University of Calgary

An Exploration into Bear Deterrents, as Related to Mountain biking, and the Design of an Ultrasonic Bear Warning Device

By
Mathew R. Schmor

A Masters Degree Project
Submitted to the Faculty of Environmental Design
In partial fulfilment of the requirements for the Degree of
Masters of Environmental Design
(Industrial Design)

Calgary, Alberta
Canada

June, 1999

0-612-48237-5

Abstract

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Mathew R. Schmor

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Denis Gadbois, Supervisor

Keywords: grizzly bear, black bear, sudden encounter, ultrasonic, BWD (Bear Warning Device).

This MDP is an exploration into current bear deterrent products and strategies available to the backcountry mountain biker. A sudden encounter with a bear, both black and grizzly, has been shown to be exceptionally dangerous. It has been argued that the high speeds and quite movement offered by a modern mountain bike, may increase the opportunity for a sudden encounter. Research indicates that one of the best ways to avoid a sudden encounter is through the production of noise, thus, warning the bear of your presence.

Through, a survey and multiple experiments, findings indicated that mountain bikers are coming dangerously close to bears and that current noise making deterrents are not appropriate Furthermore, current forms of noise making deterrents are being rejected by riders on account of their excessive audible noise.

Based on this research a Bear Warning Device has been proposed that incorporates the use of ultrasonic sound (21.5 and 23 kHz). Such tones are inaudible to the majority of humans and arguments have been given for the ability of both black and grizzly bears to hear such tones.

The final design concept is intended to be manufacturable with current levels of technology and incorporates performance specifications derived through the research conducted for this project.

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Chapter 1

Sec 1.1 Introduction

"We were riding along the Big Elbow-Little Elbow loop located in Kananaskis country. It was early afternoon around 2:00 PM and my partner Jack was slightly ahead of me as we climbed along a shallow part of the trail. Both our bikes were equipped with the quintessential bear bell and they chimed as we climbed and followed the trail off to the right and around a small grouping of trees.

We cleared the section of trail only to be stopped in our tracks by the presence of a large adult grizzly bear. Jack and I were stunned; the bear was obviously as unaware of our presence as we, were unaware of it. When we came to a stop, the bear was no more than 15 meters away and instantly rose onto its hind legs and began to growl (Bear standing on its hind legs illustrated by Fig 1.1). With the bear at such a close distance any form of retreat seemed futile. There was a stand of larger trees next to where we had stopped, and we made a dash for them just as the bear dropped to all fours and began to charge. Jack and I flung ourselves at two separate trees and climbed. Both of us being rather tall, we were able to climb relatively fast. By the time the bear reached us, we were both about 12 feet up. The bear bumped the trees a number of times and pushed on them with its forepaws; luckily, it didn't attempt to climb either tree. It pawed at the trees and bellowed at us then moved on to inspect our bikes, then back to us.

Fig. 1.1 Standing Bear

This dance went on for at least 45 minutes as Jack and I clung to the trees. The bear then turned and headed into the bush. Jack and I stayed in the trees for another 20 minutes, then scampered down, climbed on our bikes and hastily headed for home. All in all, it was a very exciting day, although getting out of that situation with only a few cuts and abrasions is awfully lucky!"

Story provided by Brent Arnholtz
illustrating one of his two grizzly
bear encounters. 1994

This short story graphically illustrates the possible dangers of riding or participating in any activity in bear country. Such extreme situations between man and bear, however uncommon, are always possible when people travel in bear country. Hikers, bikers and equestrians run the risk of encountering bears and each encounter is different and possibly dangerous. From casual sightings to maulings and death of man or bear, encounters may result in many different outcomes. Because a bear is a wild animal, its actions cannot be controlled; therefore, it is up to us to use proper caution and any means to avoid an encounter and to keep both parties safe from each other.

The following is an exploration into bear deterrents, repellents and warning devices, with particular attention paid to these products as related to the sport of backcountry mountain biking. In the following chapters, the effectiveness of current bear products will be challenged with regard to the sport of mountain biking; and a design intervention will be introduced as an alternative to current products.

Sec 1.2 Some History of Man Bear Encounters

Encounters between man and bear have been occurring since man's arrival in North America. Stories of the battles between the European cave bear and ancient man have been entrenched in the folklore of the cultures that have shared the land with the bear throughout the ages. In North America, Native Americans viewed the grizzly bear as the most dangerous animal in the North American forest, plains, and tundra, and worshipped it as one of their great spirits. The bear was known as the "Wise Brother", perhaps on account of its human like face. Both eyes pointed forward with a characteristic curious and intelligent stare. " To Native people, bears are us, or at least part of us. That wild, untameable side of us is the part that becomes the bear, when we let it.

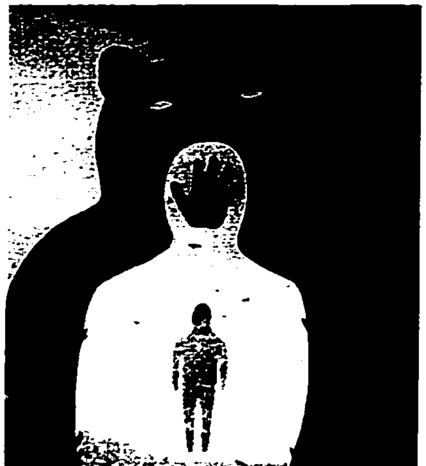


Fig. 1.2 Spirit Bear

Bears put on the intellectual skins of man and walk among us. We put on the emotional skins of bears and disappear into the dark mystery of the forest"; "The bear was referred to as the 'dark thing', 'unmentionable big animal', or the 'four legged human' (Olson, D., 1995). Native Americans both feared and revered bears and struck a unique relationship with them, allowing both species to exist in relative harmony. Figures 1.2 and 1.3 are a sample of Native American art related to bears.

Fig. 1.3 The Great Bear

As history moves on, the relationship between bear and man began to change. With the arrival of the white man and his rifles and expansion across North America, man and bear began to clash. The European settlers did not hold the same spiritual view of the bear as the Native Americans. The bear, although still feared, was now seen as a danger to families, farms and livestock. The hunting of bears as sport became fashionable. The new American view of the bear is most apparent with the story that is attached to the coining of the term "Teddy Bear".

President Theodore Roosevelt, an avid hunter, was out hunting bear with his entourage and returned without a kill. The camp owner, seeing the disappointment of the group, offered the president the opportunity to shoot the camp's caged bear. The president declined on the basis of good sportsmanship. Thus, the sparing of this caged bear is the origin of the stuffed, lovable and harmless "Teddy Bear".

In recent history, the relationship between man and bear has remained a tenuous one. The ubiquitous Teddy Bear is still among us and the circus bear still exists. The Moscow Circus on Ice includes several hockey playing bears that have been trained to ice skate on their hind legs and to hold a hockey sticks in their forepaws. However, man-bear encounters are usually confined within the constraints of the modern zoo. The great bear is held in man's idea of a representative habitat leaving us humans secure to file by and look upon the bear with emotions ranging from spiritual to mockery.


Fig. 1.4 Begging Bears

Wild bears however, can still be found in considerable numbers within the borders of our national parks. Partial sanctuaries have been established where both grizzly and black bear have been able to live. The National parks of Banff, Waterton and YoHo are excellent examples of parks where black and grizzly bear can be found. However, since the 1960's, these parks have become not only havens for bears and other animals, but for humans as well (Herrero, S., 1985). Starting in the 1960's and continuing to this day, national parks have become very popular places for humans to unwind, participate in recreational activity and to get in touch with nature. However, this and continued development into bear territory has brought man and bear into closer and closer contact. Figure 1.4 illustrates the damage to bear behaviour as a result of human activity in the parks.

With the coming of age of mountain bikes within the last decade, the number of backcountry participants has been growing (Crowther, N., 1996). With the popularity of this new sport comes the increased probability of man-bear encounters. " The chances of an encounter increases with the number of people travelling in grizzly habitat. More people in the backcountry means more injuries" (Herrero, S., 1985).

It is not my intention within this project to champion the idea that man should be kept out of our national parks and bear country. I will, however, attempt to show that man and bear can coexist to a greater extent with the incorporation of intelligent industrial design.

What follows is an exploration into current bear deterrents and repellents available to backcountry enthusiasts, specifically mountain bikers. The products reviewed are designed to reduce the chances of a bear encounter or to ward off an aggressive attack. For the purposes of this project, both black and grizzly bears will be addressed; however, the grizzly will occupy the predominant focus. It is my intention to show that a design intervention is warranted with regard to these products. It will be argued that an alternative product design is necessary for bear warning devices when combined with the sport of backcountry mountain biking.

Sec. 1.3 Design for Mountain Bikes

Fig. 1.5 MTB Ride

Anyone entering bear country runs the risk of a possible bear encounter. For years hikers have experienced the majority of encounters; however, any sport or activity exposes the participant to risk. During the course of this project, stories of bear encounters were heard from hikers, boaters, fishermen, survey crews, motorists, campers and cyclists. All of these encounters had the potential to be dangerous.

The reasons for designing a bear deterrent specifically for mountain bikes include the following:

1. At a personal level, mountain biking is my recreational passion and has been for the last 10 years. I have found the sport to offer many facets of personal enjoyment from physical fitness to a means of personal and spiritual expression. The activity also provides an excellent means to explore and experience the outdoors as illustrated by Figure 1.5.

2. Through my years of backcountry experience including biking, motorcycling, camping, hiking, skiing and fishing, I have developed a keen appreciation for the outdoors and our relationship with its natural inhabitants. I, as do many other people, believe man and animal can coexist to an extent within the boundaries of the backcountry. It is an unfortunate fact that bear encounters do happen and can result in severe human injury and even death. With

regard to human injury altercations with grizzly bears result in the most serious injuries; altercations with black bears are rare and usually result in only minor injuries. However, it is not only humans who face possible injury or death as a result of an aggressive encounter. The same is true for the bear. Aggressive confrontations between man and bear more often than not result in the destruction of the bear, either grizzly or black. Therefore, it is in both man's and bear's interest to reduce the number and severity of encounters. Considering the popularity explosion of mountain biking as a backcountry activity, the chances of man-bear encounters may increase. It is the purpose of this project to explore and help reduce the probability and severity of these encounters.

3. The characteristics of operating and riding a mountain bike in the backcountry greatly increases the chances of an encounter with a bear. This assumption will be explored further in the next section and discussed at length in Chapter 3. Furthermore, it will become a major focal point with regard to the justification of the project and the product's design.

4. The following section will illustrate the unique and adverse conditions in which the sport of mountain biking takes place. It is assumed at this point that a successful design of a product capable of performing under these conditions and characteristics could logically be applied to a variety of other backcountry activities, thus helping reduce sudden encounters between hikers, campers, survey crews, etc.

Sec. 1.4 Mountain Bike Characteristics

Mountain biking (MTB) as a recreation has only been in existence for approximately 20 years. In this short period of time it has developed from an obscure past- time to an Olympic sport. It began in Southern California in the late 1970's when a handful of riders trekked up a local mountain on 30 kg bicycles and enjoyed the gravity-assisted- ride down. From this early group a number of them started fledgling bicycle companies. In 1980 the

Specialized Rockhopper was introduced and touched off a revolution in the bicycle industry. The Stumpjumper went on to become the most popular bike in history and earned a place in the Museum of Art and Design. At present, mountain bikes account for more than half of all bikes sold world wide (Crowther. N.,1996).

The act of MTB is both physical and spiritual. It is an excellent form of exercise and offers participants a vehicle for experiencing our natural environment.

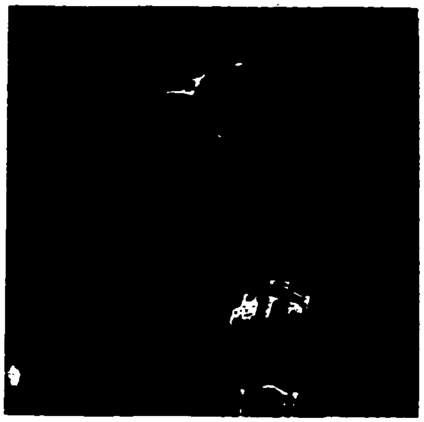


Fig. 1.6 Exhausted MTB Rider

The physical and mental requirements of riding a modern MTB can be high and at times daunting. Because the bikes are intended for off-road use, it is often the terrain that determines the extent of physical and mental output levels of the rider. It is not unheard of for MTB rides in the Canadian and American Rockies to last upwards of three hours and include 60 km loops, elevation gains of 1000 meters and descending speeds of 80 Km/h. Jumping Pound/Cox Hill trails located in the Canadian Provincial Park of Kananaskis Country are excellent examples of such rides. The physical strain of riding a MTB can be seen on the face of the rider in Figure 1.6.

Maintaining control of a modern MTB is at times a totally engrossing endeavour. The steering, shifting and braking are all controlled by the rider's hands. The manipulation of high powered brakes, shifting through a 27 speed transmission and navigating the bike through adverse terrain at high speed completely employs the rider's physical and mental faculties. As a result, there is little if any opportunity for the rider to operate additional equipment or perform additional tasks. Chapter 3 will further explore these issues with regard to current bear deterrents and repellents.

Sec. 1.5 The Sudden Encounter

A sudden encounter with a bear is precipitated by a human entering the immediate area of a bear without the others knowledge. "People who move silently through bear country without letting their presence be known at a distance, and fail to be alert of their surroundings, can find themselves in a close confrontation, causing a bear to perceive a threat to itself, its cubs, or a guarded food source" (Brown, G., 1996). "The sudden encounter is the most common situation associated with grizzly bear inflicted injury" (Herrero, S., 1989).


Fig. 1.7 Aggressive Grizzly

For the bear the sudden encounter is akin to our own idea of personal space. When someone, especially a stranger, approaches us too closely or talks to us at very close distances our "Personal Space" has been violated and our response is often that of agitation and even aggression (Atkinson et al., 1989). The same is true of a bear. However, a bear's personal space may range from 10 meters to 1 kilometre (Brown, G., 1996). Herrero (1989) states that, "each bear has an individual distance to which it will allow other bears or people to approach. As a rule of thumb, 50 meters is the distance at which a grizzly bear is very likely to react to people with aggressive action or avoidance". If a human suddenly appears within the bear's perceived area of personal space, the chances of it reacting aggressively are even greater. See Figure 1.7

It is in respect to its volatility and commonality that the sudden encounter with a grizzly bear has been isolated as the focus for this project. As well, this project will regard 50 metres as the minimal warning distance tolerable between man and bear. Encounters with black bears are far less dangerous. Even a sudden encounter with a black bear will rarely elicit an aggressive response. However, the results of the questionnaire conducted for this project indicate a large number of MTB encounters with black bears at alarmingly close distances, that could possibly become dangerous. As a result warning a black bear of an approaching MTB is also seen as advantageous. Please see Chapter 2 and Appendix E for further information.

Reducing the chances of a sudden encounter is of paramount importance for mountain bikers. As introduced earlier and to be discussed at length later, travelling by mountain bike is often characterised by high speeds and exceptionally quiet movement, which results in, limiting both the acoustic warning noise and the physical time a grizzly or black bear has to react to the presence of an on coming rider. (Brown, G., 1996). These characteristics combine to dramatically increase the chances of a sudden encounter and an aggressive confrontation between man and bear, especially a grizzly bear when mountain biking.

Summary

The relationship between man and bear has been one of conflict since the arrival of European settlers. With the recreation boom of the 1960's and with the recent advent of mountain bikes, conflict between man and bear continues. The sudden encounter with a bear is the most common and dangerous. MTB riders are particularly at risk to this type of encounter. It is the proposed objective of this project to review current bear deterrent and repellent products and attempt a design intervention with regard to backcountry mountain biking.

Chapter 2: Bears

Sec. 2.1

Physical Characteristics of Black and Grizzly Bears

Bears are the largest omnivores (meaning that they will eat a variety of foods) in North America. However, they are very adept at knowing when and where the highest quality of food can be found and will follow the emergance and ripening of specific vegetation throughout the snow- free months. Both grizzlies and black bears are capable of killing animals ranging in size up to an adult moose. However, they are relatively inefficient hunters and generally scavenge or prey on the young, old or sick. Their evolutionary trend has been towards greater reliance and efficiency for digesting seasonal vegetation (Herrero, S., 1985)

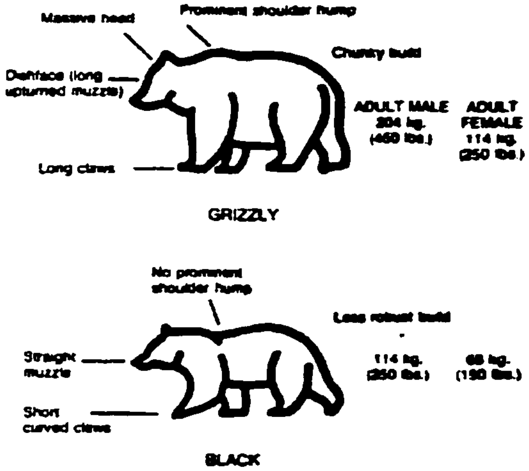


Fig. 2.1 Physical Differences Between Grizzly and Black Bear

They all have basically the same shape with heavily constructed, strong and durable bodies. They posses enormous strength and agility, and are capable of killing and carrying away animals as large as an adult elk. They have strong curved claws capable of ripping and tearing at prey. Differences are apparent between the two species in the length of the front claws and degree of toe separation which can sometimes be seen in tracks left by a bear. "However, these impressive implements can also be used with remarkable dexterity to handle foods, retrieve backpacks and open door latches" (Brown, G., 1996)

Sec. 2.2 Grizzly Bears Physical Characteristics

Several physical characteristics distinguish the adult grizzly bear from other bears as illustrated by Figure 2.1.

It has a stout, chunky build, prominent shoulder hump, a massive head with upturned muzzle, and very long claws (as long as a human's fingers). The large shoulder hump and long sharp claws make the grizzly adept at digging for roots and bulbs which make up a large portion of their diet. Grizzlies range in colour from black and brown to cinnamon or blond. They often have white-tipped or frosted hair on their backs and darker legs.

Grizzlies show local differences in size influenced by food supply. In northern and interior areas, where the growing season is short, adult males average 150-200 kg (330-440 lb.). In coastal regions, with a long season and ample fish stocks, adult male bears can reach over 650 kg (1400 lb.). Females weigh less (Bromley, M., 1985).

Although large and seemingly cumbersome, a grizzly bear is capable of tremendous running speeds and feats of endurance. An adult grizzly can attain speeds of 60 km/h (35 m.p.h.), faster than an Olympic Sprinter. Although it can only maintain this speed for short periods of time, grizzlies have been reported to "run without a break for over 10 miles and can run both up and down hills" (Brown, G., 1996).

Sec. 2.3 Black Bear Characteristics

The black bear is the smaller of the North American bear species. Black bears are sometimes confused with grizzly bears because they may appear similar in size and colour. They can be distinguished from grizzly bears by their smaller, less robust build, lack of prominent shoulder hump, their straight muzzle and curved shorter claws. They often have a patch of white fur on their chests.

Adult males weigh an average of 100-150 kg (220-330 lb.), but can reach over 275 kg (600 lb.) again, females weigh somewhat less than males (Bromely, M., 1985).

Black bears are expert tree climbers and can run almost as fast as a grizzly, 50 km/h (Bromely, M., 1985).

Sec. 2.4 Grizzly and Black Bear Ranges

Fig. 2.2 Current Grizzly Range

In decades past the grizzly bear could be found across North America. However, in recent history, its territory has shrunk from the pressures of human development and due the fact that grizzly bears do best in areas isolated from man. As a result, their territory today is limited to the western mountainous regions of Canada and the United States and continues north into Alaska, Yukon and the tundra of the North West Territories. See Figure 2.2. They prefer open or semi-open country, although they also frequent forests and lowlands. The grizzly, when not denning, is continually searching for food and, when in season, mates. In the mountains, grizzlies move up and down-slope following the emergence of ripening vegetation.

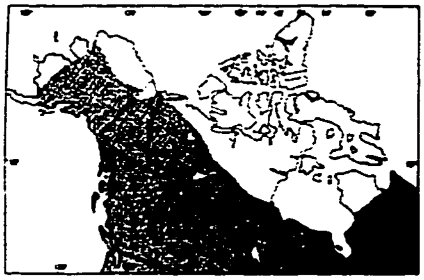


Fig. 2.3 Current Black Bear Range

Black bears have a larger distribution than grizzly bears. They are found in most forested regions of Canada and into the United States and Alaska. See Figure 2.3. Naturally shy and secretive, they rarely venture far from forest cover. Black bear distribution is essentially influenced by food availability. They will travel long distances to take advantage of a food supply. However, unlike grizzlies, they generally remain in forested areas.

Information and graphics presented in Sec 2.2-2.4 were compiled from "Safety in Bear Country" Department of Natural Resources N.W.T 1985, Bromely, M.

Sec. 2.5 Basic Bear Behaviour

The only characteristic of bear behaviour that biologists will state with certainty is that individual bears are as unique as individual people. However, through research, generalizations are possible, but it must be kept in mind that bear behaviour is complex and can be influenced by many variables.

Fig. 2.4 Grizzly with Cub

As a rule bears are shy, solitary animals that, given the opportunity, will avoid contact with humans. "Research clearly demonstrates that the normal response of grizzly bears is to avoid people and not to act aggressively" (Herrero, S.,1985). The shy nature of the grizzly bear most often leads to its avoidance of human contact if it is given time to detect the human presence. However, if cornered, threatened, or surprised, a grizzly bear can be very aggressive. "This is thought to be an adaptation to living in an open habitat. With no cover to retreat to, the grizzlies usual response to danger it can not avoid is to stand its ground or attack" (Bromely, M., 1985). Encountering a grizzly bear with cubs (See Figure 2.4) or guarding a food cache is also extremely dangerous.

The black bear is also shy and will usually avoid any human contact. Black bears use the forest for protection and will often flee into the woods or up a tree. However, an encounter with a female bear with cubs can prompt an aggressive reaction.

As previously discussed, the sudden encounter with a bear presents a high potential for danger. A bear will attempt to avoid contact with humans however; when surprised, the bear may be faced with a "Flight or Fight" decision. The bear's reaction will depend on the extent and suddenness of the intrusion, whether the bear has a viable escape route, feels cornered or is defending food or cubs and to a degree, on the personality of the individual bear.

It seems apparent that the best way to avoid such an encounter and possible attack is to warn the bear of one's presence, thus capitalizing on their natural shyness and motivation to avoid human contact. This subject will be explored at length in Chapter 3.

Sec. 2.6 Bear Sensory Modalities

The American black bear (Ursus americanus) and grizzly bear (Ursus arctos) are omnivorous mammals. In their search for food and survival they employ all of their physical senses. However, much like humans, who have become visually dominant animals, bears are stronger in some senses and weaker in others.

Sight:

In past years it was assumed that the bears vision was rather poor. However, in recent years scientific investigations have shown that their sight is probably equal to that of humans. "They are near-sighted but recognize form and movement at relatively long distances, and their peripheral, colour, and night vision are quite reliable" (Brown, G., 1996), (Bromely, M., 1985), (The Bear Compendium, 1986).

Smell:

A bear's nose is its true link to the world. Its olfactory sense allows the bear to avoid danger, locate mates and find food. "A bear has been known to detect a human scent more than fourteen hours after a person has passed along a trail" (Brown, G., 1996). They have been commonly noted to track down a carcass several kilometres away and are exceptionally adept at distinguishing between the scent of animals and humans (Herrero, S., 1985).

Taste:

Very little research has been conducted on the bear's ability to taste, perhaps due to the extreme methodological problems inherent in testing such a sensory modality. However, tests have been conducted with regard to bear deterrents and the use of food laced with noxious chemicals; these experiments and deterrents have met with some success. (Woolridge, D., 1980).

Touch:

No details have been located with regard to a bear's sense of touch. However, both the black and grizzly bear are very dexterous with their forepaws and are excellent at using their noses, tongues and lips in their search for food such as berries, roots, ants and termites.

Hearing:

Past reports of the hearing ability of bears has been anecdotal. However, it is agreed that it is more sensitive than that of a human. "They have been known to respond to the sound of a camera shutter at more than fifty yards and to detect normal level human conversation in excess of one-quarter mile" (Brown, G., 1996). " A brief bleating of a elk cafe was sufficient for two grizzly bears about 1600 feet away to hear the sound and then to locate and kill the calf (found in Herrero, S., 1985). It is agreed that , "bears share an ancient but relatively common ancestry with dogs; George Simpson has referred to bears as being like large dogs with short tails" (Herrero, S., 1985). Dogs have been traditionally perceived as an animal with excellent hearing. There are 130 breeds of domesticated dogs recognized by the American Kennel Club, this list does not include wild dogs such as wolves and dingos. With such a range, their hearing capabilities will tend to vary between breeds. As a whole, the upper range of a dog's hearing has been estimated at 50 - 60 kHz (Marder, A., 1997). However, a more conservative upper hearing threshold has been established at 35 kHz (Carars, R., 1992). Even at this lower frequency, dogs have exceptional hearing in comparison to humans. The evolutionary close relation of bears and dogs gives good indication that bears share much of the dog's hearing ability.

Other indications of the bear's advanced hearing are related to the design of their outer ear structure. Most animals with extremely acute hearing exercise precise and differential muscular control over their outer ear flaps, the pinna. Dogs and bears have muscular control over their pinna and can "perk their ears" to help hear a faint sound and slightly rotate the pinna to aid in the source's location. (Stebbins, W., 1983). This ability can be seen in Figure 2.5.

Fig. 2.5 Grizzly with Perked Ears

In addition to being related to dogs, bears are also part of the taxonomic group of mammals. As a rule the terrestrial mammals have excellent hearing. "There is little doubt that the mammals as a class have capitalized on their acoustic sense more than any other vertebrate or invertebrate group in the course of evolution. Many mammals are able to respond to acoustic energy well below the hearing threshold of other animals and their audible frequency range extends into the region of ultrasonic sound" (Stebbins, W., 1983). In the class of mammals it is only the primates, which includes humans, that have relatively limited hearing ranges or have lost their ability to hear high frequency sound energy (Stebbins, W., 1983 ; Yost & Nielson, 1977).

Specific research with regard to the ability of bears to hear high frequency sound energy comes from a study conducted by Greene in 1982. Greene found that black and grizzly bears "perked their ears" in response to a 21 kHz tone. This study will be referred to at length in later chapters.

Summary

There are physical and behavioural characteristic differences between black and grizzly bear. Both species can grow to extremely large size and are exceptionally strong and capable of astonishing running speeds. Bears are naturally shy of humans and will, under most circumstances, attempt to avoid any form of contact. However, they can respond aggressively under certain conditions. Surprising a bear within its perceived personal space creates a high potential for danger. The best way to avoid this situation is to warn the bear of your approach.

Scientific research on the sensory modalities of the bear have been limited; however, it is assumed their sense of smell is the strongest sense followed by hearing and then by sight. Bears being part of the class mammalian and their close relation to dogs indicates that they have excellent hearing. Their ability to hear ultrasonic sound has been experimentally confirmed.

Chapter 3: Current Bear Deterrents/ Repellents

Sec. 3.1 Definitions

To begin the discussion on deterrents, a working definition of what deterrents and repellents encompasses is required. The term deterrent as used in literature and by the general public covers a wide range of products and methods that can be employed to avoid contact with a bear or stop an aggressive or attacking bear. Products such as capsaicin spray, air horns, bear bells, emetics, electric fencing, cracker shells, rubber bullets, firearms, vocalization, and banging pots are a few examples of deterrents. This large range of products and techniques commonly listed under the deterrent category is ,however, lacking in distinction and clarification. As a result, the following definitions offered by Hunt, as referenced in the Grizzly Bear Compendium 1987, will be used:

1. **Deterrents**-should prevent undesirable behaviours by turning bears away before a conflict occurs. Items under this category can also be known as "Bear Warning Devices".

2. **Repellents**- are activated by humans and should immediately turn a bear away during a close approach or attack.

3. **Aversion Conditioning**- should modify previously undesirable behaviour through the use of repellents or deterrents. This is usually employed with regard to food conditioned and or habituated bears.

Confusion may still arise between deterrents and repellents, for almost all of the deterrents that will be discussed can also be used as a repellent with varying success. As a result, the situational conditions can often determine the definition of the product.

A situational example of the use of a deterrent and a repellent may clarify the differences.

Situation 1. A group of mountain bikers are riding in bear country. Each bike is equipped with a bear bell and an air horn is activated on occasion to warn any bear in the area. (The bell and horn are being used as a deterrents, or warning devices).

Situation 2. The same group of MTB's encounter a grizzly bear that begins to act aggressively. The bear barks and advances on the group. The air horn is activated and, as the bear continues its advance, one member of the party sprays the charging bear with capsaicin spray. (In this case the air horn is now being used as a possible repellent along with the mace).

Appendix A. constitutes a full list of bear deterrents and repellents that have been researched and tested on grizzly, polar, and black bears. The research was conducted and or compiled by the Department of Natural Resources of the North West Territories and referenced in "Safety in Bear Country, Bromely, M" 1985.

Sec. 3.2 Repellents

As defined in the above definitions and situational examples, there are very few true bear repellents. The following is a brief outline reviewing three possible repellents available to a backcountry mountain biker.

Loud Sounds

Some bear experts recommend the making of very loud noise in the event of an attack which may result in the bear stopping its charge, and/ or, scaring the bear away. Many different products are available for this situation and are referenced in Appendix A. The effectiveness of these products is by no means 100 % and actual field research is limited. One of the few experiments with regard to repellents including loud sound was conducted by Miller in 1980.

Miller tested a number of repellents on captured grizzly and polar bears. The bears were kept in a large unheated, modified building with a gated doorway. When researchers repeatedly approached the gate to deliver a repellent or control, the bear nearly always charged the researcher. Recorded sounds of humans shouting, and of growling grizzly and polar bears were ineffective as repellents. Only loud sharp sounds were effective. Thunder flashes, which are hand thrown explosive charges , 1 out of 1 (100%) and boat horns, 4 out of 6 (66%) caused the bears to scramble away. Air horns and sirens usually stopped the bears mid-charge but did not cause them to retreat.

Fig. 3.1 Capsaicin Spray

Noxious Chemicals

To date, one of the most promising repellents found for grizzly and black bears is capsaicin, an ingredient of cayenne peppers. The compound is a powerful local irritant effecting sensory nerve endings, mucus and tear glands. See Figure 3.1. It appears to have no long term side effects and has been effective in repelling polar, black and grizzly bears (Miller, G., 1980 ; Herrero & Higgins, 1997). The spray is deployed in most cases through an aerosol spray container and is most effective when sprayed in the face of the bear. Again, the spray is by no means 100% effective and concerns still exist with respect to its effects on a aggressive and or attacking bear (Herrero & Higgins, 1997).

Firearms

Fig. 3.2 Modified Shotgun

It is no surprise that a firearm of some kind can be an effective repellent in the event of a bear attack. Either used to scare off the bear with the loud discharge of the gun or through the actual shooting of the bear, a firearm can be a powerful deterrent or repellent (Clarkson, R., 1989). Figure 3.2 shows a shot gun modified to fire blanks and rubber bullets. Of the available weapons the following are listed as the most suitable and or common:

Shotguns- provide reliable bear protection and are the recommended weapon for people with little shooting experience. The wide dispersion of lead shot negates the necessity of having perfect aim by the user; however, several rounds maybe required to bring down or kill a bear because of the inconsistent dispersion of lead shoot.

Rifles- of calibre ranging from .30 to .60 (or comparable power) are suitable bear protection for people who are confident with the use, operation and aiming of these guns.

Handguns- for protection against a bear is controversial. Revolvers of .357 or larger are capable of killing a bear in one shot, but only in the hands of a trained shooter.

(Safety in Bear Country 1985)

Limitations to Repellents

The main limitations of all repellents is that they have to be easily accessible and properly used in the event of an attack. A charging grizzly bear is capable of running speeds up to 60 km/h. Encounter distances of 100 meters or less (characteristic of sudden encounters with grizzly bears) provide only seconds to properly deploy a repellent. As a result, the repellent must be instantly accessible, the operator must be familiar with its operation and characteristics, calm enough to use it effectively and the products must be in good working order.

Capsaicin spray, mentioned above as the most effective non-lethal repellent, suffers drastically from these drawbacks. The spray is only effective when sprayed directly in the face of the bear (Miller. G.,1980 ; Herrero & Higgins 1997). Compounding variables also limit its effectiveness. A popular brand of spray "Bear Scare" lists its maximum distance of deployment as 7-8 meters or 23 feet and a maximum spray duration of 8 seconds. Furthermore, environmental conditions can greatly effect the deployment of the spray. "Moderate to high wind, heavy rain, or thick vegetation", may limit its effectiveness (Herrero & Higgins 1997). Needless to say the use of capsaicin spray in the event of an attack requires a fast and steady hand and favourable environmental conditions.

Air horns and other noise making products face similar drawbacks. Air horns are not reliable in cold weather conditions and are liable to mechanical breakdowns or leaking. Cracker shells often misfire and are deployed by shot guns which are illegal in the national parks. Thunder flashes require enough time and steady nerves to light and throw; furthermore, their effectiveness is related to the user's throwing ability and accuracy (Bromely, M., 1985). Throwing a thunder flash too far and having it land behind the bear could multiply its aggression and direct it right towards you.

Sec. 3.3 Deterrents

As commented earlier, the labels deterrent and repellent are often interchangeable depending on the situation. Thunder flashes and cracker shells, discussed above, could be used as deterrents, by setting them off with no bear in sight, thus letting the bear know of your presence. The term "Bear Warning Device" may be a more suitable term for these products and will be abbreviated as BWD from this point forward. The true purpose of a BWD is to let the bear know of your presence, capitalize on their natural shyness and motivation to avoid humans and thus, reduce the probability of a sudden encounter.

The broad definition of a BWD could include almost any noise making device or technique. Vocalization, singing, whistling, activating an air horn and banging pots are all forms of BWD's however, the most common is the use of a bear bell.

Sec. 3.4 Effectiveness of Bear Bells

Fig. 3.3 Common Bear Bell

Although limited, the experimental research on the effectiveness of bear bells is positive. The most pivotal research found was conducted by Jope in 1985. She explored the reaction of grizzly bears to hikers on light to heavily travelled trails and the reactions of bears to hikers not wearing bear bells and to those who were. Figure 3.3 shows a common bear bell.

With regard to bear bells, she found that hikers wearing bells observed bears at similar distances as non-bell wearing hikers. However, the subsequent response of the bears was different. The following illustrates her findings:

A. Hikers who encountered a bear resting or not moving in any particular direction.

Those with bells	Those without bells
67%	26%
Bears moved away from the hiker	Bears stood their ground or moved toward hiker

B. Bears that were moving toward hikers on initial sighting.

Those with bells	Those without bells
50%	21%
Bears moved away or past hikers ground	Bears stood their ground of moved toward hikers

C. Hikers charged by bears.

Those with bells	Those without bells
0%	14%

Jope's study indicates that bear bells (in Glacier National Park, USA) appear to provide unambiguous information to the bears which they associate with hikers. Habituation and bells reduce the probability of a sudden encounter and also reduce the aggressive nature of a subsequent encounter.

Jope suggests the following with regard to reducing aggressive encounters with grizzly bears.

1. Provide a consistent context for encounters with hikers or bikers. i.e.: encounters with man take place during specific months and on well used trails.

2. Have frequent and irregularly spaced encounters between man and bear to habituate the bears to the common appearance of humans on the trails.

3. Employ an easily recognizable stimulus, such as bells, to warn the bears and announce who and what you are.

4. Have innocuous behaviour by hikers or bikers. i.e.: that the encounters do not include food giving or aggressive behaviour on the part of man.

Limitations of bear bells

I believe that the scientific research conducted with regard to bear bells or other noise makers confirms that they are an effective means of warning bears and reducing sudden encounters. However, they have their limitations, which lie predominantly in their limited sound carrying distance. "The tinkling of the bell is easily masked or degraded by environmental variables such as rushing water, wind and thick foliage" (Herrero, S., 1985). Keeping in mind that 50 meters has been previously established as the minimal safety distance, any reduction in the sound carrying distance of the bells could result in an encounter. Miller (1980) agrees that warning a bear before you intrude on its personal space is a good strategy; however, bells currently sold to hikers are really inadequate for the job.

Sec 3.5 BWD's/Repellents and Mountain Biking

The discussion of the limitations of bear deterrents and repellents also applies to their use with regards to mountain biking, and even perhaps to a greater extent. As referred to in Section 1.4 Mountain Bike Characteristics, riders are often under extreme physical stress and their cognitive abilities are fully employed with the operation of the transmission, brakes and steering of the bike. The combination of these activities and the high speed of travel eliminates the effective use and deployment of all the repellents listed in Appendix A. A rider who encounters a bear within 100 meters simply does not have the time or the free appendages to properly and accurately deploy any form of repellent. As a result, the best strategy for MTB riders is to alert the bear of their presence through the use of a BWD, providing sufficient distance between the rider and the bear to allow the bear time to avoid contact.

Of the Bear Warning Devices and/ or techniques reviewed for this project, only bear bells and vocalizing seem to be appropriate with regards to MTB's. This is because their warning sound is not dependant on the use of the rider's hands.

Vocalization:

Vocalization as a means for MTB's to warn the bear by yelling, singing or talking is limited by the physical requirements and stress incurred during a ride and is dependant on the trail conditions at the time.

Climbing- Extended climbs are often the quietest moments of a MTB ride. Their is very little mechanical noise emitted from the bike (chain noise) and rider noise (conversation). Loud and repetitive vocalizations are difficult to sustain because of the physical and mental requirements of riding a MTB up a steep grade.

Downhill- During downhill portions of a ride the physical and mental requirements remain and loud repetitive vocalizations again are difficult to maintain. However, these sections characterize the greatest amount of bike produced noise, emitted by the chain and brakes. However, reducing the effectiveness these possible warning sounds produced by the bike are the high speeds. A rider travelling 30 km/h or more will rapidly consume trail distances, reducing the reaction time of both rider and bear .

Flat Sections- On flat portions of a trail the physical and mental requirements are reduced; however, speeds are often still high and bike produced noise varies with terrain. The rider is now physically more capable of vocalizing. However, the rider must do so loudly and frequently to compensate for the bike's high speed and to warn a bear in each successive 50 meters of trail.

Field Trial #1

In order to confirm the above assumptions field tests were conducted to measure the actual sound output of a MTB with regards to trail conditions. Please refer to Appendix B for a full explanation of the study.

The trials took place in Edworthy Park, located in the South West of Calgary on single track trails characteristic of those frequented by local riders. See figure 3.4. The ambient sound level recorded during the trials was 51 dB on the linear scale. It will be important to note at this point that all of the sound levels recorded and documented in this study were done so on the linear sound scale, please refer to Appendix C for a brief review on sound and its measurement. The results of the trials were as follows:


Fig. 3.4 Trail for Field Trial #1

Flat Ground-The average sound level of the MTB was 54 dB at a speed of approximately 21 km/h.
Up Hill Climbing- The average sound level was 52 dB at a speed of approximately 5 km/h.

Downhill- The average sound level was 55.25 dB at an approximately 21 km/h. The lower rate of speed on the downhill as opposed to the flat section is a result of the high technical aspect of the downhill section reducing the speed and sound production of the bike.

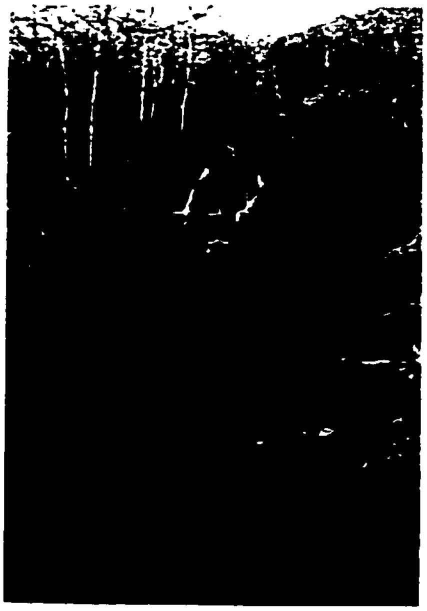


Fig. 3.5 Harsh Downhill

The section of trail for the downhill trials consisted of relatively steep but smooth terrain. In order to approximate a really harsh trail my assistant rode the MTB down a portion of stairs located in the park, thus, maximizing the noise produced from the bike's components, specifically the chain, brakes and tires. See Figure 3.5.

Harsh Downhill- The average sound level was 61.75 dB at an approximate speed of 17 km/h.

The subsequent increases in sound output over the ambient sound level ranged from 1 dB - 10.75 dB. This short study dramatically illustrates how quietly a MTB can travel on backcountry trails, it is not until the bike is ridden on extremely rough terrain that any significant increases in sound level are produced. Furthermore, such sections are not ubiquitously found on all trails, nor are such sections representative of the majority of trails found in bear country.

MTB's and Bear Bells

The use of bells by hikers has been shown to be an effective means to warn bears of your presence and help reduce the chances and risk of a sudden encounter. However, their effectiveness with regard to MTB's is arguable.

The active jingle of a bear bell is dependant on the physical movement of the bell itself. With regards to hikers, the bell is activated by their biped gate. As a result, the bell's characteristic jingle is produced consistently throughout the hiker's travels.
In contrast, a bear bell used during MTB rides is activated

by the characteristics of the trail. Bumps, ruts and roots will jostle the bike and rider with sufficient force to activate the bell. However, a smoother trail or rider will reduce the number of times the bell is activated, thus increasing the distance travelled between warning chimes and dramatically increasing the opportunity for an encounter with an unsuspecting bear. The riding of a full suspension MTB further exacerbates this problem by allowing the rider to travel smoother and faster along a trail.

A further limitation to the use of bells with regard to both hikers and MTB's is that they become useless during rest stops. As a person rests, the bells are inactive therefore allowing for the possibility of a bear to stumble across the rider.

In order to confirm the above Assumptions relating to bells and MTB's, further field trials were performed. These trials were conducted in unison with field study #1 and utilised the same trail sections.

Field Study #2

For study purposes a bear bell was fitted to the front handlebars of the MTB for study. See Figure 3.6 The bell was purchased in a local sporting goods store and is representative of bells commercially available. Trials were then conducted along the same section of trail as in Field study #1 and at comparable speeds. The following is a list of the results. Please refer to Appendix B for a full explanation of the study.


Bear Bell Locattion

Fig 3.6 Bike and Bear Bell

The ambient sound level recorded during the trials was approximately 51 dB on the linear scale.

Flat Ground- The average sound level was 56.25 dB at an approximate speed of 21 km/h.

Up Hill Climbing- The average sound level was 54.5 dB at an approximate speed of 4.75 km/h.
Downhill- The average sound level was 59.75 dB at an approximate speed of 17.5 km/h.

Harsh Downhill- The average sound level was 75 dB at an approximate speed of 18 km/h.

The sound level of a MTB with a bear bell over the ambient sound level ranged from 2.5 dB- 12.75 dB. Again the greatest gains were on extremely rough terrain which is uncharacteristic of the majority of MTB rides in bear country. Furthermore, in both field studies the extrapolated carrying distances of the sound produced by the bike and by the bells was shown to be inadequate and would offer little warning time to a bear.

The above study helps illustrate that bear bells are inadequate as a means of warning bears when used on mountain bikes. The activation of the bells is entirely dependant on the trail conditions and smoothness of the rider. Furthermore, the sound levels emitted by the bells are only substantially increased on severe trail conditions. A third study was conducted to further explore the carrying range of a bear bell.

Field Study #3 Carrying Distance of a Bear Bell

Through an extensive literature review it was found that no studies have been published exploring the sound output or carrying distance of bear bells. Although, they have been shown to be an effective BWD, no information exists on their sound signature or power. Field Study #3 was designed to attain baseline data on these characteristics. Please refer to Appendix D for full details.

Fish Creek Provincial Park located in the South West of Calgary was chosen for the site of the study. It offers a variety of terrain and geography that is consistent with

the hiking and mountain biking trails found in bear country. Two sites were selected for exploration
1. An open field with 30 cm high grasses and weeds. See Figure 3.7.

Fig. 3.7 Open Field

2. A foliage laden trail consisting of a surface of soft soil and fallen leaves enclosed by small to medium sized mature coniferous and deciduous trees. See Figure 3.8.

A bear bell was attached to a mountain bike and with the help of an assistant was tested for its decibel level (dB) at varying distances.

Fig. 3.8 Wooded Trail

At one meter the bell produced a maximum of 71 dB, which then reduced in power the farther the MTB moved away. It was found that the decrease in sound closely followed that indicated by the general equation for sound attenuation (Appendix C) The average ambient noise level was 45 dB. When the bike and bell were 30 meters away the bell's sound was not powerful enough to effect any change on the sound meter and thus became part of the ambient noise level.

When tested on the foliage trail the bell again produced 71 dB at one meter and again stopped eliciting meter results at approximately 30 meters.

On both trail conditions my assistant, yelled "Go Away Bear" at one meter and again at 50 metres. At one meter the yell registered an average of 73.5 dB and 46 dB at 50 metres. These results are consistent with the equation for attenuation, very similar in dB to the bear bell.

I believe the three studies conducted support the explanation of why bells are a viable means to avoid a sudden encounter with regard to hikers. Their bipedal gate activates the bell on regular occasions and in some places the bears have come to associate these bells with slow moving humans on foot. However, a MTB travelling on smooth to semi- rough terrain at any speed greater than a slow jog will quickly overcome the security offered by a bell.

It is not my intention to discourage the use of bells by MTB's as anything is better than nothing but the bells will not offer the same protection afforded to a hiker.

Survey Results

In the early stages of this project it was apparent that little specific information was available related to MTB encounters with bears. Thus, a survey was designed and implemented to target the MTB community. The intent was to gather basic information on encounters, attitudes, deterrents and design issues. Please refer to Appendix E for a copy of the survey, results and discussion.

One of the most serious implications of the study relates to the high number of riders that are coming dangerously close to bears before either of them become aware of each other. 35 out of 41 (84%) of riders indicated that they came closer than 50 metres with encounters as close as 3 metres (see question 9 on the survey). Furthermore, in 27 of 41 (66%) of these encounters, the rider indicated that the bear was startled by their presence (see question 12).

The results for both species of bear, black and grizzly, are as follows:

Black Bears:

Of the black bears encountered 15 of 27 (55%) were startled by the MTB. The majority of encounters 12 of 27 (44%) resulted in the bear running for cover without stopping; 3 of 27 (11%) ran a distance then stopped and looked back at the MTB; 10 of 27 (37%) had no reaction to the MTB and only 1 of 27 (3%) acted aggressively in reaction to an accompanying dog.

Grizzly Bears:

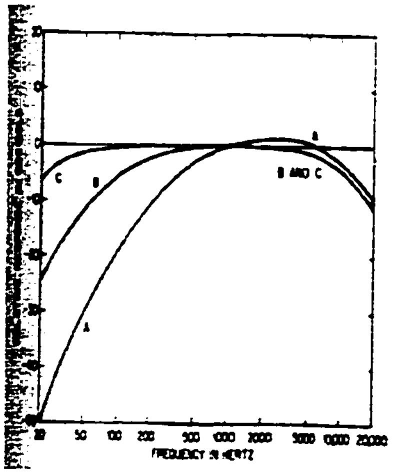


Fig. 3.9 Startled Grizzly

Of the grizzlies encountered 11 out of 13 (85%) cases were startled by the MTB; 2 of 13 (15%) ran to cover without stopping; 3 of 13 (22%) ran a distance than stopped to look back; 3 of 13 (22%) had no reaction and 5 of 13 (38%) advanced on the rider including 2 charges. Of the two bears that charged and the one that advanced on the riders, 3 of 5 (60%) were females with cubs. Figure 3.9 shows a startled grizzly bear.

A further finding of the study is with regard to mountain bikers' attitudes toward current bear deterrents. Question 21 found that 32 of 41 (77%) of the surveyed riders indicated that the thought of a bear encounter does enter their minds when they ride. However, question 18 found that 19 of 41 (46%) of the riders use no form of bear deterrent. The majority of riders 71% (21/31), indicated that current deterrents (specifically bells, horn and vocalization) were too irritating to them and to their fellow riders. Further, that the constant noise significantly reduced their enjoyment of the outdoor experience. Among those surveyed, only 3 of 31 (10%) thought a bear deterrent of some kind was not needed and 6 of 31 (19%) said that they were ineffective. Figure 3.10 illustrates the type of warnings offered to participants in the backcountry.

Fig. 3.10 Bear Warning Sign

These results indicate that the majority of people believe that deterrents can offer some measure of protection however, they are being rejected due to their invasive noise. Given the choice between current deterrents and using nothing, many people are opting for nothing and are thus endangering both themselves and the bears.

Based on the information accumulated for this project the following statements can be presented and supported:

1. All current forms of bear repellents are inadequate when applied to mountain biking.

2. The making of noise while on a MTB either through the use of a BWD or vocalization in the backcountry and thus warning a bear of your presence is the best method of avoiding a sudden encounter.

3. Although considered a good strategy for hikers, the making of noise employing current BWD's or vocalization when paired with MTB has been demonstrated to be highly suspect in its effectiveness.

4. The majority of the MTB community believe that BWD's offer some measure of protection but are being rejected because of their invasive noise.

5. The exploration of an alternative BWD is warranted and overdue.

Summary

The use of BWD and repellents was explored extensively with regard to its effectiveness when used by hikers and MTB. Through a literature review, it has been established that the making of noise while in the backcountry is the best strategy to avoid a sudden encounter while on a MTB. However, through field studies it has been proposed that no current repellent or BWD is acceptable with regard to MTB's. The exploration into alternative BWD is warranted and overdue.

Chapter 4: Ultrasonic Sound a Possible Solution

It has been established that making noise remains the best strategy for MTB's to avoid a sudden encounter with a bear; however, current BWD's are ineffective and sound invasive resulting in MTB riders rejecting their use. A possible solution may exist by utilizing sound which is inaudible to humans but fully audible to bears. Such a solution could be reached through the use of ultrasonic sound.

The incorporation of ultrasonic sound into a BWD presents the following advantages:

1. The device would be a non-obtrusive deterrent, one audible to bears and not to humans (Herrero, S., 1985; Greene, R., 1982).

2. Because ultrasonic sound must be produced through a mechanical device it can be designed to certain specifications and controlled in terms of frequency, amplitude, duration and repetition.

3. The emitter can be designed to be monitorless by the user and, unlike bells or horns, not dependant on physical movement or on conscious activation.

4. The range of the warning sound can be controlled through the design and power of the emitter.

Sec. 4.1 Ultrasound, a Definition

The term 'ultrasound or ultrasonics' is used in acoustics to denote the frequencies of sound which are beyond the limits of the human ear. At the beginning of the century the term commonly used was 'ultrasonics' ; however, following advancements in aviation technology this term is now applied to air travel beyond the speed of sound.

Human Hearing

The actual range of ultrasound is rather elusive. Because it is related to the varied physical limits of the human ear, the setting of a lower frequency limit is somewhat arbitrary. Most texts list the beginning of ultrasonic sound at 20,000 Hz or 20 kHz (Bergmann, L., 1938 ; Lenhardt, M., 1991), although some texts list it as low as 16 kHz (Ensminger, D., 1973).

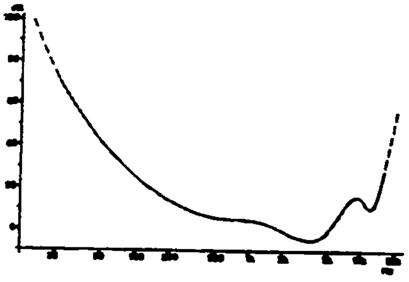


Fig. 4.1 Sensitivity of the Human Ear

The frequency range of human hearing varies greatly among individual. A person who can hear over the entire audible range of 20-20,000 Hz is very unusual; however, hearing responses up to 24,000 Hz have been recorded (Lenhardt, M., 1991). **Figure 4.1** illustrates the sensitivity of the human ear to specific frequencies. Traditionally the ear is relatively insensitive to low frequency sound. Our sensitivity to high frequency noise is greatest in early childhood and decreases gradually with age; adults may have difficulty hearing sounds beyond 10 or 12 kHz. The human ear is designed to be most sensitive to sound frequencies between 1000-4000 Hz (Rossing, T., 1982). See Figure 4.1.

Sec. 4.2 History of Ultrasound

Ultrasound as a specific branch of the science of acoustics had its origins in the study of underwater sound. Prior to the development of ultrasound, ships were warned of dangerous obstacles in the water by bells submerged from lighthouse ships. Trained crew members of passing ships could detect these warning signals by means of microphones or stethoscopes pressed against their hulls. The invention of the Fessenden oscillator in 1912 improved this system. It was capable of sending Morse-code messages between ships of up to 10 miles using frequencies of 500-1000 Hz.

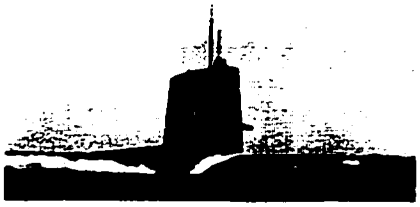


Fig. 4.2 U.S. Submarine

During World War I the use of ultrasound was experimented with for locating submarines. This technology was gradually improved through World War II and is now commonly known as sonar. Today sonar uses ultrasonic frequencies between 20-100 kHz and is used to navigate submarines. See Figure 4.2.

Since 1940, interest in ultrasound has increased. Rapid developments in other technologies have made possible the production of practical ultrasonic systems for domestic, industrial and military use. Today there are many applications for ultrasound. It is common in the medical field for imaging and rehabilitation purposes. It is used to clean objects ranging from pens and glasses to industrial sized equipment, found in switches and relays in mine sites and can be used as a method for welding specific materials (Ensminger, D., 1973).

Sec. 4.3 Characteristics of Ultrasound

Like sound energy that the human ear can detect, ultrasound is produced by the physical movement of air. The only difference is in the frequency of the sound. Again refer to Appendix C for an exploration of basic sound and acoustics. A full exploration of ultrasound is beyond the scope of this project but the following is a list and description of the basic characteristics of ultrasound that are pertinent to the understanding of this project.

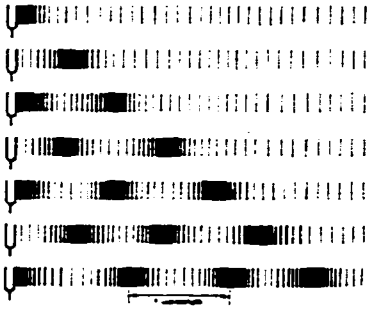


Fig. 4.3 Wavelengths

Wave Type: Ultrasonic energy can be either longitudinal or transverse. For ultrasonic energy to propagate in a gaseous environment, like the earth's atmosphere, it can only exist as longitudinal waves. Such waves are characterized by particle propagation in the same direction as the sound energy. See Figure 4.3.

Wavelength: As the frequency of sound increases, the size of the wavelength decreases. In air ultrasonic sound at 20 kHz will have a corresponding wavelength of 1.6 cm; and as the frequency increases the wavelength becomes shorter.

Speed: All sound energy travels at the same speed although it is affected by altitude, temperature and humidity. Generally its speed is taken to be 330 m/s at sea level (Carlin, B., 1949).

Attenuation: all sound attenuates or is weakened by a number of variables. Attenuation by the air, ground and obstacles are a few examples. Ultrasonic sound is, however, much more prone to attenuation by these variables than is lower frequency sound energy. Its relatively high attenuation in the atmosphere has kept ultrasound from being exploited as a means of communication. The carrying distances of ultrasound in the atmosphere is physically limited to approximately 200 metres. When distances are below 100 metres, ultrasonic sound behaves very much like lower frequency sound and obeys the general equation for attenuation : 6 dB drop in power for every doubling of the distance travelled (Bergmann, L., 1937). Appendix C offers further information on the attenuation of ultrasound in air.

Beaming: all sound has a tendency to disperse in all directions once it has left the source of the sound. This is especially true of lower frequency sound. Its larger wavelength causes the sound to wrap around objects including the source and can be heard through 360 degrees. This is known as divergence. Ultrasonic waves however, propagate through a medium with very little divergence resulting in a beaming effect of the sound. The sound energy travels closer to a straight line with very little sound wrapping around the source (Carlin, B., 1949).

Sec: 4.4 Pros and Cons between Infrasonic and Ultrasonic Sound

One of the main advantages to using ultrasonic sound energy as BWD, is the fact that it is out of the hearing range of humans, thus avoiding the complaints regarding invasive and irritating noise. However, ultrasonic sound is not the only means to this end. Infrasonic sound (energy below the range of human hearing 20 Hz), could also represent a possible solution. The following is a short discussion of the advantages and disadvantages of each type of sound and will illustrate the reasoning behind the project's focus on ultrasonic sound as a BWD.

Infrasonic Sound

Advantages:

1. Frequencies below 20 Hz are inaudible to the human ear.

2. The attenuation of lower frequency sound is much lower. Infrasonic sound would have a much longer carrying distance for it is not as easily attenuated by the atmosphere, ground and obstacles (Kinsler & Frey, 1962 ; Hopp, Owren & Evans, 1997).

3. Because of infrasonic sounds large wavelength it is able to wrap around obstacles with little to no decrease in sound power. An example of this is the low rumble of highway noise. Even with the erection of large cement barricades the low frequency noise has a tendency to flow over the top of the obstruction (Harris, L., 1991).

Disadvantages

1. Because infrasonic sound has characteristics of large wavelengths and is only produced through the physical movement of large volumes of air, it requires a substantially large sound source to properly emit such a noise. Speaker diaphragms must be excessively large and heavy in order to emit infrasonic sound.

2. Its ability to wrap around objects also represents a sizable disadvantage. When any sound is heard by a

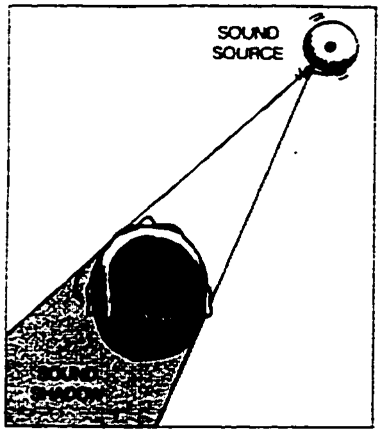


Fig. 4.4 Sound Shadow

human or animal, the location of the source is determined by the difference in time the sound takes to reach each ear. The larger the head of the animal, the more pronounced this effect. The head itself produces a sound shadow, thus reducing the amount of sound reaching the other ear and allowing the animal to localize the source of the sound. "Sounds of sufficiently low frequency and large wavelength are not shadowed by the head and fail to provide the required sound level difference between the two ears, thus limiting the animal's ability for sound localization" (Stebbins, W., 1983). Figure 4.4 illustrates how high frequency sound is shadowed by the head.

Even the massive head of a grizzly bear is insufficient to properly shadow a frequency below 20 Hz. A BWD employing such a frequency would alert the bear but offer no indication of the source's location or direction of movement. This could result in the bear moving toward a person in its confused attempt to avoid contact.

3. Low frequency sound is rather ubiquitous in the natural environment. Wind movement in open areas and foliage creates many low frequency tones; waves on the ocean and large lakes produce infrasonic sound. (Sales & Pye, 1974). The world is full of low frequency sound sources; since these sounds propagate so well, this richness results in a high background level of infrasonic sound (Hopp, Owren & Evans, 1997).

Ultrasound

Advantages

1. At Frequencies above 20 kHz it is inaudible to the human ear.

2. Because of its extremely short wavelength the equipment required to produce it is very small and light.

3. Ultrasonic sound has a characteristic beaming effect. Thus, it is very directional and little power is lost to dispersion of the sound around the source.

4. The short wavelength of ultrasonic sound facilitates the animal's ability to locate the source and direction of the sound.

5. Natural sources of ultrasonic sound in air are few, therefore, the signal would not be competing with other sounds of similar frequency (Hopp, Owren & Evans, 1997). This should facilitate the bear's ability to relate the ultrasonic signal to the approach of a human.

Disadvantages

1. Prolonged exposure to extremely high sound levels of ultrasonic sound can be irritating to humans and in extreme cases cause headache and nausea. The accepted recommendation for exposure to ultrasonic sound is a maximum of 120 dB for a period of one hour continuous exposure (Harris, L.,1991).

2. Ultrasonic sound is more susceptible to attenuation than low frequency sound; however, as stated earlier, it is marginal with regard to distances under 100 metres.

Of the two types of sound inaudible to the human ear ultrasonic sound, as illustrated in the above comparison, is more suitable for use in a bear warning device. The advantages of a small sound emitter, directionality and an animal's ability to easily locate the source and direction of the sound outweigh the disadvantages. Thus, ultrasonic sound incorporation into a BWD is the main focus for this project.

Sec. 4.5 Precedent of Ultrasound as a Deterrent

The application of ultrasound as a repellent and /or, deterrent has been explored and found to be successful with regard to a number of different animal species.

Maclean (1974) tested ultrasonic sound on rats and found it to be a repellent at 20 kHz. Today there is a wide range of ultrasonic repellents/deterrents on the market designed to repel rats and mice from human dwellings. They range in frequency from 20-40 kHz. The same products also have been successful as repellents against cats, dogs and deer. This information was acquired through an internet search of ultrasonic deterrents and pest controls.

Ultrasonic units have also been very successful against birds. They have been particularly effective in deterring nesting in and around buildings and repelling birds from entering large spacious enclosures such as aircraft hangers (Engineering and Management, 1998). Studies have also included coyotes at an exposure to 18 kHz sound (Darcy & Sander, 1975).

Sec. 4.6 Ultrasonic Sound and Bears

The exploration of ultrasonic sound on bears is limited. Research was initiated on the subject when an employee on a ESSO drilling rig was killed and consumed by a sub-adult male polar bear. ESSO expressed interest in evaluating the use of ultrasonic sound generators as a repellent. These initial investigations indicated a limited potential for effective repellency on both free-ranging and captured polar and brown bears at 16 kHz (Woolridge, D., 1980).

Greene (1982) realized that ultrasonic sound is limited as a direct repellent but could possibly be used as a deterrent. In his study Greene presented three zoo grizzly bears with a 21 kHz, 90 dB sound for a duration of 5 seconds. He immediately followed the ultrasonic sound with a 5 second blast from an air horn, which elicited an escape response from the bears. After a number of trials only the ultrasonic tone was presented. The bears' initial reaction was to freeze for several seconds, locate the source and direction of the sound, then to scramble hastily to the back of their enclosures. The experiment was then conducted on a wild black bear and under limited trials the bear was deterred from a food-baited campsite.

Attempts were made to partially repeat some of the finds found by Greene. With the help of the Calgary Zoo Three black bears were tested for any behavioural signs that they could hear various ultrasonic tones. The tests were inconclusive with regard to ultrasonic and clearly audible tones. It is assumed that the bears inner city location has jaded them to most forms of sound emissions. See Appendix F for details of the study.

The above studies give positive indication that bears, specifically grizzly and black bears, can hear ultrasonic sound up to at least to 21 kHz. Furthermore, they can make the association between ultrasonic tones and other stimulus.

Referring back to the discussion on the effectiveness of bear bells, it was shown that they present the bear with an unambiguous sound associated with hikers. I believed that bears could make a similar association between MTB and the presence of ultrasonic tones. This association could be made relatively quickly by most bears, for they are extremely intelligent, are capable of reason and can learn and remember from a single experience (Brown, G., 1996) An ultrasonic emitter, properly designed and worn by a back country participant, could function as an effective alternative to the traditional bear bell and capitalize on the advantages listed earlier.

Summary

Ultrasonic sound was introduced as a possible solution for a sound source to be used in a BWD. Advantages and disadvantages were explored between the two types of sound energy not detectable by the human ear. Ultrasonic sound was shown to be the most promising. The use of ultrasound as a deterrent with regard to other animals was explored. Further information was offered with regard to support a bear's ability to hear ultrasound. The possible use of ultrasound as a deterrent appears to be feasible.

Chapter 5 Design Considerations

Sec. 5.1 Design Philosophy

I have argued that encounters with black and especially grizzly bears can be dangerous with respect to mountain bikers. Even though serious injury to either man or bear is uncommon, a sudden encounter between MTB rider and bear can be viewed as a stressful form of contact for both parties involved. Thus, if sudden encounters between MTB riders and bears could be reduced, the fear and stress of such encounters could also be reduced. Furthermore, possible violent repercussions of a sudden encounter could also be limited. As a result, the main train of thought throughout this project has been to develop a BWD that doesn't scare a bear away by inducing fear through stimulus irritation or offence, but instead to alert the bear of a rider's presence with sufficient time to allow the bear to act on its instinctive tendency to avoid human contact (See Chapter 2).

I believe that there is a subtle yet very important difference between scaring a bear into leaving and alerting a bear of imminent contact with a human and therefore providing the bear with the necessary time to leave the area. The difference lies in the reduction of stress on the animal by possibly eliminating the fight or flight response that can occur in the event of a sudden encounter and by offering the bear at least a minor form of courtesy. This courtesy can be easily understood by viewing our own hypothetical reaction to a bear. The situation is simple: would you rather not know of a bear's travel toward you and be surprised by its presence at a short distance or be made aware of the bear with sufficient time and distance to avoid contact?

With this said, there are situations where the repelling of a bear is warranted. In the event of an encounter with an aggressive bear, means for repelling such a bear can be taken. Capsaicin spray and loud noises are two options that have shown some success. Please refer back to Chapter 3 for a discussion.

Because no BWD can truly be 100% effective in eliminating encounters with black or grizzly bears it seems apparent that some form of layered protection is appropriate, consisting of an effective BWD combined with a means for possibly repelling an aggressive bear.

Sec. 5.2 Industrial Design

Within the domain of industrial design there are many different directions and stages of completion in which a product can be resolved. Examples include the following:

Theoretical Design. The product is not based on previously existing products and doesn't have to be grounded in any current form of technology, materials science or process. Designs of movie sets and props are good examples of such design resolution. Designs that are conducted under this mode consist mainly of appearance models.

Fig. 5.1 Concept Car

Conceptual Design. The incubus for the product can be based on similar products or identified through a perceived need for a new type of product. The design can be based on current or future technologies. Concepts for the next generation of automobile are examples of such design. See Figure 5.2. Conceptual design can result in a full range of product resolution from sketches and appearance models through breadboards, prototypes and limited production runs.

Real World Design. The incubus for the design results from the identification of a current need or evolution of a product; and its design is based on current technologies, materials, knowledge and processes. Any product that is currently or will be in the near future manufactured is designed under these conditions. Such design usually results in a complete resolution of the product into manufacturing and public release.

These design categories, however, are not mutually exclusive and the design of any product usually requires the designer and product to spend some time in all of the stages. The design process for this project will fall mainly into the latter two categories. The resolution of the design will exist predominantly within the conceptual design realm. Figures 5.3-5.8 are examples of concept sketches produced during the course of the project. Energy will be allotted to providing proof of concept and resolving the final product through to working bread board (semi-functional internal mechanics/electronics) and appearance model of a possible design solution.

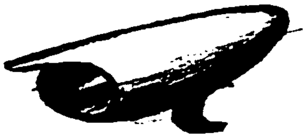


Fig 5.3 Early Sketch

However, the design will also exist within the "real world" category in terms of the internal workings, materials, manufacturing and technologies involved in reaching a suitable design solution. It is the intention of this project to provide deliverables that will validate the viability of incorporating ultrasound into a BWD and address issues with regard to ergonomics, aesthetics, product design, manufacturing and future considerations.

It must be stressed at this point that the results of this project are by no means the completion of a fully operational and field tested ultrasonic BWD. Wherever possible, an effort has been made to substantiate the design with past research and the undertaking of several project specific studies with the main purpose of establishing positive indication for the incorporation of ultrasonic sound into a BWD.

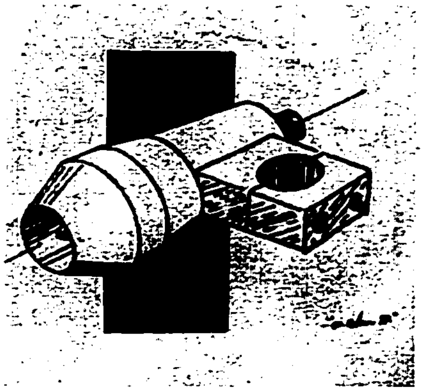


Fig 5.4 Early Sketch

Sec. 5.3 Design Objectives

Design objectives are defined as the overall goals of the project and will be accomplished through the design process. They are as follows:

1. Produce a bear warning device (BWD) that effectively reduces sudden encounters between both black and grizzly bears and mountain bike riders (MTB). Furthermore, develop a BWD that can successfully warn a bear of a MTB's presence from a minimum distance of 50 m.

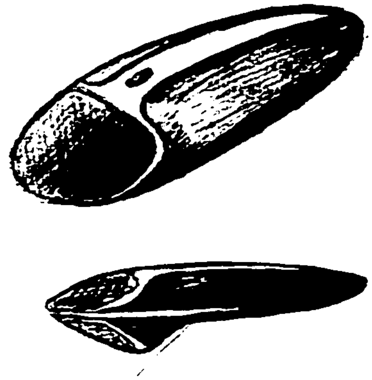


Fig. 5.5 Beetle Concept

2. Produce a BWD that addresses the particular needs, wants and desires of the MTB community. Includes addressing issues related to the functional requirement of a product intended for outdoor use and the aesthetic character of the target market.

3. Produce a BWD that specifically overcomes the reluctance of the MTB community to use current noisy BWD's by developing a non-obtrusive device through the exploration of the application of ultrasonic sound.

4. Develop a BWD that ultimately allows man and bear to better coexist.

Sec. 5.4 Constraints

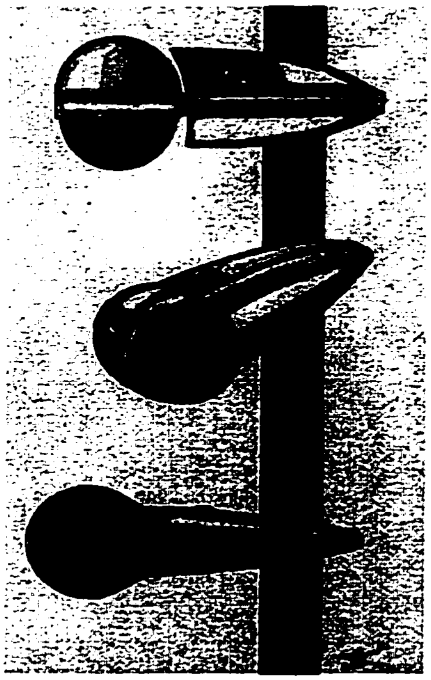


Fig 5.6 Squid Design

Constraints are defined as aspects which hinder or limit a successful design solution. This project has a number of constraints that fall into four categorises: Environmental Bear, User, and Technological.

Environmental Constraints. Targeted as a product for outdoor use, elements such as durability, weather resistance and functionality under varying conditions are of concern.

Bear Constraints. As indicated previously, both black and grizzly bears are wild and therefore are unpredictable animals. Generalizations have been offered with regard to their behaviour; however, it is impossible to be 100 % assured of a bear's behaviour under varying circumstances. With regard to black and grizzly bears' ability to hear ultrasonic sound, it must be remembered that just as human hearing shows individual differences, so too can bears hearing.

User Constraints. Any BWD is essentially a piece of safety equipment and therefore must both perform to the user's expectations and impart a true sense of safety and

Fig. 5.7 Box Design

reliability. The operation and function of the device must be clear and manageable under varying environmental conditions and the user must be motivated to use the product either through necessity or perceived benefits.

Technological Constraints. The project is intended to be partially an exercise in "real world design," meaning that the design solution is to be resolved using existing technology and processes and not rely on future advancements or hypothetical technologies. As a result, the design and performance of the device is limited to the knowledge and technology currently available.

Sec. 5.5 Criteria

The criteria by which the success of the final design should be judged is dependent on the following points.

1. **Performance.** The proposed BWD should produce a warning sound capable of travelling and being perceived by a bear (black or grizzly) up to 50 metres away.

2. **Environmental Considerations.** The proposed product should be able to perform in varied environmental conditions characteristic of outdoor activities.

3. **Functionality.** The design should successfully incorporate appropriate controls, displays and structure that minimize confusion and maximize ease of use.

4. **Aesthetics.** The design should address the issues of appropriate market aesthetics and semantics.

5. **Appropriateness.** Is the design appropriate for its intended users and does the design take into consideration, as much as possible, the bear.

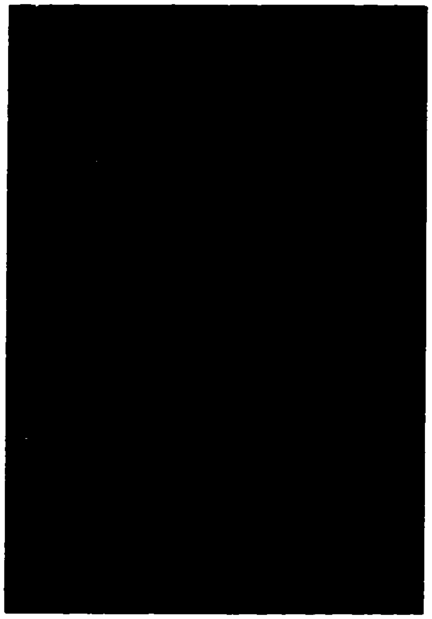


Fig 5.8 Design Concept

Sec. 5.6 Target User

The following is a discussion of the intended user of the BWD. The information presented here has been predominantly gleaned from my own personal involvement within the mountain bike community for ten years, my experience as a mechanic, and sales representative of bicycles for a period of four, the many conversations on the subject with industry representatives and participants, and the project specific survey results.

Fig 5.9 Woman Racer

The demographics of MTB's have changed dramatically over the last five years. Initially the activity was dominated by males in their late teens and twenties. Today, participation has expanded to include the younger and older segments of both genders. See Figure 5.9 and 5.10. The increased participation is a partial result of the advancing technology of MTB's. The average MTB today comes equipped with front suspension, a 27- speed drive train and a lightweight aluminium frame. By comparison, only five years ago bikes weighed close to 40 pounds, had 18 speeds, and offered no suspension. An excellent example of MTB's increased popularity can be seen in the more than doubling of participation from 350 to over 800 in the 24 hour relay race conducted at the Canmore Nordic Centre between the years 1997 and 1998. Sales of MTB's now account for over half of all types of bicycles sold worldwide.

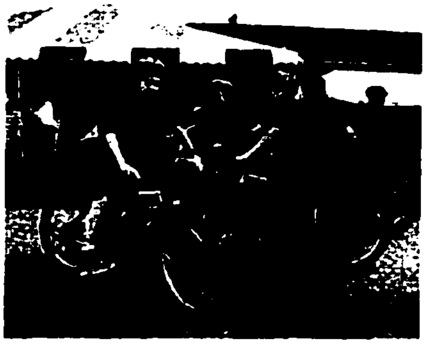


Fig 5.10 The Next Generation

The level of participation in MTBing however is varied. Many people limit themselves to city riding; others make occasional trips to nearby forested areas; and still others partake in backcountry rides that can cross the favoured terrain of both black and grizzly bears It is for this latter group that the BWD is predominantly targeted, because it carries the greatest risk of encountering a bear. However, through the course of this project, I encountered many individuals who were extremely concerned about the possibility of a bear encounter on any wilderness ride and therefore these individuals could also enjoy the added security of the BWD. The survey conducted for this project indicated that 32/41 (77%) of riders thought of a possible bear encounter on their rides regardless of their level of expertise or where they rode their bikes.

As a consumer, the mountain bike community has achieved a level of maturity that sees it being fractured into many sub groups which stipulate their own types of bikes, apparel, vocabulary and specific needs. However, running through these groups is a common demand for products that offer a high level of performance and a need to achieve this performance with the addition of as little weight to the bike as possible. It is not uncommon for riders to purchase new products or to replace components with the sole purpose of saving mere grams off the total weight of their bikes. Such relentless seeking of weight saving can be partially legitimized considering a MTB is a human powered form of transportation where less weight means more efficiency. However, it can also be attributed to consumerism and marketing.


Fig. 5.11 MTB Ride

In such a weight conscious market the participants are very reluctant to add anything redundant or ineffective onto their bikes. As a result, products need to perform a specific function exceptionally well and to weigh as little as possible in order for the rider to purchase and use the product. Figure 5.11 offers a visual example of the extreme conditions that MTB rides can take place and the need for high quality equipment. This trend is supported by the survey results indicating that 32/41, (78%) required the BWD to be of light weight and was listed as the 3 rd preferred design feature. Such a strong trend must be addressed with regard to any BWD design that is intended for the MTB market. Effectiveness of the BWD was of greatest concern 35 of 38 (92%) to those surveyed followed by weight 32 of 38 (84%) and physical size of the unit 30 of 38 (78%).

Sec. 5.7 The Outdoor Equipment Arena

Fig 5.12 Modern Hiking Boot

Initial familiarization with the possible design of a new BWD included the exploration of the outdoor equipment market as a whole. Retailers of such equipment were visited in order to immerse myself into related products, aesthetics and trends. Retailers of various outdoor equipment were visited including: cycling, hiking, climbing, camping and various water sports. Furthermore, periodicals related to these activities were studied. Figure 5.12 illustrates the aesthetics of a modern hiking boot design. Through this process, current trends in outdoor equipment were explored and, although not quantitatively analysed, provided important insights into the possible design direction of a new BWD.

Through this process two perceived trends were identified:

1. Diversification of Activity and Product. This is related to the sizeable diversification in outdoor activities that people are participating in and the related equipment that goes along with these activities. Diversification can be seen in almost every outdoor activity. Downhill skiing, for example, has fractured from individuals participating in traditional skiing methods into snowboarding, monoskiing, shaped skiing, carving skis and now into excessively short skis like the Soloman Snow Blades. See Figure 2.13 Each one of these separate yet related activities requires different and specific products and equipment. Thus, individuals who want to partake in such activities are required to purchase ever increasing amounts of equipment.

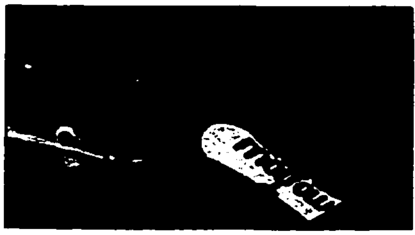


Fig. 5.13 Diversification of Downhill Sports

The activity of mountain biking has followed a similar path. Currently there exist several different categories of bikes including: cross country, downhill, slalom, freeride, city, one-speed and cruisers. Along with these categories of bike, different related products have been developed and are required of the user.

As an industrial design project, the design of a new BWD could follow one of two directions:

A. Follow the trend of diversified groups and develop a BWD that is specific to each group and different activity. Thus, separate models could be developed to be attractive to the cross country rider and another for the freerider. This separation could then be extended into related outdoor sports such as hiking and camping resulting in each related activity with its own specific BWD.

B. Acknowledge that through proper design a single BWD could be produced that could be used in a wide spectrum of outdoor activities. The focus of this project has been on the development of a BWD for use by mountain bikers. As stated in Chapter 1, I believe that the development of an ultrasonic BWD could easily be transferred to other related outdoor activities outside the mountain bike category. As a result, the use of such a device for other activities should be anticipated and ,where possible, addressed in the design.

Fig. 5.14 Explosion of Foot Wear

2. Technological Advancements. The amount of new and high technology materials that are being designed and incorporated into new outdoor equipment is incredible. Figure 5.14 illustrates the explosion and variety of modern athletic foot wear. This trend is related to the reduction in the cost of high end technologies and the demand of the consumer for its incorporation. Once rare materials such as carbon fibre and kevlar can now be found in mainstream products ranging from hiking boots to windsurfing masts. Figure 5.15 shows a modern snow shoe design using carbon fibre. Figure 5.16 illustrates the variety of high-tech materials available today. Piezo electric vibration dampeners which were originally designed for the Space Shuttle can be found on K2 skies and computers can be found regulating the suspension systems of some mountain bikes. The functionality of these materials and technologies is debatable. They may add to the performance of the equipment or may simply be used as a marketing tool. As a result, the design of an ultrasonic BWD within this project will try to incorporate appropriate levels of technology and specify materials that are consistent with the product's use and performance requirement and not pander to the inclusion of materials or technologies for the sake of marketing.

Fig 5.15 Modern Snowshoe

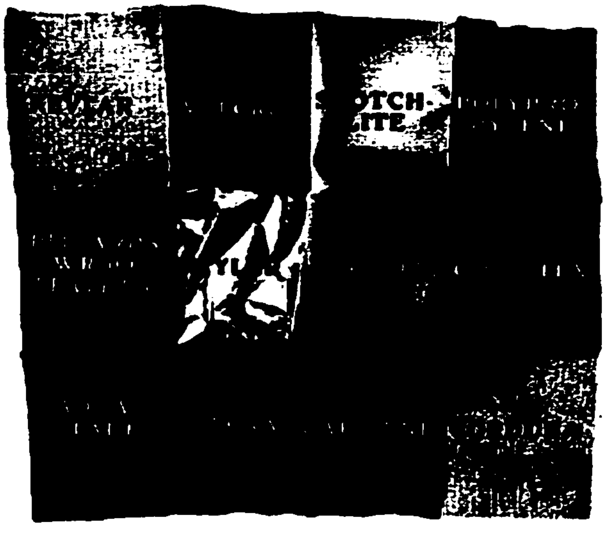


Fig. 5.16 Technical Fabrics

Summary

The philosophy for the design of the BWD has been established, focusing on alerting the bear of a rider's presence with sufficient time to allow the bear to act on its instinctive tendency to avoid human contact. The final deliverables of the project will exist within the conceptual and real world design categories. Design objectives, constraints and final criteria have been established. The target user has been explored. Results indicate that performance and weight of a BWD are of greatest concern. The outdoor equipment market has been explored and found to be exploding in terms of diversification and technological advancement.

Chapter 6. Product Design

The preliminary chapters of this document and accompanying appendices have explored issues related to mountain biking and current methods of avoiding and dealing with encounters with black and specifically grizzly bears. Within these pages the following arguments have been raised.

- At present the best way to avoid a sudden encounter while travelling on a MTB is to warn the bear of your presence through the use of noise.

- Current methods of employing noise as a means to reduce sudden bear encounters have been found ineffective. Furthermore, these methods are being rejected by the MTB community because they are irritating to the user.

- MTBers are encountering bears well within the 50 metre range set by this project.

- The advantages of incorporating ultrasonic sound into a BWD has been established. Furthermore, positive research has been collected indicating black and grizzly bears' ability to hear ultrasonic sound.

Fig. 6.1 Final Design

The following is an incorporation of these arguments and design considerations into an ultrasonic BWD. Figure 6.1 offers a view of the final design. In order to follow a logical and pedagogical path through the design, the project will be discussed from the inside out starting with the **Internal** workings and performance requirements of the BWD; proceeding to **Surface** Aesthetics and Ergonomics; then to **External** Relationship between the BWD/ Bicycle and Environment; and concluding with **User** Perceptions and Relations.

Sec. 6.1 Internal

Sound Production

The means to produce ultrasonic sound is limited. Appendix F offers an exploration of natural and man-made means of producing sound frequencies above 20 kHz. For this project, the piezo electric speaker was chosen as the best candidate for achieving a successful design solution. Such a speaker is the most common means of producing ultrasonic sound and, at present, the least expensive. A piezo speaker produces sound through the use of a crystal that vibrates when an electric current is passed through it. These speakers are characterized by extreme light weight, durability and efficiency which are all features required in the successful design solution of the BWD. (Please see Appendix F for full details.)

Performance

The most pivotal component of the project is related to performance. The main goal of the project is to design a BWD that is functional to a minimum of 50 metres. To attain this performance requirement, a number of issues must be addressed and satisfied in order to achieve a successful design solution. A full understanding of these issues by the reader can only be reached through reference to Appendices B, C, D, G and H.

Frequency: Throughout this project ultrasonic sound has been defined as sound energy above 20 kHz, just above the range of most humans. Through related research and species comparisons it has been proposed that black and grizzly bears are capable of hearing above 20 kHz. However, it is not clear where their upper frequency limit lies. It can be estimated to correspond to that of dogs (30 kHz). Keeping this information in mind, the frequencies chosen for the BWD have been established at 21.5 kHz and 23 kHz. The initial 21.5 kHz tone has been elevated 1.5 kHz above 20 kHz in order to further distance it from the upper hearing range of humans. A second frequency of 23 kHz has been added to allow the unit to oscillate. Oscillation is based on the design of current warning sirens, where the presentation of two tones reduces the ear's satiation response compared to the presentation of only one tone (Atkinson et al, 1982). If presented with only a single continuous or pulsed tone the ear will become less sensitive to that tone (Sanders & McCormick, 1987). The choice of limiting the second tone to 23 kHz is to present a significant increase in tone above 21.5 kHz. Furthermore, it was in response to the uncertain upper limit of a bear's hearing range and to closely correspond with the research conducted on the sound signature of a dog whistle which peaked at approximately 22 kHz. (See Appendix H.)

Unit Output: One of the main objectives of the project is to design a BWD that is functional to a minimum of 50 metres. There are two related constraints acting on the unit's acoustical ability to satisfy this requirement.

1. Sound Output. In a perfect environment sound travels outward from the source in all directions; if the sound is louder (increase in dB) then that sound will travel farther then a sound of lesser dB. This relationship holds true for most frequencies. However, when dealing with ultrasonic sound, the relationship becomes more complicated. In general the distance that an ultrasonic sound will carry in the atmosphere will correspond to an increase in dB. However, at 200 metres, no increase in dB will result in the ultrasonic sound carrying a greater distance (Bergmann, L.,1937). This distance limitation is the result of attenuation.

2. Attenuation. Is the reduction of a sound power through friction with air molecules and obstacles. (Please see

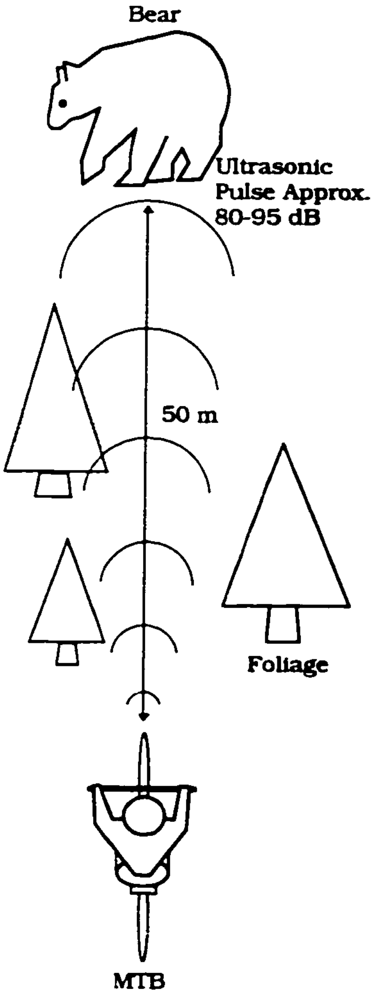


Fig. 6.2 BWD dB at 50 m

Appendix C.) As frequencies increase, the effects of attenuation becomes more pronounced and limit sound propagation to 200 metres. However, these effects are negligible for ultrasonic sound of low frequency (20 - 25 kHz) (Haris, L., 1991). As a result, ultrasonic sounds like 21-23 kHz will behave essentially like sound of a much lower frequency. However, even with this information great lengths were taken to properly estimate the total amount of attenuation. Research revealed that the total amount of atmospheric attenuation for a sound of 21-23 kHz would approximate 0.4 dB per metre with an additional reduction of 3 dB per 50 metres on account of foliage (Appendix C). Based on research with regard to the perception of sound a minimum sound level was established at approximately 80 dB. See Figure 6.2. Research on the perceived loudness of varying sound characterize levels of 80 dB as noisy. Highway traffic is an example of a 80 dB noise (Rossing, 1982).

With this information the output characteristic of the unit could be determined. As illustrated in Figure 6.1a. Using the numbers attained above, the unit should perform with the following output capacity:

Sound level at 50 m = 80 dB
Attenuation by air = 20 dB
Attenuation by foliage= 3 dB
Total required dB 103 dB

The above numbers represent the performance of an ultrasonic BWD under ideal conditions. However, such conditions are rarely encountered. Thus, the power output has been increased to facilitate in overcoming varying environmental conditions. For the production of the working rig of the internal components the output was increased to approximately 118 dB.

Sound Envelope- It has been shown that an ultrasonic BWD can transmit a warning pulse 50 metres down a trail. However, a bear may be travelling tangentially to the mountain biker; thus the BWD must be able to alert a bear not only directly in front of the rider but to the sides as well. Ultrasonic sound has a tendency to beam, meaning that the sound energy will travel away from the sound source in relatively straight lines, limiting the sound envelope. Figure 6.2a is an estimation of the sound envelope based on the polar plot of a 21 kHz pulse attained from the acoustic labs at the University of Alberta and sited in Appendix H. The most efficient area of the speaker is approximately 18 degrees around the centre axis. Beyond this area the dB level of the speaker drops by 10 dB. When these 18 degree lines are extended to 50 metres the sound envelope covers an area of approximately 30 metres. Figure 6.2 is a polar plot of the test speaker emitting a 21 kHz tone. A polar plot illustrates the dB output 360 degrees around a noise source. The large plumb indicates the area of greatest dB and helps illustrate the beaming effect of ultrasonic sound. This is not to say that no sound will be transmitted outside of this 30 m but only that this envelope constitutes the most effective coverage. Appendix I illustrates the coverage of the BWD.

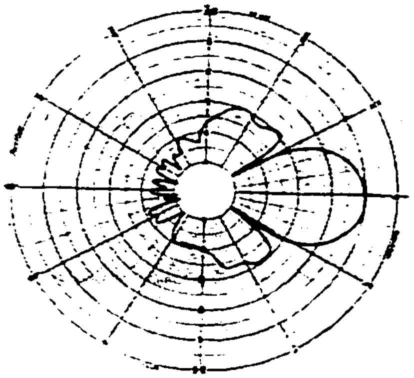


Fig. 6.2a Polar Plot of a 21 kHz Tone

A means of increasing the effective sound envelope can be achieved through the placement of the BWD onto the bicycle's handle bars which allows minor course adjustments of the MTB to physically sweep the BWD across a wider area. Appendix I shows the effects of a 5 degree course adjustment on the sound envelope. The placement on the bars also facilitates the carrying distance of the ultrasonic pulse by elevating the sound source above the ground and allowing the sound waves to travel parallel to the ground. See Figure 6.3. The orientation of the sound propagation in relation to the ground is known as the grazing angle. A sound source pointed directly at the ground would have a grazing angle of 0 degrees. In the case of the BWD the grazing angle is 90 degrees allowing for optimum carrying distances.

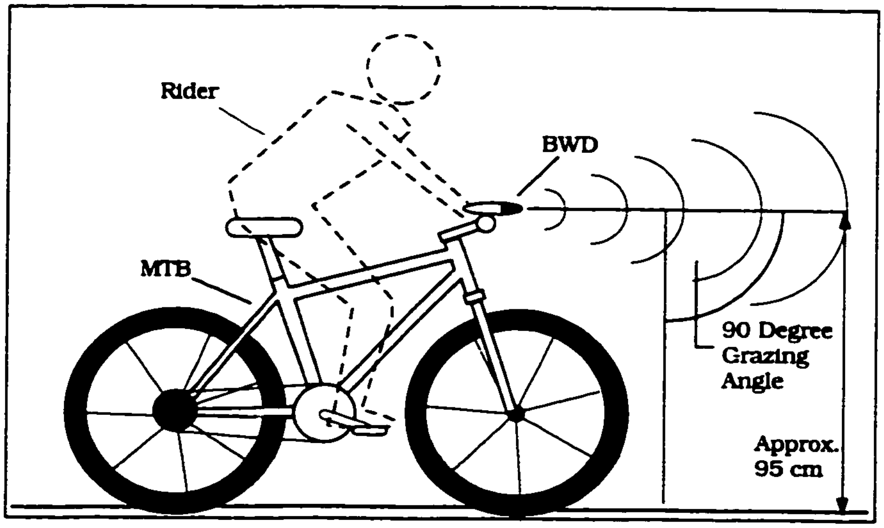


Fig. 6.3 Grazing Angle

Output Sequence- The ultrasonic emission of the unit can be modified and altered exhaustively through the use of electronic timers and alternative circuit designs. As mentioned earlier, an oscillation between 21.5 and 23 kHz was chosen. However, options remain with regard to the timing of the pules. These options area as follows:

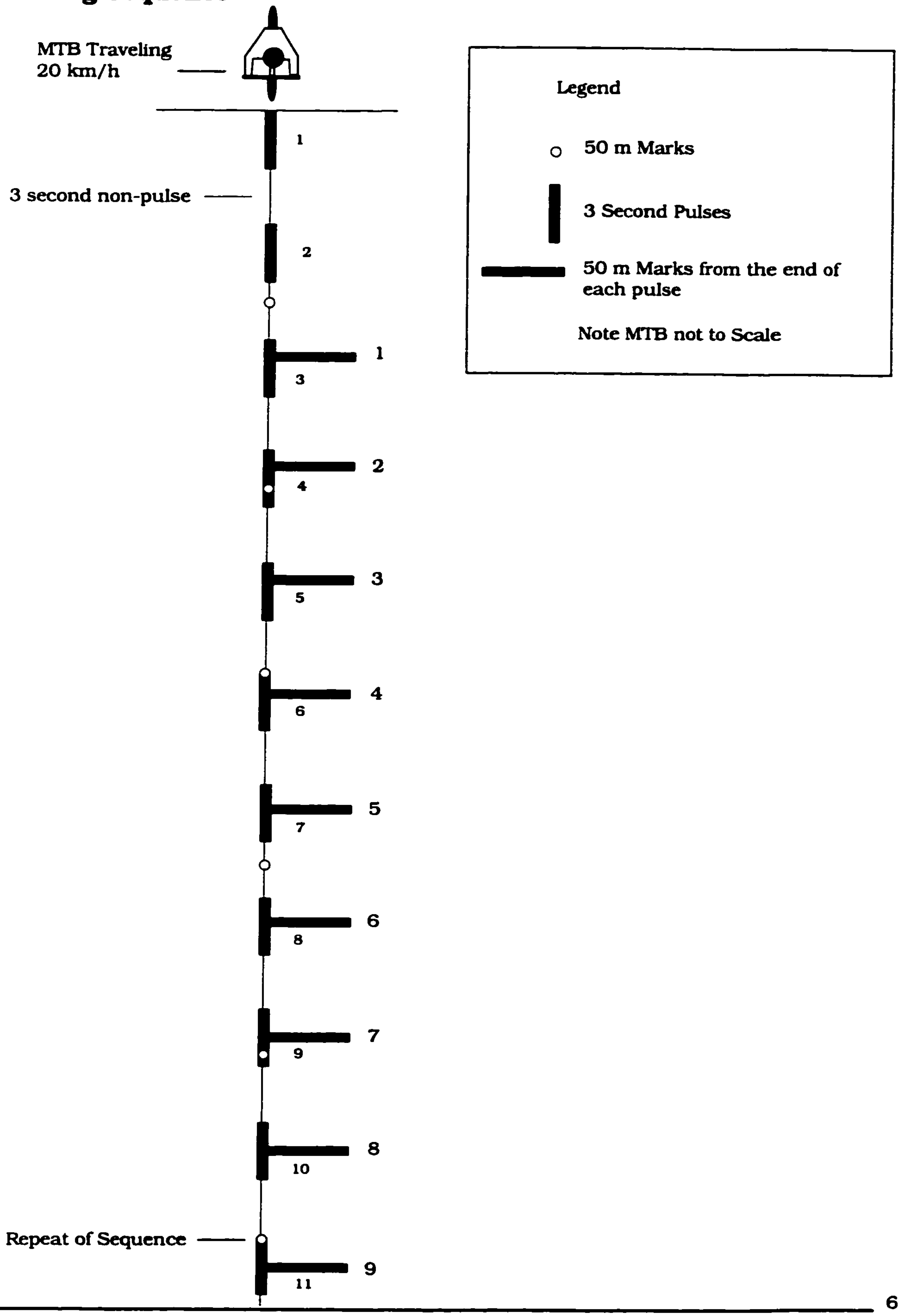
1. Constant pulse- The unit would present a constant ultrasonic signal, oscillating between the two tones. This option would maximize protection against a sudden encounter but would also maximize the intrusiveness of the BWD into the environment. A continuous pulse would also present a constant maximum drain on the power supply of the unit.

2. Timed pulse- The unit could be programmed to present the warning signal at pre-selected time intervals and could be an effective compromise to a constant pulse and still offer as much protection as possible. It would minimize intrusion into the environment and reduce power consumption.

The "timed pulse" is seen as the most effective means of presenting the warning sound. Returning to the survey results, the speed at which riders encountered black or grizzly bears averaged 20 km/h and has been used as a

guide to develop an appropriate timing sequence. It was assumed that, if possible, the bear should be warned of an on coming MTB at least twice within a given 50 metres. (This statement is only an assumption and is intended to illustrate the issues related to the development of a possible timing sequence. Actual field studies would be required to establish accurate sequences). Operating under this assumption and using 20 km/h as a benchmark for encounter speeds a sequence of 3 seconds of no pulse followed by 3 seconds of sound emission would be the most effective in terms of warning bears and conservation of the unit's power supply.
Figure 6.4 illustrates the units possible operation sequence.

Fig 6.4 Timing Sequence



The Circuit Board and Working Rig

The circuit board design was developed through a collaboration between my external supervisor Dr. Maundy, Dave Malenski (University technician) and myself. Through conversations with Dr. Maundy and research on my own, the basic components for the BWD were ascertained and specifications determined. This information was handed off to Mr. Malenski who developed the circuit and assembled the working rig. Appendix J offers another presentation of the circuit and a specific parts list. The purpose of producing the rig was to help establish proof of concept, determine the complexity of the required circuit, and establish a possible final physical size of the BWD. Figure 6.5 is a schematic of the circuit design and Figure 6.6 illustrates the working rig.

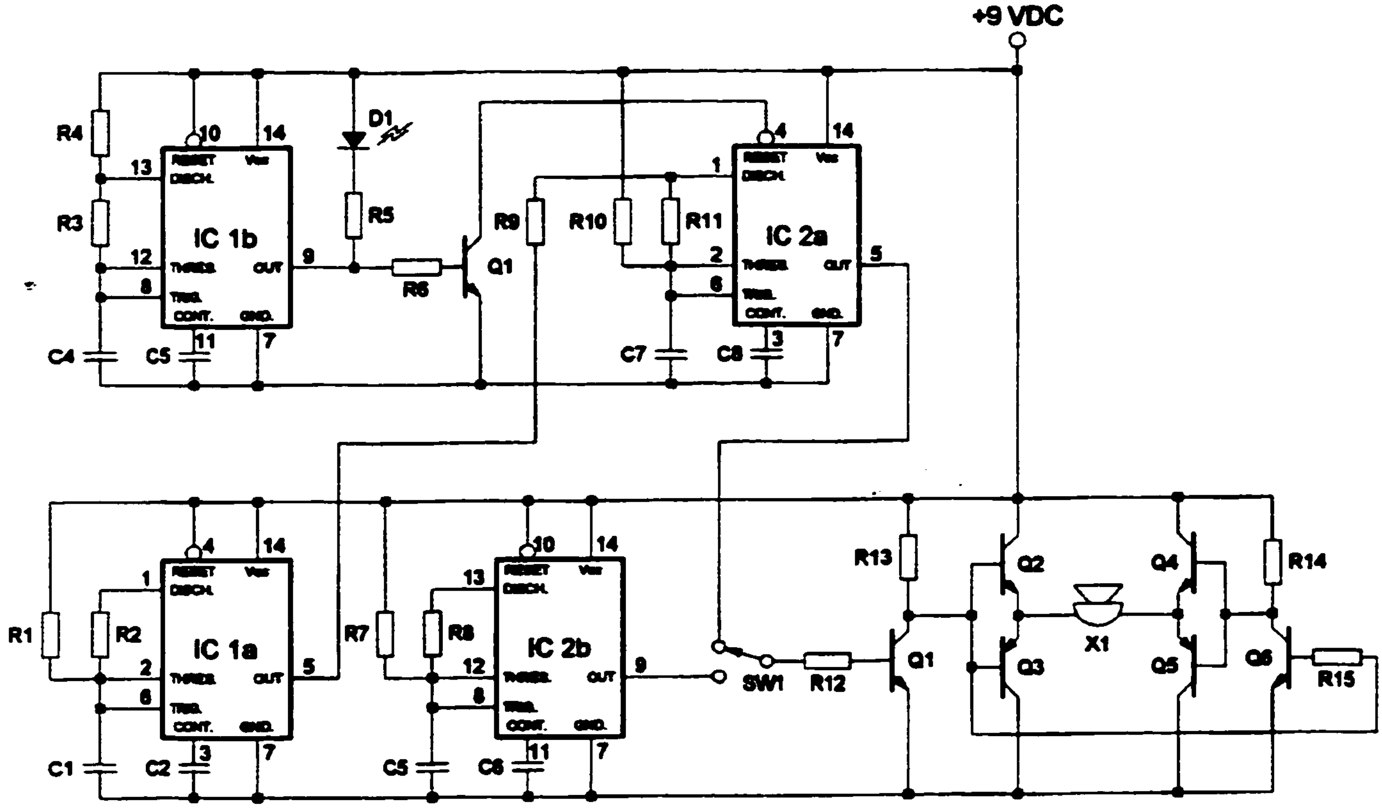


Fig. 6.5 Circuit Design

Processor Functions:

IC 1a- allows the BWD to oscillate (warble) between the two prescribed ultrasonic frequencies.

IC 1b- takes care of the timing duties of the BWD, controlling the duration of ultrasonic pulses and period between pulses.

IC 2a- produces the two distinct ultrasonic tones 21.5 kHz and 23 kHz.

IC 2b- provides the audible tone of 3600 Hz

Q1-Q6- provide the increase in voltage from 9 volts to 12 volts.

Fig 6.6 Working Rig

Power Requirements:

The current circuit is designed to operate using a 9 volt power supply. This current is amplified to 12 volts at the transducer (speaker) and is capable of producing a 118 dB ultrasonic tone. The power drain on the battery to sustain the BWD in an operational mode "On" is 26 miliamps, which is elevated to 160 miliamps during ultrasonic pulses and audible tone modes. It must be stressed that the power requirements and drain are specific to this circuit design and transducer. The average rechargeable 9 volt battery has a capacity of 1500 miliamp hours. Incorporating the proposed 3 second ultrasonic pulse followed by 3 seconds of no pulse the BWD would function for approximately 15 hours.

Physical Size:

At present the working rig occupies a circuit board of 4 cm by 8 cm and represents only the size required to easily manufacture the working rig. If the circuit was to be professionally manufactured a single dedicated intigrated circuit would be used along with several external timing components. Such an alteration would reduce the size of the board down to approximately 4 cm by 4 cm.

Power Source- The piezo electric speaker and accompanying electronics require an electric power supply. There are a variety of methods available to supply the unit with the required power: solar, battery, generator and chemical to name only a few. Exploration of current outdoor electronic devices revealed a high use of rechargeable batteries. Such a means to power the BWD was seen as advantageous for the following reasons:

1. The consumer has accepted rechargeable batteries as a viable and effective means to power electronic equipment.

2. Rechargeable batteries offer consistent performance and power supply;

3. It elevates the perception of quality of the product;

4. It eliminates the addition of external wires (generator) and reduce body cavity openings and required seals related with expendable batteries and or chemical power supplies.

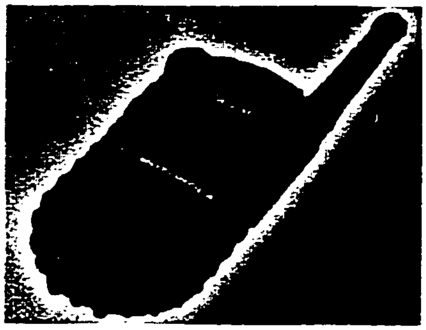


Fig. 6.7 Motorola Talkabout

At present there are a number of rechargeable batteries on the market. However, the Nickel Cadmium (NiCA) and Nickel Metal Hydride (NiMH) are the most common. The main difference between the two lies in their charge memory. A NiCA battery must be completely discharged before attempting to recharge. If this is not done the battery will only charge to a smaller percentage of its capacity and successive charges will eventually eliminate the batteries capacity to hold any usable charge. A NiMH battery however, can be recharged at any point without reducing its effectiveness. It is because of this characteristic that the NiMH battery has become increasingly popular in modern electronics and specifically outdoor equipment (Motorola cellular phones and Talkabouts see Figure 6.7) and for its specification in the BWD.

Fig. 6.8 Getting to Close

Emergency Alarm- It has been stressed within this project that no BWD is 100 % effective for the reduction of sudden encounters. As seen in Figure 6.8. Thus, the possibility of an encounter exists and along with it the possibility of encountering an aggressive bear (black or grizzly). On account of this possibility, a second layer of protection has been deemed appropriate. Studies have indicated that the presentation of loud, sharp (humanly audible) sounds can in some cases stop an advancing bear. Miller (1980), found that air horns and sirens often stopped a bear in mid-charge. Again, the results are not 100% effective.

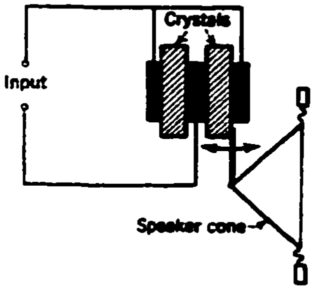


Fig. 6.9 Piezo Specker

The piezo electric speaker used to produce the ultrasonic tone is also capable of producing a very loud (118 dB) audible sound and with the introduction of appropriate circuity and a manual switch, this loud audible tone can be employed at the user's discretion. Figure 6.9 Illustrates a modern piezo specker. Based on the results of the Alpine Whistle tested at the University of Alberta sound lab, a tone of approximately 3600 Hz is seen as a reasonable starting point for the frequency of the emergency tone. The emergency alarm would be used in the event of a rider encountering an aggressive bear. The user would have to personally ascertain the environmental variables and individual bear behaviour and use the emergency alarm at his/her own discretion.

Sec. 6.2 Surface

The surface of any product forms the point of interaction with the user. Both through visual details and tactual responses the human user interacts with the product and is offered information regarding its purpose, quality, orientation, control and operation. For ease of understanding the surface of the BWD will be discussed under three headings: 1. Aesthetics, 2. Ergonomics, and 3. Safety. It should be noted that the three are not mutually exclusive but in fact connect in a relationship between form and function that in the end determine the overall visual and tactile language of the product. Many items that will be discussed under the ergonomics and safety heading could also be listed under aesthetics. Many of the ergonomic details denote a significant contribution to the overall aesthetics of the product.


Fig. 6.10 Binoculars

1. Aesthetics

The physical design of the BWD started with an extensive exploration of current electronic consumer goods. A variety of equipment was examined including: home, personal and car audio, computers, video games, MTB, hiking and camping accessories, safety gear and radar detectors. Figures 6.10 - 6.12 represent some designs of current outdoor equipment products. Because the design of the BWD constitutes the design of a historically new product, it is important that it not only develop its own visual language specific to its function but that it incorporates current trends and accepted design language of related equipment. This incorporation will theoretically increase the ease of acceptance of the new product and allow the user the ability to visually and functionally relate the new product to past experience.

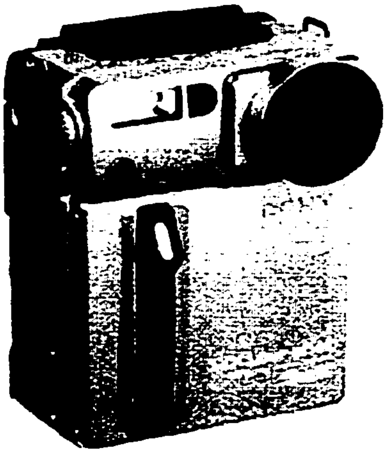


Fig. 6.11 Camera

Considering the freedom offered by current manufacturing techniques and miniaturization of electronic circuitry the limitations placed on the design of the primary form of the B.W.D. were few. Initial sketches for the B.W.D. were driven by the incorporation of appropriate materials such as elastomers for grips and harder A.B.S. plastics for the main body. Initial aesthetic inspiration was derived from current camera designs. As with the B.W.D. a cameras design must communicate its function, orientation and operation to the user through subtle design details. Furthermore, a camera is intended to be handled by the human hand and therefore must impart this information both visually and tactually. The camera aesthetic also imparts a certain level of consumer attitude with regard to quality. The actual science of taking photographs is rather complicated, current cameras make this process exceptionally easy. The so called "Idiot Proof" cameras with many auto features allow anyone to take high quality


Fig. 6.12 MTB Lighting System

pictures. Throughout the development of the B.W.D. the camera aesthetic and design constraints were reflected upon.

A further issues related to the aesthetics of the B.W.D. have to do with the intended target market as covered in Sec. 5.6 and 5.7. In reality the B.W.D. could simply be designed as a "Black Box". Referring to a product that functions as intended but offers little to no information to the user with regard to how it accomplishes its function. Such a design would be inappropriate for the MTB community. As stated in Sec. 5.6 MTBers are very concerned with the functionality of biking accessories and as a whole are very curious with regard to how a product works and its specific function. Furthermore, as discussed in Sec. 5.7 MTBers are demanding higher and higher levels of design sophistication with regard to their sport specific products and accessories. As a result, the design of the B.W.D. must communicate its intended function to the user effectively and be visually pleasing for it to be accepted by the MTB community.

Physical Size- The overall physical size of the BWD was predominantly driven by the real world constraints poised by the battery, circuit board and piezo electric speaker. See Appendix J for General Dimensions. The current dimensions of the BWD were considered appropriate for the following reasons:

A. In order to satisfy the constraints of a partial "real world" design scenario sufficient room was allotted to house the internal electronics of the BWD.

B. Because the unit is intended for outdoor use under extreme conditions, the size affords more impact protection to the internal electronics.

C. The size facilitates the user's perception of the BWD as a piece of safety equipment as opposed to a delicate piece of electronics.

D. The size increases the units visibility when in use and reduces the possibility of losing the unit if removed from the bike.

Fig. 6.12a BWD

Physical Shape- The BWD casing was also designed to be tactually friendly and inviting to the human hand, soft curves and edges offer few sharp edges the user. As seen in Fig. 6.12a. The soft curves further, provide an aerodynamic form with out resorting to excessive streamlining aesthetics. The asymmetrical design provides for interesting curves and hollows offering a unique visual and tactual presence. One that could easily be picked out from other related MTB products or located by touch at the bottom of a backpack.

The controls and corresponding indicator lights are housed in raised ellipses extending away from the smooth casing, demarcating their significance to the look and operation of the unit. As seen in Figure 6.12b. Appendix K offers a General Assembly of the proposed BWD.

The operational end of the speaker is protected by a domed, perforated enclosure consisting of fine outdoor grade audio speaker mesh. The choice of a domed enclosure is to mirror the characteristic shape of related audio equipment and offers a significant visual clue to the user of the acoustic nature of the device and its directional orientation.

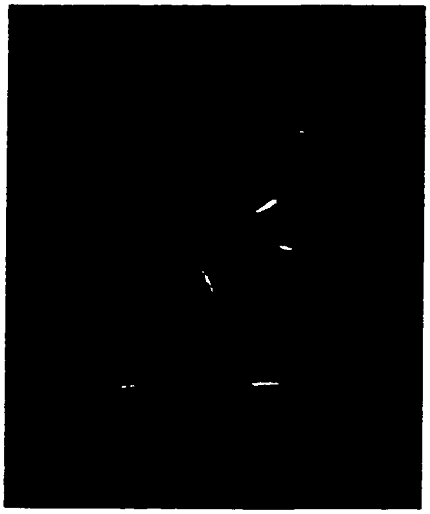


Fig. 6.12b Top View

Colour- Traditional safety equipment has been designed with the incorporation of brighter colours; typically red, orange, green and yellow. These colours also have become part of the outdoor equipment design aesthetic with many products that are designed for all weather and marine use are manufactured in the colour yellow. Within the category of MTB electronic accessories; computers, radios, bells and lights colour choices have traditionally been based in black, grey and silver. However yellow is also a prominent choice.

In order to stay consistent with the preexisting expectation for safety equipment to appear in a yellow the appearance model of the BWD for this project has been finished in a light yellow which also offers a high contrast to the black detailing of the santoprene grips and speaker covering.

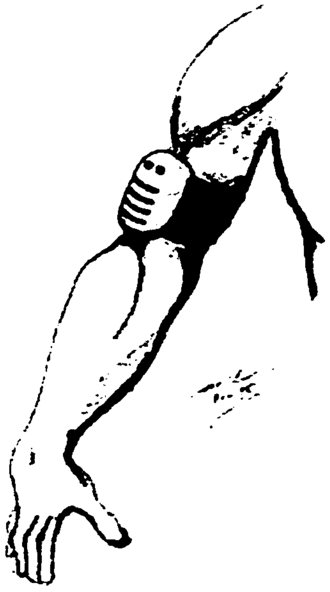


Fig. 6.13 Early Placement Design

2. Ergonomics

Definition- The study of ergonomics discovers and applies information about human behaviour, abilities, limitations and other characteristics to the design of products, tools, machines, systems, tasks, jobs, and environments for productive, safe, comfortable and effective human use (Sander & McCormick, 1987).

Because the BWD is essentially a piece of safety equipment its interface of both visual and tactile fields are of extreme importance. Discussion of the ergonomic considerations with regard to the BWD will be conducted under the heading Placement, Visual and Tactual.

Placement

Fig. 6.14 Early Helmet Placement Design

Locating the BWD on the MTB handlebars was deemed appropriate for the following reasons.

1. The location allows for minor adjustments in the MTB's path to pan the effective sound envelope of the BWD over a wider area.

2. The handlebar placement affords the ultrasonic signal to propagate away from the MTB parallel with the ground. This results in a very low grazing angle and facilitating in the reduction of attenuation.

3. The MTB handlebars are historically a location exploited for the mounting of cycling accessories such as: computers, lights and bells. The consumer is already familiar with related products and their placement on the bars.

4. The handlebar location affords the user with excellent sightlines to the device and related controls and displays. Figures 6.13 and 6.14 illustrate early concepts for the possible placement of the BWD. Figure 6.15 illustrates the selected handlebar location.

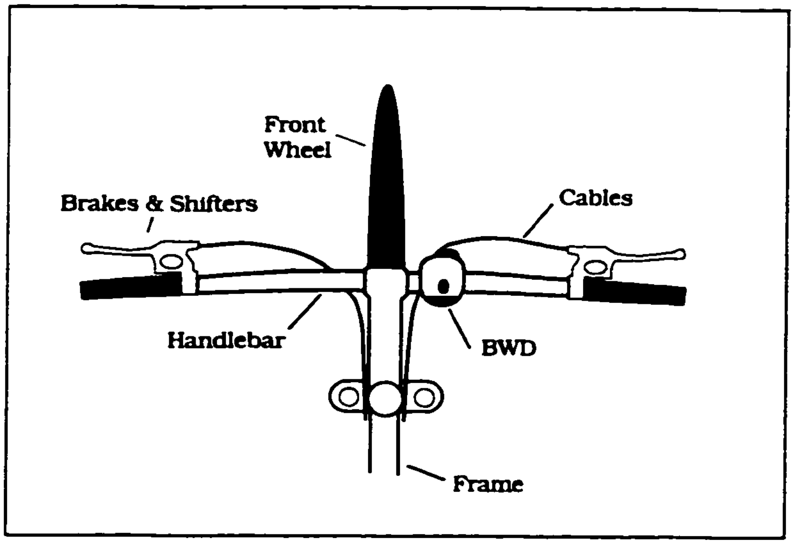


Fig. 6.15 BWD Placement

Visual

The visual ergonomics of the BWD are best understood using the concepts of spacial and conceptual compatibility (Sanders & McCormick, 1987).

Conceptual Compatibility deals with the degree to which codes and symbols correspond to the conceptual associations of people. The association of the colour yellow, discussed earlier, with safety or outdoor equipment is a good example of such an association. People's conceptual associations however, are culturally based. An individual in another part of the world may see the colour yellow as offensive. As a result, any discussion of compatibility issues of any kind must be taken in context of the cultural biases of the target population. In the case of the BWD the compatibility issues and biases of North America are of greatest concern.

One of the main conceptual biases taken advantage of in the design of the BWD is the North American association of the colour green and red to denote a products operational status. Green denotes, "On, Operational, Power". Red denotes, "Stop, Low Power, Off, Alert". These common colour associations have been exploited in the design of the controls and operational indicators of the BWD (Sanders & McCormick, 1987).

The On/Off switch incorporates the green glow of a small L.E.D. which denotes the state of the BWD as "On". The light of the L.E.D. will illuminate a raised elliptical ring surrounding the power switch and afford the user a clear visual indication of the operational status of the device. The light's large size will facilitate the user's ability to view and ascertain the status of the device from considerable distance and under extreme environmental conditions. See Figure 6.16.

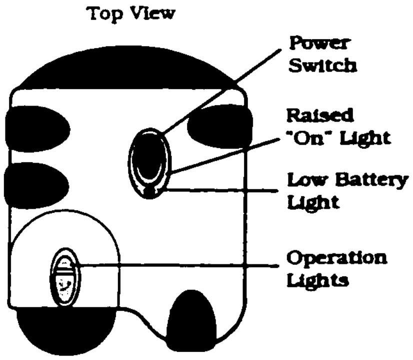


Fig. 6.16 Controls

Human Scale suggests the minimum size for an index finger button to be 0.6 cm. The power switch on the BWD has a dimension of 1 cm by 0.5 cm.

The L.E.D. lights indicating operation and low battery are 2.5 mm in diameter and will offer excellent viewing up to a distance of 46 cm. (Humanscale 5b, Displays)

A second L.E.D. light has been specified to act as a warning to the user in the event of a low battery. In such a situation a red light would be presented to the user. The green operational light would remain on, indicating that the device is currently operational; however, the inclusion of a red light denotes that the operational status of the unit will terminate in an allotted amount of time. See Figure 6.16.

The use of a green L.E.D. is also incorporated into the BWD denoting the functionality of the device. It is natural for North Americans to associate the turning "On" of a machine or device with a visual, tactile or auditory response. For example when a television is turned on a picture appears; when an automobile is started the engine produces a particular sound and vibrations are felt by the occupants. In the case of the BWD turning it on effectively offers nothing to the user to indicate that it is functioning. As a result, L.E.D. lights have been specified in the design to correspond to the emitting of the ultrasonic pulse. The two lights will oscillate as the pulse is emitted in a sequential order of the inner most light to the outer most light. Such an oscillation will strenghten the directional orientation of the device by using the lights to visually parody the direction of the inaudible ultrasonic pulse. As a safety measure, the lights would be wired in such a manner to insure their operation only if the piezo electric speaker is functioning. Thus, if a malfunction occurred that terminated the operation of the speaker the function lights would remain off giving the user clear indication of a problem. Such a safety feature, although not present in the working rig, would be designed into any marketable version of the BWD.

Spacial Compatibility- refers to the physical arrangement in space of controls and their associated displays. This is of particular importance when multiple controls and displays are being used at one time. In the case of the BWD there exists only one set of controls and displays, eliminating many of the concerns of spacial compatibility. However, the BWD does offer a good relationship between the placement of the power switch, indicator lights and speaker. These details exist spacially very close together and in a straight line, however, slightly angled, offering a tight visual representation of controls, function and operation.

A further visual relation has been set up between the controls and the indicator lights through the enclosure of each in similar raised elliptical details. The similar design detailing further enforces the relationship between the controls and the response of the device (Roukes, N. 1988).

Tactile

As we pass through our environment, we as humans rely heavily on our sense of touch. However, this sense has been used only to a limited degree as the basis for the intentional transmission of information (Sanders & McCormick, 1987). In the case of the BWD the use of tactual details has been exploited to afford the user information with regard to the operation of the device and its handling.

The raised ellipse surrounding the power switch not only visually isolates this area but further tactually isolates it as well. The juxtaposition of the raised area with the surrounding smooth casing offers the user a clear tactile response of the location of the power switch. It is intended that the tactile response be significant enough to facilitate locating and operating the power switch without visual aid. The concave depression enclosing the actual elastomer button offers further tactual information to the user of the exact location of the power switch.

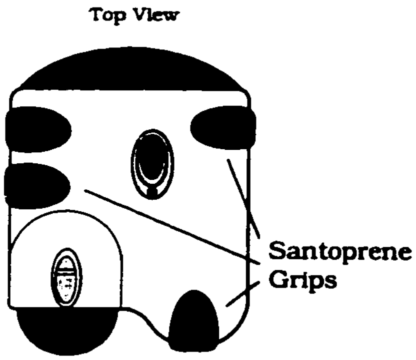


Fig. 6.17 Grip Areas

Varying textures have also been incorporated into the design to offer the user clues to the proper handling of the unit and to assist in its operation. Through the use of a "two shoot" injection moulding process the hard casing of the BWD can be manufactured with areas of lower duromiter material. This material, known as "Santoprene (TM)" can be seen on a myriad of consumer products where the human hand is required to hold a product. It is found on tooth brushes, cameras, personal audio equipment and sporting goods and affords the users hand an exceptional positive contact point. Its incorporation affords the user positive locations to grip the BWD under all environmental conditions. Furthermore, the santoprene can be specified as an alternative colour to the main casing of the product, thus visually delineating its purpose. The Santoprene Grips are shown in Figure 6.17.

Safety

The safe operation of the BWD can be discussed under two headings. Power Switch and Emergency Alarm.

Power Switch

The ability of the user to easily locate and activate the device is very important. As discussed earlier, the power switch is placed in a convenient location on the device. However, this location could increase the possibility of the user or a foreign object coming in contact with the power switch and accidentally turning the unit off. For this reason, the raised elliptical detail surrounding the power switch not only visually and tactually locates the control but also helps protect the switch from accidental operation. The elastomer button is recessed 2 mm below the raised edge and requires a further 2 mm of throw to make contact with the internal circuit. Such design details help ensure that it is only the user who can actively turn the BWD on or off and is illustrated by Figure 6.18.

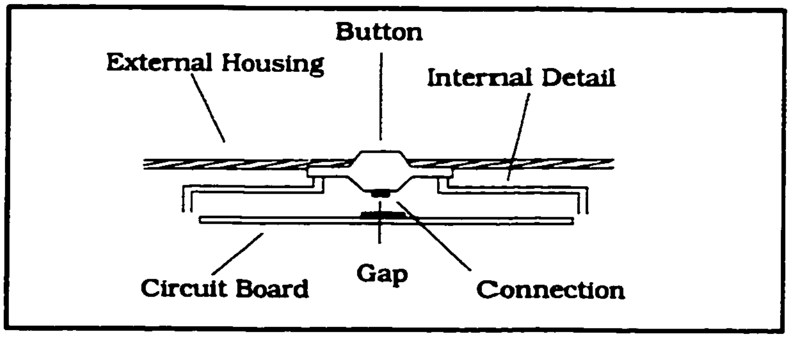


Fig. 6.18 Button Detail

Emergency Alarm

As stated earlier, the emergency alarm has been introduced as a layer of protection against the possibility of a MTB rider encountering an aggressive bear (black or grizzly) and would consist of a 120 dB, 3500 Hz tone. An encounter with an aggressive bear can be characterised as a very stressful situation for the rider. As discussed in Chapter 3 any form of bear deterrent must be easily retrieved and deployed. In order to facilitate the activation of the emergency tone by the user in a panic situation the activation button was made extremely large and placed in a very accessible location on the device. The location of the activation button at the back of the unit, directly facing the rider, allows the user to quickly locate the button. Furthermore, the button's large size eliminates the user's fumbling for its location and allows its activation through gross non-refined motor movements, which are ideal for a panic situation.

The drawback to the location and size of the button is accidental activation. In order to counter this situation, the emergency alarm button has been highly negatively sprung and required to travel through a throw of approximately 4 mm, this will allow the unit to be handled under normal conditions without triggering the alarm.

Sec. 6.3 External

The external issues of the BWD are related to its physical relationship with external objects. The following issues will be discussed: MTB Mount, Hiker Mount, Related Wildlife, and Water Resistance.

MTB Mount

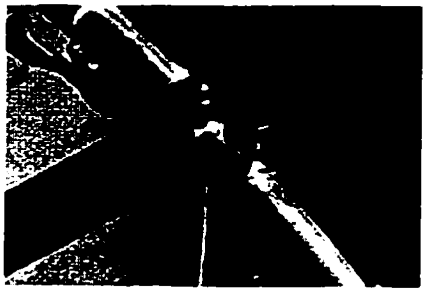


Fig. 6.19 MTB Mount

As discussed earlier, the mounting of the BWD to MTB's handlebars facilitates the effective performance of the device. However, this requires the ability to attach the device to the bars. One of the most crucial requirements of the mounting system is to allow the BWD to be securely mounted to the bike and also to be easily removed. The removal of the unit allows the user to recharge the internal batteries, leave the unit off the bike for non-bear country riding and be able to use the BWD for other activities (see next heading).

The designed mounting system consists of a single injection moulded piece consisting of a collar and mounting head and mounting port located on the bottom of the BWD. Appendix L offers a General Assembly of the mounting system and a photo of the finished model is shown in Figure 6.19. The collar is designed to match the standardized diameter of MTB handlebars (26.2 mm) and will be tightened to the bar with a single Phillips screw and nut combination. The design details of the mounting head (male) include a negative groove in the top of the head (stabilizing groove) which is matched by a positive structure on the BWD (stabilizing blade). This feature assists in proper orientation and enables the BWD to resist any rotational forces.

On the sides of the head are two negative grooves that accept the attaching pins located on the BWD. The male end incorporates a sloped top surface which separates the attachment pins allowing them to snap inside the allotted grooves, securing the BWD to the MTB.

Fig. 6.20 BWD Attachment

To remove the BWD from the mount involves depressing the release button located at the bottom of the BWD which, in turn, lifts the stabilizing blade out of the mounting head and enables the BWD to rotate freely. As the device is rotated 10 degrees the attachment pins are physically separated by the release plane on the mounting head and the BWD is then released. Figures 6.20 and 6.20a illustrate the attachment of the BWD to the MTB.

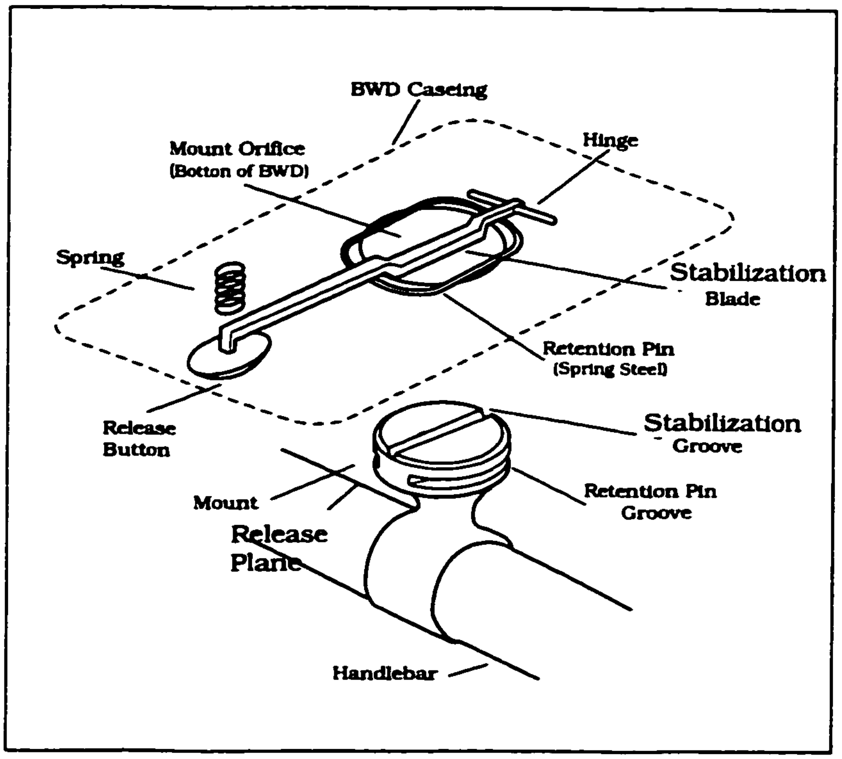


Fig. 6.20a BWD and Bike Mount

Removal of The BWD from the mount involves depressing the release button located at the bottom of the BWD (see Figure 6.21) which, in turn, lifts the stabilization blade out of the mounting head and enables the BWD to rotate freely. As the device is rotated 20 degrees, the attachment pins are physically separated by the release plane on the mounting head and the BWD can then be removed.

Fig. 6.21 Release Button

A further detail of the stabilizing groove in the mounting head is the incorporation of 3 degree sloped sides. The sloped sides are advantageous with regard to the injection moulding processes (draft angles) and further to force the stabilizing blade out of the groove in the event of a significant sideways blow to the BWD. This detail sustains the BWD in the proper orientation during normal operation of the MTB and limits the possibility of damaging this crucial design detail in the event of a serious crash.

Hiking Mount

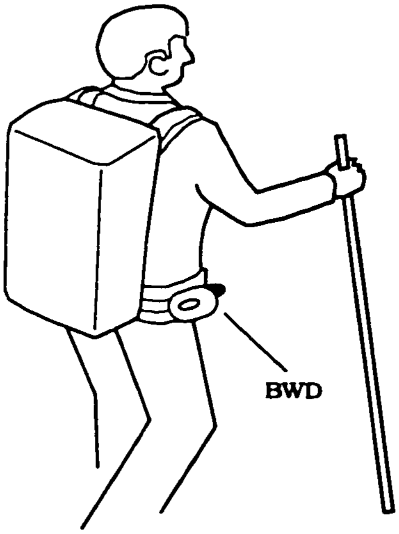


Fig 6.22 Hiker and BWD

The main focus of this project has been to develop a BWD for use by MTB's. However, as stated in Sec. 5.6, it would be short sighted not to anticipate the applications of this device to other activities. To address this issue, some effort has been paid the BWD's application to the activity of hiking. In this case hiking is defined as any activity undertaken in bear country where the mode of personal transportation is predominantly by foot.

In order for the BWD to be used in such activities it must be able to be mounted on the user. To satisfy this scenario, a belt clip attachment has been designed and functions in a similar manner to the MTB mounting system. (See Figure 6.22) Further effort was made to ensure that the design of the controls, indicator lights and emergency alarm button to be accessible and functional to a hiker wearing the BWD on their belt. Appendix M offers a General Assembly of the hiking mount.

The glowing raised ellipse surrounding the power switch and protruding operational indicator lights are visible to the user when worn on the belt. Furthermore, the emergency alarm button is still easily accessible and only requires the gross motor movements of squeezing the entire unit with the hand.

Other Wildlife

In this project the main focus of research was devoted to establishing the ability of bears, both black and grizzly, to hear ultrasonic sound. As stated in Chapter 4, in terms of mammals humans have relatively poor high frequency hearing (Stebbins, W., 1983). It can be assumed, therefore, that most other mammals within the bear's habitat will be capable of hearing the BWD to some extent. Extrapolating the results and finding with regards to other common species of animal such as the 'ungulates' (deer, moose and elk) existing in bear country is difficult. Based on their high reliance on hearing as one of their main sensory modalities (Stebbins, W., 1983) the BWD would hypothetically result in a similar avoidance response. However, generalization at this point would be strictly based on educated assumptions and therefore would require further specific field studies. Please see Sec. 7.2 Future Recommendations.

Water Resistance

Many precautions have been incorporated into the design of the BWD to ensure its effectiveness under extreme weather conditions. (See Appendix N for an exploded view of the BWD) These precautions refer predominantly to water resistance and have been addressed as follows:

1. One of the greatest concerns is the piezo electric speaker. One of the advantages of a small piezo speaker producing the required ultrasonic pulse is that the speaker diaphragm can be used to seal off the piezo crystal and electronics from the external environment.

This entails that the diaphragm itself be water resistant. This can be accomplished with the use of a speaker diaphragm constructed out of plastic or a paper composite with plastic lamination or impregnation. Such diaphragms are commonly found in the majority of acoustic equipment intended for outdoor use.

2. The inclusion of O-ring and rubber gasket seals between any externally connecting surfaces and parting lines.

3. The specification and characteristics of the elastomeric control button allows for its flanges to be sealed by the product's external casing and internal design details. These buttons are commonly used for this reason in outdoor electronic products such as: cellular phones, cycle computers and cameras.

4. If considered necessary the internal circuit board of the BWD could be 'Potting', referring to the encasing of the board in a plastic resin, permanently sealing the board from the external environment. This process, although effective, is rarely used with regard to electronic equipment targeted for the cycling consumer and was determined through the disassembly of many cycling related consumer goods.

Section 6.4 User

The interaction of the user and the BWD occurs on two different levels, 1. Perceptual and 2. Operational.

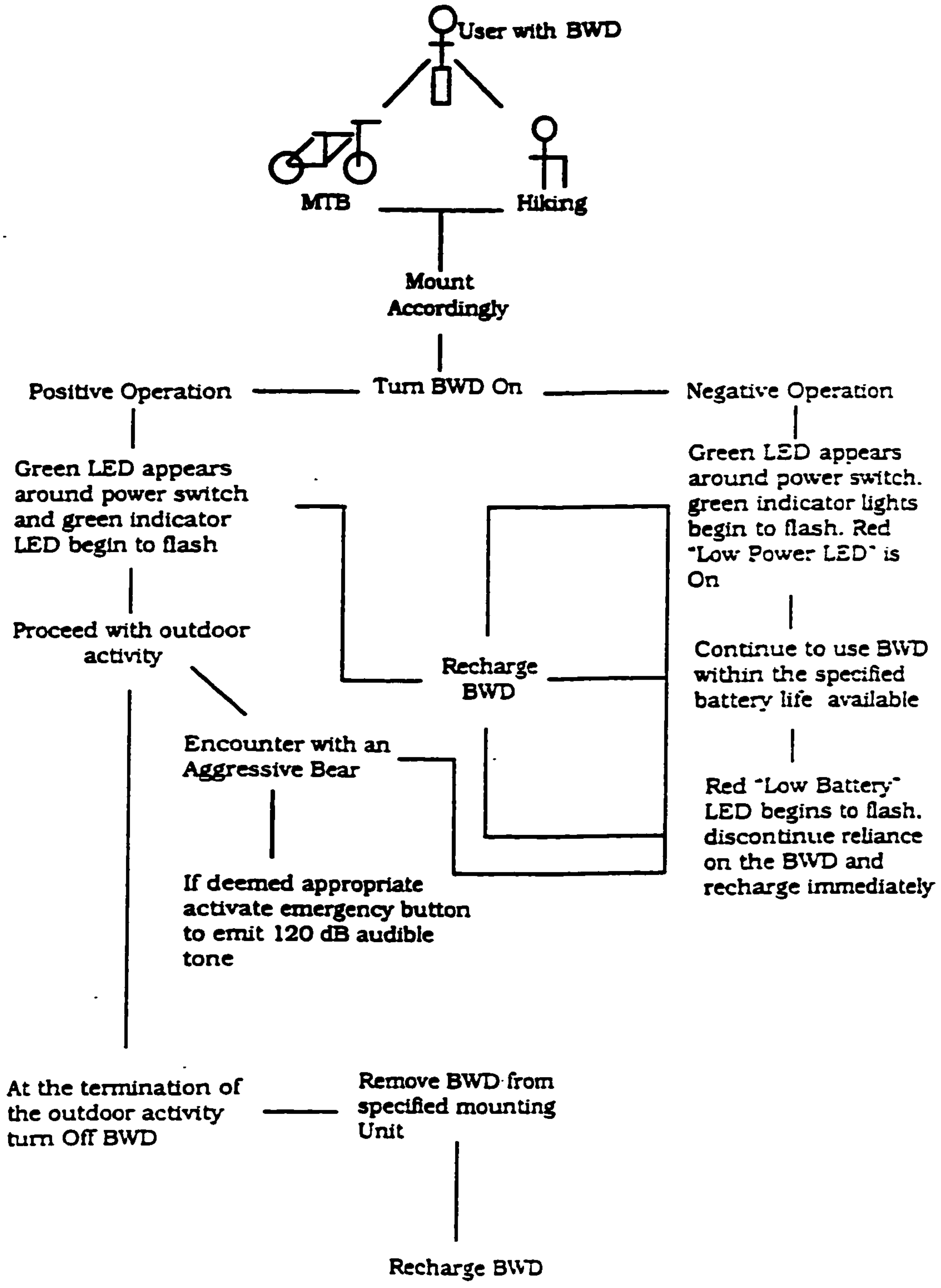
1. **Perceptual**- refers to the user's psychological perception of the BWD and is related to the product's significance or meaning to the user (Roukes, N., 1988). As discussed in Sec. 6.2 the aesthetics and ergonomics of the BWD have been based on the fact that the BWD is essentially a piece of outdoor safety equipment and therefore has been designed with corresponding 'design analogs'. Design analogs refer to visual imagery or constructions which bare a direct similarity or reference

to an object in terms of its form, structure or configuration (Roukes, N., 1988).

The initial familiarization with outdoor electronic and safety equipment provided a quick observation of current design trends and accepted forms for these products. The analog of brighter colours denoting products designed for safety, and or, outdoor use was exploited. The incorporation of an acoustical mesh and a domed speaker enclosure strengthens the user's visual perception of the product as an acoustical device. The santoprene details provide a perception for the user's ability to handle the product in extreme weather conditions. Finally, the physical size of the BWD denotes a sense of durability to the user. In combination, all of these design analogs culminate to produce an effective overall product "Gestalt", offering the user effective clues to the product's purpose, quality and operation.

2. Operational- refers to the user's operational relationships with the product. To address this issue Figure 6.23 illustrates the sequence of interaction.

Figure 6.23 Operational Sequence



Sec. 6.5 Manufacturing

The final design and appearance model completed for this project is intended as an exercise in conceptual design. However, the design is intended to be fully manufactured within current levels of technology, materials and processes. The following is a short discussion of possible choices in materials and manufacturing processes.

Materials

The majority of the BWD would be manufactured with Acrylonitrile-Butadiene-Styrene Terpolymer (ABS) plastic which would be involve in the construction of the main casing, mounting attachments and internal details. Through alterations in the plastic's component polymers its characteristics of strength, impact strength and aging resistance can be maximized. See Figure 6.24. Furthermore ABS is available in a variety of colours and responds well to the injection moulding processes. For these and other reasons ABS is the plastic of choice for the production of electronics, communication devices, furniture, recreational vehicles and sporting goods (Schwartz & Goodman, 1982).

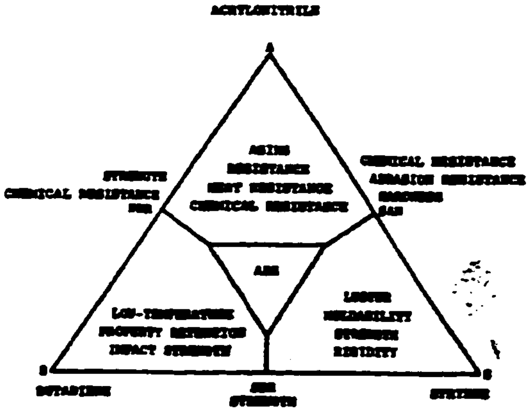


Fig. 6.24 Properties of ABS

A second plastic referred to in this project as santoprene (trade mark) is derived from the family of plastics known as elastomers. Elastomers may be defined as natural or synthetic materials which exhibit rubberlike properties of high extensibility and flexibility, and is available in varying hardnesses (Schwartz & Goodman. 1982). This material offers low temperature flexibility, high coefficients of friction, abrasion resistance and a wide range of colour choices, making it ideal for the production of hand grips and aesthetic detailing on outdoor equipment. Elastomers can be specified in a wide range of hardnesses known as shore durometer. Elastomer predominantly range from 30- 100 on the Shore Scale; for the purposes of the BWD a shore of approximately 50, would be appropriate, (similar to that of a rubber stamp.)

Injection Moulding

Injection moulding is a process of heating thermoplastic granules or pellets in a cylinder until they are liquid, then injecting the liquid under pressure into a relatively cold mould where it freezes and takes the shape of the mould cavity. The major advantages of the process are the speed with which parts can be made, the high quality finish and the ability to make more than one part at a time (Schwartz & Goodman, 1982). Recent advancements in the injection moulding process allows for the ability to produce a product out of two different plastics using the same mould and machine. This is known as a 'Two Shot' process and would allow the main casing of the BWD to be manufactured from durable ABS and the hand grips areas from santoprene.

The effective use of the injection moulding process, however, requires special attention to be taken in the design of the product. The product's casing can contain no undercuts and exhibit varying degrees of draft angles. (Referring to the sides of the product being designed at a number of degrees less than 90.) The advantages and restrictions of the injection moulding process were taken into account throughout the design of the BWD. However, the design would require further refinement and include the addition of internal details and mounting bosses for electronics and assembly.

Summary

A comprehensive discussion on the specific design details of the BWD has been offered. Attention has been paid to the internal workings, surface, external and the user. The extremely important issues of the performance specifications of the BWD have been addressed along with safety issues, ergonomics and aesthetics. Furthermore, issues of manufacturing have been introduced.

Chapter 7 Conclusions

Sec. 7.1 Achievement of Objectives

The specific objectives of the project were extremely varied and complex however, through extensive research and the undertaking of project specific studies the project objectives have been addressed in the following fashion.

Objective 1. The design of a BWD that could facilitate in the reduction of sudden encounters between MTB riders and bears (black and grizzly) has been addressesed through the following means:

A. The ultrasonic BWD is designed to alert a bear of an on coming MTB at a minimum distance of 50 m, and also includes substantial tangent coverage, which theoretically should allow a bear time to avoid contact.

B. The short wavelength of the ultrasonic beam allows for excellent perception of the sound source direction, thus reducing the possibility of the bear being confused and moving toward the on coming MTB.

Objective 2. The specific needs, wants and desires of the MTB community have been addressed through:

A. Designing a BWD that has been reduced in physical size to a point that does not compromise functionality, durability or performance.

B. Keeping the weight of the BWD to a minimum via the use of light yet strong ABS plastics, Solid State circuitry and an educated selection of sound driver and power supply.

C. Undertaking precautions to maximize the performance and durability of the BWD in extreme weather conditions through the incorporation of seals and material selection.

D. Exploring current MTB accessories, related electronic products and sporting equipment design. The aesthetics of the BWD were partially based on current and accepted visual analogs.

Objective 3. Addressing the issue of the MTB community's rejection of current forms of BWD due to their intrusive and irritating audible noise. The specified ultrasonic tones of 21.5 and 23 kHz will make the BWD inaudible to the majority of MTB riders.

Objective 4. The ultrasonic BWD may facilitate a better coexistence between man and bear (black and grizzly). Through the reduction of sudden encounters the extreme levels of stress incurred by both man and bear may be reduced, along with the reduction of possible aggressive outcomes. The BWD offers the bear the ability to act on its natural affinity to avoid human contact and for man to participate in backcounty activities in bear country with a higher degree of safety.

Sec. 7.2 Fulfilment of Criteria

The criteria by which the design solution should be judged successful have been addressesed through the following:

1. Through experimentation and related research it has been argued that the ultrasonic pulse emitted by the proposed BWD would be capable of travelling a minimum of 50 m under environmental conditions characteristic of MTB trails in bear country. Furthermore, it has been argued that the ultrasonic pulse could be perceived by both black and grizzly bears.

2. The durability and operation of the BWD in adverse weather conditions has been satisfied through the exploration of current outdoor electronic equipment and the incorporation of preventative design details.

3. Through the use of conceptual and spacial compatibility and the incorporation of appropriate visual and tactual analogs, the controls and displays of the BWD have been designed for excellent user understanding and interaction.

4. Aesthetically the BWD has been designed to emulate related electronic equipment and to further develop its own unique visual language. Whenever possible its design follows current and accepted trends in colour and material selection that relate to its intended uses as an item of safety equipment.

Sec. 7.3 Future Recommendations

As stated earlier, the culmination of this project has not resulted in a fully functional, field tested ultrasonic BWD. Through the course of this project, arguments have been posed that highlight the inadequacies of current BWD as related to the activity of mountain biking. The use of ultrasonic sound within the context of a BWD has been argued as a possible option, substantiated through research and experimentation. The true viability of the proposed BWD can only be attained through further extensive field research. The following is a list of studies that would be required for the evolution of the BWD into an effective and viable product.

1. As it exists today the available research on the specific hearing abilities of bears is minimal. Although this project has been completed using quality research, for the design to evolve into a marketable product accurate and reproducible tests with regard to the specific high frequency hearing abilities and sensitivities of both black and grizzly bears would be required. Results could be attained through experimentation on Zoo bears. Through the techniques of classical conditioning (food rewards) bears could be trained to physically respond to perceived sounds. Through their behaviour and responses their upper hearing limit and subsequent sensitivity to ultrasonic sound could be established.

Zoo bears could also be used to establish the effectiveness of the proposed audible Emergency Alarm of the BWD.

2. Actual field tests are required to test the response of bears in their natural habitat to the presentation of ultrasonic sound. Such tests would establish the following:

A. The ability of bears to perceive an ultrasonic sound in their natural environment.

B. Establish the rate at which bears (black and grizzly) associate the ultrasonic warning with the presence of human activity.

C. Establish bears' response to the ultrasonic sound.

D. Establish bears' response to the Emergency Alarm.

3. similar tests as in #2 need to be conducted on related animals that exist within the habitat of the bear to ascertain their responses to the presentation of the BWD.

4. Testing the durability of the BWD design would be a further requirement. This could be accomplished through the production of a number of prototypes, mounting them on bikes, and testing them on various mountain bike trails under varying conditions.

Appendix A. Review of Current Bear Deterrents and Repellents
As Found in "Safety in Bear Country 1985

Method	Effectiveness	Practicality	Advantages	Limitations
Warning shots	- sometimes effective - will not scare some bears - better than nothing - effectiveness may decrease with repetition	- practical for most situations where portable, short term deterrent is needed - suitable for anyone working, living or travelling in bear country	- readily available - easy - portable - inexpensive	- may injure bear if not carefully placed
Cracker shells (Twinshots) (Teleshots)	- same as for warning shots - should not be relied on for personal protection	- same as for warning shots	- same as for warning shots	- not dependable - shells can misfire or fail to explode - limited to open areas - may be a fire hazard
Thunderflashes	- same as for warning shots - should not be relied on for personal protection	- very portable, but effectiveness is limited	- same as for warning shots	- same as for cracker shells - limited range
Airhorns (Boat horns)	- same as for warning shots - may be used as noise-maker to prevent surprise encounter - should not be relied on for personal protection	- same as for warning shots	- same as for warning shots	- not reliable in very cold temperatures - may provoke aggressive or curious reactions from some bears - source of noise is on person
Vehicles (snowmachines, 3-wheeled vehicles, helicopter)	- engine noise often frightens bears away - chasing bears for a short distance is quite effective	- useful while travelling or in small camps where vehicles are used - use of helicopter limited by availability - helicopter should be used as a last resort	- easy if vehicle is accessible	- may be hazardous to person and bear if not used properly

Method	Effectiveness	Practicality	Advantages	Limitations
Relocation	- usually ineffective as a long-term deterrent	- not practical for polar bears - may be short-term solution to immediate problem (e.g. at campground, near residential area) - personnel and means for trapping must be available	- bear is removed from area at least temporarily	- expensive - time-consuming - temporary - i.e., bears often return to capture site - fails to address true cause of problem - limited by road access or helicopter expense
Rubber bullet	- very effective	- available only to Renewable Resource Officers and R.C.M.P. - useful in most situations when an Officer can be contacted	- highly effective - bears have not reacted aggressively toward person firing gun - may cause behavioural changes resulting in long-term deterrence	- restricted to Renewable Resource Officers and R.C.M.P. in Canada - intensive training and practice necessary - need for special rifle - cost of bullets - single shot weapon
Birdscaring flare cartridge	- more effective than cracker shells but do not scare some bears	- same as for warning shots	- same as for warning shots - reliable - consistent trajectory - flare component useful in darkness	- limited to open areas - may be a fire hazard
Electric fences	- fence built to proper specifications will keep out grizzly and black bears - not effective for polar bears except in wet locations	- suitable for semi-permanent or permanent installations where grizzly bears or black bears are a problem - may not be practical for very large sites	- permanent deterrent method - 24 h protection	- expensive - effort required for installation - regular maintenance required - can be hazardous to people
12-gauge plastic/rubber slugs	- good potential but still in experimental stages - see text for details	- when perfected, should be suitable for most bear problems	- use is not restricted - accurate - can be fired from a shotgun - portable - inexpensive	- still in experimental stages

Method	Effectiveness	Practicality	Advantages	Limitations
Dogs	- specially trained dogs may be effective in some cases - not reliable	- suitable for semi-permanent and permanent camps of all sizes	- inexpensive - easy	- poorly trained dogs can aggravate a bear and/or lead it back to camp - dogs can be killed - require a responsible handler
Chemical repellent sprays	- still in experimental stages - not recommended at this time - see text for details			
Pencil flare guns	- same as for warning shots - should not be relied on for personal protection	- same as for warning shots	- same as for warning shots	- same as for cracker shells
Bear monitors	- can be highly effective if experienced with bears and well trained in the use of deterrents and firearms	- especially useful at large, established camps in polar bear habitat	- only responsibility is detecting and deterring bears - flexible	- need several monitors for 24 hour protection - need good system of communication
Acoustic deterrents	- still in experimental stages, but some frequencies (0.1 - 9 khz) have good potential			

Appendix B. Field Study #1 and #2

One of the assumptions made in this project is that a mountain bike (MTB) is capable of travelling through the backcountry with remarkably little noise, therefore offering little to no deterrent capabilities. No published research on the sound characteristics of a moving bicycle was found. Furthermore, no studies were found with regard to the sound characteristics of a bear bell on a MTB. As a result, two field studies were conducted to explore these issues.

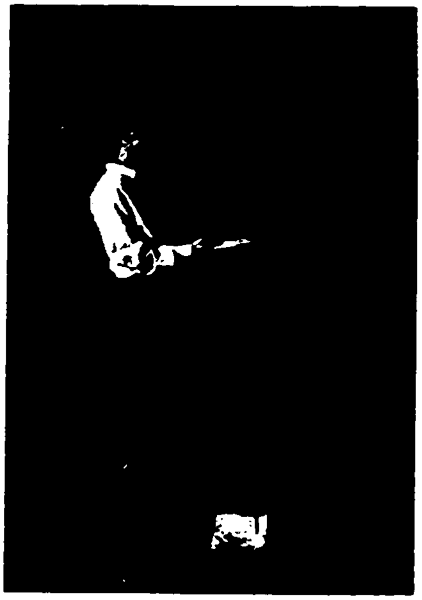


Fig. A 1.1

Field Study #1 Bicycle Noise on Varying Terrain

The first study was conducted to gather base data on the natural sound output produced by a mountain bike and rider while travelling on various trail conditions.

Location:

Edworthy Park located in the South West section of Calgary was chosen as the test site. This park contains single-track hiking and mountain bike trails through a natural landscape similar to that found farther west in bear country. A section of trail was chosen that contained sections of uphill, downhill and flat ground.

Apparatus:

- B&K sound meter model #2333
- Litespeed Obed (MTB) with front suspension
- camera
- Specialized cycle computer
- assorted recording equipment (written)

Methodology:

Following the selection of a suitable trail, ambient noise readings were taken using the sound meter. Readings of a MTB on flat ground were obtained by having my assistant ride past me at a relatively consistent speed. Sound level readings were taken when the bike was approximately 1 metre away with the sound meter held at chest height (1 metre) above the ground. As seen in Fig. A 1.1. As the rider rode past he would take note of his speed using the bike mounted computer. This procedure was then repeated for the uphill and downhill section of the trail.


Fig. A 1.2

Results:

Flat Ground (See Fig. A 1.2) :

Trial	dB	km/h
1	52	20
2	55	21
3	54	21
4	55	21

The average dB on flat ground was 54 dB at an average speed of 20.75 km/h.

Uphill:

Trail	dB	km/h
1	51	5
2	51	4.5
3	54	5
4	52	5

The average dB on an uphill was 52 dB at an average speed of 4.87 km/h.

Downhill:

Trial	dB	km/h
1	54	21
2	56	22
3	55	21
4	56	21

The average dB on a downhill was 55.25 dB at an average speed of 21.25 km/h.

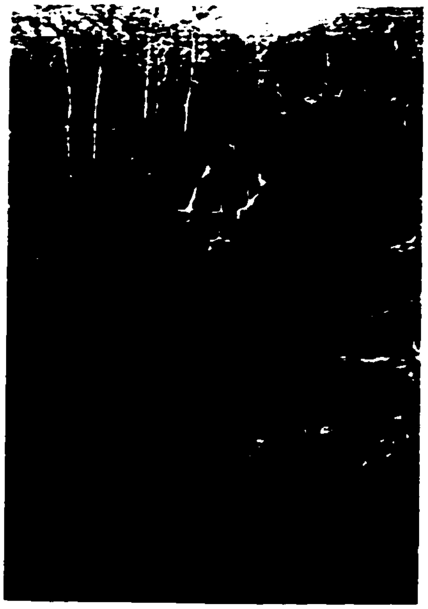


Fig. A 1.3

Harsh Downhill (See Fig. A 1.3) :

Trial	dB	km/h
1	63	17
2	61	18
3	61	17
4	62	17

The average dB on a harsh downhill was 61.75 dB at an average speed of 17.25 km/h.

The ambient sound during the time of the study was 51 dB.

Discussion:

The results of this study clearly show that the amount of sound produced by a rider and mountain bike on an off- road trail is relatively small. A 3 dB increase over ambient sound levels on flat ground and only a 1 dB increase during uphill sections is minimal. It is not until the bike was ridden on extremely harsh trail sections that any significant increase in sound production is reached, ie. an increase of 10.75 dB.

Taking the sound readings obtained in this study and determining the distance required for the sound of a MTB to reach ambient sound levels, it can be shown that the MTB is an exceptionally quiet mode of backcountry transportation.

Flat ground, uphill and downhill sections with dB readings of = 54, 52, and 55.25 dB, will reach ambient sound levels almost instantaneously.

On harsh downhill sections with a dB reading of 61.75, such a level will reach ambient sound levels in approximately 4 metres.

Such sound levels and their corresponding carrying distances are completely inadequate in providing any form of bear warning capability.

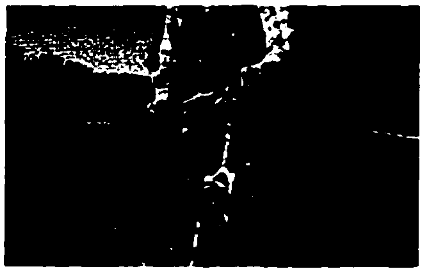


Fig. A 1.4

Field Study #2: Bear Bell Noise on Varying Terrain

To test the increase in sound output with the use of a bear bell, the study was repeated with the addition of a "Silver Foot" bear bell mounted to the front of the mountain bike, as seen in Fig A 1.4. The same sections of trail were used along with the same measuring techniques and apparatus as in Field study #1.

Results: MTB with a Bear Bell

Flat Ground:

Trial	dB	km/h
1	55	21
2	58	21
3	55	20
4	57	21

The average dB on flat ground= 56.25 at an average speed of 20.75 km/h.

Uphill:

Trial	dB	km/h
1	52	5
2	55	4.5
3	58	5.5
4	53	4

The average dB on an uphill= 54.4 at an average speed of 4.75 km/h.

Downhill:

Trial	dB	km/h
1	59	17
2	61	18
3	60	18
4	60	17

The average dB on a downhill= 59.75 at an average speed of 17.5 km/h.

Harsh Downhill:

Trial	dB	km/h
1	75	16
2	76	19
3	75	19
4	74	18

The average dB on harsh downhill= 75 dB at an average speed of 18 km/h.

Discussion:

The addition of a bear bell onto the mountain bike accounted for only a marginal increase in sound output. On flat ground and uphill sections, increases of approximately 2.5 dB were recorded. Only on the downhill sections was there any real increase in sound production (4.5 and 12.75 dB). However, these increases only marginally affected carrying distances.

If the equation for attenuation is used to approximate the distance the sound will carry before degrading to ambient sound levels the results are as follows:

On flat and uphill sections the additional sound output does not add any significant increase in carrying distance.

On the downhill the sound will reach ambient levels in approximately 3 metres.

On the harsh downhill the sound will reach ambient levels in approximately 19 metres.

Even on trail conditions that produced the greatest amount of noise from the bike and bell the dB levels were not sufficient to provide an adequate carrying distance to warn a bear. Furthermore, the trail conditions required in order to achieve the loudest results in this test are not characteristic of the majority of backcountry trials. Such conditions are only found predominantly on expert

Fig. A 1.5

MTB trials and are unlikely on general use trails. This study helps confirm why bear bells are an appropriate form of BWD for hikers (Fig. A 1.5). Their slow moving bipedal gate will activate a bell and alert a bear within just enough distance (Jope, 1985). However, this study also indicates that using a single bell on a MTB as a BWD will not provide sufficient warning. Any rider travelling faster than a slow jog will quickly overcome any warning capabilities of a bear bell and risk a sudden encounter.

Appendix C. Basic Acoustics

A full exploration into acoustics is far beyond the scope of this project. This section will attempt to convey information pertinent to the understanding of this project.

All sound is the result of vibration or friction; anything that vibrates within a medium (gas, solid or liquid) will produce sound. These vibrations can take place very slowly, such as those caused by atmospheric changes, or very rapidly, like ultrasonic waves emitted by a submarine's sonar. The only situation where a vibrating object will not produce sound energy is when that object vibrates within a vacuum.

Sound Propagation:

All sounds propagated through a gas or the earth's atmosphere are 'longitudinal waves'. Imagine the diaphragm of a speaker. As the speaker moves back and forth it compresses and uncompresses the air around it. Since the compressed air has a greater pressure than the surrounding atmosphere the air particles tend to move in an outward direction. These high pressure air molecules then push against the next layer of air transmitting the sound energy to them, and so on. When the speaker relaxes back to its starting position an area of low pressure is established which is then followed by another compression as the speaker moves forward again (Harris, L., 1991).

Frequency:

The term frequency can be used in many different situations outside of acoustics. Basically any event that happens with a specific period of time between the event happening again can be said to have a frequency. A dripping tap, ice ages, appearance of a comet and sound waves all have a frequency. The specific period of time could be seconds, minutes or centuries. In the case of sound waves " it is the number of times in one second that this sound repeats itself" (Harris, C. 1991). With sound, the number of compression waves that can be counted within one second represents the frequency of the sound and is usually given the unit Hertz (Hz).

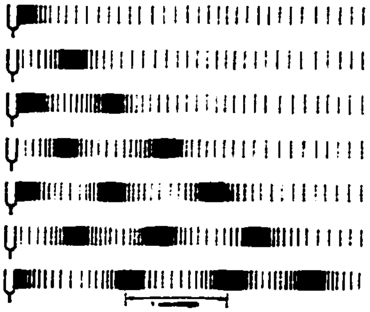


Fig. A 2.1 Wavelength

Wavelength:

The wavelength of a sound is the distance between two successive compressions. This length is the same distance as that travelled by the sound wave in one complete cycle of vibration. See Fig. A 2.1. The size of a sounds wavelength is related to its frequency. As frequency increases, the size of the wavelength decreases.

It is determined by the following equation:

Wavelength = Velocity / Frequency

where velocity = 330 m/s
frequency = Hz
wavelength = metres

Thus, a frequency of 21 kHz or 21, 000 Hz has a wavelength of 15.7 mm (Smith, B., 1972).

Decibel:

The term decibel (dB) is an extraordinarily complicated unit in acoustics. It is basically a unit that helps quantify the atmospheric pressure of sound waves. However, the magnitudes of pressure affecting the human ear are vast. Because of the inconveniently large numbers and the fact that the ear response is more sensitive to different sound pressures, a logarithmic scale is used. A dB is basically a ratio comparison between a sound pressure that the ear can just respond to and one that has slightly more power.

The logarithmic base for the decibel is 10. Thus an increase from 10 - 20 dB is not an increase in power of 10 but of 10 times and an increase from 10 - 30 dB is an increase of 100 times.

The following is a list of dB related to common noises:

Jet takeoff (60 m)	120 dB	
Construction site	110 dB	Intolerable
Shout (1.5 m)	100 dB	
Heavy Truck	90 dB	Very loud
Urban Street	80 dB	
Automobile interior	70 dB	Noisy
Normal conversation	60 dB	
Living room	40 dB	Moderate
Bedroom at night	30 dB	
Broadcast studio	20 dB	Quiet
Rustling of leaves	10 dB	Barely audible

(found in Rossing, T., 1982)

Sound Meters and Scales:

The basics of all sound meters are the same. They convert sound pressure waves into electrical voltage fluctuations which are amplified and output to a visual calibrated meter displaying decibels.

Almost all sound meters have different weighting scales built into them. Each scale gives preference to different frequencies. (See Fig. A 2.2)

A- Scale:

It has been shown that the readings on the A scale (dBA) correspond most closely to the response of the human ear. The human ear is most sensitive to sound frequencies between 1000 Hz and 4000 Hz. This scale is used when noise levels and impact are being studied with regard to humans.

B- Scale:

The B scale is not usually found or used with regard to acoustical measurement, but may be found on some older meters.

C- Scale:

The C scale or "Linear" scale gives flat response to sound. It is most often used for wide band measurement of sound level. The C scale was chosen for this project on account of this uniform response to a wider range of frequencies.

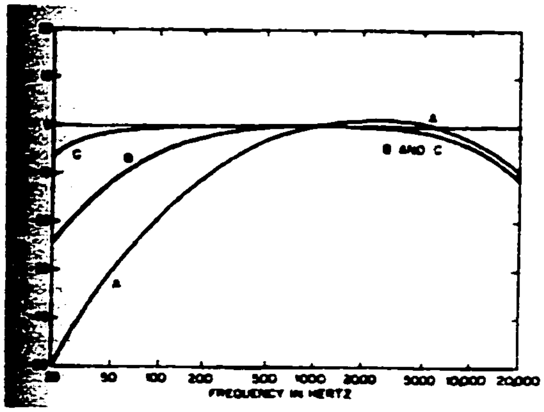


Fig. A 2.2 Sound Scales

Attenuation of Sound

Sound propagating outdoors through the air generally decreases in level with increasing distance between source and receiver. The general attenuation of sound in the open air is generalized to be 6 dB for every doubling of the distance between source and receiver and is described by the following equation:

$$L(R2)=L(R1)-20\mathrm{Log}(R2/R1)$$

$R1$= distance to sound source in metres
$R2$- disatnce to sound source in metres
L= sound level in dB

There are many different variables that collectively cause attenuation:

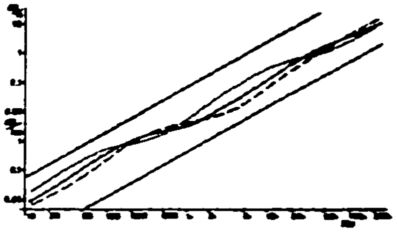


Fig. A 2.3 Attenuation by Air

1. Absorption of acoustic energy by the air. As the sound energy is transferred through the air some of its energy is lost to heat. This attenuation is minimal in lower frequency sounds but can be excessive with regards to ultrasonic sound. Typical values are about 3 dB per 100 metres and increasing to 1 dB/metre at 100 kHz. However as Figure A 2.3 shows when dealing with 21 kHz, sound energy will have an attenuation of approximately 0.4 dB per metre. Remember that the dB scale is logarithmic and therefore, the visual middle between 0.1 dB and 1.0 dB is actually represented by 0.3 dB (Hopp, Owen & Evans, 1997).

2. Atmospheric conditions, wind and temperature and humidity can have major effects on the propagation of sound waves. However, this is only a concern for sound travelling over 100 metres (Harris, L., 1991).

3. Attenuation due to geometrical divergence relates to sound's natural tendency to disperse in all directions once it has left the sound source. Divergence is the reason we can hear people speaking even when they are not facing us. As discussed in Chapter 4 low frequency sound has a corresponding large wavelength. The larger the wavelength of the sound, the more attenuation due to divergence. The sound will literally wrap right around the source and propagate in a 360 degree fashion.

High frequency sound, or ultrasound, has a very short wavelength and as a result the sound will beam straight out from the sound source with very little energy being lost to divergence.

4. Attenuation due to foliage is also a large concern with regard to this project. Any BWD will have to be effective within a forested environment. The attenuation of a 21 kHz sound by foliage is approximately 6 dB at 50 metres on light visual foliage obstruction but with very leafy undergrowth (Smith, B., 1971).

Human Hearing

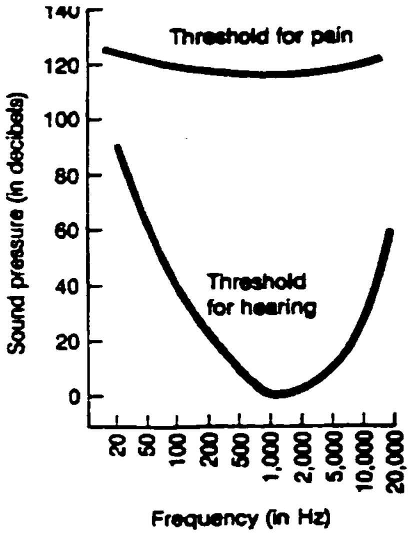


Fig. 2.4 Human Hearing

The study of human hearing is complex and an exhaustive exploration of it is far beyond the boundaries of this paper. However, establishing the general hearing range of the human ear is of great importance with regard to this thesis.

Within the scientific acoustic community, the consensus for the range of human hearing is from 20 Hz to 20 kHz. However, both ends of this range are not fixed, for there are significant individual differences (See Fig. A 2.4). This is most evident in an individual's ability to hear high frequency sound. As humans age, their ability to hear high frequency sound is rapidly decreased. Very young children can often hear very well up to 20 kHz . However, in adults the frequency threshold is often reduced down to 15 kHz and sometimes even as low as 10 kHz (Harris, 1991) ; (Atkinson et al, 1987). As illustrated in Fig. A 2.5.

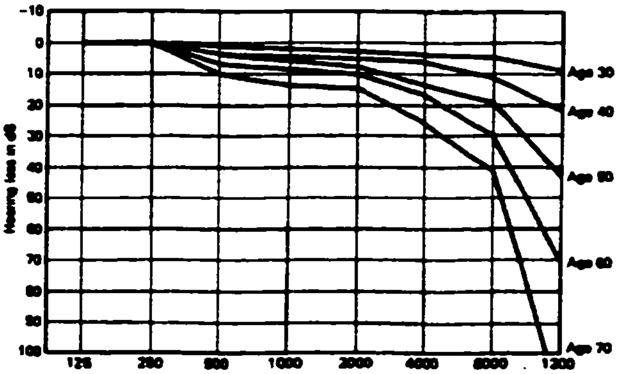


Fig. A 2.5 Reduction of
Human Hearing
with Age

Appendix D. Carrying Distance of a Bear Bell Field Study #3

The effectiveness of bear bells in reducing the probability and effects of a sudden encounter with regard to hikers has been confirmed by Jope (1984, 1985). However, no information has been published determining the sound output and carrying distance of these bells. One of the main hypotheses of this project has been that the sound and carrying distances of bear bells are too limited to be effective in combination with a fast moving mountain bike. This study was designed to collect base data on the sound characteristics of bear bells and furthermore, to determine if the general equation for sound attenuation can be used with regard to the environmental conditions pertinent to this project.

Location:

Fish Creek Provincial Park was chosen as the site of the study. It offers a variety of terrain and geography that is consistent with the hiking and MTB trails found farther west in bear country. Two sites were selected within the park.

1. An open field with 30 cm high grasses and weeds. This site is consistent with the survey results indicating that a large percentage of sudden encounters occur in open area, as seen in Fig. A 3.1

2. A foliage-laden single-track trail consisting of a surface of fallen leaves and soft soil. The trail was flanked by small to medium sized mature coniferous and deciduous trees, as seen in Fig. A 3.2.

Apparatus:

-B&K sound meter model #2333
-Brodie Sovereign MTB with front suspension
-wooden stakes
-measuring tape
-camera

Methodology:

At each location wooden stakes were placed into the ground at 5 metre intervals. A "Silver Foot" bear bell was attached to the MTB handle bars and was tested for any impediment to its movement. The bell's height above the ground was measured at 1 metre.

Ambient sound measurements were recorded during lulls in the wind. The tests were conducted tangent to the wind direction to negate its effect on sound transfer.


Fig. A 3.1

An initial sound level of the bell was recorded at 1 metre, then at 5 metre increments until a distance of 50 metres was reached. During all tests the sound metre was held pointing in the direction of the bells at a height of 1 metre. To activate the bells my assistant jostled the front end of the bike vigorously for 2-5 seconds. I recorded the appropriate sound level. The meter's settings were placed on Fast (sound pulse) and on the linear scale. Further my assistant yelled "Go Away Bear" at 1 metre and at 50 metres. At each site two trials were conducted.

Results:

Open Grass Field

Distance	Trial #1 (dB)	Trial #2 (dB)
1	71	71
5	60	60
10	55	57
15	52	50
20	50	51
25	47	48
30	45	45
35	45	48
40	45	46
45	43	44
50	45	45

Yelling "Go Away Bear"= 73 dB at 1 metre and 47 dB at 50 metres.

Ambient sound levels for the open grass site= 45 dB

Foliage Trail

Distance	Trial #1 (dB)	Trial #2 (dB)
1	70	71
5	60	63
10	53	55
15	48	51
20	45	
25	43	44
30	40	41
35	40	43
40	38	40
45	42	40
50	40	39

My assistant yelling "Go Away Bear" had an SPL= 74 dB at 1 metre and 42 dB at 50 metres (SPL is sound pressure level). Ambient sound level for the Foliage Trail was 39 dB.

Discussion:

The two experiments were consistent with the general equation for sound level attenuation which predicts that a sound will attenuate 6 dB for every distance doubled. Please reference Appendix C.


Fig. A 3.2

The equation predicts that the bells in the open field will be 43.1 dB at 25 metres. SPL's of 47 and 48 were obtained; however, the discrepancy can be attributed to the environmental conditions, predominantly wind. In the open field the bell stopped eliciting sound level meter results at approximately 35 metres.

On the foliaged trail, sound levels at 25 metres were recorded at 43 and 44 dB. Again consistent with the general equation. The bells stopped eliciting meter results at approximately 35 metres. The results of my assistant yelling were again consistent and share similar sound levels as the bear bell.

I believe this study was successful on two fronts for the following reasons:

1. It has established that the general equation for sound attenuation is applicable to the type of environmental conditions pertinent to this project.

2. The sound power of bear bells is insufficient and offers very little carrying distance. I believe this study helps explain why bear bells are adequate with regard to hikers' slow bipedal gate and not for faster moving MTB's. A MTB travelling at 20 km/h will quickly overcome the security offered by a bell. This is especially relevant when the modest trail conditions and smooth style of the rider reduces the number of times a bell gives off its warning chime, reducing the effectiveness even more. Furthermore, the effectiveness of human vocalization as a deterrent is also questionable, considering the loud shout of "Go Away Bear" created sound levels similar to the bear bell.

Appendix E. Survey; Results; Discussion

Questionnaire

Study of Grizzly Bear Deterrents and Mountain Biking

The purpose of this questionnaire is to explore bear encounters with respect to mountain biking and evaluate current bear deterrent products and techniques. The project is being conducted as part of a Masters Degree in Industrial Design at the University of Calgary.

The term **Deterrent** is defined as any product or technique used to reduce the chances of a bear encounter or ward off an aggressive bear. Examples include: Bear Bells, Air Horns, Cracker Shells, Vocalization...yelling..., Pepper or other chemical sprays...etc.

The term **Encounter** is defined as any visual sighting of a bear, including charges and attacks.

Questions 1-4 are optional. Names and addresses are requested so the researcher may personally contact you to clarify any responses. Your name ,and or, address will not appear in any reports or be relayed to a third party.

If you have had more than one bear encounter please fill out a separate questionnaire for each encounter.

1. Name: (Last)________________________ (First)__________________

2. Age:________

3. Sex: male____ female____

4. Phone Number: area code_______ number__________________

5. Have you ever experienced an encounter with a bear during a mountain bike ride? Yes____ No____ If no please skip to question 18.

6. Can you identify the species of bear?

Black bear positive identification ____
Black bear possible identification ____
Grizzly bear positive identification ____
Grizzly bear possible identification ____
Unknown ____

7. Were any cubs seen or known of? Yes____ No____ Number________

8. How many were in your riding party?_____

9. What was the distance between the bear and you at the time you first noticed the bear? (Yards, Meters, Feet) ____________________

10. What was your activity at the time of the encounter?

Riding Flat terrain _____
Riding Downhill _____
Walking _____
Riding Uphill _____
Resting _____
Other _____

11. If you where riding please estimate your speed at the time (km/miles)

____

12. Did the Bear appear to be startled? ___________________________

13. What was the visibility at the time of the encounter, between you and the bear?

high (clear) _____
medium (15 meters) _____
low (0-5 meters) _____

14. What was the reaction of the bear?

No reaction _____
Ran to cover without stopping _____
Ran then turned to watch form a distance (meters) ____________
Stood up ______
Advanced slowly towards you ______
Advanced rapidly towards you _____
reacted with aggressive actions (paw swats, woofing sounds) _____
Charged (head down, ears back) _____
Other ____

15. What was the closest distance reached between you and the bear?

____

16. Prior to the encounter were you, or anyone in your party, employing any product (Bear Deterrent) or technique to warn the bear of your presence?

Bear Bells _____
Air horns _____
Whistle _____
Other ____
Vocalizations (shouting, singing...) _____
Cracker shells _____
Bike Bells _____

17. Did you report the encounter to park officials? Yes _____ No _____

18. Do you normally carry some form of bear deterrent, or vocalize during a ride to warn the bear of your presence? Yes _____ No _____

If yes please list the products and or techniques. _______________________
____

19. If no! Please indicate why.

Cost ____ Believe them not to be effective ____
Irritating ____ Not needed ____
Other ____

20. If you were to carry a bear deterrent what features would you like to see it have? Number 1 as most important and 9 as least.

Hands free operation ____
Portable ____
Transferable to other activities (hiking, fishing...) ____
Monitorless operation ____
Non-obtrusive deterrent (people can't hear, smell...the deterrent) ____
Non-aggressive deterrent ____
Aggressive deterrent ____
Mount on bike ____
Mount on your person ____

21. Does the thought of encountering a bear enter your mind during the course of your rides? Yes ____ No ____

22. Please rate the following variables in order of most importance to you. 1 being the most important and 9 the least important.

Effectiveness ____
Weight ____
Durability ____
Price ____
Size ____
Aesthetics ____
Easy Control ____
Transferable to other activities ____
Non-Obtrusive ____

23. Would you purchase such a product. Yes____ No____

24. What would the maximum price you would pay for such an item? ________

25. Comments ____
____
____
____
____

Thank you for your time and support.
Mathew Schmor.

Methodology

The purpose of the questionnaire was two fold. The first aim was to gather information directly related to mountain biking and bear encounters. Attempts to find such data through conversations with park wardens in charge of gathering data in the major parks including: Glacier, Banff, Peterlougheed, Waterton and Kananaskis yielded little specific information on encounters between bears and cyclists. The first part of the survey was designed to specifically target the mountain bike community and gather data on cyclist related bear encounters.

The second part of the survey probed issues concerning the possible design of a new bear deterrent, emphasizing the wants and needs of this specific group and activity. It is hoped that this section will facilitate the design process and help flag personal biases and assumptions that are not reflected in the population at large.

The questionnaire was distributed and openly available for a period of six weeks at Soma Cycle located at 4210 Bow Trail in Calgary. During this period of time, a trip to Jasper National Park was made and a number of surveys left with Jasper cycle stores. Unfortunately, none of the Jasper surveys were returned. Further surveys were filled out at a number of cycle stores located in Calgary after personal visits to these establishments.

The survey was also made available at the information desk of the Nordic Centre in Canmore Alberta between the months of August and September. Furthermore, postings were placed throughout the University of Calgary and related outdoor retail stores in Calgary.

Results

In total 41 questionnaires were completed. The following is an overview of the pertinent results and discussion of the findings.

The most common type of bear seen on the trail by mountain bikers (MTB) is the black bear. 27 black bears were encountered and 13 grizzlies (Question 6).

Riding parties consisting of 1-2 individuals (24 of 41) accounted for 58% and groups of more than 2 (17 of 41) accounted for 42%. When this information is cross-referenced with question 12 concerning whether the bears were startled by the MTB, groups of 2 or less startled a bear in 27 of 41 (66%) of the encounters. Groups of 2 or more startled a bear in only 11 of 41 (27%) of the encounters (Question 8).

Question 12 indicates that 35 of 41 (84%) of riders were unaware of the bear's presence until within 50 m of the bear, with the closest approach reported at less than 3 metres.

Question 10 found that the majority of encounters occurred while riding flat terrain 21 of 41 (51%). Riding downhill accounted for 12 of 41 (29%) and uphill 6 of 41, (15%).

Rider speeds estimated at the time of the encounter included: speeds of 1-10 km/h accounted for 10 of 41 (24%), speeds of 11-30 km/h accounted for 25 of 41 (61%), and above 30 km/h 4 of 41 (10%). The average speed of encounter was 20 km/h (Question 11).

Analysis of whether the bear was startled by the MTB resulted in 27 of 41 (66%) of the bears being startled. When this data is cross referenced with the distance at which the rider became aware of the bear, we find that at distances less than 50 metres 21 of 33 (66%) were startled. At distances greater than 50 m only 3 of 10, (30%) of the bears were startled by the MTB.

Conducting a Chi Square, the startling of a bear by a MTB is highly dependent on the distance between the biker and bear (chi square=7.165, d.f.=2, p=0.0278, at 0.05 level).

The environmental variables limiting visibility at the site of the encounter found that 32 of 41, (78%) of MTB bear encounters took place in high visibility areas, or areas with greater than 15 metres of open ground between the rider and bear.

The use of any bear deterrent or technique was explored in Question 16, 24 of 41 (59%) of rides used some form of deterrent, the majority being bear bells, followed by some form of vocalization. However, 19 of 41 (46%) used nothing at all. When probed (Question 19) for the reason why no deterrent were used, 22 of 31 (71%) of riders indicated that the current offering of bear deterrents were viewed as irritating. Comments included, "Irritating to me and my fellow riders." ; "Drive me crazy" ; "Take away from the experience of the ride". Among those surveyed 3 of 31 (10%) thought a bear deterrent of some kind was not needed an 6 of 31 (19%) said deterrents were ineffective.

Question 17 probed whether riders had reported the encounter to park officials: 31 of 41 (76%) indicated that they had not reported the encounter.

Riders were asked if the thought of a bear encounter enters their minds during most MTB rides and 32 of 41, (78%) indicated that it did (Question 21).

Riders were probed for what they most wanted to see in a new deterrent. The three most desired features included: a non-obtrusive deterrent, portable design and hands free operation (Question 20)

When questioned about possible performance variables about the design the following were listed as most important: effectiveness (35 of 38; 92%), weight (32 of 38; 84%) and then price (30 of 38; 78%) (Question 21).

When probed if they would purchase such a product 31 of 41, (76%) said yes (Question 23).

The individual results for both species of bear, black and grizzly, are as follows:

Black Bears:

Of the black bears encountered 15 of 27 (55%) were startled by the MTB. The majority of encounters 12 of 27 (44%) resulted in the bear running for cover without stopping; 3 of 27 (11%) ran a distance then stopped and looked back at the MTB rider; 10 of 27 (37%) had no reaction and only 1 of 27 (3%) acted aggressively in reaction to being chased by the MTB rider's dog.

Grizzly Bears:

Of the grizzly bears encountered, 11 of 13 (85%) were startled by the MTB; 2 of 13 (15%) ran to cover without stopping; 3 of 13 (22%) ran a distance then stopped to look back; 5 of 13 (38%) advanced on the rider including 2 charges. Of the two bears that charged and one that advanced on the riders, 3 of 5 (60%) were females with cubs.

Discussion

Many of the results compiled in this survey are consistent with past studies on bear behaviour and reaction to human presence. This is particularly true with regard to effects of the number of individuals in a party. The high percentage 67% (21 of 31) of bears being startled by riding parties of 2 or less is consistent with Jope 1985 and Herrero 1985 and follows the commonly held belief that more individuals in a riding or hiking group reduces the chances of startling a bear.

One of the most serious implications of the study relates to the high number of riders that are coming dangerously close to bears before either of them become aware of each other. 35 of 41 (84%) of riders indicated that they came closer than 50 metres to the bear. 50 metres is considered the distance at which a bear may respond with a fight or flight response. This response is conditional on many environmental variables such as: foliage, trail conditions, existence of cubs, food resources and the availability of escape routes. 32 of 41 (78%) of the encounters occurred in open areas indicating that escape routes were available and taken advantage of by the bears. However, if these subtle environmental variables were altered, a fight response could become a more prominent response of bears, especially grizzlies.

These results also indicate that the bears are not being sufficiently warned of the human presence and do not have the opportunity to avoid contact. This is evident when the data for startled bears is cross-referenced with riders that got within 50 metres. 21 of 31 (66%) of these bears were startled by the MTB. This is especially true of the encounters with grizzly bears where 11 of 13 (85%) were startled by the MTB.

The majority of encounters took place while the rider was travelling on flat terrain which has been argued in this project as a trail condition that could limit the effectiveness of deterrents such as bear bells and reduces the amount of ambient noise produced by the MTB (See Appendix B).

The results with regard to the design questions also yielded interesting results. 78% (32 of 41) of the surveyed riders indicated that the thought of a bear encounter enters their minds on MTB rides. However, 19 of 41 (46%) said that they use no form of deterrent. The majority of riders 22 of 31 (71%) indicate that current bear deterrents are to irritating on account of their noise. Among those surveyed only 3 of 31 (10%) thought a deterrent was not needed and 6 of 31 (19%) thought that current deterrents were ineffective. These responses indicate that the majority of MTB riders believe that deterrents can offer some measure of protection. However, such products are being rejected. Given the choice of current deterrents and using nothing, people are opting for nothing, thus increasing the chances of a sudden encounter with a bear. The survey questions with regard to possible features of a new deterrent found that non-obtrusive, portable design and hands free operation were the most valued features. These results are consistent with MTB riders' rejection of current products. A hands free design will reduce the mental and physical requirements of operating and attending to a deterrent and a portable design will eliminate bulk and increase usage of the product. The non-obtrusive aspect of the design would eliminate the MTB community greatest concern of sound irritation.

When questioned on performance variables, effectiveness, weight, and price were of greatest concern. These results are consistent with regard to other products related to the activity of cycling.

The overall results of the survey have helped confirm a number of assumptions and theories with regard to the project. It is apparent that current bear deterrents are not effective with regard to the mountain biking for two significant reasons:

1. They are not warning the bears of a rider's presence within the crucial 50 metre distance. As a result riders are startling bears and eliciting a fight or flight response.

2. Current deterrents are being avoided and rejected on the basis of their irritating noise.

The issues brought to light by this survey facilitates in the illustration of the need for exploration into possible design changes with regard to bear deterrents aimed at mountain bikers.

Appendix F: Zoo Study: Ultrasonic Hearing of Bears

An attempt was made to partially repeat the study conducted by Greene, An Application of Behavioural Technology to the Problem of Nuisance Bears, 1982. This study indicated that grizzly and black bears are capable of hearing ultrasonic sound. The Calgary Zoo allowed me access to the black bear enclosure which contained three adult black bears. I was given access to a cat walk structure surrounding the encloser which afforded me an unobstructed view of the bears. Tests were not conducted on the Zoo's grizzly bears on account of their recent move to another enclosure and subsequent agitation.

Apparatus:

- Motorola piezo electric speaker model # F114
- Frequency Generator (maximum. output of 1 volt)
- 2 tripods
- JVC Video Camera
- Silver Foot Bear Bell
- B& K Sound Meter

Procedure:

The piezo electric speaker was set up at one end of the enclosure. With the use of a tripod the speaker was elevated and directed into the encloser. The frequency generator and camera were set up at the opposite end of the enclosure. Through the help of an assistant each bear was identified and watched for any reaction to the presentation of varying acoustical stimuli.

The bears were presented with an initial sound pulse of 30 kHz for a period of 10 seconds, such a high frequency was assumed to be well beyond the hearing limits of the bears. The bears were then presented with a descending frequency pulse with the hope of isolating their upper hearing limits.

Results:

The results of the earlier study conducted by Greene, 1982 were not reproduced. As the bears were exposed to lower and lower frequency noise the bears elicited no physical reactions that could be associated with hearing the test signal. This was the case for all ultrasonic sounds emitted (21+kHz at 99 dB) as well as audible sounds (3000 Hz at 102 dB), bear bells (80 dB) and shouting (72 dB).

Discussion:

The results of this study are inconclusive with regards to the ability of bears to hear ultrasonic sound. In fact the results are inconclusive with regard to bears ability it hear at all. However, it must be remembered that the test bears where Zoo animals and can be assumed to have become heavily jaded to many forms of man made noise including ultrasonic ones. The study indicates that proper results can only be achieved through more complex research methodologies with regard to these particular black bears.

Appendix G. Methods of Ultrasound Production

Natural:

As mentioned in Appendix C there are very few natural sources of ultrasonic sound. The restling of leaves, some wind noise, walking on loose gravel and some nasal fluctuations in humans can produce very high frequency noise (Hopp, Owren & Evans, 1997).

Animal / Insect:

The investigation of ultrasound pertaining to animals remains experimental. It is recognized that many animals are known to use ultrasonic sound for communication, defence and hunting.

Bats:

Early in 1794 the ability of bats to use sound to find prey was proposed by Lazzaro Spallanzani, but it was not until 1920 that any further research was conducted on bats. After extensive research, bats have been found to navigate and hunt almost exclusively through the use of ultrasound. Small bats can fly at full speed through barriers of vertical wires only 0.4 mm in diameter and spaced only one wing span apart. They can catch small insects such as mosquitoes at a rate of one every ten seconds. They use frequencies as low as 50 Hz all the way up to 90 kHz for localizing prey. Some bats have been recorded producing ultrasonic cries up to 190 dB; with the right equipment they can be heard over 100 metres away (Griffin, D.,1974).

Moths:

Just as bats use ultrasound to detect prey, one of their prime targets, the moth, uses it for self defence. The moth's sound organs are tuned to the very high frequency cries of the bat and can detect when a bat has located it in flight as far as 100 feet away (Ensminger, D.,1973).

Other insects such as crickets, locusts and grasshoppers produce ultrasonic songs as high as 45 - 60 kHz (Sales & Pye, 1974).

Rodents:

Many members of the rodent family produce ultrasonic squeaks and cries. Infant mice and rats will produce cries ranging in frequency from 45- 88 kHz used as a signal of distress usually brought on by cold or hunger. Adult rats will often emit ultrasound during aggressive behaviour ranging from 25- 45 kHz (Sales & Pye, 1974).

Porpoises:

Porpoises or dolphins use ultrasound much like bats. Their ability to echo locate obstacles and food is highly sophisticated. Their characteristic clicks and whistles can be produced hundreds of times per second and reach frequencies of 170 kHz. As is true of bats, their echo location appears to be unaffected by jamming or interfering noise. Even broadcasting recordings of their own signals fails to disturb them (Ensminger, D., 1973).

Birds:

At least two families of birds, Steatornis and Collocalia, are echo locators using lower frequencies of around 6-10 kHz. Many bird songs contain frequencies as high as 50 kHz (Stebbins, W., 1983).

Man-made:

The propagation of ultrasonic sound by the hands of man is numerous. Almost any piece of machinery will produce some ultrasound output. Bearing noise, the humming of transformers, fluorescent lights, computers, even the jingling of keys will all emit ultrasound. However, the intended production of ultrasonic energy is limited to only a few methods.

Mechanical Generators:

Ultrasonic waves can be produced by the means of extremely small tuning forks. These forks have prongs only a few millimetres long and are capable of frequencies of 90 kHz. The waves produced in this way are strongly dampened and of such small energy that they are of no practical use.

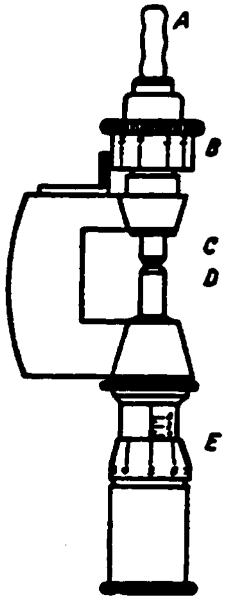


Fig. A 4.1 Galton Whistle

Pneumatic:

The Galton Whistle (Figure A 4.1) produces ultrasonic sound up to 100 kHz using compressed air. Such whistles were used extensively in the early days of ultrasonic research and can still be found in some labs and in the field. However, every whistle is very prone to fluctuations in output due to changes in temperature, humidity and pressure changes, and prone to obstructions from dirt and other foreign particles (Bergmann, L., 1938 ; Ensminger, D., 1973).

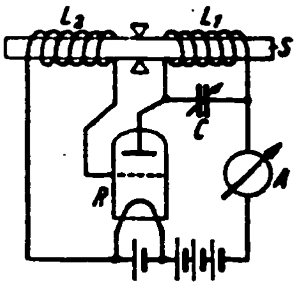


Fig. A 4.2 Magnetostriction

Magnetostriction Generator:

These generators exploit the characteristic of magnetic material to change shape when the applied magnetic field is varied in strength, see Figure A 4.2. The physical length of the material will change and can be made to oscillate at very high frequencies and produce ultrasonic sound waves. These types of transducers are relatively heavy on account of the magnetic material and coils involved in their production and the magnetic material is subject to loss of its magnetic capabilities (Ensminger, D., 1973).

Dynamic Tweeter:

A dynamic tweeter (or loud speaker) is the most common form of generator of sound and is common in home, concert and car stereo systems. Until recently such speakers have not been capable of producing ultrasonic sound. However, units available from the audio manufacturer JBL produce speakers using a traditional magnetic yoke and the addition of a titanium diaphragm are capable of producing very high frequency sound. Unfortunately, their significant weight and price make them inappropriate for this project.

Piezo Electric:

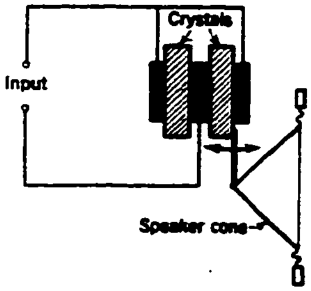


Fig. A 4.3 Piezo Electric Specker

Of the different possible means to produce ultrasound the most common and practical is through the use of quartz crystals. The quartz crystal has the property of expanding and relaxing when a voltage is applied to it, which in turn can be used to send out ultrasonic sound waves. "From every point of view, durability, economy, ease of manufacture, and simplicity the quartz crystal is the most desirable of all the types of generating units that may be chosen for ultrasonic work" (Carlin, B.,1947). Even today, the piezo speaker is the most common and cost effective means of producing ultrasonic sound. At present almost all of the world's production of quality piezo elements is supplied by Motorola.

Further advantages of piezo units include their small size and light weight. Most commercially available piezo electric units range in weight from 1 to 60 grams and range in size from 5 mm to 26 mm with a 25 mm thickness. They have an astonishingly wide output range and actually become more efficient the closer they are run to their maximum frequency output (Harris, C., 1991).

Although all of the means of producing ultrasonic sound were considered for this project, piezo electric technology offered the best characteristics in terms of sound production and physical scale. As a result, the incorporation of a piezo driver for the production of ultrasonic sound for use in a BWD became the technology of choice for this project.

Appendix H. Studies Conducted at the University of Alberta's Acoustics Lab

The acoustic investigation of Bear Warning Devices (BWD) was extremely difficult especially with regard to the investigation of ultrasonic sound. The equipment required is debilitatingly expensive and rare. The University of Alberta, however, contains a full acoustics lab including a large Anacohic Chamber, assorted measuring instruments and microphones capable of measuring ultrasonic sound. The following is a series of studies conducted using the U of A's Lab with the assistance of the lab director, Gerald Kiss.

Study #1 Sound Signatures of Three Related Products

The purpose of this study was to determine the sound signature of several noise making devices that could possibly be used, or are being used as a BWD.

1. Bear Bells- The bells that have been used throughout the project were tested.

2. Ultrasonic Dog Whistle- Because bears are closely related to dogs they may share many of the dogs' sensory abilities. Thus, the ultrasonic whistle was tested to approximate an appropriate ultrasonic frequency.

3. Alpine Whistle- During explorations of current BWD's, the Alpine Whistle was suggested by many outdoor equipment retailers as a suitable BWD device.

Procedure:

All three products were tested inside the anacohic chamber. Each product was activated by myself two times. During the first activation the lab director calibrated the instruments and on the second, recorded the corresponding frequency plot.

Results and Discussion:

Bear Bells:

The traditional bear bell emits a wide spectrum of frequencies. As Figure A 5.1 indicates, the sound signature of a bear bell range from 2100 Hz all the way up to 28 kHz. The average dB of a bell being vigorously shaken was 80 dB. The inclusion of large numbers of frequency spikes in the ultrasonic range along with their sizeable dB output was very unexpected. With such large portions of the bell's signature being ultrasound it can be speculated that bears that have been exposed to bear bells have also been exposed to ultrasonic noise.

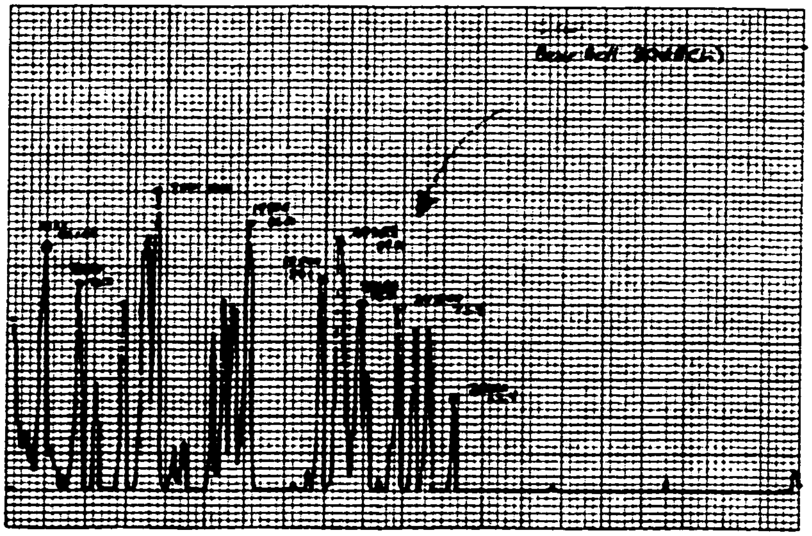


Fig. A 5.1 Sound Spectrum of a Bear Bell

As stated in Chapter 3, some bears have come to associate the sound of bear bells with the presence of humans. The results of this study may further indicate that they have come to associate the presence of humans with the emission of ultrasonic sound, thus giving further evidence that the use of ultrasonic sound could be used as a practical BWD.

Ultrasonic Dog Whistle:

As Figure A 5.2 illustrates the dog whistle has two primary frequency spikes, at 11 kHz and again at 22 kHz with a combined dB of 87. The 11 kHz spike corresponds to the noise of the air rushing out of the whistle body giving off a sound much like that of air through a constricted drinking straw.

The second spike is a strong ultrasonic one at 22 kHz. Such a frequency is out of the hearing range of the majority of humans, and is easily attainable through the use of piezo electic speakers. This study gives good indication to what frequency an ultrasonic BWD should initially be designed to emit.

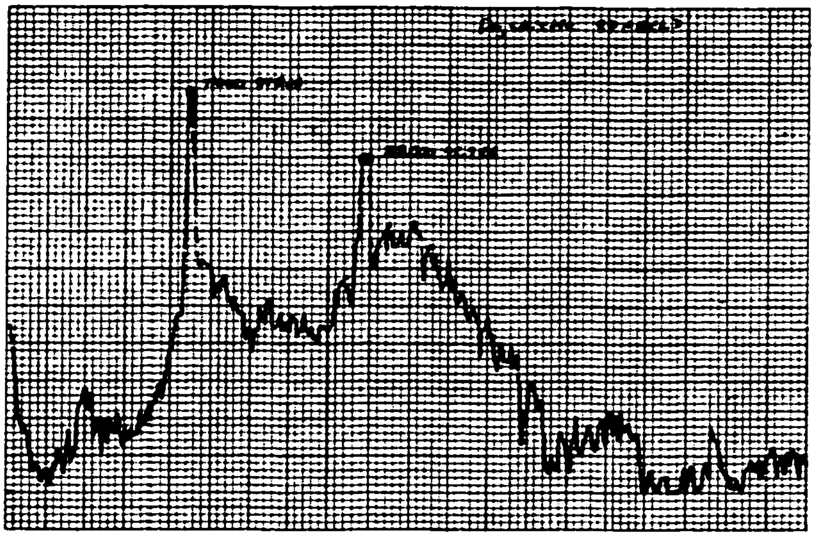


Fig. A 5.2 Sound Spectrum of an Ultrasonic Dog Whistle

Alpine Whistle:

The alpine whistle's sound signature is maximized within the audible range between 3600 and 4500 kHz with only a minor spike farther up the frequency range (Figure A 5.3 The maximum output of the whistle was 102 dB. The whistles high dB and frequency output make it an excellent device for alerting humans and animals. However, its loud ear piercing sound does little to address the problems of BWD's being rejected on account of intrusive noise.

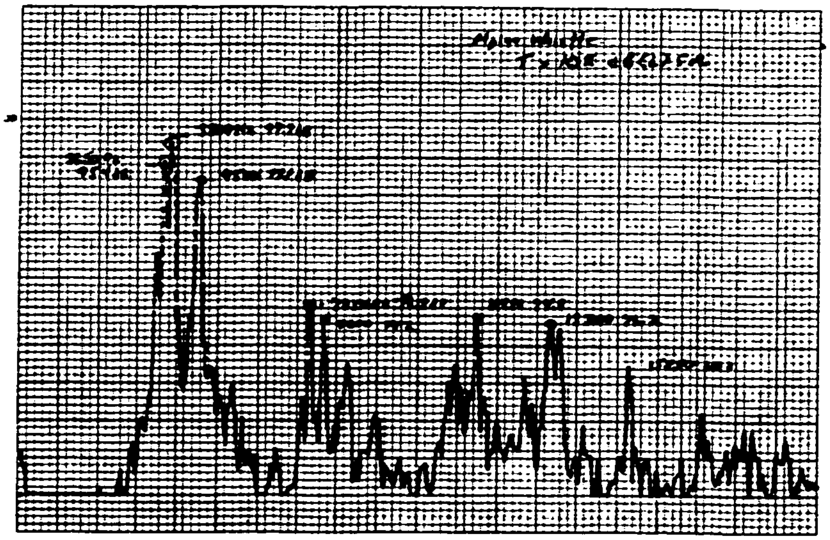


Fig. A 5.3 Sound Spectrum of an Alpine Whistle

Study #2 Decibel Output of Ultrasonic Test Unit with Regard to Volts

Based on the results of field studies #2 and #3 any proposed ultrasonic BWD must produce a sound pulse of sizable dB. At present a pulse of 115-120 dB is dimmed appropriate (See Chapter 5 for further details). Using the test unit consisting of a Motorola piezo electic speaker and a frequency generator, the volts required to generate such a decibel pulse at 21 kHz was determined.

Procedure:

The speaker was placed into the anacohic chamber and increasing amounts of power was supplied to the speaker. At each increment the voltage was recorded along with the corresponding dB output of the speaker. The sound output (amplitude) of the speaker was recorded as a Peak to Peak measurement.

Results:

Voltage to dB output at 21 kHz

Volts	dB
.238	85.7
.523	91.9
.624	93.4
.777	95.3
.878	96.3
.941	96.9
1.01	97.5

Using the equation dB=20 Log (V/V ref)
With V ref being established as 0.0000145
The test unit would produce a sound emission of 118 dB at a frequency of 21 kHz at a voltage of 12 v.

Discussion:

In order to attain a sound emission with a suitable dB the test unit would require 12 volts of power at the speaker. Such a power supply would produce a sound emission of 118 dB. It must be remembered that these figures only correspond to the Motorola speaker used for these tests. This speaker was sourced through an extensive but not exhaustive search of existing piezo electric speakers. Furthermore, the results may not correspond to possible future peizo units designed specifically for use as a BWD.

Study #3 Effects of Different Horn Lengths on the dB Output of the Test Unit

In the realm of audible acoustics the addition of a directional horn onto a speaker can at times increase the output by as much as 20 %. The literature on horn design is extensive and complex; however, very little information was found with regard to the effects of horns on ultrasonic emitters. As a result three different horns were tried and tested for their effects on sound output. Through literature review and discussion with sound experts three horns were produced with mounting attachments to fit the Motorola test speaker. Because ultrasonic sound is very unidirectional and has such a short wavelength the horns took the form of wave guides (long tubes). The hope was that the wave guides would further contain the ultrasonic sound and perhaps increase the dB output.

Apparatus:

- B & K 1/4 inch microphone

- sound chamber

- assorted acoustical equipment

- Guide #1- Consisted of a PVC pipe of the same diameter as the motorola speaker throat. 20 mm by 60 mm. The guide was connected to the speaker with duct tape.

- Guide #2- Consisted of a copper tube 10 mm wide by 60 mm. The guide was connected to the speaker with the use of an MDF adaptor.

- Guide #3- Consisted of a aluminium tube 5 mm wide by 60 mm. The guide was connected to the speaker with the use of an MDF adaptor.

- Speaker alone- The speaker was also tested with no horn.

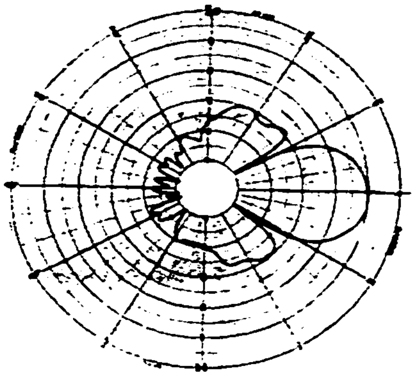
Procedure:

The test speaker was placed inside the anibolic chamber on a remote turntable that would turn the speaker through 360 degrees. A Microphone was placed 1 metre away. Each horn and the speaker alone was than tested at 21 kHz and polar plots of the units output in dB was recorded.

Results:

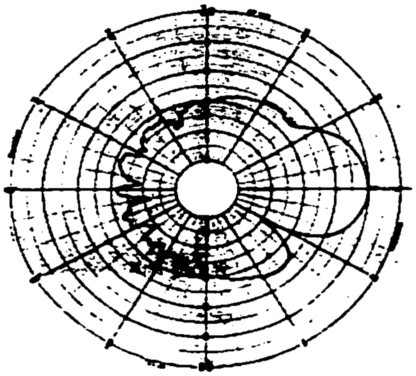
The following are polar plots of the speaker and different horns. At the 0 degree the speaker is facing directly at the microphone and at 180 degrees it is facing opposite to the microphone. All plots were done at 21 kHz. The reasoning for the design of the guides steams from the research done on audible horns that predicts that as the throat size of the horn decreases in comparison to the sounds wavelength, the dB output will go up, within limits (Smith, B. 1971 ; Newitt, J. 1953).

Speaker Alone: Figure A 5.4 Speaker Polar Plot



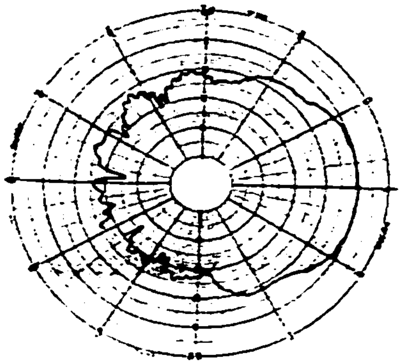
The very directional nature of ultrasonic sound is apparent in this plot. With an output of 99 dB.

Guide #1: Figure A 5.5 Guide #1 Polar Plot



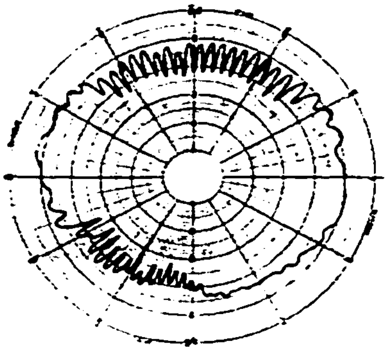
Guide #1 Changes the sound direction by increasing the output to the sides and back. Maximum output dropped to 96.7 dB.

Guide #2: Figure A 5.6



Dispersion of the sound has increased dramatically and the maximum output has dropped to 73.8 dB.

Guide #3:Figure A 5.7 Guide #3 Polar Plot



Dispersion has become almost equal in all directions and maximum output has dropped to 70.6 dB.

Discussion:

The results indicate that the wave guides had a detrimental effect on the performance of the speaker. It was hope that the directional nature of ultrasonic sound could be strengthened by the guides and result in a louder sound however, the speaker with no guide performed the best. In effect the guides were causing sound resonance, keeping the sound within the unit and causing the entire unit to vibrate. Upon further discussion with experts it was established that no horn design would increase the output of the ultrasonic sound and that the shortest length of guide feasible would result in the best performance.

Study # 4 Attenuation of Ultrasonic Sound: A Test of the General Equation of Attenuation

In general audible sound, attenuation caused by the atmosphere corresponds with a 6 dB reduction in the strength of the sound per distance doubled from the sound source. Such a relationship enables the estimation of a sound's strength at specific distances away from the source. This study was conducted to determine if a sound of 21 kHz would follow this general rule.

Apparatus:

- B&K 1/4 inch microphone
- Motorola piezo electric speaker
- assorted acoustical equipment
- sound chamber

Procedure:

The speaker was set up with, in the anibolic chamber and directed towards the microphone and placed at a corresponding height to the speaker. A 21 kHz pulse was emitted by the speaker and sound levels were recorded. The distance between the speaker and microphone was than doubled until restricted by the dimensions of the chamber.

Results:

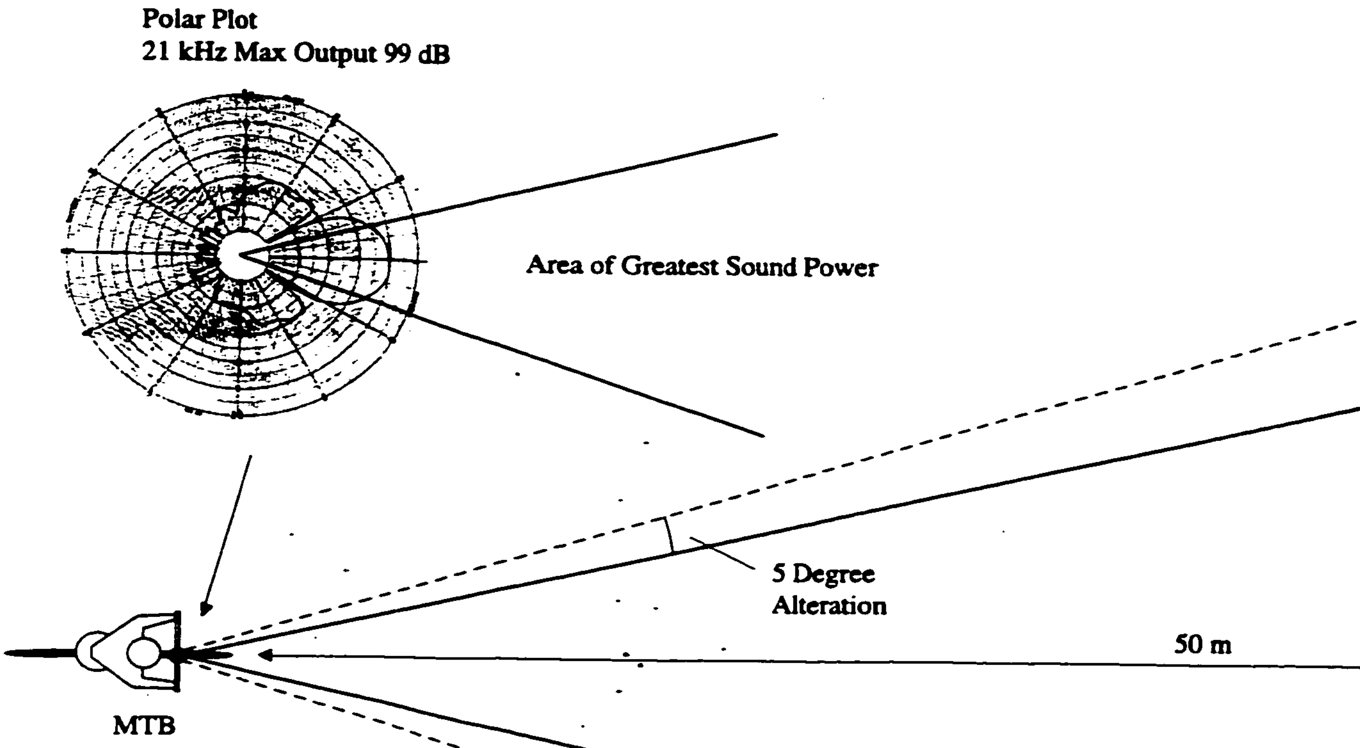
	Microphone Distance	dB Level
1	10 cm	117.2
2	20 cm	111.2
3	40 cm	104.7
4	80 cm	98.6
5	160 cm	92.

Trial 1-2= 6.0 dB
Trail 2-3= 5.8 dB
Trial 3-4= 6.2 dB
Trail 4-5= 6.2 dB

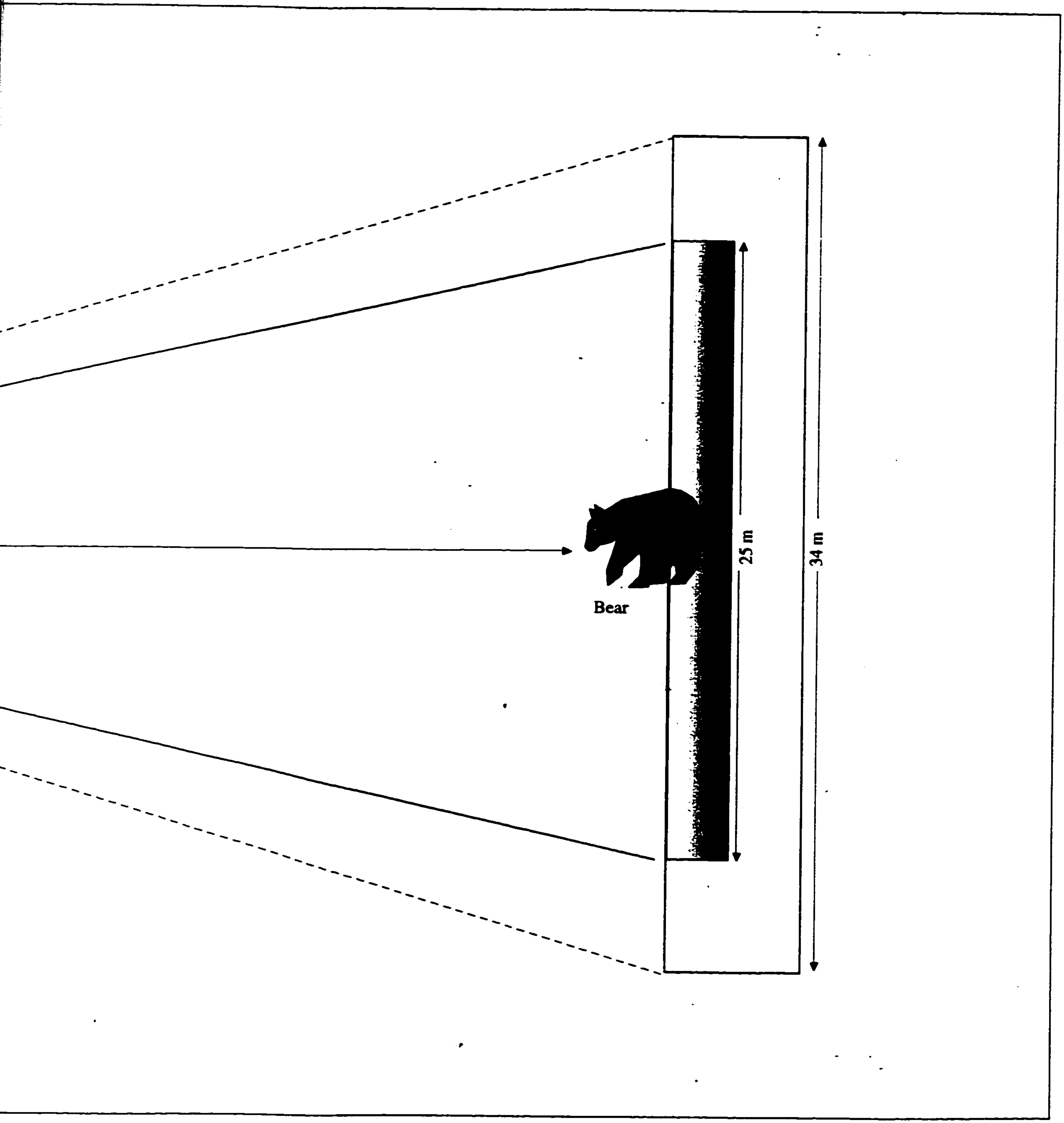
Discussion:

The data indicates that the sound attenuation of a 21 kHz pulse within the confines of the anibolic chamber corresponds to the general equation of attenuation. Through this test and conversations with acoustical experts I believe that the attenuation rule of 6 dB of sound reduction per distance doubled can be used with regard to a 21 kHz sound pulse through to the working distance of 50 metres in this project.

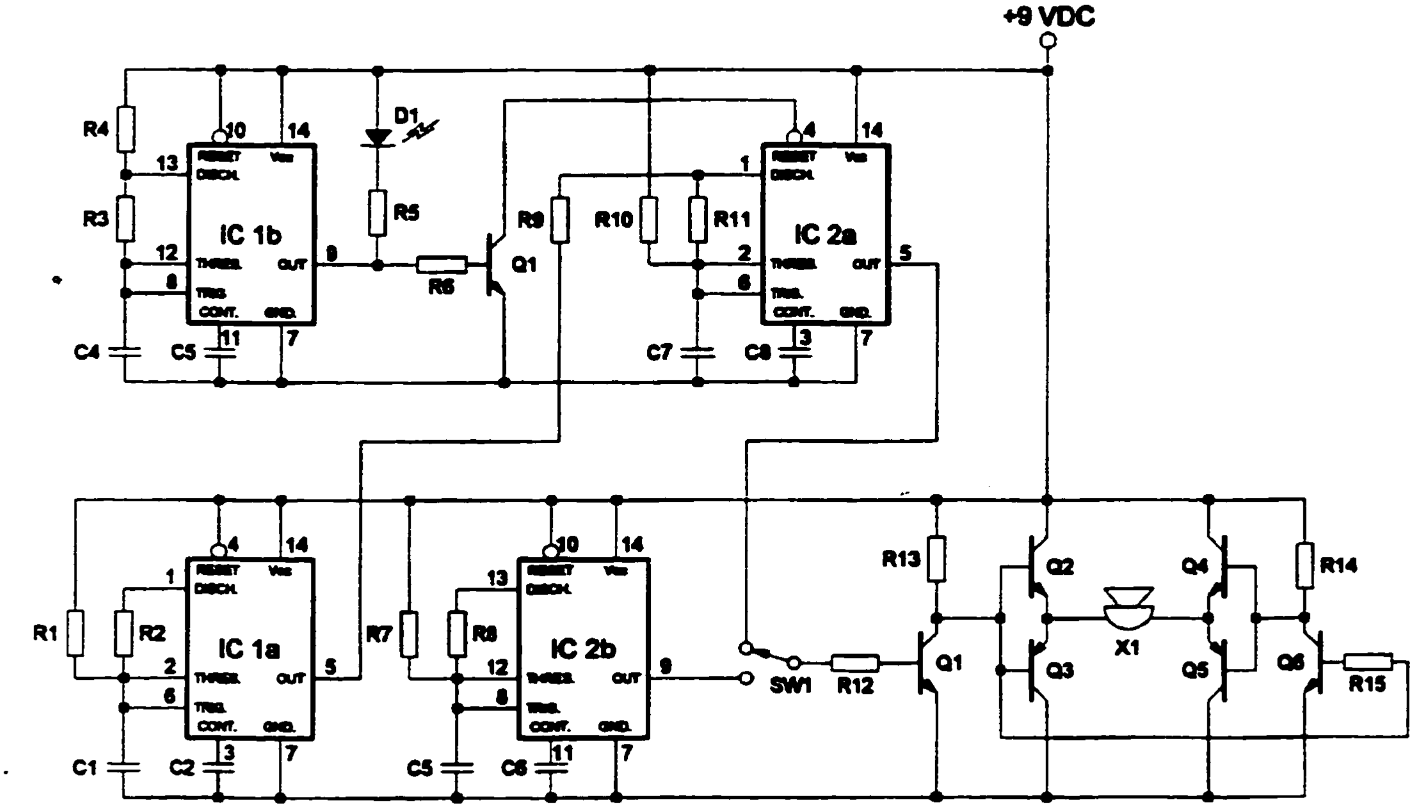
Appendix I. Sound Envelope



Note: Graphics of Mountain Bike
and Bear are not to Scale


Bear
25 m
34 m

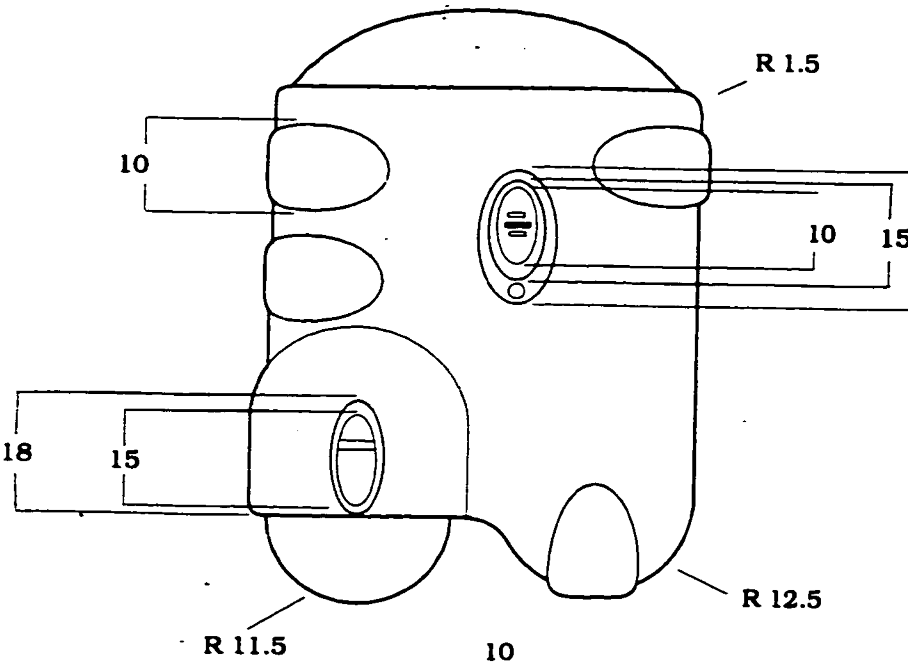
Appendix J. Circuit and Parts List

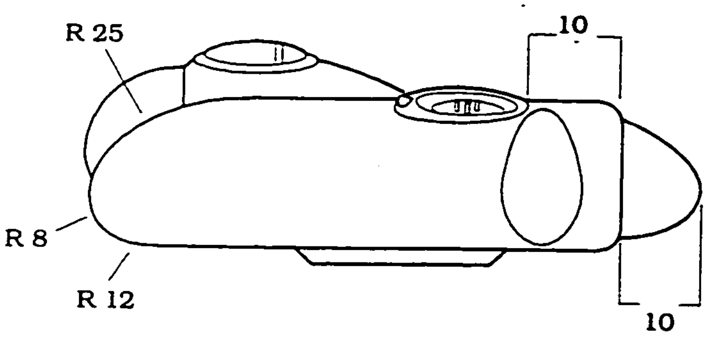


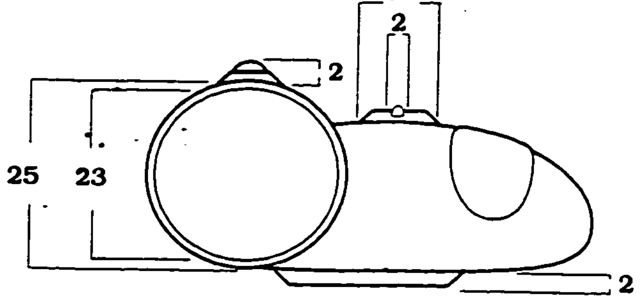
Parts List

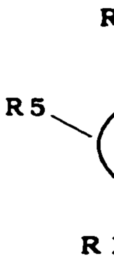
C1	15 µf / 15 volt electrolytic capacitor
C2	0.01 µf capacitor
C3	47 µf / 15 volt electrolytic capacitor
C4	0.01 µf capacitor
C5	0.015 µf capacitor
C6	0.01 µf capacitor
C7	0.0075 µf capacitor
C8	0.01 µf capacitor
C9	10 µf / 15 volt electrolytic capacitor
D1	Light Emitting Diode
IC1	TLC556CN Dual CMOS Timer
IC2	TLC556CN Dual CMOS Timer
R1	51 kΩ resistor
R2	22 kΩ resistor
R3	91 kΩ resistor
R4	120 kΩ resistor
R5	270 Ω resistor
R6	8.2 Ω resistor
R7	51 kΩ resistor
R8	22 kΩ resistor
R9	47 kΩ resistor
R10	5.1 kΩ resistor
R11	2.2 kΩ resistor
R12	2.2 kΩ resistor
R13	270 Ω resistor
SW1	SPDT Momentary Contact Switch
T1	2N2222 Transistor
T2	MJE 510 Transistor
T3	MJE 370 Transistor
X1	Audio High Frequency Transducer
Q1	2N4401
Q2	MJE 520
Q3	MJE 370
Q4	MJE 520
Q5	MJE 370
Q6	2N4401

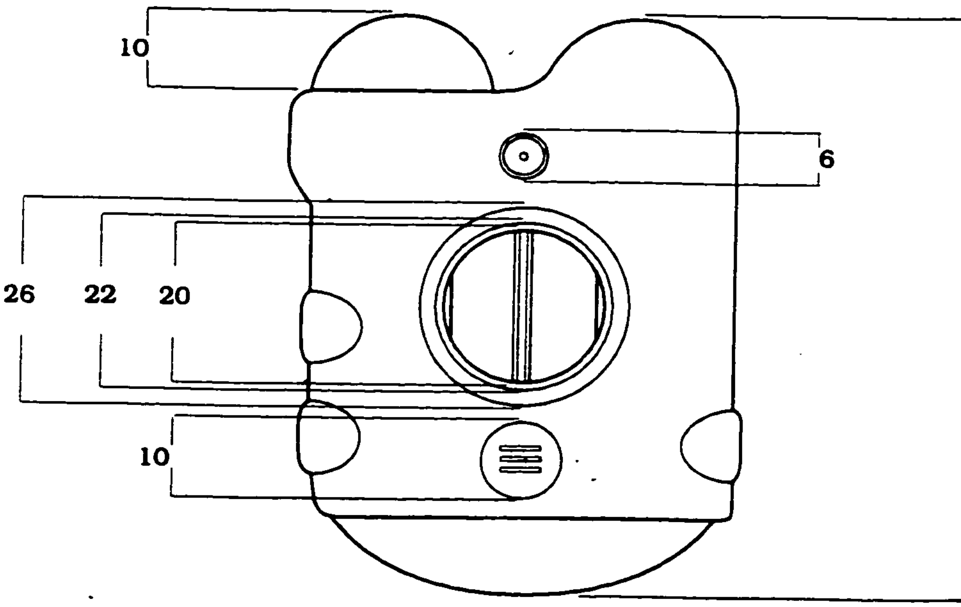
Appendix K. BWD General Assembly

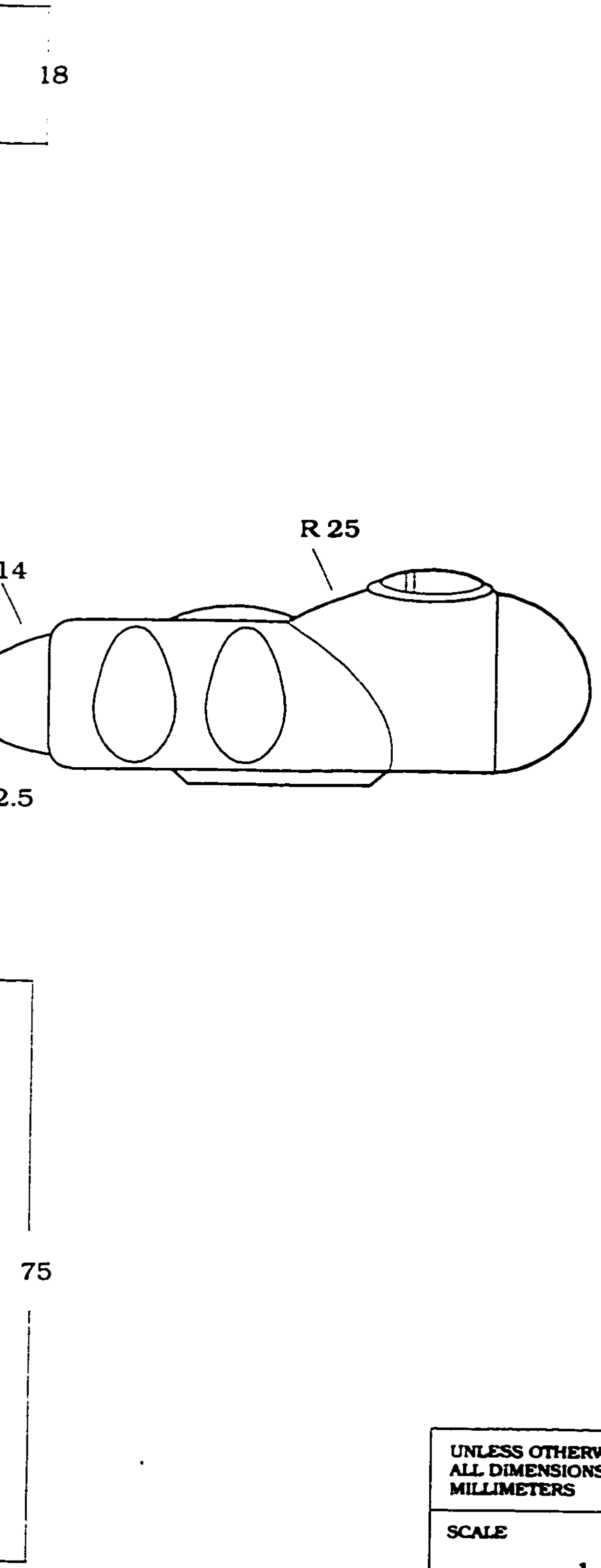


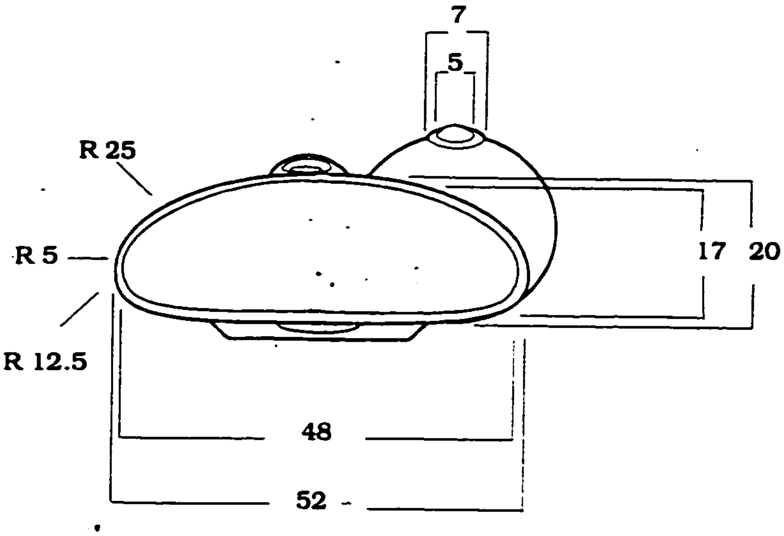






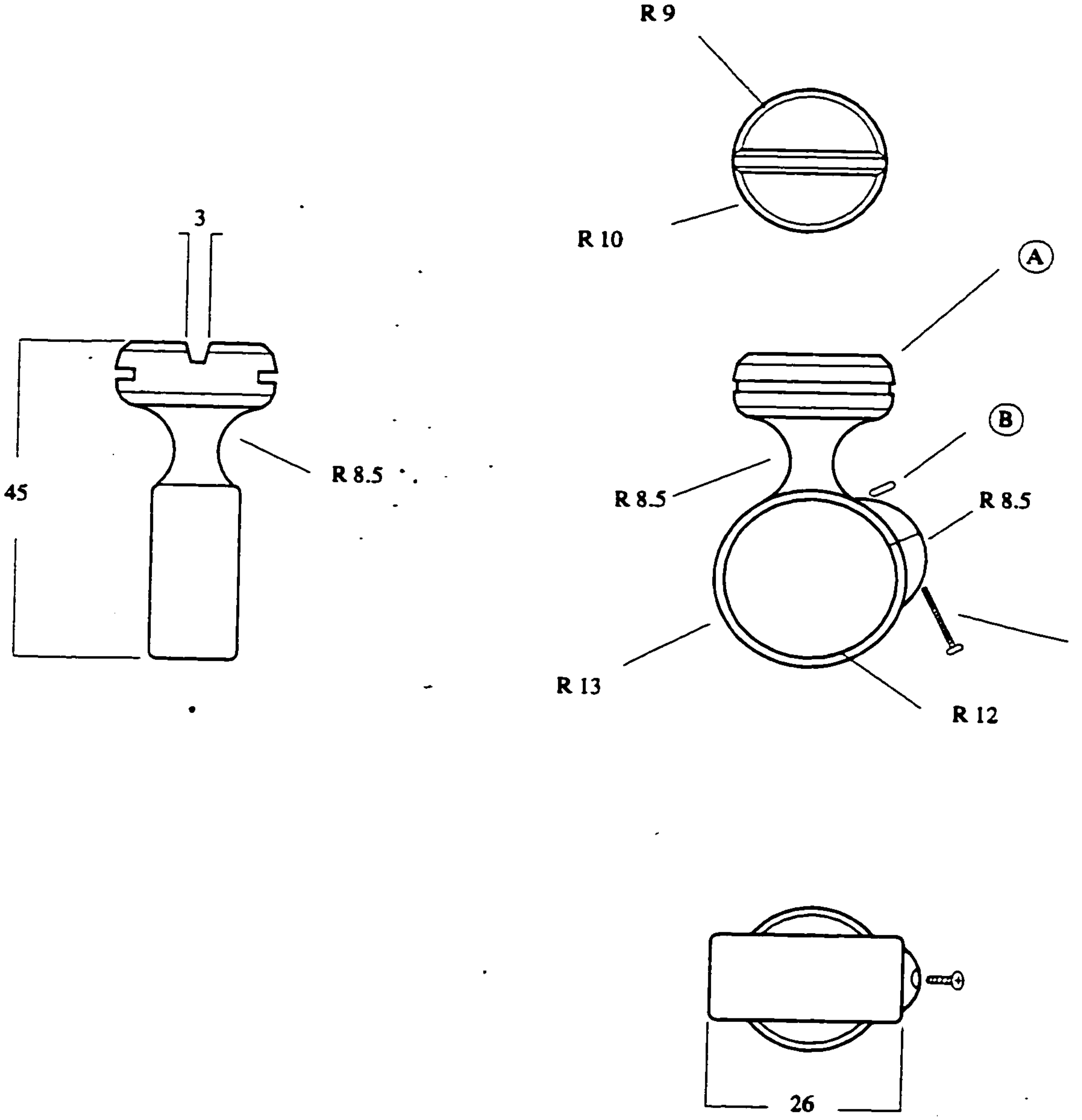


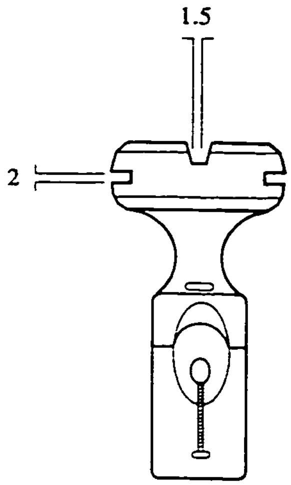




UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN MILLIMETERS	DRAWN M.SCHMOR	DATE FEBUARY 24, 1999	MATHEW SCHMOR
SCALE 1:1	CHECKED		MDP PROJECT
			GENERAL ASSEMBLY
DO NOT SCALE DRAWING	DWG. NO. MDP 1		ULTRASONIC BEAR WARNING DEVICE

Appendix L. General Assembly of MTB Mount





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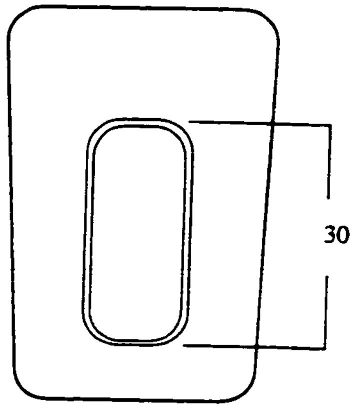
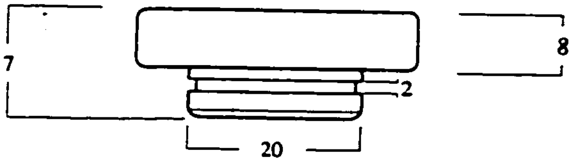
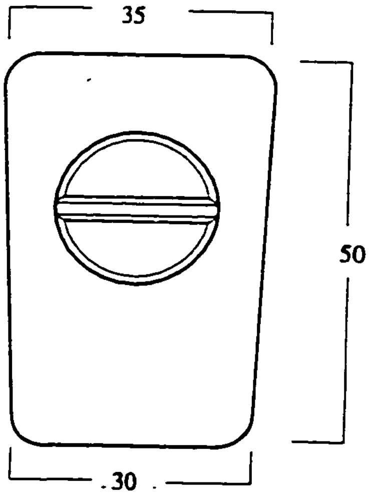
PARTS LIST			
Item	Description	#	Specifications
A	Mountain Bike Mount	1	One-Piece Design: ABS Injection Moulded
B	Nut	1	Stainless Steel
C	Phillips Screw	1	Stainless Steel

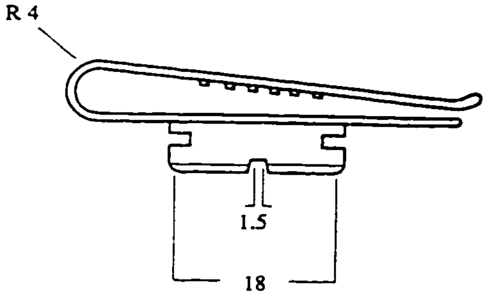
UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN MILLIMETERS	DRAWN -M.SCHMOR	DATE FEBUARY 24, 1999	MATHEW SCHMOR
SCALE 1:1	CHECKED		MDP PROJECT GENERAL ASSEMBLY
DO NOT SCALE DRAWING	DWG. NO. MDP 2		ULTRASONIC BEAR WARNING DEVICE

Appendix M. Hiker Mount General Assembly





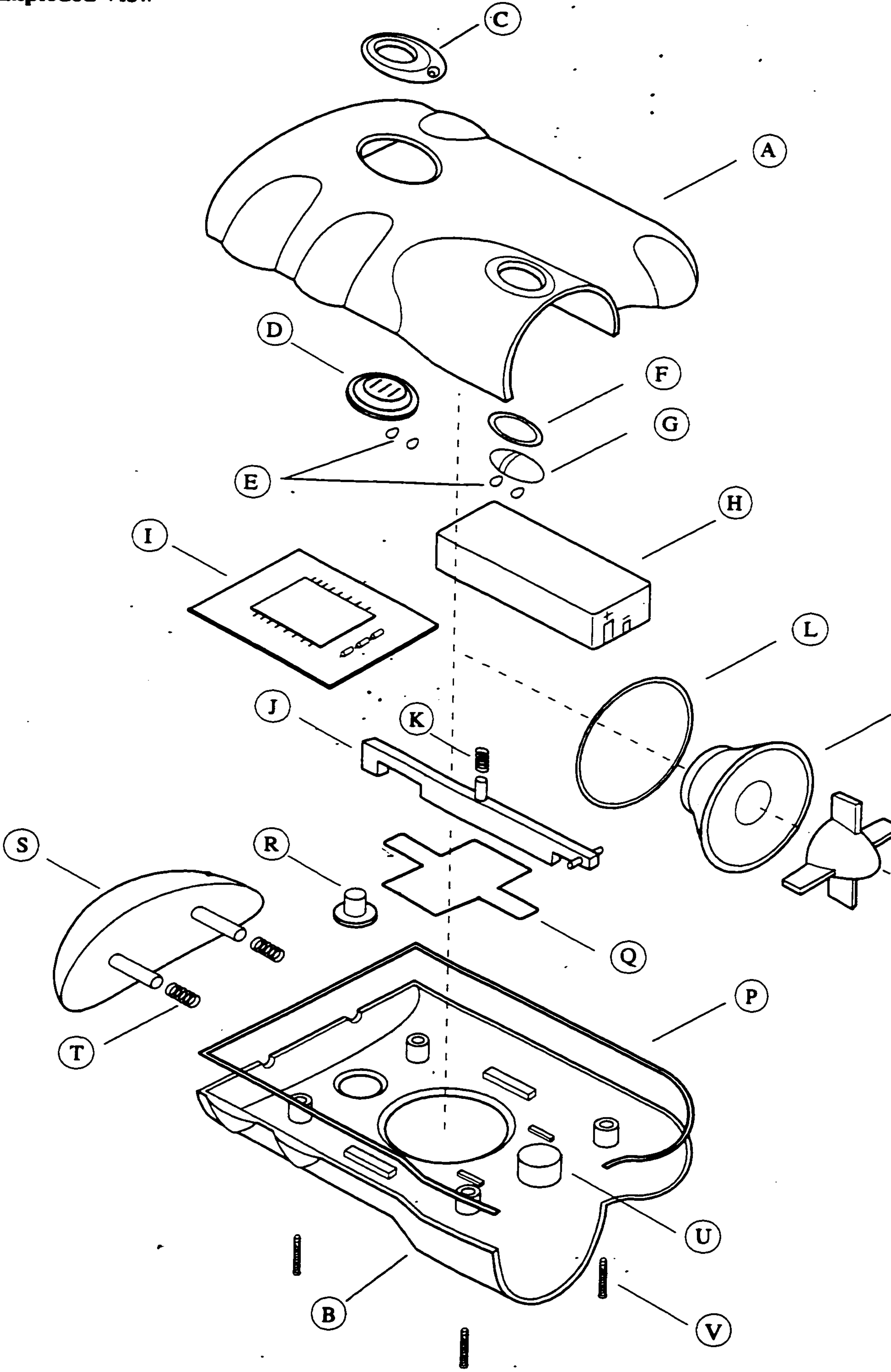


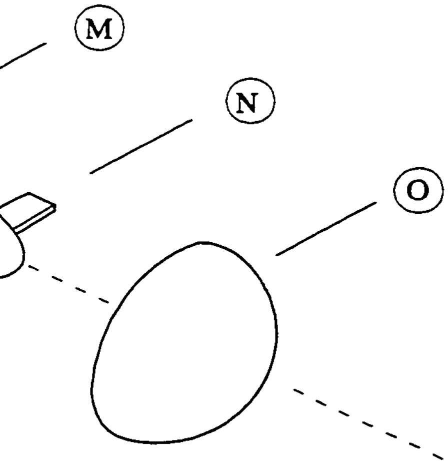


PARTS LIST			
Item	Description	#	Specifications
A	Belt Clip Mount	1	One-Piece Design: ABS Injection Moulded

UNLESS OTHERWISE SPECIFIED ALL DIMENSIONS ARE IN MILLIMETERS	DRAWN M.SCHMOR	DATE March 26, 1999	MATHEW SCHMOR
SCALE 1:1	CHECKED		MDP PROJECT
			GENERAL ASSEMBLY
DO NOT SCALE DRAWING	DWG. NO. MDP 3		BELT CLIP for ULTRASONIC BWD

Appendix N. BWD Exploded View

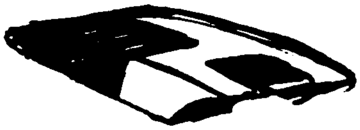


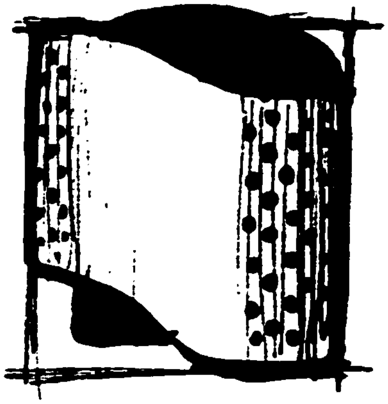


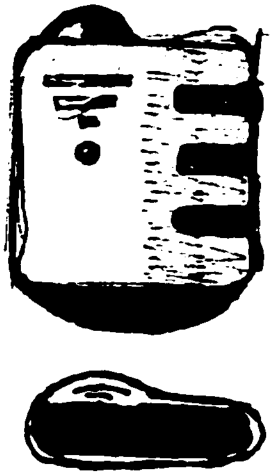
PARTS LIST			
Item	Description	#	Specifications
A	Upper Casing	1	Injection Moulded ABS Double Shot Santoprene
B	Lower Casing	1	Injection Moulded Abs Double Shot Santoprene
C	Operation Lens	1	Injection Moulded Acrylic
D	On/Off Button	1	Injection Moulded Elastomer
E	Operation Lights	4	L.E.D Lights
F	Rubber Seal	1	Eliptical Seal
G	Operation Lens	1	Injection Moulded Acrylic
H	Battery	1	9 Volt NiMH Rechargable
I	Processor	1	16 Pin Dedicated Microprocessor
J	Stabilization Blade	1	Injection Moulded ABS
K	Spring	1	Stainless Steel
L	O-Ring Seal	1	Rubber Seal
M	Transducer	1	Piezo-electric Waterproof Diaphram
N	Phaze Plug	1	Injection Moulded ABS
O	Transducer Cover	1	High Grade Acoustic Mesh
P	Rubber Seal	1	Flat Rubber Seal
Q	Retention Pin	1	Stainless Steel
R	Release Button	1	Injection Moulded ABS
S	Emergency Button	1	Injection Moulded ABS Double Shot Santoprene
T	Spring	2	Stainless Steel
U	Recharge Plug	1	110 Volt/9 Volt Recharger Unit
V	Assembly Screws	4	Stainless Steel Screws

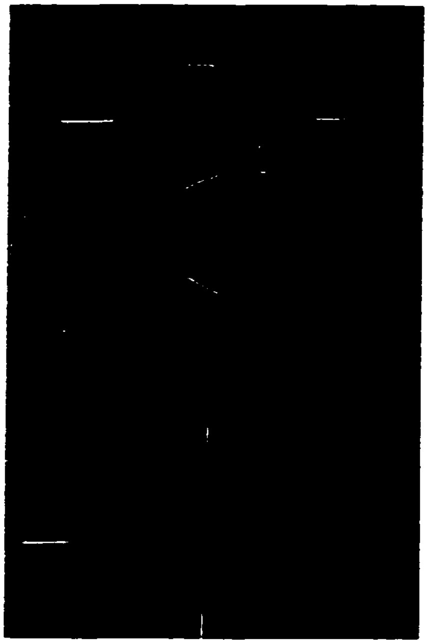
EXPLODED ISOMETRIC NOT TO SCALE	DRAWN M.SCHMOR	DATE March 24, 1999	MATHEW SCHMOR
	CHECKED		MDP PROJECT
			EXPLODED VIEW
	DWG. NO.	MDP 4	MTB ULTRASONIC BEAR WARNING DEVICE

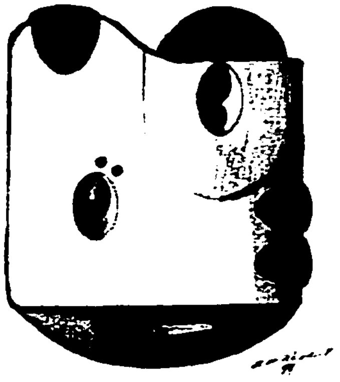
Appendix O. Further Design Sketches

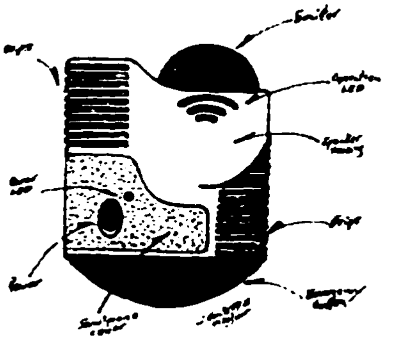












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