CLAIMS

1. A bass enhancement system comprising:

   an adaptive low frequency signal extractor configured to extract low frequency signals from an input audio signal;
   a nonlinear processor configured to generate from the low frequency signals harmonic signals having inter-modulation controllable to remain below a threshold level;
   an adaptive adjustor configured to set a gain used with the nonlinear processor for adjusting harmonic signal decay associated with the harmonic signals;
   a high-pass filter positioned in an output path from the non-linear processor and configured to pass harmonic signals which are reproducible by an output transducer; and
   an output mixer which sums high-pass filtered input audio signals with psychoacoustic bass corresponding to the harmonic signals generated by the nonlinear processor.

2. The system as recited in claim 1 further comprising a loudness matching block configured to compensate the loudness of the desired harmonics to match the loudness of the low frequency signals.

3. The system as recited in claim 2 wherein the adaptive adjustor generates a harmonic decay rate that is implemented by an automatic gain related to at least one of an input audio level or a cut-off frequency of the output transducer.

4. The system as recited in claim 1 wherein the adaptive adjustor generates full-harmonic generation and inaudible inter-modulation.

5. The system as recited in claim 1 wherein the nonlinear processor generates both even and odd harmonics.

6. The system as recited in claim 1 wherein the nonlinear processor is designed as a fifth order polynomial.

7. The system as recited in claim 2 wherein the output path from the nonlinear processor to the output mixer does not include a low pass filter.

8. The system as recited in claim 1 wherein the system filters out low frequency signals from the audio input signal by subtracting the output of the low frequency extractor from the audio input signal.

9. The system as recited in claim 2 wherein the loudness matching is performed by a loudness compressor.

10. The system as recited in claim 9 wherein the loudness compressor operates on a high pass filtered output from the nonlinear processor.

11. The system as recited in claim 2 configured to adjust the harmonic decay rate optionally by controlling the adaptive adjustor of harmonic decay pattern or by altering the coefficients of the nonlinear processor.

12. The system as recited in claim 2 wherein the audio signal comprises at least a first and second channel and the output mixer comprises a first and second channel output mixer, and wherein the low frequency extraction is applied to a combination of the first and second channels and the harmonics passed by the high pass filter are added to both the first and second output mixers.

13. A method for enhancing bass perception of an audio signal, the method comprising:

extracting low frequency components from the audio signal;
generating harmonic signals using a nonlinear processor that operates on the low frequency components and controls inter-modulation to remain below a threshold value;
adjusting, by the nonlinear processor, harmonic signal decay associated with the harmonic signals based upon a gain set by an adaptive adjustor;
passing, by a high-pass filter positioned in an output path from the non-linear processor, harmonic signals reproducible by an output transducer; and
summing, by an output mixer, high-pass filtered input audio signals with the psychoacoustic bass corresponding to the harmonic signals generated by the nonlinear processor.

14. The method recited in claim 13 further comprising compensating the loudness of the desired harmonic signals to match the loudness of the original extracted low frequency signal.

15. A computer program product for enhancing bass perception of an audio signal reproducible on a loudspeaker in a listening space, the computer program product being embodied in a non-transitory computer readable medium and comprising computer executable instructions for:

receiving the audio signal;
extracting low frequency components from the audio signal;
generating harmonic signals using a nonlinear processor that controls inter-modulation to remain below a threshold value;
adjusting the harmonic signals adaptively, by setting, by an adaptive adjustor, a gain used with the nonlinear processor so that the signal decay associated with the harmonic signals is responsive to a measurement of the low frequency components;
passing, by a high-pass filter positioned in an output path from the non-linear processor, harmonic signals reproducible by an output transducer; and
summing, by an output mixer, high-pass filtered input audio signals with the psychoacoustic bass corresponding to the harmonic signals generated by the nonlinear processor.