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Low-level EMF effects on wildlife and plants: What research tells us about an ecosystem approach

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There is enough evidence to indicate we may be damaging non-human species at ecosystem and biosphere levels across all taxa from rising background levels of anthropogenic non-ionizing electromagnetic fields (EMF) from 0 Hz to 300 GHz. The focus of this Perspective paper is on the unique physiology of non-human species, their extraordinary sensitivity to both natural and anthropogenic EMF, and the likelihood that artificial EMF in the static, extremely low frequency (ELF) and radiofrequency (RF) ranges of the non-ionizing electromagnetic spectrum are capable at very low intensities of adversely affecting both fauna and flora in all species studied. Any existing exposure standards are for humans only; wildlife is unprotected, including within the safety margins of existing guidelines, which are inappropriate for trans-species sensitivities and different non-human physiology. Mechanistic, genotoxic, and potential ecosystem effects are discussed.

KEYWORDS

non-ionizing electromagnetic fields, static/extremely-low frequency electromagnetic fields, radiofrequency radiation, wildlife, electro/magnetoreception, DNA, cryptochromes

Introduction

Contrary to popular opinion, we know a great deal about how non-ionizing electromagnetic fields (EMF) affect non-human species because we have been using animal and plant models in research going back at least to the 1930's (1). Such research may have been conducted with humans in mind but can also be extrapolated to non-human species protection if we choose to apply it that way.

Mice and rats have been the primary animal species used in research, but also rabbits, dogs, cats, chickens, pigs, non-human primates, amphibians, insects, nematodes, various microbes, yeast cells, plants, and others. Effects have been seen in all taxa, in various frequencies, intensities, and exposure parameters. To non-human species, these are highly biologically active exposures, often functioning as stressors. This includes non-ionizing EMF in the static, extremely low frequency (ELF; 0–300 Hz) through the radiofrequency (RF) ranges used in all modern technology between 3 kHz and 300 GHz.

Extrapolations to wildlife from carefully controlled laboratory conditions, however, are difficult to quantify due to myriad variables such as: genetic variation and mobility, weather/climate change, site/region-specific environmental aspects, duration of exposure and variations in movements across habitats, species specialized physical characteristics, animal size, and orientation toward the field source—all of which can confound precise data assessment. Sometimes controlled studies correlate with patterns seen in wildlife, e.g., genetic, behavioral, reproductive, and other effects. Where this is the case, more confidence is possible. But often effects to wildlife manifest in the negative—species simply disappear. Nevertheless, increasing evidence has found effects to different species near communication structures in studies where extrapolations to field exposure have been made (2–9).

In addition, there have been extensive EMF wildlife reviews published between 2003 and 2021 (10–22). Recently, Levitt et al. (23–25) extrapolated to broad ecosystem level effects for the first time, including extensive tables that match rising ambient levels to effects seen at vanishingly low intensities now common in the environment as chronic exposures, and offer policy recommendations based on existing environmental laws.

The measured rising EMF levels in ambient environments (23) certainly elevate concerns, especially with 5G on the horizon using higher frequencies and novel signal characteristics/waveforms that are capable of affecting insects in particular with implications for the entire biome as discussed below. 5G is now increasing as a network platform in many places even as we are trying to figure out how to measure and distinguish its wideband signals from the larger scheme of 3–4G LTE networks with which it interacts. Already some of the unusual aspects of 5G (e.g., significantly higher peak emissions), are distinguishable from the background of other exposures as an environmental factor (26).

Functioning misconceptions and terminology

There are two prevalent misconceptions today about how low-level non-ionzing EMF couples with and affects non-human species: (1) There is no need for environmental concern since exposures as currently regulated are too low to cause effects; and (2) Existing exposure standards for humans are sufficient to cover non-human species too. Neither supposition is accurate.

No radiofrequency (RFR) emission guidelines today take non-human species into consideration, despite constant measured rising background levels in urban, suburban, and rural areas [see Supplement 1 in reference (23)] that are capable of affecting wildlife and plants [see Supplement 3 and 4 in reference (24)]. This includes guideline allowances for RFR (100 kHz-300 GHz) created by the International Commission on Non-ionizing Radiation Protection (ICNIRP) (27), as well as a member organization of the American National Standards Institute (ANSI) called the International Electronics and Electrical Engineers (IEEE) that has written exposure guidelines for frequencies between 0 Hz and 300 GHz (28). Once countries or regulatory agencies, such as the U.S. Federal Communications Commission (FCC) (29), adopt such guidelines, they can become enforceable standards if those entities choose to do so within their statutory authority. The FCC can, and sometimes does, enforce RFR emission standards based partially on IEEE guidelines (For the purposes of this paper, we will refer to recommendations as exposure guidelines as applied to the environment). In addition, ICNIRP and IEEE/FCC only control for short-term acute exposures capable of heating tissue, not the long-term low-level chronic exposures common today for which they say there is not enough evidence to warrant change in recommendations (These authors disagree). They also fail to include important signaling characteristics (29), like modulation with significant biological effects particular to different transmission features (30). Many European countries, as well as Canada and Australia, have traditionally adopted ICNIRP guidelines (sometimes with slight variations) while others, like Switzerland, have adopted more stringent levels (25).

One complexity (among many) regarding writing EMF safety guidelines in general—but especially with wildlife in mind—involves the semantic difference between "emissions" (characteristics of the field at the transmission source) and "exposures" (the characteristics of the field absorbed by an object). ICNIRP/IEEE/FCC have guideline components for both emissions (expressed as a value of radiant energy in space for far-field encounters at some distance from the generating source) and exposures [expressed as a specific absorption rate (SAR) that is also pertinent to near-field exposures such as from cell phones held against the human head]. Emissions, of course, result in exposures; it is just a question of degree. Depending on species and environment, wildlife is capable of experiencing both near- and far-field exposures like humans. Once emissions leave the transmitting source, they are capable of creating broad exposures and becoming a chronic source of pollution. For the purposes of this paper, we will use "emissions" to denote transmission values and "exposures" to denote uncontrolled, unregulated ambient exposures.

There are many things in the environment that can affect how non-ionizing electromagnetic energy is absorbed, including atmospheric moisture and/or particulate content, soil composition, natural and/or artificial obstacles (trees/buildings), and the presence of other waveforms which can augment and/or diminish exposures, among others. Such complexities should not be used as an excuse to do nothing. Writing guidelines for all species is clearly a yeoman's task that will take far more than simply turning the power down; it may take significant electrical and RF re-engineering, alterations in frequency allocation, and societal change too (30).

A current effort to include non-human species in emission guidelines

There is a current effort by the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), which uses the ICNIRP standards, to investigate broad information regarding effects to wildlife (31). ARPANSA, like ICNIRP/IEEE/FCC, has traditionally focused on human exposures with no recognized guidelines specifically addressed to the protection of plants and animals (31). The ARPANSA inquiry's emphasis thus far is on study design, i.e., how to sort research according to predefined inclusion/exclusion criteria, then incorporate the knowledge into "systematic maps" to see if the current human exposure criteria are sufficient to cover wildlife.

While this is a significant undertaking heretofore overlooked by guidelines-setting groups, the described approach may prove little more than a formula to verify the status quo. The defined exclusion criteria will likely eliminate from review most of the salient research on non-human sensitivity to the lowest intensity exposure levels to which many species are exquisitely sensitive at, or near, natural background levels that are clearly far below current guidelines. The resulting data will inevitably be skewed since the lowest level exposure research will be mixed in with controls and essentially disappear into the proposed analysis as a non-exposure, or it may be eliminated from review altogether. Example: the elimination criterion defines study controls as: "Sham exposure, no exposure beyond the background exposure level (which can be assumed to be negligibly low), or exposure at a lower level" (31). Since "lower level" is not defined and many ambient background levels are now artificially high [see Supplement 1 in reference (23)], this may not be the best methodology to quantify real-world field exposures to non-human species, let alone match it to relevant studies. Any true inquiry into EMF wildlife effects must begin from environmental/biological realities, not pre-existing dosimetry perspectives.

Different frequency ranges may adversely affect one species but have no impact on another. ICNIRP/IEEE/FCC's singular focus on heating effects may be particularly insupportable regarding insects, which can reach resonant matches with higher frequencies such as those used in the top ranges of 5G (>6 GHZ) due to insect's reduced size (32, 33). Insects do not dissipate heat and can suffer extreme effects within short periods of exposure even in much lower ranges (<3 GHZ), leading to reproductive problems and death (1). Existing exposure standards may prevent humans from heating effects due to thermo-regulatory mechanisms but not with other species such as insects, small amphibians and reptiles.

Wildlife exposures today are just a question of degree. Many wildlife species constantly traverse varying artificial fields in all environments with many flying species—such as birds, bats, and insects—reaching extremely close proximity to transmission sources to which humans are rarely, if ever, exposed. Some of the highest power density areas, e.g., near broadcast antenna farms, are specifically located away from human populations with the assumption that if wildlife were impacted, they would abandon such sites for more favorable ones. But because of complex avian magnetoreception, RFR-generating infrastructure may be functioning as an attractant instead. Many such exposures may simply damage wildlife and go unnoticed, likely from near-field thermal effects as well as far-field non-thermal effects, among other causes (34–36).

Research on anthropogenic EMF has found non-linear effects that function differently from classic linear dose-response toxicology models. EMF effects may be fundamentally different than thermal effects, possibly working *via* different mechanisms (37). Effects may be more damaging to some species at lower intensities—the exact opposite of how emission guidelines that can become exposure standards are currently written and a primary reason to include the lowest level exposures in new research efforts. Even once pristine wilderness regions are now RFR-exposed environments from ground-based cell networks rimming national parks and wilderness areas, and from the exponential increase in satellites delivering internet connectivity to anywhere on Earth (23).

The true trans-species biological realities of today's exposures are enormously difficult to quantify, given the inherent variables of species differences, macro and microclimate adaptations, mating/migration patterns, and vastly different environments—e.g., aerial, ground-based, and aquatic—all with unique species-specific adaptions and electromagnetic receptor mechanisms. New methodological approaches that take the lowest exposures at ecosystem levels into consideration are needed.

Natural sensitivities vs. manmade EMF

Many non-human species have highly specific vulnerabilities to anthropogenic EMF due to unique physiology that depend upon, and constantly use, the Earth's static geomagnetic fields for seasonal migration/orientation, nest/den building, mating, reproduction, offspring care, food finding, territorial defense, simple daily/seasonal circadian rhythms, and even longevity and survivorship. Electromagnetic perceptual factors include multi-system environmental species-specific mechanisms. Many species have specialized electroreceptor cells and/or magnetoreception abilities pertinent to their environments that far surpass human sensitivity. For instance, many species can sense natural DC magnetic fields in diverse ways including: migratory bird species (38, 39); numerous insect species including honey bees (40, 41); fish (42–47); mammals (48);

bats (49); mollusks (50), and bacteria (51, 52). Some bird species may actually 'see' the Earth's magnetic fields *via* complex magnetoception capabilities (53) located in their eye and beak areas.

As noted in Panagopoulos et al. (54), natural and manmade EMF are significantly and fundamentally different. Unlike natural EMF, all anthropogenic EMF is polarized, meaning it is more biologically active *via* the ability to amplify intensities (called constructive interference) as well as alter cellular charged/polar molecule oscillations into parallel planes in phase with the applied field. This can result in irregular gating in cell membrane ion channels and thereby disrupt the normal cellular electrochemical balance. In other words, manmade EMF can capture, entrain, and manipulate living cells' basic functioning architecture unlike natural EMF with which most living things have evolved. In addition, anthropogenic EMF typically functions at higher intensities for longer durations thereby increasing exposures in frequency ranges that are minimal in the natural environment, introducing signaling characteristics (modulation, phasing, pulsing etc.) that simply do not exist in nature but are now greatly amplified as a novel exposure due to technology. All these factors may account for the myriad biological effects seen in the literature over the last several decades.

Magnetoreception: Mechanisms

There are three primary mechanisms involved with magnetoreception in non-human species:

- An induction process in which weak electrical signals are induced by magnetic stimulation in specialized sensory receptors (55).
- A magnetomechanical method in which localized deposits of single-domain magnetite crystals create signal information interactions (56, 57).
- A specialized-cell model in which radical-pair photoreceptor molecules create dedicated information pathways—an area getting significant research attention today (19, 30, 58–73).

In the induction model, according to Tenforde (57), specialized organs are involved with electrodynamic interactions with weak electromagnetic fields. In aquatic species this is seen in sharks, rays, and skates (elasmobranch fish) with heads that contain jelly-filled canals that have high electrical conductivity called Ampullae of Lorenzini. Small voltage gradients are induced in these canals *via* DC electric fields as low as 0.5 μV/m as these fish swim through the Earth's geomagnetic flux lines. Directional information is provided by the polarity of the induced field in relation to Earth's geomagnetic field. This may be an aqueous environment/species-specific factor as such organs have not been found in birds, insects, or land-based animals (58) although other physiological mechanisms may function in a similar capacity in some land-based species.

Many animals have evolved other special receptor organs. For example, the duck-billed platypus (*Ornithorhynchus anatinus*), a semi-aquatic egg-laying mammal, has thousands of electric sensors on its bill skin that allow for vital information processing in the somatosensory cortex (74). A platypus can detect an electric field of 20 μV/cm (equivalent to that produced by the muscles of a shrimp) *via* these electroreceptors interacting with a mechanoreceptor. Such electroreception is also seen in two aquatic species of monotremes: the long-bill (*Zaglossus bruijni*) and short-bill (*Tachyglossus aculeatus*) echidna. Other electric fish (including elasmobranchs) emit their own electric fields extending several centimeters for location/orientation, food-finding, and defense (75, 76). This unique ability allows electric fish to distinguish subtle differences in electrical properties within its immediate vicinity, including the electric fields of other fish, *via* electroreceptors capable of detecting a field of 5 nV/cm. While such evolutionary perceptual adaptations are extremely efficient and sensitive, they also render such species exceptionally vulnerable to unnatural anthropogenic fields. Some researchers postulate that electro-receptors in fish are a form of alternate touch and communication (77). The primary concern for aquatic species is from AC-ELF exposures from underwater cabling and other technologies, not RF which is of more concern for ground-based and aerial species (24).

The magnetomechanical model involves the naturally occurring iron-based crystal called magnetite (78–80) that has been found in most species studied, often in very different physiological areas. Magnetite-based orientation/interactions are patterned according to the geomagnetic field. Magnetite is highly reactive to external electromagnetic fields—a million times more strongly than any other known magnetic material. The abdominal areas of honey bees, for instance, contain magnetite with complex nerve endings feeding into it and can detect static magnetic field fluctuations as weak as 26 nT against background earth-strength magnetic fields that are much higher (79). They can also sense weak alternating fields at frequencies of 10 and 60 Hz (79). Bees are also affected by RFR as discussed below.

The third mechanistic model involves a complex conversion of electrons (singlet-triplet inter-conversion) and a free-radical-pair reaction in a group of proteins called cryptochromes.

As reviewed in Levitt et al. (24), cryptochromes have been found in the retinas of nocturnal migratory songbirds indicating intricate communication between avian eye and brain for orientation when relying on magnetoreception (38, 39). Cryptochromes were also found to be a critical magnetoreception component in fruit flies (*Drosophila melanogaster*) (81). Some other animals are also known to have retinal cryptochromes (38). Radiofrequency radiation (82) and

oscillating magnetic fields have been reported to disrupt the migratory compass orientation in migratory birds (83). There are also reports of cryptochromes in plants which may account for the effect of EMF on plant growth (66). Cryptochromes are also known to be involved with circadian rhythms (72). Ritz et al. (63) published a review on the theories, plausibility, and complexities of cryptochrome/radical pairs.

Some species rely on combinations of mechanisms, e.g., two mechanisms exist side-by-side in some birds that mediate, as needed, different types of magnetic information. That is what facilitates flight on sunny vs. cloudy days and/or nocturnal flights. Both mechanisms can be easily disrupted (63, 84–86). It is thought that birds can co-process natural DC magnetic information with visual information and are able to distinguish them from each other (87, 88). According to Wiltschko and Wiltschko (88) and Wiltschko et al. (89), the likely mechanism occurs in the higher brain area and eyes *via* radical pair and light-dependent information processing (blue light absorbing photopigment cryptochromes have been found in avian retinas). The avian magnetic compass—an inclination compass—reacts to more than natural magnetic fields. RFR fields in the Larmor frequencies near 1.33 MHz were found to disrupt birds' orientation in an extremely sensitive resonance relationship (24). Radiofrequency radiation in particular may interfere with magnetoreception and be able to disable the avian compass while the exposures remain (4, 84). There are many uncertainties with this area in need of clarification.

Radiofrequency radiation may also affect natural "natal homing behavior"—the astounding ability of some species like sea turtles (90); eels (91); and salmon (42–44), among others—to return to their original birth location to reproduce. The underlying mechanism, though imperfectly understood, involves such species being "imprinted" with the exact location of their birth, likely through geomagnetic configurations, then "remembering" it at reproduction time even when thousands of kilometers away. The local geomagnetic field intensity and inclination angle are somehow impressed on newborns—information later used to return at breeding time. Landler et al. (92) found multiple effects of EMF in turtles that reproduce on land too, e.g., that RFR can alter natural orientation, establish its own orientation, and completely reverse natural orientation. This bellwether study is reason to protect sensitive breeding/nesting grounds from cell towers/transmitters being located nearby.

Different aspects of EMF and molecular mechanisms are likely used in many species and possibly more subtle stimuli as yet defined. The intensity and/or inclination of a stimulus, when combined with the vector of the geomagnetic field, may afford directional information. Avian behavioral studies (93) found birds used both cryptochrome and magnetite in response to a short intense pulsed magnetic field. It was also found that avian orientation was light-dependent and easily disrupted by high-frequency magnetic fields in the MHz range (83) suggesting that along with electrophysiological and histological studies, avian eyes have a radical pair mechanism providing compass-like directional information while magnetite in the upper beak senses magnetic intensity, thus providing positional information. The authors (83), however, pointed out that the songbird magnetic compass can be disrupted by an oscillating 1.403-MHz magnetic field of 2–3 nT—a level that cannot be explained by the radical-pair mechanism.

In 2014, Engles et al. (3) found magnetic noise between 2 kHz and 9 MHz disrupted the magnetic compass orientation of the migratory European Robin (*Erithacus rubecula*) at a vanishingly low level of 0.01 V/m, or 0.0000265 $\mu W/cm^2$ (That frequency range is within AM radio transmission). Similar RFR magnetoreception interference has also been reported in the same species, with broadband being the most detrimental (8), as well as in other species (4).

Another long-distance migratory species—the iconic Monarch butterfly (*Danaus plexippus*) in the U.S.—is known to have magnetite in their antennae (94, 95) and to contain cryptochromes (96, 97). A 1982 study (98) found the head and thorax areas of monarchs contained magnetic materials and a 2014 study (99) found that monarchs' longest fall migration from Canada to wintering grounds in Mexico is assisted by a magnetic compass.

The above information indicates potential adverse effects at ecosystem levels to some avian, aquatic, and insect species from RFR at current ambient levels [see Supplement 1 in reference (23)].

Genetic effects and EMF effects on insects

Despite classic assumptions that non-ionizing radiation cannot directly damage DNA, genotoxic effects have been seen in land-based, aerial, aquatic, and plant species at very low intensity RFR exposures far below ICNIRP/IEEE/FCC guidelines. There are at least 48 papers showing DNA damage after exposure to RFR at <0.4 W/kg [see Supplement 1 in reference (24)]. Genotoxic effects are also seen in animal and plant species that are found exceptionally sensitive to both natural and man-made EMF [also see Supplement 2 in reference (24)]. Insects are of special concern as populations are being decimated globally (24).

At 1.2 MHz range—known as the Larmor frequency—insects demonstrated the strongest effects (100). The Larmor frequency is also related to radical pair resonance and superoxide formation. This indicates that RFR effects are frequency-dependent. 5G and broadband include this range. Extremely low frequency EMF was also found by Shepherd et al. (101) to disrupt the directional sense of honey bees *(Anthophila).*

Depending on insect type and exposure duration, Michaelson and Lin (1) back in 1987 noted sequential insect reactions to RFR (at high intensities): insects first tried to escape,

followed by motor disturbance and coordination problems, including stiffening, immobility, rigidity, and eventually death. At the same field intensity, *D. melanogaster*, for instance, survived longer than 30 min, whereas some tropical insects lived only a few seconds. Also seen were metabolic concentration changes and embryogenesis effects with gastrulation and larval growth being accelerated (102) (Embryogenesis is the period needed for a butterfly to complete metamorphosis). In 1961—in one of the earliest studies to find that pulsing alone is a biologically active exposure—Heller and Mickey (103) discovered that pulsed RFR between 30–60 MHz caused a 10-fold rise in sex-linked recessive mutations. In later studies using *D. melanogaster* models, Panagopoulos et al. (104) found severe effects in early and mid- stage oogenesis when flies were exposed *in vivo* to either GSM 900-MHz or DCS 1,800-MHz radiation from common digital cell phones, at non-thermal intensities for a few minutes per day during the first 6 days of adult life. The decrease in oviposition—as also previously reported by Panagopoulos et al. (105–107)—was hypothesized as due to degeneration of large numbers of egg chambers after DNA fragmentation of constituent cells. This was induced by both GSM and DCS mobile phone radiation. For the first time, induced cell death was documented in all cell types that constitute an egg chamber—including follicle cells, nurse cells, and the oocyte—and in all stages of early and mid-oogenesis from germarium to stage 10, during which programmed cell death does not physiologically occur (The most sensitive developmental stages to electromagnetic stress induced by the GSM and DCS fields were found to be germarium and stages 7–8). These papers, taken collectively, signify serious potential effects from cell phones/infrastructure and WiFi devices to all similar size insect species. Panagopoulos (108) further discussed the subject in an extensive review on genetic effects in 2019.

Ants also react adversely to RFR (109–111). Cammaerts et al. (111) found that memory and association between food sites and visual/olfactory cues in ants (*Myrmica sabuleti*) was significantly inhibited, with memory eventually wiped out altogether, from exposures to GSM-900 MHz signal at 0.0795 $\mu W/cm^2$. A cumulative effect was seen even at very low intensity with subsequent exposure. The exposed colonies' overall condition eventually resembled that of honeybee (*Apis mellifera*) colony collapse disorder. The researchers concluded that exposures common to cell phones/towers and other transmission sources are capable of disastrous effects on a wide range of insects that rely on olfactory and/or visual memory, including bees.

For nearly 100 years, researchers have known that bees have an acute sense of the Earth's DC magnetic fields (40, 112–115) and rely on that perception for survival. Because of bees' outsize pollinator significance to human food supplies, and their current significant population declines, they are a much-studied model for ELF EMF and RFR effects (see below). Early studies were conducted in the ELF ranges (24) and are ongoing. For an excellent review of ELF/RFR-EMF effects to insects, including bees, see Balmori (16) and a recent article by Li et al. (114) for ELF-EMF exposure/developmental defects.

Some RFR effects seen in bees include: significant inhibitory effects on sensory olfactory excitability and short term memory impairment after 24-h WiFi-router exposure (116); induced worker piping—the sound that initiates swarming behavior in colonies, or as a warning/distress signal—that demonstrated 900-MHz GSM is a stressor to bees (117); reduced motor activity and changes in biomolecules in the body (118); reduction of worker bees and reduced egg laying by queens exposed to cell phone radiation (119); reduced hatching and altered pupal development after cell phone radiation exposure (120); decrease in comb weight and delayed return or hive abandonment after exposure to DECT phone radiation (121, 122); changes in carbohydrate, lipid, and protein concentrations in the body with cell phone radiation exposure (123, 124); and increased mortality with exposure to HF (13.56 MHz) and UHF (868 MHz) RFR (125). RFR has also been implicated in colony collapse disorder (117, 126, 127). Most of the above studies were conducted in non-thermal ranges and non-linear effects were often seen, with the lower exposures causing the greater effects.

Insect size, non-linear effects, waveform characteristics, frequencies, and RFR transmission direction/antenna tilt are critical concerns with 5G radiation today due to that technology's extremely complex near- and- far-field ambient exposures in all environments from ubiquitous macro- and micro-cells, as well as increased low Earth orbit satellite networks (23). The range of frequencies used for wireless telecommunication systems will increase up to 120 GHz for 5G from below 6 GHz for 3G, 4GLTE, and WiFi. The shorter wavelengths at such higher frequencies are a far better resonant match with small insects. Both heating and non-heating effects are likely to occur. Flora is also known to be adversely affected by RFR with implications for small cell placement on utility poles near trees [see Supplement 4 in reference (24)].

An alarming study by Thielens et al. (32) computer modeled (as a function of frequency alone) absorbed RFR from 2 GHz to 120 GHz in four different insect types. All insects indicated an increase in frequency-dependent absorbed RFR at and above 6 GHz compared to absorbed RFR below 6 GHz. Computer modeling demonstrated that an upward conversion to frequencies above 6 GHz at just 10% of the incident power density could lead to increased RFR absorption between 3-to-370%. This is a large differential indicating potentially serious consequences to numerous insect species and consequently the entire food web.

In 2020, Thielens et al. (33) investigated western honeybees (*A. mellifera*) with a combination of computer simulations and *in-situ* RFR exposure measurements near bee hives. Five models were exposed to frequencies already carved out for 5G—plane waves from 0.6 GHz to 120 GHz. Frequency simulations quantified averaged absorbed whole-body RFR. Depending on

the specimen, they found the average increased by factors of 16-to-121 when a fixed incident electric field strength increased from 0.6 GHz to 6 GHz. Measurements were also taken near five different locations at 10 beehive sites. Results estimated a realistic absorption rate between 0.1 and 0.7 nW from an average total incident RFR field strength of 0.06 V/m, from which they concluded that an assumed 10% incident power density shift to frequencies higher than 3 GHz would cause increased RFR honeybee absorption between 390 and 570%. 5G involves just such a frequency shift.

The Thielens et al. (32, 33) studies alone raise serious concerns about ambient environmental invertebrate effects at these higher frequency exposures. There is a broad presumption of safety at ICNIRP/IEEE/FCC due to 5G millimeter-waves superficial penetration ability to affect skin tissue in humans. But shallow penetration in humans can equal whole body penetration in insects. This one technology has the ability to create significant holes in the food web with implications throughout the biome, yet no significant environmental reviews have been conducted prior to buildout and to date most emissions criteria adopted in various countries are primarily guidelines without consequence for violation.

Discussion

It is clear that non-human species experience EMF as environmental stressors and biological effects can occur at anthropogenic levels in our present environment. This largely unrecognized variable can conceivably alter delicate ecosystems, arguably including the biosphere where all living organisms are located—and may, in fact, be doing so. Traditionally, other than in small localized situations, e.g., near powerline corridors or broadcast antennas, ELF/RFR-EMF environmental effects have not been of serious concern to regulating authorities. But this subject now requires immediate attention with 5G on the horizon, as well as a reexamination of chronic rising ambient levels across all non-ionizing electromagnetic frequency ranges today.

Investigators have known since the early 1970's how EMF and RF couples with most animal species (128, 129). Given our increasing ambient EMF levels, far more precise understanding of the molecular and cellular processes of electro- and magneto-reception in non-human species is suddenly critical. We may already be overwhelming some species' natural biological sensors that evolved over eons. Electroreception mechanisms, including magneto/electroreceptors, magnetite, and cryptochrome/radical-pairs, enable vast living organisms in all environments to detect the presence of, and immediate changes, in non-ionizing electromagnetic fields at very low intensities across a range of frequencies. Such heightened sensitivities function far beyond human perception and create unique vulnerabilities that can easily be disturbed by novel man-made fields. Since technology changes so fast, no evolutionary adaptation is possible.

Radiofrequency radiation is a form of energetic air pollution and should be regulated as such (25). U.S. law (130) [42 USC § 7602 (g)] defines air pollution as:

"The term "air pollutant" means any air pollution agent or combination of such agents, including any physical, chemical, biological, radioactive (including source material, special nuclear material, and byproduct material) substance or matter which is emitted into or otherwise enters the ambient air. Such term includes any precursors to the formation of any air pollutant, to the extent the Administrator has identified such precursor or precursors for the particular purpose for which the term "air pollutant" is used."

Unlike classic chemical toxicology pollutants in which a culprit can typically be identified and quantified, RFR may function as a "process" pollutant in the air not unlike how endocrine dysruptors function in food and water in which the stressor causes a cascade of unpredictable systemic effects. The stimulus in the RFR analogy would be physical/energetic rather than chemical.

Long-term chronic low-level EMF exposure guidelines, which do not now exist, should be set accordingly for wildlife; mitigation techniques where possible should be developed; full environmental reviews should be conducted prior to the licensing/buildout of major new technologies like 5G; and environmental laws/regulations should be strictly enforced (25). We have a long over-due obligation to consider potential consequences to other species from our current unchecked technophoria—an obligation we have thus far not considered before species go extinct. In the views of these authors, the evidence requiring action is clear.

Data availability statement

The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding author.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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BEFORE THE HEARINGS EXAMINER
FOR THURSTON COUNTY

In the Matter of the Appeal of Chris Nubbe and Alison Baker
On behalf of Deschutes Neighborhood Group, Re: Verizon's August 7, 2018 Applicant's Response to Appellant's Dispositive Motion

No. APPL 18-106835 VE

Declaration of: Albert M. Manville, II, Ph.D., C.W.B. (to be Submitted by Appellant)

I, Albert M. Manville, II, Ph.D., C.W.B., declare as follows:

1. I make this declaration based on my personal knowledge, academic and field training, and professional experience as the former U.S. Fish and Wildlife Service (USFWS or Service) national agency lead on effects to protected migratory birds from human built structures, equipment and radiation. I am over the age of 18 and competent to testify to the matters herein.
2. I am the principal of Wildlife and Habitat Conservation Solutions, LLC, located in Falls Church, Virginia. I have been contracted by the Deschutes Neighborhood Group to analyze and assess likely impacts to migratory birds and other wildlife from the proposed siting of a Verizon Wireless (VW) cellular (cell) Wireless Communications Facility (WCF) near Yelm, Washington.
3. I am employed part-time as an Adjunct Professor for the Krieger School of Arts and Sciences, Advanced Academic Programs, Johns Hopkins University, Washington, DC campus. I retired from the Division of Migratory Bird Management, USFWS, in late June 2014, after working for USFWS for 17 years on avian-structural issues.
4. I submit the following testimony for the record.

I declare under penalty of perjury under the laws of the State of Washington that the foregoing is true and correct.

DATED: 13th of August of 2018, Falls Church, VA

Albert M. Manville, II, Ph.D., C.W.B.

8/13/2018

Testimony of Albert M. Manville, II, Ph.D., C.W.B., and Principal, Wildlife and Habitat Conservation Solutions, LLC, in regard to Applicant's Response to Appellant's Dispositive Motion (August 7, 2018) filed with the Hearings Examiner, Thurston County, for Thurston County Project 2015103966, Re: a Verizon Wireless Cellular (cell) Tower Wireless Communications Facility (WCF) at 16244 Vail Road SE, Yelm, WA 98597. Comments Submitted on Behalf of the Deschutes Neighborhood Group for the record.

Date: August 13, 2018

ISSUES REFUTED BY VERIZON WHICH NEED TO BE CLARIFIED OR CORRECTED FOR THE RECORD

Building Communication Towers Next or Adjacent to Wetlands

Avoiding Risk

Dr. Paul Kerlinger, Verizon's avian risk consultant, continues to dispute the considerable scientific evidence that supports increased risk from placing communication towers next to or adjacent to wetlands. Specifically, *"Applicant will present expert scientific evidence by Paul Kerlinger, Ph.D., based on the bird studies undertaken by the Applicant and Appellant, demonstrating that there will be no significant impacts to any such birds or interference with migratory flyways documented by state or federal agencies. See Attachment 3 (Avian Risk Assessment for the Verizon Wireless Vail Road Wireless Communications Facility, by Dr. Kerlinger, April 13, 2018)."* (Applicant's Response to Appellant's Dispositive Motion, August 7, 2018).

Quite to the contrary, there is substantial and highly credible scientific evidence of risk from human-built structures (e.g., communication towers, power lines, buildings, bridges and other structures) based on decades of research on many species of migratory birds in and around wetlands where many species tend to concentrate (i.e., to breed, nest, fledge, roost, feed, defend territories, stage and migrate). This risk (called a "taking" — i.e., the unpermitted injury, crippling loss and/or death of a protected migratory bird) results from the placement, operation and maintenance of a communication tower, including this proposed tower at 16244 Vail Road SE, Yelm.

On September 14, 2000, USFWS Director Jamie Clark sent a memo to all Service Regional Directors regarding Service Guidance on Siting, Construction Operation and Decommissioning of Communication Towers which Robert Willis and I co-authored for the Service earlier that year. In her memo, she stated that "*... all Service personnel involved in the review of proposed tower sitings and/or evaluation of impacts of towers on migratory birds should use the attached interim guidelines when making recommendations to all companies, license applicants, or licensees proposing new tower sitings. These guidelines were developed by Service personnel from research conducted in several eastern, midwestern and southern States, and have been refined through Regional review. They are based on the best information available at this time, and are the most prudent and effective measures for avoiding bird strikes at towers. We believe they will provide significant protection for migratory birds*" (p. 2 of Director Clark's memo; emphasis added).

Specifically on p. 4 of Director Clark's memo, in Service guideline #4, it was stated that, *"towers should **not** be sited in or near wetlands, other known bird concentration areas (e.g., State or Federal refuges, staging areas, rookeries), in known migratory or daily movement flyways, or in habitat of threatened or endangered species. Towers should **not** be cited in areas with a high incidence of fog, mist, and low ceilings"* (Attachment p. 4 of the Director's memo). In Service guideline #8 the following was recommended: *"If significant numbers of breeding, feeding, or roosting birds are known to habitually use the proposed tower construction site, relocation to an alternate site should be recommended"* (Attachment p. 5 of the Director's memo). To suggest as Dr. Kerlinger does that there will be "*no significant impacts to*

any such birds or interference with migratory flyways documented by state or federal agencies" is preposterous. By implementing these specific guidelines, USFWS believed their use would be key to avoiding or minimizing risk — steps necessary to avoid or minimize "take." As I stated in previous comments rebutting Dr. Kerlinger's risk assessment findings sent to Tony Kantas on May 17, 2018, a **"significant impact"** was agreed to and defined both by independent scientific experts serving on the Communication Tower Working Group which I chaired and by experts within the USFWS's Division of Migratory Bird Management which I represented as **"at least 3 bird deaths/tower/year"** (Manville testimony to Tony Kantas, Thurston County, May 17, 2018:4). Admittedly, this is a small number of annual bird deaths; the concerns, however, are over cumulative (nationwide) impacts resulting in an estimated 7+ million bird deaths/yr. in the U.S.

Revised 2013 USFWS Guidelines.

In 2013, on behalf of the Service, I updated the 2000 interim communication tower guidelines (Manville 2013) to include several additional recommendations based on previous more recent scientific findings on tower lighting (not applicable to the proposed Yelm Road tower), refined suggestions involving avoiding wetlands, buffers for Bald Eagles and other raptors, suggestions for specific types of security lighting, and consultation with members of the Research Subcommittee, Communication Tower Working Group. Most notable are three 2013 guidelines directly applicable to the proposed Vail Road tower. These include:

1. Guideline 4: *"The topography of the proposed tower site and surrounding habitat should be clearly noted, especially in regard to surrounding hills, mountains, mountain passes, ridge lines, rivers, lakes, wetlands, and other habitat types used by raptors, Birds of Conservation Concern, and state and federally listed species, and other birds of concern."*
2. Guideline 5: *"Towers should not be sited in or near wetlands, other known bird concentration areas (e.g., state or federal refuges, staging areas, rookeries, and Important Bird Areas), in known migratory, daily movement flyways, areas of breeding concentration, in habitat of threatened or endangered species, or key habitats of Birds of Conservation Concern (USFWS 2008). Disturbance can result in effects to bird populations which may cumulatively affect their survival. The Service has recommended some disturbance-free buffers, e.g., 0.5 mi around raptor nests during the nesting season, and 1-mi disturbance free buffers for Ferruginous Hawks and Bald Eagles during nesting season* [sic: based on studies] *in Wyoming (FWS WY Ecological Services Field Office, referenced in Manville 2007:23)."*
3. Guideline 9: *"If, prior to tower design, siting and construction, if it has been determined that a significant number of breeding, feeding and roosting birds, especially Birds of Conservation Concern (USFWS 2008), state or federally-listed bird species, and eagles are known to habitually use the proposed tower construction area, relocation to an alternate site is highly recommended."*

Current April 2018 USFWS Tower Guidelines.

The Service just updated the guidelines published in 2013 (Manville 2013) with new recommended best practices for communication towers (USFWS 2018). These include **virtually all** the recommendations published in 2013. Additionally, there is a new section on vegetation management, some new links to online tools for determining bird breeding seasons and professional contacts, and recent FCC and Federal Aviation Administration lighting changes. These guidelines are intended *"to replace all previous recommendations for communication tower construction and operation ... modified and updated from previous versions to incorporate the state of the science..."* (USFWS 2018:1).

Most notable are recommendations for applicants to *"contact the nearest FWS field office; towers should not be sited in or near wetlands, other known bird concentration areas (e.g., state or federal refuges, staging areas, rookeries, and Important Bird Areas; ... towers should avoid wetlands or other known bird concentration areas; ... establish a buffer zone around the nest and no activities will occur within that zone until nestlings have fledged ... (0.5 — 1 mile for hawks and eagles). The buffer should be a distance that does not elicit a flight response by the adult birds and can be 0.5 — 1 mile for hawks and eagles."*

The Service did recommend *"no activities within that* [buffer] *zone until nestlings have fledged"* which would effectively preclude construction, maintenance, and daily operation of the tower until Bald Eagles and other raptors have fledged their young. Bald Eagle nests are "active" (meaning territorial defense, stick placement and nest repair, egg laying, incubation, nestling feeding, and caring for young until chicks are fledged and actually leave the nest — a period that can run from winter into mid-summer depending on nest success, chick loss, and other variables).

Take Homes and Service 2007 Comments to FCC on Effects of Communication Towers to Migratory Birds

Virtually all the aforementioned conditions spelled out in USFWS guidelines in 2000, 2013 and 2018 regarding wetland risk and disturbance apply to the proposed Vail Road tower site. Clearly the Service has recognized for decades that structural risk to birds in or near wetlands is important and should be avoided by not building there and by selecting degraded, more developed areas (e.g., antenna farms, industrial parks, and other degraded areas of low risk to birds — referenced in all 3 sets of guidelines).

In official agency comments I authored submitted to the FCC by USFWS Acting Deputy Director Kenneth Stansell to Louis Peraertz, Esq. of the FCC's Wireless Telecommunications Bureau on February 2, 2007 (Manville 2007: 32 pages), the Service suggested that the FCC adopt our 2000 guidelines as part of an *"environmentally preferred industry standard"* (Manville 2007:25) which FCC did subsequently implement. FCC also used the 2013 guidelines as the "*preferred industry standard.*"

Further, in USFWS comments to FCC, it was suggested that *"We recommend that FCC implement the Service's 2000 voluntary communication tower guidelines into rulemaking. The FCC would be responsible for informing license permit applicants of the guidelines, overseeing implementation of the guidelines, and would not depend on applicants independently contacting the Service for recommendations"* (Manville 2007:26). While FCC did not then nor have they now implemented Service guidelines into rulemaking, FCC strongly encouraged applicants and tower companies to use them, and FCC staff continue to work with Service representatives and tower developers to implement USFWS guidelines as seamlessly as possible today. It remains unclear why Dr. Kerlinger continues to dispute these risk findings and question the agency determinations and actions based on the best scientific evidence available.

Smith Ranch Wetlands Restoration Project

A significant, $1.6 million wetland restoration mitigation effort by the cities of Olympia, Lacey and Yelm was required in the last several years by the State in exchange for the water rights in and surrounding these wetlands. After completion, the floodplain area will essentially become a new, publicly owned wildlife refuge.

It is exciting to note that the Smith Ranch Wetlands Restoration Project continues to be developed and the new wetlands — adjacent to the proposed Verizon cell tower site — are being colonized in astonishingly quick ways by migratory birds and other wildlife. As recently as July 28, 2018, local landowner Alex Foster photo-documented the presence of Great Blue Herons, Gadwalls, Virginia Rails, and several species of upland songbirds using the site as the wetlands are filling. He intends to submit these photos for the hearing record. It is clear these new wetlands are providing important territorial, feeding, nesting, roosting and staging habitats for a growing list of migratory birds. However, increased bird presence will only elevate the risk of collisions with the proposed Verizon cell tower if it is built. It is also important to note that at the emergent wetland marsh around Lake Lawrence, the 2 other adjacent wetlands, and the surrounding woodland habitats, that at least one nesting pair of Bald Eagles (a species of State concern), Vaux's Swift (species of State concern, especially its nesting forested habitat), and a host of other migratory birds are present in and around this wetland area. The proposed Verizon communication tower 156-ft tall will extend ~ 54 ft above the forest canopy. This will only exacerbate collision risk, especially when fog, rain, winds and other inclement weather events impact birds flying at dawn, dusk, migrating at night,

and unable to effectively navigate in poor visibility during the daytime — conditions which frequently occur in and around the emergent wetlands. Additionally, the checkerspot butterfly (Federally Endangered), the Oregon spotted frog (Federally Threatened), and the Puget Oregonian snail (Federally proposed) may be present in the wetlands areas, further elevating construction and operation risks. Verizon has clearly failed to investigate let alone evaluate these growing risks.

Impacts of Non-thermal, Non-ionizing Radiation from Cell Towers on Migratory Birds

Applicant's attorney misrepresented the impacts of radiation on migratory birds by stating that the hearings examiner is preempted from considering issues regarding the *"environmental effects of RF emissions"* (Applicant's Aug. 7, 2018 Response:11), citing the FCC's regulation — based on Section 704 of the 1996 Telecommunications Act (TCA) — implying that these wildlife effects cannot be presented in testimony. While it is true that county, city and state governments have been constrained in some ways by Section 704 of the TCA regarding discussions about radiation effects on human health and safety, there is nothing in the Act or its implementing regulations that prohibit discussion of impacts from radiation on wildlife. In fact, no agency or commission (i.e. FCC) has yet developed any radiation standards for wildlife exposure, including the licensing and regulatory rules and procedures of the FCC. It is also important to note, however, that for human exposures to RF at towers, the FCC has operating rules available to the public. These rules require that power to cell and other broadcast towers must be turned off when workers are on and/or climbing the towers — due to health impacts and safety concerns from the impacts of thermal and non-thermal radiation.

USFWS in coordination with the U.S. Commerce Department's National Telecommunications and Information Administration (NTIA) began a process in 2014 with which I was involved to include impacts from radiation as part of NTIA's National Environmental Policy Act (NEPA) review process, but that effort has since stalled. As I have stated in earlier testimony to Thurston County, impacts from radiation on migratory birds and other wildlife must be evaluated as part of the NEPA review process for cumulative effects analysis. None to date have been performed by Verizon or its consultants. I believe Washington State has similar State NEPA requirements.

While there are many recent published, peer-reviewed studies about impacts from non-thermal radiation on laboratory animals and wildlife — with new findings being published each month — laboratory studies conducted by DiCarlo et al. (2002) are extremely telling. T. Litovitz (2000 pers. comm.) and DiCarlo et al. (2002) irradiated chicken embryos using the standard 915 MHz cell phone frequency at durations of several hours per day. Most striking, they showed that radiation from extremely low levels (0.0001 the level emitted by the average digital cell phone) caused heart attacks and deaths in some embryos while controls were unaffected (DiCarlo et al. 2002). Impacts were based on extremely low, non-thermal effects — now being documented to impact DNA single strands and helices (Manville 2016b). Results of the DiCarlo et al. (2002) study have been replicated by Grigor'ev (2003), Xenos and Magras (2003), and others.

It is important to note that the entire thermal model and all FCC categorical exclusions for all the devices we see today, rests on the incorrect assumption that low-level, non-ionizing non-thermal radiation cannot cause DNA breaks because is it *"so low power"* (B. Levitt and H. Lai, Comments Filed Jointly to FCC, ET Docket No. 13-84, 2013). The evidence to the contrary is clear and growing in laboratory animals and wildlife. The implications — including from this proposed Verizon tower — are very troubling.

While field studies on wildlife, including wild birds, have yet to be conducted in North America, considerable **field research** has been conducted in Europe. For example, in field studies on wild birds in Spain, Balmori (2005) found strong negative correlations between levels of tower-emitted microwave radiation and bird breeding, nesting, roosting and survival in the vicinity of electromagnetic fields. He documented nest and site abandonment, plumage deterioration, locomotion problems, and death in Wood Storks, House Sparrows, Rock Doves, Magpies, Collared Doves, and other species. While these species had his-

torically been documented to roost and nest in these areas, Balmori (2005) did not observe these symptoms prior to construction and operation of the cell phone towers. Results were most strongly negatively correlated to proximity to antennas and Stork recruitment and survival. Twelve nests (40% of his study sample) were located within 200 m of the antennas and never successfully raised any chicks, while only 1 (3.3%), located further than 300 m, never had chicks. Strange behaviors were observed at Stork nesting sites within 100 m of one or several cell tower antennas. Those birds that the main beam impacted directly (i.e., electric field intensity/EFI > 2 V/m) included young that died from unknown causes. Within 100 m, paired adults frequently fought over nest construction sticks and failed to advance the construction of the nests with sticks falling to the ground while nests were being constructed. Balmori (2005) reported that some nests were never completed and the Storks remained passively in front of cellsite antennas. The electric field intensity was higher on nests within 200 m (2.36 ± 0.82 V/m) than on nests further than 300 m (0.53 ± 0.82 V/m). However, the EMF levels, including for nests < 100 m from the antennas, were not intense enough to be classified as thermally active. Power densities need to be at least 10 mW/cm2 to produce tissue heating of even 0.5 C (Bernhardt 1992). These troubling findings raise similar potential concerns over impacts from the Verizon tower.

Balmori and Hallberg (2007) and Everaert and Bauwens (2007) found similar strong negative correlations among male House Sparrows and electromagnetic radiation in their studies. In another review, Balmori (2009) reported health effects to birds which were continuously irradiated. They suffered long-term effects including reduced territorial defense posturing, deterioration of bird health, problems with reproduction, and reduction of useful territories due to habitat deterioration. These same conditions will also be present at the Vail Road site, possibly producing the same effects (i.e., "takes").

There are other potential effects on birds which need to be evaluated before tower siting is permitted. Engels et al. (2014) investigated ***"electromagnetic noise"*** emitted everywhere humans use electronic devices including from cell phones and their towers. While prior to their study on European Robins, no *"noise effect"* had been widely accepted as scientifically proven, the authors in this double-blind experiment were able to show that migratory birds are unable to use their magnetic compass in the presence of urban electromagnetic noise. The magnetic compass is integral to bird movement and migration. Several other more recent scientific studies replicate Engels et al. (2014) findings. The findings clearly demonstrated a non-thermal effect on European Robins and clearly serves as a predictor for effects to other migratory birds including those in North America.

Birds may also be attracted to cell towers, compounding impacts of collisions and radiation. In a cutting-edge study, Beason and Semm (2002) demonstrated that microwave radiation used in cell phones produces non-thermal responses in several types of neurons of the nervous system of Zebra Finches. The brain neurons of anesthetized birds were tested with a 900 MHz carrier, modulated at 217 Hz. Stimulation resulted in changes in the amount of neural activity by more than half of the brain cells with most (76%) of the responding cells increasing their rates of firing by an average 3.5-fold as opposed to controls — a clearly definitive study showing non-thermal effects. The other responding cells exhibited a decrease in their rates of spontaneous activity suggesting potential effects to humans using hand-held cell phones affecting sleep (Borbely et al. 1999). The Beason and Semm (2002) theoretical model could also help explain why birds **may be attracted to cell towers**, an important theoretical premise that they previously hypothesized in regard to Bobolinks (Semm and Beason 1990).

Efficacy of Proposed Bird Hazing Structures on Top of the Monopole Cell Tower

Verizon and its consultants have been attempting to develop an Osprey bird-hazing and nest-deterrent device that would be placed atop the proposed 156-ft. monopole (a so-called "bird-be-gone" nest deterrent structure; Slide 25, Appellant's Dispositive Motion).

As the Service's lead representative serving on the Avian Power Line Interaction Committee (APLIC) for 17 years, as a co-author of the 2005 Service/APLIC Avian Protection Plan Guidelines, co-author of *Sug-*

gested Practices for Avian Protection on Power Lines: State of the Art in 2006 (Edison Electric Institute), co-author of *Reducing Avian Collisions with Power Lines: State of the Art in 2012* (EEI); and recipient of the 2016 Morley Nelson Conservation Service Award by APLIC for my work as a Federal wildlife biologist with the electric utility industry, I have a detailed understanding of which deterrent devices (including on structures other than power poles) work and which do not. These assessments are based on field evaluation, testing, monitoring, and collaboration with other agency and industry colleagues and private vendors.

Migratory birds — including Ospreys, Red-tailed Hawks, Bald Eagles and many songbird species — are very adaptable, and frequently use well-intentioned and well designed deterrent devices for purposes opposite those intended. Based on field evaluation and critique, the vast majority of nesting and perching deterrents do **not**, in fact, work as intended. APLIC presented many "short courses" on Avian Power Line Interactions — generally several each year to which I was invited to present. In our "short course" presentations (e.g., PowerPoint slides) and in its peer-reviewed publications, APLIC purposely included photographs of nest deterrents which completely failed. These, for example, included an Osprey nest on a power pole with plastic spikes (APLIC 2006, Fig. 6.27:128), a Red-tailed Hawk nest on a pole with triangle perch discouragers (APLIC 2006, Fig. 6.25:128), an Osprey nest on a pole with plastic owl intended to haze the birds (APLIC 2006, Fig. 6.26:128), and an Osprey nest on a dead end pole with nest discourager (APLIC 2006, Fig. 6.23:127), among numerous others. A copy of Figures 6.23, 6.25, 6.26 and 6.27 is included in the Appendix of this document.

Based on my professional expertise and opinion, the "bird-be-gone" Osprey nest deterrent will **not** preclude Osprey nesting (these birds are ingenious at making an inhospitable nest structure work for them). Further, even if the structure does deter Osprey, other birds may exploit the platform, possibly even Bald Eagles given their need to exploit the tallest structure in the surrounding wetland. It is highly likely that other raptors, songbirds and other avifauna would also exploit this deterrent for purposes of nesting. Both thermal and non-thermal radiation impacts could affect any nesting birds and their offspring, as well as entanglement problems, all resulting in "takings."

Conclusions and Recommendations

- While the proposed VW WCF is relatively short (156 ft AGL), unguided and unlit (at least on the tower), it will extend approximately 54 ft above the tree canopy, significantly elevating collision risk, especially during nighttime inclement weather events when birds are moving/migrating and during instances of daytime high fog episodes. Inclement weather is a significant issue at the site. Migratory birds have been documented killed by collisions with unlit monopole and lattice towers < 200 ft AGL, sometimes in significant numbers of hundreds of birds/cell tower/night (e.g., W. Evans cited in Manville 2007:7). These are facts documented in the literature, in official agency comments, and by leading scientific experts.

- Tall structures adjacent to and surrounding wetlands create high risk habitats for migratory birds. Asserting that they are not fails to be base findings on scientific fact and on decades of research and action by USFWS and other Federal and State agencies and NGOs to "avoid or minimize take."

- USFWS voluntary communication tower guidelines — including the most recent April 2018 version — have been ignored by Verizon.

- The Smith Ranch Wetlands Restoration Project is turning out to be an incredible success for waterbirds, waterfowl, wading birds, songbirds and others — and it is still being constructed. However, a VW cell tower will only exacerbate risk to these and other birds if allowed to be built adjacent to this new wetland.

- The effects of low level radiation are of growing concern and have not been addressed by Verizon or the County. The effects of radiation from field studies conducted on wild birds near cell towers in Europe are troubling, as are the results from studies on laboratory animals here in North America and elsewhere.

- "Electromagnetic noise" and possible bird-radiation attraction to cell towers needs considerable further investigation — including through NEPA analysis. It was not.

- The "bird-be-gone" nest deterrent device will likely fail, allowing Ospreys, Bald Eagles, hawks, songbirds and other avifauna to exploit the platform — and subsequently be negatively affected by the radiation as a result.

In conclusion, for all the reasons I stated above — including those previously stated on the record in earlier testimony — I recommend that the Thurston County Hearings Examiner reject this VW tower application.

Respectfully submitted,

8/13/2018

Albert M. Manville, II, Ph.D., C.W.B.
Wildlife and Habitat Conservation Solutions, LLC

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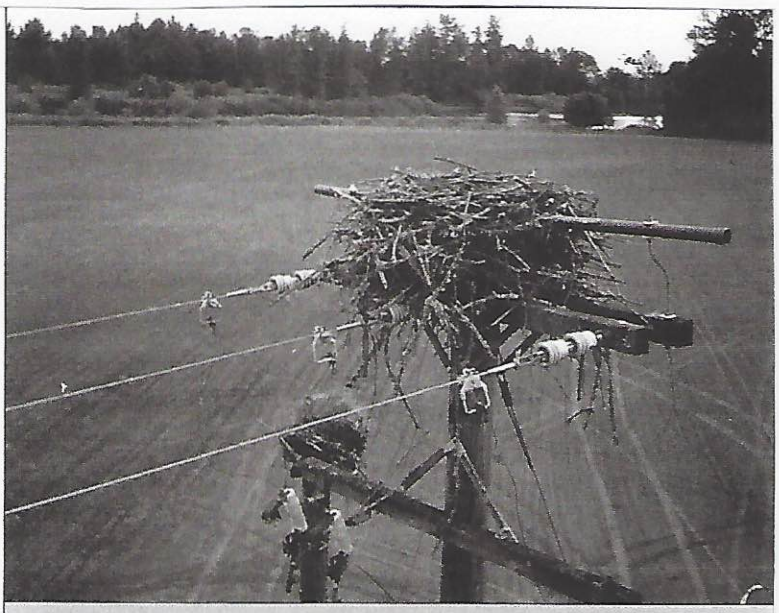
APPENDIX

Osprey and Red-tailed Hawks nesting on power poles with nest and perch deterrents previously installed to discourage bird use — all which failed to work.

Figures 6.23, 6.25, 6.26, and 6.27 (with photo credits included), *Suggested Practices for Avian Protection on Power Lines: the State of the Art in 2006*. Pier Final Project CEC-500-2006-022, Avian Power Line Interaction Committee, Edison Electric Institute and California Energy Commission, Washington, DC and Sacramento, CA: pp. 127-128



© JIM KAISER, USGS

FIGURE 6.23: A segment of plastic pipe was installed on a dead-end pole in Oregon to discourage osprey nesting. However, the osprey pair continued nest construction after the pipe was installed.

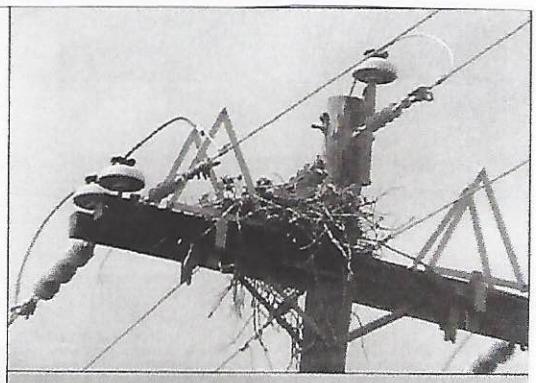


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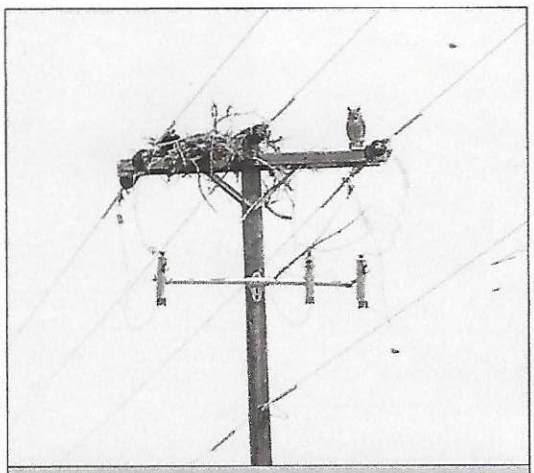
FIGURE 6.25: Red-tailed hawk nest on pole with triangle perch discouragers.



© PACIFICORP

FIGURE 6.26: Osprey nest constructed on pole with plastic owl intended to haze birds.

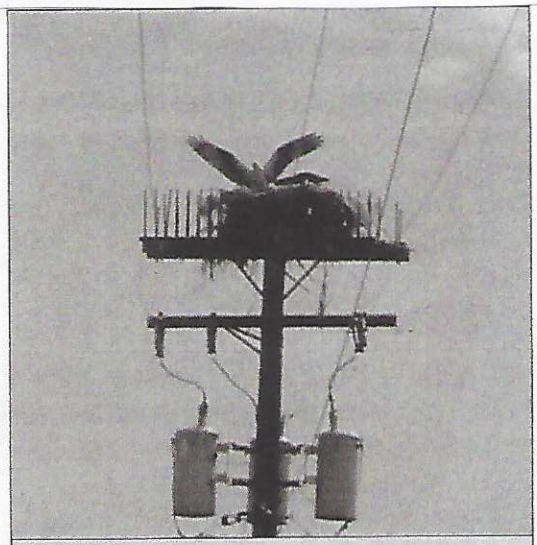


FIGURE 6.27: Osprey nest on pole with plastic spikes.

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Bäume in Hallstadt (2008-2018)

Der Zustand von Bäumen in Hallstadt wurde zwischen Juni 2008 und März 2018 auf 29 Rundgängen dokumentiert. Aus dieser Dokumentation werden 33 Beispiele vorgestellt. Stadtplan mit den Standorten der Bäume und der Mobilfunksendeanlagen S. 39, Standortbescheinigungen tabellarisch S. 40, Inhaltsverzeichnis S. 41.

Im Funkschatten von Gebäuden haben sich Bäume zwischen 2008 und 2017 gut entwickelt.

1 Bahnhofstraße, Walnuss (2008- 2017)

2008	**2010**	**2016**	**2017**
16.10.08 Walnuss (von SW)	22.06.10	08.07.16	06.10.17
Bahnhofstraße			

2 Bahnhofstraße/An der Angelbrücke, Feldahorn (2011-2017)

2011	2014	2016	2017
05.05.11 Feldahorn (von SW)	03.06.14 (von SW)	08.07.16 (von S)	06.10.17 (von S)
Bahnhofstraße/An der Angelbrücke			

Im Strahlungsfeld von Mobilfunksendeanlagen hingegen traten zahlreiche, schwere Baumschäden auf.
Etliche Bäume mussten gefällt werden. Junge Bäume entwickelten sich nicht richtig.
Die Messungen der Leistungsflussdichte wurden mit dem Breitbandmessgerät HF 59B
und der Ultrabreitband-Antenne UBB_G3 (27 MHz-3300 MHz) durchgeführt.

3a Johannesstraße, Nordrand des Friedhofes, Linde (2008-2014)

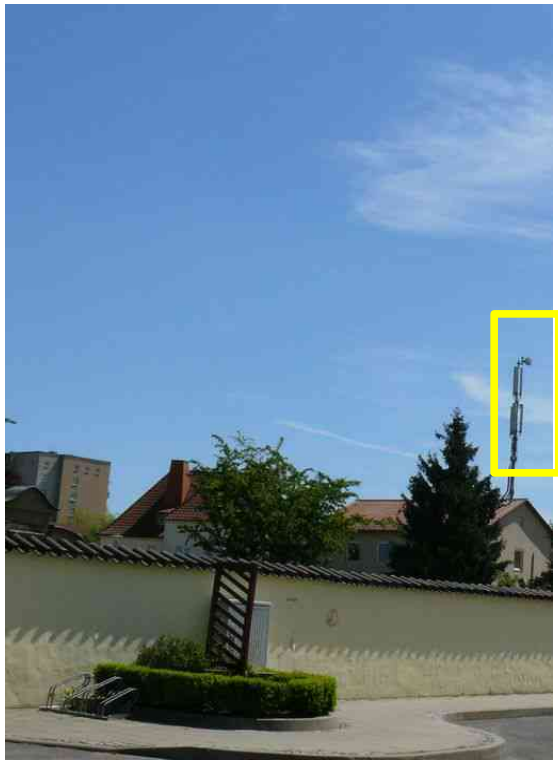
Juni 2008	**Mai 2009**	**2014**
27.06.08 Linde (Blick von N)	07.05.09 Es besteht Sichtverbindung zu der Mobil-	03.06.14
Johannesstraße, Messwert: 5.360 µW/m²	funksendeanlage Landsknechtstr. 23a (Entf. 150 m)	

Auch die östlich und westlich der obigen Linde stehenden Linden zeigten schwere Schäden.

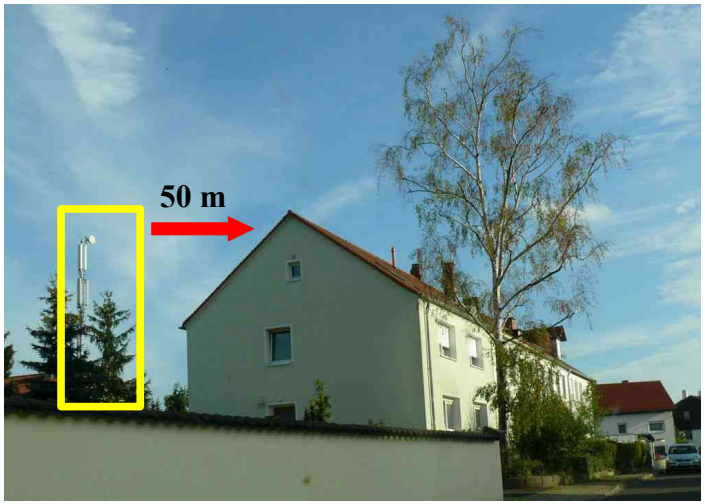
3b Johannesstraße, Nordrand des Friedhofes, zwei Linden (2014-2016)

2014	2016
03.06.14 Zwei Linden (Blick von NW). Die mittlere Linde ist bereits gefällt.	08.07.16 Die beiden geschädigten Linden mussten ebenfalls gefällt werden.
Johannesstraße. Es besteht Sichtverbindung zur Sendeanlage Landsknechtstraße.	

4 Friedhofstraße, Linde (2008-2009)

2008	2009	2016
		
17.08.08 Linde (von NW)	29.09.09	09.05.16
Friedhofstraße	Mobilfunksendeanlage Landsknechtstraße (Entfernung: 80 m)	Fällung bereits mehrere Jahre vorher

5 Friedhofstraße, Birke (2008-2017)

2008	2015	2017
		
27.06.08 Birke, Nadelbäume (von NW)	05.10.15	19.01.17
Friedhofstraße	Mobilfunksendeanlage Landsknechtstraße (50 m)	Wie geht es den Menschen?

6 + 7 Königshofstraße/Friedhof, zwei Spitzahorn (2008-2017)

2008	**2009**	**2017**
27.06.08 zwei Spitzahorn (Blick von NO)	29.09.09	06.10.17
Königshofstraße/Friedhof	Ahorn links wurde später gefällt.	**Ahorn rechts ist Nr. 14 in einer Studie von 2016.**

Studie „Radiofrequency radiation injures trees around mobile phone base stations“ von

Waldmann-Selsam C, Balmori-de la Puente A, Breunig B und Balmori A, veröffentlicht 2016 in Science of the Total Environment

https://www.researchgate.net/publication/306435017_Radiofrequency_radiation_injures_trees_around_mobile_phone_base_stations

7 Studie Nr. 14, Spitzahorn, Königshofstraße/Friedhof (2008-2018)

	2008	**2015**	**2017**	**2018**
Nr. 671234	27.06.08 Spitzahorn (von **SO**)	05.10.15 (von **O**) Messung in 6 m H	06.10.17 (von O)	31.03.18 (von O)
Höhe: 14-17 m	Königshofstr./Friedhof	links: 3.380 µW/m² rechts: 500 µW/m²		Erneuter Rückschnitt

8 Michael-Bienlein-Straße, Apfelbaum (2008-2009)

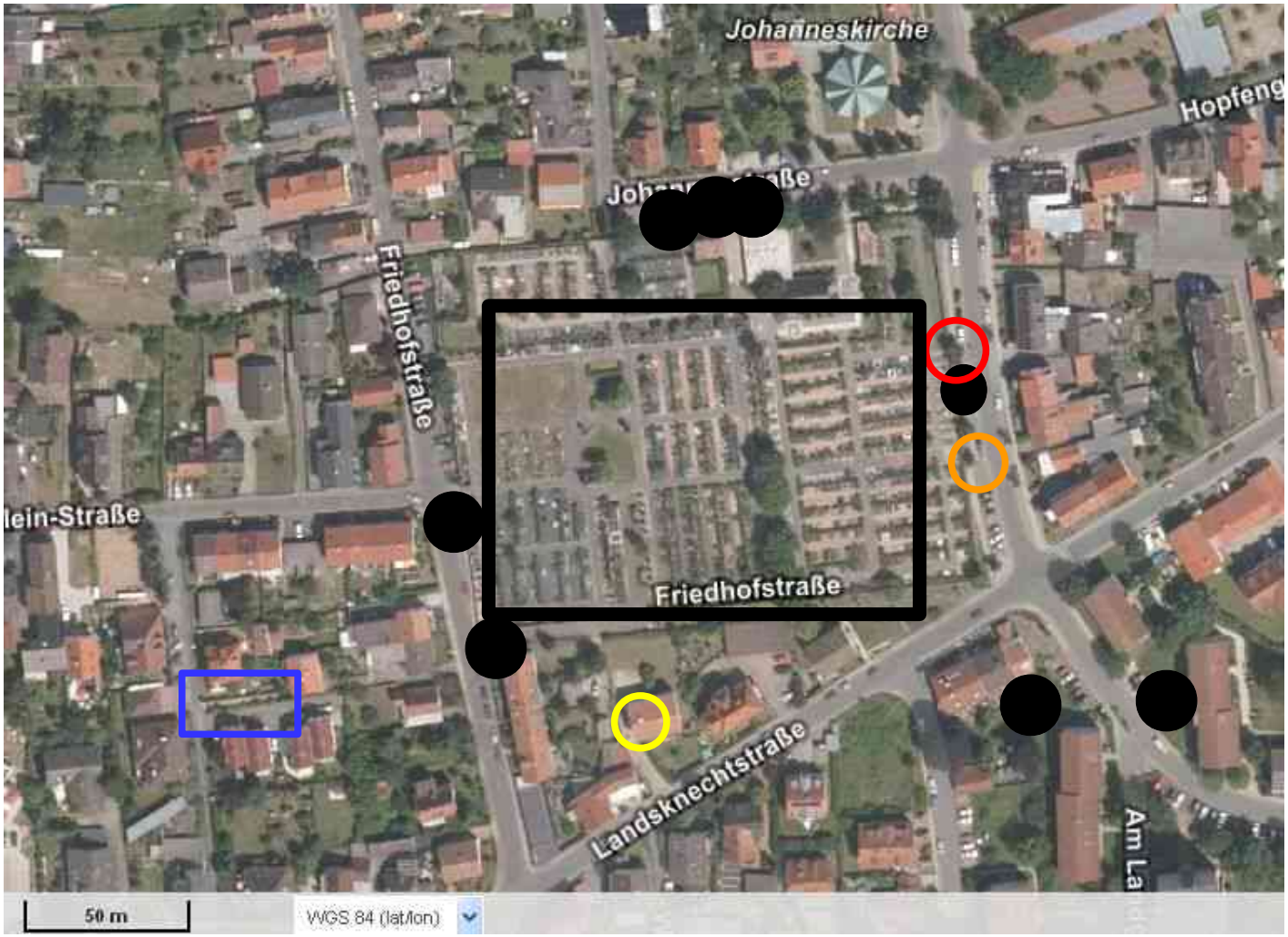
115 m

Juni 2008	**Juni 2008**	**Juli 2008**	**Sept. 2009**
27.06.08 Sträucher, Spalierobst (von W)	27.06.08 Apfelbaum (von S), Sichtverbindung Sender Landsknechtstraße	14.07.08 (von S0) Entfernung: 115 m	29.09.09 (von SSO)

9 Michael-Bienlein-Straße, Flieder (Mai bis September 2009)

Mai 2009	Juli 2009	Sept. 2009
07.05.09 Flieder und Sträucher (von W)	01.07.09	29.09.09
Michael-Bienlein-Straße	Mobilfunksendeanlage Landsknechtstraße (130 m)	

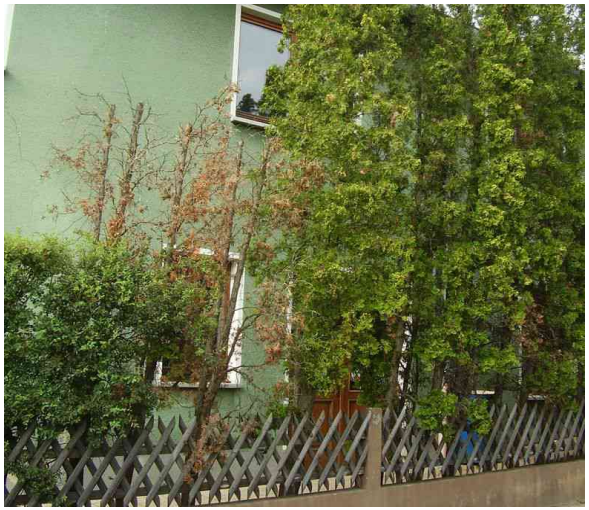
Standorte dokumentierter und gefällter Bäume im Umkreis der Mobilfunksendeanlage Landsknechtstr. 23a im Luftbild



Landesamt für Vermessung und Geoinformation, 2017, Hallstadt, Friedhof mit Umgebung.
Standortbescheinigung Nr. 671234 vom 23.08.13: Höhe 14,2 m bis 16,8 m, 9 Sektorantennen (3 x 95°, 3 x 215°, 3 x 335°), Sicherheitsabstände 4,2 m bis 6,8 m.
Markierungen: Mobilfunksendeanlage gelb, gefällte Bäume außerhalb des Friedhofes schwarz, Spitzahorn Studie Nr. 14 rot, Apfelbaum und Flieder blau, Linde Königshofstraße orange. Innerhalb des Friedhofes wurde eine große Zahl von Bäumen gefällt.

10 Michael-Bienlein-Straße, Lebensbaumreihe (2009-2017)

2009



01.07.09 Lebensbaumreihe (Blick von SW)

2014

Westen: 220 µW/m² Osten: 23 µW/m²

04.06.14 Von Westabschnitt Sichtverbindung Sender

2016

Westen: 200 µW/m² Osten: 30 µW/m²

08.07.16 Von Ostabschnitt **keine** Sichtverbindung

2017

Westen: 2.330 µW/m² Osten: 190 µW/m²

06.10.17 Erheblicher Anstieg der Messwerte.

2017

Landesamt für Vermessung u. Geoinformation, 2017

Sender Seemarter gelb, Lebensbaumreihe grün

2017

Messung Westabschnitt: 2.330 µW/m²

Messung Ostabschnitt: 190 µW/m²

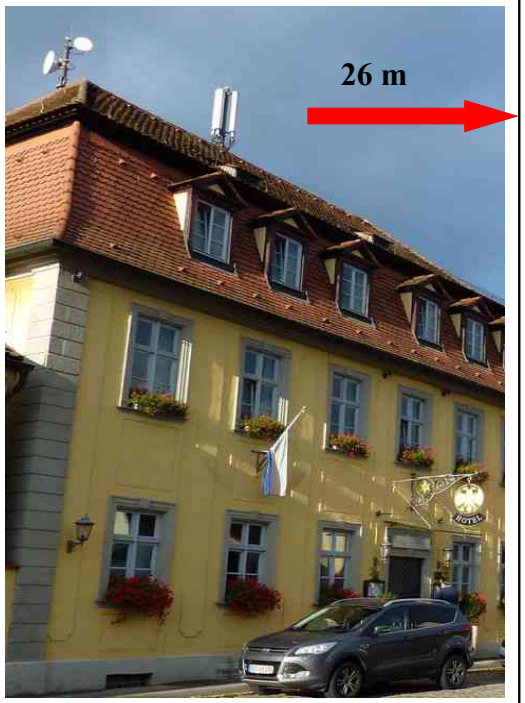
Entfernung zu Sender Seebachmarter: 272 m

06.10.17

11a Lichtenfelser Straße, zwei Spitzahorn und Linde am 14.07.08

2008	2008	2008	2008
14.07.08 Spitzahorn (Blick von O)	Spitzahorn jung mit Mobilfunksendeanlage (von O)	Spitzahorn jung vor Haus (v N)	Linde, zwei Feldahorn (von NW)
Studie Nr. 12			

11b Studie Nr. 12, Spitzahorn, Lichtenfelser Straße (2009-2017)

	2009	2015	2017
06.10.17 Sendeanlage Nr. 671291	26.09.09 Spitzahorn (von NW)	14.09.15 Messung in 6 Höhe	06.10.17
Höhe: 16 m, 18 Antennen	Hallstadt, Lichtenfelser Straße	links: 11.800 µW/m² rechts: 400µW/m²	

12 An der Angelbrücke, zwei Feldahorn (2008-2017)

2014 **1** **2**	**2016** 	**2017**
03.06.14 Feldahorn 1+ 2 (Blick von **Süden**) An der Angelbrücke/Lichtenfelser Straße	08.07.16 Von Baum 2 Sichtverbindung zu Sender Lichtenfelser Str., Baum 1 teils durch Haus geschirmt.	06.10.17 Deutlicher Unterschied zwischen den beiden Bäumen.
2014 Baum 1: 510 µW/m² Baum 2: 2.760 µW/m²	**2017** 	**2017** 19.380 µW/m²
03.06.14 Messungen	06.10.17 zwei Feldahorn, Linde, Sender (von **Osten**)	06.10.17 Erheblicher Anstieg der Messwerte

Von der Lichtenfelser Straße aus war der Unterschied bereits 2008 aufgefallen.

2008

2 **1**

14.07.08 Zwei Feldahorn (Blick von **NW**)
Lichtenfelser Straße/An der Angelbrücke

2010

22.06.10 **Von Feldahorn 2 Sichtverbindung** zu
Sendeanlage Lichtenfelser Straße (Entfernung 75 m)

2011

05.05.11

2015

24.09.15

2015

24.09.15 Blick aus Richtung Sendeanlage
Feldahorn 1 ist durch Linde und Haus teils geschirmt.

2017

06.10.17 Deutlicher Unterschied zwischen den
beiden Feldahornbäumen (Blick von N) 16

Standorte dokumentierter Bäume im Umkreis der Mobilfunksendeanlage Lichtenfelser Str. 35 im Luftbild

Landesamt für Vermessung und Geoinformation, 2017, Hallstadt, Lichtenfelser Straße/Kemmerner Weg/An der Angelbrücke
Standortbescheinigung Nr. 671291 vom 28.02.13: Höhe 16 m, 18 Sektorantennen (3 x 0°, 3 x 30°, 3 x 120°, 3 x 150°, 3 x 240°, 3 x 270°), Sicherheitsabstände 4,6 m bis 7,9 m.
Markierungen: Sendeanlage gelb, Walnuss und Feldahorn im Funkschatten weiß, Spitzahorn Studie Nr. 12 rot, Feldahornpaar orange, Walnuss Kemmerner Weg magenta, Lebensbaum Studie Nr. 49 blau, junger Bergahorn grün.

13 Studie Nr. 30, Linde, Marktplatz, von Süden (2009-2017)

2009	**2015**	**2017**	
26.09.09 Linde (Blick von Süden)	24.09.15 Messung in 6 m Höhe	06.10.17	19.01.17 Sendeanlage Nr. 671291
Hallstadt, Marktplatz	links: 420 µW/m² rechts: 3.800 µW/m²		Höhe: 16 m, 18 Sektorantennen

13 Studie Nr. 30, Linde, Marktplatz, von Westen (2009-2017)

2009	2015	2017
26.09.09 Linde (von Westen)	24.09.15 Messung in 6 m Höhe	06.10.17 Sendeanlage Lichtenfelser Str. 35
Marktplatz	Westseite: 420 µW/m² Ostseite: 3.800 µW/m²	Höhe: 16 m, 18 Sektorantennen

14 Mainstraße, Feuerwehr, Linde (2008-2017)

2008	2009	2017	
27.06.08 Linde (Blick von W)	06.06.09 Von Krone Sichtverbindung	06.10.17	16.10.09 Sendeanlage Seebachmarter 1
Feuerwehr	zu Sendeanlage Seebachmarter		Höhe: 27 m, 8 Sektorantennen

15 Feuerwehr, Mainstraße/Valentinstraße, zwei Linden (2016-2017)

2016

14.03.16 Überblick Feuerwehr, Mainstraße und zwei Linden (Blick von N)

Aus dieser Perspektive ist die Sichtverbindung von der Krone zu der Mobilfunk-

2017

06.10.17 Linde links: vorzeitiger Laubfall; Linde rechts: Laubverlust oben

sendeanlage Seebachmarter 1 (Montagehöhe 27 m) leichter vorstellbar.

Mobilfunksendeanlage Seebachmarter 1 (Blick von SW) **13.01.15**

16 a St.-Kiliansplatz, Sechs Linden (2009-2017)

Linde 2 bis Linde 6 **2009**

01.07.09 Von 2008 bis 2014 war der Platz eine **funkarme Nische** (von SW).

Linde 3 bis Linde 5 **2014** **2014**

04.06.14 Dicht belaubte Linden (von SW)

Installation eines Senders an der SW-Ecke des Platzes

Linde 1 bis Linde 5

02.09.16 In der Folgezeit traten Verlichtung und Braunfärbung auf (von SW).

Linde 1 bis Linde 6 **2017**

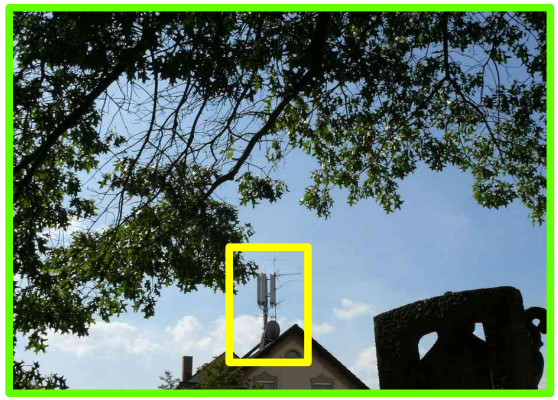
06.10.17 Anfang Oktober waren bereits viele Blätter gefallen (von SW).

Standorte dokumentierter Bäume im Umkreis der Mobilfunksendeanlage Mainstr. 36a im Luftbild

Luftbild, Landesamt für Vermessung und Geoinformation, 2017.

24.09.15 Linde 6
Blick von **Osten**

02.09.16 Roteiche +
Sträucher (von **Osten**)



02.09.16 Ausschnitt Roteiche von **Osten**

Die Mobilfunksendeanlage Mainstr. 36a (gelb) wurde im Jahr 2014 in Betrieb genommen.
Standortbescheinigung Nr. 6601302, Höhe 14,5 m, 9 Sektorantennen (3 x 60°, 3 x 180°, 3 x 300°), Sicherheitsabstände 4,4 m bis 7 m.
Markierungen: Sendeanlage gelb, Linde 6 rot, Roteiche grün (s. unten), Sträucher im Funkschatten grau.

16b St.-Kilians-Platz, Roteiche (2015-2017)

Okt. 2015	**Juli 2016**	**Sept. 2016**	**Okt. 2017**
09.10.15 Roteiche (Blick von **N**)	08.07.16 Sichtverbindung Sender	02.09.16	06.10.17

St.-Kilians-Platz
Blick von **NO**

17 Lichtenfelser Straße, Gemeindezentrum, Linde (2010-2017)

2010	2014	2015	2017
22.06.10 Linde (Blick von N)	03.06.14 Die Entfernung zum Sender	24.09.15 Die Funkwellen werden an	06.10.17
Hallstadt, Gemeindezentrum	Lichtenfelser Straße beträgt 210 m..	den Dächern reflektiert und treffen zu-	rück auf die Linde.

18 Bamberger Straße, Spitzahorn (2014-2017)

2014	2016	2017
03.06.14 Ahorn (Blick von W)	08.07.16	06.10.17
Bamberger Straße	Sichtverbindung Sender Seebachmarter (Entf. 480 m)	

19 Seebachstraße/Pfarrer-Wachter-Straße, Walnuss (2014-2017)

2014	2016	2017	2017
04.06.14 Walnuss (Blick von NW) Seebachstr./Pfarrer-Wachter-Str.	08.07.16 Von oberer Hälfte Sichtverbindung zu Sender Seebachmarter	26.01.17 Entfernung: 400 m	Landesamt für Vermessung und Geo-Information, Standort Walnuss grün.