

Hypersonic Sound

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In the near future hypersonic sound could actually become a mainstream reality. The practical applications of hypersonic sound could range from public safety to home entertainment. For instance, a lifeguard could watch multiple people and use a bullhorn using hypersonic sound to talk to one individual in the water and warn him or “yell” at him. This is because the hypersonic sound equipped bullhorn would project the lifeguard’s voice at ultrasonic levels then due to the directionality of ultrasonic waves and the non-linearity in the air an audible sound would be produced and constrained to the same direction. In a different situation one could create surround sound in their television or computer area without any rear speakers. In this situation the speakers containing using hypersonic sound would project an inaudible sound off the back wall of the room, and when it reflects it appears that the sound came from the rear, creating a surround sound effect. Hypersonic sound could also be used in the work environment, on phone, pc speakers, or other audio devices. This would be increasingly beneficial in a cubicle workspace because then the neighbors would not be bothered by external audio distractions. The future of audio devices and entertainment is most definitely going to cross paths with hypersonic sound, and the possibilities are limitless.

The discovery of hypersonic sound like many other inventions was more of an accident combined with something of a stroke of genius. Elwood Norris from American Technology Corporation (ATC) was the “inventor” or pioneer of hypersonic sound in the United States. While investigating the non-linearity generated difference signal, he discovered that while producing a signal above the range of hearing and interfering it with another signal that is slightly greater than the first, an audible difference signal will result. The resultant signal was comparable to beats, which are created during the

constructive and destructive interference of linear waves. Norris was puzzled until he realized that by sending both signals through one transducer it would eliminate all possibilities of linearity. After this it was proved that some non-linearity in air was the actual cause of the audible frequency produced in the experiment. These experiments lead to the creation of hypersonic sound and hopefully the eventual explosion of new sound devices and products.

Sound is one of the senses that can amaze and perplex in the same instant. Many species can hear varying frequencies of sound and sometimes one species can here sounds that another cannot, like in the case of dogs and humans. Every now and then sound quality, sound devices, and the production of sound is advanced into a new state, due to a recent understanding. In 1996, sound took a turn towards hypersonic sound when Elwood Norris helped discover that the non-linearity in air under certain circumstances can produce audible frequencies. This was the birth of a new type of sound. Although hypersonic sound still has not reached its full potential, it has remained under development in attempts to revolutionize the sound frontier. The experiments of Norris and others exploring the frontier were complex and well funded in attempts to be the first, the first to create hypersonic sound and define the non-linearity found in air. We, Adam Koehler and Bao Huynh, will attempt to recreate Norris's experiment using less expensive materials, but hoping for the same results.

Our experiment is modeled after the one done by Elwood Norris of ATC. We wanted to see for ourselves if air really is nonlinear. For our experiment, we used two identical piezoelectric transducers that are about 3 cm in diameter. They're rated with a frequency range of 2 KHz – 8 KHz, and a resonance frequency at 5 KHz. The function

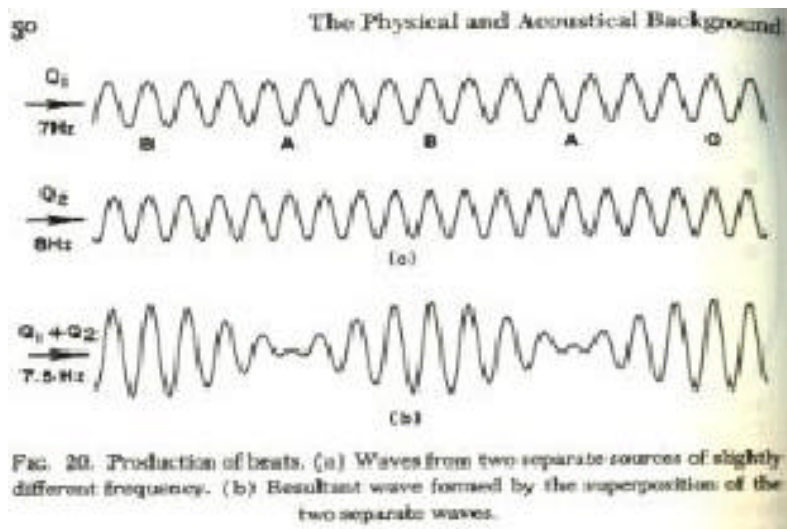
generators that we used did not allow us to set them any higher than 9 volts, thus limiting the amplitude as well. With these ratings, it was apparent that we could not replicate Norris' experiment exactly because there was no way of getting the transducers to respond strong enough at ultrasonic frequencies for us to detect. Especially since the sum and difference frequencies are expected to have even smaller amplitudes than the original frequencies.

First, we wanted to see how waves in the audible range interfere with each other so we would know what to look for in nonlinearity. We hooked the transducers up to their respective function generators and swept the frequency on one function generator from 0 – 10 KHz while keeping the frequency of the other transducer constant at 5 KHz. With our transducers, it was necessary to hold them back to back and slide them around to find the spots where the waves would interfere. Once that spot had been found, there was a noticeable warble in the sounds. There were still two distinct audio frequencies, but the sweeping frequency made them go in and out of phase, changing the amplitude as they interfere constructively and destructively. The interference of frequencies can be graphically explained by the following:

For the second part of our experiment, we wanted to find any nonlinearity in response since nonlinearity in air is out of the question. But before we did anything, we had to make sure that the transducers we had did anything at all at frequencies beyond 20 KHz. Much to our amazement, not only did the transducers produce the requested frequencies, but the microphone we had was also able to pick up those frequencies. Satisfied that the transducers will work, we did the same thing as before, but with a

sweeping range of 20 – 30 KHz and a constant frequency of 24 KHz. Again to our amazement, we heard the difference frequencies! For example, when one transducer is at 20 KHz and the other is 24 KHz, we heard a 4 KHz frequency. This frequency got lower and less audible as we swept from 20 KHz to 24 KHz, and then higher as we swept from 24 KHz to 30 KHz. The loudest difference frequency was around 5 KHz.

Being able to hear the difference frequencies was much unexpected since we already decided that there was no way we would be able to detect the nonlinearity with our microphone and oscilloscope setup, much less be able to hear it. Ultimately, the only explanation for it is some nonlinearity with the transducer setup. To test this, we pointed the transducers at each other. When we couldn't detect the difference frequency, it obliterated any suspicion that the difference frequency was a result of air nonlinearity. In fact, the only way to get the difference frequencies is by holding the transducers back to back. This led us to believe that the nonlinearity is in the plastic casings that hold the transducers. Since the casings were touching each other, it was possible that their individual vibrations interfered to produce what we heard. To further support our



hypothesis that the casings were the factors of nonlinearity, we found that when the casing is removed the resonance frequency is no longer 5 KHz but 6 KHz. This shows that the casings played an important role in the response of the transducers as a whole, thus giving it high probability of being the reason for the nonlinear response.