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A New Version of the Helicopter Aural Detection Program--ICHIN

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SUMMARY

NASA Langley Research Center personnel have conducted an evaluation of the helicopter aural detection program "I Can Hear It Now" (ICHIN version-5). This was accomplished using flight noise data of five helicopters, obtained from a joint NASA and U.S. Army acoustics measurement program. The evaluation consisted of presenting the noise data to a jury of 20 subjects and to the ICHIN-5 program. A comparative study was then made of the detection distances determined by the jury and predicted by ICHIN-5. This report presents the changes made in the ICHIN-5 program as a result of this comparative study. The changes represent current psychoacoustics and propagation knowledge.

INTRODUCTION

NASA Langley personnel, in a joint effort with U.S. Army personnel, obtained an extensive flight acoustics data base for five Army helicopters. As part of this effort Langley personnel conducted a study to evaluate the current version of the helicopter acoustics detection program "I Can Hear It Now", (ICHIN), originally derived by Abrahamson (ref. 1). The purpose of the evaluation was to use the current acoustics data base and research to determine if ICHIN could be improved. The purpose of this report is to present a brief discussion of the unclassified results of the study, and of the changes made in the ICHIN program.

The ICHIN program was the result of a basic experiment to measure helicopter aural detectability (ref. 1). This experiment, conducted by Abrahamson, consisted of three helicopters flown at constant altitudes and speeds. A group of 25 subjects was seated along the flight path of the aircraft and listened to determine when they could detect its acoustic signals. The study concluded that it was possible to predict the range at which a helicopter may be aurally detected. Based on these results and a set of measured acoustics and weather data, the ICHIN aural detection program was structured to require measured helicopter and ambient noise spectra, weather data, and ambient noise and weather conditions under which it was desired to determine if the helicopter could be detected. ICHIN-predicted results are then provided in an output listing of one-third octave band frequencies, detected ranges of the aircraft, and the probability of detection at those ranges.

DISCUSSION

The evaluation of the most current version of ICHIN (version-5) consisted of two parts. First, psychoacoustics research was conducted in an anechoic laboratory with a jury of 20 subjects listening to some of the measured helicopter flight noises obtained from the current data base. Secondly, after these tests, predicted detection distances were determined by using the measured flight noise data as input to the ICHIN-5 program . The results from these two parts were then compared and the ICHIN program was separated into four basic modules. Each module was then studied to determine if any improvements could be made.

ICHIN Modules: For the purposes of this research, the ICHIN program was separated into four modules. These modules were named the input, aural detectability, propagation, and output modules. The input module accepts weather and helicopter operations data, ambient acoustic noise and the measured one-third octave band or discrete power spectral density noise of the helicopter. ICHIN requires the input spectra to be converted into a working master data format by a subroutine named STRETCH. This subroutine changes either one-third octave band or discrete power spectral density input spectra, into a constant bandwidth spectrum as specified by the researcher. The aural detectability module then accepts the spectra which have been passed through STRETCH and converts them into critical-band spectra. These critical-band spectra are operated on by routines within the propagation module to produce "propagated spectra." They are then compared to the detectability criteria in the aural detectability module. Once a complete detectability analysis has been performed on these "propagated spectra", the detectability results are then listed by the output module. This module lists the ranges at which ICHIN predicts the input spectra would be detected. Also the output module, if specified, will list the intermediate computations used in the detectability analysis.

Good agreement between measured and predicted detection ranges is obtained if the acoustic input data are derived from measurements of aircraft noise at a distance which approximates the subject detection ranges. It was observed that if spectra measured at ranges on the order of a few thousand feet were submitted to the ICHIN-5 program, the predicted ranges of detection were less than those determined by the subjects. Based on these results, each of the elements in the four modules was evaluated to determine if any improvements could be made.

MODULE CHANGES

Input Module: Several changes were made to the input module to facilitate working with ICHIN. It has been modified (a) to accept narrow-band SPL spectra, (b) to compute sound speed as a function of measured temperature, (c) to compute helicopter Mach number as a function of temperature, (d) to accept direct input of relative humidity, and (e) to compute absolute humidity. It was observed during the study of the input and aural detectability modules that the subroutine STRETCH contained several significant programing errors. These errors were corrected.

Aural Detectability Module: Masking noise experiments in the past 10 years have led to an improved understanding of the human auditory system. The aural detectability module within version-5 includes research by Fidell, et al., (ref. 2), who suggested there was an apparent increase in the auditory filter bandwidth at low frequencies relative to those implemented in the original version of ICHIN (ref. 1). Recent masking experiments, (refs. 3-6) using wideband noise with a notch in the spectrum indicate that instead of an increase in bandwidth, there is a decrease in the observer's detection efficiency. This permits a reevaluation of the current, and the original auditory filter bandwidth expressions of Greenwood (ref. 7) used in the original ICHIN (ref. 1). As a consequence of the research presented in references 3-7, the detection efficiency now may be thought of as a function of frequency rather than as a constant as expressed in the ICHIN (version-5) model evaluated by the Langley staff. The result of the reevaluation was that a greater signal-to-noise ratio is required for detection at the low frequencies than previously thought necessary. Additionally, the shape of the auditory filter, as proposed by Patterson (ref. 4), is currently believed to be more appropriate to include in ICHIN.

In summary, the following changes have been made in the aural detectability module: (a) the equivalent rectangular bandwidths described by Greenwood are used; (b) the detection efficiency is expressed as a function of frequency; and (c) the rounded exponential shape described by Patterson (ref. 4) is used.

Propagation Module: The propagation module of ICHIN, version-5, is in the same form as the original version (ref. 1). This module consists of three elements using expressions to account for the energy losses experienced by the acoustics signal (assumed to be a point source) as it propagates over long ranges. The loss mechanism elements considered are (1) spherical spreading or "inverse square law", accounted for by decreasing the signal amplitude 6 dB for each doubling of distance, (2) atmospheric absorption losses expressed by ARP 866 (ref. 8), and (3) "excess attenuation" losses expressed by empirical relationships derived from measured data.

Each of these elements within the propagation module was evaluated at frequencies below 200 Hz (those which propagate best over long ranges). The spherical spreading loss expression was thought to be acceptable over the propagation distances considered in ICHIN. Extensive research has shown that the atmospheric absorption loss as expressed by ARP 866 is better represented by expressions contained in the American National Standard ANSI S1.26-1978 (ref. 9). Additionally, the model of atmospheric absorption losses developed by Zuckerwar (ref. 10) was evaluated. There were no significant differences between the losses computed with the ANSI model and the Zuckerwar model. Thus the ARP expressions in ICHIN-5 were replaced by those contained in reference 9. The ANSI expressions show that less energy (dB per thousand feet) is removed from the propagated signal than if the expressions in ARP 866 are used. At ranges larger than 30,000 feet, the use of ANSI in lieu of ARP 866 will result in higher predicted signal amplitudes, with differences as large as 6-8 dB in the frequencies below 200 Hz. At distances up to 20,000 feet, these differences between ANSI and ARP 866 are not as large, being on the order of 1 to 2 dB.

The "excess attenuation" (EA) element within ICHIN (ref. 1) consists of all other unexplained influences. These include ground impedance effects, refraction, diffraction, background noise, source changes, radiation pattern effects, and turbulence in the atmosphere. The EA expressions appear to remove significantly more energy from the "propagated" signal than the measured results show in the current data base. The expressions in the EA element were based on one-third octave band data analyses from a single microphone. Reference 1 also notes that the acoustics results are based on nonstationary data. Because of the wide range of EA results and in some cases only a few data points in the

ICHIN basic experiment, double-linear regression analysis techniques were used to obtain the EA expressions. This results in contradictory math expressions for EA under a "no-wind case" using the "up-wind" and "down-wind" expressions.

It was believed that the data base obtained in the joint NASA/Army tests would permit a significant improvement in the EA expressions. The amplitudes of the data evaluated had 90% confidence interval of ± 1dB, were approximately statistically independent and stationary. The data were reduced for all of the flight conditions and intensively studied. In general, it was observed that the data showed greatly reduced values of "excess attenuation" as compared to those in ICHIN-5. However, the EA values obtained from the current data base also exhibited significant data scatter. This resulted in producing EA expressions which were inconsistent from one data set to another. Because of this, it was decided to not suggest a replacement EA element for that in ICHIN-5.

CONCLUSIONS

The helicopter aural detection program "I Can Hear It Now" (ICHIN, version-5) has been evaluated using the results of current laboratory and field experimental research. Based on this evaluation, the most current version, ICHIN-5, was separated into four modules for study. It was concluded that each module, except for the output module, required changes to reflect the status of current research. Changes made in the version-5 program were:

1. A modification of the input module to accept narrow-band sound pressure level spectra, to compute sound speed as a function of measured temperature, to compute helicopter Mach number as a function of temperature, to accept direct input of relative humidity, and to compute absolute humidity.

2. The correction of several significant programing errors in the subroutine STRETCH, which is preliminary to the aural detectability and propagation modules.

3. A modification of the aural detectability module to include the original auditory filter bandwidth expressions of Greenwood (ref. 7), the expression of the detection efficiency as a function of frequency, and the use of the rounded exponential auditory filter shape of Patterson (ref. 4).

4. A modification of the propagation module to implement the American National Standard for atmospheric absorption of sound, ANSI S1.26-1978 (ref. 9).

In summary, improvements were made in the documentation, the input module, the subroutine STRETCH, the aural detectability module, and the propagation module. The changes, incorporated in ICHIN-6, provide an improved agreement between the predicted and subject detection distance regardless of the distances measured for the input spectra.

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16. Abstract

NASA Langley Research Center personnel have conducted an evaluation of the helicopter aural detection program "I Can Hear It Now" (ICHIN version-5). This was accomplished using flight noise data of five helicopters, obtained from a joint NASA and U.S. Army acoustics measurement program. The evaluation consisted of presenting the noise data to a jury of 20 subjects and to the ICHIN-5 program. A comparative study was then made of the detection distances determined by the jury and predicted by ICHIN-5. This report presents the changes made in the ICHIN-5 program as a result of this comparative study. The changes represent current psychoacoustics and propagation knowledge.

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