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# *Some Preliminary Results of an Acoustic Sounding System*

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*Introduction.*

The field of acoustic sounding of the atmosphere did develop in a very fast way in the last years. Two different tendencies did show up (1):

1) the construction of small sounding systems for use in the studies of the atmosphere first few hundred meters: such systems are applied in a routine way to detect and follow local specific situations in densely inhabitated areas, in industrial zones, etc. (2);

2) the development of sophisticated probes of high acoustic power and with refined electronic signal analysis (3). Such systems are mainly employed for research purposes, and are continuously changed in order to improve their performances.

After the pioneering works of McALLISTER (4) and LITTLE (5), many papers did appear in the literature [e.g. (6,7)]. Up to now, two main technical problems did not yet reach a completely satisfactory solution: the optimization of the acoustic antennas and the isolation of the receivers from the environmental noise. Evidently both are aspects of the same problem, that is the increase of the system range by a better use of the transmitter power and an improvement of the signal to noise ratio. Both problems become particularly critical inside inhabitated areas. Furthermore, it does not seem yet that a completely satisfactory way of numerical treatment of the received signal has been obtained.

*Description of the system.*

An acoustic sounding system has been realized by the working group operating in Torino through the collaboration between the Istituto di Elettronica - Politecnico di Torino and the Reparto di Acustica of the Istituto Elettrotecnico Nazionale Galileo Ferraris. Such a system consists of a large transmitting parabolic antenna (with a geometric area of 7 square meter) illuminated by a 1000 W electric power feeder. Up to now, only a small part of this power has ever been supplied to the system since the experiments have been performed within a residential area. In order to reduce the acoustic pollution, an improved shield will be built in the future. The receiving system, that is an electrete microphone placed in the focus of a 1.2 m paraboloid, has been located on the roof of a 25 m high building, within a light acoustic barrier. The noise reduction of the shield has been measured using as acoustic source the traffic noise. The sounding system operates on a pulse echo ranging, transmitting 1000 Hz bursts, 50 msec long, with 5 sec pulse repetition period. The received echo has been conveniently filtered and recorded on one of the two tracks of a magnetic tape. On the second track, the transmitted signals have been recorded for reference. For a preliminary and direct inspection of the received echoes, a paper-tape level recorder has also been used. In this way, any particularly interesting phenomenon can be easily pinpointed, and then isolated on the magnetic tape for numerical analysis. Fig. 1 shows the data acquisition system and Fig. 2, the data analysis system.

A large part of the working effort has been spent in building a set of numerical programs for the analysis of the signal on a small computer. The following are the main processing capabilities:

1) equidensity mapping of the atmospheric reflection layers as a function of time and virtual height with an accurate quantization of the levels;

2) noise reduction by preliminary numerical treatment;

3) computation of the autocorrelation function of the signal envelopes of echoes from different layers, to analyze and detect the typical time scale of the fluctuations at the different heights;

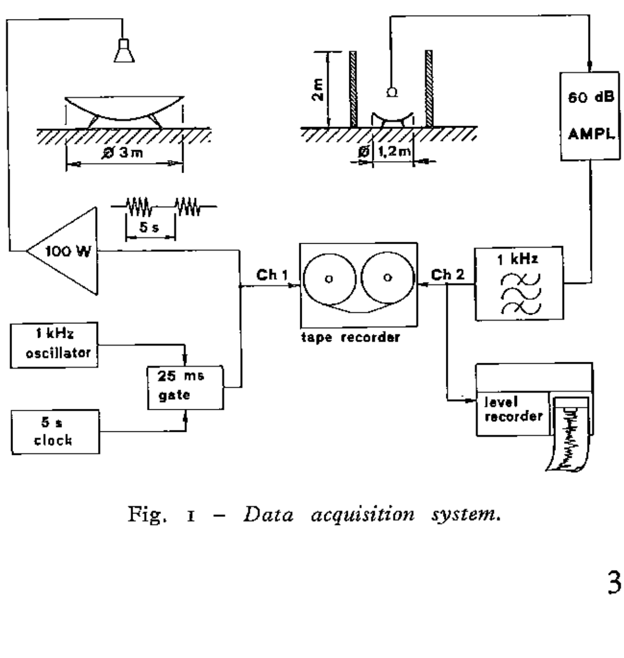


Fig. 1 – *Data acquisition system.*

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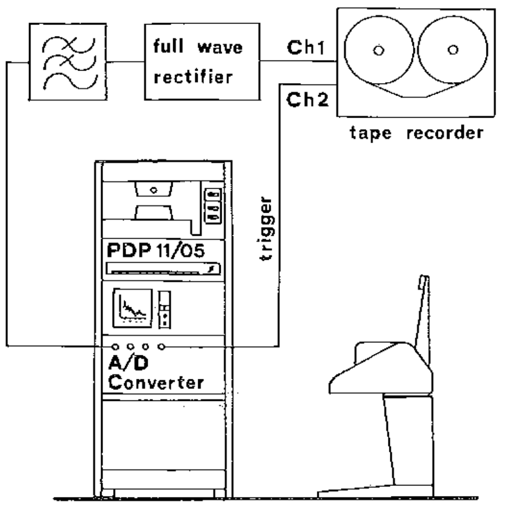


Fig. 2 – *Data analysis system.*

4) cross-correlation function between signal envelopes of echoes from different layers, to analyze the vertical movements of atmospheric structures;

5) fast Fourier analysis of the non-rectified signal to put in evidence Doppler shift, spectrum expansion, etc.

*Some preliminary results.*

A few atmospheric soundings have been carried on using only 100 W electric power, in different atmospheric conditions. The purpose of these experiments was just to check the system and to test the performances of the computer software prepared. The received signal, recorded according to the schemes described above (see also Fig. 1), has been first analogically treated, namely full-wave rectified, low-pass filtered at 150 Hz, and then fed into an analog-digital converter of the computer (Fig. 2). In order to show some of the capabilities of the system, the following partial results are reported. The data analyzed have been collected at 7 a.m. on the 21st of September, in Torino. The weather was partially clouded. Fig. 3 shows, in a log-scale, the amplitude of some successive soundings. Only a small part of the received signal has been numerically treated, to check the software analysis system, namely that part were an evident and rapidly time-varying phenomenon did appear. For this purpose a time-window, $\Delta t$, was set, 1.2 sec long, starting 0.4 sec after the beginning of the transmitted pulse. Fig. 4*a*) shows the portion of one of the received signals, within the time-window just described, and Fig. 4*b*) shows the average of the string of 64 successive signals examined. In Fig. 4 the first peak of the signal is still mainly due to multiple reflections from nearby buildings. Some of the possible analysis are reported in the following figure.

The left-hand side of Fig. 5 shows the value of the

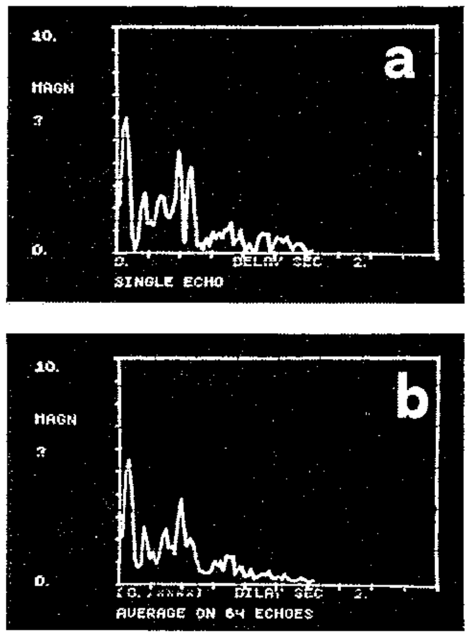


Fig. 4 – a) *An example of a single sounding limited by the described time-window* (Sept. 21, 7 a.m.). b) *the average on* 64 *soundings.*

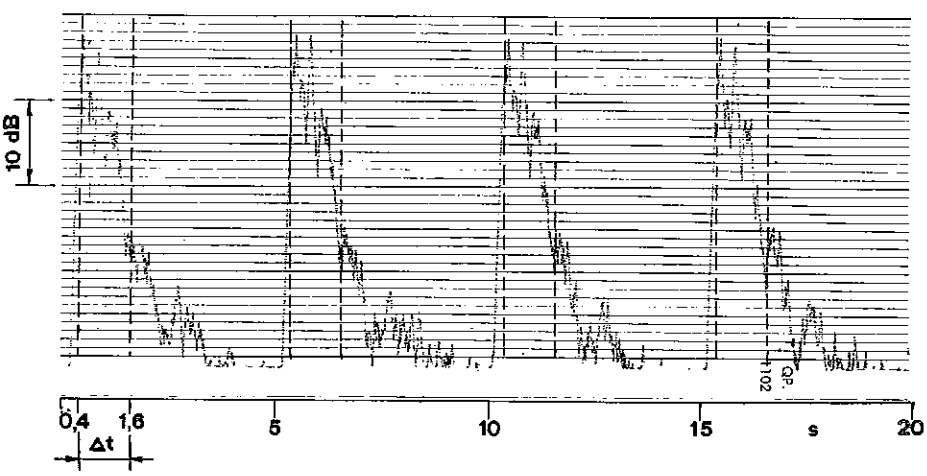


Fig. 3 – *Level record of some successive soundings. The intervals denoted by* $\Delta t$ *will be studied in the paper.*

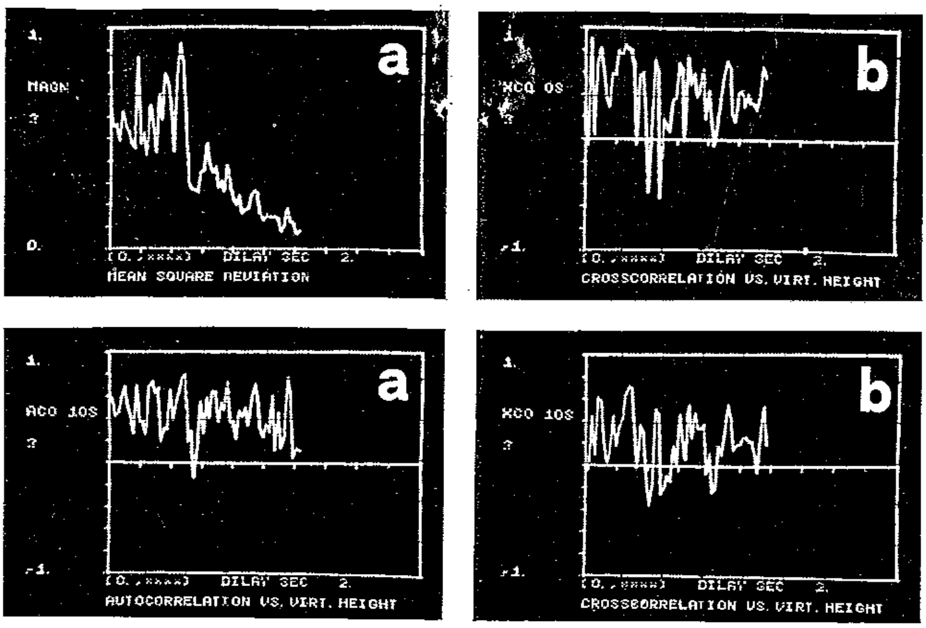


Fig. 5 – a) *Mean square deviation and value of the autocorrelation function computed at* 10 *sec delay time as a function of virtual height* (see text); b) *values of the cross-correlation functions between signals samples delayed* 25 *msec* (*approximately* 8.57 m( *as a function of virtual height* (see text).

mean square deviation and the autocorrelation function vs. time delay. It is to be noted that the time delay can be related with the virtual height by multiplying it for the mean sound velocity in the atmosphere. The autocorrelation has been computed for 10 sec time shift after normalyzing the null mean value data with respect to the mean square deviation. The reduction of the mean value of the autocorrelation in the window examined, with time shift, gives a measure of the time-constant in the evolution of the global structure of the layer considered. However, it is also very interesting to note the detailled structure in the value of the autocorrelation for a fixed time-shift as a function of virtual height. Indeed, it appears from the figure that changes of the order of 0.5 in the value of the autocorrelation for 10 sec time-shift may be found in virtual height layers boundaries of the order of 10 m.

Furthermore, the minimum negative value of the autocorrelation corresponds to a large value of the quotient between the mean square deviation and the average value at the same virtual height. Viceversa, at a slightly lower virtual height, a relatively large average value is accompained by large mean square deviation and by a positive peak in the 10 sec autocorrelation. From a physical point of view these facts imply the presence of a very turbulent boundary layer.

The right-hand side of Fig. 5 shows the cross-correlation between echoes received from layers giving a delay in the received signal of 20 msec, corresponding to an approximate separation in virtual height of only 3.4 m. It is to be pointed out that the transmitted pulse is 50 msec long, that corresponds to a length of 17 m. Notwithstanding this fact, a negative cross-correlation appears both for time-shift of just 20 msec (0 s in the figure) and of 10 sec implying the presence of important structures uncorrelated with characteristic lengths smaller than the pulse length. Consequently, the need of shorter pulses for sounding, and the need of analyzing not just the envelope of the pulse but the pulse itself, does appear quite clearly.

*Future programs.*

The acoustic sounding system will be shortly moved to another location in order to diminish the annoyance caused to the community by the use of the full transmitter power. Furthermore, the location of the shielded system in a quiet sorrounding will increase the dynamic of the echo received, and consequently, the height that can be possibly reached.

In the near future, a swept frequency sounding method will be used. A theoretical analysis of such approach is to be published. Furthermore, the possibilities of the system will be largely increased using three separated receivers in order to see the spatial behaviour of the atmosphere, and connecting the acoustic system with an electromagnetic radar.

*Conclusions.*

From the results described in the literature, and from our direct experience, it appears that only the digital elaboration of the received signal in real time will be able to fully exploit the capabilities of atmospheric soundings. For this reason, our main efforts in the past and in the near future has been and will be in such a direction.

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*Summary* — An acoustic sounding system is described, both in its technical realization and in some of its capabilities of numerical analysis. Some preliminary results are presented in order to show the system ability to follow the evolution of the meteorological situation of a chosen atmospheric layer. Future programs are briefly outlined.

*Riassunto* — Si descrive un sistema di sondaggio acustico della troposfera sia nella sua attuazione tecnica che in alcune sue possibilità di analisi numerica. Si riportano alcuni risultati preliminari per dimostrare la possibilità del sistema a seguire l'evoluzione meteorologica di uno strato dell'atmosfera. Infine si accenna al programma futuro.

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