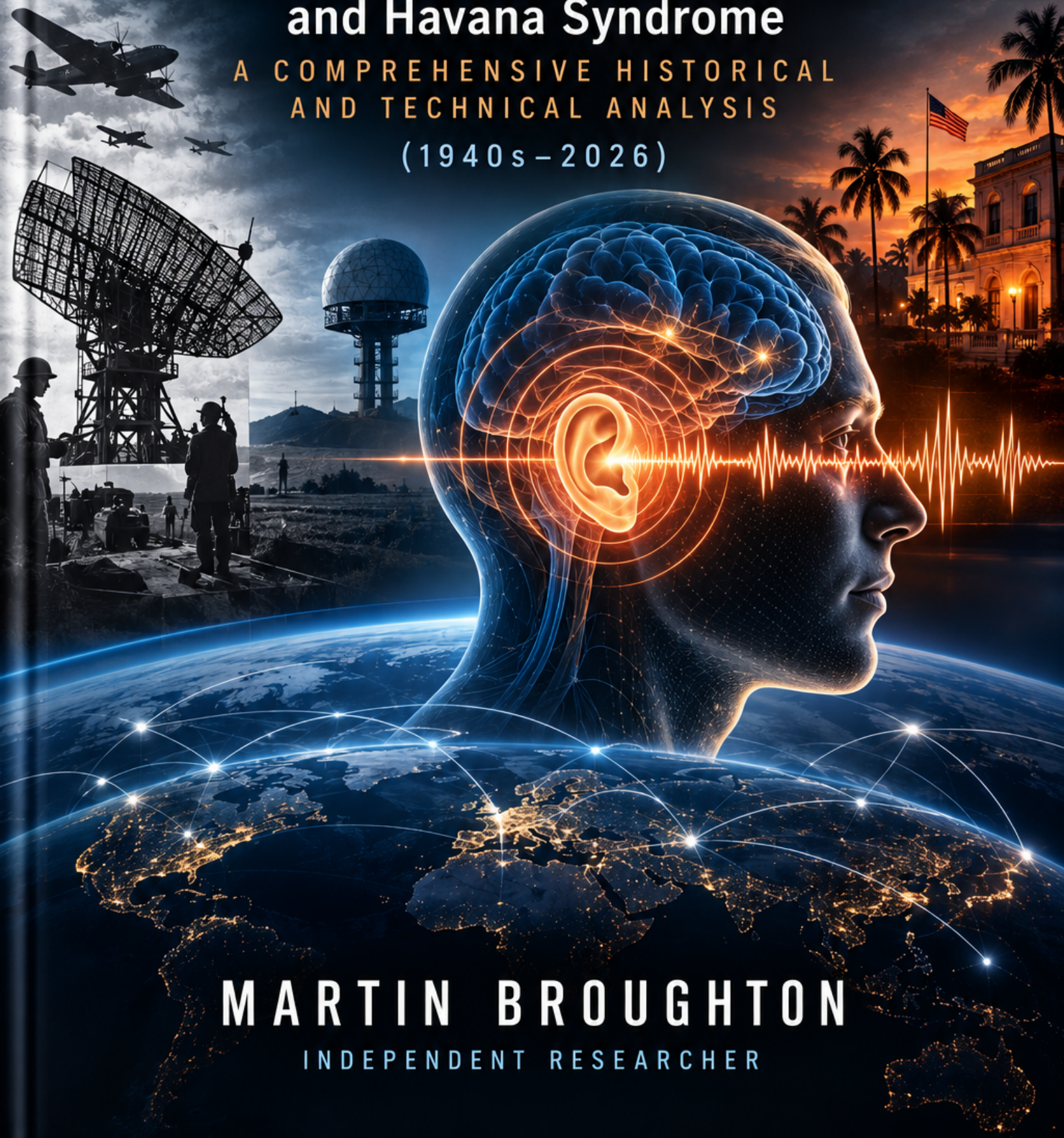


The **MICROWAVE** **AUDITORY EFFECT**

Radar Research, RF Bioeffects,
and Havana Syndrome

A COMPREHENSIVE HISTORICAL
AND TECHNICAL ANALYSIS

(1940s–2026)



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Preface

This volume presents a comprehensive historical and technical examination of the microwave auditory effect—often referred to as the Frey effect—alongside the broader scientific and geopolitical contexts in which research on radiofrequency (RF) bioeffects developed. Spanning more than eight decades, the work traces the evolution of scientific understanding from the earliest radar operations of the Second World War to contemporary discussions surrounding unexplained health incidents among diplomatic personnel.

The study of electromagnetic radiation and biological systems occupies an unusual position in scientific history. Advances in radar, telecommunications, and satellite technology produced environments in which humans were exposed to radiofrequency fields of unprecedented intensity and modulation. As these technologies proliferated, researchers began to investigate whether such fields could produce measurable physiological or perceptual effects.

Among the most intriguing findings was the discovery that pulsed microwave radiation could produce auditory sensations in humans without conventional acoustic transmission. First documented experimentally in the early 1960s, this phenomenon—known as the microwave auditory effect—generated a research field combining physics, engineering, neuroscience, and biomedical science.

The Cold War added further complexity. Concerns about foreign research programs and unexplained microwave exposure incidents led to classified investigations, including Project Pandora and related biomedical studies conducted by military and intelligence agencies. Although much of this work was eventually declassified, its interpretation remains subject to debate.

In the twenty-first century, renewed attention emerged following reports of unexplained health incidents affecting diplomatic personnel in Cuba and other locations beginning in 2016. Popular media often called these incidents directed-energy weapons, invoking historical microwave auditory research. Scientific and intelligence assessments, however, have offered more cautious conclusions.

This book seeks to clarify the scientific record by examining the historical development of microwave auditory research, the institutions and researchers involved, and the technical mechanisms underlying the phenomenon. By integrating peer-reviewed literature, historical documentation, and contemporary policy discussions, the work aims to distinguish established scientific knowledge from speculation.

Part I

Past – Origins, Discovery, and Cold War Programs

Chapter 1

Radar Origins of Microwave Bioeffects (1940s–1950s)

The development of microwave radar during the Second World War represented one of the most significant technological achievements of the twentieth century. Radar systems operating in the centimeter wavelength range enabled the detection of aircraft, ships, and other objects at distances previously impossible using optical methods. These systems relied on pulsed microwave transmitters, often operating at extremely high peak power levels.

Although radar technology was designed primarily for detection and communication, its introduction also created new environmental conditions for personnel operating or maintaining such equipment. Engineers, technicians, and radar operators frequently worked in close proximity to transmitters, waveguides, and antenna arrays capable of producing intense electromagnetic fields.

In the years following the war, anecdotal reports began to circulate among radar technicians describing unusual auditory sensations experienced near active radar systems. Complaints had

been made at the Airborne Instruments Laboratory in Mineola, NY in 1947. When standing close to a 75-foot-tall antenna, individuals reported perceiving sounds such as buzzing, clicking, or knocking despite the absence of any audible acoustic source. In many cases, these sensations appeared to originate internally within the head rather than through the normal auditory pathway. This was published in Proceedings of the IRE Ad AIL (Cutler-Hammer division) in an advertisement in 1956. It was also mentioned in 1957 when Henning von Gierke, a German-American aviation medicine expert at Wright-Patterson AFB, published "Otological Effects of Mechanical and Microwave Acoustic Stimuli", cataloguing directed USAF biodynamics research (binaural beats, infrasound, microwave bioeffects).

Because the phenomenon occurred in environments where high-power pulsed microwave signals were present, some engineers speculated that the electromagnetic radiation itself might be responsible. At the time, however, the idea that radiofrequency energy could produce direct sensory effects in humans was considered unlikely by most scientists.

The absence of systematic experimental investigation meant that these observations remained largely anecdotal for nearly two decades. Nevertheless, the reports persisted within engineering communities, particularly among radar specialists familiar with pulsed microwave transmitters. The recurring nature of these observations suggested that they were not simply isolated experiences.

By the late 1950s, the rapid expansion of radar systems in military and civilian applications brought increasing attention to potential biological effects of microwave radiation. Governments began commissioning studies to evaluate occupational exposure to radiofrequency fields, particularly in environments where personnel might encounter high-power transmitters.

These early investigations focused primarily on thermal effects. Microwave radiation, like other electromagnetic radiation in the radiofrequency range, can produce heating when absorbed by biological tissue. Scientists therefore concentrated on determining safe exposure limits based on the potential for tissue heating.

Yet the unusual auditory reports remained unexplained. The mechanism by which electromagnetic radiation could produce the perception of sound without acoustic vibration was not yet understood. The question would remain unresolved until the early 1960s, when controlled laboratory experiments began to investigate the phenomenon systematically.

Those experiments would lead to the formal identification of what became known as the **microwave auditory effect**.

Chapter 2

Discovery of the Microwave Auditory Effect (1960s)

The first systematic experimental investigation of microwave-induced auditory perception was conducted by neuroscientist Allan H. Frey in the early 1960s. Working within a research environment associated with General Electric's Advanced Electronics Center, Frey designed experiments to determine whether radiofrequency radiation could directly stimulate the human auditory system.

Frey's research involved exposing human subjects to pulsed microwave radiation while carefully controlling environmental conditions. Unlike the anecdotal radar reports that preceded his work, these experiments were conducted under laboratory conditions that allowed precise measurement of frequency, power density, and modulation parameters.

The results were striking. Subjects exposed to pulsed microwave radiation reported hearing distinct sounds even though no acoustic source was present. The sounds were commonly described as clicks, buzzing, or hissing. Importantly, some individuals who were clinically deaf also reported perceiving these sensations, suggesting that the mechanism did not rely on normal sound transmission through the ear canal.

Frey's findings were published in 1961 and 1962 in the journal *Journal of Applied Physiology*. The papers demonstrated that microwave radiation modulated in short pulses could reliably produce auditory sensations in human subjects. Because the phenomenon had been experimentally verified, it quickly attracted attention from both biomedical researchers and military scientists.

One particularly intriguing aspect of the experiments was the range at which the effect could occur. Frey reported that subjects could perceive microwave-induced sounds even when located **thousands of feet from the transmitting antenna**. This observation suggested that relatively low average power densities could produce perceptible effects when delivered in short pulses.

The phenomenon soon became known as the **microwave auditory effect** or, informally, the **Frey effect**. Although the discovery generated interest within the scientific community, it also raised important questions regarding the underlying mechanism.

At first, researchers proposed several competing explanations. Some hypothesized that microwave radiation might interact directly with neural structures in the brain. Others suggested that the effect could involve mechanical vibrations within the skull caused by electromagnetic energy absorption.

Resolving these questions required a theoretical framework capable of explaining how pulsed electromagnetic energy could generate acoustic sensations without conventional sound waves. Such a framework emerged during the following decade through the development of the thermoelastic theory.

Chapter 3

Thermoelastic Mechanism and Theoretical Foundations

The discovery that pulsed microwave radiation could produce auditory sensations raised an immediate and important question: how could electromagnetic energy, which normally produces heating, generate the perception of sound without a conventional acoustic source?

Early speculation suggested several possible mechanisms. Some researchers proposed that microwaves might directly stimulate neural tissue within the brain. Others suggested that the effect might arise from interactions with the inner ear or vestibular system. These hypotheses, however, lacked a clear physical explanation.

A decisive step toward resolving the mechanism came through the work of physicist **Richard M. White** in 1963. White published a theoretical analysis describing how rapid surface heating of a material could produce **elastic waves**. When electromagnetic energy is absorbed in a medium, even a very small temperature increase can cause the material to expand. If the heating occurs extremely rapidly—as it does when energy is delivered in short pulses—the resulting expansion can generate mechanical pressure waves.

This process is known as **thermoelastic expansion**.

In biological tissue, the same principle applies. When a short microwave pulse is absorbed by the head, the energy deposition produces a minute temperature increase—typically on the order of one-millionth of a degree Celsius. Although the temperature rise is extremely small, it occurs rapidly enough to produce a brief pressure wave that propagates through the surrounding tissue.

These pressure waves travel through the skull and reach the inner ear, where they stimulate the cochlea in a manner similar to ordinary sound waves. The brain then interprets these signals as auditory sensations.

This explanation provided a plausible physical mechanism for the microwave auditory effect. The theory predicted that the strength of the perceived sound should depend on several parameters, including:

- pulse duration
- peak power density
- repetition rate
- carrier frequency

The hypothesis received strong experimental support in 1974 when **Kenneth R. Foster** and **Edward D. Finch** published a landmark paper in *Science*. Their study demonstrated that the microwave auditory effect could be quantitatively explained by thermoelastic expansion within brain tissue. By calculating the acoustic pressure generated by pulsed microwave absorption, they showed that the predicted sound levels corresponded closely with those reported in human experiments.

Subsequent research expanded upon this theoretical framework. **James C. Lin**, working at the University of Washington, conducted extensive studies examining the dosimetry and physiological parameters associated with microwave hearing. Lin's work helped establish the relationship between absorbed microwave energy and the resulting acoustic pressure within the head.

These studies confirmed several important characteristics of the phenomenon. First, the microwave auditory effect depends strongly on **pulsed radiation** rather than continuous-wave exposure. Continuous microwave radiation primarily produces heating, whereas pulsed radiation produces rapid temperature changes that generate acoustic waves.

Second, the effect occurs within specific ranges of pulse duration and repetition frequency. Experiments demonstrated that pulses lasting between approximately **1 and 100 microseconds** were particularly effective at producing perceptible auditory sensations.

Finally, the total energy involved is extremely small. The energy required to generate a perceptible microwave auditory signal is far below the levels that would cause tissue damage or significant heating. This finding was important for evaluating potential health risks associated with RF exposure.

By the mid-1970s, the thermoelastic mechanism had become widely accepted as the primary explanation for microwave hearing. Although research continued to refine the details of the phenomenon, the fundamental physics underlying the effect was largely understood.

The scientific clarification of this mechanism also influenced discussions regarding the possible technological applications of microwave auditory phenomena. Some researchers speculated that modulated microwave pulses might be capable of transmitting information directly to the human auditory system. Experimental demonstrations suggested that simple signals could indeed be perceived.

Nevertheless, the practical limitations of such approaches quickly became apparent. The power densities required to transmit complex speech signals approached levels that exceeded established safety guidelines. As a result, most investigators concluded that large-scale communication applications were unlikely.

Despite these limitations, the microwave auditory effect remained a scientifically intriguing example of the complex ways in which electromagnetic radiation can interact with biological systems.

The next phase of research would take place within the broader geopolitical context of the Cold War, where concerns about microwave exposure and foreign technological capabilities led to a series of government-sponsored investigations.

Chapter 4

U.S. Cold War Microwave Bioeffects Programs

During the Cold War, scientific research into microwave bioeffects acquired strategic significance. The rapid development of radar systems, electronic surveillance technologies, and satellite communications created new environments in which military personnel and technical staff could be exposed to radiofrequency radiation.

At the same time, intelligence agencies became increasingly concerned about the possibility that adversarial nations might investigate the biological effects of microwave radiation for military purposes. These concerns prompted several government programs aimed at understanding the physiological and behavioral impacts of RF exposure.

One of the most frequently discussed initiatives was **Project Pandora**, a research effort initiated by the United States government during the 1960s. The project was partly motivated by reports that microwave radiation had been detected at the U.S. Embassy in Moscow. Intelligence officials sought to determine whether such exposure might produce biological effects in embassy personnel.

Project Pandora involved collaboration between several institutions, including:

- the Department of Defense
- the Central Intelligence Agency
- biomedical laboratories affiliated with military research facilities

Researchers investigated a wide range of potential effects, including:

- neurological responses
- behavioral changes
- auditory perception

- cognitive performance

Although some experiments examined microwave auditory phenomena, the primary focus of the program was broader RF bioeffects research rather than the Frey effect specifically.

Parallel investigations were conducted at the **Naval Medical Research Institute (NMRI)**. NMRI played a crucial role in compiling and cataloging scientific literature related to microwave radiation and biological systems. Under the direction of **Zorach R. Glaser**, the institute produced extensive bibliographies documenting hundreds of studies on RF exposure.

These compilations became an important resource for scientists and policymakers attempting to understand the state of knowledge regarding microwave bioeffects.

Other research programs were conducted by the **U.S. Air Force** and by laboratories associated with the **Walter Reed Army Institute of Research**. At Walter Reed, investigators explored the behavioral and perceptual effects of microwave exposure under controlled laboratory conditions.

Among the experiments reported in the open scientific literature were studies described by **Don R. Justesen**, who published an article titled *Microwaves and Behavior* in the journal *American Psychologist* in 1975. The article discussed research involving pulsed microwave signals capable of producing auditory sensations in experimental subjects.

Some of the most widely discussed experiments from this period involved the work of **Joseph C. Sharp** and **Mark Grove**, who reportedly demonstrated that modulated microwave signals could be perceived as simple speech-like sounds.

The Cold War research programs significantly expanded scientific understanding of microwave bioeffects. They also contributed to the development of safety guidelines governing occupational exposure to RF radiation.

By the late 1970s, the combination of theoretical work on thermoelastic mechanisms and experimental studies in laboratory settings had established the microwave auditory effect as a well-characterized physical phenomenon.

Chapter 5

Speech, Morse Code, and “Receiverless” Communication

By 1975, the experimental literature on **microwave-induced auditory perception** had reached a level of refinement that allowed not only theories of sensation but also demonstrations of active information transfer. **Don R. Justesen’s “Microwaves and Behavior,”** published in *American Psychologist* that year, summarized these efforts and articulated both their physical principles and their **communicative implications**.

At the time, evidence had already challenged the early assumption that water content was essential to the perception of microwave-induced sounds. Materials lacking in water were found to produce **acoustic transduction when exposed to pulsed microwave fields**, reducing the likelihood that a purely thermohydraulic process explained the phenomenon. Nonetheless, Justesen noted that thermoacoustic conversion—where rapid heating creates mechanical pressure waves—continued to provide the most plausible basis for the auditory response. Crucially, simple heating was not sufficient; perception depended on the rate of thermal change. This requirement pointed to an underlying **thermodynamic mechanism**.

Experiments by Frey and Messenger (1973), later confirmed by Guy, Chou, Lin, and Christensen (1975), established that the **auditory perception depended on the rise time of the pulse**. Microwaves with a slow rise time failed to elicit an auditory response, but when the pulse rose sharply—effectively forming a **square wave at the leading edge of its envelope**—the sensation of sound was clearly produced. In technical terms, the first derivative of the waveform, or its rate of change, determines perceptibility. This insight not only confirmed the thermoelastic interpretation but also implied that **information could be encoded within such pulsed energy**, enabling a **primitive form of microwave communication**.

Justesen described two striking demonstrations that illustrated this capability.

In the first, Arthur W Guy, a skilled telegrapher, devised an experiment with his father, a retired railroad operator. Each press and release of a telegraph key triggered a brief pulse of microwave energy directed toward Guy's own head. Through this setup, he was able to **receive and interpret complex messages** transmitted by his father using the Continental Morse Code, demonstrating that microwave pulses could carry symbolic information directly to a listener **without any conventional receiving equipment**.

The second experiment, conducted by Joseph C. Sharp and Mark Grove at the Walter Reed Army Institute of Research, extended this concept to **speech communication**. The researchers first recorded single-syllable words representing the digits one through ten. The analog electrical forms of these recordings were then processed so that each time the waveform crossed zero in the negative direction, a short microwave pulse was emitted. When Sharp and Grove directed these **voice-modulated microwave signals** toward themselves, they were able to hear and correctly identify nine distinct words. The perceived sounds were reminiscent of speech produced by individuals using electronic larynx devices—mechanical yet intelligible. They did not attempt full sentences, as higher energy densities would have approached the accepted occupational exposure limit of 10 mW/cm². Still, the experiments proved that direct, **“receiverless” radio communication with the human auditory system was feasible within those constraints**.

Justesen observed that this capability possessed **“obvious potentialities, both within and without the clinic,”** yet he cautioned that unresolved safety controversies would inevitably limit future development. In the United States, exposure guidelines of 10 mW/cm² stood an order of magnitude below what many considered the threshold for thermal hazards, based on Schwan's (1970) analyses. Two opposing schools of thought persisted: one accepted Soviet assertions

that chronic exposure to fields as low as 1 mW/cm² might cause long-term pathological effects, such as the ocular lesions reported by Milton Zaret, while others found no conclusive evidence for such nonthermal harm. The Soviet occupational limit of 10 µW/cm², by contrast, was three orders of magnitude stricter, reflecting fundamentally different philosophies of biological risk.

Through this synthesis, Justesen placed the **microwave auditory effect** in a broader context—at once a **precise physical phenomenon and a potential medium of information transfer** constrained by human biology and safety regulation. The twin demonstrations by Guy and by Sharp and Grove exemplified the boundary between established bioacoustics and speculative communication: a technically verified pathway of perception that hinted, tantalizingly, at the possibility of **direct electromagnetic speech**.

Chapter 6

The Moscow Embassy Signal

One of the most widely discussed microwave exposure incidents of the Cold War occurred at the United States Embassy in Moscow. Beginning in the early 1950s, U.S. officials detected microwave radiation directed toward portions of the embassy building. The phenomenon became known as the **Moscow Signal**.

The signal was first identified in 1953 during routine technical monitoring of the embassy environment. Engineers discovered that microwave radiation in the **2.5–4 GHz range** was being directed toward the upper floors of the building. Measurements indicated power densities on the order of a few **microwatts per square centimeter**, significantly below levels typically associated with biological heating.

The discovery generated concern within the U.S. government, particularly because the signal appeared to originate from Soviet-controlled buildings located near the embassy. Intelligence agencies sought to determine both the purpose of the irradiation and the potential health implications for embassy personnel.

Investigations were conducted under several classified programs, including the research initiative later known as **Project Pandora**. Scientists examined the characteristics of the signal, its possible sources, and its potential physiological effects.

Measurements conducted over several years revealed that the radiation was **continuous-wave rather than pulsed**. This distinction was significant because the microwave auditory effect identified in laboratory experiments required pulsed radiation to produce perceptible auditory

sensations. Continuous-wave signals primarily produce thermal effects rather than acoustic pressure waves.

Further analysis suggested that the signal's primary purpose was likely related to **electronic surveillance**. One hypothesis proposed that the microwave radiation was being used to power passive listening devices hidden within the embassy structure. Another explanation suggested that the signal may have been intended to interfere with or probe communications equipment.

Medical monitoring of embassy personnel was conducted to evaluate possible health effects. Although some individuals reported health concerns, investigators did not identify consistent evidence linking the microwave exposure to significant medical conditions.

By the mid-1970s, the consensus among most scientific investigators was that the Moscow Signal did **not represent a directed biological attack** and did not involve the pulsed radiation necessary to produce microwave auditory effects. Instead, the incident was interpreted primarily as an intelligence-related surveillance operation conducted within the broader context of Cold War espionage.

Nevertheless, the Moscow Signal played an important role in stimulating research into microwave bioeffects. The episode prompted governments to fund studies examining the biological impacts of radiofrequency radiation, thereby accelerating the development of the scientific field of **bioelectromagnetics**.

Chapter 7

Soviet and Eastern Bloc RF Bioeffects Research

While microwave bioeffects research expanded in the United States during the Cold War, similar investigations were conducted in the Soviet Union and other Eastern Bloc countries. Soviet scientists devoted considerable effort to studying the biological consequences of long-term exposure to radiofrequency radiation.

Soviet research programs differed in several respects from those conducted in Western laboratories. Rather than focusing primarily on acute thermal effects, Soviet investigators emphasized the possibility that **low-level microwave radiation might produce non-thermal physiological changes**.

This approach led Soviet scientists to adopt exposure limits that were considerably more conservative than those used in the United States. Soviet occupational guidelines often permitted microwave exposure levels several orders of magnitude lower than American standards.

Many Soviet studies examined workers employed in radar installations, communications facilities, and electronic manufacturing environments. Researchers reported a variety of symptoms associated with chronic microwave exposure, including:

- headaches
- fatigue
- dizziness
- irritability
- sleep disturbances

The collection of symptoms was sometimes referred to as **microwave sickness** or **neurasthenia** in Soviet medical literature. Western scientists often interpreted these reports cautiously, noting that many of the symptoms were non-specific and could arise from numerous environmental or psychological factors.

In contrast to Western research on the microwave auditory effect, Soviet investigations rarely focused on auditory perception phenomena. Most Soviet publications addressed broader physiological responses to RF exposure rather than the specific mechanism of microwave hearing.

One notable exception involved the work of **V. V. Tyazhelov**, who in 1979 conducted experiments involving high-power microwave exposure within a **waveguide system**. His work was called “Some Peculiarities of Auditory Sensations Evoked by Pulsed Microwave Fields” and was featured in *Radio Science*. Tyazhelov reported that test subjects exposed to pulsed microwave radiation within the waveguide environment perceived auditory sensations consistent with microwave hearing leading him to agree with the thermoacoustic explanation.

However, this experiment appears to have been an isolated investigation rather than part of a sustained Soviet research program on the microwave auditory effect.

Overall, Soviet research on RF bioeffects emphasized occupational health and long-term exposure considerations. Although the Soviet scientific literature contained numerous reports of physiological responses to microwave radiation, it did not produce a large body of experimental work focused specifically on microwave auditory perception.

Chapter 8

Academic Bioelectromagnetics Laboratories (1960s–1980s)

Following the discovery of the microwave auditory effect and the development of the thermoelastic theoretical framework, research into RF bioeffects increasingly moved into academic laboratories. Universities provided environments in which controlled experiments could be conducted using increasingly sophisticated instrumentation.

Among the most important research centers during this period was the **University of Washington**, where a group of investigators conducted extensive studies on microwave auditory perception and related bioelectromagnetic phenomena.

The laboratory led by **Arthur W. Guy** became one of the principal centers of microwave bioeffects research in the United States. Guy and his colleagues investigated the thresholds at which microwave pulses produced audible sensations in both human and animal subjects.

Working alongside Guy were several researchers who would become prominent figures in the emerging field of bioelectromagnetics. **James C. Lin** conducted experiments examining the dosimetric parameters associated with microwave hearing, analyzing how pulse duration, frequency, and power density influenced the perception of sound.

Another key contributor was **Chung-Kwang Chou**, whose work helped clarify the relationship between microwave exposure and auditory perception thresholds. Chou also participated in experiments examining the physiological responses of laboratory animals exposed to RF radiation.

The research conducted at the University of Washington played an important role in establishing experimental standards for studying microwave auditory phenomena. Investigators developed specialized exposure systems capable of delivering precisely controlled microwave pulses while monitoring biological responses.

In addition to auditory perception experiments, these laboratories conducted studies on:

- tissue heating and absorption
- RF dosimetry
- cochlear microphonics
- behavioral responses to electromagnetic exposure

The results of these experiments contributed to the development of safety standards governing exposure to radiofrequency radiation. As microwave technologies expanded into

telecommunications, satellite systems, and consumer electronics, understanding the biological effects of RF fields became increasingly important.

Academic research during this period helped transform microwave bioeffects from a relatively obscure phenomenon into a recognized area of interdisciplinary scientific inquiry.

Chapter 9

The Researchers and Institutions of Microwave Auditory Research

The scientific study of microwave auditory phenomena was shaped by a relatively small but influential network of researchers working across multiple institutions. The interdisciplinary nature of the field brought together physicists, engineers, neuroscientists, and biomedical researchers.

Among the most important contributors was **Allan H. Frey**, whose early experiments demonstrated that pulsed microwave radiation could produce auditory sensations in humans. Frey's work established the experimental foundation upon which subsequent research would build.

At the University of Washington, **Arthur W. Guy**, **James C. Lin**, and **C. K. Chou** formed one of the most productive research groups investigating microwave auditory perception. Their experiments refined measurement techniques and clarified the relationship between microwave exposure parameters and perceived sound intensity.

The theoretical explanation for microwave hearing was significantly advanced by **Kenneth R. Foster** and **Edward D. Finch**, whose 1974 *Science* paper provided strong evidence supporting the thermoelastic mechanism.

Physicist **Richard M. White** contributed essential theoretical groundwork through his analysis of elastic waves generated by rapid thermal expansion. White's work provided the physical basis for understanding how microwave pulses could produce acoustic pressure waves in biological tissue.

Other important contributors included **Omar P. Gandhi**, whose research on RF dosimetry helped quantify the absorption of electromagnetic energy in biological systems.

Government laboratories also played a role in advancing research. At the **Naval Medical Research Institute**, **Zorach R. Glaser** compiled extensive bibliographies documenting hundreds of studies related to microwave bioeffects.

At the **Walter Reed Army Institute of Research**, experiments involving microwave-induced auditory perception were conducted in behavioral research settings.

Taken together, these scientists and institutions formed the intellectual foundation of microwave auditory research. Their work established the theoretical, experimental, and dosimetric frameworks that continue to inform contemporary discussions of RF bioeffects.

Part II

Present – Havana Syndrome and Contemporary Debate

Chapter 10

Unexplained Health Incidents and Havana Syndrome

In late 2016, several members of the United States diplomatic mission in Havana, Cuba reported unusual health symptoms following what they described as sudden sensory events. These reports marked the beginning of what would later become known as **Havana Syndrome**, a term used to describe a series of unexplained health incidents affecting diplomatic, intelligence, and government personnel stationed abroad.

The initial cases involved individuals who reported hearing unusual sounds or experiencing sensations such as pressure within the head while inside their residences or hotel rooms. In some instances, the reported events were accompanied by acute symptoms including dizziness, nausea, headaches, and disorientation.

Medical evaluations conducted in the United States identified a range of neurological and vestibular symptoms among some of the affected individuals. Researchers examining the cases noted that several patients exhibited signs consistent with **balance disorders, cognitive difficulties, and persistent headaches**. These findings raised concerns within the U.S. government that the incidents might represent a previously unknown environmental exposure.

The unusual nature of the reported symptoms quickly attracted attention from both scientific researchers and intelligence agencies. Some investigators suggested that the symptoms might be linked to **directed energy exposure**, including pulsed radiofrequency radiation similar to that used in historical microwave auditory experiments.

The hypothesis emerged partly because several of the early reports described the perception of sound without an identifiable acoustic source. In a few cases, individuals described hearing buzzing or clicking sounds immediately before experiencing physical symptoms.

Because such sensations resembled descriptions associated with the microwave auditory effect, comparisons were drawn between the Havana incidents and earlier research on microwave hearing.

As reports continued to emerge from diplomatic personnel stationed in other countries, the issue became a subject of intense investigation by multiple government agencies. The State Department, the Central Intelligence Agency, the Department of Defense, and the National Institutes of Health all conducted inquiries aimed at determining the cause of the reported symptoms.

At the same time, the incidents became the focus of considerable media attention. News organizations described the phenomenon as a potential **“sonic attack”** or **“directed energy weapon,”** terms that captured public interest.

By the late 2010s, Havana Syndrome had evolved from a series of medical reports into a major international policy issue. Governments sought to determine whether the incidents represented environmental exposures, technological interference, psychological stress, or some combination of factors.

Despite extensive investigations, the cause of the reported symptoms remained uncertain.

Chapter 11

Symptom Patterns Across Historical Contexts

In evaluating the Havana Syndrome reports, researchers attempted to determine whether the symptoms described by affected individuals corresponded with known biological responses to radiofrequency radiation. This effort involved comparing contemporary medical reports with historical accounts of microwave exposure.

The microwave auditory effect documented during the 1960s and 1970s produced a relatively specific set of perceptual experiences. Subjects exposed to pulsed microwave radiation typically reported hearing **brief clicks, buzzing sounds, or hissing noises**. These sensations occurred without external sound waves and were interpreted by the brain as auditory signals generated internally.

Importantly, the microwave auditory effect itself did **not normally produce lasting neurological symptoms**. The perceived sounds ceased when the microwave pulses stopped, and experimental subjects generally did not report persistent health effects.

By contrast, the symptoms reported in Havana Syndrome cases often extended beyond transient auditory perceptions. Many affected individuals described **longer-term neurological and vestibular symptoms**, including:

- balance disturbances
- difficulty concentrating
- memory impairment
- chronic headaches
- sensitivity to light and sound

These extra symptoms more closely resembled forms of traumatic brain injury or vestibular dysfunction than the temporary auditory sensations associated with microwave hearing.

Researchers also examined historical reports from radar technicians and workers exposed to microwave radiation in occupational settings. Some Soviet studies had described clusters of symptoms referred to as **microwave sickness**, including fatigue, headaches, and irritability. However, these reports were based largely on observational studies rather than controlled experiments.

The differences between microwave auditory experiments and Havana Syndrome reports complicated attempts to establish a direct connection between the two phenomena. Although some aspects of the reported events appeared superficially similar, the overall clinical presentations differed in important ways.

As a result, scientists approached the comparison cautiously. While pulsed microwave radiation can produce certain auditory sensations, there was limited evidence that such exposures could explain the full range of symptoms described in Havana Syndrome cases.

The question therefore remained open: whether the modern incidents represented a previously unrecognized environmental exposure, a combination of physiological and psychological factors, or an entirely different mechanism.

Chapter 12

Official Assessments and Intelligence Community Findings

In response to the growing number of reports, several government bodies initiated formal investigations into the unexplained health incidents. These inquiries sought to determine whether the events represented deliberate attacks, environmental hazards, or other causes.

One of the most influential scientific evaluations was conducted by the **National Academies of Sciences, Engineering, and Medicine**, which published a report in 2020 examining the available medical and technical evidence. The committee concluded that **directed pulsed radiofrequency energy was a plausible mechanism** capable of producing some of the symptoms described in certain cases.

However, the report emphasized that the evidence was limited and did not demonstrate that such exposures had actually occurred. The committee noted that other explanations, including medical conditions or environmental factors, could not be ruled out.

Subsequent investigations by intelligence agencies reached more skeptical conclusions. Reviews conducted by the **Office of the Director of National Intelligence (ODNI)** and other agencies assessed hundreds of reported incidents worldwide.

By 2023, intelligence assessments indicated that it was **unlikely that a foreign adversary was responsible for a coordinated campaign using directed energy technology**. Analysts found no consistent technical evidence supporting the existence of such attacks.

Medical research conducted by the **National Institutes of Health (NIH)** also examined neurological imaging data from individuals reporting Havana Syndrome symptoms. Although some abnormalities were observed in certain cases, researchers did not identify a consistent biological marker that could explain the phenomenon.

The combination of scientific uncertainty and conflicting interpretations contributed to ongoing debate. Some investigators continued to explore the possibility of electromagnetic exposures, while others suggested that psychological stress, environmental factors, or preexisting medical conditions might account for the reported symptoms.

Despite years of investigation, the underlying cause of the incidents remained unresolved.

Chapter 13

Media Narratives and Public Perceptions

The public understanding of Havana Syndrome has been shaped heavily by media coverage. News reports describing unexplained health incidents among diplomatic personnel quickly captured public attention, particularly when the possibility of novel technological weapons was raised.

Several major media organizations—including **NBC News**, **BBC News**, and **CBS's 60 Minutes**—produced investigative segments examining the phenomenon. These reports often highlighted parallels between Havana Syndrome and historical research on microwave auditory effects.

Scientific researchers generally emphasized that the microwave auditory effect, although well documented, involves specific exposure conditions and the energy levels required to produce auditory sensations are typically very low therefore unlikely to cause lasting neurological damage.

Nevertheless, the association between Havana Syndrome and microwave technologies remained a persistent theme in public discourse. The historical existence of Cold War microwave research programs provided a narrative framework that made such explanations appear plausible to many observers.

The resulting mixture of scientific uncertainty, geopolitical tension, and media attention transformed Havana Syndrome into a widely debated phenomenon at the intersection of science, intelligence, and public policy.

Understanding this intersection requires careful distinction between established scientific findings and interpretations that extend beyond the available evidence.

Chapter 14

Technical Foundations: Dosimetry, Parameters, and Exposure

Understanding microwave auditory phenomena requires careful analysis of the physical parameters governing electromagnetic exposure. Unlike conventional sound waves, which propagate through air, microwave radiation interacts with biological tissue through electromagnetic absorption.

When microwave radiation encounters the human body, part of the energy is absorbed and converted into heat. The rate at which this energy is absorbed is quantified using a parameter known as the **Specific Absorption Rate (SAR)**.

SAR measures the amount of electromagnetic energy absorbed per unit mass of tissue and is typically expressed in **watts per kilogram (W/kg)**. In microwave auditory experiments, the energy delivered during each pulse is extremely small, producing only microscopic temperature changes.

The microwave auditory effect occurs when pulsed microwave radiation generates **rapid temperature changes within tissue**. Even a temperature increase as small as **10^{-6} degrees Celsius** can produce a pressure wave if it occurs quickly enough. These pressure waves propagate through the skull and stimulate the cochlea.

Experimental research has identified several key parameters influencing the effect.

Frequency

Microwave auditory experiments have typically used frequencies between **300 MHz and 3 GHz**, which correspond to wavelengths capable of penetrating biological tissue efficiently.

Pulse Duration

Pulse durations between **1 and 100 microseconds** are particularly effective at generating thermoelastic pressure waves. Short pulses produce rapid heating that leads to mechanical expansion.

Repetition Rate

The repetition frequency of the pulses determines the perceived sound characteristics. Repetition rates between **50 and 400 pulses per second** can produce buzzing or tonal sensations.

Energy Per Pulse

The total energy required to generate an audible microwave signal is relatively small. Typical experimental exposures correspond to **1–10 millijoules per kilogram per pulse**, well below levels associated with tissue damage.

These parameters illustrate why the microwave auditory effect is fundamentally different from thermal microwave heating. Instead of producing sustained temperature increases, the phenomenon depends on rapid, transient temperature changes.

Researchers in the field of **RF dosimetry** have developed sophisticated models to predict how electromagnetic energy is absorbed in different parts of the human body. Scientists such as **Omar P. Gandhi** have contributed extensively to computational modeling techniques used to estimate SAR distributions within biological tissues.

These models play an important role in establishing safety guidelines for telecommunications technologies. Modern exposure limits used for devices such as mobile phones are based partly on the understanding of RF absorption developed through decades of bioelectromagnetics research.

Chapter 15

Scientific Synthesis and Unresolved Questions

After more than sixty years of research, the microwave auditory effect remains one of the most intriguing examples of electromagnetic interaction with biological systems. The phenomenon illustrates how pulsed electromagnetic energy can produce sensory experiences through purely physical mechanisms.

The basic scientific explanation for microwave hearing is now widely accepted. The thermoelastic mechanism provides a coherent theoretical framework supported by experimental data and computational modeling. Under appropriate conditions, pulsed microwave radiation can generate acoustic pressure waves within biological tissue that stimulate the auditory system.

However, the broader implications of microwave bioeffects research continue to generate discussion. Questions remain regarding the potential physiological effects of long-term RF exposure, particularly as modern telecommunications technologies introduce new sources of electromagnetic radiation into everyday environments.

The controversy surrounding Havana Syndrome has further complicated public understanding of microwave bioeffects. Although historical research demonstrates that microwave radiation can produce auditory sensations, the connection between these experiments and modern unexplained health incidents remains uncertain.

Scientific investigations have not produced consistent evidence supporting the existence of directed microwave attacks against diplomatic personnel. At the same time, the absence of definitive explanations for some reported symptoms continues to motivate further research.

The history of microwave auditory research highlights the importance of careful scientific investigation when evaluating unusual phenomena. Many early observations that initially appeared mysterious were eventually explained through advances in physics and biomedical science.

Future research may continue to refine our understanding of how electromagnetic radiation interacts with biological systems. New experimental methods, computational models, and

medical imaging techniques may provide further insight into both the capabilities and limitations of radiofrequency technologies.

Ultimately, the microwave auditory effect stands as a reminder that even familiar physical forces can produce unexpected interactions when applied under novel conditions.

Recent Investigative Claims (2026)

In March 2026, the television program 60 Minutes broadcast an investigative report describing claims that U.S. authorities had obtained a portable microwave device from a Russian criminal network during a covert operation. Sources cited in the report said the device was capable of producing rapidly pulsed electromagnetic signals and could operate covertly through walls without producing audible sound or visible heat.

According to the report, the device had been tested in a U.S. military laboratory, where some of the physiological effects observed in animal experiments were described as resembling symptoms reported in cases of Havana Syndrome. The report also noted that the device could be small enough to be carried by an individual and programmable for different pulse patterns, suggesting a potential capability for directed radio-frequency exposure.

At the same time, the investigation acknowledged that no definitive evidence has established that such a device was used in any confirmed Havana Syndrome incident, and previous intelligence community reviews have stated that a coordinated **foreign campaign** using directed-energy technology remains **unlikely**.

The report nevertheless illustrates how historical microwave auditory research continues to influence interpretations of modern unexplained health incidents, particularly when pulsed radio-frequency technologies are discussed in intelligence and media narratives.

Appendices

Appendix A – Extended Historical Timeline (1940–2026)

- 1940s — Development of microwave radar systems during World War II
- 1953 — Microwave radiation detected at U.S. Embassy in Moscow
- 1961–1962 — Allan Frey publishes microwave auditory experiments
- 1963 — Richard White publishes thermoelastic wave theory
- 1970s — University of Washington MAE research program
- 1974 — Foster & Finch publish thermoelastic explanation in *Science*
- 1975 — Justesen Documents Sharp & Grove transmit speech at Walter Reed Army Institute

Research Center

2016 — First Havana Syndrome reports in Cuba

2020 — National Academies report on unexplained health incidents

2023–2025 — Intelligence assessments find no evidence of foreign attack

Appendix B – Researcher and Institution Index

Allan H. Frey

Arthur W. Guy

James C. Lin

C. K. Chou

Kenneth R. Foster

Edward D. Finch

Richard M. White

Don R. Justesen

Joseph C. Sharp

Mark Grove

Omar P. Gandhi

Zorach R. Glaser

Appendix C – Consolidated Bibliography

Frey, A. H. (1962). Human auditory system response to modulated electromagnetic energy. *Journal of Applied Physiology*.

Glaser, Z. R. (1971). Bibliography of reported biological phenomena attributed to microwave radiation.

Foster, K. R., & Finch, E. D. (1974). Microwave hearing: Evidence for thermoacoustic auditory stimulation. *Science*.

Justesen, D. R. (1975). Microwaves and Behavior. *American Psychologist* March 1975.

Lin, J. C. (1978). *Microwave Auditory Effects and Applications*.

National Academies of Sciences (2020). *Assessment of illness in U.S. government personnel*.

Glossary

Microwave Auditory Effect (MAE) – Perception of sound produced by pulsed microwave radiation.

Specific Absorption Rate (SAR) – Measure of electromagnetic energy absorbed by biological tissue.

Thermoelastic Expansion – Rapid heating of a material causing mechanical expansion and acoustic waves.

Waveguide – Structure used to guide electromagnetic waves in radar and laboratory systems.

Pulsed RF – Radiofrequency radiation delivered in discrete pulses rather than continuous waves.