“ Antenna development for astroparticles and radioastronomy experiments”

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Outline

- Wide bandwidth antennas concept
- Evolution from CODALEMA active antenna to Butterfly active antenna
- Technique to enlarge the antenna bandwidth ?
- LNA
- Measurements and simulation comparison with the Butterfly antenna
- linearity and sensitivity
- vector effective height
- transient response
- Conclusion

Development of Wide bandwidth antenna

- first possibility: wide bandwidth passive antennas
  - example: Log Periodic Dipole Antennas (LPDA)
  - example: Log Periodic Spiral Antenna (decametric array of the Nançay radio telescope)
  - Advantage : - Rrad ~ constant and Xa ~ 0 within the bandwidth

    - Antenna can easily be matched to a 50Ω LNA through a Balun transforme
  - Drawback : Huge size of antenna: for 25MHz, longest arm should be ~ 6m !
- second possibility: active dipole antennas
  - example: the CODALEMA dipole antenna or the 'Butterfly' antenna
  - the LNA is placed near the antenna radiator
  - Drawback: need to design a dedicated LNA with a specific input impedance
  - Advantage: - power matching is not needed

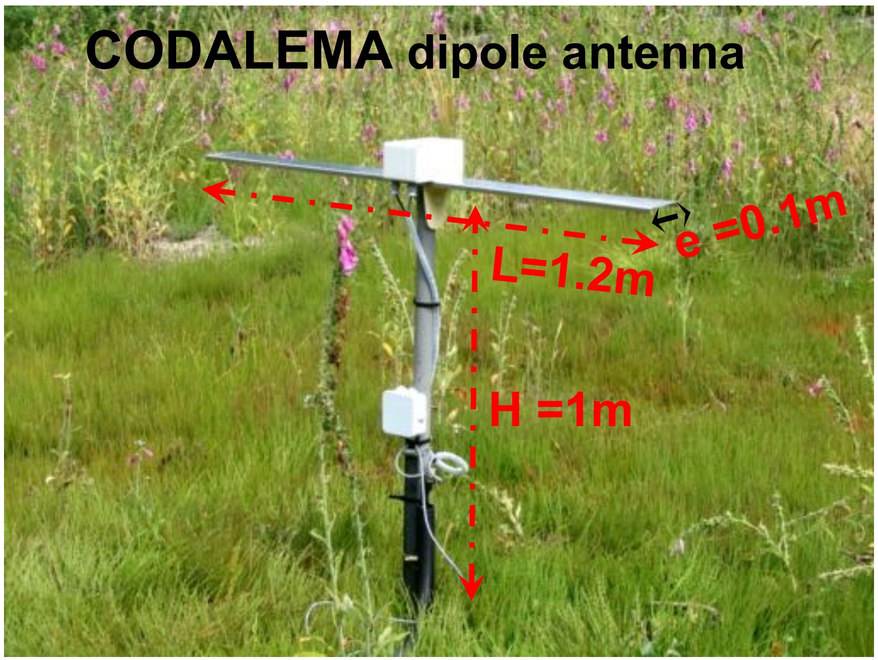
    - Small size antenna becomes possible (electrically short antenna)

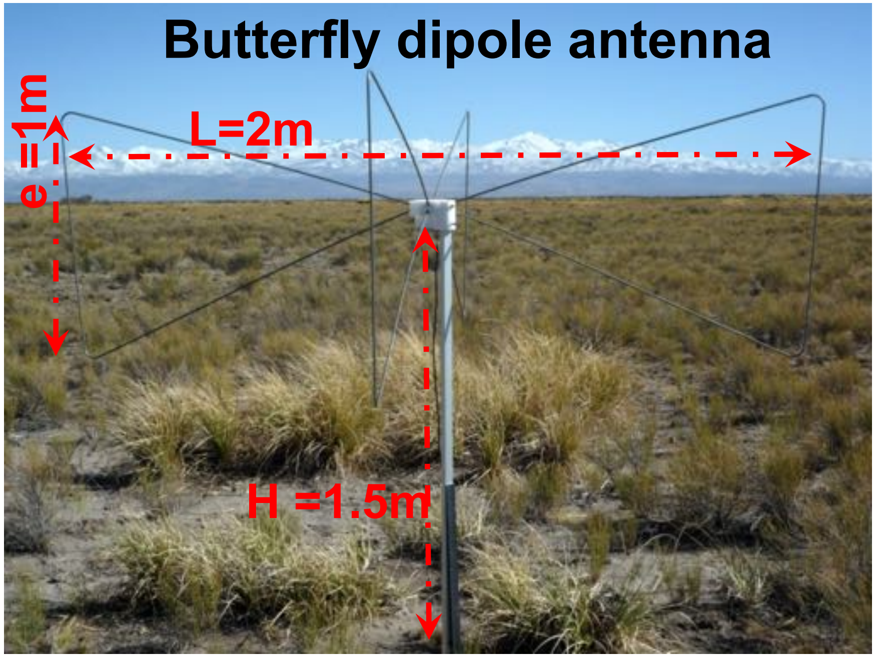
    - antenna is easier to built

CODALEMA active dipole Antenna / Butterfly active dipole antenna

• 16 dipole antennas and 3 Butterfly antennas are in operation on the field for the CODALEMA experiment (Nançay, Cher, France) since 6 years

• 3 Butterfly antennas with autonomous station are in operation on the field at Augers Radio (Malargüe ,Argentina) since one month

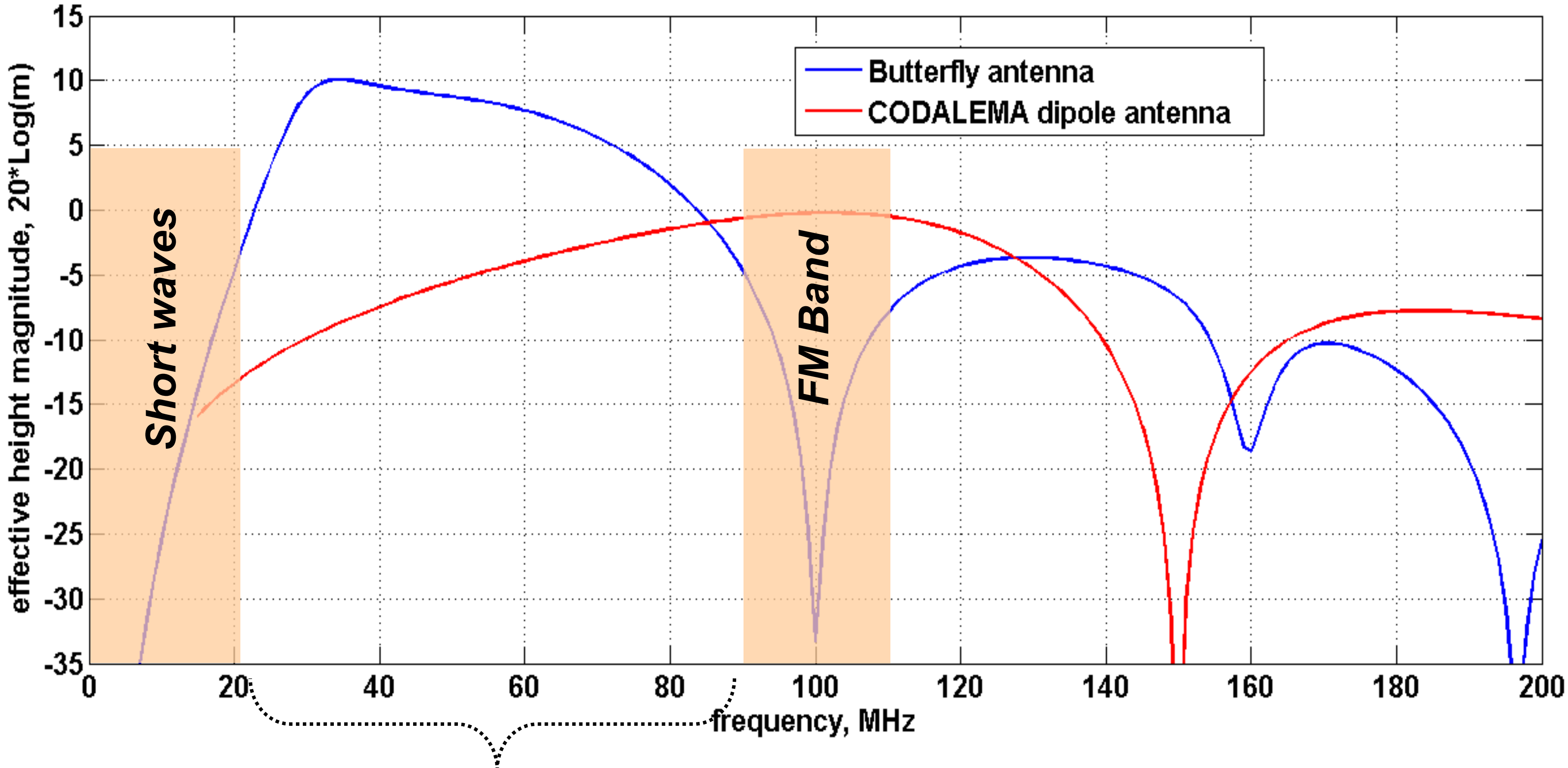




• Both antennas are fat active dipole
• The CODALEMA dipole antenna is mono polarization
• The Butterfly antenna is a Dual polarization

Evolution from the CODALEMA active dipole to the Butterfly antenna

20*Log₁₀(Abs(Vlna/E)), for θ=0° (zenith)



- The radio background can't be used at DC-20MHz and 88-108MHz band
- Cosmic rays detection is supposed to be better with low frequencies

⇒Frequency range of the butterfly is maximized for the 25-90MHz band

- Butterfly sensitivity is much better for this frequency range

1- Wide band active dipole antenna need a fat antenna radiator !

0 + ++ +++

FAT Dipole

building's easiness: 0 + ++ +++

Example of fat dipole antennas used for astroparticles detection experiments or low frequency radio-astronomy

Advantages of fat dipole / thin dipole:

- **Rrad: resistance variation is decreased**
- **Xant: reactance variation is decreased**

UTR-2

volume

LWDA

surface

BUTTERFLY

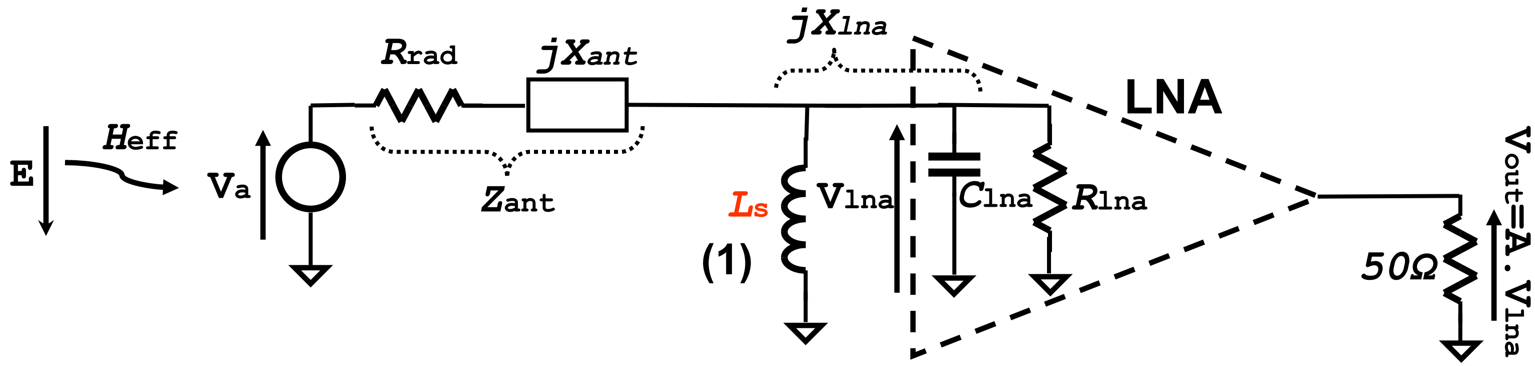
outline

The radiator shape of the butterfly antenna is a trade off between complexity and bandwidth capabilities

LOFAR

wire

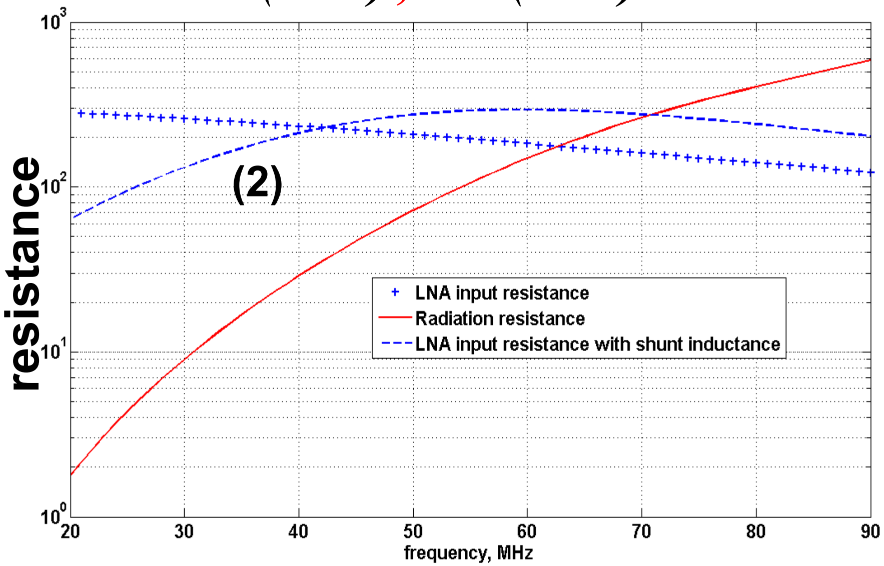
2- Wide band active dipole antenna need a dedicated LNA !



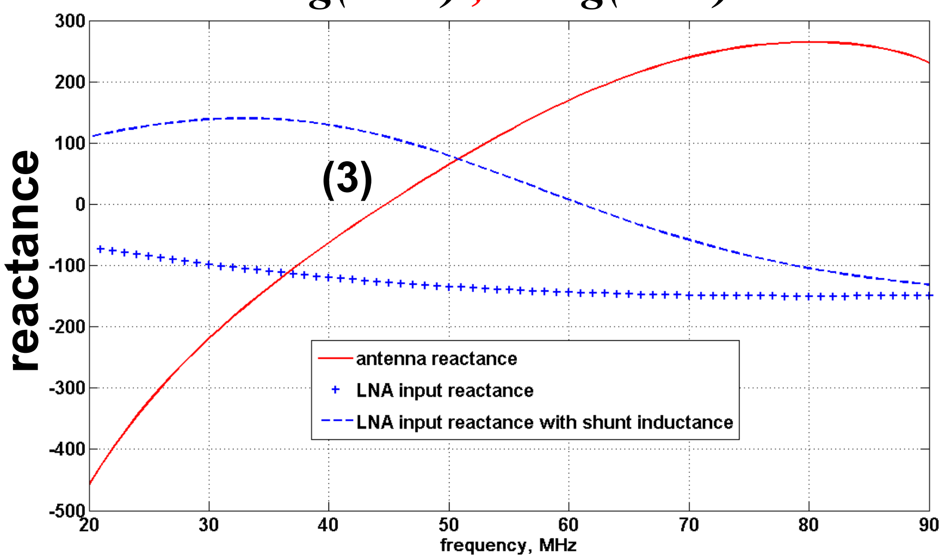
Shunt input inductance Ls parallel to the LNA input impedance

- **(1)- Necessary to cut low frequencies transmitters**
- **(2)- LNA input resistance is greather than radiation resistance for a wider bandwidth**
- **(3)- the sum of the LNA input reactance and antenna reactance is nearer to zero**

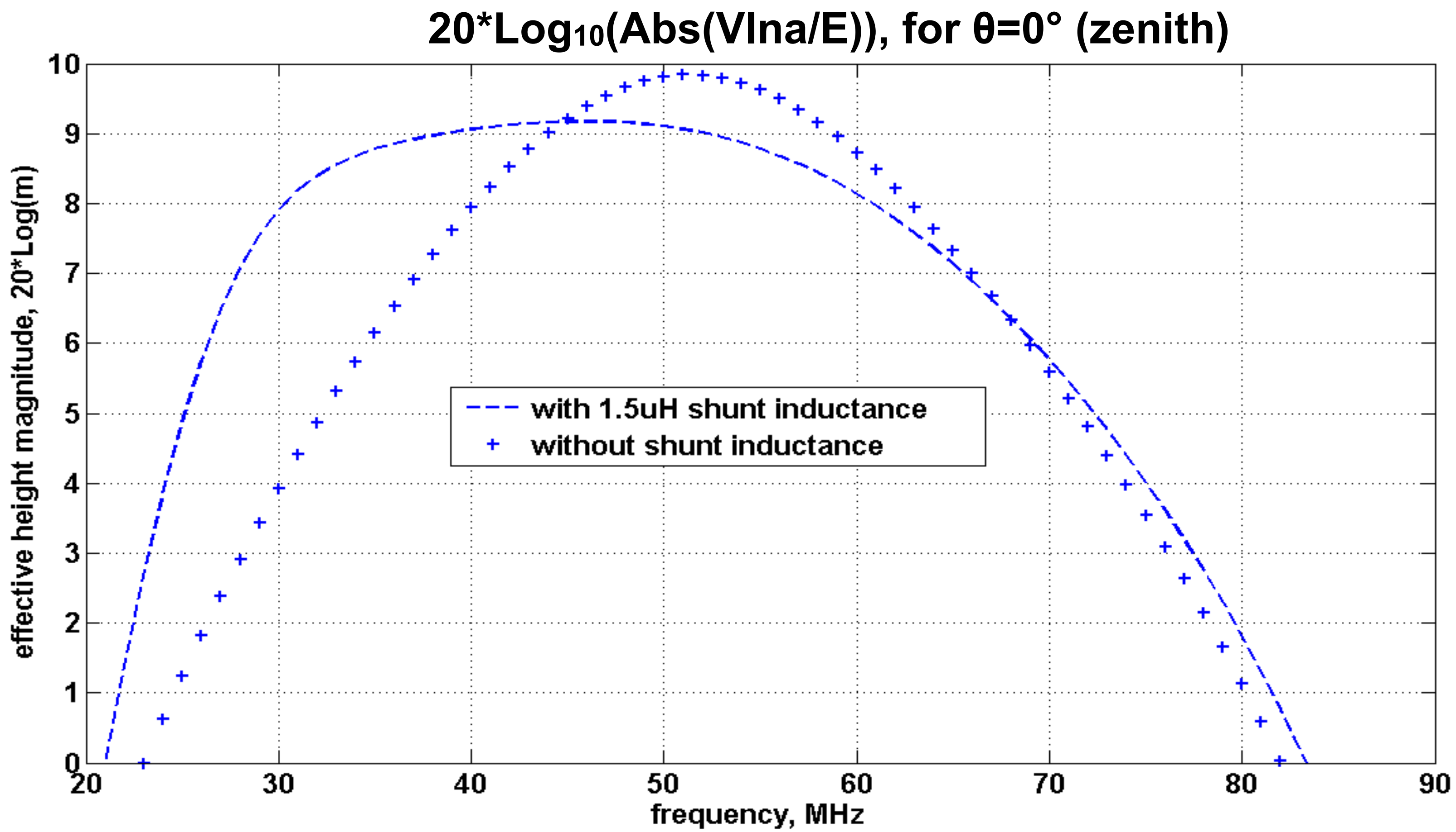
Real(Zant) , real(Zlna)



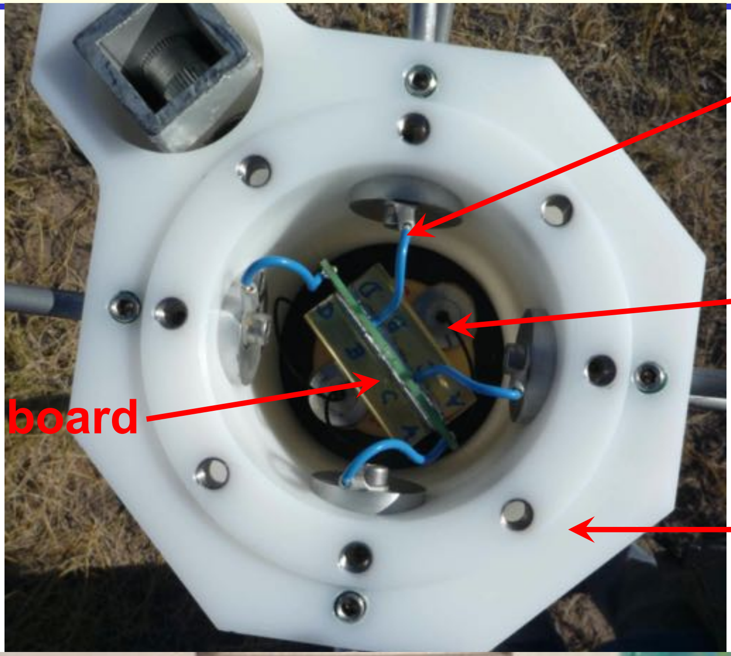
Imag(Zant) , imag(Zlna)

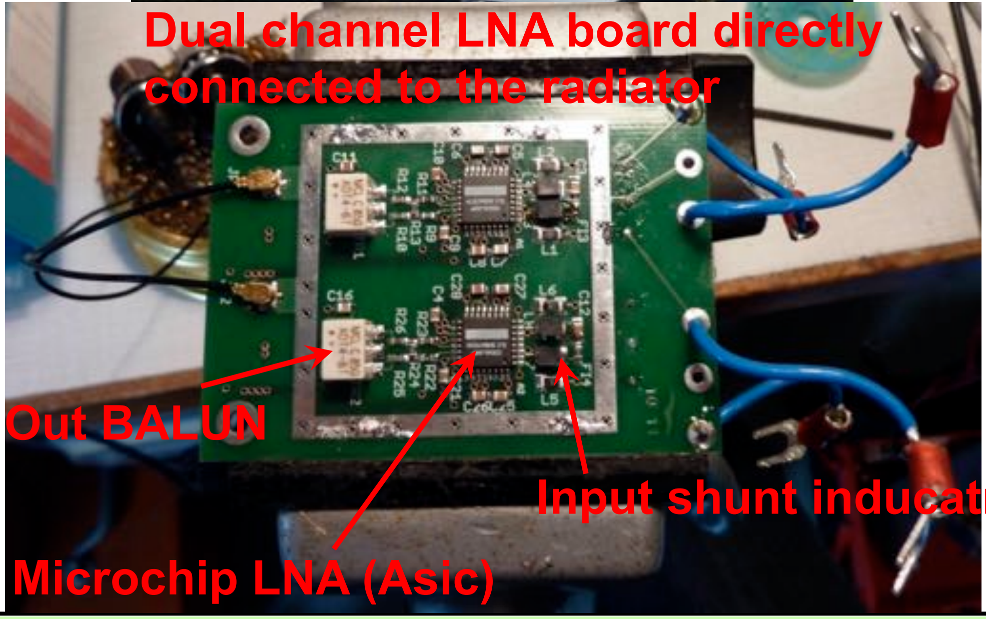


3- Effect on the antenna bandwidth



- **With a 1.5uH shunt inductance, the bandwidth is increased since the transfer function Vlna / Va is optimized**
- **The low frequency sensitivity is increased**



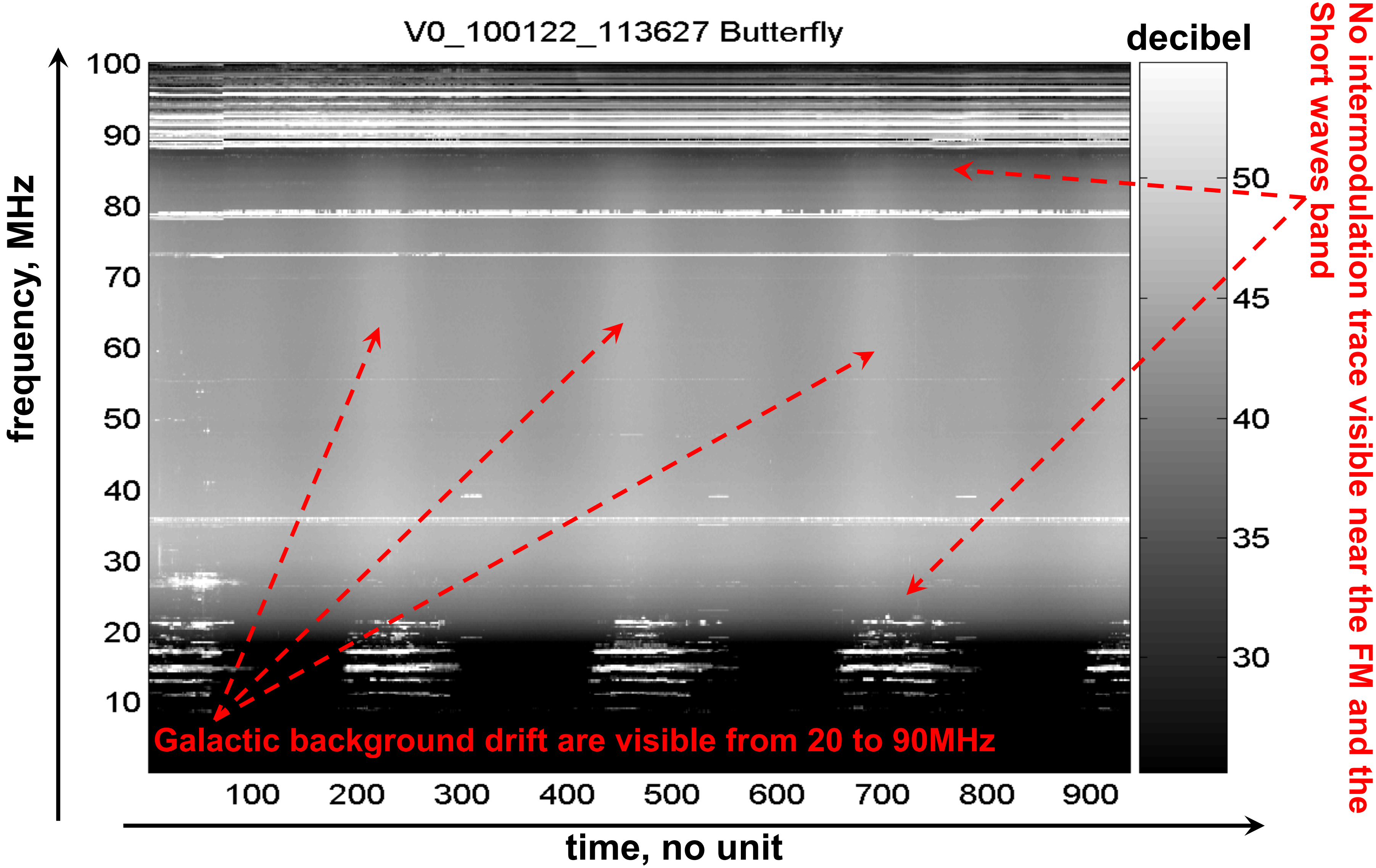


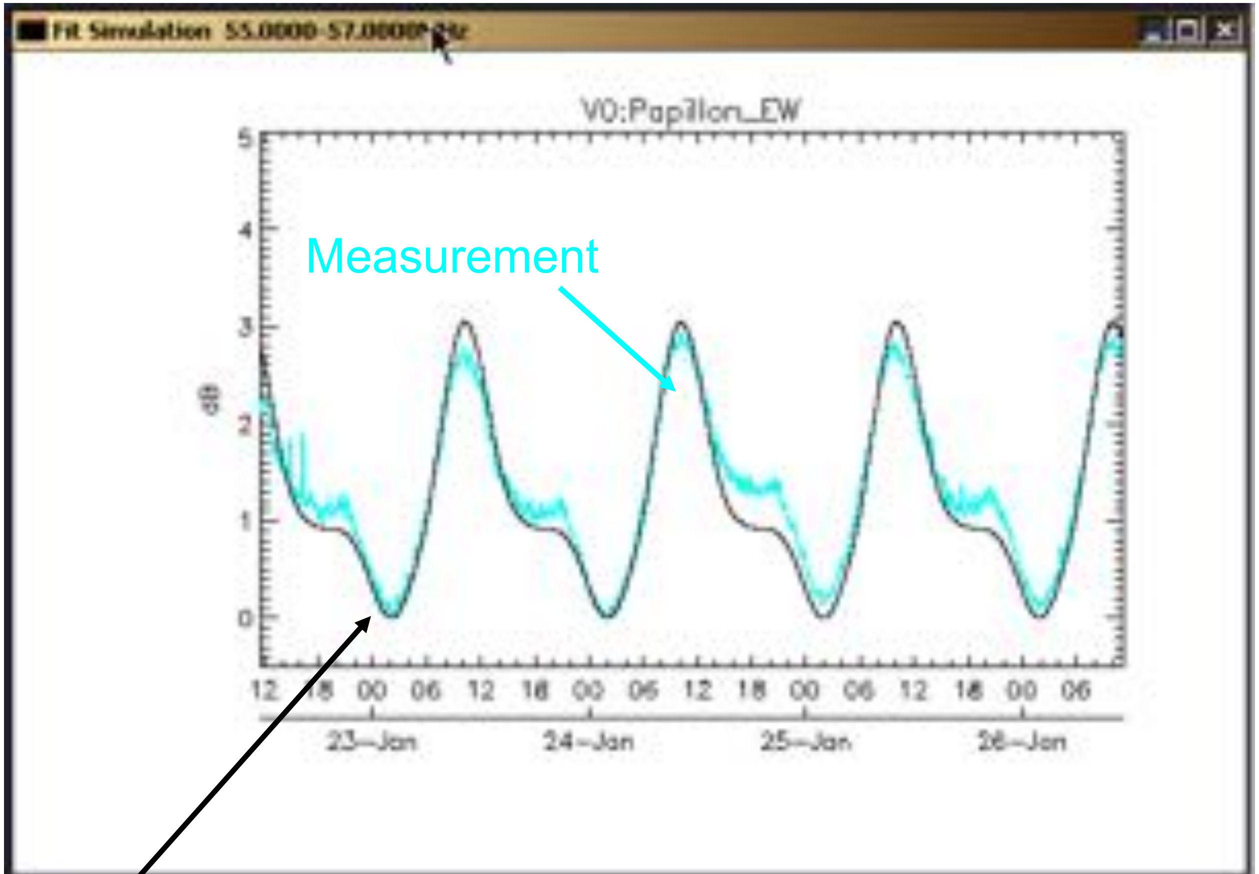
LNA board characteristics

Input type	Differential
Input resistance	300Ω
Input reactance	6pF // 1uH
Voltage gain	A=26dB
1dB compression point	OCP=7dBm ICP=8.8mV on 300Ω
Out reflection coefficient	|S22|<-20dB [4-210MHz]
Power supply	6V to 15V by signal
Consumption	2 x 52mA, 625mW
Gain temperature drift	-0.026 dB/°C

Butterfly sensitivity and linearity measurements over 4 days

• Spectra were continuously stored by a spectrum analyser (by a 24-82MHz band pass filter) at the Nançay radio-observatory

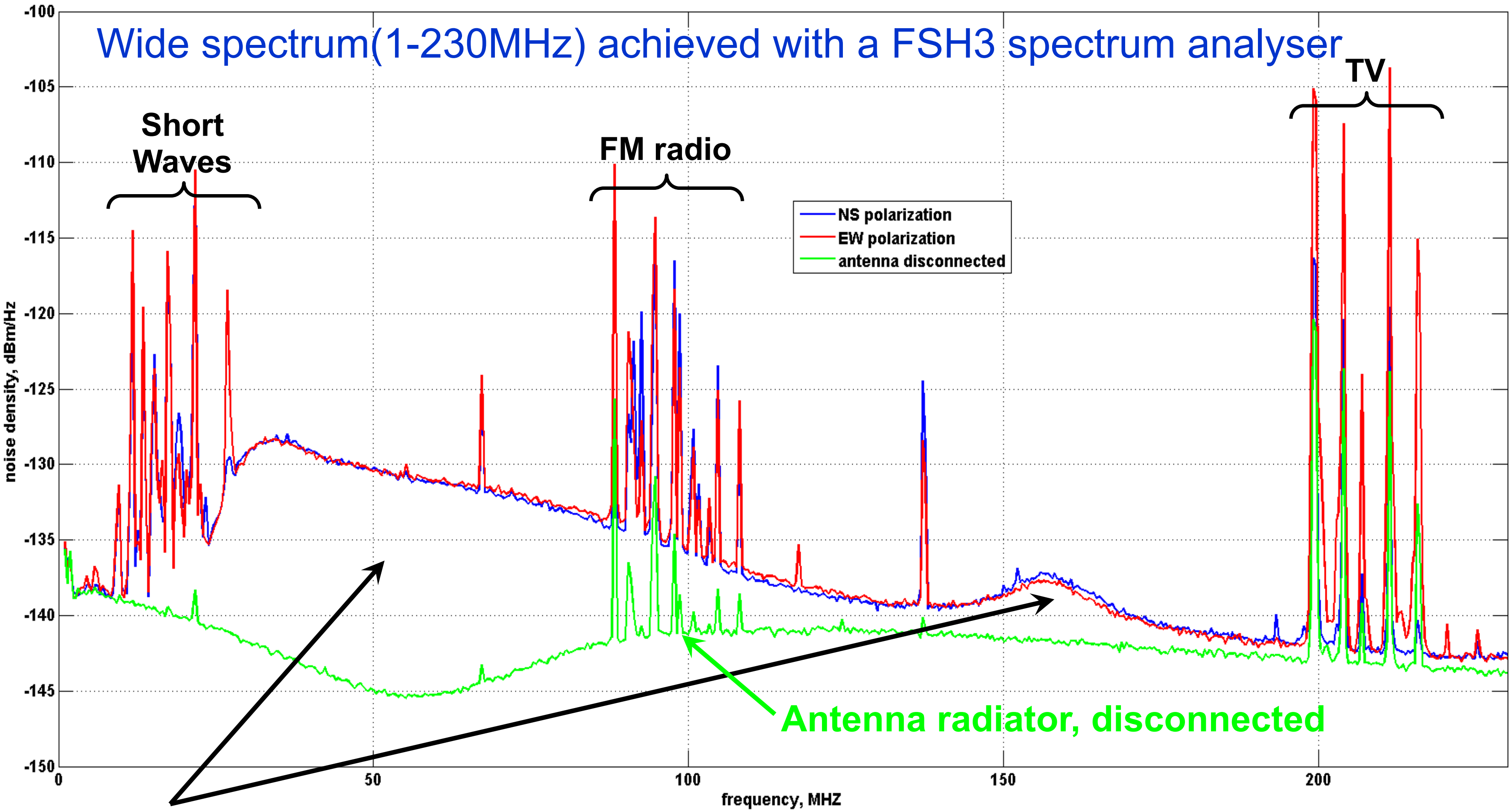




Measurement Galactic drift summary	
30MHz	2.5dB
50MHz	2.8dB
80MHz	2.7dB

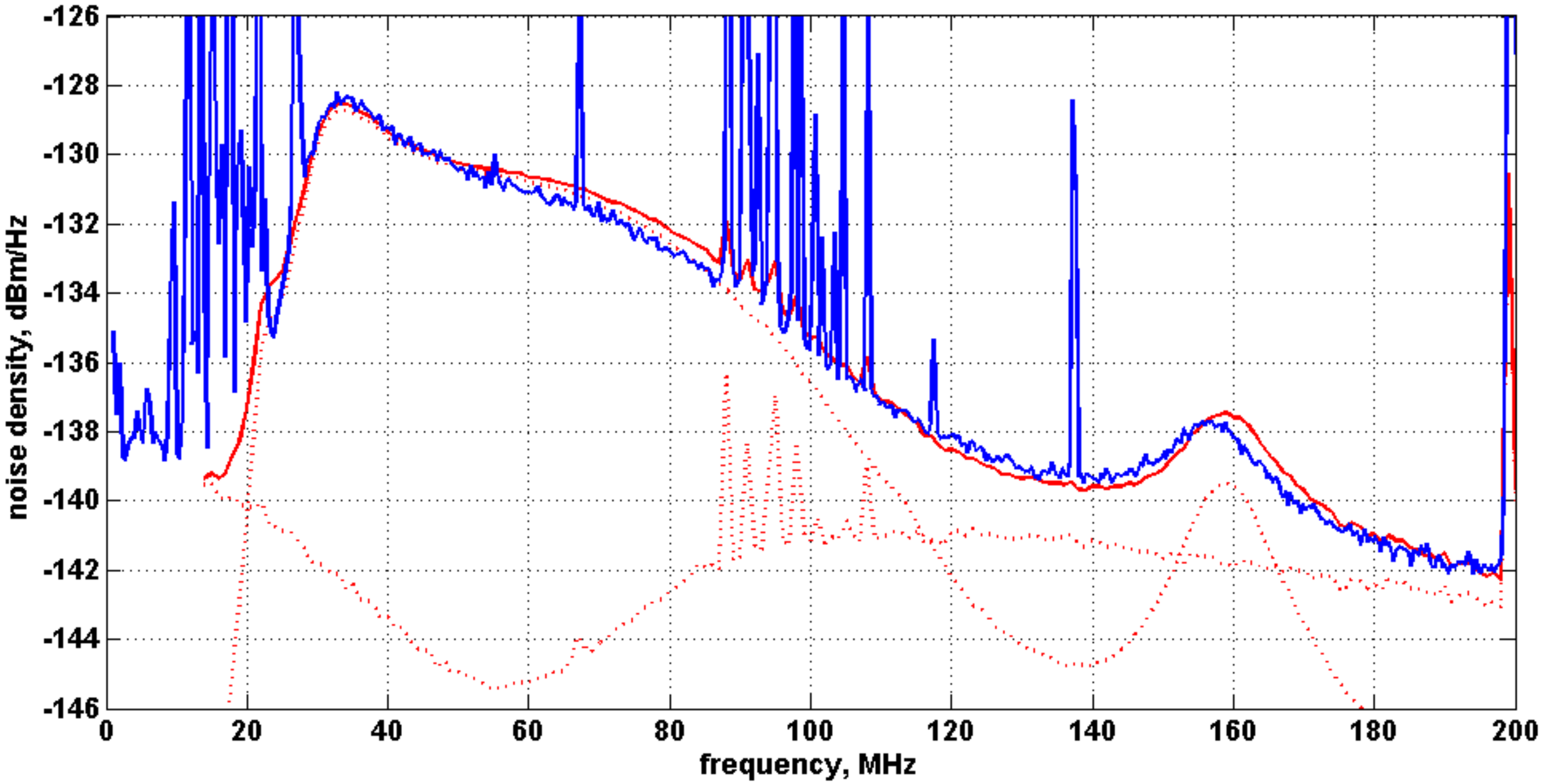
- **Simulation computed from a NEC description (ground: ε=10m σ=14). Butterfly directivity is projected on the sky map. It gives a maximum measurable drift of 3dB at 55MHz**
- **The sensitivity is excellent since it detects almost the 3 dB of galactic drift with a very similar shape**
- ***Good agreements between measurements and simulation of the galactic drift.***

Spectrum up to 230MHz with the Butterfly antenna at Augers Radio (CLF)



- **Galactic background visible up to 170MHz**
- **Very Quiet area ! : strongest transmitters are only 25dB over galactic background**
- **⇒ No intermodulation**
- ***Good symmetry between North-South and East-West polarization***

Galactic noise, measurement / simulation



Simulation: computed from typical values of galactic temperature (antenna directivity is neglected), simulated value of antenna impedance and measured value of LNA gain, input impedance and noise.

Measurement of galactic background

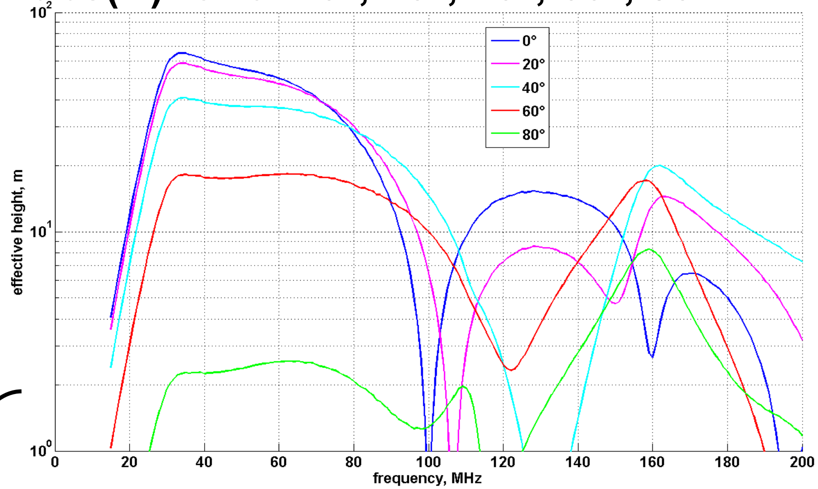
Calculation is very similar to measurement without any adjustment !

Butterfly antenna vector effective height (H) computation (NEC2+Matlab)

H:computed for a perfect ground plane, include the measured LNA characteristics)

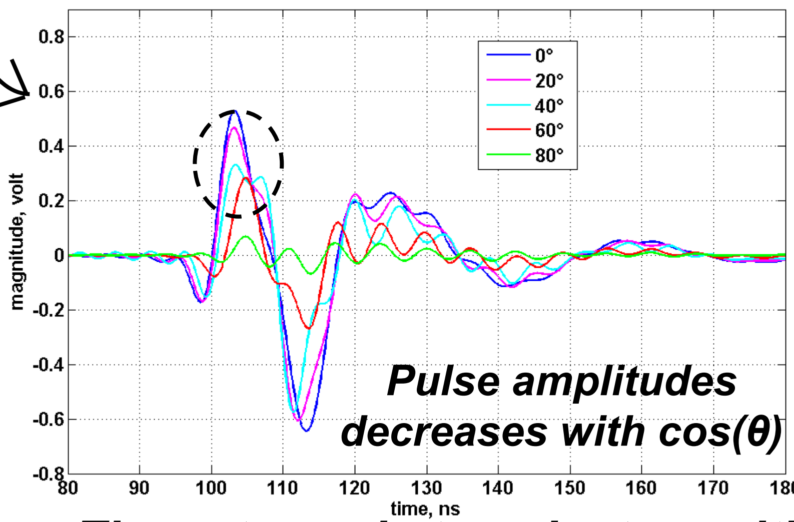
E-plane

abs(H) for θ = 0°, 20°, 40°, 60°, 80°



DFT⁻¹(H)

E-plane: Dirac response



H-plane

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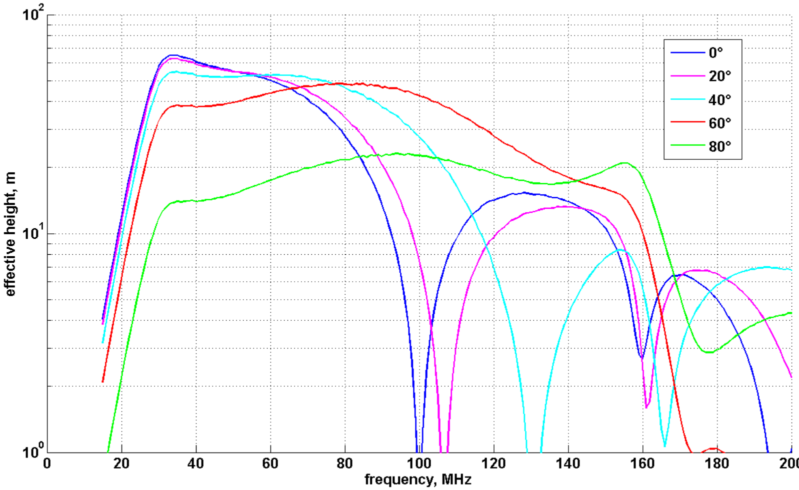
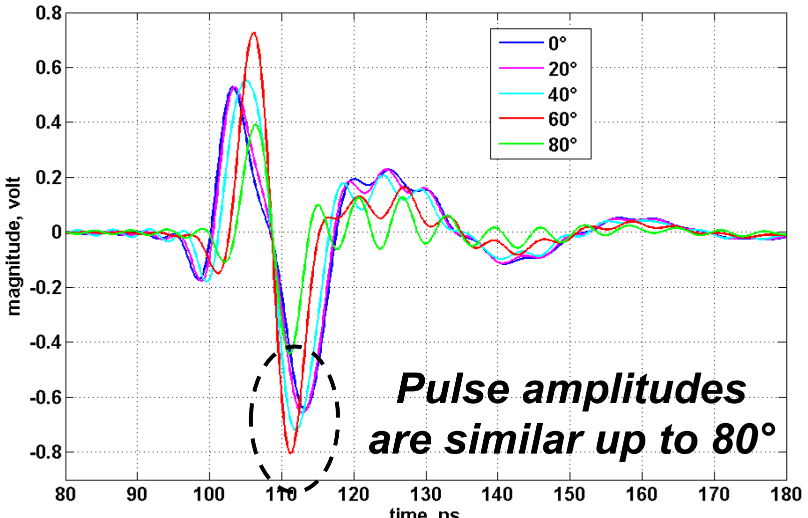


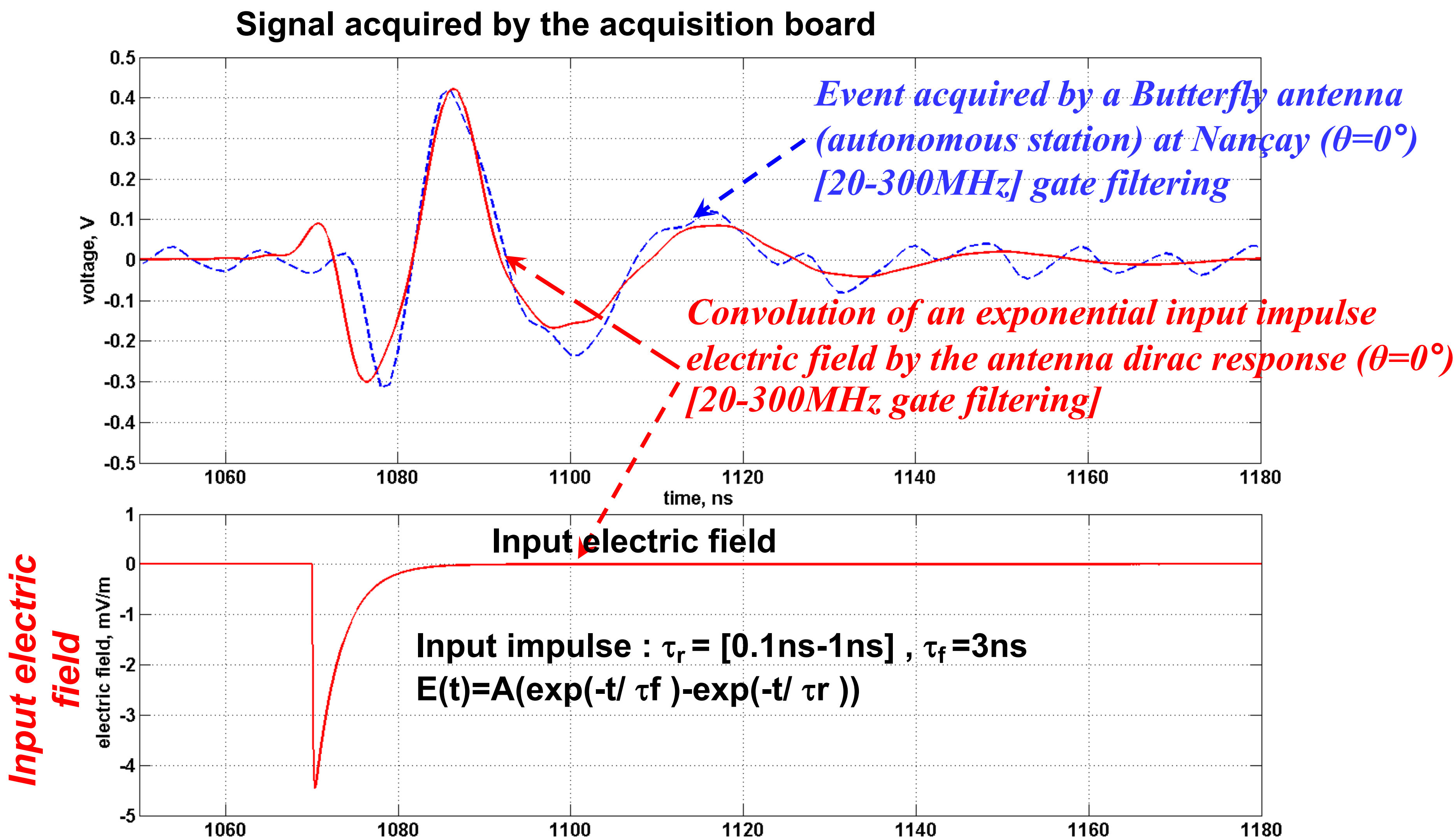
DFT⁻¹(H)

H-plane: Dirac response



The antenna is transient sensitive on a wide range of elevation

Very preliminary result on the induced Electric field shape



- ***The Butterfly antenna transient response model seems to be good***
- ***Electric field shape has to be investigate with more accuracy and with statistics***

Conclusion

- **It is possible to design both a compact (2mx2m) and sensitive antenna for the 25-90Mhz bandwidth.**
- **There is a good agreement between measurements and simulations with the butterfly antenna for:**
    - **The galactic background drift**
    - **The impulse antenna response**
- **The sensitivity to the galaxy will at least allow to verify that an antenna is operational (online checking) and should allow to calibrate this antenna**
- **The knowledge of the antenna impulse response should allow to measure the Electric field shape and amplitude by deconvolution**
- **The Butterfly antenna is ready for a mass production before end 2010 (125 antenna)**
- **The butterfly antenna is sensitive to the galaxy on a wide bandwidth which is important for radio-astronomy experiments: this is why this antenna has been chosen by the Lofar Super Station (LSS) experiment**