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AN OVERVIEW OF THE LONG RANGE IMPULSE SOUND PROPAGATION MEASUREMENTS MADE IN NORWAY

G Kerry

Dept of Applied Acoustics, University of Salford, Salford, UK

INTRODUCTION

Firing range operators are aware of their responsibility to minimise the nuisance caused in the surrounding community by their activities. Over the past few years considerable efforts have been made to control noise emissions and one area where major advances have taken place has been in the prediction of explosive noise propagation. A number of PC based prediction models have been or are currently under development. To test these models and identify necessary improvements, reliable and comprehensive data are required from field trials. Much data has been obtained with propagation over unobstructed surfaces such as grass, concrete and water [1] and it is evident that the surface does influence the pressure waveform and its parameters. It is also common knowledge that the meteorological conditions have a considerable effect on propagation over large distances[2]. There is, however, very little information on propagation through or over forest where micrometeorology as well as the trees, foliage and groundcover may influence propagation and where, in northern regions, the effect of the ground cover and foliage may be grossly affected by deep snow cover during winter.

Following an invitation from the Norwegian Defence Construction Service a series of trials was arranged to study blast noise propagation through forests in both summer and winter conditions. The work was carried out by a multinational team with representatives from Norway, Germany, UK and USA.

MAIN AIM OF TRIALS

To study blast noise propagation under different meteorological conditions in both summer and winter to distances of 12km and beyond through mature coniferous forest over mixed terrain from 1kg, 8kg and 64kg unconfined calibrated charges of C4 plastic explosive.

During the above study to investigate meteorological and micrometeorological conditions in and above the forest and to study ground impedance, to classify ground cover, tree density, snow cover both on the ground and in the trees, and ground response to incoming air overpressure.

TRIALS LAYOUT AND PROCEDURE

The area selected for the trials lies 100km NE of Oslo close to the Swedish border. A long range trial site was set up in Finnskogen, ESE of Elverum, and a short range trial at Haslemoen, SE of Elverum.

The long range trials

The ground was undulating with a series of ridges running NW-SE rising gradually from the river Glama to the border. The intervening valleys were silt-filled with large areas of marshland and lakes. The area was covered with coniferous forest. A cross array was set up (figure 1) with radials running 12km to each of the cardinal points from the centre position located at latitude north 60°,15",43.2', longitude east 12°,5",10.0'(altitude 471m). At the centre position (0,0) and at the position 12km north (1,12) and 12km west (4,12), 30m towers were erected with microphones located at 30m, 24m (not winter), 16m, 8m, 4m, 2m and either 1m or just above the ground. At the centre position the 8,4 and 2m microphones were carried on a separate tower. On the southern arm it was agreed not to erect a mast at 12km because that location was shielded behind a hill so a position 6km to the south (3,06) was selected and a 12m mast was erected with microphones at 8m, 4m and 2m above the ground, with additional microphones at 1m and at ground level a short distance away. For the winter trial an additional 30m mast was erected at this site to carry microphones at 30m and 16m. Twelve kilometres to the east (2,12) a 12m mast was erected with microphones at 8m, 4m and 2m above ground. This was replaced by a 4m mast with microphones at 4m and 2m above ground during the winter trial.

Firing positions were selected on each arm of the array at 1, 2,4,8,10 and 11km from the centre. It was not possible to use all positions because of the proximity of dwellings or because permission could not be obtained from the landowner. In the event the prime firing positions were selected on the north and west arms to take advantage of the prevailing weather and these were supplemented by additional positions on the southern arm. At all positions the 1kg charges were fired when suspended 1m above ground and the 8k charges at 2m above ground. The 64kg charges, fired at 1,08 and 3,08 only, were placed on the ground. All firings were initiated locally following a countdown from the centre position, each firing team having a firing device that transmitted a tone by radio at the time of detonation which could be recorded alongside the signals at each of the measuring points.

Firings normally followed a set sequence of north-south shots from 1,11, 1,10, 1,08, 1,01, 3,02 and 3,04 or west-east shots from 4,11, 4,10, 4,08, 4,04, 4,02. Three minutes were allowed between shots and the sequence was repeated three times during a session. The direction was selected with the aid of the weather forecast for the day and succeeding days so that measurements could be carried out under several different weather conditions. Charges of either 1kg or 8kg were used for the each sequence. Another sequence was fired from 1,08 and 3,08 to study the effect of charge weight. In this case charges of 1, 8 and 64kg were fired in turn, first from position 1,08 and then from 3,08 and repeated three times. During the winter trials additional charges were fired from 4,02 using short delays between each to study the short term weather effects on propagation.

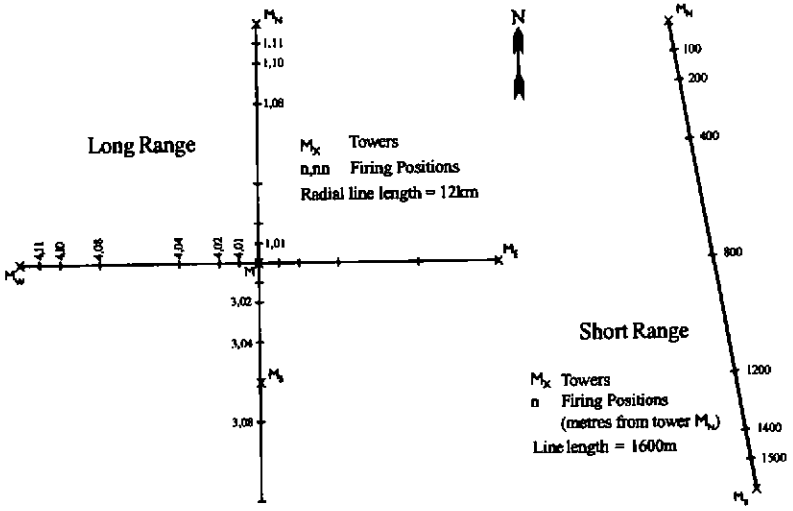

Figure 1: Trial layout

The short range trials

To assist with the study of propagation through the forest and to test equipment for use on the long range trial a short range site was selected where the forest was more uniform and the ground essentially flat. An array was set up in the forest 1.6km long at a bearing of 341° true(fig 1). At the northern end of the array a 30m mast was erected approximately 10m into the forest from a roadway. Microphones were placed at 30m, 24m, 16m, 8m, 4m and 2m, the latter three being on a separate mast, 3m to the side. At the southern end another 30m mast was erected with microphones at 30m, 16m, 4m and 2m above ground. The latter two were on a separate mast. Firing points were located on a line between the masts at distances of 100m, 200m, 400m, 750m, 1100m, 1300m and 1400m from both ends.

Due to a small fire in the undergrowth, started by the third shot, the majority of the trial was completed by firing the charges along the edge of the forest. An additional ad hoc trial was carried out to investigate the propagation of the wave into the forest. The firing point closest to the north station was used for detonating a series of seven unconfined 1kg charges of C4 at 2m agl. A B12 blast gauge was set up at 2m agl to make a series of measurements at distances of 10m, 20m, 30m, 50m, 70m, 100m and 125 m from the source towards the north tower.

The winter short trial followed the same format but microphones were placed at 30m, 16m, 4m and 2m agl on both the north and south masts. Most of the charges were fired in the forest at the previously designated positions but in addition one series was fired along the forest edge to replicate the summer arrangement.

The opportunity was also taken to carry out a similar trial under winter

conditions out in the open in a large field to one side of the forest. A similar layout was used but microphones were placed on short masts at both the northern and southern ends at 2m, 4m and 8m agl and also just above the snow level. 1kg and 8kg charges were fired 2m agl.

Charge calibration measurements were carried out in an open area away from the forest. The ground was concrete in poor condition. Five unconfined 1kg charges were detonated, three at 8m agl, one at 1m agl and one at 0.5m agl. The levels were measured on a B12 blast gauge located 8m agl and 20m from the firing point.

ACOUSTIC MEASURING EQUIPMENT

All the microphone systems on the main array at the central mast (long range) and the northern and southern masts (short range) and most systems on the other masts had extended low frequency responses (-3dB below 1Hz). The basic system comprised a B&K 4147 sealed microphone on a 2639 preamplifier with rain shield and windshield fitted. The microphones were orientated such that their diaphragms were parallel to the ground. Field calibrations were carried out by pistonphone and additional checks were made during each trial by a variety of methods to ensure that the systems did not drift. Most signals were recorded on multichannel DAT recorders with 20kHz bandwidth. During the short range summer trial signals at the northern tower were recorded directly onto a 200kHz sampling digital measuring system.

The opportunity was taken during the trials to evaluate several different types of transducer[2]. This took place at the central position (long range trial) and the northern mast (short range trial). Included in the evaluation were transducers by Chaparral, Validyne and Kulite. Also recorded alongside the acoustic data were time signals from either GPS satellite or radiocoded transmissions and a warble tone transmitted during the firing sequence on a mobile communications link.

METEOROLOGICAL MEASUREMENTS

A daily weather forecast was provided with interpretations for the day itself and for several days ahead to assist with trials planning. All the trials were supported by a comprehensive set of meteorological measurements. In the forest, meteorological data were sampled above, in and below the tree canopy and tethersonde balloons were used at several locations to measure wind and air temperature up to 1000m. A mobile radiosonde station, manned by the Norwegian Defence Forces, provided wind and temperature profiles to 3000m at the centre location. Additional information was obtained from Oslo and was supplied by the Norwegian Weather service.

Four automatic weather stations were used on each long range trial, one at each 30m mast site and one on a 10.5m high wooden tower (with an 11.5m extension mast) located in the forest at position 4,03. In addition during the summer a 10m mast and fifth automatic monitoring station was positioned on a small island on the lake to the east of the centre position. Wind speed and direction and temperature were measured at the top of each 30m mast and wind speed and temperature at 10m, 5m and 2m on a separate mast nearby and on the lake. The wooden tower had wind and temperature sensors at

24m, 15m, 10m, 5m and 2m with additional pressure sensors at 15, 10 and 2m. A sonic wind transducer was located at 15m to study turbulence. All sensors were sampled at 10 minute intervals throughout the trials period.

The tethersonde was used mainly at location 4,03 but some additional measurements were made at the centre location adjacent to the radiosonde equipment and at 1,12. The tethersonde recorded temperature, wet bulb temperature, pressure, wind speed and direction and relative humidity.

For the short range trials three automatic monitoring stations were set up, one at the north tower, one on a wooden tower located approximately in the centre of the trials site and one on a similar tower approximately 100m north of the south mast. During the winter trials an additional mast was set up in the centre of the field next to the forest.

The northern mast carried wind speed and direction sensors at 30m and wind speed and temperature sensors at 20m and 15m for the summer trial only. Wind speed and temperature sensors were also located on a separate mast at 10m and 2m for both sets of trials. The centre and southern towers carried wind speed and direction and temperature sensors at 24m (26m south) and wind speed and temperature sensors at 19m and 15m(centre), 18m and 14m (south), 10m and 2m. The centre tower had pressure transducers at 14m, 10m and 2m and sonic wind sensors at 18m and 14m(summer only). The mast in the open field carried wind speed and direction and temperature sensors at 10m and wind and temperature sensors at 5m and 2m. Sampling took place at 10 minute intervals. Tethersondes were operated from the centre of the open field at various times throughout the trials. Comments on the general weather during the trials and observations and examples of some of the data obtained are provided in reference [4].

ANCILLARY MEASUREMENTS

A number of ancillary experiments were carried out to support the main trials.

Acoustic characterisation of the ground and snow. The acoustic characterisation of the forest floor was determined using a multi length sequence (MLS) and correlation technique developed by the University of Trondheim[5]. An impedance tube and a two microphone technique was used to measure the normal acoustical impedance of snow samples taken at selected locations at the trials sites[6].

Classification of the snow. A general classification of the snow cover on the ground and on the trees was carried out during the trials and also a mapping of the frozen crust of the ground. Snow depth sticks were placed and snow pits were prepared at the Haslemoen site and at each of the measurement locations on the long range site. Parameters measured were grain shape and diameter, snow hardness, snow density, wetness and temperature The results were presented according to the international classification for seasonal snow on the ground. There is no standard method for the classification of snow cover on trees and this was presented as a verbal and photographic description[7].

Permeability and snowpack liquid water measurements and measurements on the dynamic properties of the snow using a pulse technique and microphone array were also carried out[8]. On the long range measurement site a mobile team used ground penetrating radar to determine snow layering, frost crust and water layering.

Classification of the forest. A description, by sampling, of the trees, including height, diameter and density was also made.
Ground response. The ground motion induced by the airblasts was measured at the southern mast on the short range site and at 3,06 on the long range site using both microphone and geophone arrays[9].

RESULTS

A total of 532 charges were fired during the trials resulting in excess of 10,000 waveform recordings. These data together with the relevant meteorological, ground and forest parameters are being collated and will be stored in a database[10] for future use by researchers. Analysis is currently being undertaken by several teams [11][12] and further reports will be available in the near future.

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