Tranquility as a Service

Crafting Peaceful Spaces for Home and Office

We all need our space—both at work and at home, not only in physical dimensions but also in an environment of our choosing.

What if our personal space could sense the mood & occasion and adapt to it? Ranging from youthful vibes at leisure to a serene blissful workspace

What if our space evolves as we grow & mature?

The barrier to a peaceful personal space is easy to breach with noise & it often is. We helplessly accept the intrusions. Or move away - to another location and/or to another time.
What if we could demand tranquil environments at our convenience & place?
Our vision of a quiet world - in a perfect world - need no longer to be an illusion.
While we cannot change the world, technology can transform personal spaces into sanctuaries of calm. Our commitment is to craft serene environments where peace and quiet are not just dreams, but realities.

Article by Engineering Support Team

Discover Tranquility with Jasmin

At Jasmin, we create serene environments, turning peace into an experience. Following our Previous article *Bliss Home, Peace@Work…No Room for Noise*, which

included Adaptive ANC simulations, this article focuses on real-time ANC with the Modified Filtered-x LMS Algorithm. Figure 1 represents noise control and adaptive performance from concept to execution.

Jasmin designs bespoke soundscapes for optimal acoustics, offering genuine serenity beyond noise Control. With our expertise, we promise to craft your personal retreat of tranquility. Future projects/articles will explore AI-enabled adaptive environments to further enhance peaceful spaces.

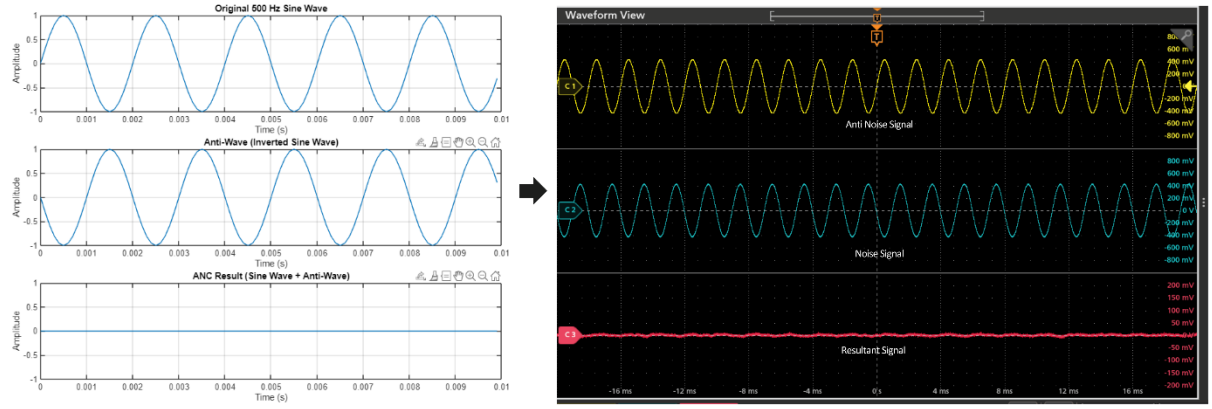

Figure1: From Simulation to Real-Time Results: A Significant Leap

Case Study: Residential Settings

In residential settings, noise reduction solutions play a significant role in improving quality of life. A family with young children and frequent home-based work discovered the benefits of real-time ANC technology in their living space. By using real-time ANC for free space, they were able to create a quieter, more conducive environment for both relaxation and productivity. The system's adaptability allowed for seamless integration into various household activities, demonstrating the versatility of real-time noise reduction technologies.

Real-Time ANC for Optimizing Open Space Acoustics

Real-time ANC systems utilize a combination of microphones, speakers, and sophisticated algorithms to detect and neutralize ambient noise. These systems continuously process sound data, enabling them to adapt to varying noise levels and frequencies. For instance, in an office setting, real-time ANC can filter out the constant hum of air conditioning units while maintaining speech intelligibility for conversations and video calls.

Modified Filtered-x LMS Algorithm in Active Noise Control Systems

Our previous exploration established the importance of adaptive noise - control (ANC) technologies in fostering peaceful environments. Now, we focus on the practicalities of real-time implementation. Real-time noise reduction involves deploying advanced technologies that continuously analyze and counteract unwanted sounds. Unlike static solutions, real-time systems dynamically adjust to changing noise conditions, providing optimal results in various environments.

The Modified Filtered-x LMS (Least Mean Squares) algorithm is an advanced technique widely employed in Active Noise Control (ANC) systems to enhance noise cancellation performance in dynamic environments. Unlike the standard Filtered-x LMS algorithm, the modified version includes optimizations in its adaptation and filtering processes, enabling it to estimate the noise propagation path more accurately and rapidly adjust to fluctuations in ambient noise. Due to these features, we have selected and implemented the Modified Filtered-x LMS algorithm in our application to ensure precise and robust noise cancellation under varying conditions.

Signal Flow for Creating Tranquil Audio Environments

"Explore the meticulous setup that brings our tranquil soundscapes to life, designed to transform any space into an oasis of calm."

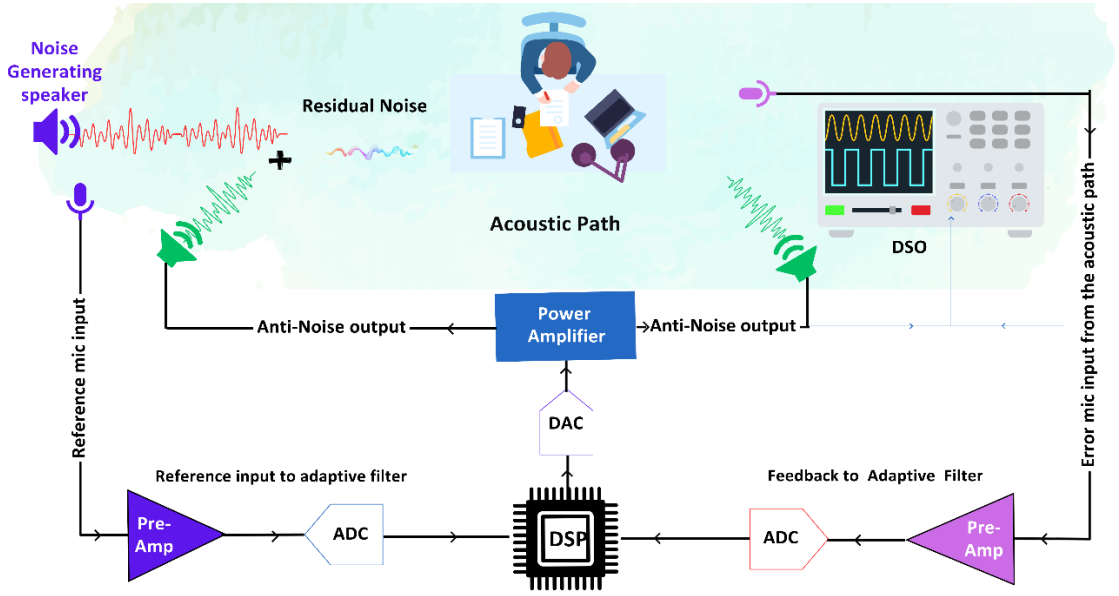

Figure 2: Serenity Sound Analysis

As shown in 'Figure2 Serenity Sound Analysis' the **DSP** continuously detects and analyses ambient noise, generating a real-time anti-noise signal to counteract it. The **pre-amplifier** boosts the weak microphone signal to a level suitable for the ADC. The **power amplifier** then amplifies the anti-noise signal from the DSP to drive the speaker effectively. The **power supply** provides power to the entire ANC system. The **Digital Storage Oscilloscope (DSO)** captures and displays the ANC system's output.

Testing and performance evaluation of the Tranquility as a Service

To validate the performance of Active Noise Control (ANC) system based on the Modified Filtered-x LMS algorithm, we conducted comprehensive testing to evaluate its noise reduction capabilities across various frequencies and its real-time adaptability to change environmental conditions. The testing setup involved capturing ambient noise using microphones and processing it in real-time through a DSP unit running the Modified Filtered-x LMS algorithm. The system then generated an anti-noise signal, which was output through speakers to cancel the noise. A Digital Storage Oscilloscope (DSO) was used to analyze the resulting signals in both the time and frequency domains, ensuring accurate assessment of the system's performance.

1. Frequency-Based Noise Reduction Testing

The ANC system was evaluated for its ability to reduce noise over a wide frequency spectrum, representative of typical residential and office noise sources. Frequencies such as 150Hz, 200Hz, 300Hz, and up to 3200Hz were included in the evaluation. Noise levels were measured in decibels (dB) both with and without the ANC system, allowing us to calculate the reduction achieved at each frequency.

2. Testing Results

Our testing methodology focused on evaluating the ANC system's performance across a wide range of frequencies to reflect typical noise conditions in residential, office, and industrial environments. By targeting both low and high-frequency noise, we aimed to highlight the system's adaptability and capability in handling diverse noise profiles. The noise reduction values were recorded for each frequency by measuring the difference in decibel levels with and without the ANC system, as shown in **Table 1** below.

These results highlight the system's effectiveness in reducing noise across various environments, demonstrating its ability to maintain consistent performance in diverse acoustic conditions.

Frequency (in Hz)	Without ANC (in dB)	With ANC (in dB)	Reduction in noise (in dB)
150	-33.00	-37.43	-4.43
200	-45.60	-70.20	-24.6
300	-38.00	-63.00	-25.78
500	-30.10	-44.21	-14.11
800	-36.87	-60.65	-23.78
1000	-43.46	-67.65	-23.89
1200	-34.65	-51.10	-16.45
1500	-42.63	-55.19	-12.56
2000	-36.54	-47.54	-11.00
2400	-34.86	-46.52	-11.66
2600	-34.69	-47.83	-13.14
3000	-44.50	-49.56	-5.06
3200	-39.86	-50.42	-10.56

Table 1: Noise Reduction Results through the Modified Filtered-x LMS Algorithm

As observed, the ANC system demonstrated significant noise reduction, particularly at 200Hz with a reduction of 24.6 dB and at 300Hz with a reduction of 25.78 dB. This confirms the effectiveness of the ANC system in mitigating unwanted noise across a variety of frequencies.

3. Time-Domain Comparison

To illustrate the ANC system's performance, the noise signals were analyzed in the time domain. Without ANC, the noise signal was dominant, overwhelming the primary audio content. When the ANC system was active, the generated anti-noise signal effectively canceled out the unwanted noise, leaving only minimal residual noise. This real-time cancellation capability improved the clarity of the desired audio signal.

Figure 3: Time Domain without ANC

Figure 4: Time Domain with ANC

4. Frequency-Domain Comparison

The ANC system's performance has been evaluated in the frequency domain, where its ability to attenuate specific noise components was clearly demonstrated. For instance, a significant noise reduction of approximately 15.11 dB was observed around 500Hz, aligning with common low-frequency environmental noise sources such as air conditioning hum. With ANC enabled, the prominent noise peaks visible in the spectrum without ANC were effectively suppressed.

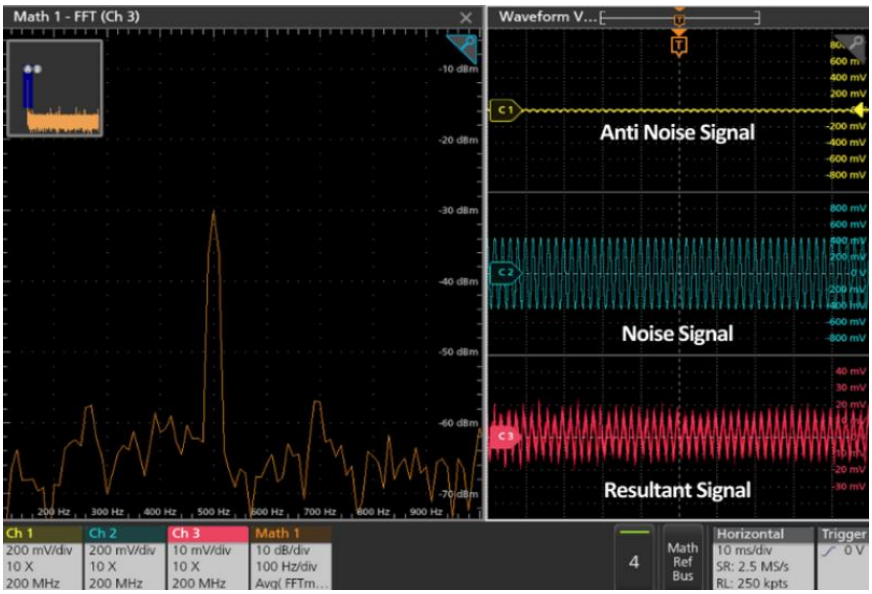

Figure 5: Frequency Domain without ANC

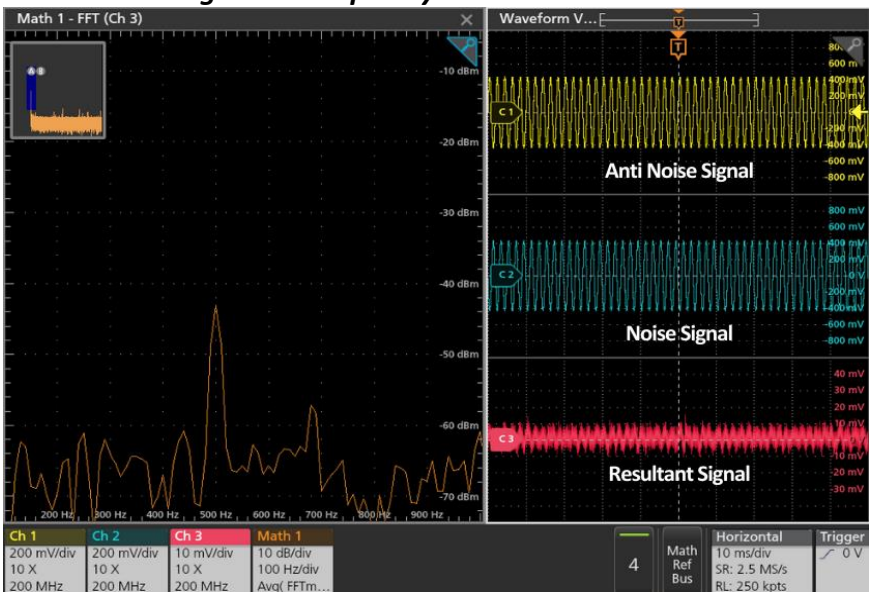

Figure 6: Frequency Domain with ANC

Real-Time Adaptation

The ANC system demonstrated its ability to adapt continuously to dynamic noise environments. It adjusted its anti-noise output in real-time as ambient noise levels fluctuated, highlighting the strength of the Modified Filtered-x LMS algorithm. This adaptability ensures consistent noise control even in rapidly changing conditions.

Through systematic testing, the effectiveness of the ANC system was validated across a wide frequency range. The results confirmed significant noise reduction, with time-domain and frequency-domain analyses reinforcing the system's capability to improve audio clarity in dynamic environments. These findings highlight the potential of ANC technology to enhance acoustic comfort in residential and office spaces.

Challenges involved in Real-Time ANC for free space

Real-time Active Noise Control (ANC) for free space faces several notable challenges in their implementation and operation.

Including Cost and Accessibility, as high-quality models can be prohibitively expensive. Technical Complexity requires specialized expertise for setup and maintenance, while Integration with Existing Systems can be problematic. User Adaptation may take time, and Latency Issues and Environmental Variability can affect performance by reducing the effectiveness of noise cancellation.

Conclusion

The shift from theoretical noise reduction solutions to practical, real-time applications represents a significant advancement in creating peaceful and productive environments. As demonstrated through various case studies, the real-time implementation of adaptive ANC technologies offers substantial benefits across different settings, from corporate offices to residential homes and healthcare facilities. While challenges exist, the continued evolution and refinement of noise reduction technologies promise to enhance our ability to manage noise effectively in an increasingly noisy world.

As we move forward, embracing these technologies and addressing their challenges will be crucial for optimizing our environments and enhancing our overall quality of life. The future of noise reduction is not just about mitigating sound but about creating spaces where peace and productivity can flourish harmoniously.

DISCLAIMER

Initially developed in various industries, Adaptive ANC technology has set new standards in noise reduction, particularly within automotive contexts. The Jasmin Engineering Support Team is dedicated to adapt and implementing this technology in non-automotive environments, aiming to create tranquil spaces that enhance productivity and well-being.

By embracing innovative noise reduction solutions, we aim to transform everyday environments into personalized havens of peace and focus.

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