

TINNITUS.FOUNDATION

Differential Spectral Tinnitus Detection & Adaptive Human – Frequency Interference

User Manual

IMPORTANT NOTICE — READ BEFORE USE

This product is a research-stage self-help tool. It is NOT a medical device, NOT a diagnostic instrument, and NOT a treatment or cure for tinnitus or any other condition. Always have new or changing tinnitus assessed by an ENT physician (otolaryngologist) or audiologist before using this system. Tinnitus can be a symptom of conditions that require prompt medical attention (e.g., sudden hearing loss, vestibular schwannoma, vascular disorders).

Discontinue use immediately if your symptoms worsen, or if you experience pain, dizziness, or new hearing changes, and consult a physician.

This document combines practical operating instructions with the full scientific rationale behind the system, including open hypotheses and unresolved limitations. It is a working document, not a peer-reviewed publication or a regulatory submission.

1. The Overall Principle of this System

This system measures the physical vulnerability in the ear itself — a frequency region where the cochlea's own amplifier operates close to its stability limit, and from which a tinnitus percept can arise, or may already have arisen. What follows explains the physiology behind that distinction.

2. What This Document Covers

This document explains how to use the TINNITUS.FOUNDATION system and sets out, in full, the scientific rationale behind it. At its core is an in-ear-microphone-based measurement method that locates and quantifies structural regions of heightened sensitivity and instability within your ear — the physical vulnerabilities from which a tinnitus percept can arise, or may already have arisen — together with a companion frequency - human interaction engine that generates a personalized notched sound signal based on this vulnerability profile.

Sections 2, 3, 5, and 7 provide the underlying physiology and methodology in full scientific detail, including competing explanatory hypotheses, preliminary pilot data, and open limitations. Sections 4, 6, and 8–11 provide practical operating instructions, safety information, and reference material for day-to-day use.

3. Tinnitus Explained

3.1 What is Tinnitus

Tinnitus is the perception of sound (ringing, hissing, buzzing) without any external acoustic source. It affects roughly 10–15% of adults, with 1–2% experiencing a severe impact on quality of life.

3.2 Central and peripheral mechanisms

Most tinnitus follows damage to the inner ear (cochlea), commonly from noise exposure, aging, or ototoxic medication. Two mechanisms are thought to contribute, and current research does not consider them mutually exclusive:

- Central mechanism: after the ear sends less signal to the brain (due to hair-cell damage), the auditory brain increases its internal gain to compensate. This overcompensation can be perceived as a phantom tone, and emotional and attentional circuits can reinforce that perception (Eggermont & Roberts, 2004).
- Peripheral (cochlear) mechanism: the cochlea is not a passive receiver — outer hair cells actively amplify vibration, functioning as an active biomechanical amplifier. Under normal physiological conditions this amplifier operates in a stable regime, close to but short of an intrinsic instability threshold. When damage reduces the natural damping of the underlying feedback system at a given location, the local operating point can shift toward, or beyond, this threshold, and the region can begin to oscillate spontaneously — analogous to a microphone approaching acoustic feedback in proximity to a loudspeaker. This self-oscillation is a real, physical, and in principle measurable acoustic event, not merely a neural construct (Shera, 2003).

These two mechanisms can act together: a genuine peripheral change provides the initial signal, and the brain's compensatory amplification and emotional weighting render it more prominent and more difficult to suppress.

The current biophysical consensus model describes this peripheral amplifier not as a fixed mechanical resonator, but as a system self-tuned close to a dynamical instability — a so called Hopf bifurcation. A critical oscillator operating near this instability characteristically exhibits signal amplification, sharply tuned frequency selectivity, and a specific form of compressive nonlinearity (Eguíluz, Ospeck, Choe, Hudspeth, & Magnasco, 2000; Hudspeth, Jülicher, & Martin, 2010). Depending on which side of this instability a given cochlear region occupies, the same underlying system can behave either as an extremely sharp, high-gain resonator requiring external excitation to become observable, or as a self-sustained spontaneous oscillator — the two regimes invoked directly in Section 3.3.

3.3 Tinnitus is usually not a single tone but a spectrum of frequencies

Contrary to the traditional characterization of tinnitus as a single pure tone, published measurements indicate that most tinnitus percepts consist of a narrow cluster of several simultaneous frequencies, more closely resembling a chord than a single note. This is one reason single-slider matching applications often perform poorly: by design, they can capture only one component of a multi-frequency percept.

3.4 Why this vulnerability signature is present in most individuals

A reasonable objection to this measurement principle is the following: if it captures a genuine physical vulnerability, why does it also register a signal in individuals without tinnitus? This follows directly from the physiology described in 2.2. The active cochlear amplifier, and the range of operating points it can occupy, is a normal feature of a healthy ear, not a phenomenon confined to tinnitus sufferers.

Population studies report a strikingly high baseline prevalence of measurable spontaneous cochlear activity: approximately 60% of adults (up to 80% of children), with a marked sex difference — comparable figures of 64–81% in females and 39–55% in males across measurement conditions, pooling to 83% and 62% respectively, are reported by Penner and Zhang (1997). Such activity is therefore not a tinnitus-specific phenomenon, but a normal feature of a healthy, actively functioning cochlea.

The causal attribution of a specific tinnitus percept to this activity is a substantially narrower claim. Penner (1990) estimated that only a small minority of tinnitus cases are attributable, even in part, to a spontaneous emission. A retrospective clinical cohort study at a specialized tinnitus clinic found measurable emissions in 22% of ears (30.5% of patients), with no correlation between emission frequency and matched tinnitus pitch, and a lower prevalence among patients with hearing loss and tinnitus relative to the general population — plausibly because hearing loss exceeding 40–50 dB HL suppresses the emission (Shi, 2006).

What typically differs in tinnitus, then, is not the presence of this activity, but its magnitude at a given frequency, and the proximity of the underlying cochlear region to its instability threshold. The

measurement is therefore expected to register a signal in most individuals, but at a substantially higher amplitude in those experiencing tinnitus at the corresponding frequency.

3.5 Frequency-specific vulnerability: Threshold microstructure

A finding of particular relevance to this system concerns threshold microstructure: periodic fluctuations in hearing threshold across frequency that correlate closely with the presence of elevated cochlear amplifier activity. Systematic measurement across a wide frequency range (1.2–13.9 kHz) shows that this microstructure is observable at all frequencies where such activity is present, and that psychophysical tuning curves are measurably altered by it, showing shifted or multiple tuning tips (Baiduc, Lee, & Dhar, 2014).

Of particular relevance is the finding that the threshold at this frequency is itself the most sensitive to short-term intense noise exposure: brief wideband noise exposure produces a temporary reduction in emission frequency and amplitude and reversibly alters the surrounding threshold microstructure, with the frequency of minimum threshold shifting more at this frequency than at neighboring frequencies (Furst, Reshef, & Attias, 1992). This provides a plausible mechanistic link between the location of a measurable vulnerability and the location of preferential future damage: the measured frequency need not mark the cause of an existing tinnitus percept, but may instead mark a pre-existing, functionally vulnerable cochlear region from which a percept can subsequently arise.

4. How the Measurement Works

4.1 The Principle

Unlike conventional tinnitus applications, which require the user to manually adjust a slider until a tone perceptually matches their tinnitus, this system does not attempt to reproduce or match the perceived sound at all. Instead, it locates and measures a physical vulnerability of the ear directly — a frequency region where the cochlear amplifier described in Section 2.2 operates close to its instability threshold — using consumer noise-cancelling (ANC) in-ear headphones with an integrated microphone.

Two short recordings are obtained with the same headphones in ANC mode: a baseline recording with the earphones not inserted in the ear (capturing electronic and ambient room noise only), and an in-ear recording with the earphones sealed within the ear canal (capturing electronic noise, ambient noise, and any faint acoustic signal generated by, or reflected within, the ear itself). Subtracting the baseline spectrum from the in-ear spectrum removes the electronic and environmental components, leaving predominantly the narrow-band signals that mark these vulnerable regions of the ear.

4.2 Why ANC mode specifically

Active noise-cancelling headphones incorporate two microphones and a signal-processing stage that actively attenuates sound arriving from outside the ear. Sound generated or reflected within the sealed ear canal is not attenuated by this same process, as it never reaches the outward-facing

microphone. The noise-cancelling circuit therefore functions as a built-in filter that suppresses external noise while leaving faint, internally generated or internally reflected signal relatively more exposed on the internal microphone. The system additionally applies automated filtering to exclude known electronic artifacts, such as interference from the headphones' wireless radio or transient bursts associated with the Bluetooth connection interval, to prevent their misclassification as biological signal.

4.3 Why this measurement is physically meaningful

A sealed, actively noise-cancelled ear canal constitutes one of the most acoustically isolated environments readily achievable outside a laboratory setting. Once external sound and electronic noise are removed by subtraction, little remains within this volume capable of producing a sharp, narrow-band spectral component other than the ear itself. At least three non-trivial, non-mutually-exclusive hypotheses account for the origin of this residual signal.

Active cochlear emission (classical spontaneous otoacoustic emission)

The measured energy corresponds to a genuine, self-sustained oscillation of a cochlear region beyond the Hopf-bifurcation threshold (Section 2.2). This signal propagates outward through the middle ear and tympanic membrane and is captured directly by the in-ear microphone. This hypothesis predicts two specific nonlinear behaviors: frequency entrainment under a nearby external tone, and a compressive, nonlinear response to increasing excitation energy.

Passive coloration of device noise by ear-canal/middle-ear resonance

Consumer headphone electronics, including active noise-cancelling systems, exhibit a small but measurable intrinsic noise floor; independent laboratory characterization of AirPods Pro under hearing-aid test standards (ANSI S3.22-2014) documented an equivalent input noise level sufficient to be perceptible as a faint background hiss under quiet conditions, together with transducer resonances that vary across manufacturing batches (Chong-White, Mejia, Galloway, & Edwards, 2021). Under this hypothesis, this noise floor is spectrally colored and partially reflected by the individual acoustic transfer function of the sealed ear canal — a linear filtering effect rather than active cochlear amplification, but still person-specific, as canal and middle-ear geometry vary between individuals.

Elevated, sub-threshold gain (continuum hypothesis)

Consistent with the Hopf-bifurcation model, an intermediate position is plausible: a cochlear region sitting just short of the self-oscillation threshold shows no spontaneous emission, but exhibits a strongly enhanced, sharply tuned resonant response to any weak external excitation present — including the device noise floor invoked in Hypothesis B. Under this hypothesis, the observed signature is neither a pure spontaneous emission nor a pure passive resonance, but the acoustic expression of substantially reduced, though not fully absent, cochlear damping — the same region that, per Section 2.5, also shows the greatest vulnerability to noise-induced threshold shifts.

All three hypotheses converge on the same underlying physiological state: a cochlear region with reduced damping, operating in close proximity to its instability threshold. In every case, the measurement identifies a frequency region of locally elevated cochlear gain, which is why the

system is described throughout this document as measuring vulnerability rather than detecting a tinnitus tone.

4.4 Known confounds and methodological limitations

Critical evaluation of the method identifies several mechanisms capable of generating spectral peaks in the absence of genuine biological activity, which the system's automated classification is designed to exclude:

- Occlusion effect: the sealed versus open ear canal represents two acoustically distinct loading conditions for the microphone (differing impedance and resonance), not merely a difference in the presence of a target signal.
- Active ANC feedback transients: the adaptive filter re-tunes according to acoustic load; the transition from unsealed to sealed can generate reproducible, non-biological spectral structure.
- Device self-noise and transducer resonance: as noted in Hypothesis B above, consumer headphone electronics carry a small intrinsic noise floor and batch-dependent transducer resonances (Chong-White et al., 2021).
- Bluetooth transmission artifacts: periodic transients tied to the audio codec's connection interval, identifiable as short repeating time-domain events, are filtered prior to spectral classification.

5. Step-by-Step: Taking a Measurement

Phase 0 — Preparation

Tinnitus.foundation works with a web compatible devices (e.g. Iphone™, Ipad™ or Android™, Notebooks) and ANC-capable in-ear headphones. All testing has been performed on Iphones and AirPods 3 pro achieving great subjective results. The ANC Earpods must be connected with the device. The automatic ear detection must be turned OFF.

Phase 1 — Baseline Measurement (about 15 seconds)

Put your ANC-capable in-ear headphones in ANC mode but do NOT insert them in your ears. Hold them still in a quiet room and start the baseline recording.

Phase 2 — In-ear Measurement (about 15 seconds)

Insert the same headphones snugly into your ears, keeping ANC mode on, in the same quiet room, and start the in-ear recording. Sit still and avoid talking, swallowing, or moving during this recording, as this can create artifacts.

Phase 3 — Analysis

The system automatically computes the difference between the two spectra and classifies the resulting peaks as likely human (biological), electronic artifact, or too weak to classify. This step requires no action from you.

Phase 4 — Generating your sound

Based on the detected vulnerability regions, the app builds a personalized filtered sound (see Section 6) that you can play back live or export as a WAV file.

Tips for a reliable measurement

Use the same headphones for baseline and in-ear recordings.

Choose the quietest room available; avoid fans, traffic noise, or other people talking.

Keep the headphones and your head still during both recordings.

If a measurement looks inconsistent, simply repeat Phases 1–2. Some frequency variation between sessions is expected: tinnitus pitch and loudness are well documented to fluctuate day to day, and the underlying measurement can be expected to vary accordingly.

6. The Sound – The Human Frequency Interference

6.1 The 'Mexican Hat' filter

For each vulnerability region identified in your ear, the system applies a three-part filter, centered on that frequency, to a background sound (by default, pink noise):

- A central notch directly at the vulnerability frequency, reducing energy at that point.
- A gentle boost just below that frequency.
- A gentle boost just above that frequency.

This shape is intended to reduce input exactly at the affected frequency while stimulating the immediately neighboring, healthier frequency regions — a principle related to lateral inhibition described in prior published research on notched sound spectrum.

6.1.1 *The neuroscience behind the flanking boosts: lateral inhibition*

Using magnetoencephalography (MEG), Pantev et al. (2004) directly compared two distinct mechanisms by which the auditory cortex's response to a tone can be reduced: passive habituation, in which the response diminishes with repeated exposure, and active lateral inhibition, in which neurons tuned to a given frequency are actively suppressed by activity in neighboring frequency channels. Lateral inhibition was found to produce a stronger and more rapid reduction of the cortical response at the target frequency than habituation alone. Building on this mechanism, Okamoto, Stracke, Stoll, and Pantev (2010) applied tailor-made notched music — ordinary music with a narrow band removed precisely at each patient's tinnitus frequency — for approximately one hour daily over an extended period, and observed a reduction in both subjective tinnitus loudness and the amplitude of the cortical response specific to that frequency.

The central notch and flanking boosts used in this system apply that same principle to each individually measured vulnerability frequency. Note that Pantev and Okamoto's work targeted a single, psychoacoustically matched tinnitus tone; extending it here to multiple, objectively measured frequencies and to a noise-based (rather than music-based) carrier is a plausible but not separately clinically validated adaptation of their findings.

6.2 Stochastic attention clicks

In addition to the continuous filtered background sound, brief clicks (about 25 ms) are periodically inserted at each detected vulnerability frequency. These are intended as attention-anchors on the flanking, healthy frequency regions rather than as a masking element in their own right.

The rationale for randomizing their timing (3–11 s between clicks, plus a small random pitch/FM modulation) rests on a well-established body of auditory-neuroscience evidence. Neurons in the auditory pathway show pronounced stimulus-specific adaptation: their response to a repeated, predictable stimulus shrinks progressively with each repetition (Ulanovsky, Las, & Nelken, 2003). Conversely, rare, temporally unpredictable ('oddball' or deviant) stimuli continue to evoke a comparatively large, non-habituating neural response and preferentially capture attention — a phenomenon documented extensively in the mismatch-negativity literature (Näätänen, Paavilainen, Rinne, & Alho, 2007). A click delivered at a fixed, predictable interval would itself quickly become just another repeating pattern that the brain adapts to, defeating its purpose.

This is an engineering application of general principles from auditory adaptation and deviance-detection research, not a claim backed by a dedicated clinical trial of this specific click paradigm in tinnitus patients; its benefit for tinnitus specifically has not been separately proven.

6.3 Preventing predictive suppression: stochastic parameter drift

Continuous playback of an identical filtered signal would likely produce habituation over time, reducing functional benefit. Rather than treating this as mere sensory fatigue, it is more precisely understood within a predictive-coding framework of auditory processing, in which the cortex continuously maintains a generative model of expected input and responds primarily to the residual prediction error (Friston, 2005). A static filtered signal — however carefully shaped by the notch-and-flank configuration of Section 6.1 — is, by definition, a highly learnable pattern: as the auditory system's internal model converges onto it, the associated prediction error, and with it the functional salience of the flanking lateral-inhibition contrast, approaches zero. This is the same computational principle that accounts for the mismatch negativity itself, where a detailed neuronal model based on predictive coding has been shown to reproduce its key empirical properties, including the re-emergence of a prediction-error response whenever a regularity is violated (Wacongne, Changeux, & Dehaene, 2012).

To counteract this convergence, filter position, notch depth, and left/right balance are perturbed continuously by a bounded stochastic process around each measured vulnerability frequency (internally designated 'Neural Mirage' in the app interface). Rather than a static target, the auditory system is presented with a target configuration whose fine structure is deliberately non-stationary and only partially predictable, preventing the generative model from settling into a precise, low-error

prediction. Stochastic parameter drift is thus not a cosmetic or engagement-oriented feature, but a direct extension of the same predictive-coding logic that motivates the discrete oddball clicks of Section 6.2 — applied continuously to the background filter itself, and intended to sustain a non-zero prediction-error signal at the target frequency over the full duration of use.

6.4 Stages of use

The app offers three intensity stages, intended to be used progressively over a period such as 12 weeks, moving from a stronger initial setting toward a gentler one as you go:

- ACUTE — strongest notch and boost, most frequent attention clicks.
- MODERATE — reduced intensity.
- RESOLVED — mildest setting, for maintenance.

An Expert Mode allows limited fine-tuning of notch depth and boost strength around each stage's defaults. The filter width is fixed and cannot be changed, as this is set to preserve the intended effect.

6.5 Custom sound source

Instead of pink noise, you may load your own audio sample (e.g. wind, ocean, or nature recordings). The same personalized filter is applied to your chosen sound; short samples are looped automatically.

7. Discussion

7.1 Reinterpretation: from 'detection' to 'quantification of elevated gain'

The observation in Section 5.3 — a similar number and distribution of peaks in individuals with and without tinnitus, differing primarily in level — argues against a simple binary presence/absence criterion and in favor of a quantitative model: the tonotopic locations of elevated cochlear activity are anatomically similar across most individuals (consistent with the high baseline prevalence in Section 2.4), while the degree of amplification at these locations correlates with the presence and severity of tinnitus. This aligns directly with the central-gain mechanism of Section 2.2: a damaged region compensatorily increases its gain, which should manifest as measurably elevated emitted or reflected energy at precisely that frequency.

This reinterpretation carries an important consequence for how the system's claims should be framed: not 'detection of a tinnitus frequency absent in healthy individuals,' but 'quantification of cochlear amplifier activity, elevated relative to an age- and frequency-matched normal population, at tinnitus-relevant frequencies.' The diagnostic or personalization value would then reside primarily in the relative level offset from a population norm, rather than in the mere presence of a peak.

7.2 Regulatory and clinical implications

This reinterpretation is not regulatorily neutral. A claim of the form 'we objectively measure your tinnitus' implies diagnostic intent that would likely necessitate medical-device classification; a claim of the form 'we quantify patterns of elevated, individually measured cochlear activity at frequencies known to be tinnitus-relevant, as a basis for personalized frequency – human interaction

is more conservative, more scientifically precise, and remains closer to the system's current positioning as a research-stage self-help tool. Both framings are compatible with the pilot observations in Section 5; the more conservative framing is more robust to the hypotheses left open in Section 3.3.

8. Warnings and Limitations

Medical warning

This system does not diagnose tinnitus or any ear condition, and it is not a substitute for examination by an ENT physician or audiologist.

New, sudden, one-sided, pulsatile, or rapidly worsening tinnitus should be evaluated by a physician promptly, as it can (rarely) indicate a more serious underlying condition.

Stop use and seek medical advice if your tinnitus, hearing, or general wellbeing worsens while using the system.

Do not use at volumes that are loud or uncomfortable. Follow safe-listening guidance for headphone use.

Technical limitations you should be aware of:

- Measurement accuracy depends on your specific headphone model and its microphone/ANC characteristics.
- The method addresses the peripheral (cochlear) component of tinnitus described in Section 2.2. Tinnitus generated primarily within the central auditory pathways, without a measurable peripheral correlate, may not produce a clear result; this outcome is expected under the model presented in this document and does not indicate measurement failure.
- The measurement reflects the current proximity of the user's cochlear amplifier to its instability threshold. As this proximity can vary with factors including fatigue, stress, and recent acoustic exposure, results may vary between sessions.
- No formal clinical trials of effectiveness have been conducted for this system to date. Any benefit is not guaranteed.

9. Liability

The developer of this system accepts no liability for direct or indirect harm arising from the use of the described methods or software. Use is entirely at your own risk. This document and the underlying methods represent an experimental research project and are not a certified medical device.

10. Conclusion

The TINNITUS.FOUNDATION measurement principle — baseline subtraction using consumer ANC hardware — rests on a physically plausible foundation, well grounded in the cochlear-mechanics literature: the existence of spontaneous otoacoustic emissions as an expression of an active cochlear amplifier operating near a critical instability, and the documented association of these emission frequencies with locally elevated vulnerability (threshold microstructure). The preliminary pilot observations — a multi-component, physiologically plausible drifting spectrum, and a level-based rather than binary distinction between individuals with and without tinnitus — are consistent with this model and motivate the system's core framing: quantification of frequency-specific elevated cochlear amplifier activity, rather than detection of a tinnitus tone.

At the same time, non-trivial, methodologically sound alternative hypotheses remain open — in particular, passive or near-critical resonant coloration of device-intrinsic noise by the individual ear-canal/middle-ear transfer function — that cannot be excluded on the basis of current data. Further targeted empirical work, designed specifically to discriminate between the hypotheses set out in Section 3.3, represents the necessary next step in advancing the system from a mechanistically plausible concept to an empirically substantiated method. A larger, controlled cohort study, incorporating concurrent subjective daily logging of tinnitus pitch and loudness for correlation with measured peak shifts, is recommended as the most informative next validation step.

11. Quick Reference

Before you start, every time

1. Same headphones, ANC on, quiet room. Automatic Ear Detection « OFF »
2. Baseline (out of ear) → 15 s.
3. In-ear (sealed, still, silent) → 15 s.
4. Let the app analyze automatically.
5. Choose a stage (ACUTE / MODERATE / RESOLVED) and start listening at a comfortable volume.
6. If in doubt about your hearing or tinnitus itself: see an ENT physician or audiologist first.

12. References

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