High Frequency Radar Astronomy and Radio Astronomy with the Over-The-Horizon Radar NOSTRADAMUS

Degurse J-F.[1,2], Molinié J-Ph.[1], Savy L.[1], Marcos S.[2]
[1]ONERA, Electromagnetism and Radar Department, Palaiseau, France
[2]Laboratoire des Signaux et des Systèmes - UMR8506 - CNRS-Univ.ParisSud-Supélec, Gif-sur-Yvette, France

The NOSTRADAMUS Over-The-Horizon Radar

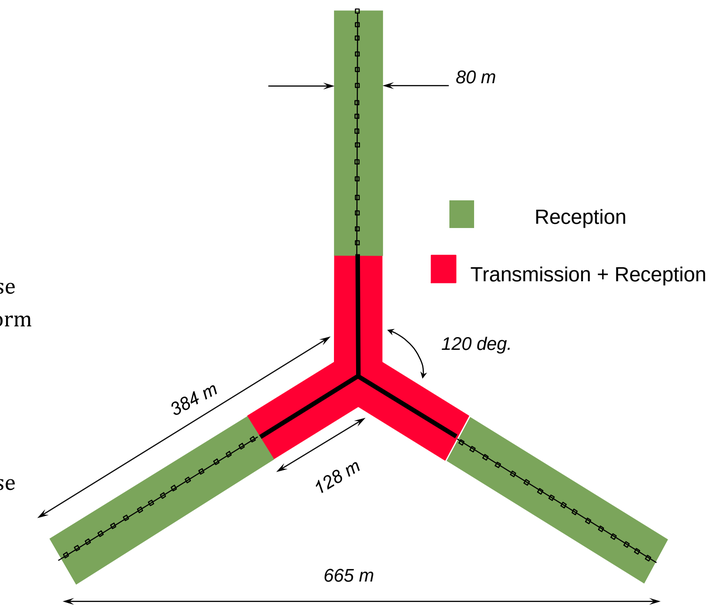
NOSTRADAMUS radar is a concept of monostatic, surface array HF sky-wave system. It is made of 288 bi-conical antenna elements distributed over the arms of a three-branch star, with a buried infrastructure to shelter the transmission and reception electronics. This choice of structure allows 360 degrees coverage in azimuth and the control of the beam in elevation.

NOSTRADAMUS Radar

Array
- 96 biconical antennas by arm
- 32 for T and R by arm
- 64 for R only by arm

Transmitting
- 96 (3x32) transmitters
- control interface : gain and phase
- coded impulsion, pulsed waveform

Receiving
- 288 (3x96) antennas
- 18 sub arrays, 18 receivers
- control interface : gain and phase
- digital beam forming



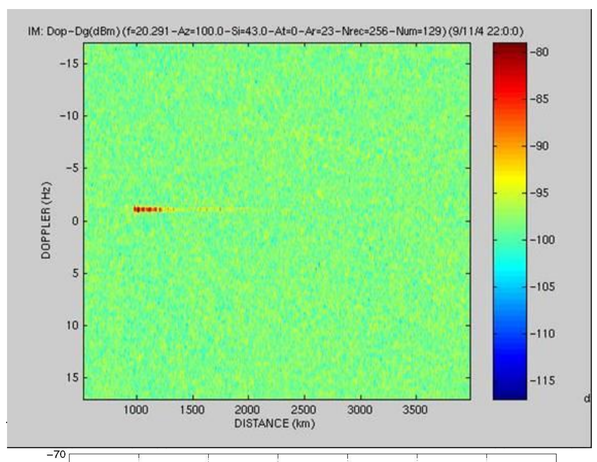
Frequency domain: 6-28 MHz

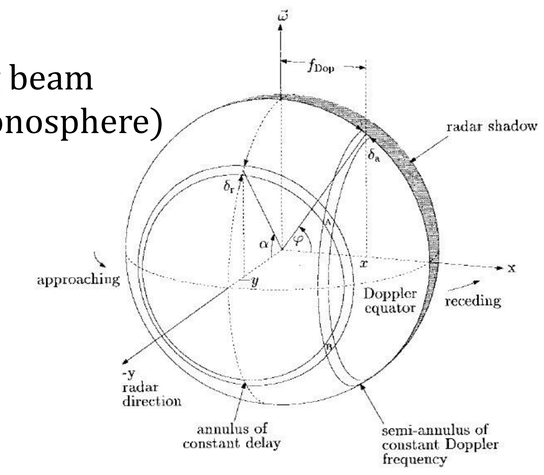
Objectives: Early warning system, very long range tracking

Radar Astronomy: Moon observations and Meteor detection

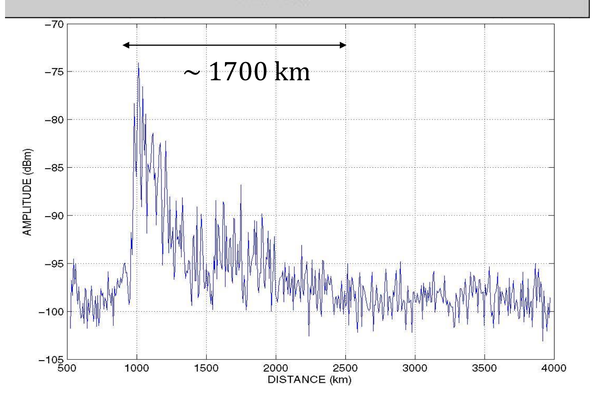
Moon observations:

The moon is completely within the receiving beam
Radar frequency: 20,29 MHz (crossing the ionosphere)
Ambiguous range measurement

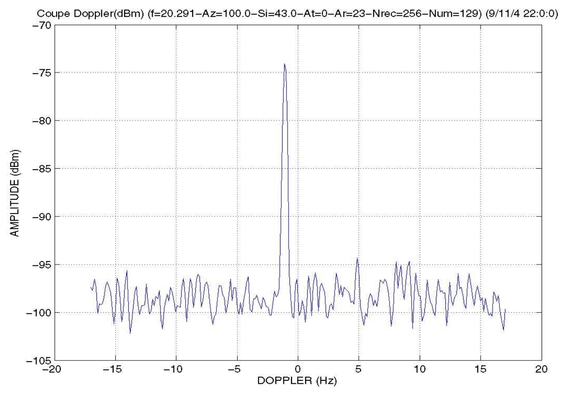




Good Signal-to-Noise Ratio (SNR)
Radial extension of the backscattered echo



Range profile

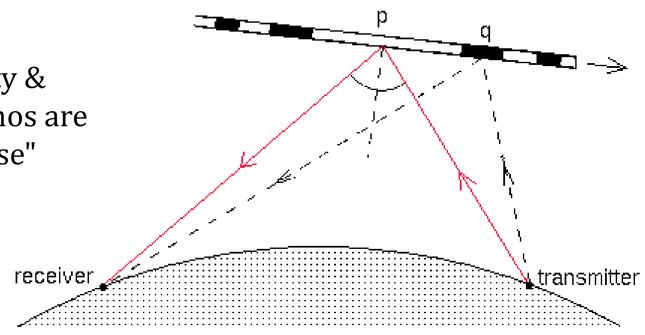


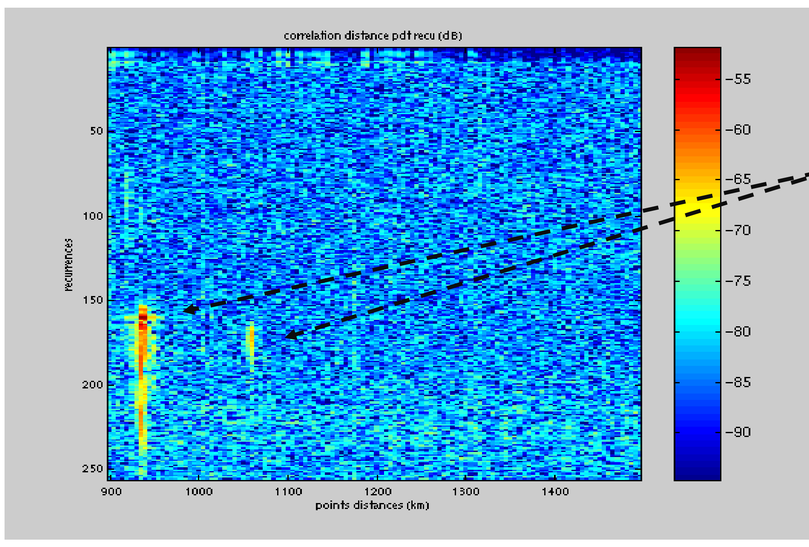
Doppler profile

Meteor detection:

Fast particles passing through the ionosphere create an ionized channel [1]

Ionospheric plasma density & frequency determine if echos are "overdense" or "underdense"





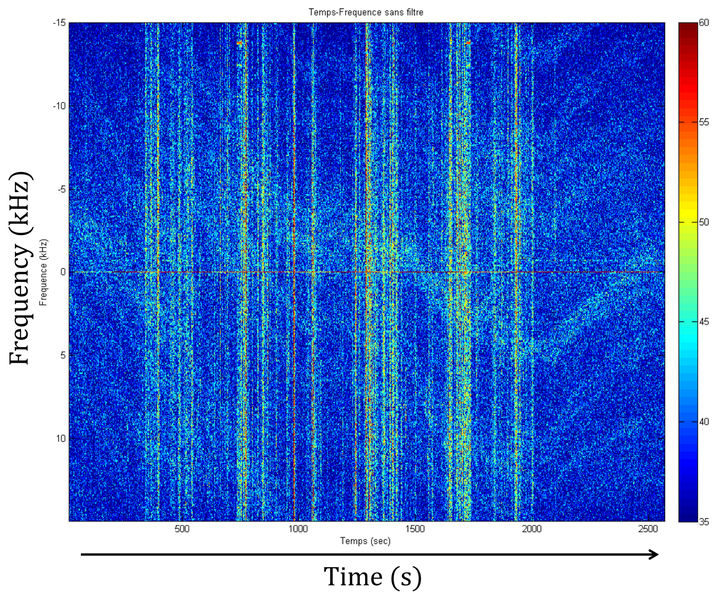
Applications: Ionospheric bias study, ISAR imaging (ground penetration of HF waves)

Applications: Detection of Extensive Air Shower caused by cosmic rays

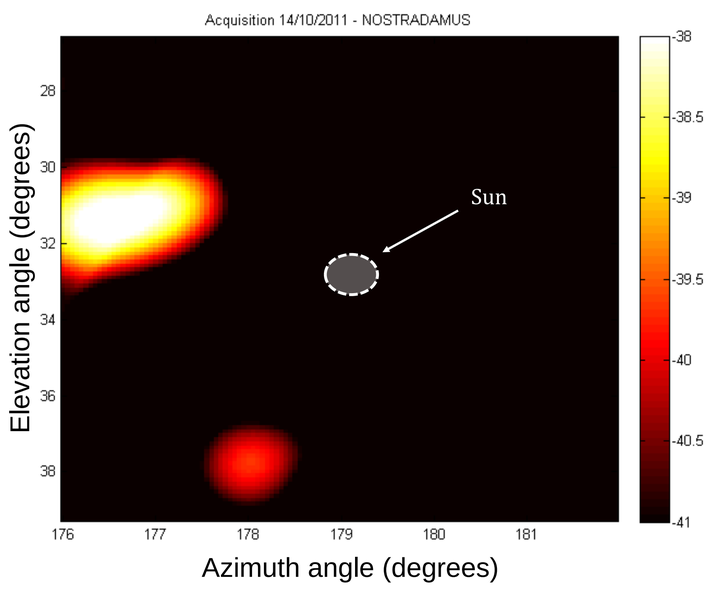
Radio Astronomy and Prospects

Radio Astronomy at long wavelengths: Passive mode (transmitters turned off)
Observations of Jupiter's and Sun's radio bursts
Comparisons with Nancay Decameter Array's data

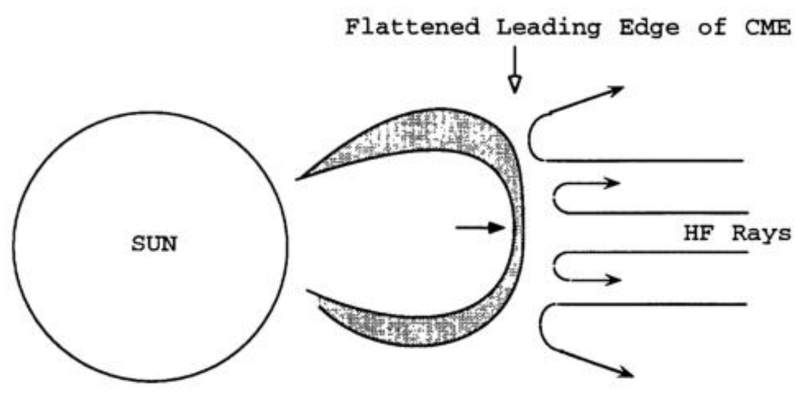
Jupiter - 21,437 MHz – 14/12/2012, 21h15 UT:



Sun- 25,600 MHz – 14/10/2011, 11h37 UT:



Prospects:
Detection of Coronal Mass Ejection (CME)
Backscattered HF rays should be observed [2][3]



- Low SNR: long integration time needed
- Important Doppler shift (~5-15kHz)

[1] Thomas, R. M., and D. J. Netherway. "Observations of meteors using over-the-horizon radar." Proceedings of the Astronomical Society of Australia. Vol. 8. 1989.

[2] Rodriguez, Paul. "Radar studies of the solar corona: A review of experiments using HF wavelengths." *Radio Astronomy at Long Wavelengths* (2000): 155-165.

[3] Rodriguez, Paul; Kennedy, E.; Kossey, P., "High frequency radar astronomy with HAARP," Radar Conference, 2003. Proceedings of the 2003 IEEE , vol., no., pp.154,159