

ULTRASONIC COMMUNICATION

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October 23, 2025

RECOMMENDED CITATION

mohammad looti (2025). *ULTRASONIC COMMUNICATION*. PSYCHOLOGICAL SCALES.
Retrieved from <https://scales.arabpsychology.com/?p=53579>

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Primary Disciplinary Field(s): Bioacoustics, Zoology, Ethology, Sensory Ecology

1. Core Definition

Ultrasonic communication refers to the biological utilization of acoustic energy at frequencies that exceed the upper limit of the average human hearing range, which is typically considered to be 20 kilohertz (kHz). This specialized form of animal correspondence involves the production, transmission, and reception of high-frequency sounds, which often span from 20 kHz up to well over 100 kHz in certain species. Unlike infrasound, which involves frequencies below 20 Hz, ultrasound is characterized by short wavelengths, allowing for highly directional signaling and precise spatial resolution. This definition encompasses both active signaling (such as mating calls or alarm cries) and the sophisticated process of echolocation, which utilizes ultrasonic pulses for navigation and prey localization.

The principal advantage of employing such high frequencies lies in the ability to transmit information without alerting predators or competitors that rely on the lower frequency spectrum used by humans and many other mammals. Furthermore, the short wavelength of ultrasound enables the formation of narrow acoustic beams, which is crucial for precise targeting and environmental sensing. While the primary function identified in many highly evolved species, such as bats and dolphins, relates to navigation and foraging, ultrasonic signals are also fundamental for maintaining social cohesion, defining territory, and mediating reproductive behavior across a wide phylogenetic range.

2. Etymology and Historical Development

The term **ultrasound** itself derives from the Latin prefix *ultra-*, meaning "beyond," coupled with *sound*, indicating frequencies beyond the audible range. Although the general principles of acoustics have been studied for centuries, the specialized biological application of ultrasonic frequencies remained largely unknown until the mid-20th century. Early hypotheses regarding the navigation of certain nocturnal species, particularly bats, date back to the late 18th century, but the exact mechanism remained obscure until technological advancements allowed for the accurate detection and recording of these high-frequency pulses.

A pivotal moment in the understanding of biological ultrasonic communication occurred with the pioneering work on echolocation in bats by Donald Griffin and Robert Galambos in the 1940s. Using specialized equipment, they demonstrated conclusively that bats emit high-frequency squeaks and interpret the returning echoes to form a precise acoustic map of their environment. This discovery shifted the focus of bioacoustics, leading researchers to investigate other species previously thought to communicate solely within the human hearing range. Subsequent research

confirmed similar sophisticated ultrasonic capabilities in marine mammals, rodents, and various insect species, establishing **ultrasonic communication** as a pervasive and evolutionarily significant phenomenon.

3. Key Characteristics

High Directionality: Due to their short wavelengths, ultrasonic waves exhibit minimal diffraction. This allows the transmitting organism to focus the sound energy into narrow, highly directional beams, which is essential for accurate spatial mapping (echolocation) and targeted communication between specific individuals, minimizing eavesdropping by non-target species.

Rapid Attenuation: While directionality is advantageous, ultrasonic frequencies suffer greater attenuation (loss of energy) over distance compared to lower frequencies, especially in air. This limits the effective range of communication and sensing, necessitating either high power output or short-range interactions. Conversely, in water, attenuation is generally less severe than in air, allowing marine mammals like dolphins to utilize ultrasonic frequencies over relatively longer distances.

High Information Capacity: The vast frequency bandwidth available in the ultrasonic range allows for complex modulation schemes, including variations in amplitude, frequency, and temporal patterns (chirps and clicks). This capability permits the rapid transmission of large amounts of detailed information, crucial for complex tasks like discriminating between different types of prey or communicating precise social statuses.

Ecological Stealth: The utilization of frequencies above 20 kHz provides a degree of acoustic camouflage. Many common predators or prey animals cannot perceive these sounds, allowing the communicating or navigating organism to operate effectively without compromising its position to a broader spectrum of the ecosystem.

4. Biological Mechanisms and Examples

The classic examples illustrating the profound utility of **ultrasonic communication** are found in Chiroptera (bats) and Odontocetes (toothed whales and dolphins). For these animals, ultrasound is not merely supplementary communication but is integral to their survival, facilitating crucial activities such as locomotion and foraging. Bats, which navigate primarily in darkness, rely heavily on emitting ultrasonic calls and processing the echoes to build a three-dimensional representation of their surroundings. The specific characteristics of these calls (e.g., constant frequency vs. frequency-modulated) vary based on the bat species and the ecological context, such as searching for prey versus close-range pursuit.

Similarly, marine mammals, exemplified by dolphins, employ complex ultrasonic clicks generated primarily in the nasal passages (specifically the phonic lips) and focused by the melon (a fatty organ in the forehead). These clicks, often reaching frequencies far exceeding 100 kHz, serve dual

purposes: they are used for long-range communication within pods, and, critically, they are utilized to **locate prey** and navigate through the often opaque marine environment. The precision of dolphin echolocation allows them to discern the size, shape, distance, and even internal density of submerged objects.

Beyond the well-known examples of bats and dolphins, numerous other animal groups utilize ultrasound. Many species of rodents, including rats and mice, produce ultrasonic vocalizations, particularly during social interactions, mating rituals, and when pups are distressed. These high-frequency calls are essential for mother-offspring recognition and signaling alarm without alerting mid-frequency hearing predators like certain owls or foxes. Furthermore, certain species of insects, such as moths, have evolved sophisticated hearing organs specifically to detect the ultrasonic hunting calls of bats, leading to an ongoing, high-frequency evolutionary arms race.

5. Significance and Impact

The ability to communicate or sense using ultrasound represents a significant evolutionary adaptation, providing competitive advantages in diverse ecological niches. Its primary impact lies in facilitating survival tasks in environments where vision is limited, such as deep water, dark caves, or during nocturnal hours. The fine spatial resolution afforded by the short ultrasonic wavelengths allows users to exploit niche resources, dramatically expanding their available foraging time and geographic range. For example, without ultrasonic echolocation, bats would be largely confined to daytime hours, forcing them into intense competition with avian predators.

Furthermore, **ultrasonic communication** profoundly impacts intraspecies social organization. In dense environments, the directional nature of ultrasound minimizes signal overlap and confusion, allowing complex social groups, such as dolphin pods or bat colonies, to maintain organization and coordinate hunting behaviors efficiently. The study of these intricate biological systems also has significant technological consequences, inspiring advancements in artificial sonar, medical ultrasonography (ultrasound imaging), and robotic navigation systems, demonstrating a cross-disciplinary influence from biology to engineering.

6. Debates and Criticisms

While the study of ultrasonic communication is robust, several challenges and areas of debate persist. One major limitation is the inherent difficulty in observing and recording these signals in natural environments without intrusive methods, leading to potential biases in data collection regarding signal usage and intent. Researchers often grapple with distinguishing between genuine communicative signals and those pulses strictly dedicated to echolocation, particularly in species like dolphins where the functions often overlap or occur concurrently.

Another area of focus involves understanding the trade-offs associated with signal attenuation.

Because ultrasound dissipates rapidly in air, species relying on it must expend considerable energy to produce high-amplitude calls, potentially imposing metabolic costs. Moreover, environmental noise pollution, particularly high-frequency anthropogenic noise (e.g., from naval sonar or industrial machinery), poses a growing threat by interfering with the delicate processes of both ultrasonic communication and navigation in sensitive species like marine mammals, leading to ongoing scientific and conservation debates regarding noise mitigation strategies.

Further Reading

[Ultrasonic Vocalization \(Wikipedia\)](#)

[Echolocation \(Wikipedia\)](#)

[Ultrasonic Communication in Animals \(ScienceDirect\)](#)

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