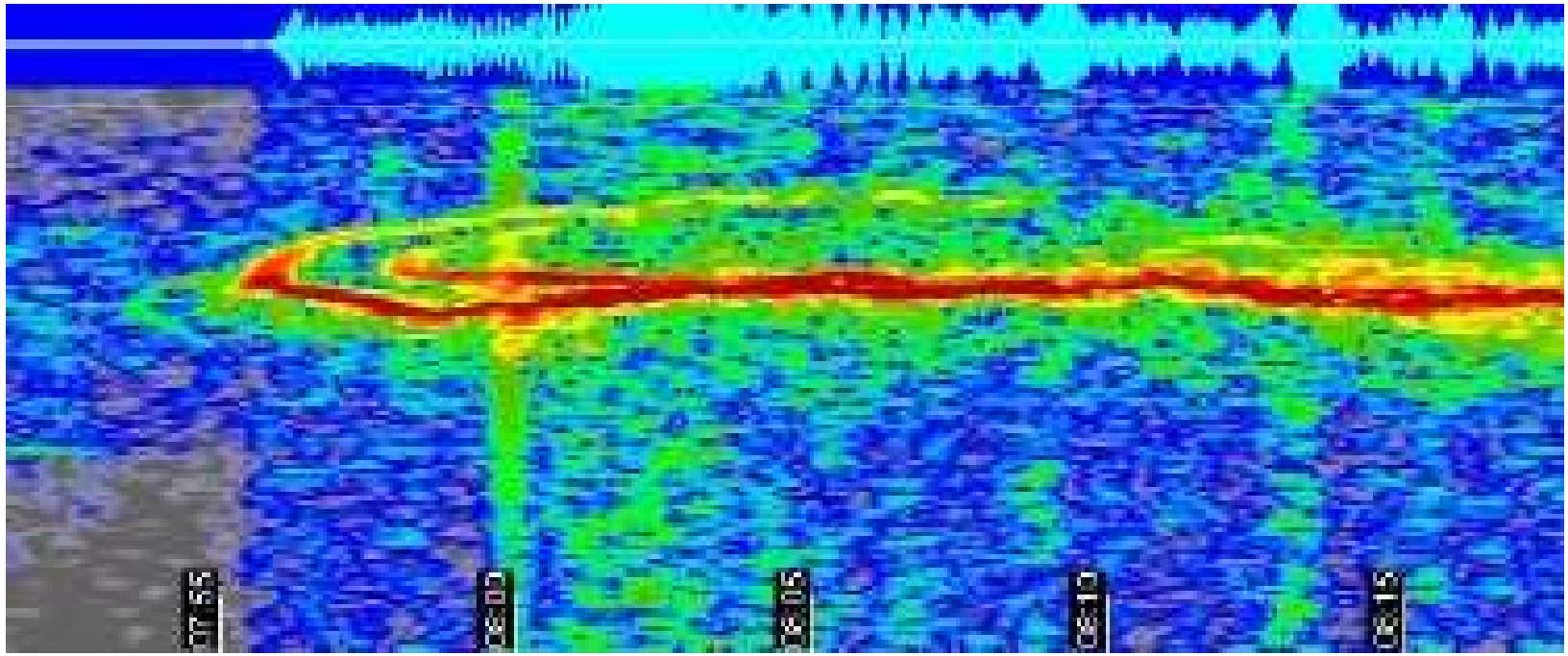
Wide band receiver

Results

- Narrow band reception (2 Hz)
- Wide band reception (10 kHz)
- Comparison narrow band/wide band

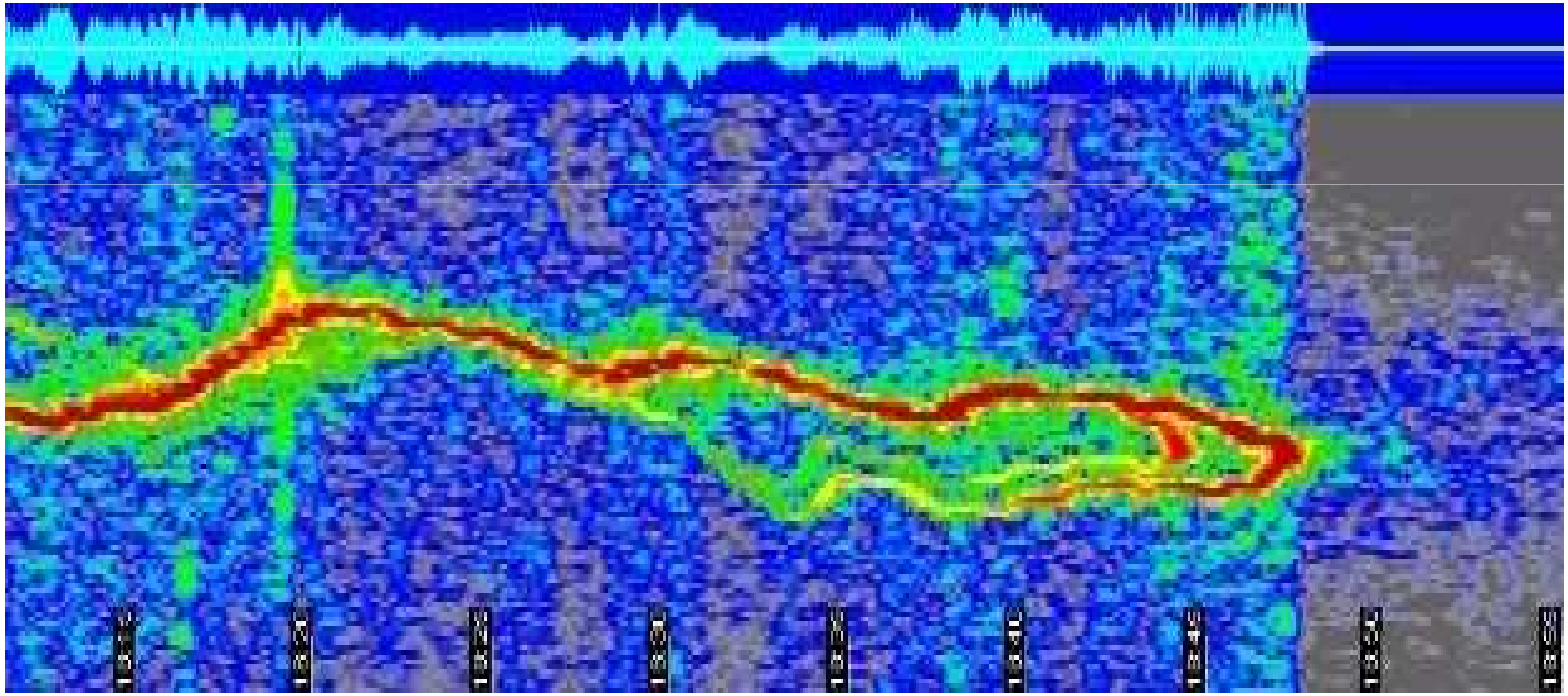
Narrow band

- Start of morning F layer single hop propagation



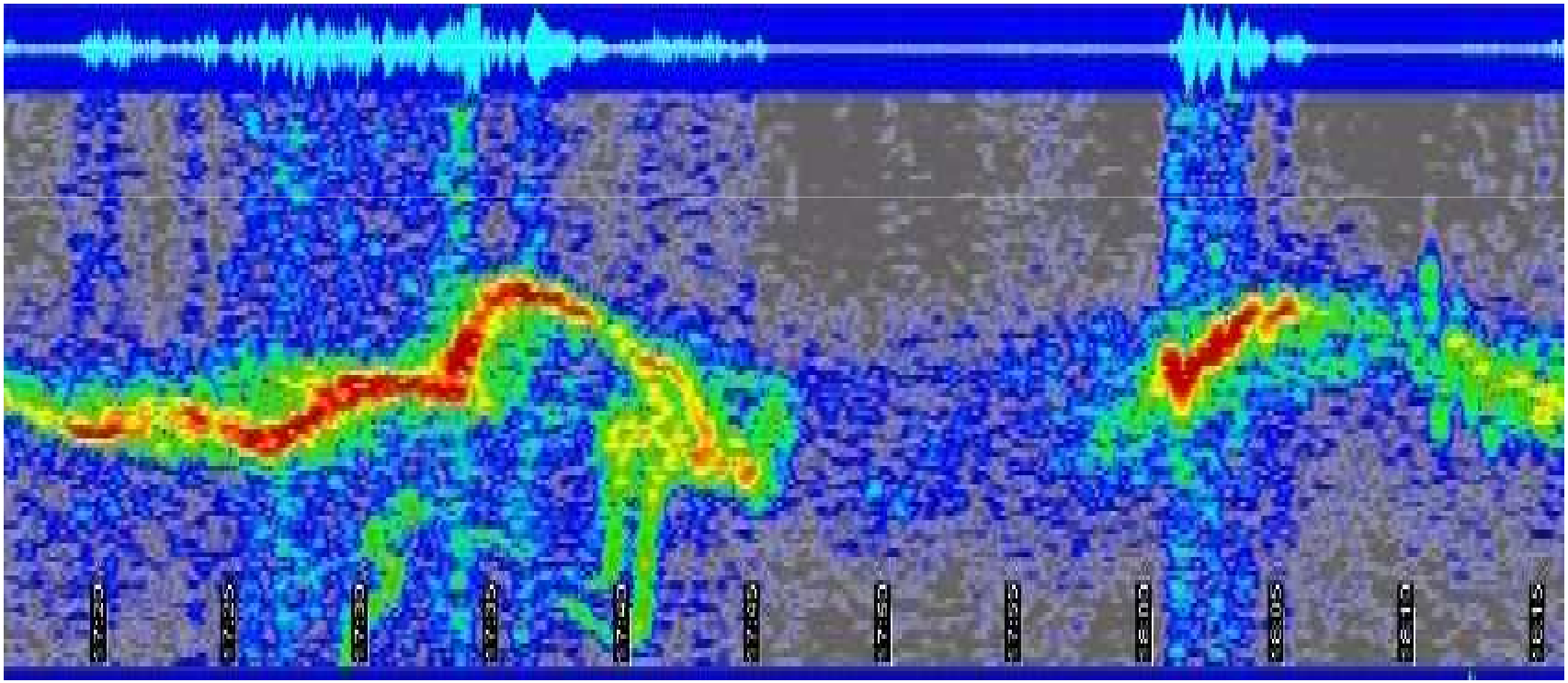
Narrow band

- End of evening F layer single hop propagation



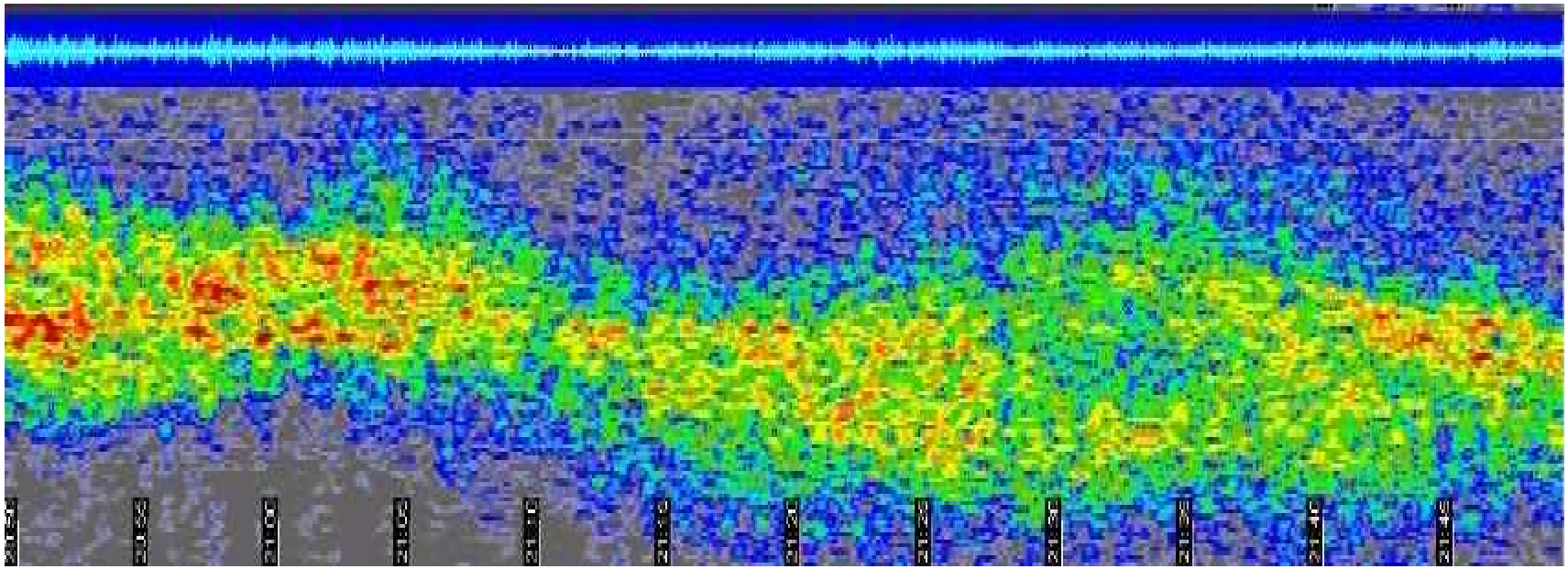
Narrow band

- Absorption phenomena



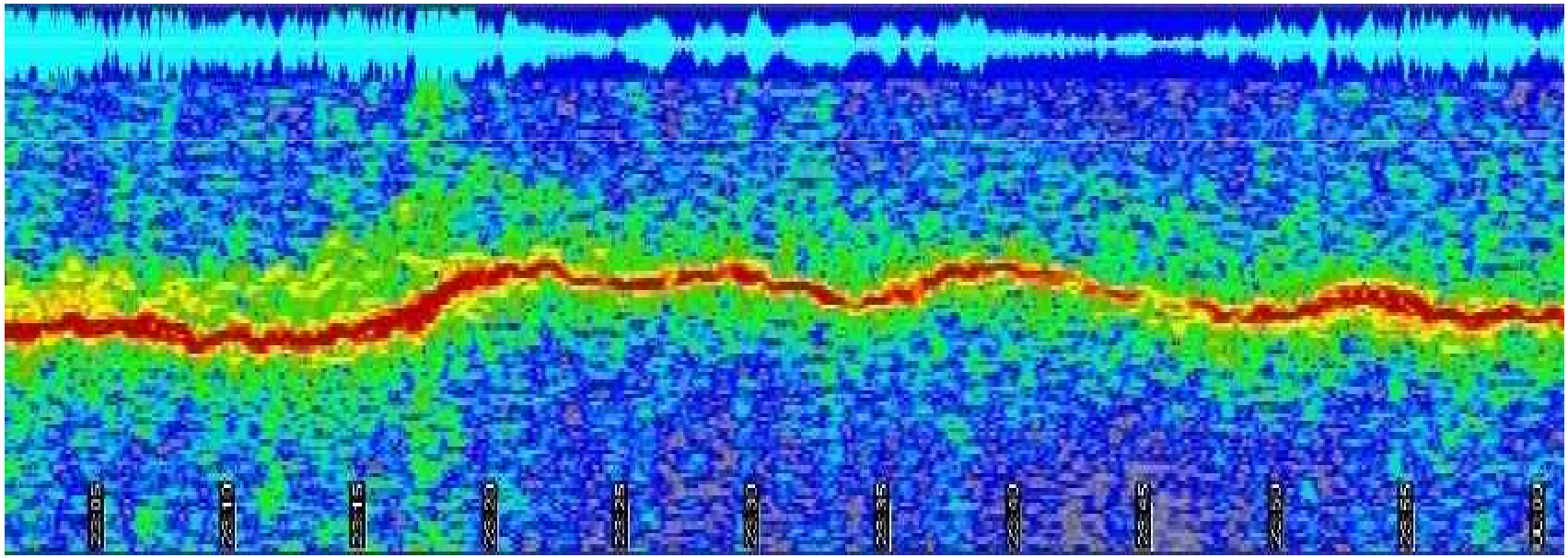
Narrow band

- Diffusion phenomena



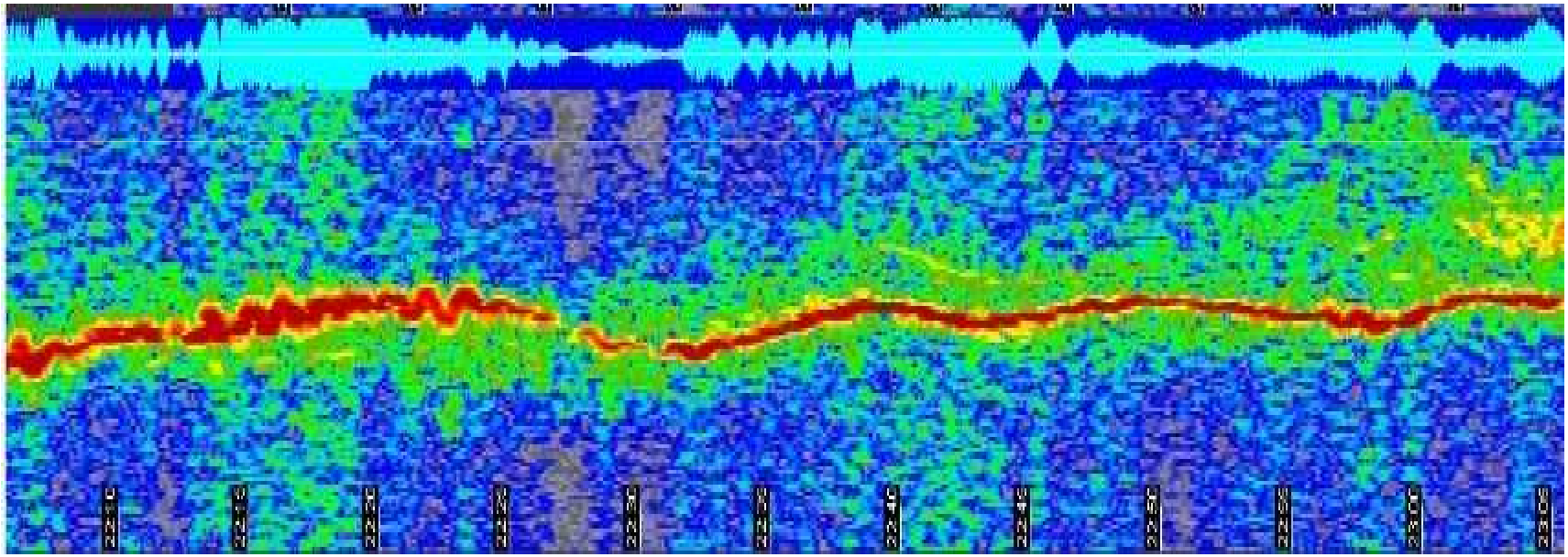
Narrow band

- Gravity wave travelling



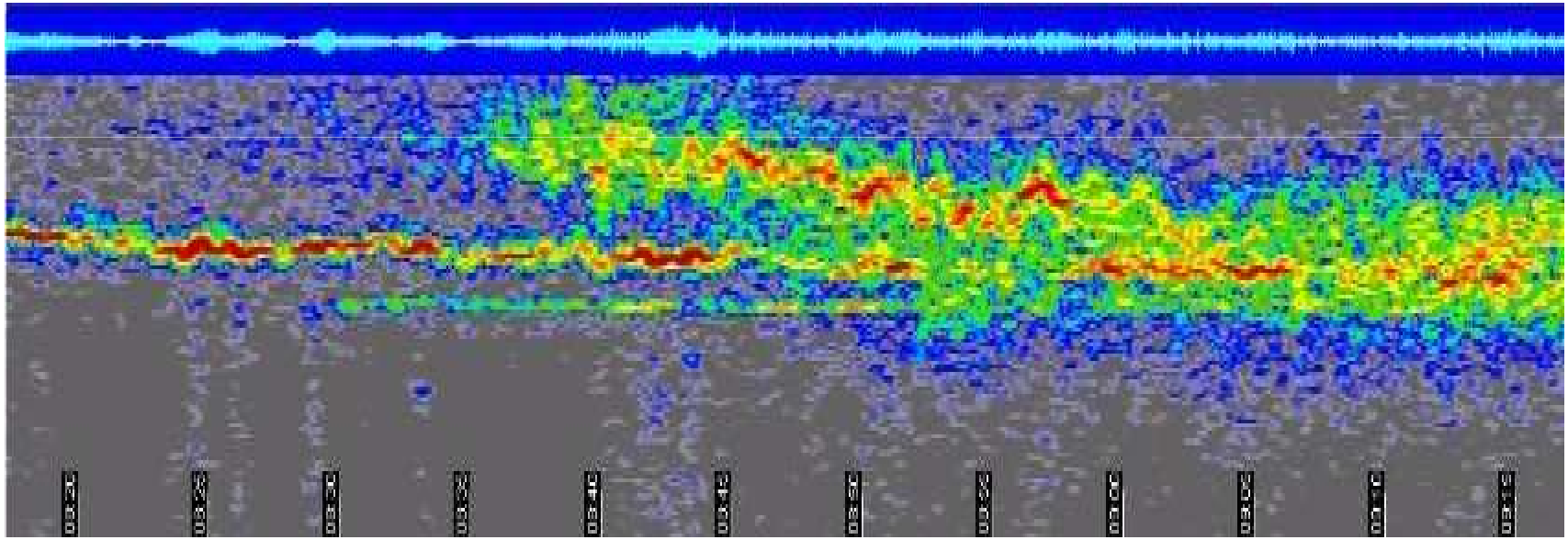
Narrow band

- Phase variation



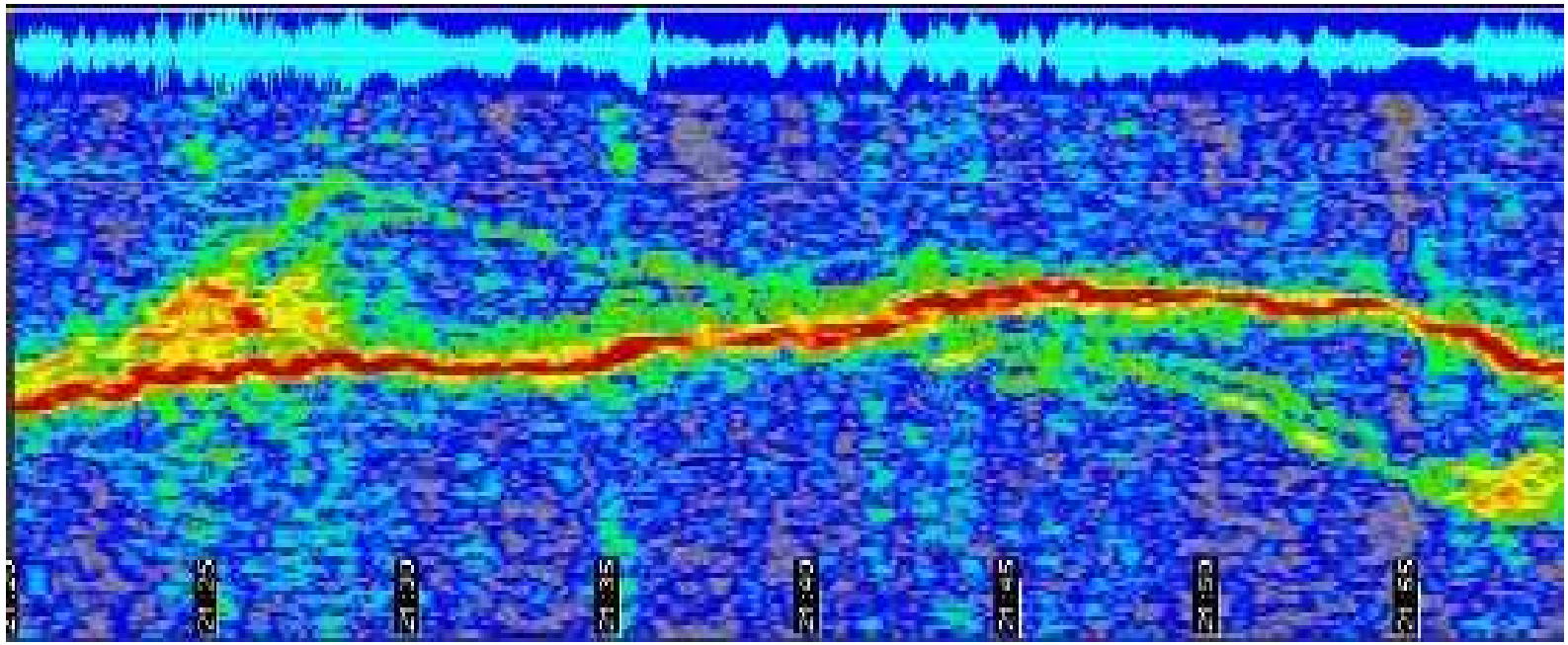
Narrow band

- Multi paths presence



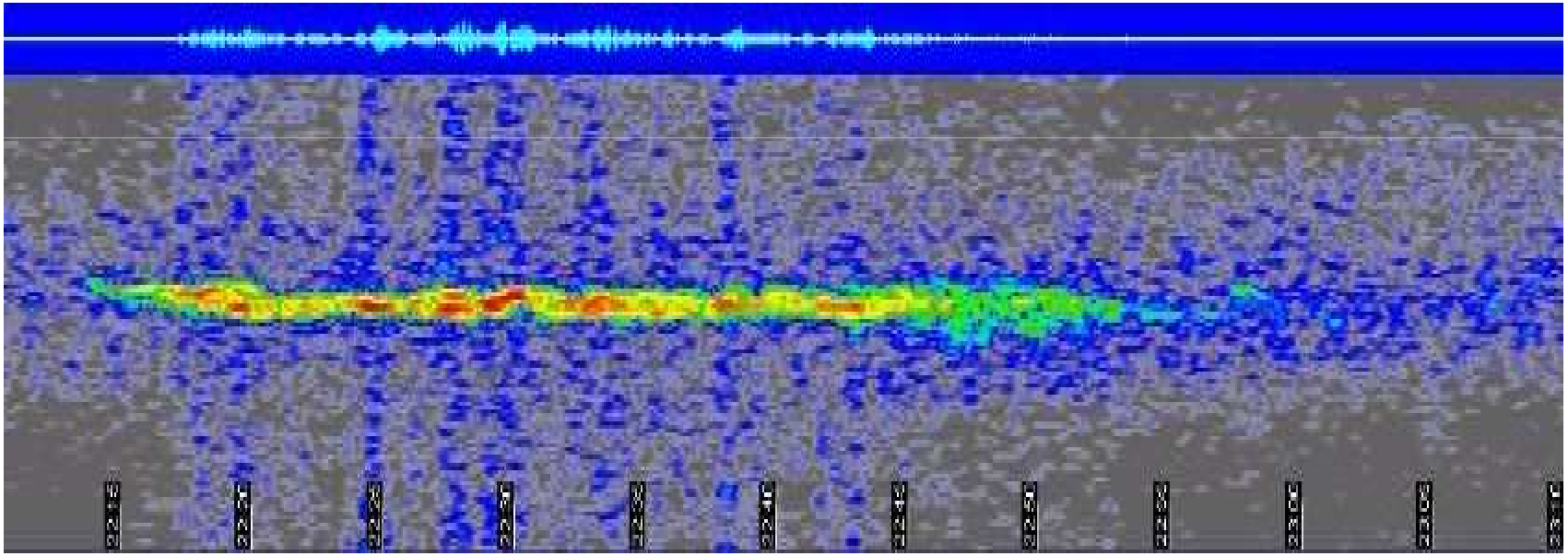
Narrow band

- Multi paths présence



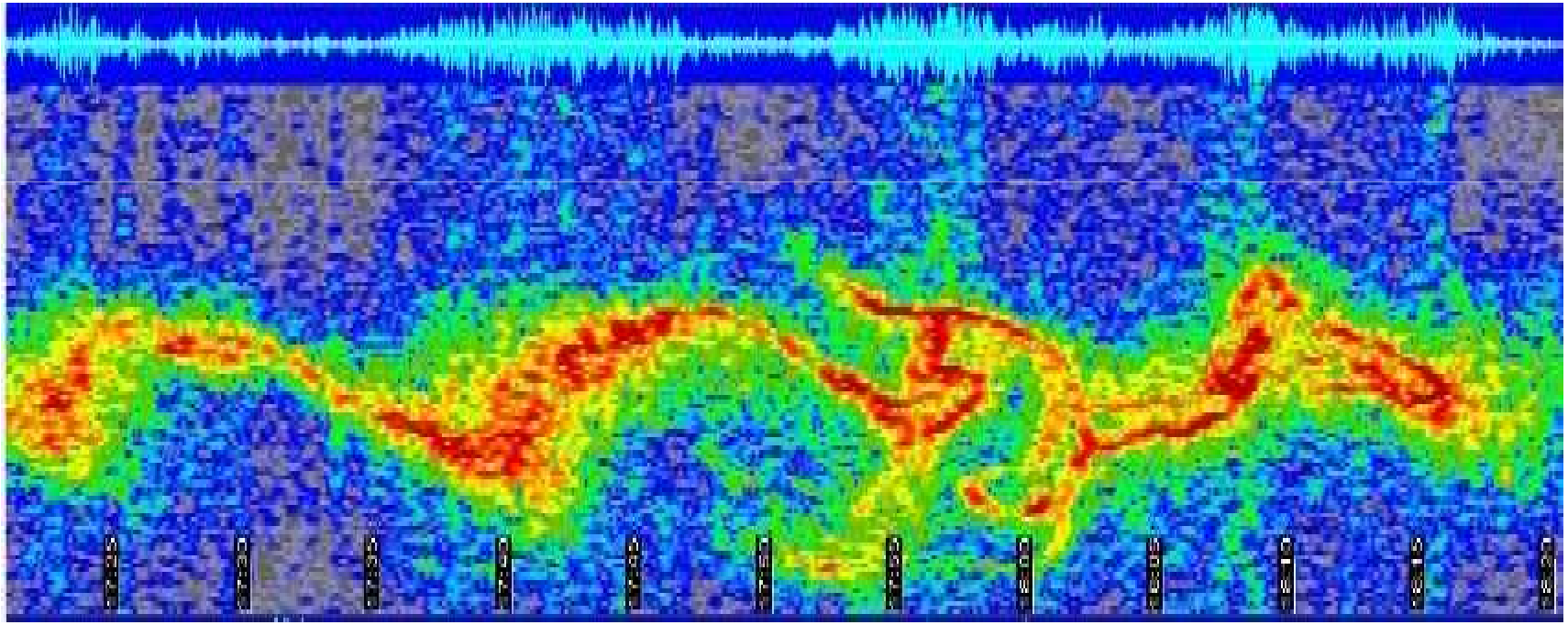
Narrow band

- Reflection on a plasma cloud



Narrow band

- Complex event



Analogies

- Reflection on the sea

- Reflection on the ionosphere

Reflection on the sea

The sea surface agitated by wrinkles, waves, is a mirror that distorts the reflection of the sun sheens (reflexions)

Appearance of black areas

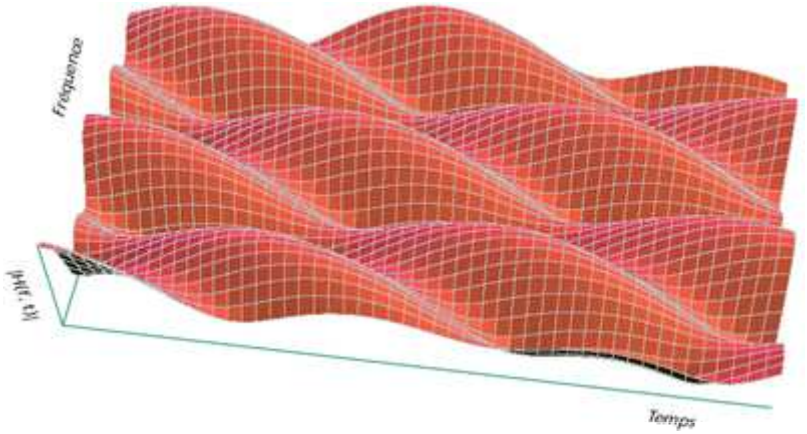
Deformation of the solar disk due to the change in the inclination of the reflected rays

Reflection on the ionosphere

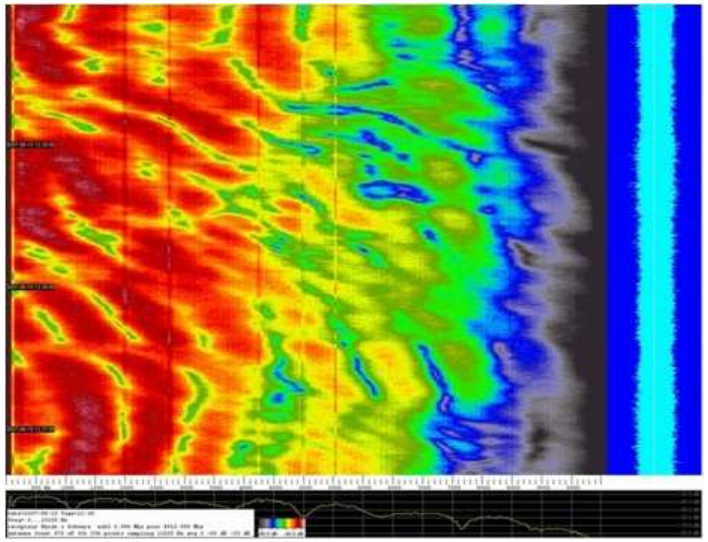
- Reflection on a distorted surface
  - Perturbations of the reflected radiowaves
    - Positive interferences
    - Negative interferences
- Time variable deformation
  - Radio reception variability
- If interferences depend of the frequency
  - Frequency selective fading

Reflection on the ionosphere

- Surface 3D spectrogram showing the temporal spectral deformation

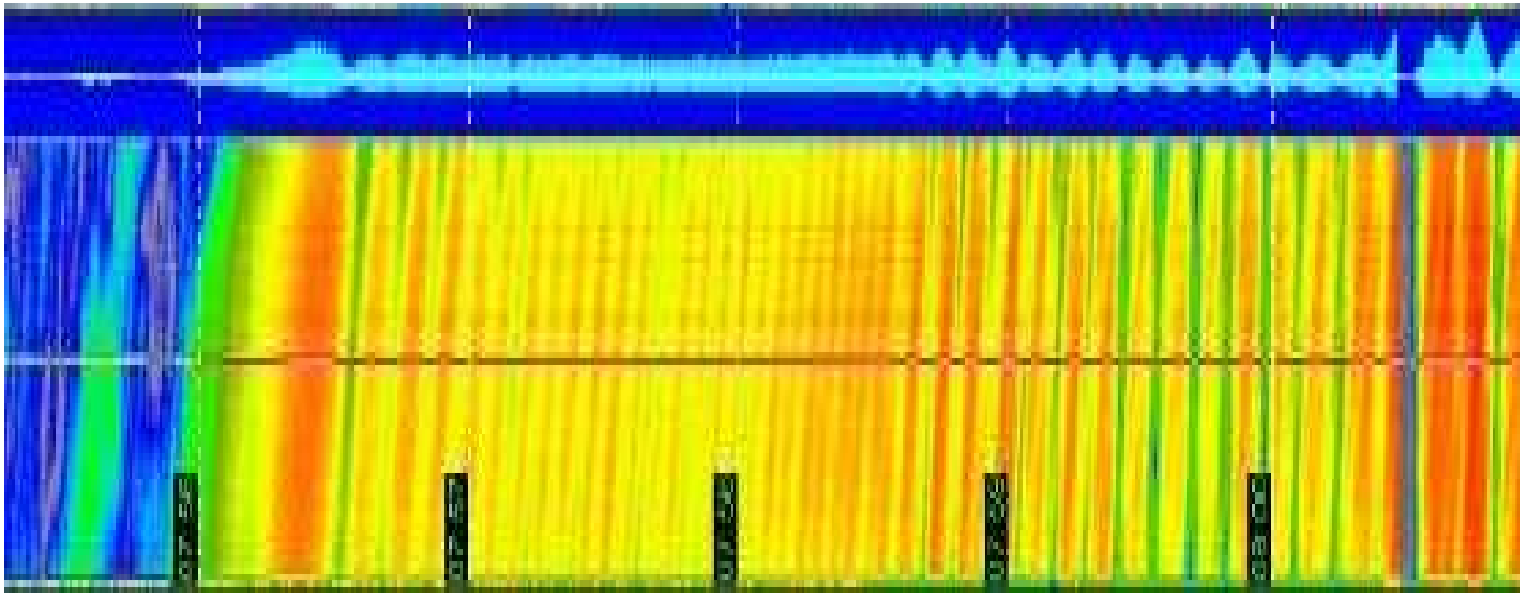


- 3D spectrogram with colors.



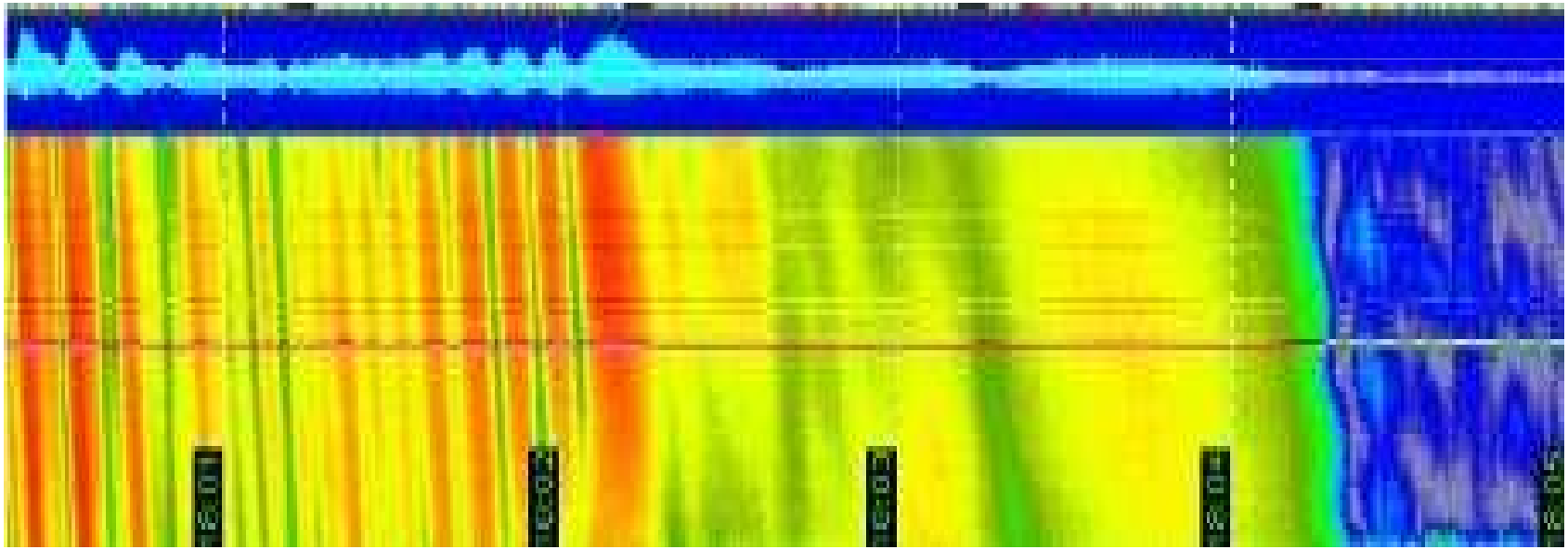
Wide band

- Start of morning F layer single hop propagation
  - Selective fading with increasing frequency



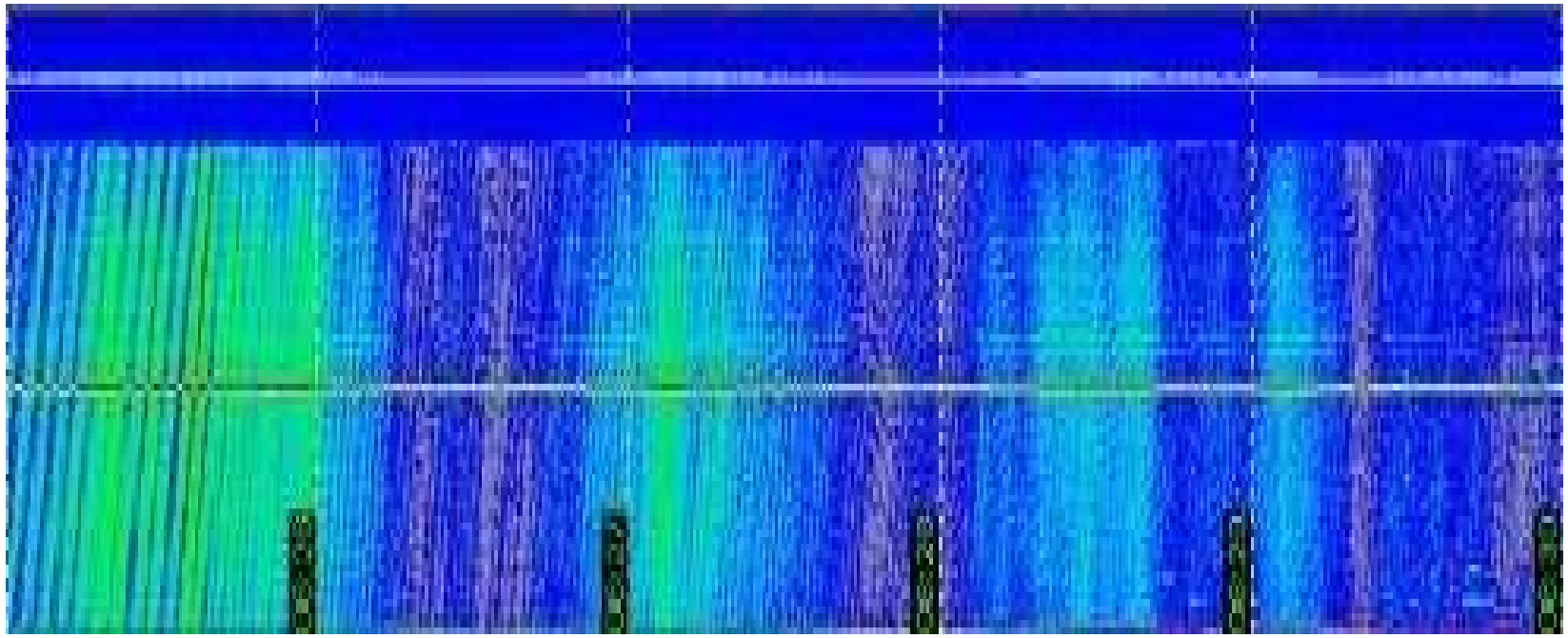
Wide band

- End of evening F layer single hop propagation
  - Selective fading with decreasing frequency



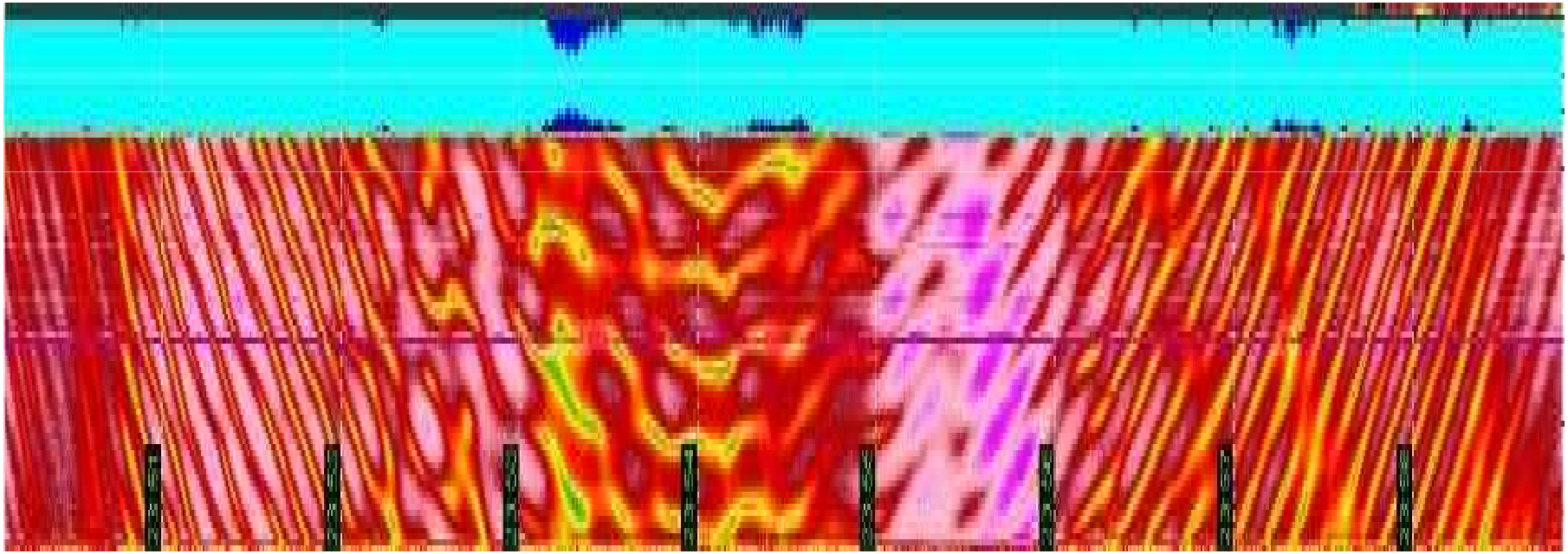
Wide band

- Weak amplitude wrinkles



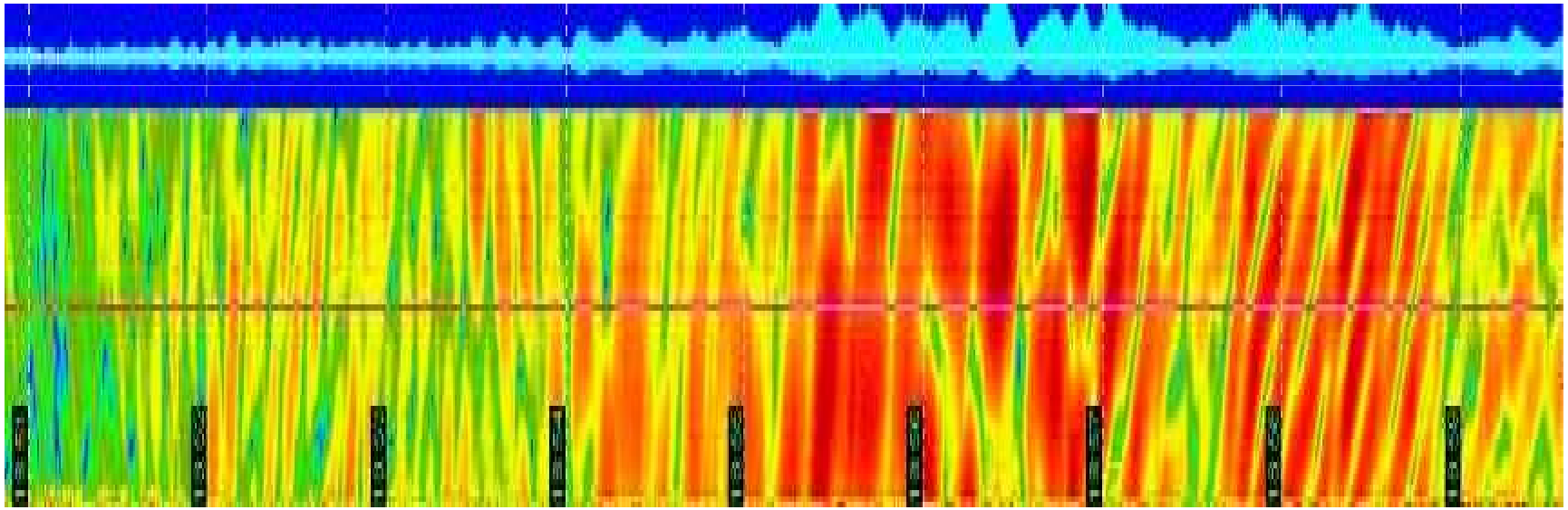
Wide band

- Complex event



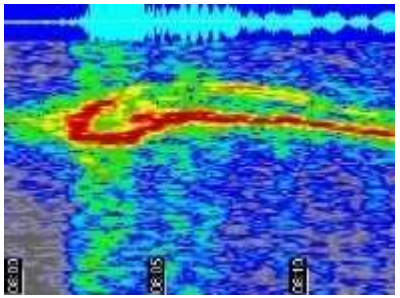
Wide band

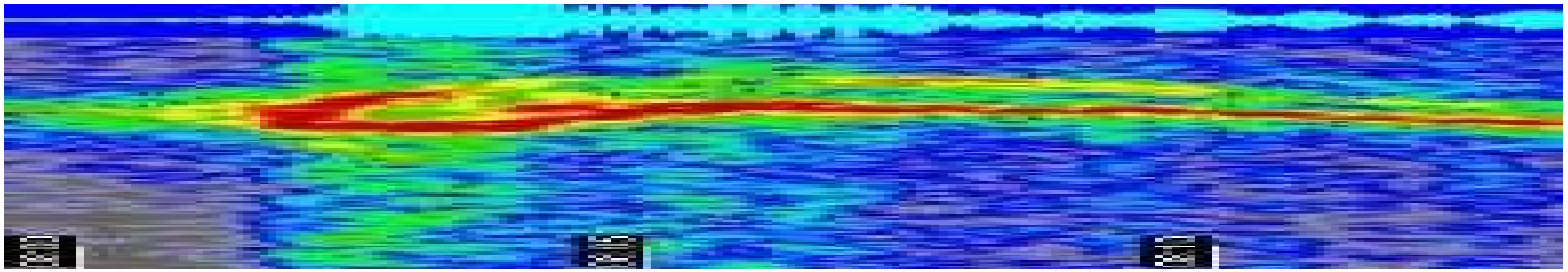
- Complex event

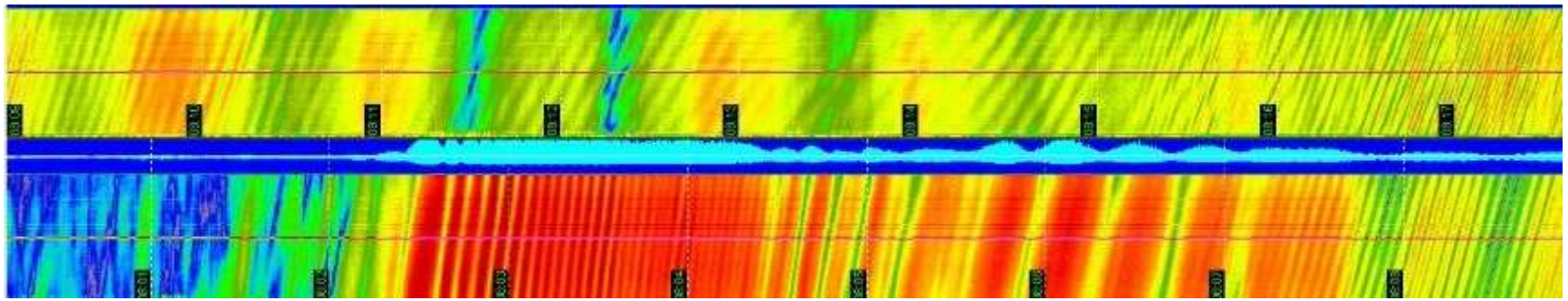


Narrow band – Wide band

- Start of morning F layer single hop propagation

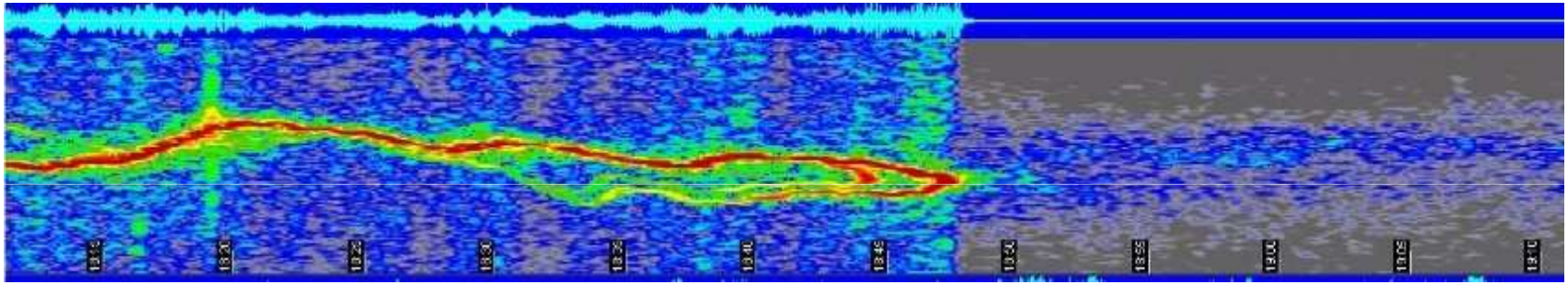


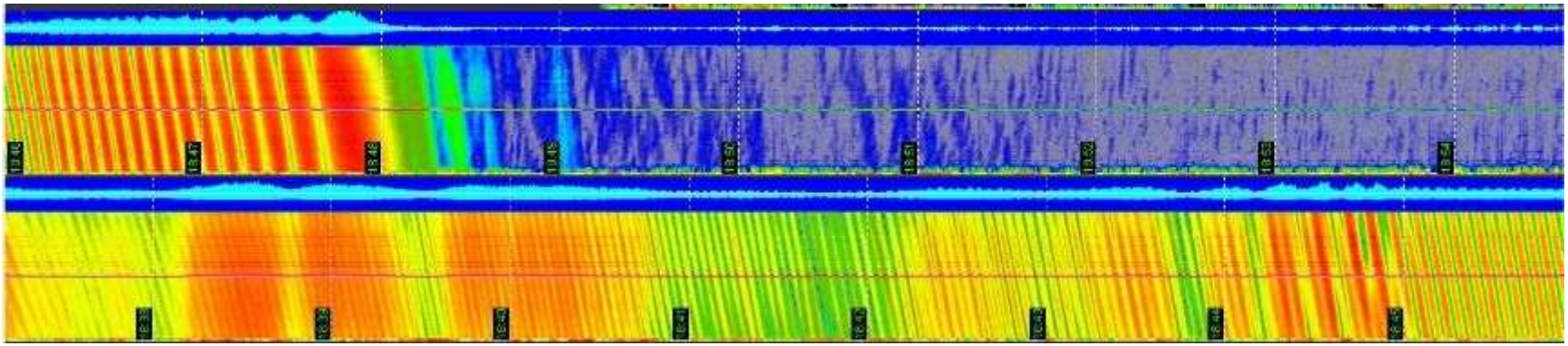




Narrow band – Wide band

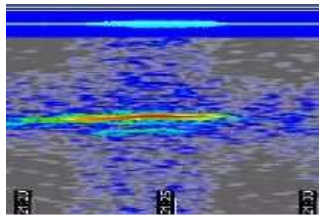
- End of evening F layer single hop propagation

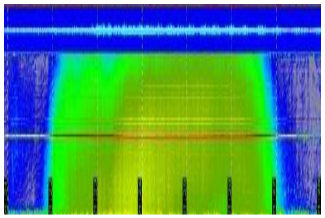


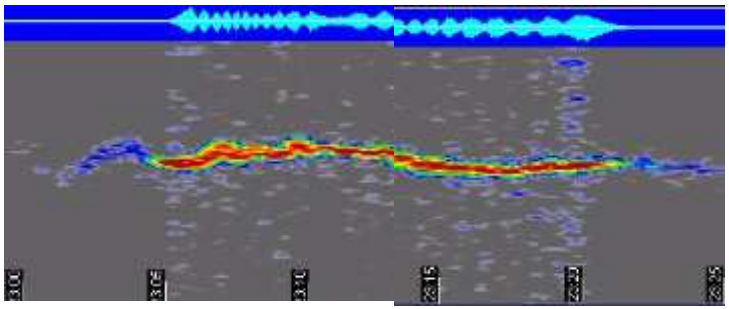


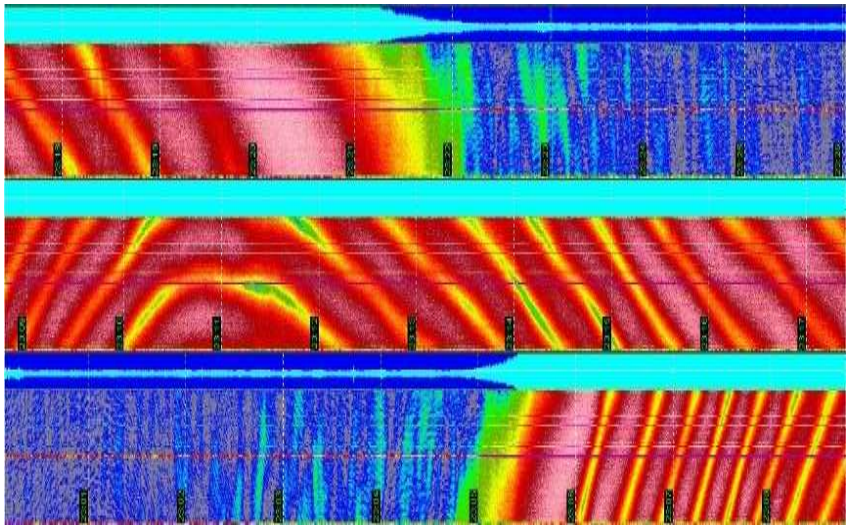
Narrow band – Wide band

- Reflection on a plasma cloud



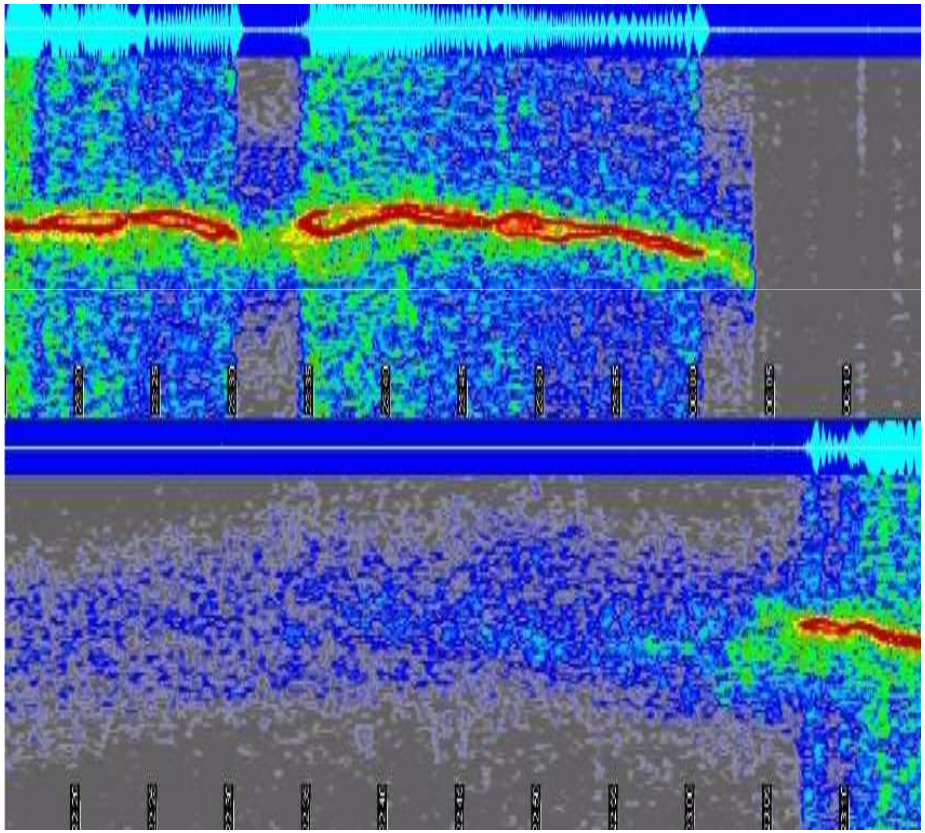


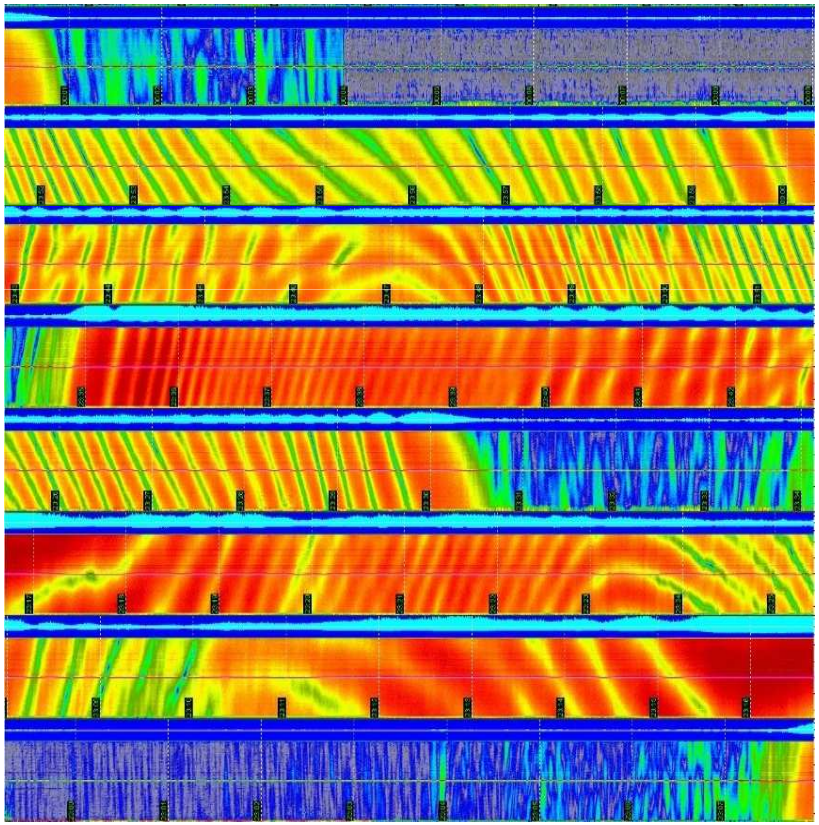




Narrow band – Wide band

- Evolution on more one hour





Conclusion

- The analysis of frequency variations allows to determine:
  - the link working hours
  - The reflection height variations
  - The travelling gravity waves
  - The frequency selective fading (multi paths)
  - The ionospheric disturbances
- Known technic
- Novelty
  - Public aspect of the experiment
  - Type amateur radio equipment
    - Sound card
    - Using free softwares
    - Recycling obselete laboratory equipment
  - Using a radio transmitter instead of a deterministic probe (opportunistic aspect of the experiment)
- Future activities
  - Simulation on Spectrumlab of the different phenomena
    - Interferences of different frequencies
    - Superposition of signals whose frequencies are separated
    - …
  - Comparison of simulations and observed phenomena
  - Enhancement in the teaching of radiocommunication as an illustration of a real very uncertain radio channel.