A NEW MINIRADAR TO INVESTIGATE URBAN CANOPY: CURIE CANOPY URBAN RADAR FOR INVESTIGATION OF EXCHANGES

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Introduction

Inside large cities, air dynamics knowledge is necessary for several kinds of investigations. For example pollution studies have to be connected to the city boundary layer and exchange between the city itself which concerns particularly the city canopy. However due to traffic, acoustic sounding does not seem to be the most relevant technique. Acoustic ambient noise mainly related to automobile traffic prevents from using Sodar. More, Sodar noise itself does not seem to be socially accepted by city inhabitants though as shown by Little (1972), the acoustic backscattering intensity can be considered as the most efficient information to retrieve atmospheric boundary layer turbulence. These considerations indicate an interest to develop an instrument able to give an information equivalent to Sodar but not sensitive to ambient noise and with no acoustic noise generation. About Doppler acoustic sounders abundant literature has been published, see for example Brown et Hall (1978), Neff and Coulter (1985), Weill et al. (1978), Weill and Lehmann (1990). We therefore decided to study the possibility to develop a very cheap low power small radar, to investigate the lower part of the urban canopy. The first idea was to work about the feasibility of a small FMCW radar as those designed by Konrad (1970), Richter (191969) or recently Eaton (1995) but the solution of a pulse system as used by Gossard et al., 1978, Browning (1971) was not excluded.

The aim is to document at least two domains: inside canopy corresponding to a height range from 20 m up to 100 m (with a 20 m gate resolution) and a boundary layer height domain between 100 m and 500 m (with a 50 m gate resolution). The antenna has to be small, with a dish diameter value close to one meter.

At first a low power FMCW radar has been evaluated but eliminated due to the difficulty and high associated cost to limit coupling between transmitter and receiver. The concept of a mobile pulse X band radar has then been chosen which involves to solve several questions as:

ability to perform sounding with a first gate close to 20 m height

systematic elimination of fixed echoes (ground clutter)

feasibility of different sounding modes for both domains (20m-100m and 100m-500m) which corresponds to what was usually performed by acoustic Doppler sounders in quiet atmosphere.

The project therefore aims to realize a miniradar prototype able to perform wind profiling in the lower part of the ABL (Atmospheric Boundary layer) with an orientated antenna.

We point out different topics from which it is necessary to get knowledge such as building vortex documentation, computation of entrainment processes across the canopy top and other questions that have to be solved: measurement of wind profiles upon forests, nuclear plants monitoring and survey, eolian fields speed limit survey, air-sea interactions study.

2. The CURIE radar system

The radar architecture is given on figure 1. The radar frequency is 9.48 GHz and is obtained by the mixing of a 9.6 GHz phase locked source and a 120 MHz signal generated by frequency multiplication from a 10 MHz OCXO. The pulse modulation is performed on the 120 MHz signal. After mixing and filtering the 9.48 GHz pulse can be phase modulated before amplification. The transmitter is a solid state power amplifier delivering a peak power of 100 W. The pulse is radiated by a Cassegrain antenna through a circulator acting as a TR

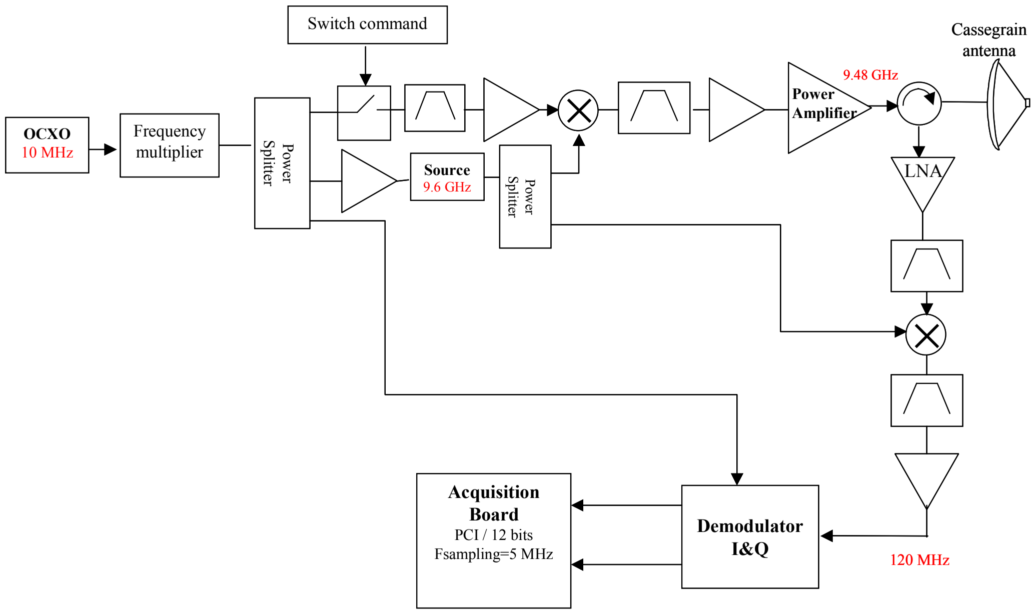


Figure 1. Curie radar architecture

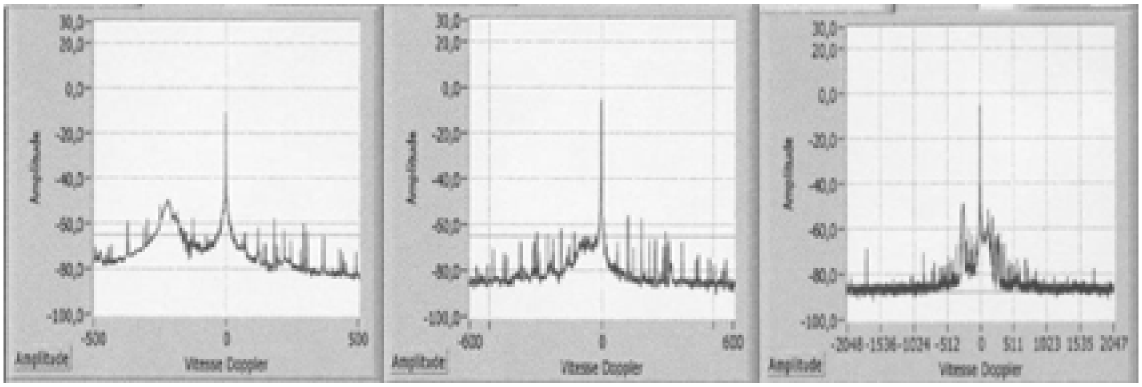
(Transmit-Receive) switch.

The third port of the circulator feeds a LNA (Low Noise Amplifier).After filtering the signal is translated back to the 120 MHz frequency by mixing with the 9.6 GHz frequency. The last stages of the receiver are the 120 MHz band-pass filter, amplifier and the complex demodulator which delivers the I and Q video signals to the sampling and data processing unit. The architecture is rather standard but some features must be emphasized. To obtain a useful first range gate at a height of about 20m a low peak power transmitter has been selected. The choice between solid state or TWT technology is dictated by cost level which leads to a 100W peak power solid state amplifier. A specific design is implemented inside the power amplifier to limit the leakage after the pulse. The side-lobes of the antenna must be very low to limit the power received from ground clutter. High stable frequency sources and frequency multiplication techniques are used to yield very low phase noise X band signals. For the data processing a trade-off is made between the number of coherent additions and the FFT-point number.

3. First results.

The first step was to develop a first realization of the concept to show it was relevant to make atmospheric sounding for range as low as 30m with a 10 watts solid state amplifier.

As shown on the following figures (2 a, b, c) during clear air conditions, we can observe different kinds of Doppler spectra representative of different kinds of atmospheric activities. Let us point out that the central peak is narrow and peaks of small Doppler shift can be easily identified. However, several spurious spectral line attributed to power supplies have to be eliminated to analyze correctly the Doppler shift.



a) b) c)

Figures 2. a, b, c "Classical" Doppler spectrum corresponding to a) a non – atmospheric echo, b) an atmospheric echo (air velocity of .78 m/s and c) several echoes corresponding probably to tree leaves clutter.

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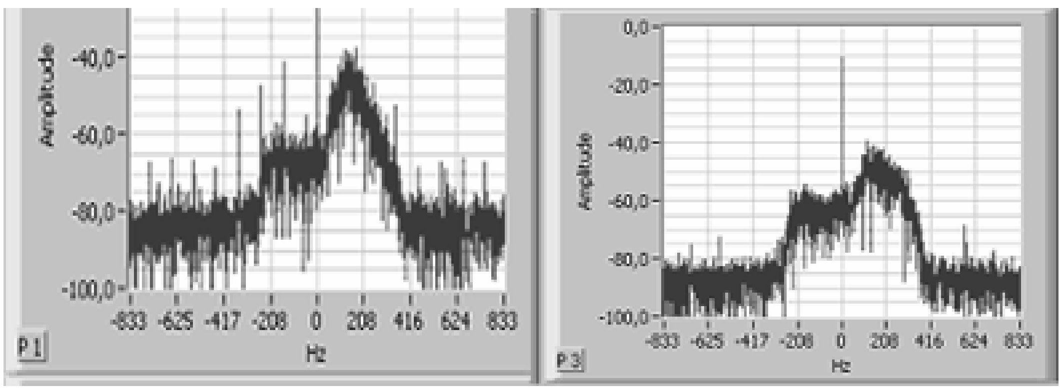

a) b)

Figure 3 a) spectrum during precipitation at gate n°1 (25m height) b) at gate n°3 (90 m height). The two peaks corresponding to precipitation and turbulence are here well separated.

The figures 3 a, b show spectrum obtained during precipitation conditions at 25 m and 90m height respectively taking into account the antenna orientation. On these spectrum two main spectral parts can be identified: one part related to turbulence and one part related to precipitation as already observed with acoustic sounder (Weill et al., 1986). It can be observed that at 90 m height the spectrum seems less noisy and a peak associated with precipitation is better identified

Conclusions.

It is difficult to conclude with these limited results, but we think that the CURIE miniradar is now feasible with two height ranges of observation (with a 100 W power amplifier). It remains a lot of questions to be solved and particularly the backscattering intensity interpretation in case of turbulence since probably as pointed by Kropfli; 1985, packets of particles of small dimensions can produce Bragg scattering just as turbulence does.

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