BBE®
High Definition Sound

What is *BBE* ?

Rev. 2

April 22, 2004

The BBE technology is used to recover the clarity of sound by compensating for the idiosyncrasy that inherently occurs in speakers and headphones. The BBE process is widely known as the most advanced sound enhancement technology in the recording, professional sound and broadcasting world. The following is a simple explanation of the BBE theory.

The sound we hear in the natural world consists of fundamentals and harmonics. The fundamentals are the sine waves that provide no more than pitch information of the sound. The harmonics, on the other hand, contain very important information which represent the specific character of sound (just like our finger prints). By analyzing the harmonics (mostly higher harmonics), we can tell the difference of a sound. When we hear a sound, we can instantly recognize who is talking (your friend, your parent, somebody you don't know), what is approaching you (a car, train, airplane) or what is ringing (telephone, door bell, emergency bell). When we hear an orchestra playing a symphony, we can identify the different instruments through the differences in the patterns of their harmonics. Some trained people can tell even the make of the instrument from the sound! Some enthusiasts can tell the type of the car from its exhaust note. Such great ability of recognizing sound is 100% depending on the harmonics.

A set of harmonics of a sound consists of series of higher order (2^{nd}, 3^{rd}, 4^{th}, 5^{th}, and so forth) harmonics. Every harmonic note has its own particular amplitude and location (time-wise) in the relationship to the fundamental. The most important factor, though, is that in live sound, the majority of harmonics reach the ear before the fundamental and only a few of them are behind it. This is explained by the mechanism of sound generation. For example, when you bang a drum, at the moment the stick touches the drum skin it generates noise. Then the whole skin starts to vibrate. The noise we hear first is the harmonics and the skin vibration generates the fundamentals. *(This is a quite simplified model of sound just to explain the theory easier. The actual waveforms of sound, however, are extremely complex. Many cycles repeat changing their forms and many different sounds overlap each other.)*

When our ear senses a sound, it analyzes its frequency spectrum. This information is then passed to the brain. When the spectrum information arrives, the brain starts to

analyze the sound. This is done in a time-sharing fashion. The phase analysis is done by the brain rather than the ears because it takes a lot more processing power. In the millions of years of human development, our brain has created a very efficient method of analyzing sound. Our brain knows that the beginning of a cycle of incoming sound is more important than the rest. But, as soon as it comes to the middle of the cycle the brain takes the fundamental note as a reference and ignores (masks) the insignificant tailing harmonics. The brain must analyze the sound as fast as possible so that the body can react quickly. This is a part of our self-defense reaction called Precedence Effect.

A similar effect is known as the Haas Effect. When the same sound arrives from two different directions the first arrival sound is heard but the late arrival sound is masked and hard to hear. In movie surround sound, we usually add 10 to 20mS delay to the surround chain compared to the center channel. This is to avoid the leakage of the center channel into the surround speakers, making it difficult to hear the dialog from the center channel. By adding a specific delay to the surround channel, we make the center channel reach to the ears of the audience first. That makes it a lot easier for us to hear the center channel.

Speakers have a tendency of delaying higher frequencies compared to lower frequencies due to their voice coil inductance and moving mass that is also inductive. This tends to mask the higher frequencies, making them less audible. When we hear such sound we feel the sound lacks high frequencies and the clarity and realism are lost, even though the acoustic spectrum appears exactly the same as that of the electronic input signal. The sound appears to be muffled. To try to recover the clarity and intelligibility, we typically increase the amount of high frequencies by using tone control or equalizer. The sound is improved somewhat but it tends to become harsh and unnatural.

Instead of simply boosting the high frequencies, BBE first time-aligns the frequency spectrum by delaying the mid and low frequencies, thereby allowing the important high frequencies to reach the ear in the proper time sequence, in front of the mids and lows as they would in live sound. BBE dynamically restores high frequency energy to restore the attenuated highs. The BBE processed sound is a lot more natural and clear compared to tone control or equalizer's. Many broadcasters, recording studios and sound reinforcement specialists have been using BBE over 20 years. In fact, more than 250 thousand BBE professional products are being used worldwide and many musicians use BBE for their instrument and vocal channels to improve the sound quality.

Going into some details of the BBE process. There are several different versions of BBE process. The most authentic BBE process works as follows; BBE divides the frequency band into three. The low frequency range is below 145Hz, mid range is 145Hz to 2.5KHz and the high frequency range is over 2.5KHz. Most of fundamental frequencies are inside the mid frequency range, and the higher harmonics are in the high frequency range. The low and mid frequency ranges are delayed 2.5mS and 0.5mS (smooth linear delay with no steps) respectively compared to the high frequency range. The high frequency range is not delayed. Therefore the higher frequencies reach the ear before the fundamentals as they do in natural live sound.

The mid range and high frequency range signals are used as references for BBE's adaptive amplitude compensation. By carefully watching the mid and high frequency

range signals, the absolute value circuits and supporting circuitry continuously outputs higher harmonics' dominance ratio. The output is applied to a VCA control to automatically adjust the higher harmonics amplitude to the optimum amount.

After using BBE to restore time alignment and amplitude of the higher harmonics, you may feel that you want a little more bass for the best balance. To obtain the best frequency balance, BBE processors have a low contour boost function, which boosts 50Hz area in a linear fashion up to 145Hz. Although this boost is not VCA controlled, it has a progressively longer delay as frequencies become lower. It gives a 2.5mS delay at 20Hz compared to the higher frequencies. This low contour boost provides very tight and clear (not boomy) bass. This is the reason that many bassists like to use BBE.

The BBE processed sound is very close to the original live sound. The sound is natural and crisp. Unlike tone control or graphic equalizer's simple boost, the BBE process can provide greater clarity with less boost.

Recently, digital compression technique such as MPEG Layer (MP2, MP3), Dolby Digital (AC-3), ATRAC (MD), etc. have become popular in digital recording, broadcasting and Internet distribution. Such lossy (in comparison to loss-less compression) digital compression has an inherent problem in the time alignment when it is reproduced. The delay in the high frequency occurs while reconstructing the waveform from the digitally compressed signals. Even though the frequency response is flat, the high frequencies are delayed. This is one reason for the fogginess of MD and MP3 sound. To restore the live sound quality, the high frequencies need to be advanced. That is exactly what BBE does. Dolby Digital, MPEG and MP3 sound are therefore greatly benefited by BBE.

Virtual surround is another excellent application for BBE. It is relatively easy to get a 180° surround using two front speakers, but getting 360° surround is extremely difficult. Even though the virtual surround process is done correctly, due to the same higher harmonics delay, we are not able to hear it. By compensating for the high frequency delay using BBE, we can hear a much wider angle surround sound.

In digital systems, BBE can be written into the software/firmware or conventional BBE ICs can be used after A/D conversion.

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