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MILITARY AIRCRAFT NOISE PREDICTION AND MEASUREMENT

Bernard F Berry and Anthony L Harris
National Physical Laboratory
Teddington
TW11 0LW U.K.

INTRODUCTION

For a number of years the National Physical Laboratory has been developing AIRNOISE, a mathematical model for computing military aircraft noise contours. The model is used by the Royal Air Force Institute of Community and Occupational Medicine (RAF ICOM) to determine eligibility for compensation for noise nuisance. Details of the criteria applied by the Ministry of Defence (MoD) and the background to them have been described by Boardman (1), and by Weston and Berry(2). This paper describes the AIRNOISE model including the extension of its capabilities to include the Harrier V/STOL aircraft in vectored thrust mode. It then goes on to discuss recent work on noise from low-altitude, high-speed operations and to outline the directions in which future developments are likely to take the work.

THE AIRNOISE MODEL

The mathematical model holds a database of information on source noise and operational flight profiles for the RAF's current aircraft inventory, from Jetstream to Tornado, and for a number of relevant USAF types. The basic model - AIRNOISE I - can compute the noise footprint in terms of five of the common single event noise descriptors. For a number of repetitions of the same event in a period of hours, the equivalent continuous A-weighted sound pressure level $L_{Aeq,h}$ can also be computed. Sets of footprints covering a range of levels of a given descriptor can be displayed graphically and plotted either directly onto a map or onto a transparent overlay, usually on a scale of 1:25000 or 1:50000. An improved and extended version - AIRNOISE II - has now been developed which has the capability of mapping noise exposure contours in $L_{Aeq,h}$ resulting from various operations including circuits. It takes into account both the number and mixture of aircraft types and their varied flight tracks. A sample set of contours is shown in Figure 1.

The basic source data were determined in a series of flight trials - codenamed Exercise Bedlam - designed to represent the airfield environment. These have been described in detail by Fethney and Hazell (3). One representative aircraft of each of the major types in service was required to fly over an array of microphones, on a straight and level path, at various engine power settings and in both "clean" and approach configurations. Aircraft were accurately tracked so that positional information was synchronised to the recorded noise. 1/3-octave band spectra were obtained for successive time intervals throughout each overflight and these were then extrapolated to a range of slant distances from 200 to 10000 feet using standard formulae to account for spherical spreading and atmospheric absorption (4). The values of the various noise descriptors were calculated from these extrapolated spectra and the numerical tables stored as disk files. Data for USAF types was taken from reports on the equivalent American model NOISEMAP (5).

Segmented flight profiles showing the variation in height along the ground track, together with the corresponding values of engine power, speed and aircraft configuration for each segment, were produced from information supplied by the operators and by AAEE Boscombe Down. A library of profiles is stored on disk and these can be displayed graphically on a monitor and modified via the keyboard as required. The alignment and curvature of ground tracks are entered in the form of headings and turn radii.

The model assembles the appropriate source noise and flight profile data and computes the noise level at each point in a rectangular grid or array of points, the grid spacing being selectable in the range 62.5 to 500 metres. Corrections are made for lateral attenuation using the SAE procedure (6). The effects of directivity and of acceleration from rest at the start of takeoff roll are incorporated using methods recommended by ICAO (7).

Although the Harrier V/STOL aircraft was included in the original source noise measurements, it was not possible at that time to obtain data with the aircraft operating in its unique vectored thrust mode. In order to improve the capability of modelling Harrier noise, a series of flight trials was conducted at RNAS Yeovilton using a Sea Harrier (8). In the first part of the trials the aircraft operated in hover mode, performing a number of vertical takeoffs, landings and turns. Later nine level fly-bys were made at a range of engine settings (68% - 94%), nozzle angles (0 - 65 degrees), and speeds (109 - 200 knots). Video recordings were made which were later analysed to give accurate information on height, lateral position and speed. Digital recordings were made of all noise events and the data were analysed and corrected in the same way as for Exercise Bedlam to give source data for incorporation into the model. An example is shown in Figure 2.

The mathematical model has been applied in a broad range of situations, in addition to routine production of contours to determine eligibility. These have include planning advice to UK local authorities and Tornado contours in connection with construction projects in the Middle East. The model was also included in a comparison of military aircraft noise prediction models used by Germany, Netherlands, Norway, USA and the UK, which formed part of a recent study of aircraft noise by the NATO Committee on the Challenges of Modern Society (CCMS) (9,Annex G).

A number of noise measurement exercises have been conducted which have allowed the evaluation of the accuracy of the model. An example was the trial with two Tornado F2 aircraft at RAF Leeming in 1985 (10). This exercise emphasised the importance of having correct information on flight profiles actually used. A measurement technique developed by NPL for tracking aircraft on takeoff using two video cameras/recorders showed the actual flight profiles were significantly lower than those assumed in modelling. A comparison between measured values of sound exposure level and the levels predicted using the modified profiles is shown in Figure 3.

NOISE FROM LOW-ALTITUDE OPERATIONS

In the UK as in other NATO countries, there is growing concern about noise from high-speed low-altitude operations. The House of Commons Defence Committee recently reported on noise and other aspects of such operations.(11). At the Fifth International Conference on Noise as A Public Health Problem, Galloway referred to "of the order of 150,000 sorties" expected in the UK during 1986 (12).

The problem of measuring, predicting and rating this type of noise has been studied in some depth in recent years in the USA and the role of the onset rate has been emphasised to the extent that a special descriptor termed "onset rate adjusted sound exposure level" has been proposed (13). To help in answering a number of questions about UK operations, we are currently extending the mathematical model to include low-flying. The objective is to predict not only maximum levels but also the onset rate of the noise of these very rapid events. A prediction model has been designed and implemented in software, based on an initial trial which has provided basic source noise directivity information. To aid further refinement and validation of the model, a special joint NPL/RAF ICOM trial - "Exercise Luce Belle" - has been conducted at RAE West Freugh in which Tornado, Harrier, Jaguar, Hawk and two USAF aircraft, F-15 and F-16, have flown straight and level at altitudes such as 250 and 100 feet at various speeds and engine power settings. Some conditions were used in the trial which are not flown in the course of ordinary low flying, e.g. speeds of 550 knots.

At the primary site, directly under the flight path, a linear array of six microphones was deployed. Two of these were on concrete with one of them being at the conventional height of 1.2 m, whilst the other was in the ground plane using the configuration recommended by Payne (14). The remaining four microphones were on grass, comprising two at 1.2 m and two at the ground plane. A further pair of 1.2 m / ground plane microphones were deployed at 100 m to the sideline. At a secondary sideline site 1000 m away, a similar pair was used. Each of the microphone signals was recorded digitally, using either DAT or PCM recorders along with time-code signals. Video recordings were made, to determine aircraft position and speed etc. The exercise has generated a large quantity of data, of the order of 1000 noise "events" for the NPL sites alone. A detailed NPL report is in preparation but some preliminary results can be given here.

Figure 4 compares the time-histories of the A-weighted sound pressure level (F time-weighting) for the two extreme sets of conditions used in the trial for the Harrier aircraft. The onset rates are 25 dB/s and 50 dB/s and the 10dB-down durations are 2.0 and 0.8 seconds. The maximum levels for the two sets of conditions differ by 13 dB. Figure 5 summarises the data on maximum levels for the Tornado for one of the 1.2 m microphones at the primary site. The values are the average of three events at each condition. The effects of altitude and power/speed can be clearly seen. When the analysis is complete, comparisons will be made between the measurements and the NPL model predictions. It will also be interesting to compare the data with extrapolations from the original Bedlam data and with data acquired in similar trials in the USA at the Aerospace Medical Research Laboratory at Wright Patterson AFB (15), and with information reported by Marohn on measurements in Germany (16).

FUTURE PLANS

Since the first version of AIRNOISE was delivered to RAF ICOM in 1982, there has been a continuous programme of development to meet the evolving needs of MoD. Plans are in hand to extend the model to include helicopter operations. Other studies are envisaged to incorporate in predictions the variability of flight tracks, for both airfield and low-altitude operations, and to model meteorological and terrain effects. There is also a constant need for systematic updating of source noise information as new aircraft types, or major modifications, from Tucano to EFA, come into service.

ACKNOWLEDGEMENTS

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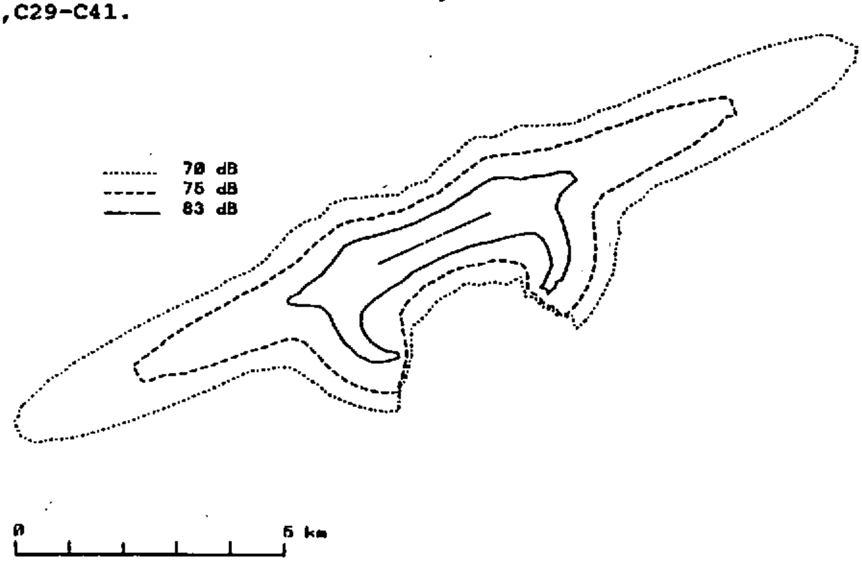

Figure 1. Example of contours of $L_{Aeq,12h}$ from AIRNOISE II

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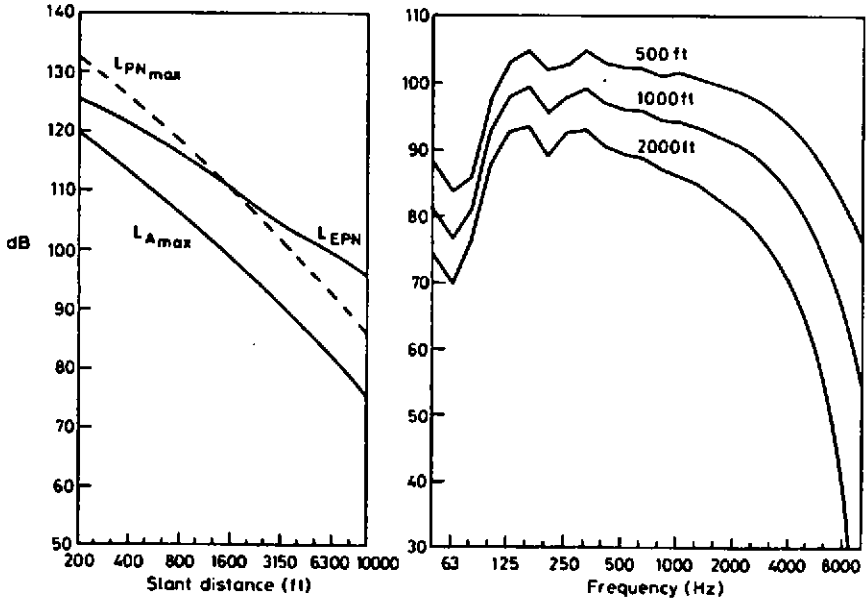

Figure 2. Derived noise-distance curves and spectra for Harrier in vectored thrust, 93% power

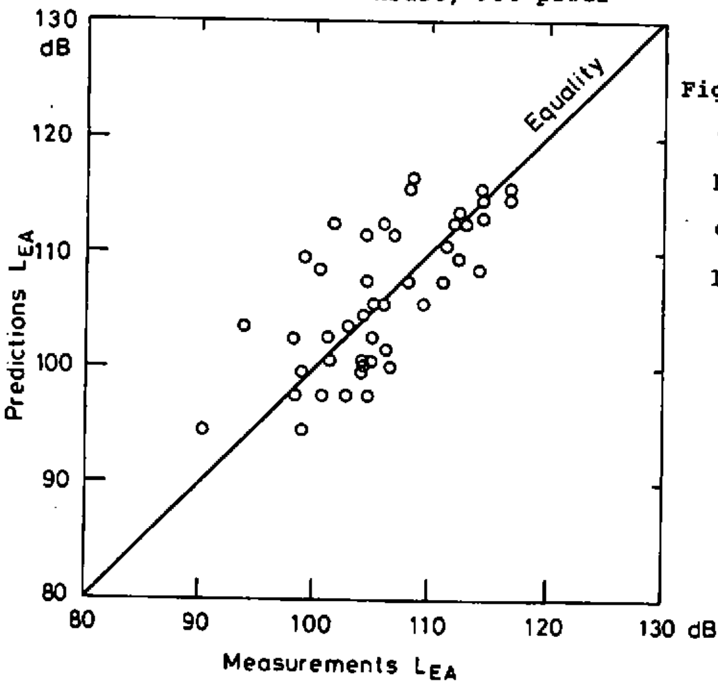

Figure 3. Comparison of measured and predicted values of sound exposure level.

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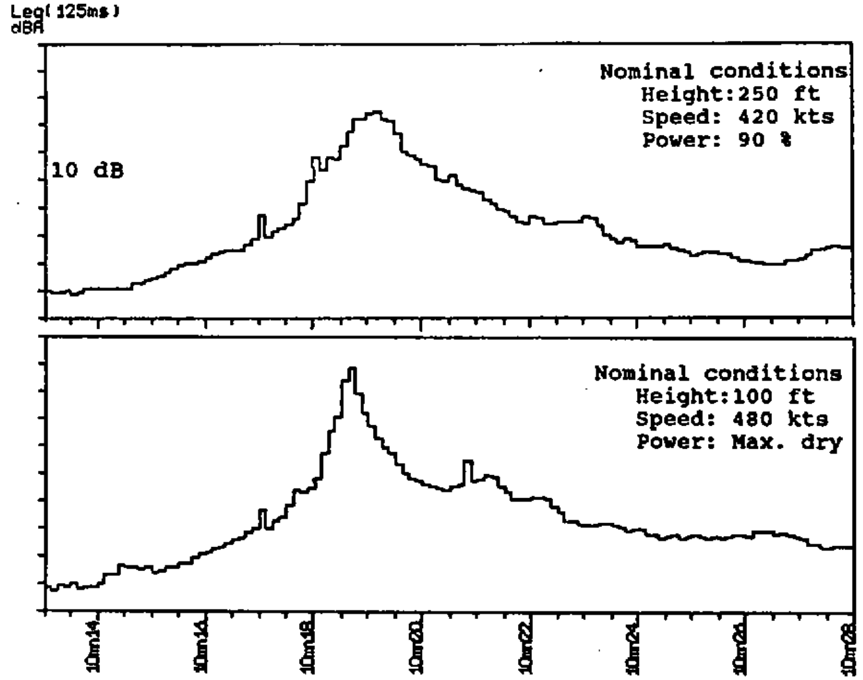

Figure 4. Time-histories for Harrier at low altitude.

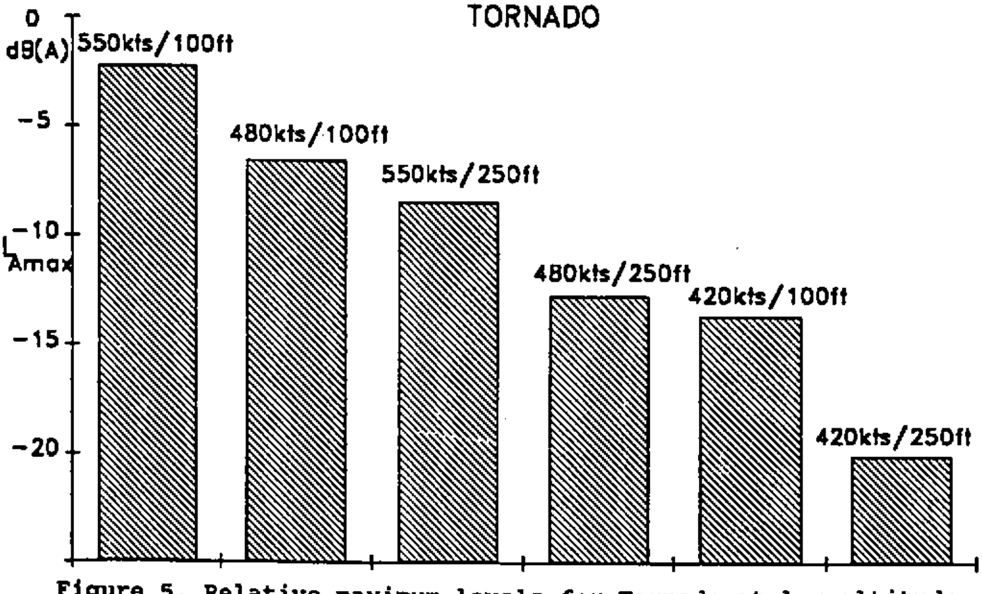

Figure 5. Relative maximum levels for Tornado at low altitude.