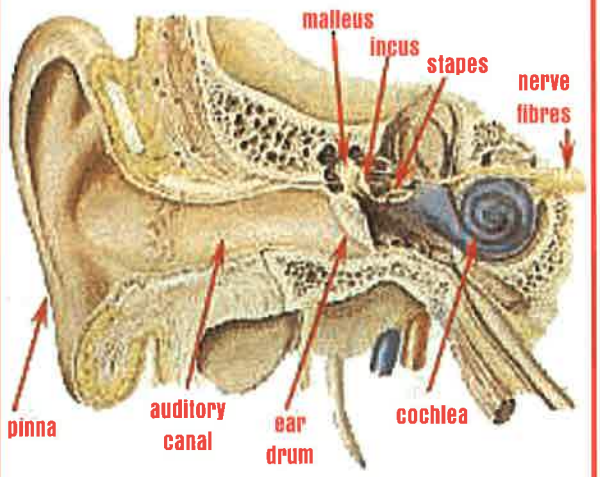


The Ear

Introduction

The ear is a wonderful thing ... a magnificent piece of engineering! The normal range of audibility for man covers about 10 1/2 octaves, from a lower limit of about 15 cycles per second to an upper limit of somewhat more than 20,000 cycles. Tones below the lower limit affect the human ear, but they give noisy effects and not distinct pitches. Tones above the upper limit are altogether inaudible. Generally speaking, two tones of equal volume but different frequency will not seem equally loud; this is true because the ears sensitivity varies over its range. In the animal kingdom, the hearing range of humans is good, but far from the best. Animals, like cats and dogs for example, have a hearing range comparable to man's in the lower ranges but much greater in the higher ranges. They respond to tones of at least 60,000 cycles per second. Of all the human senses, hearing is high on the list.

A passenger on an airplane may watch a movie without a headphone, but it is certainly not as rich an experience as it is when matched with a soundtrack. Put the ear into the equation and the experience becomes so much more. Good IFE needs good sound. That need for "sound" is also what many airlines depend on to defray their Inflight Entertainment (IFE) costs. For airline passengers, that sound comes through headphones. The revenue gained from "rental" of those headphones to passengers for onboard entertainment can have a major impact on a carrier's IFE expenses.

What Is A Headphone?

To begin with, it is not "headset". Although many use the terms headphones and headsets interchangeably (and incorrectly), they are not the same. Headsets contain one or two headphones and a microphone ... as commonly used by pilots in the cockpit, telephone agents, etc. A headphone is, basically, a small loudspeaker ... or two small loudspeakers. Thus, understanding a bit about audio physics and the construction and operation of loudspeakers will also provide a basic understanding of how a headphone works.

Loudspeakers

Loudspeakers have been in existence for over 75 years and are used to reproduce audio from TVs, VCRs, CD and DVD Players, Cassette Tape Players, etc.

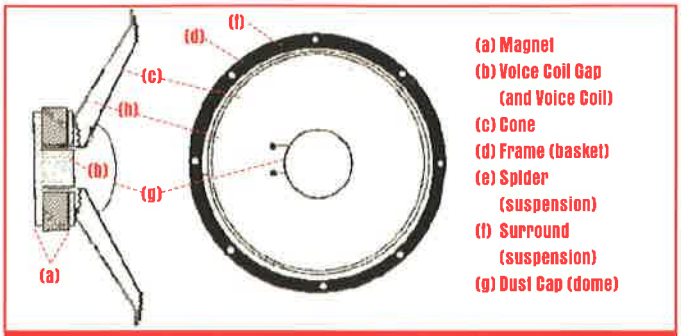
The photo depicts a typical loudspeaker used in a hi-fi system speaker enclosure. It is about 10" in diameter and usually acts as the "Woofer" or low frequency audio reproducer. It's an electro-mechanical device in which a reasonably high power electrical signal causes it to move the air in front of it to make sounds. The signal usually is derived from an amplifier and an audio source such as a CD, DVD, or Cassette Tape player, VCR audio, etc.

Everything You Ever Wanted to Know About

IFE Headphones

- But Were Afraid To Ask

By Bill Baltra



Cross Section of Cone Type Driver

The diagram illustrates a "cross section" (side view) of a loudspeaker. The letters identify the major components of the loudspeaker.

The vast majority of loudspeakers are built around electromagnetic linear "motors". As such, they are close relatives of other simple electric motors, solenoids, etc.

As shown in the drawing, the Voice Coil is surrounded by a permanent magnet. Typically made of a Ferrite material (iron), the magnet sets up stationary lines of magnetic force. A signal current is passed through the coil (audio signal from the amplifier), which is connected to terminals mounted on the Frame. The terminals are connected to the output of the audio amplifier. The flow of electrons in the wire creates a second magnetic field around the Voice Coil. The magnetic polarity (north-south) of this field is dependent on the direction of the current flow through the wire. As an audio signal goes from positive to negative and back again, the electromagnetic field interacts with the field of the permanent magnet, which surrounds the Voice Coil. Assuming that the permanent magnet's position is fixed, the force resulting from the interaction of the two fields causes the coil to move back and forth in the gap. The Voice Coil, moving back and forth in response to the "motor" action described above, sits in the Voice Coil Gap and is attached to a suitable diaphragm called the Cone by the Spider and Surround suspensions shown. The Voice Coil movement is transferred to the Cone, which is moved back and forth, following the audio signal from the amplifier. The Cone is what really moves the air and causes the audio to be reproduced. The moving air creates sound waves that are detected by the ear drum (see Ear on page 50), and converted into signals that are transmitted to the brain by nerve fibers. The brain perceives the audio signal and interprets it to be similar to the recording.

Electronic Headphones

The photo on page 50 shows a typical IFE electronic headphone. It consists of a headband, with an earpiece attached to each end of the band. Each earpiece contains a small loudspeaker. In the model shown, two pairs of wires are wrapped in plastic, and one pair goes to one loudspeaker in one earpiece and the other pair goes through the headband to the other loudspeaker in the other earpiece. The other ends of the two pairs are connected inside a plug (which may be a Single Stereo plug or a Dual Mono plug, one for each ear). This plug connects to the Seat Jack and allows the audio signals from the audio amplifiers to be passed to the headphones.

The picture to the right shows a partially disassembled headphone with the earpiece back cap to the top right, the headphone to the middle left and the loudspeaker in the middle (with the two wires connected to it). The connecting Terminals are easy to spot and are connected to the Voice Coil inside the Dome cover.

The picture to the left shows the reverse side of the loudspeaker. A clear Mylar diaphragm is used as the loudspeaker Cone. The permanent magnet is in the center and the Voice Coil sits in its Gap.

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Each component of a loudspeaker is important to the final performance capability of the headphone, as well as its cost. For example, by using Cobalt instead of Ferrite material for the Permanent magnet, a much more efficient headphone results. However, the cost of Cobalt is about 50 times more than Ferrite.

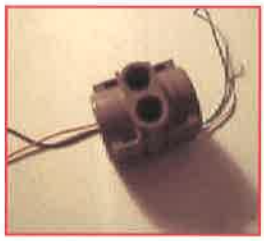
The Cone material is also important, as is the number of wire turns of the Voice Coil. If the proper number of turns of wire (this translates to the length of the wire) is not used, the impedance of the loudspeaker will not exactly match the audio amplifier in the Seat. Mismatched impedance can cause distortion and low levels of audio. It is important to control the impedance by using the proper length (and/or diameter) of wire. Some manufacturers have been known to "skimp" here to save some pennies on the amount of wire they have to buy ... which could represent a significant savings when a million headphones are involved.

The size of the magnet is crucial to efficiency, as is the material of the magnet. Magnet size represents an additional area in which a manufacturer may skimp on the size to control costs; however, a smaller magnet would impact performance.

Lastly, another potential cost-cutting area involves the use of recycled plastic. The problem with using recycled plastic is that once plastic is heated (to form a headset or whatever it is originally used on) recycling it and reusing can cause the molecular structure of the plastic to become brittle and can make headphones more susceptible to breakage. Some airlines attributing a headphone breakage problem to the post-flight collection process by Cabin Staff may, in fact, be using headphones made of less than virgin plastic. Obviously, this also applies to pneumatic headphones.

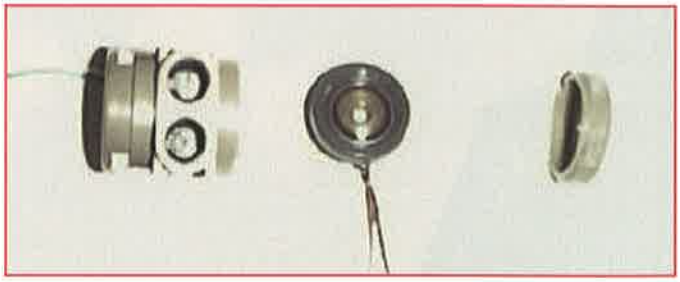
Pneumatic Headphones

The pneumatic headphone was the first type used in the IFE market. It is still used by some airlines in Economy Class, as it can be much less expensive than an electronic headphone. However, it still requires loudspeakers to be able to reproduce the audio. In the case of pneumatic headphones, the location of the loudspeakers is in a device called an "Audio transducer".



The transducer (pictured at left) actually contains two loudspeakers within and is normally contained in the passenger control unit (PCU). Because it is part of the aircraft seat, there is no need to use a more expensive headphone. This is where the biggest price difference occurs for a pneumatic versus an electrical headphone. This has its problems though as the loudspeaker is probably the part with the least reliability in the IFE system. If it is installed in the seat and "fails", a greater effort by maintenance personnel is required to resolve the problem. When using electronic headphones, one just replaces the headphone. Not so with a transducer. Sometimes, a failed transducer is carried on many flights before a replacement can be made. The two ports in the picture of the transducer are where the pneumatic headphone is plugged in. There is a "plunger" in each port that is spring loaded to keep the audio from filtering into the cabin when no headphone is plugged in. Notice the two pair of wires egress from the transducer.

The picture below shows the loudspeaker in the middle. There is one on either side of the transducer underneath the cap.



Noise Canceling Headphones

Noise cancellation has been around since the dawn of man. It comes in two forms: passive and active. Passive noise cancellation, in its simplest form, comes by putting your hands over your ears. In its modern form in the IFE industry, it's embodied in the foam cushions that surround pneumatic and electronic headsets or in the plastic inserts that surround the tips of an in-the-ear earpiece. The picture to the left above shows what some believe to be the finest Passive Noise Compensation headphones in the market today. The Etymotic earphones block out about 24 dB of ambient noise and sell for $330. Etymotic calls their system, Noise Exclusion. (These earphones actually go in the ear). They are mentioned here mainly to show the possibility of the 24 dB noise reduction they afford.

The most marvelous form of active noise reduction technology that we experience emanates from that amazing super computer called the human brain. We hear many sounds ... but so many can often be too many. Our brains have a wonderful way of "canceling out" many of those sounds and allowing us to hear selectively. If that weren't so, we'd probably go crazy. A mechanic can cancel out the sounds around him and concentrate on a specific sound in an engine. A mother's ear can be attuned to a baby's cry and sleep obviously through other noises. Our brains

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have the fantastic capability of allowing us to concentrate on specific sounds and cancel out other background noises.

Electronic noise cancellation has been around since the 30s and much of that technology was pioneered in Germany by Sennheiser. Personal noise cancellation took a giant leap forward with the advent of integrated circuitry and miniaturization. Since then, BOSE and the firm Noise Cancellation Technologies have also been leaders. Sennheiser and BOSE introduced the technology into the aviation market by manufacturing headsets for military and commercial pilots.

Sennheiser introduced the first NC headphone into the IFE industry in 1989 (industry standard two-plug and three-plug NC jacks were both originally Sennheiser designs). All of the noise cancellation headphones combine both passive and active techniques, but their emphasis is on electronic active noise cancellation (BOSE makes a strong stab at doing both).

Noise Canceling Headphones probably should be called Noise Compensation Headphones - as Sennheiser does. Sennheiser calls their Active Noise Compensation "NoiseGard™" with the definition shown by the formula: Sound Signals + Anti-sound Signals = Silence. NoiseGard cancels out low disturbing noises. A necessary feature of the active types is that an Electronic Circuit is required to provide the "Anti-sound Signals" to cancel out the ambient cabin noise which is detected by a "microphone" placed strategically in each ear piece.

These microphones "listen" to the ambient cabin noise and feed it to a microprocessor that converts it to digital, analyzes it, produces the opposing sound, and sends it back to the speaker or driver, and we hear that "zone of silence". It all happens in a fraction of a second. Some noise cancellation headsets are of a "feedforward" type, some of a "feedback" type, and some incorporate a combination of both. The feedforward models analyze the sound from a microphone located near the exterior of the earpiece, and the feed-back types analyze the sound inside the earpiece closer to the ear canal that is heard through the headphones earpieces back to the electronic circuit. This circuit may take the form of an "Inline Module" in the wire from the headphone to the plug, or it may be "built-into" the aircraft audio distribution system at the seat. The "Inline" application requires a power source - one or more batteries must be used to power the

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module. The "built-in" application eliminates the need for batteries to power the Noise Compensation circuitry by deriving the power from the IFE hardware.

Please remember that the entire process is not so efficient as to "block" all noise. This is where the numbers 10 dBs (decibels) and/or 15 dBs noise reduction come into play (and in this writer's mind, a good percentage of that dB reduction is "hype").When you realize that the ambient cabin noise of a typical airplane may vary from 80 to over 100 dBs and compare that of a typical home at 43 dBs, then 10 or 15 dBs may not seem to be much. However, the human ear can perceive the effect to be much greater.

The popularity of NC headphones has precipitated many manufactures to enter this market, and the range (and quality) of their offerings becomes broader each year.

Summary

The common thread throughout this topic is the loudspeaker! Each device addressed operates in a similar manner, and the physics is the same for all. The tradeoffs of using an Electronic Headphone versus a Pneumatic versus a Noise Cancellation model are many. Which to use? Which to buy? There are a multitude of things to be considered when making a decision about presenting audio to the airline passenger, and it can be very confusing. It all represents a challenge to the IFE headphone buyer. The transducer in a PCU may deliver the same audio to the plug of a pneumatic headphone as an electronic headphone delivers directly to the ear, but the plastic tubes of the pneumatic deliver the audio to the ear "cutoff" at a frequency of 6kHz. The electronics may deliver 16kHz reproducing a hi-fi signal with greater dynamic range and frequency response that makes for better intelligibility of movie audio. Noise cancellation headphones have some advantages and are becoming so popular that it's not uncommon to see passengers travel with their own or to see an airline passenger reading a book or sleeping and taking advantage of the relative "quiet". But noise cancellation headphones are more expensive. They can range from several hundred dollars to a low-end model (that utilizes built-in seat electronics) of $5 or $10. A reasonably good electronic headphone can now be purchased for less than $1.00, and a pneumatic headphone can be well below half that. There are recycling costs to be considered ... cleaning, new ear pads or foam plugs, repackaging, etc. Are any parts replaceable or is the headphone repairable?

Conclusion

Today's IFE industry consumes a lot of headphones. There are well over 100 member airlines in the WAEA ... not counting many smaller carriers, charter airlines, and business aircraft that utilize IFE headphones. A rough estimate of the annual purchases of IFE headphones of just the top three carriers alone totals over 12.4 million and the number of headphones in their systems at any one time approaches 50 million. All in all, the industry purchases a staggering number of headphones!

There are some notable exceptions, but most IFE headphone manufacturers today confront the prospect that the overriding consideration given to headphone purchases is cost ... on price relative to the competition. At some carriers, the purchasing agent is supreme, and the decision to buy a pneumatic, electronic, or NC headphone is based on bottom-line cost only. There may be no further definition to the purchase other than the cost

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of the type of headphone. An airline may invest $15 million or more on a sophisticated IFE system with all the "bells and whistles" for an airplane, but the audio delivery of that system to the onboard passenger is of minimal concern.

Some airlines have marketing departments that become involved in the purchasing process. Such an involvement may interject the aspects of quality into the decision making process. In the best of circumstances, an airline's engineering department will become involved, and this "troika" may also consider such "esoteric" matters as quality, service, and price. Matters such as plastic quality, tested and certified impedance, magnet weight and composition, etc. may enter into the purchasing process. It is recommended that before issuing an RFQ (Request for Quotation), an airline's engineering department create a Specification particularly covering the "technical" requirements. Much too often, the technical requirements are overlooked and, since headphones represent such a "small cost" item (as opposed to any one of a number of multi-million dollar airline purchases), many airline engineering departments do not have time to write a specification. Additionally, it's a good idea to ponder the best "Life Cycle Cost" for your headphone program. Life Cycle Cost is an extremely important factor when buying headphones. A headphone purchased for a slightly lesser cost that has a "life" that's 25% less than one costing several percentage points more is a very false bargain. Unfortunately, it happens frequently.

Unfortunately also, the sheer volume of IFE headphone usage and purchasing has attracted a number of vendors who promise more than they deliver and are adept at "skimping" in areas that many airlines do not perceive. The "smoke and mirrors" presentations that some airlines object to most vocally in industry meetings about major hardware manufacturers are also prevalent in the IFE headphone industry.

Fortunately, there are IFE headphone manufacturers that are anxious to please, that delight at receiving a "tight" and well-specified RFQ, and that will provide an airline with documented test results and finite specifications. There are some who have been around for years and plan to be around for years more. There are some that have full appreciation for the quality of audio and take pride in delivering a quality audio channel or soundtrack to the ears of an airline passenger.

About the Author:

Bill Baltra began his career in the IFE world as a Product Support Engineer with Telephonics in 1965. During his fourteen years at Telephonics, he assumed positions of greater responsibility and became VP of Product Support. In 1979, he joined Tracor in Austin, Texas, as Director of Product Support to assist their entry into the commercial aviation market with Tracor's Omega Navigation system. In 1980, he joined Matsushita Avionics as Assistant GM and participated in the group's growth from a $3 million Boeing contractor to a diversified $50 million IFE supplier by 1985. Baltra served as the Engineering liaison to MAS factory from 1985 through 1988. In 1988, he represented LPE for North and South America and, since 1992, has been partnered with Airphonics International.