DEVELOPMENT OF IMPROVED EARPHONE-EARCUP SYSTEM FOR AVC HELMET

Michael A. Bryson
ELECTRO-VOICE, INC.
600 Cecil Street
Buchanan, MI 49107

November 1979
Final Report for Period August 1978 - October 1979

DISTRIBUTION STATEMENT
Approved for public release; distribution unlimited.

Prepared for:
CENCOMS

CORADCOM
US ARMY COMMUNICATION RESEARCH & DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703
NOTICES

Disclaimers

The citation of trade names and names of manufacturers in this report is not to be construed as official Government indorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.
This document covers the technical details of work performed to improve the noise attenuation characteristics and frequency response of an earphone-earcup system used in DH-132 AVC Helmet. This new design results in a system that is rugged, lightweight, has improved intelligibility, and reduced medical hazard for crewmen in tracked armored vehicles.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBJECTIVE</td>
<td>1</td>
</tr>
<tr>
<td>Problems with DH-132 Helmet</td>
<td>1</td>
</tr>
<tr>
<td>Goals of Development Effort</td>
<td>5</td>
</tr>
<tr>
<td>SYSTEM DESIGN</td>
<td>6</td>
</tr>
<tr>
<td>THE EARCUP</td>
<td>6</td>
</tr>
<tr>
<td>Additional Earcup Design Details</td>
<td>9</td>
</tr>
<tr>
<td>THE EARPHONE</td>
<td>12</td>
</tr>
<tr>
<td>Design of Closely Coupled Assembly</td>
<td>13</td>
</tr>
<tr>
<td>DESIGN TESTS</td>
<td>17</td>
</tr>
<tr>
<td>Weight</td>
<td>17</td>
</tr>
<tr>
<td>Impedance</td>
<td>17</td>
</tr>
<tr>
<td>Dielectric Strength, Insulation Resistance and Overload</td>
<td>18</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>18</td>
</tr>
<tr>
<td>Frequency Response</td>
<td>18</td>
</tr>
<tr>
<td>Harmonic Distortion</td>
<td>19</td>
</tr>
<tr>
<td>Linearity</td>
<td>19</td>
</tr>
<tr>
<td>Attenuation</td>
<td>20</td>
</tr>
</tbody>
</table>
# TABLE OF CONTENTS (Con't)

<table>
<thead>
<tr>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENVIRONMENTAL TESTS</td>
<td>21</td>
</tr>
<tr>
<td>Low Temperature</td>
<td>21</td>
</tr>
<tr>
<td>High Temperature</td>
<td>21</td>
</tr>
<tr>
<td>Rain</td>
<td>21</td>
</tr>
<tr>
<td>Immersion</td>
<td>21</td>
</tr>
<tr>
<td>Dust, Fungus and Blast</td>
<td>22</td>
</tr>
<tr>
<td>Humidity</td>
<td>22</td>
</tr>
<tr>
<td>Vibration</td>
<td>22</td>
</tr>
<tr>
<td>Shock, Drop</td>
<td>22</td>
</tr>
<tr>
<td>Salt Fog</td>
<td>22</td>
</tr>
<tr>
<td>Altitude</td>
<td>23</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>24</td>
</tr>
<tr>
<td>APPENDIX A, SAMPLE TEST DATA</td>
<td>25</td>
</tr>
</tbody>
</table>
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Envelope of Noise Sound Pressure Levels for Prototype Combat Tracked Vehicle</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Model 993 Earphone Response on 6cc Coupler, 1 mW Applied</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Model 993 Earphone in DH-132 Earcup, 1 mW Applied</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Electrical Circuit Simulation of Earcup System</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Mean Attenuation of 20 Helmets</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>Cross Section of Earphone-Earcup System</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>Variations in Response Caused by Clamping Pressure</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean Attenuation of Twenty (20) Helmets Produced on Contract DAAB07-78-C-0176</td>
<td>10</td>
</tr>
</tbody>
</table>
OBJECTIVE

The objective of the technical effort described herein was a two-fold development project to improve the noise-attenuating and intelligibility properties of the earphone-earcup system used in the DH-132 Armored Vehicle Crewman Helmet.

Problems with DH-132 Helmet

High sound pressure levels of noise are generated within tracked armored vehicles which necessitates the use of hearing protection for all crewman in the vehicle. When used in the prototype Mechanized Infantry Combat Vehicle (MICV) the noise attenuation characteristics of the DH-132 Helmet permit only one hour of exposure to the noise to comply with the requirements of U.S. Army publication TB MED 251.1

The Electro-Voice Model 993 earphone element which was designed to operate against the ear, approximately a 6cc cavity volume, has a very non-linear frequency response when operated in the large cavity volume of the DH-132 earcup.

The seriousness of these problems is shown in Figures 1, 2, and 3 which show the sound levels generated within the MICV, and frequency response of the Model 993 when operated into a 6cc coupler and when operated in the DH-132 earcup.

1USAARL REPORT NO. 77-8, Medical Assessment of Acoustic Protective Devices Proposed for Use in a Prototype Mechanized Infantry Combat Vehicle.
ENVELOPE OF NOISE SOUND PRESSURE LEVELS FOR PROTOTYPE COMBAT TRACKED VEHICLE

Figure 1
MODEL 993 EARPHONE RESPONSE
ON 6cc COUPLER, 1 mW APPLIED

Figure 2
MODEL 993 EARPHONE IN DH-132 EARCUP, 1 mW APPLIED

Figure 3
Goals of Development Effort

One of the goals of this effort was to improve the noise attenuation of the earcup to allow eight hours of continuous exposure to noise encountered in the MICV and other tracked armored vehicles. The other goal was to generate a linear frequency response from the earphone when operated in the new earcup. This report demonstrates how these goals were attained.
THE EARCUPE

In order to understand the noise-attenuation of the earcup we used a simulation of the system to find areas where improvement could be made. An electrical equivalent circuit of the earcup was used along with a computer to evaluate the effects of changing the various parameters of the earcup on its attenuation. The model shown in Figure 4 is an improved version of a model used on a previous contract which has been modified to include the effects of the stiffness of the earcup. Changes to the earcup system are subject to the following conditions, however:

1. Weight of the earcup shall not be more than the existing DH-132 earcup.
2. A means to retain the earphone element shall be incorporated.
3. The earcup shall be physically interchangeable with the existing DH-132 earcup.
4. The earcup shall be constructed of an insulating material.
5. Earcups shall use the same switch and boom mounting hardware as the existing DH-132 earcups.

Analysis of the noise of the MICV shows that attenuation of the low frequencies is the most important area of improvement required. It was determined that the earcup volume could be increased approximately 25% and still meet the above restrictions. The improvement in attenuation by the larger earcup volume fell short of the DS-AF-0265A(A) design.
\[ M_e = \text{Mass of total earcup system} \]
\[ R_e = \text{Damping of earcup plastic material} \]
\[ C_e = \text{Compliance of earcup} \]
\[ R_c = \text{Damping of earcushion (ignores damping of skin as earcushion value is much larger)} \]
\[ C_c = \text{Compliance of earcushion} \]
\[ C_s = \text{Compliance of skin} \]
\[ C_{ca} = \text{Compliance of earcup cavity} \]

**ELECTRICAL CIRCUIT SIMULATION OF EARCUP SYSTEM**

*Figure (4)*
requirements. Working with the computer simulation and experimenting with various materials, it was determined that a new earcushion filler material could provide the greatest improvement in low frequency noise attenuation.

Examining the circuit in Figure 4, we see that reducing the series compliance represented by the earcushion and the skin on the wearer's head decreases the signal presented to the ear via the cavity of the earcup at low frequencies. Using the computer simulation and tests on our dummy head, we have determined that the compliance of the skin limits the maximum attenuation of the earcup, with mass and volume fixed by restrictions above, between 30 and 35 dB, assuming a perfect seal and an earcushion with no compliance. Because of the differences in wearer's heads and comfort when wearing the helmet, an earcushion with some compliance must be used.

To meet the earcushion compliance requirements a new earcushion filler was needed. We tried a foam material called "Low-Perm" foam which has improved characteristics over the present filler; yet, this material is only produced in one compliance and has a closed cell construction. Another material called "Temper Foam" was found that is made in an open cell construction which is produced in five different compliances. Temper Foam is sensitive to both pressure and temperature along with a slow recovery rate property. A compliance that provides good comfort and low frequency attenuation is obtainable with this material. The compliance is highly temperature dependent, becoming very stiff at low temperatures. In actual use the wearer would warm the cushion with their hands and, when placed on the head, the warmth from the body would keep the cushion soft for comfort.
We are not able to obtain all the minimum attenuation values required by the specification, even with the increased volume and new cushion filler (see Table I and Figure 5). We feel the attenuation obtained at low frequencies is close to the highest practical value for this type of earcup design. A stiffer earcushion is available in Temper Foam, yet it will be uncomfortable and would require excess pressure against the head to obtain a seal.

Additional Earcup Design Details

In order to increase the volume and keep the mass of the earcup the same, requires changes in the design of the earcup shape and material. The wall thickness had to be decreased which makes the earcup construction less stiff, reducing high frequency attenuation. In order to reduce the weight additionally and retain the stiffness of the thick ABS wall in the thinner wall, we used a nylon foam plastic material. When properly foamed and assembled, a nylon and nylon-foam earcup will be the same weight as the existing design and more rugged than the ABS design now used. Our prototypes used an ABS and nylon-foam construction because we would have to make four injection molds to produce the parts, where only two of the parts are of a new design configuration. Weight of the prototypes was higher than that which will be realized in the production models of the new design; however, the performance should be the same or better for the lighter versions.

For the earcushion cover we used a polyether polyurethane film. This film has been found to have superior properties when compared to the
<table>
<thead>
<tr>
<th>1/3 Octave Band in Hertz</th>
<th>SPL of Noise Used for Test</th>
<th>Specification (Minimum)</th>
<th>Attenuation in dB</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>93</td>
<td>22</td>
<td>16.9</td>
</tr>
<tr>
<td>100</td>
<td>102</td>
<td>22</td>
<td>16.4</td>
</tr>
<tr>
<td>125</td>
<td>107</td>
<td>22</td>
<td>14.5</td>
</tr>
<tr>
<td>160</td>
<td>105</td>
<td>22</td>
<td>15.7</td>
</tr>
<tr>
<td>200</td>
<td>102</td>
<td>23</td>
<td>16.1</td>
</tr>
<tr>
<td>250</td>
<td>108</td>
<td>24</td>
<td>22.4</td>
</tr>
<tr>
<td>315</td>
<td>108</td>
<td>24</td>
<td>20.3</td>
</tr>
<tr>
<td>400</td>
<td>105</td>
<td>26</td>
<td>24.8</td>
</tr>
<tr>
<td>500</td>
<td>103</td>
<td>28</td>
<td>30.4</td>
</tr>
<tr>
<td>630</td>
<td>101</td>
<td>30</td>
<td>29.9</td>
</tr>
<tr>
<td>800</td>
<td>99</td>
<td>31</td>
<td>32.7</td>
</tr>
<tr>
<td>1000</td>
<td>99</td>
<td>34</td>
<td>35.4</td>
</tr>
<tr>
<td>1250</td>
<td>99</td>
<td>34</td>
<td>38.4</td>
</tr>
<tr>
<td>1600</td>
<td>98</td>
<td>34</td>
<td>38.0</td>
</tr>
<tr>
<td>2000</td>
<td>98</td>
<td>34</td>
<td>39.1</td>
</tr>
<tr>
<td>2500</td>
<td>95</td>
<td>38</td>
<td>39.6</td>
</tr>
<tr>
<td>3150</td>
<td>95</td>
<td>43</td>
<td>40.3</td>
</tr>
<tr>
<td>4000</td>
<td>91</td>
<td>45</td>
<td>44.2</td>
</tr>
<tr>
<td>5000</td>
<td>90</td>
<td>45</td>
<td>47.5</td>
</tr>
<tr>
<td>6300</td>
<td>88</td>
<td>40</td>
<td>47.8</td>
</tr>
<tr>
<td>8000</td>
<td>86</td>
<td>40</td>
<td>45.8</td>
</tr>
<tr>
<td>10000</td>
<td>79</td>
<td>40</td>
<td>41.9</td>
</tr>
</tbody>
</table>
MEAN ATTENUATION OF 20 HELMETS
(SEE TABLE I)

--- Specification (Minimum)
----- Mean

Figure 5
vinyl film used presently. We tested this film on a previous development contract (DAAB07-76-C-0149) in which it was shown to be flexible at sub-zero temperatures, fungus resistant and tear resistant.

**THE EARPHONE**

As explained in the beginning of this report, the Model 993 and other earphones which are designed to operate into a 6cc cavity do not perform well in a large earcup. Two possible design modifications are:

1. Mount the earphone to closely couple it to the ear as it was designed to operate.

2. Redesign the earphone to operate in the large earcup.

From past experience we decided to concentrate our efforts on placing the earphone against the ear. To make a lightweight earphone element operate in a large earcup, we would have to sacrifice efficiency and frequency response which is undesirable.

Positioning and sealing the earphone against the ear are the most difficult problems caused by the closely coupled design approach. Variations in user ear dimensions necessitate a loose attachment of the earphone to the earcup. The positioning mechanism must be lightweight, exert a small force to hold the earphone in the proper position, and allow easy placement and removal of the helmet. An additional requirement is to make the earphone a replaceable item separate from the earcup. Since the earphone cover presents a hard, flat surface to the ear, some form of cushion between the ear and earphone is required to provide a good seal and comfort to the wearer.
Design of Closely Coupled Assembly

Figure 6 shows the method chosen to support the earphone in the earcup. A compression spring is attached to the earphone element and a mounting bracket. We chose to permanently attach the spring assembly to the earphone as this provided the lightest weight construction and only required minor modifications to the earphone case. For the prototypes the spring was soldered to metal brackets at each end—an assembly method that would not be used on a production version. The reliability of the soldered connection has been found to be poor even though the unit used in the drop test held together. Production units should incorporate some sort of metal tabs from the brackets which could be crimped over the spring and lock it in place.

A force of 1/3 to 1/2 kilogram was chosen to be applied by the spring when pressing against the ear. Most earcups are designed with a one kilogram force. If we used one kilogram of force for this application, then the earcup would have to apply two kilograms force against the head, which is excessive! The spring force was selected as a reasonable compromise for the total force applied to the wearer’s head.

Various materials and earpad shapes for sealing the earphone to the ear were tested. A lightweight ring fashioned out of polyurethane foam was evaluated. The foam provided a good seal but has two drawbacks. Because of its compliance it allows the earphone to move in relationship to the head and thus lowers the noise attenuation of the earcup system. Also, the foam would be difficult to clean, presenting a hygiene problem. The selected material is a soft, rubber-like plastic that can be molded into
Cross Section of Earphone-Earcup System

Figure 6
the desired shape. This material, "Satinflex", has a compliance almost identical to human skin, is fungus resistant and is easy to clean. We have molded it as a replaceable earpad to be placed over the earphone element.

Since we had to compromise the force applied to the ear, the seal obtained is not adequate to obtain a response that is flat to 200 Hertz. When properly fitted, the frequency response measured at the ear consistently falls within a 6 dB envelope from 400 to 5000 Hertz. Figure 7 shows the variation in response obtained because of differences in sealing. The frequency response is better than we would expect to obtain from an earphone modified to work in the earcup and should provide good intelligibility. We feel the loss in low frequency response is acceptable as the added force for a good seal would be uncomfortable when the helmet is worn for extended periods.
VARIATIONS IN RESPONSE CAUSED BY CLAMPING PRESSURE

- - - - 6cc Frequency Response
- - - - - 1 Kg Force
- - - - - 1/3 Kg Force

Figure 7
DESIGN TESTS

Weight

Our prototypes weigh approximately 25 grams more than the earcups they are to replace. Examining the density of the nylon foam parts, we found that the parts were not processed by the vendor correctly. In order to make good parts, water cooling would have to be added to the tooling and an injection molding machine with better control is required. The added delay and cost to modify the tooling and make new parts would only result in parts with reduced weight and have little effect on evaluating the performance of the earcup. We chose to go ahead and use the nylon foam plastic parts as received.

Impedance

The impedance of all the earphones was measured with the units mounted to the dummy head test fixture. The impedance of the earphones was 10 to 15 ohms lower than the value of the impedance measured when the earphones are unloaded. Because the impedance changes less than 2% from a loaded to unloaded condition, the measurement technique has little effect on the result. Measuring the impedance in free air is easier and yields the desired results.
Dielectric Strength, Insulation Resistance and Overload

These tests are common to all our earphone designs. We use materials and construction techniques that allow our earphones to consistently pass these tests. All the earphones made on this contract were subjected to and passed the above tests.

Sensitivity

With one milliwatt of power applied to the earphone, the output pressure was always above 104 dB SPL. The specification allowed a minimum level of 85 dB SPL for an earphone which would operate into the earcup. Since the closely coupled approach has been used, 104 dB SPL should be the new minimum level for one milliwatt input in this application.

Frequency Response

As explained in the section on the earphone, the frequency response measured at the ear is dependent on the pressure applied to provide a seal to the ear. When measured on a 6cc coupler or with sufficient pressure applied and measured at the ear, the response falls within a 6 dB envelope between 200 and 5000 Hertz. The high mass of a practical 1000 ohm voice coil limits the response to a 5000 Hertz maximum. It might be possible to use smaller wire in the voice coil to extend the response to 6000 Hertz as the specification calls for, but past experience shows the resulting unit is difficult to build, would be less reliable, and might have difficulty passing an overload test.
Because of the variations in microphone placement and human ear dimensions, we recommend that the 6cc coupler be the standard for testing the earphone with the limits between 200 and 5000 Hertz rather than the in ear technique which is not standardized.

Harmonic Distortion

Measuring the distortion per the design specification presented a problem. Our earphones, when operated into a 6cc coupler and against the ear 'typically', have less than 1% distortion. We placed the dummy head in our large anechoic chamber, which is the quietest room we have, where the ambient noise level is on the order of 45 dB SPL. The noise level in the chamber looks like 1% harmonic distortion at the measurement level of 85 dB SPL. Only the 105 dB SPL measurement level gave us a signal to noise level sufficient to measure harmonic distortion.

Because of the low distortion levels and expense of testing, only the 105 dB SPL measurement level should be used as a specification requirement for harmonic distortion of the earphone.

Linearity

A constant voltage versus frequency at three voltage levels was applied to the earphones. The output sound pressure was recorded for the three input levels. The output sound level varied linearly with the input voltage level.
Attenuation

Various ways of measuring the noise attenuation of the earcup system were used for evaluation. The values obtained in Table I were measured on a dummy head with a noise spectrum that simulated that of a tracked armored vehicle. These values are not as good as expected, but are representative of those to be realized in actual usage. When a flat sound spectrum at lower sound pressure levels is used instead of the shaped spectrum, the values of attenuation are greater and correlate better with our computer simulation. We do not report the latter attenuation values as they apply to a test method which is not representative of actual use. Tests were made with a miniature microphone placed in a subject's ear to further verify the attenuation values of the dummy head test fixture. Because of electrical signal to noise, the attenuation at high frequencies could not be measured accurately. This is because the sensitivity of the miniature microphone is much lower than the one inch B & K microphone used in the dummy head. The values in the low to middle frequencies agreed with that recorded with the dummy head. More theoretical study is needed to determine why the attenuation at high sound levels decreases when compared to moderately high sound levels.
ENVIRONMENTAL TESTS

Low Temperature

An earphone-earcup system was exposed to -50°C temperature as specified in DS-AF-0265A(A). After the temperature of the unit had stabilized, a signal was applied and the level recorded. At the low temperature the level increased 2 dB. When returned to ambient temperature, the level and response were identical to that taken before the test.

High Temperature

No change in performance of the earphone-earcup system was experienced as a result of exposure to 160°F temperature. When checked at 160°F the level had decreased one dB from the level at ambient temperature.

Rain

The rain test trapped more water in the front cover than expected. Only a slight shake was used to remove the water before testing the unit's response. Minor degradation was noted immediately after the rain test. Later, when the rest of the water trapped had been removed, the unit showed no degradation.

Immersion

Immersion tests were run twice on the earphone-earcup system as required by the design specification. We recorded the frequency response before and after the test, and only minor differences were noted.
Dust, Fungus and Blast

These tests were not performed on this contract. The design and materials used in the earphone and earcup have been shown to be resistant to these tests, thus, we passed over these tests to concentrate on other tasks in the design.

Humidity

Examination of the unit after exposure showed no visible change. No degradation of the sensitivity was noted after the test.

Vibration

Exposure to the vibration test caused a minor change to the frequency response. The unit still met specification requirements as a result of the exposure.

Shock, Drop

Dropping a unit 26 times on to a two inch thick piece of plywood backed by concrete from a height of four feet caused no degradation to the unit's performance, even after immersing it in water as specified by DS-AF-0265A(A)

Salt Fog

One unit was exposed to the 48 hour salt fog test of MIL-STD-810C, Method 509.1, Procedure I. Only a slight discoloration on the spring assembly was observed with no degradation in the frequency response.
Altitude

The earphone-earcup system was subjected to an operating and non-operating altitude test. Because of the air tight seal of the earcup to the dummy head test fixture, the unit would not equalize rapidly at a 15,000 feet simulated altitude. When a small leak was provided in the earcushion seal, the unit equalized normally and the response changed only 3 dB at the high frequencies relative to the ground level response. In actual use this sealing characteristic should not present a problem. If data from the field shows this to be a problem, then an equalization port can be added. A non-operating altitude test of a simulated 40,000 feet altitude caused no degradation to the frequency response when the unit was tested afterward.
SUMMARY

A new earphone-earcup combination has been developed that will directly replace the earcup system now used in the DH-132 helmet which has improved intelligibility and reduced medical hazard to hearing for crewmen in tracked armored vehicles. This new design can be produced without adding weight to the helmet and does not sacrifice mechanical ruggedness for the larger volume and thinner walls of the new earcup.

Physical constraints of size and weight, plus practical considerations of comfort and fit prevented the obtainment of all the goals of DS-AF-0265A(A). Within the restraints of this design approach we have been able to show that an improved communications helmet system for use in tracked armored vehicles can be produced.
APPENDIX A

SAMPLE TEST DATA
UNIT #3

____ Before Overload Test

------ After Overload Test
Frequency Response Spread of All Units Tested

Form 1396
UNIT #6

Frequency Response
UNIT #1

Harmonic Distortion
UNIT #8

Linearity
DISTRIBUTION LIST

101 Defense Technical Information Ctr.
ATTN: DDC-TC
Cameron Station (3ldgs)
012 Alexandria, VA 22314

210 Commandant, Marine Corps
HQ, US Marine Corps
ATTN: CODE LHC
Washington, DC 20380

102 Director
National Security Agency
ATTN: TTL
001 Fort George G. Meade, MD 20755

211 HQ, US Marine Corps
ATTN: CODE INTS
Washington, DC 20380

103 Code R123, Tech Library
DCA Defense Comm Engrg Ctr
1860 Wiehle Ave
001 Reston, VA 22090

212 Command, Control & Communications Div
Development Center
Marine Corps Development & Educ
Cond
Quantico, VA 22134

104 Defense Communications Agency
Technical Library Center
Code 205 (P. A. Tovoli)
001 Washington, DC 20305

215 Naval Telecommunications Command
Technical Library, Code 91L
4401 Massachusetts Avenue, NW
Washington, DC 20390

200 Office of Naval Research
Code 427
001 Arlington, VA 22217

217 Naval Air Systems Command
Code: AIR-5332
Washington, DC 20360

203 GIDEPS Engineering & Support Dept
TE Section
PO Box 398
001 NORCO, CA 91760

300 AUL/ LSE 64-235
001 Maxwell AFB, AL 36112

205 Director
Naval Research Laboratory
ATTN: CODE 2627
001 Washington, DC 20375

301 Rome Air Development Center
ATTN: DOCUMENTS LIBRARY (TILD)
Griffiss AFB, NY 13441

206 Commander
Naval Electronics Laboratory Center
ATTN: LIBRARY
001 San Diego, CA 92152

304 Air Force Geophysics Lab
L.G. Hanscom AFB
ATTN: LIR
Bedford, MA 01730

207 CDR, Naval Surface Weapons Center
White Oak Laboratory
ATTN: Library, Code WX-21
001 Silver Spring, MD 20910

307 AFGL/SULL
S-39
HAFB, MA 01731

308 HQ, AFCS
ATTN: EPDGRN Mall Stor 105B
Richards-Gebaur AFB, MD 64030
312  HQ, Air Force Electronic Warfare Center
ATTN:  SURP
002  San Antonio, TX 78243

314  HQ, Air Force Systems Command
ATTN:  DLCA
Andrews AFB
001  Washington, DC 20331

314  HQ, Air Force Systems Command
ATTN:  DLCA
Andrews AFB
001  Washington, DC 20331

403  CDR, MIRCOM
Redstone Scientific Info Center
ATTN:  Chief, Document Section
001  Redstone Arsenal, AL 35809

406  Commandant
US Army Aviation Center
ATTN:  ATZQ-D-MA
003  Fort Rucker, AL 36362

408  Commandant
US Army Military Police School
ATTN:  ATSI-CD-M-C
003  Fort McClellan, AL 36201

417  Commander
US Army Intelligence Center & School
ATTN:  ATSI-CD-MD
002  Fort Huachuca, AZ 85613

418  Commander
HQ, Fort Huachuca
ATTN:  TECHNICAL REFERENCE DIV
001  Fort Huachuca, AZ 85613

419  Commander
US Army Electronic Proving Ground
ATTN:  STEEP-MT
002  Fort Huachuca, AZ 85613

432  Dir, US Army Air Mobility R&D Lab
ATTN:  T. GOSSETT, BLDG 207-5
NASA Ames Research Center
Moffett Field, CA 94035

436  HQDA (DAMO-TCE)
002  Washington, DC 20310

437  Deputy for Science & Technology
Office, Assist Sec Army (R&D)
Washington, DC 20310

438  HQDA (DAMA-ARZ/DR F.D. Verderame)
001  Washington, DC 20310

470  Director of Combat Developments
US Army Armor Center
ATTN:  ATZK-CD-MS
Fort Knox, KY 40121

475  Cdr, Harry Diamond Laboratories
ATTN:  Library
2800 Powder Mill Road
Adelphi, MD 20783

477  Director
US Army Ballistic Research Labs
ATTN:  DWR-LB
Aberdeen Proving Ground, MD 21005

479  Director
US Army Human Engineering Labs
001  Aberdeen Proving Ground, MD 21005
482 Director
US Army Materiel Systems Analysis
ATTN: DRXSY-T
001 Aberdeen Proving Ground, MD 21005

518 TRI-TAC Office
ATTN: TT-SE
001 Fort Monmouth, NJ 07703

483 Director
US Army Materiel Systems Analysis 001
ATTN: DRXSY-MP
ABERDEEN Proving Ground, MD 21005 531

519 CDR, US Army Avionics Laboratory
AVRADCOM
ATTN: DAVAA-D
Fort Monmouth, NJ 07703

504 Chief, CERCOM Aviation Electronics 001
Office
ATTN: DRSEL-MME-LAE(2)
St Louis, MO 63166

533 CDR, US Army Inst For Military Assistance
ATTN: ATSU-CTD-MO
001 Fort Bragg, NC 28307

507 CDR, AVRADCOM
ATTN: DRAVA-E
PO Box 209
001 St Louis, MO 63166

536 Commander
US Army Arctic Test Center
ATTN: STEAC-TD-MI
002 APO Seattle 98733

512 Commander
Picatinny Arsenal
ATTN: SARPA-ND-A-4 (Bldg 95)
001 Dover, NJ 07801

514 Director
Joint Comm Office (TRI-TAC)
ATTN: TT-AD(Tech Docu Cen)
001 Fort Monmouth, NJ 07703

542 Commandant
US Army Field Artillery School
ATTN: ATSFA-CTD
002 Fort Sill, OK 73503

515 Project Manager, REMBASS
ATTN: DRCPM-RBS
002 Fort Monmouth, NJ 07703

554 Commandant
US Army Air Defense School
ATTN: ATSACD-MC
001 Fort Bliss, TX 79916

516 Project Manager, NAVCON
ATTN: DRCPM-NC-TM
Bldg 2539
001 Fort Monmouth, NJ 07703

563 Commander, DARCOM
ATTN: DRCDE
5001 Eisenhower Ave
002 Fort Monmouth, NJ 07703

517 Commander
US Army Satellite Communications Agency
ATTN: DRCPM-SC-3
001 Alexandria, VA 22333
DEVELOPMENT OF IMPROVED EARPHONE-EARCUP SYSTEM
FOR AVC HELMET

Michael A. Bryson
ELECTRO-VOICE, INC.
600 Cecil Street
Buchanan, MI 49107

November 1979
Final Report for Period August 1978 - October 1979

DISTRIBUTION STATEMENT
Approved for public release;
distribution unlimited.

Prepared for:
CENCOMS

CORADCOM
US ARMY COMMUNICATION RESEARCH & DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703
NOTICES

Disclaimers

The citation of trade names and names of manufacturers in this report is not to be construed as official Government endorsement or approval of commercial products or services referenced herein.

Disposition

Destroy this report when it is no longer needed. Do not return it to the originator.
**Development of Improved Earphone-Earcup System for AVC Helmet**

**Author(s):** Michael A. Bryson

**Performing Organization Name and Address:**
Electro-Voice, Inc.
600 Cecil Street
Buchanan, Michigan 49107

**Controlling Office Name and Address:**
US Army Communications Research & Dev. Command
Attn: DRCO-COM-RN-4
Fort Monmouth, New Jersey 07703

**Report Date:** November 1979

**Number of Pages:** 34

**DISTRIBUTION STATEMENT (of this Report):**
Approved for Public Release
Distribution Unlimited

**ABSTRACT:**
This document covers the technical details of work performed to improve the noise attenuation characteristics and frequency response of an earphone-earcup system used in DH-132 AVC Helmet. This new design results in a system that is rugged, lightweight, has improved intelligibility, and reduced medical hazard for crewmen in tracked armored vehicles.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OBJECTIVE</td>
<td>1</td>
</tr>
<tr>
<td>Problems with DH-132 Helmet</td>
<td>1</td>
</tr>
<tr>
<td>Goals of Development Effort</td>
<td>5</td>
</tr>
<tr>
<td>SYSTEM DESIGN</td>
<td>6</td>
</tr>
<tr>
<td>THE EARCUP</td>
<td>6</td>
</tr>
<tr>
<td>Additional Earcup Design Details</td>
<td>9</td>
</tr>
<tr>
<td>THE EARPHONE</td>
<td>12</td>
</tr>
<tr>
<td>Design of Closely Coupled Assembly</td>
<td>13</td>
</tr>
<tr>
<td>DESIGN TESTS</td>
<td>17</td>
</tr>
<tr>
<td>Weight</td>
<td>17</td>
</tr>
<tr>
<td>Impedance</td>
<td>17</td>
</tr>
<tr>
<td>Dielectric Strength, Insulation Resistance and Overload</td>
<td>18</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>18</td>
</tr>
<tr>
<td>Frequency Response</td>
<td>18</td>
</tr>
<tr>
<td>Harmonic Distortion</td>
<td>19</td>
</tr>
<tr>
<td>Linearity</td>
<td>19</td>
</tr>
<tr>
<td>Attenuation</td>
<td>20</td>
</tr>
</tbody>
</table>
## TABLE OF CONTENTS (Con't)

<table>
<thead>
<tr>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENVIRONMENTAL TESTS</td>
<td>21</td>
</tr>
<tr>
<td>Low Temperature</td>
<td>21</td>
</tr>
<tr>
<td>High Temperature</td>
<td>21</td>
</tr>
<tr>
<td>Rain</td>
<td>21</td>
</tr>
<tr>
<td>Immersion</td>
<td>21</td>
</tr>
<tr>
<td>Dust, Fungus and Blast</td>
<td>22</td>
</tr>
<tr>
<td>Humidity</td>
<td>22</td>
</tr>
<tr>
<td>Vibration</td>
<td>22</td>
</tr>
<tr>
<td>Shock, Drop</td>
<td>22</td>
</tr>
<tr>
<td>Salt Fog</td>
<td>22</td>
</tr>
<tr>
<td>Altitude</td>
<td>23</td>
</tr>
<tr>
<td>SUMMARY</td>
<td>24</td>
</tr>
<tr>
<td>APPENDIX A, SAMPLE TEST DATA</td>
<td>25</td>
</tr>
</tbody>
</table>
# LIST OF ILLUSTRATIONS

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Envelope of Noise Sound Pressure Levels for Prototype Combat Tracked Vehicle</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Model 993 Earphone Response on 6cc Coupler, 1 mW Applied</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>Model 993 Earphone in DH-132 Earcup, 1 mW Applied</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Electrical Circuit Simulation of Earcup System</td>
<td>7</td>
</tr>
<tr>
<td>5</td>
<td>Mean Attenuation of 20 Helmets</td>
<td>11</td>
</tr>
<tr>
<td>6</td>
<td>Cross Section of Earphone-Earcup System</td>
<td>14</td>
</tr>
<tr>
<td>7</td>
<td>Variations in Response Caused by Clamping Pressure</td>
<td>16</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TABLE</th>
<th>TITLE</th>
<th>PAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mean Attenuation of Twenty (20) Helmets Produced on Contract DAAB07-78-C-0176</td>
<td>10</td>
</tr>
</tbody>
</table>
OBJECTIVE

The objective of the technical effort described herein was a two-fold development project to improve the noise-attenuating and intelligibility properties of the earphone-earcup system used in the DH-132 Armored Vehicle Crewman Helmet.

Problems with DH-132 Helmet

High sound pressure levels of noise are generated within tracked armored vehicles which necessitates the use of hearing protection for all crewman in the vehicle. When used in the prototype Mechanized Infantry Combat Vehicle (MICV) the noise attenuation characteristics of the DH-132 Helmet permit only one hour of exposure to the noise to comply with the requirements of U.S. Army publication TB MED 251.\(^1\)

The Electro-Voice Model 993 earphone element which was designed to operate against the ear, approximately a 6cc cavity volume, has a very non-linear frequency response when operated in the large cavity volume of the DH-132 earcup.

The seriousness of these problems is shown in Figures 1, 2, and 3 which show the sound levels generated within the MICV, and frequency response of the Model 993 when operated into a 6cc coupler and when operated in the DH-132 earcup.

\(^1\)USAARL REPORT NO. 77-8, Medical Assessment of Acoustic Protective Devices Proposed for Use in a Prototype Mechanized Infantry Combat Vehicle.
Figure 1

ENVELOPE OF NOISE SOUND PRESSURE LEVELS FOR PROTOTYPE COMBAT TRACKED VEHICLE
MODEL 993 EARPHONE RESPONSE
ON 6cc COUPLER, 1 mW APPLIED

Figure 2
MODEL 993 EARPHONE IN DH-132 EARCUP, 1 mW APPLIED

Figure 3
Goals of Development Effort

One of the goals of this effort was to improve the noise attenuation of the earcup to allow eight hours of continuous exposure to noise encountered in the MICV and other tracked armored vehicles. The other goal was to generate a linear frequency response from the earphone when operated in the new earcup. This report demonstrates how these goals were attained.
THE EARCUP

In order to understand the noise-attenuation of the earcup we used a simulation of the system to find areas where improvement could be made. An electrical equivalent circuit of the earcup was used along with a computer to evaluate the effects of changing the various parameters of the earcup on its attenuation. The model shown in Figure 4 is an improved version of a model used on a previous contract which has been modified to include the effects of the stiffness of the earcup. Changes to the earcup system are subject to the following conditions, however:

1. Weight of the earcup shall not be more than the existing DH-132 earcup.

2. A means to retain the earphone element shall be incorporated.

3. The earcup shall be physically interchangeable with the existing DH-132 earcup.

4. The earcup shall be constructed of an insulating material.

5. Earcups shall use the same switch and boom mounting hardware as the existing DH-132 earcups.

Analysis of the noise of the MICV shows that attenuation of the low frequencies is the most important area of improvement required. It was determined that the earcup volume could be increased approximately 25% and still meet the above restrictions. The improvement in attenuation by the larger earcup volume fell short of the DS-AF-0265A(A) design
$M_e = \text{Mass of total earcup system}$

$R_e = \text{Damping of earcup plastic material}$

$C_e = \text{Compliance of earcup}$

$R_c = \text{Damping of earcushion ( ignores damping of skin as earcushion value is much larger )}$

$C_c = \text{Compliance of earcushion}$

$C_s = \text{Compliance of skin}$

$C_{ca} = \text{Compliance of earcup cavity}$

**ELECTRICAL CIRCUIT SIMULATION OF EARCUP SYSTEM**

Figure (4)
requirements. Working with the computer simulation and experimenting with various materials, it was determined that a new earcushion filler material could provide the greatest improvement in low frequency noise attenuation.

Examining the circuit in Figure 4, we see that reducing the series compliance represented by the earcushion and the skin on the wearer's head decreases the signal presented to the ear via the cavity of the earcup at low frequencies. Using the computer simulation and tests on our dummy head, we have determined that the compliance of the skin limits the maximum attenuation of the earcup, with mass and volume fixed by restrictions above, between 30 and 35 dB, assuming a perfect seal and an earcushion with no compliance. Because of the differences in wearer's heads and comfort when wearing the helmet, an earcushion with some compliance must be used.

To meet the earcushion compliance requirements a new earcushion filler was needed. We tried a foam material called "Low-Perm" foam which has improved characteristics over the present filler; yet, this material is only produced in one compliance and has a closed cell construction. Another material called "Temper Foam" was found that is made in an open cell construction which is produced in five different compliances. Temper Foam is sensitive to both pressure and temperature along with a slow recovery rate property. A compliance that provides good comfort and low frequency attenuation is obtainable with this material. The compliance is highly temperature dependent, becoming very stiff at low temperatures. In actual use the wearer would warm the cushion with their hands and, when placed on the head, the warmth from the body would keep the cushion soft for comfort.
We are not able to obtain all the minimum attenuation values required by the specification, even with the increased volume and new cushion filler (see Table I and Figure 5). We feel the attenuation obtained at low frequencies is close to the highest practical value for this type of earcup design. A stiffer earcushion is available in Temper Foam, yet it will be uncomfortable and would require excess pressure against the head to obtain a seal.

Additional Earcup Design Details

In order to increase the volume and keep the mass of the earcup the same, requires changes in the design of the earcup shape and material. The wall thickness had to be decreased which makes the earcup construction less stiff, reducing high frequency attenuation. In order to reduce the weight additionally and retain the stiffness of the thick ABS wall in the thinner wall, we used a nylon foam plastic material. When properly foamed and assembled, a nylon and nylon-foam earcup will be the same weight as the existing design and more rugged than the ABS design now used. Our prototypes used an ABS and nylon-foam construction because we would have to make four injection molds to produce the parts, where only two of the parts are of a new design configuration. Weight of the prototypes was higher than that which will be realized in the production models of the new design; however, the performance should be the same or better for the lighter versions.

For the earcushion cover we used a polyether polyurethane film. This film has been found to have superior properties when compared to the
### TABLE I

Mean Attenuation of Twenty (20) Helmets Produced on Contract DAAB07-78-C-0176

<table>
<thead>
<tr>
<th>1/3 Octave Band in Hertz</th>
<th>SPL of Noise Used for Test</th>
<th>Specification (Minimum)</th>
<th>Attenuation in dB</th>
<th>Mean</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>93</td>
<td>22</td>
<td>16.9</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>100</td>
<td>102</td>
<td>22</td>
<td>16.4</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>125</td>
<td>107</td>
<td>22</td>
<td>14.5</td>
<td>3.8</td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>105</td>
<td>22</td>
<td>15.7</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>102</td>
<td>23</td>
<td>16.1</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>108</td>
<td>24</td>
<td>22.4</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>315</td>
<td>108</td>
<td>24</td>
<td>20.3</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>105</td>
<td>26</td>
<td>24.8</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>500</td>
<td>103</td>
<td>28</td>
<td>30.4</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>630</td>
<td>101</td>
<td>30</td>
<td>29.9</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>800</td>
<td>99</td>
<td>31</td>
<td>32.7</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>1000</td>
<td>99</td>
<td>34</td>
<td>35.4</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>1250</td>
<td>99</td>
<td>34</td>
<td>38.4</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>1600</td>
<td>98</td>
<td>34</td>
<td>38.0</td>
<td>2.7</td>
<td></td>
</tr>
<tr>
<td>2000</td>
<td>98</td>
<td>34</td>
<td>39.1</td>
<td>2.0</td>
<td></td>
</tr>
<tr>
<td>2500</td>
<td>95</td>
<td>38</td>
<td>39.6</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>3150</td>
<td>95</td>
<td>43</td>
<td>40.3</td>
<td>5.5</td>
<td></td>
</tr>
<tr>
<td>4000</td>
<td>91</td>
<td>45</td>
<td>44.2</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>5000</td>
<td>90</td>
<td>45</td>
<td>47.5</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>6300</td>
<td>88</td>
<td>40</td>
<td>47.8</td>
<td>3.6</td>
<td></td>
</tr>
<tr>
<td>8000</td>
<td>86</td>
<td>40</td>
<td>45.8</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>10000</td>
<td>79</td>
<td>40</td>
<td>41.9</td>
<td>1.8</td>
<td></td>
</tr>
</tbody>
</table>
MEAN ATTENUATION OF 20 HELMETS
(SEE TABLE I)

--- Specification (Minimum)

--- Mean

Figure 5
vinyl film used presently. We tested this film on a previous development contract (DAAB07-76-C-0149) in which it was shown to be flexible at sub-zero temperatures, fungus resistant and tear resistant.

THE EARPHONE

As explained in the beginning of this report, the Model 993 and other earphones which are designed to operate into a 6cc cavity do not perform well in a large earcup. Two possible design modifications are:

1. Mount the earphone to closely couple it to the ear as it was designed to operate.

2. Redesign the earphone to operate in the large earcup.

From past experience we decided to concentrate our efforts on placing the earphone against the ear. To make a lightweight earphone element operate in a large earcup, we would have to sacrifice efficiency and frequency response which is undesirable.

Positioning and sealing the earphone against the ear are the most difficult problems caused by the closely coupled design approach. Variations in user ear dimensions necessitate a loose attachment of the earphone to the earcup. The positioning mechanism must be lightweight, exert a small force to hold the earphone in the proper position, and allow easy placement and removal of the helmet. An additional requirement is to make the earphone a replaceable item separate from the earcup. Since the earphone cover presents a hard, flat surface to the ear, some form of cushion between the ear and earphone is required to provide a good seal and comfort to the wearer.
Design of Closely Coupled Assembly

Figure 6 shows the method chosen to support the earphone in the earcup. A compression spring is attached to the earphone element and a mounting bracket. We chose to permanently attach the spring assembly to the earphone as this provided the lightest weight construction and only required minor modifications to the earphone case. For the prototypes the spring was soldered to metal brackets at each end—an assembly method that would not be used on a production version. The reliability of the soldered connection has been found to be poor even though the unit used in the drop test held together. Production units should incorporate some sort of metal tabs from the brackets which could be crimped over the spring and lock it in place.

A force of 1/3 to 1/2 kilogram was chosen to be applied by the spring when pressing against the ear. Most earcups are designed with a one kilogram force. If we used one kilogram of force for this application, then the earcup would have to apply two kilograms force against the head, which is excessive! The spring force was selected as a reasonable compromise for the total force applied to the wearer's head.

Various materials and earpad shapes for sealing the earphone to the ear were tested. A lightweight ring fashioned out of polyurethane foam was evaluated. The foam provided a good seal but has two drawbacks. Because of its compliance it allows the earphone to move in relationship to the head and thus lowers the noise attenuation of the earcup system. Also, the foam would be difficult to clean, presenting a hygiene problem. The selected material is a soft, rubber-like plastic that can be molded into
Cross Section of Earphone-Earcup System

Figure 6
the desired shape. This material, "Satinflex", has a compliance almost identical to human skin, is fungus resistant and is easy to clean. We have molded it as a replaceable earpad to be placed over the earphone element.

Since we had to compromise the force applied to the ear, the seal obtained is not adequate to obtain a response that is flat to 200 Hertz. When properly fitted, the frequency response measured at the ear consistently falls within a 6 dB envelope from 400 to 5000 Hertz. Figure 7 shows the variation in response obtained because of differences in sealing. The frequency response is better than we would expect to obtain from an earphone modified to work in the earcup and should provide good intelligibility. We feel the loss in low frequency response is acceptable as the added force for a good seal would be uncomfortable when the helmet is worn for extended periods.
VARIATIONS IN RESPONSE CAUSED BY CLAMPING PRESSURE

--- 6cc Frequency Response
••••• 1 Kg Force
----- 1/3 Kg Force

Figure 7
DESIGN TESTS

Weight

Our prototypes weigh approximately 25 grams more than the earcups they are to replace. Examining the density of the nylon foam parts, we found that the parts were not processed by the vendor correctly. In order to make good parts, water cooling would have to be added to the tooling and an injection molding machine with better control is required. The added delay and cost to modify the tooling and make new parts would only result in parts with reduced weight and have little affect on evaluating the performance of the earcup. We chose to go ahead and use the nylon foam plastic parts as received.

Impedance

The impedance of all the earphones was measured with the units mounted to the dummy head test fixture. The impedance of the earphones was 10 to 15 ohms lower than the value of the impedance measured when the earphones are unloaded. Because the impedance changes less than 2% from a loaded to unloaded condition, the measurement technique has little effect on the result. Measuring the impedance in free air is easier and yields the desired results.
Dielectric Strength, Insulation Resistance and Overload

These tests are common to all our earphone designs. We use materials and construction techniques that allow our earphones to consistently pass these tests. All the earphones made on this contract were subjected to and passed the above tests.

Sensitivity

With one milliwatt of power applied to the earphone, the output pressure was always above 104 dB SPL. The specification allowed a minimum level of 85 dB SPL for an earphone which would operate into the earcup. Since the closely coupled approach has been used, 104 dB SPL should be the new minimum level for one milliwatt input in this application.

Frequency Response

As explained in the section on the earphone, the frequency response measured at the ear is dependent on the pressure applied to provide a seal to the ear. When measured on a 6cc coupler or with sufficient pressure applied and measured at the ear, the response falls within a 6 dB envelope between 200 and 5000 Hertz. The high mass of a practical 1000 ohm voice coil limits the response to a 5000 Hertz maximum. It might be possible to use smaller wire in the voice coil to extend the response to 6000 Hertz as the specification calls for, but past experience shows the resulting unit is difficult to build, would be less reliable, and might have difficulty passing an overload test.
Because of the variations in microphone placement and human ear dimensions, we recommend that the 6cc coupler be the standard for testing the earphone with the limits between 200 and 5000 Hertz rather than the in ear technique which is not standardized.

Harmonic Distortion

Measuring the distortion per the design specification presented a problem. Our earphones, when operated into a 6cc coupler and against the ear 'typically', have less than 1% distortion. We placed the dummy head in our large anechoic chamber, which is the quietest room we have, where the ambient noise level is on the order of 45 dB SPL. The noise level in the chamber looks like 1% harmonic distortion at the measurement level of 85 dB SPL. Only the 105 dB SPL measurement level gave us a signal to noise level sufficient to measure harmonic distortion.

Because of the low distortion levels and expense of testing, only the 105 dB SPL measurement level should be used as a specification requirement for harmonic distortion of the earphone.

Linearity

A constant voltage versus frequency at three voltage levels was applied to the earphones. The output sound pressure was recorded for the three input levels. The output sound level varied linearly with the input voltage level.
Attenuation

Various ways of measuring the noise attenuation of the earcup system were used for evaluation. The values obtained in Table I were measured on a dummy head with a noise spectrum that simulated that of a tracked armored vehicle. These values are not as good as expected, but are representative of those to be realized in actual usage. When a flat sound spectrum at lower sound pressure levels is used instead of the shaped spectrum, the values of attenuation are greater and correlate better with our computer simulation. We do not report the latter attenuation values as they apply to a test method which is not representative of actual use. Tests were made with a miniature microphone placed in a subject's ear to further verify the attenuation values of the dummy head test fixture. Because of electrical signal to noise, the attenuation at high frequencies could not be measured accurately. This is because the sensitivity of the miniature microphone is much lower than the one inch B & K microphone used in the dummy head. The values in the low to middle frequencies agreed with that recorded with the dummy head. More theoretical study is needed to determine why the attenuation at high sound levels decreases when compared to moderately high sound levels.
ENVIRONMENTAL TESTS

Low Temperature

An earphone-earcup system was exposed to -50°C temperature as specified in DS-AF-026S5A(A). After the temperature of the unit had stabilized, a signal was applied and the level recorded. At the low temperature the level increased 2 dB. When returned to ambient temperature, the level and response were identical to that taken before the test.

High Temperature

No change in performance of the earphone-earcup system was experienced as a result of exposure to 160°F temperature. When checked at 160°F the level had decreased one dB from the level at ambient temperature.

Rain

The rain test trapped more water in the front cover than expected. Only a slight shake was used to remove the water before testing the unit's response. Minor degradation was noted immediately after the rain test. Later, when the rest of the water trapped had been removed, the unit showed no degradation.

Immersion

Immersion tests were run twice on the earphone-earcup system as required by the design specification. We recorded the frequency response before and after the test, and only minor differences were noted.
Dust, Fungus and Blast

These tests were not performed on this contract. The design and materials used in the earphone and earcup have been shown to be resistant to these tests, thus, we passed over these tests to concentrate on other tasks in the design.

Humidity

Examination of the unit after exposure showed no visible change. No degradation of the sensitivity was noted after the test.

Vibration

Exposure to the vibration test caused a minor change to the frequency response. The unit still met specification requirements as a result of the exposure.

Shock, Drop

Dropping a unit 26 times on to a two inch thick piece of plywood backed by concrete from a height of four feet caused no degradation to the unit's performance, even after immersing it in water as specified by DS-AF-0265A(A)

Salt Fog

One unit was exposed to the 48 hour salt fog test of MIL-STD-810C, Method 509.1, Procedure I. Only a slight discoloration on the spring assembly was observed with no degradation in the frequency response.
Altitude

The earphone-earcup system was subjected to an operating and non-operating altitude test. Because of the air tight seal of the earcup to the dummy head test fixture, the unit would not equalize rapidly at a 15,000 feet simulated altitude. When a small leak was provided in the earcushion seal, the unit equalized normally and the response changed only 3 dB at the high frequencies relative to the ground level response. In actual use this sealing characteristic should not present a problem. If data from the field shows this to be a problem, then an equalization port can be added. A non-operating altitude test of a simulated 40,000 feet altitude caused no degradation to the frequency response when the unit was tested afterward.
A new earphone-earcup combination has been developed that will directly replace the earcup system now used in the DH-132 helmet which has improved intelligibility and reduced medical hazard to hearing for crewmen in tracked armored vehicles. This new design can be produced without adding weight to the helmet and does not sacrifice mechanical ruggedness for the larger volume and thinner walls of the new earcup.

Physical constraints of size and weight, plus practical considerations of comfort and fit prevented the obtainment of all the goals of DS-AF-0265A(A). Within the restraints of this design approach we have been able to show that an improved communications helmet system for use in tracked armored vehicles can be produced.
APPENDIX A

SAMPLE TEST DATA
UNIT #3

_____ Before Overload Test

------- After Overload Test
Frequency Response Spread of All Units Tested
UNIT #1

Harmonic Distortion
UNIT #8

Linearity
<table>
<thead>
<tr>
<th>Code</th>
<th>Organization</th>
<th>Address 1</th>
<th>City, State, Zip</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>Defense Technical Information Ctr.</td>
<td>31dgs</td>
<td>Alexandria, VA, 22314</td>
</tr>
<tr>
<td>102</td>
<td>National Security Agency</td>
<td>TDL</td>
<td>Ft George G. Meade, MD, 20755</td>
</tr>
<tr>
<td>103</td>
<td>Code R123, Tech Library</td>
<td>1860 Wiehle Ave</td>
<td>Reston, VA, 22090</td>
</tr>
<tr>
<td>104</td>
<td>Defense Communications Agency</td>
<td>Code 205</td>
<td>Washington, DC, 20305</td>
</tr>
<tr>
<td>105</td>
<td>Office of Naval Research</td>
<td>Code 427</td>
<td>Arlington, VA, 22217</td>
</tr>
<tr>
<td>106</td>
<td>GIDEP Engineering &amp; Support Dept</td>
<td>PO Box 398</td>
<td>NORCO, CA, 91760</td>
</tr>
<tr>
<td>107</td>
<td>Director</td>
<td>Code 2627</td>
<td>Washington, DC, 20375</td>
</tr>
<tr>
<td>108</td>
<td>Commander</td>
<td>ATTN: LIBRARY</td>
<td>San Diego, CA, 92152</td>
</tr>
<tr>
<td>109</td>
<td>CDR, Naval Surface Weapons Center</td>
<td>ATTN: Library, Code WX-21</td>
<td>Silver Spring, MD, 20910</td>
</tr>
<tr>
<td>210</td>
<td>Commandant, Marine Corps</td>
<td>HQ, US Marine Corps</td>
<td>Washington, DC, 20380</td>
</tr>
<tr>
<td>211</td>
<td>HQ, US Marine Corps</td>
<td>ATTN: CODE INTS</td>
<td>Washington, DC, 20380</td>
</tr>
<tr>
<td>212</td>
<td>Command, Control &amp; Communications Development Center</td>
<td>Marine Corps Development &amp; Educ.</td>
<td>Quantico, VA, 22134</td>
</tr>
<tr>
<td>215</td>
<td>Naval Telecommunications Command</td>
<td>Technical Library, Code 91L</td>
<td>Washington, DC, 20390</td>
</tr>
<tr>
<td>217</td>
<td>Naval Air Systems Command</td>
<td>Code: AIR-5322</td>
<td>Washington, DC, 20360</td>
</tr>
<tr>
<td>300</td>
<td>AUL/LSE 64-235</td>
<td>001 Maxwell AFB, AL, 36112</td>
<td></td>
</tr>
<tr>
<td>301</td>
<td>Rome Air Development Center</td>
<td>ATTN: DOCUMENTS LIBRARY (TILD)</td>
<td>Griffiss AFB, NY, 13441</td>
</tr>
<tr>
<td>304</td>
<td>Air Force Geophysics Lab</td>
<td>ATTN: LIR</td>
<td>Bedford, MA, 01730</td>
</tr>
<tr>
<td>307</td>
<td>AFGL/SULL S-29</td>
<td>HAFB, MA, 01731</td>
<td></td>
</tr>
<tr>
<td>310</td>
<td>US Army Corps</td>
<td>ATTN: EPEC SW Mail Stop 1056</td>
<td>Richards-Gebaur AFB, ND, 54050</td>
</tr>
</tbody>
</table>
312  HQ, Air Force Electronic Warfare Center
    ATTN: SURP
    002  San Antonio, TX  78243

314  HQ, Air Force Systems Command
    ATTN: DLCA
    Andrews AFB
    001  Washington, DC  20331

403  CDR, MIRCOM
    Redstone Scientific Info Center
    ATTN: Chief, Document Section
    001  Redstone Arsenal, AL  35809

406  Commandant
    US Army Aviation Center
    ATTN: ATZQ-D-MA]
    003  Fort Rucker, AL  36362

408  Commandant
    US Army Military Police School
    ATTN: ATSJ-CG-M-C
    003  Fort McClellan, AL  36201

417  Commander
    US Army Intelligence Center & School
    ATTN: ATSI-CD-MD
    002  Fort Huachuca, AZ  85613

418  Commander
    HQ, Fort Huachuca
    ATTN: TECHNICAL REFERENCE DIV
    001  Fort Huachuca, AZ  85613

419  Commander
    US Army Electronic Proving Ground
    ATTN: STEEP-MT
    002  Fort Huachuca, AZ  85613

432  Dir, US Army Air Mobility R&D Lab
    ATTN:  T. GOSSETT, BLDG 207-5
    NASA Ames Research Center
    001  Moffett Field, CA  94035

436  HQDA (DAMO—TCE)
    002  Washington, DC  20310

437  Deputy for Science & Technology
    Office, Assist Sec Army (R&D)
    001  Washington, DC  20310

438  HQDA (DAMO—AR2/DR F.D. Verderame)
    001  Washington, DC  20310

470  Director of Combat Developments
    US Army Armor Center
    ATTN: ATZK—CD—MS
    002  Fort Knox, KY  40121

475  Cdr, Harry Diamond Laboratories
    ATTN: Library
    001  2800 Powder Mill Road
        Adelphi, MD  20783

477  Director
    US Army Ballistic Research Labs
    ATTN:  DRXSR—L3
    001  Aberdeen Proving Ground, MD  21005

479  Director
    US Army Human Engineering Labs
    001  Aberdeen Proving Ground, MD  21005
<table>
<thead>
<tr>
<th>Page</th>
<th>Name</th>
<th>Title</th>
<th>Location</th>
<th>Address</th>
<th>Phone</th>
<th>Office</th>
<th>Address</th>
<th>Phone</th>
</tr>
</thead>
<tbody>
<tr>
<td>482</td>
<td>Director</td>
<td>US Army Materiel Systems Analysis</td>
<td>Fort Monmouth, NJ</td>
<td>07703</td>
<td>518</td>
<td>TRI-TAC Office</td>
<td>519</td>
<td>CDR, US Army Avionics Laboratory</td>
</tr>
<tr>
<td>483</td>
<td>Director</td>
<td>US Army Materiel Systems Analysis</td>
<td>Fort Monmouth, NJ</td>
<td>07703</td>
<td>519</td>
<td>CDR, US Army Avionics Laboratory</td>
<td>001</td>
<td>Aberdeen Proving Ground, MD</td>
</tr>
<tr>
<td>504</td>
<td>Chief, CERCOM Aviation Electronics</td>
<td>Office</td>
<td>Research Triangle Park, NC</td>
<td>27709</td>
<td>533</td>
<td>US Army Inst For Military Assistance</td>
<td>001</td>
<td>St Louis, MO</td>
</tr>
<tr>
<td>512</td>
<td>Commander</td>
<td>Picatinny Arsenal</td>
<td>APO Seattle, 98733</td>
<td>002</td>
<td>Commandant</td>
<td>536</td>
<td>US Army Arctic Test Center</td>
<td>002</td>
</tr>
<tr>
<td>514</td>
<td>Director</td>
<td>Joint Comm Office (TRI-TAC)</td>
<td>Fort Sill, OK</td>
<td>73503</td>
<td>542</td>
<td>Commandant</td>
<td>554</td>
<td>US Army Air Defense School</td>
</tr>
<tr>
<td>515</td>
<td>Project Manager, REMBASS</td>
<td>002</td>
<td>Fort Monmouth, NJ</td>
<td>07703</td>
<td>542</td>
<td>Commandant</td>
<td>554</td>
<td>US Army Air Defense School</td>
</tr>
<tr>
<td>516</td>
<td>Project Manager, NAVCON</td>
<td>Bldg 2539</td>
<td>Fort Monmouth, NJ</td>
<td>07703</td>
<td>542</td>
<td>Commandant</td>
<td>554</td>
<td>US Army Air Defense School</td>
</tr>
<tr>
<td>517</td>
<td>Commander</td>
<td>US Army Satellite Communications Agency</td>
<td>Alexandria, VA</td>
<td>22333</td>
<td>563</td>
<td>Commandant, DARCOM</td>
<td>563</td>
<td>Eisenhower Ave</td>
</tr>
</tbody>
</table>
566 CDR, US Army Signals Warfare Laboratory
ATTN: DELSM-AQ
Vint Hill Farms Station
Warrenton, VA 22186

606 Chief
Intel Materiel Dev & Support Cfc
Electronic Warfare Lab, E2CM
001 Fort Meade, MD 20755

680 CDR, US Army Communications Research and Development Command
000 Fort Monmouth, NJ 07703

572 Commander
US Army Logistics Center
ATTN: ATCL-VC
002 Fort Lee, VA 22801

575 Commander
US Army Training & Doctrine Command
ATTN: ATCD-TBE
001 Fort Monroe, VA 23651

577 Commander
US Army Training & Doctrine Command
ATTN: ATCD-TM
001 Fort Monroe, VA 23651

578 Cdr, US Army Garrison
ATTN: IAVAAF
Vint Hill Farms Station
001 Warrenton, VA 22186

602 Director, Night Vision Laboratory
US Army Electronics Command
ATTN: DRSEL-NV-D
001 Fort Belvoir, VA 22060

603 Cdr/Dir, Atmospheric Sciences Laboratory
US Army Electronics Command
ATTN: DRSEL-BL-SY-S
001 White Sands Missile Range, NM 88002