Tree damage caused by mobile phone base stations

An observation guide

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Why an observation guide?

Since the rollout of GSM mobile phone networks in the 1990s, scientists have criticized that the effects of radiofrequency or RF radiation (microwaves) on living organisms and the environment have not been sufficiently studied. In the setting of exposure limits for mobile phone base stations, RF radiation effects on plants have not been considered. In view of the explosive proliferation of the diverse wireless communication technologies across the entire environment and almost all areas of life, this represents an uncovered risk. This is why available studies and documentations on how RF radiation affects and damages trees engage our particular attention. They contain important evidence that justifies the urgent call for further thorough investigations. No research, however, has been initiated by the established science community and official radiation protection agencies to date.

The observation guide presented here is meant to encourage independent observations and documentations of trees and any damage they may sustain through exposure to radiofrequency radiation. It builds on the work and foundational findings of BERNATZKY, BALMORI, SCHORPP, HALLBERG, WALDMANN-SELSAM, and others.

In light of the increasingly visible consequences of climate change, the continuation of their work is an important step toward forming an independent judgment. This is all the more important since the observations described here will take extra efforts – especially in view of the massive climatic changes – to ensure that this issue is not denied the scientific recognition by the established research community it deserves.

This call for research is based on the reasonable suspicion suggesting an association between health symptoms in humans and damage in trees at locations in the line of sight of mobile phone base stations, which was pointed out by EGER and WALDMANN-SELSAM.

Why observe trees?

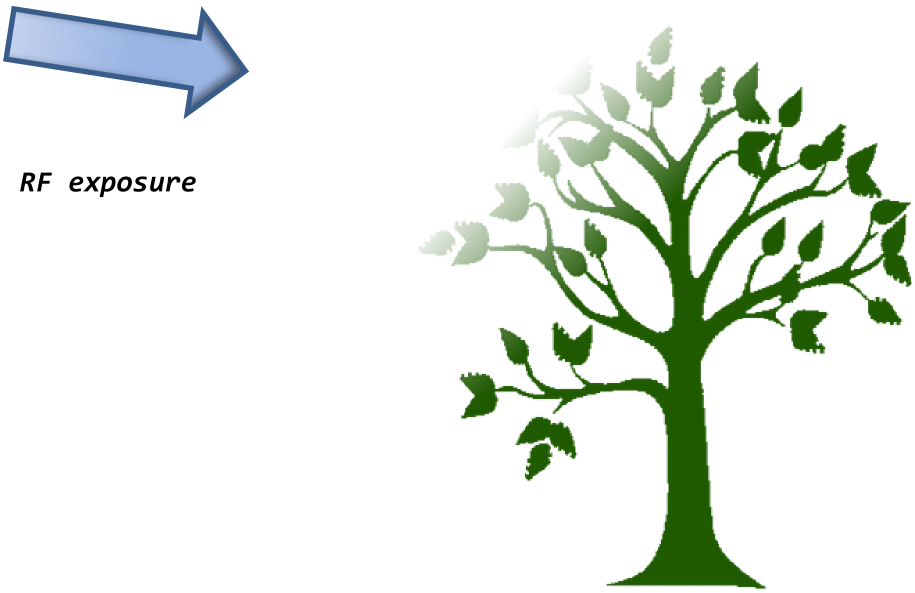
As stationary and perennial living organisms, trees are well suited for studying the question as to whether radiofrequency emissions from phone masts may cause damage in plants. The observation guide is designed to help *observers recognize visible crown damage in free-standing trees exposed to radiofrequency radiation. The photos show typical damage patterns and thus can sharpen the observer's eye. Based on this observation guide, scientists and laypersons alike can systematically observe trees in their immediate living environment or in other regions when they travel.*

In urban areas, it is not uncommon that trees are located within the exposure area of different phone masts from multiple directions. In crowns of free-standing (solitary) trees, which are exposed to RF radiation from one side only, it is rather easy to show the signs that may indicate a possible exposure to RF radiation. Advanced stages of sustained damage are best suited for describing the typical characteristics. This is also how the examples for this observation guide have been selected. The majority of the examples are deciduous trees.

Based on the analysis of advanced patterns of damage and their development, general characteristics for the crown damage in exposure areas of RF transmitters can be derived, which, in turn, can help recognize damage in trees with a less advanced stage and under conditions where the exposure occurs from multiple directions.

Observation of one-sided crown damage in trees in the line of sight of mobile phone base stations

Visual signs include irregular leaf coloration, leaf wilt, leaf loss, temporal and spatial irregularities in the seasonal leaf color change and leaf loss, fewer shoots, greatly elongated shoots with foliage at the tip and bare patches farther down the shoot, changes in branching patterns, and dead limbs and branches. The damage is most prominent at the edge on one side of the crown. This area is referred to as the starting point of damage. From there, the damage decreases in its intensity toward the opposite side of the crown that may be less affected or not at all. The crown volume, which is damaged within this geometric space, is referred to as the damage area. It will continue to develop further over the course of several growing seasons.



The geometry of the crown damage points to an abiotic, atmospheric, exposure-related factor of influence.

If, in the case of a free-standing tree, the starting point of damage is in line of sight of an RF transmitter, it is reasonable to suspect that the damage pattern may be caused by the exposure to the RF radiation of the RF transmitter.

The RF measurements, as stated for selected photos below, were taken by WALDMANN-SELSAM, using the EMF-broadband analyzer HF59B (27–3300 MHz) with the horizontal-isotrope antenna UBB27_G3 (Gigahertz Solutions), in some cases in conjunction with a 6 m (ca. 20 ft) long telescopic rod. It is not the intention of the RF measurements to provide a detailed RF radiation exposure analysis for a given location. This basic measurement method, however, is sufficient in demonstrating that a given crown may only be exposed from one side, that the worst damage occurs at the side of the tree with the highest RF exposure levels facing the RF transmitter, and that the damage patterns described in the observation guide occur at exposure levels well below currently valid exposure limits.

The presented agreement of the measurement results with the visual observations makes existing associations more transparent and thus demonstrates that the observation method described here is well suited to

generate meaningful documentations, even without measuring the actual RF exposure levels.
In conjunction with heat, cold, drought, soil composition, soil compaction and sealing, salting, air pollutants, soil contaminants, and pests, different types of crown damage can occur. By observing negative effects on the foliage, spatial orientation and crown damage development over time described here, specific characteristics of the exposure pattern due to radiofrequency radiation become apparent.

Linden tree, July 2015
Well-developed tree crown in the city
No RF transmitter in the line of sight

Norway maple tree, August 2012
Badly damaged tree crown on the side facing an RF transmitter

At both locations, soil sealing is a concomitant adverse factor. The difference in the crown pattern, therefore, is most likely not a result of soil sealing.

At the location of the red oak tree shown here, none of the known stress factors are obvious. Still, the crown is damaged in a way that corresponds to the above-shown graph. The tree is in the line of sight of a nearby mobile phone base station.

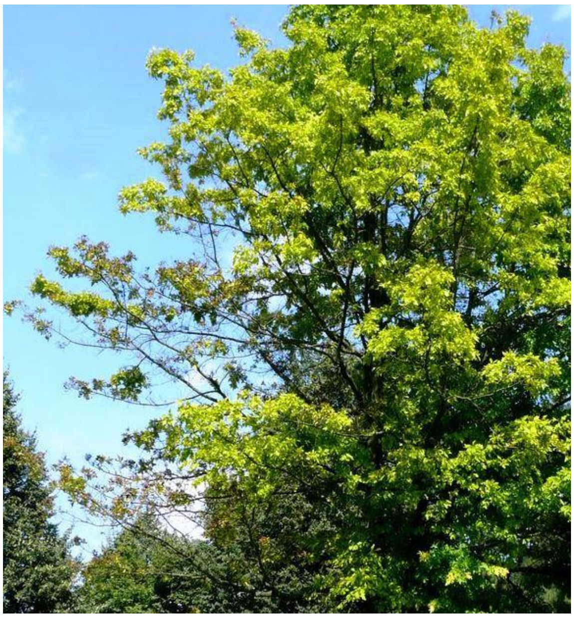
Exposure ->

Red oak tree, August 2013

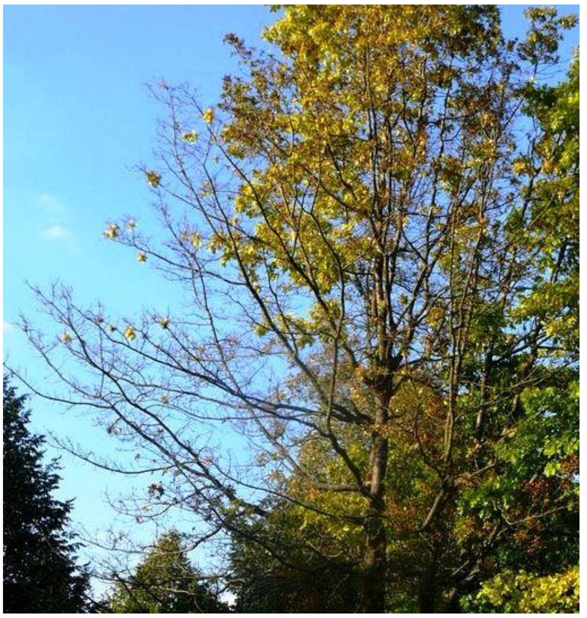
The direction of the RF emission source and the location of the starting point of damage on the side of the tree facing the mobile phone base station coincide with each other.

Red oak tree, August 2013

Red oak tree, August 2015



Section of red oak tree, August 2013



Section of red oak tree, August 2015

The damage area spreads across the crown over the course of the coming years. At the individual branches, the sight is similar to drought damage. The spatial and temporal development of the damage area as a whole, however, is not typical for drought damage that occurs as a result of a lack of water at the roots.

The loss and discoloration of the leaves is most prominent where the tree faces the RF transmitter. The spread of the damage area follows a pattern independent of the branch architecture of the tree.
The location of the damage area is independent of the natural environment and the sky direction.

Tree damage in the line of sight of RF transmitters has already been extensively documented. The damage in these documentations shows diverse patterns and developmental stages (see Documentations).

The photos presented here place a special emphasis on the unique damage pattern due to RF radiation exposure from one side.

Some of the photos also show the location of the tree crown in relation to the associated RF transmitter within sight. If the RF transmitter is not shown, the distance to the RF transmitter is given.

Examples of different spruce trees show that similar damage patterns can also be observed in conifers to various degrees.

Exposure from the right side,
260 m (ca. 850 ft)

Spruce, October 2010

Exposure from the right side,
190 m (ca. 620 ft)

Spruce, March 2012

Exposure from the left side,
200 m (ca. 660 ft)

Spruce, June 2003

Exposure from the left side,
310 m (ca. 1000 ft)

Spruce, October 2008

The damage decreases on the side of the crown facing away from the RF transmitter (damage gradient), which can be explained by the attenuation effect of the foliage. Due to the absorption and scattering of the RF radiation along its path through the foliage, the power flux density of the RF radiation decreases (used measurement unit: microwatt per square meter = μW/m²). Comparison measurements between the side of the tree crown facing the RF transmitter and the side facing away from it confirm this.

Exposure from upper left ->

Norway maple tree, June 2015

Measurement:	*Side facing the RF transmitter:*	*Opposite side:*
14 July 2015	*2,100 μW/m²*	*290 μW/m²*

The agreement between the spatial orientation of the damage gradient and the gradient of the RF measurements suggests that the damage is associated with the RF radiation exposure from the RF transmitter.

According to the Twenty-sixth Ordinance Implementing the Federal Immission Control Act, *German exposure limits for mobile phone base stations range from 4,500,000 to 10,000,000 μW/m², depending on the respective mobile phone network.*

May 2013

July 2016

The damage increases over the years and spreads from the direction of the RF transmitter across the crown. No regeneration can be seen. This is a sign of chronic exposure to a damaging factor. The RF exposure from the mobile phone base station within sight began between 2006 and 2008.

Observing the development of the damage over the long term provides insight into the unique characteristics of the damage.

May 2013

June 2014

June 2015

The tree is located at a strip of greenery, running in a north-south direction. To the east (foreground), the root area is sealed by a traffic area. The damage area points toward south where the RF transmitter is located. Despite the less than favorable climate conditions at this side, the crown on the north side has expanded.

At the upper left – where the RF radiation hits the crown – the dieback at the edge is the most severe.

The annual increase in leaf loss most likely can be traced back to an impairment of the buds in the year before. The resulting decreased level of shoots for leaves and branches causes the closed crown to open at those points, whereby one quarter of the crown outline starts breaking up.

With increasing leaf dieback, the attenuation effect of the foliage decreases, starting at the edge of the crown.

Inside the crown, there are naturally less leaves because of shadow

July 2016

effects. This is why – after the more dense foliage at the crown edge has receded – it is easier for the RF radiation to cross over to the other side of the crown. As a result of the increasing RF exposure level, the crown then also starts to lose leaves in this opposite area and thus the tree's inherent attenuation also decreases. In this way, the damage area spreads from the inside to the outside of the side of the crown edge facing away from the RF transmitter.

April 2015
In bloom

The more the branches and buds are protected by the attenuation inherent to the crown, the higher the density of the flowering shoots will be.

Due to the crown dieback at the side facing the RF transmitter, more light reached the inside of the crown, resulting in shorter shoots with buds on branches closer to the trunk compared to the right side.

February 2017

After renewal pruning

Because the right side of the crown had denser foliage, the inside of the crown experienced more shade. Consequently, the shoots are more elongated, trying to reach the edge with more light exposure, resulting in less branching along the way. After pruning, the crown then has less buds for renewal at this side.

The renewal of pruned crowns, which are exposed to radiofrequency radiation, should be included in observations.

If trees, which are lined up in a row, show all damage on the same side, this may also be a sign of RF radiation causing damage to the crowns.

June 2016

<-Exposure from upper right

Distance 730 m (ca. 2400 ft)

July 2008

Month not known 2010

Sycamore maple tree

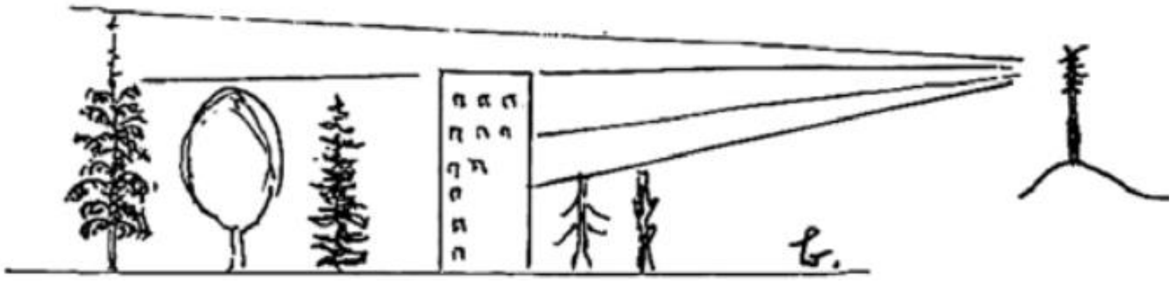
Starting point of damage and damage gradient coincide with the direction of the RF emission source. The damage increases over the years.

If the RF radiation exposure comes from above, the damage is particularly prominent at the top of the tree.

Gleditsia tree
September 2011

Beech trees,
June 2009

Crowns can show damage when a tree stands in front of a building that faces an RF transmitter and also when a tree stands behind such a building if the treetop reaches above the rooftop.



(Figure taken from BERNATZKY 1994)

The following example shows a situation similar to the tree in the above graphic in the upper left.

Exposure from the right above the rooftop

Cherry tree, September 2012

Distance to multiple RF transmitters 150-500 m (ca. 500-1600 ft)

June 2015

Trees of the same species planted along a roadside are especially well suited for comparing RF radiation exposure patterns. The trees in the radio shadow of the building show a different pattern compared to those exposed directly to RF radiation.

RF radiation exposure ->

Tree-lined road Turkish hazel trees,

June 2008

Tree-lined road Turkish hazel trees,

August 2013

The Turkish hazel trees on the left are mostly in the radio shadow of the buildings. The line of trees on the right side of the road are more exposed; both directly and indirectly (reflection from buildings). The bare shoots and dead twig tips of the transparent crowns of the trees on the right side of the road reveal the level of stress caused by the RF radiation.

The shielding effect of buildings can be demonstrated with measurements of the RF exposure levels. In the radio shadow, the tree crowns are only marginally affected.

Distance to RF transmitter 130 m (ca. 430 ft)

Exposure and view from south — *Maple tree*, *Hornbeam tree*

View from north — *Hornbeam tree*, *Maple tree*

October 2009

In spring, dead branches were removed

July 2012

8,000

200

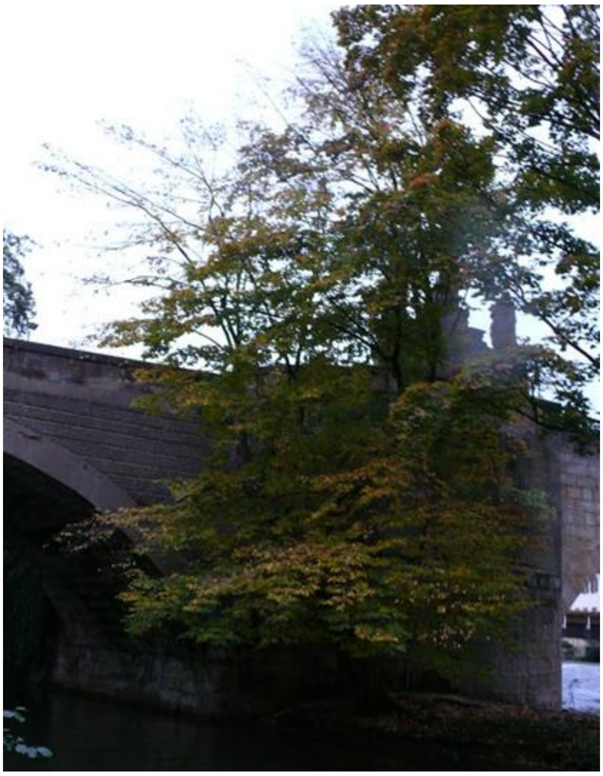
30

µW/m²

RF measurements, May 2012

Maple tree *Hornbeam tree*

October 2014



Hornbeam tree *Maple tree*

The upper part of the crown that reaches above the bridge structure is exposed by an RF transmitter. Despite excellent light conditions and a good water supply, leaf loss occurs at this location. The lower part of the foliage is dense and healthy because it is protected by the bridge structure.

Microwave exposure from a traffic radar <-

Viburnum hedge in a strip of greenery

The damage area in the foliage of the hedge clearly delineates the focused exposure area of the radar.

A disparate fall coloration inside the crown with regard to its timing can be conspicuous. The one-sided discoloration of the foliage occurs on the side facing the RF transmitter.

RF exposure from the upper left ->

Distance to RF transmitter 60 m (ca. 200 ft)

Hornbeam tree, October 2010

At the edge facing the RF transmitter, the leaf loss and the coloration differences within the crown show the damage gradient from the starting point of damage to the damage area.

Ash trees naturally lose their leaves in fall without major discoloration. If the leaves of one tree start falling in different areas of the crown at different times, this can be the result of a one-sided RF exposure. This characteristic requires observing the tree over several years. Thus it would be possible to distinguish the damage from the acute effects of late frost, which can be caused by cold air in spring that blows in from the side.

Ash tree, October 2016

No late frost in this location in spring 2016

Tree site at a slope

<- Exposure from the right from RF transmitter a the same height, distance 500 m (ca. 1600 ft)

In winter, bare crowns of deciduous trees will reveal differences in their sides, if applicable, which would indicate an exposure to RF radiation.

RF exposure from the left from a distance of 320 m (ca. 1050 ft)

->

Sycamore maple tree, February 2017

The branching differs between the left and the right side.
On the side of the crown facing the RF transmitter, less branching of branches and shoots occurs. The closed crown starts opening from the left and above.

*At the side **facing the RF transmitter,** the closed crown starts opening and areas of dieback become visible as a result of less branching.*

*At the side of the crown **facing away from the RF transmitter,** branching is clearly much denser. The edge of the crown looks smoother and closed.*

Characteristics of damage to the foliage of free-standing trees in the case of one-sided radiofrequency exposure from mobile phone base stations over a longer period:

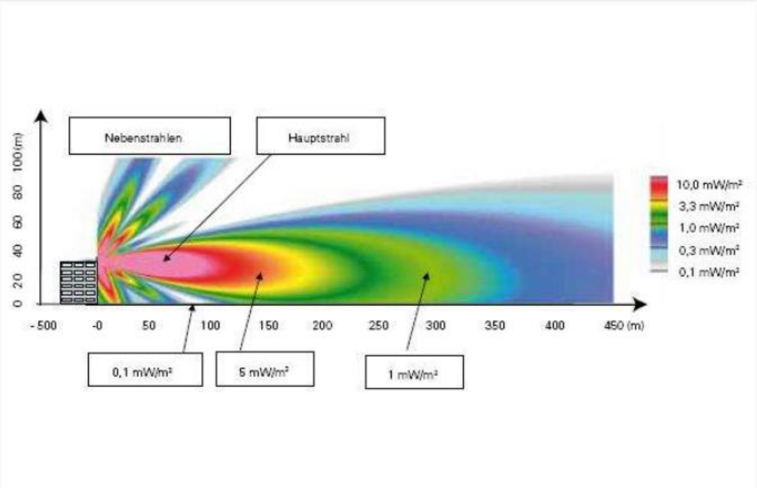
- ***The decrease in foliage starts at the edge of the crown (starting point of damage).***
- ***Over the following growing seasons, the process of receding foliage will spread from the starting point of damage across the crown to other areas (damage area).***
- ***The gradual spread of the damaged area follows the spatial pattern of decreasing attenuation provided by the foliage.***
- ***At all sites, the tree crown is in the line of sight of a RF transmitter.***
- ***This type of damage occurs at sites where conditions vary in their suitability for tree growth.***

The damage patterns described here, which are suspected of being caused by adverse effects of RF radiation, require observations over several years. It is possible then to follow the characteristic development of the damage area over time to distinguish it from the damaging effects of other factors.

You can sharpen your observational eye to detect the typical damage patterns by observing trees over longer periods that have mobile phone base stations installed nearby or have been newly planted next to RF transmitters. When older trees are cut or pruned, checking if the tree is in the line of sight of RF transmitters can be revealing.

Evaluation of observations

Conventional antennas of mobile phone base stations emit RF radiation either in all directions (omnidirectional antennas) or in a particular direction with main and side lobes, focused vertically and horizontally (directional or sector antennas). A sector antenna commonly covers a horizontal area of 120°.



The simulation shows how the transmit output of a sector antenna propagates through space. In addition to the main lobe, which covers the far-field area, there are also side lobes at certain angles.
Source: LfU

Haupstrahl = main lobe

Nebenstrahlen = side lobes

(Figure taken from Bayerisches Landesamt für Umwelt*)*

The incident RF radiation is reflected, scattered, and diffracted at buildings and the landscape. As a result, the spatial distribution and intensity of the RF electromagnetic field is rather inhomogeneous. In turn, the RF exposure levels at trees in the same location, which are standing in *the line of sight of an RF transmitter, can vary greatly. Even the area of the crown that sustains the highest exposure can be at different heights. For example, the pictures of the red oak tree (p. 5-6) clearly show how the opening up of the closed crown can occur midway up the crown.*

Both in general and in the vicinity of mobile phone base stations, damage to tree crowns can occur in different locations for various reasons.
If, in a line-of-sight exposure area of RF transmitters, there are trees with clear patterns of damage and trees with little or no obvious damage, the best practice approach in epidemiology (BRADFORD-HILL) does not allow for the conclusion that the existing damage could not have been caused by the exposure to the RF radiation from the RF transmitters as long as this has not been verified by an in-depth investigation of the matter.
Therefore, the exposure to RF radiation should always be considered by the environment and parks agencies when assessing damaged trees.

Typical city view with trees in the vicinity of mobile phone sites
July 2015

The linden trees to the left in the blind spot near the antennas (marked) don't seem to be adversely affected. Other trees in the background along the road and the newly planted tree in front of the building all are in the line of sight of the RF transmitters on the rooftop. Here we can recognize damage to the shape of the top of those trees and to the density of their foliage.

Due to the limited knowledge in this research area, it cannot be ruled out at this time that differences among trees in the line of sight of a given RF transmitter may also be traced back to characteristics of the tree species and their provenances.

The expectation that trees within the exposure area of a given mobile phone base station should respond in the same way is therefore unfounded as long as this matter has not been studied in depth.

Furthermore, crown damage can be caused by different factors that overlap with each other. In laboratory studies, it could be demonstrated that RF radiation is capable of triggering physiological stress responses in plants. This finding suggests that we should focus our observations on whether the damaging effect of a possible additional stress factor tends to be more prominent on the side of the crown exposed to RF radiation. For example, it should be noted if the point from which the damage spreads and the incidence and degree of infestations with e.g. fungi, viruses, worms, and insects are associated in any way with the side of the tree facing an RF transmitter.

The same basically also applies to other common natural and technical factors, which may only affect one side of the tree such as wind direction, solar exposure, traffic exhausts, road salt, root and trunk damage.

The initial stages of damage development caused by heat, drought due to a lack of water in the soil, root damage, damage to the water pathways in the tree, and limited frost damage may at first sight look like a crown damaged by the exposure to radiofrequency radiation.

The more the damage of the crown advances, as can be observed as the result of the chronic exposure to radiofrequency radiation over several growing seasons, the clearer the distinguishing characteristics become. "The damage follows a path along the direction of the RF radiation" (see the documentation by SCHORPP, 2007).

At any location without RF radiation exposure, it should be rather unlikely to find a damage pattern as shown here.

Maple tree, September 2006

SCHORPP points out that the inhomogeneous emissions of the antennas as well as the reflection, diffraction, and scattering effects at buildings may lead to well-defined, small-area differences in power density levels.
These types of crown dieback are new and only occur around built environments.
In this case, an explanation that only refers to known damaging factors does not cut it.

The above presentation regarding one-sided crown damage – describing the characteristics of temporal and spatial patterns in shape and color, while considering various site factors – demonstrates that no other damaging factor is known at this time that could regularly cause the above-described damage patterns in crowns of free-standing trees.

In this observation guide, the selection of damage patterns is limited to the ones presented for didactic reasons. There are many additional types and developmental stages of visible crown damage caused by radiofrequency radiation (see Documentations). We lack comprehensive documentations on the hazard assessment to date. To justify the lack of a systematic investigation into this type of crown damage with the notion that only a few such observations have been made so far bears the risk of overlooking a new threat to the environment and humanity.

In times of climate change, to what extent will efforts to maintain trees in urban areas for their balancing effect be challenged if we do not consider the consequences of chronic RF radiation exposure?

Tree crowns in a strip of greenery become damaged through the exposure to ***radiofrequency radiation***
July 2008

In an urban green space, healthy tree crowns in the radio shadow
August 2015

Scientific application of the observation method

Owing to the new and unique type of damage pattern, an in-depth investigation into its causes seems indicated and can be carried out with relatively little effort. The above-described observation method can serve as a guide for locating and assessing crown damage in trees. By applying the knowledge of the developmental characteristics of the above-described type of crown damage, it is possible to also include less advanced levels of damage.

For the study **Radiofrequency radiation injures trees around mobile phone base stations,** *60 trees with the above-described damage pattern were located in the cities of Bamberg and Hallstadt, some of which have been documented over the course of several years.*

The visual inspections at each location revealed that, in the case of one-sided crown damage, it was exclusively the damaged side facing an RF transmitter. The RF exposure level measurements on the damaged side were on average about 2,000 µW/m² and on the opposite side about 200 µW/m².

Another group of 30 trees was randomly selected. Thirteen trees of this group had crown damage. The visual inspections revealed that six of the trees had crown damage only on one side of the tree, which was facing an RF transmitter; five of the trees had damage on more than one side all of which were facing RF transmitters on the respective damaged sides. One tree (spruce) with a damaged top also was in the line of sight of an RF transmitter, as was another tree that had dead parts of the crown removed. The RF radiation exposure levels for the trees of this group were on average about 1,600 µW/m² on the side facing an RF transmitter and about 600 µW/m² on the opposite side.

The crown damage occurred regardless of different soil characteristics of the tree locations such as sealing, strips of greenery, gardens, parks, in the vicinity of water bodies, etc.

The RF radiation exposure levels for the 17 trees of the randomly selected group that were not in the line of sight of any RF transmitter ranged from about 8 to 50 µW/m², both on the side with the highest reading and the opposite side.

In addition, a third group of 30 trees was located in an area with lower RF background levels where the trees were not in the line of sight of any RF transmitter. In those areas, the RF radiation exposure levels ranged from 3 to 40 µW/m². The difference in the RF radiation exposure levels between the two sides of a given tree was negligibly small, max. 10 µW/m². All 30 tree crowns did not show any signs of damage.

At all locations of the 47 trees with no line-of-sight connection to an RF transmitter and an overall low RF background level, no crown impairments as described above were visible.

The assumption that the type of crown damage described in this guide is caused by the exposure to radiofrequency radiation proves to be justified because

- ***this particular crown damage occurs at exposed locations in the line of sight of mobile phone base stations, and***
- ***at unexposed locations outside the line-of-sight exposure areas of RF transmitters, however, this crown damage does not occur.***

Documentations *(selection)*

- *SCHORPP, V., http://www.puls-schlag.org/dr-volker-schorpp.htm*
  2007: Baumschäden durch chronische Hochfrequenz-Belastungen?
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  http://www.puls-schlag.org/download/Schorpp-2011-02-18.pdf
- *WALDMANN-SELSAM, C., 2016: Trees in Bamberg*
  http://kompetenzinitiative.net/KIT/wp-content/uploads/2016/09/Trees-in-Bamberg-and-Hallstadt-Documentation-2006-2016.pdf

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- *Waldmann-Selsam, C., Balmori-de la Puente, A., Breunig, H., Balmori, A., 2016: Radiofrequency radiation injures trees around mobile phone base stations* *https://www.researchgate.net/publication/306435017_Radiofrequency_radiation_injures_trees_around_mobile_phone_base_stations*

Contact:

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http://kompetenzinitiative.net/KIT/KIT/new-observation-guide-tree-damage/

German version: http://kompetenzinitiative.net/KIT/KIT/beobachtungsleitfaden-baumschaeden-durch-mobilfunkstrahlung/

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Feedback and suggestions are always welcome. If you wish to send me photos, please contact me by e-mail before sending any photos.