Applied Acoustics 109 (2016) 61–68

Contents lists available at ScienceDirect

Applied Acoustics

journal homepage: www.elsevier.com/locate/apacoust

Factors affecting sound exposure from firing an SA80 high-velocity rifle

Gurmail S. Paddan [a,*], Michael C. Lower [b]

[a] Institute of Naval Medicine, Crescent Road, Alverstoke, Hampshire PO12 2DL, UK
[b] ISVR Consulting, University of Southampton, University Road, Southampton SO17 1BJ, UK

ARTICLE INFO

Article history:
Received 26 June 2015
Received in revised form 19 February 2016
Accepted 25 February 2016
Available online 21 March 2016

Keywords:
Noise
Rifle
Shock wave
Muzzle blast
Hearing protection
Localisation

ABSTRACT

The effect of distance on the peak sound pressure level and sound exposure level from an SA80 rifle has been investigated. Sound pressure waveforms were measured in two directions from the gun: downrange, from 50 m to 300 m, and to the left-hand side, from 0.3 m to 32 m. Some additional measurements were made to the right of the gun. Measurements made downrange showed three distinct features of the waveform; the shock wave from the supersonic bullet, the reflection from the ground, and the muzzle blast. The time elapsed between the shock wave and the muzzle blast increased with increasing distance: 94 ms for a distance of 50 m, and 507 ms for a distance of 300 m. The highest peak sound level downrange from a single round was between 151 dB(C) and 148 dB(C) at distances from 50 m to 300 m, and varied little if at all with distance. To the left of the gun, the peak sound pressure level of 161 dB(C) at 0.3 m reduced to 128 dB(C) at 32 m. The peak sound pressure level was estimated to be 137 dB(C) at a distance of approximately 20 m to the left-hand side. Hearing protection must therefore be worn by anyone closer than 20 m to a person firing. The peak sound pressure level was estimated to be 135 dB(C) at a distance of approximately 25 m and therefore hearing protection is recommended at distances of up to 25 m. The sound exposure level of 98 dB(A) at 20 m indicated that an observer at this distance could hear about 1440 rounds without hearing protection before the noise exposure reached the upper exposure action value specified in the *Control of Noise at Work Regulations 2005*. Peak sound pressure levels were on average 2.4 dB higher at the left ear compared with the right ear.

1. Introduction

The noise produced by high-velocity rifle fire has two main components. These are often referred to as the 'crack and thump' or 'crack and boom'. The 'crack' is from the supersonic shock wave which travels with the bullet and the 'thump' is from the muzzle blast radiating from the open end of the rifle barrel. The generation of these sounds is discussed by Markula [1] and by Mäkinen and Pertilä [2] among others.

For the person firing, and for those nearby in the firing line, only the thump of the muzzle blast is apparent and the noise presents a hazard to unprotected hearing. For persons being fired at, for those in the line of fire, the 'crack' always occurs before the 'thump'. A perceptible time delay between the two sounds can give an experienced listener a rough indication of the distance of the firer, while the thump may give an indication of the direction. The 'crack' can be localised separately, but does not indicate the direction of the firer [3].

Research is currently underway to develop functional hearing tests for military personnel [4,5], and one aspect of this is the ability to localise small arms fire. As part of that research, binaural recordings were made at various distances from a rifle in the line of fire on an outdoor military firing range. An opportunity therefore arose to make conventional sound pressure level measurements at various distances downrange of the rifle, and also at various distances to the side of the person firing, at positions which could be occupied by other firers training on the range. This paper describes the conventional sound level measurements only.

2. Measurements made and methods used

2.1. Noise source, location, and environment

All noise measurements were made on a Ministry of Defence outdoor firing range at Warminster. The range, shown in Fig. 1, is generally flat with short grass. The rifle used in these tests was an SA80 (L85A2) 5.56 mm calibre "Individual Weapon" [6] as used by the British Armed Forces with standard NATO ammunition (5.56 mm × 45 mm). The rifle was fitted with a front grip incorpo-

* Corresponding author.
E-mail addresses: Gurmail.Paddan472@mod.uk (G.S. Paddan), M.C.Lower@soton.ac.uk (M.C. Lower).

http://dx.doi.org/10.1016/j.apacoust.2016.02.003

Fig. 1. The firing range from the viewing platform.

rating a retractable bipod support. It was fired from a prone position on a slightly raised platform, and aimed using an optical sight which was "zeroed" before each set of tests for maximum accuracy.

Sound levels were measured downrange from the rifle and to the side of the firer's head. Fig. 2 shows a plan of the measurement positions, which are described in detail below.

2.2. Measurements downrange

Sound level measurements were made at 50 m, 100 m, 200 m and 300 m downrange from the rifle using a Brüel & Kjær (B&K) 4938 "quarter-inch" pressure microphone. The microphone was mounted on a weighted tripod and connected to a B&K 2250 sound level meter via a microphone extension lead. The microphone was 75 cm to the right of a 'Kemar' manikin (as viewed from the firing position) and level with the manikin's ear, approximately 1.6 m above ground level. Fig. 3 shows the manikin and microphone as seen from the firing position.

The manikin was used for a separate study, but its presence dictated the location of our measurement microphone. The firer aimed approximately 30 cm above the head of the manikin, and fired one round at a time, not bursts. The axis of the quarter-inch microphone was vertical, i.e. the diaphragm was at grazing incidence to the sound from the muzzle, but slightly off grazing incidence, by about 30°, for the bullet shock wave. The microphone was fitted with a foam windscreen.

The sound level meter was programmed to record the microphone signal as a 'wav' audio file with 24 bit resolution and 48 kHz sampling rate. The meter, being downrange and close to the line of fire, was left to record unattended. Therefore it was not possible to measure levels of individual shots on site, only the single peak level of the complete recording period at each distance; levels of individual shots were obtained from the recordings later. Forty-eight single rounds were recorded and measured at 50 m and 100 m, while twenty-six rounds were recorded at 200 m and 300 m. The recordings at 50 m were made on 13 January 2014, and the remaining recordings were made on 12 March 2014. Temperatures were between 9 °C and 14 °C during the tests. Wind speeds were very low, between 0.5 m/s and 2.0 m/s on both days.

Fig. 3. View, from behind the firer, of the Kemar manikin with the quarter-inch microphone to the right. (The more distant microphone was not in use.)

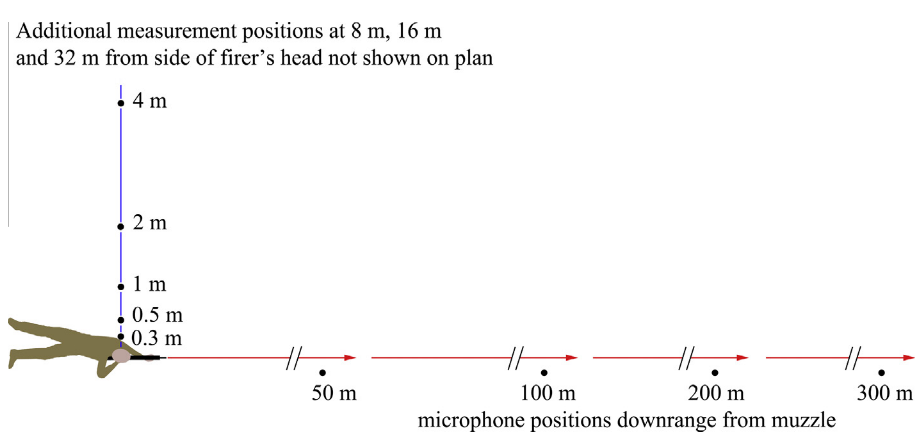

Fig. 2. Plan showing the sound measurement positions.