



Radiofrequency radiation injures trees around mobile phone base stations



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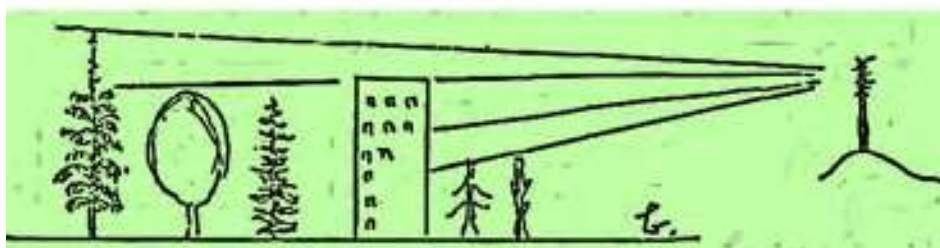
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HIGHLIGHTS

- High frequency nonionizing radiation is becoming increasingly common.
- This study found a high level of damage to trees in the vicinity of phone masts.
- Deployment has been continued without consideration of environmental impact.

GRAPHICAL ABSTRACT

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ABSTRACT

In the last two decades, the deployment of phone masts around the world has taken place and, for many years, there has been a discussion in the scientific community about the possible environmental impact from mobile phone base stations. Trees have several advantages over animals as experimental subjects and the aim of this study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure. To achieve this, a detailed long-term (2006–2015) field monitoring study was performed in the cities of Bamberg and Hallstadt (Germany). During monitoring, observations and photographic recordings of unusual or unexplainable tree damage were taken, alongside the measurement of electromagnetic radiation. In 2015 measurements of RF-EMF (Radiofrequency Electromagnetic Fields) were carried out. A polygon spanning both cities was chosen as the study site, where 144 measurements of the radiofrequency of electromagnetic fields were taken at a height of 1.5 m in streets and parks at different locations. By interpolation of the 144 measurement points, we were able to compile an electromagnetic map of the power flux density in Bamberg and Hallstadt. We selected 60 damaged trees, in addition to 30 randomly selected trees and 30 trees in low radiation areas ($n = 120$) in this polygon. The measurements of all trees revealed significant differences between the damaged side facing a phone mast and the opposite side, as well as differences between the exposed side of damaged trees and all other groups of trees in both sides. Thus, we found that side differences in measured values of power flux density corresponded to side differences in damage. The 30 selected trees in low radiation areas (no visual

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contact to any phone mast and power flux density under $50 \mu\text{W}/\text{m}^2$) showed no damage. Statistical analysis demonstrated that electromagnetic radiation from mobile phone masts is harmful for trees. These results are consistent with the fact that damage afflicted on trees by mobile phone towers usually start on one side, extending to the whole tree over time.

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1. Introduction

For many years, there has been a discussion in the scientific community about whether artificial radiofrequency radiation has harmful effects on living organisms and, more specifically, on the environmental impact from mobile phone base stations (Panagopoulos et al., 2016). Trees have several advantages over animals as experimental subjects: they are continuously exposed to radiation in a constant orientation in the electromagnetic field due to their inability to move (Vian et al., 2016). Additionally, it is possible to easily document changes over time, such as disturbed growth, dying branches, and premature colour change of leaves. Moreover, the damage to trees is objective and cannot be attributed to psychological or psychosomatic factors.

Plants are specialized in the interception of electromagnetic radiation (light) but radiofrequency radiation impact on plants, which is becoming common in the environment because of the exponential use of mobile phone technology, has received little attention and his physiological effect has long been considered negligible.

Since the mid-twentieth century, several researchers have investigated the effects of electromagnetic radiation on plants, both in the laboratory (Kiepenheuer et al., 1949; Brauer, 1950; Harte, 1950, 1972; Jerman et al., 1998; Lerchl et al., 2000; Sandu et al., 2005; Roux et al., 2006, 2008; Sharma et al., 2009; Tkalec et al., 2005, 2009; Beaubois et al., 2007; Kundu and IEEE, 2013; Pesnya and Romanovsky, 2013; Cammaerts and Johansson, 2015; Grémiaux et al., 2016; Vian et al., 2016), and in nature (field observations) (Bernatzky, 1986; Volkrodt, 1987, 1991; Selga and Selga, 1996; Balodis et al., 1996; Haggerty, 2010). Both kinds of study have frequently found pernicious effects.

Around the world, phone masts have been deployed in the last two decades everywhere. Preliminary published studies have indicated deleterious effects of radiofrequency radiation on trees (Balmori, 2004; Van't Wout, 2006; Schorpp, 2011; Waldmann-Selsam, 2007; Waldmann-Selsam and Eger, 2013), cautioning that research on this topic is extremely urgent (Balmori, 2015). However, these early warnings have had no success and deployment has been continued without consideration of environmental impact.

In a review of the effects of environmental microwaves on plants (Jayasanka and Asaeda, 2013), it was indicated that effects depend on the plant family and the growth stage, as well as the exposure duration, frequency, and power density. This review concluded that most studies that address the effects of microwaves on animals and plants have documented effects and responses at exposures below limits specified in the electromagnetic radiation exposure guidelines and it is therefore necessary to rethink these guidelines (Jayasanka and Asaeda, 2013).

Since 2005, on the occasion of medical examinations of sick residents living near mobile phone base stations, changes in nearby trees (crown, leaves, trunk, branches, growth...) were observed at the same time as clinical symptoms in humans occurred. Since 2006 tree damages in the radiation field of mobile phone base stations were documented (<http://kompetenzinitiative.net/KIT/KIT/baeume-in-bamberg/>). In the radio shadow of buildings or that one of other trees, the trees stayed healthy.

Additionally, unilateral crown damage, beginning on the side facing an antenna, pointed to a possible link between RF-EMF (Radiofrequency Electromagnetic Fields) and tree damage. We carried out measurements on both sides of unilaterally damaged trees. Most of the trees had been exposed to RF-EMF for at least five years. Each time we

found considerable differences between the measured values on the damaged and on the healthy side.

The aim of the present study was to verify whether there is a connection between unusual (generally unilateral) tree damage and radiofrequency exposure.

2. Materials and methods

The official information of 65 mobile phone sites in the neighbouring cities Bamberg and Hallstadt was extracted from the EMF database (EMF-Datenbank) of the German Federal Network Agency (Bundesnetzagentur, in March 2011 and October 2015). Each site certificate ("Standortbescheinigung") provides information on the mounting height of antennas, the number and main beam direction of the sector antennas, the number of omnidirectional antennas (ND), the number of other transmitters, as well as the horizontal and vertical safety distances. The current specifications of the transmission facilities are available at: <http://emf3.bundesnetzagentur.de/karte/Default.aspx>

On most of the 65 mobile phone sites several sector antennas emitting RF-EMF with differences in frequency, modulation and other physical characteristics are installed (GSM 900, GSM 1800, UMTS, LTE (4th generation), TETRA). In 2011 there was a total of 483 sector antennas, in 2015 a total of 779 sector antennas.

Numerical code, address and UTM 32N coordinates for the 65 Mobile phone (base stations) sites in Bamberg and Hallstadt are shown in Table 1.

Between 2006 and 2015 there was observation and documentation of tree damages. There were some preliminary measurements on both sides of unilaterally damaged trees and approximately 700 trees in Bamberg and Hallstadt were visited. The condition of numerous trees has been documented in photographs. The photographs record the state of trees showing damage patterns not attributable to diseases, pests, drought or other environmental factors in order to monitor damage and growth over several years (in 2006, Olympus FE-100 was used; since 2007, Panasonic DMC-FZ50 was used).

In 2015 we selected a polygonal study site, with an approximate area of 30 km^2 , which includes partial municipalities of Bamberg and Hallstadt (70 km^2). The study area with the location of the phone masts in the layer of natural areas and municipalities is shown in Fig. 1. In this area, different measurements (see below) were done both for having a radiation map and for knowing which are the incident power densities beside different trees. In spite of the fact that measurements are changing continuously, they do not show significant differences between times (own data, see below).

In this polygon, we performed 144 measurements of the radiofrequency electromagnetic fields at a height of 1.5 m at different points in the city. These measurements were taken in streets and parks and allowed the preparation of an electromagnetic map of Bamberg and Hallstadt with their interpolation. The measurements were carried out with an EMF-broadband analyzer HF 59B (27–3300 MHz) and the horizontal-isotrope broadband antenna UBB27_G3, (Gigahertz Solutions). Measurements of the sum peak values of power flux density were in $\mu\text{W}/\text{m}^2$, which can be converted in V/m.

In general, a sector antenna covers an angle of 120° and the radiation of the sector antennas is distributed in main and secondary beams, bundled vertically and horizontally. The high-frequency emissions are reflected/diffracted and/or absorbed by buildings and trees. Therefore,

Table 1
Official information of the 65 mobile phone base stations in Bamberg and Hallstadt.

| Code number | Adress in Bamberg and Hallstadt | X | Y | Code number | Adress in Bamberg and Hallstadt | X | Y |
|-------------|------------------------------------|--------|---------|-------------|---------------------------------|--------|---------|
| 1 | Altenburg | 634268 | 5527019 | 34 | Ludwigstr. 25 (Post) | 636318 | 5529177 |
| 2 | Am Borstig 2 | 636070 | 5531636 | 35 | Luitpoldstr. 51 | 636241 | 5529232 |
| 3 | Am Hirschknock | 637511 | 5532267 | 36 | Mainstraße, Ladekai 2 | 633924 | 5530319 |
| 4 | An der Breitenau 2 | 637253 | 5530650 | 37 | Mainstraße, Ladekai 3 | 633816 | 5530130 |
| 5 | (An der Breitenau, P&R) ca. | 637259 | 5526912 | 38 | Margaretendamm 28 | 635341 | 5529331 |
| 6 | (Artur-Landgraf-Straße) | 635183 | 5526912 | 39 | Memmeldorfer Straße (Post) ca. | 637769 | 5531392 |
| 7 | Breitäckerstr. 9 | 632965 | 5529621 | 40 | Memmeldorfer Str. 208a | 637568 | 5531191 |
| 8 | Coburger Str. 6a | 635877 | 5529951 | 41 | Memmeldorfer Str. 208a | 634861 | 5528541 |
| 9 | Coburger Str. 35 | 635252 | 5530468 | 42 | Mußstr. 1 | 634949 | 5528827 |
| 10 | Erllichstr. 47/51 | 637291 | 5527903 | 43 | Pödeldorfer Str. 144 | 637828 | 5529305 |
| 11 | Franz-Ludwig-Str. 7 | 635843 | 5528490 | 44 | Rheinstr. 16 ca. | 632910 | 5530367 |
| 12 | Geisfelder Str. 30 | 637689 | 5528020 | 45 | Robert-Bosch-Str. 40 | 637767 | 5528292 |
| 13 | Grüner Markt 1 | 635624 | 5528370 | 46 | Schildstr. 81 | 637049 | 5529049 |
| 14 | Grüner Markt 23 | 635640 | 5528565 | 47 | Schranne 3 | 635511 | 5528166 |
| 15 | Gutenbergsstr. 20 | 638448 | 5527180 | 48 | Schützenstr. 23 | 636197 | 5527961 |
| 16 | Hainstr. 4 | 635945 | 5528229 | 49 | Schwarzenbergstr. 50 | 636762 | 5528732 |
| 17 | Hainstr. 39 | 636341 | 5527550 | 50 | Siemensstr. 37–43 | 638091 | 5528505 |
| 18 | Hauptsmoorstr. 26a | 638223 | 5530558 | 51 | Theresienstr. 32 | 637487 | 5527866 |
| 19 | Hauptsmoorwald, Pödeldorfer Straße | 639683 | 5529635 | 52 | Unterer Kaulberg 4 | 635350 | 5528084 |
| 20 | Hauptsmoorwald, Geisfelder Straße | 639890 | 5528022 | 53 | Von-Ketteler-Str. 2 | 637905 | 5527553 |
| 21 | Heiliggrabstr. 15 | 636054 | 5529240 | 54 | Wilhelmsplatz 3 | 636316 | 5528259 |
| 22 | Heinrichsdamm 1 | 635849 | 5528723 | 55 | Zollnerstr. 181 | 637772 | 5530133 |
| 23 | Heinrichsdamm 33a, P&R | 636748 | 5527529 | 56 | Heganger 18 | 634327 | 5530982 |
| 24 | Hohenlohestr. 7 | 634794 | 5526480 | 57 | Biegenhofstr. 13 | 633963 | 5531045 |
| 25 | Kantstr. 33 | 637161 | 5530333 | 58 | Seebachstr. 1 | 634399 | 5531764 |
| 26 | Katzenberg | 635374 | 5528266 | 59 | Landsknechtstr. | 634800 | 5531918 |
| 27 | Kirschäckerstr. 37 | 636649 | 5530756 | 60 | Lichtenfelser Str. | 634864 | 5532621 |
| 28 | (Kloster-Langheim-Str. 8) | 637190 | 5529182 | 61 | Michelinstr. 130 ca. | 635629 | 5532106 |
| 29 | Kronacher Str. 50 | 636722 | 5531496 | 62 | Margaretendamm | 634991 | 5529497 |
| 30 | Lagerhausstr. 4–6 | 634850 | 5529871 | 63 | Mainstr. 36a/Kiliansplatz | 634326 | 5532386 |
| 31 | Lagerhausstr. 19 | 634304 | 5530136 | 64 | Bamberger Straße | 635964 | 5526050 |
| 32 | (Laurenziplatz 20) | 635207 | 5527404 | 65 | Würzburger Str. 76 | 635359 | 5526709 |
| 33 | Ludwigstr. 2 | 635207 | 5529103 | | | | |

due to existing obstacles there is an inhomogeneous radiofrequency field distribution. Buildings and vegetation (trees and foliage) can shield and reduce radiation and thus affect the quality of signal propagation (e.g. Meng and Lee, 2010). Living material is not a perfect dielectric object and interferes with high frequency electromagnetic fields in a way that depends upon several parameters, including the general shape,

conductivity, and density of the tissue, and the frequency and amplitude of the electromagnetic radiation (Vian et al., 2016).

In the polygon mentioned before we selected 60 trees showing unilateral damage. The selection was limited by the fact that we were able to measure with the telescopic rod only up to a height of 6 m. Many trees (*Tilia*, *Betula*, *Quercus*, *Populus*, *Picea*) showing damage above the

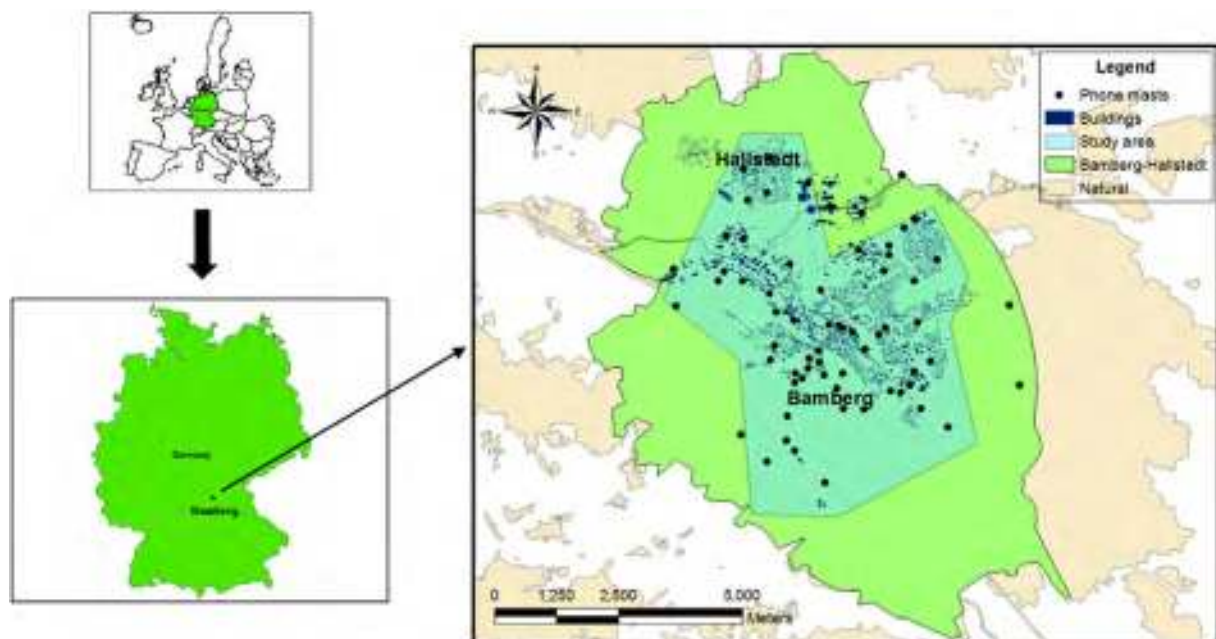


Fig. 1. The study area with the location of the phone masts in the layer of natural areas, buildings, and municipalities.

height of 6 m could not be included. The measurements at the trees were done between April and October 2015. *Acer platanoides*, *Carpinus betulus*, *Tilia* sp., *Taxus baccata* and *Thuja occidentalis* are widely spread in Bamberg and Hallstadt and can be reached for measurements. Therefore they are the most represented species.

The selected 60 trees from the study polygon show damage patterns that are not usually attributable to harmful organisms, such as diseases (fungi, bacteria, viruses) and pests (insects, nematodes) or other environmental factors (water stress, heat, drought, frost, sun, compaction of the soil, air and soil pollutants).

The main features of damage from this source are:

- Trees are mainly affected on one side (showing side differences and unilateral damage) and can appear in any orientation. The damage only originates on one side.
- Damage appears without external indications that the tree is infested with insects, nematodes, fungi, bacteria or viruses.

- Damage appears on trees, which have previously grown well. Damage appears on once healthy trees within one or two years after Antennas were put into operation.
- Damage increases from the outside to the inner part of the crown over time.
- Trees of different species in the same location also show damage.
- Damage appears in favourable (gardens, parks) as well as in unfavourable locations.
- Trees in the same location, but that are shielded by buildings or other trees, are healthy.

For these damaged trees, we used 13 damage codes that may be recognised with the naked eye (for explanations, see Table 2). In order to explain each type of damage visually, a photograph was added for each damage code.

Table 2
Tree damage codes.



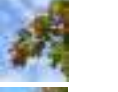








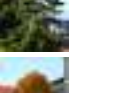

- | | |
|--|---|
| 01 Damage only on one side: The tree shows damage only on one side. The damage can be recognized with the naked eye. |  |
| 02 Crown transparency (sparse leaves or needles): The number of leaves or needles is reduced. The crown transparency increases from year to year. |  |
| 03 Brown leaves (start at leaf margins): The leaves begin to turn brown in June. The browning starts at the leaf margins. It looks similar to effects by salt. |  |
| 04 Colour change of leaves prematurely: Leaves become yellow, red or brown (in the whole) early in the year. |  |
| 05 Tree leaves fall prematurely: The leaves begin to fall already from June on. |  |
| 06 Dead branches: Over a period of some years it can be observed how little and big branches die. |  |
| 07 Tip of the main trunk dried. |  |
| 08 Irregular growth. The growth of deciduous and coniferous trees can be disturbed in different manners. One observation is that trees bend to a side. |  |
| 09 Not grow in height: Trees often stop to grow in height. The height was not measured. Only the visual impression was valued. |  |
| 10 Colour change of needles. Needles can change their colour to yellow, red or brown. |  |
| 11 Dead parts were trimmed down: When bigger branches die, it becomes necessary to remove these parts for the sake of security of people passing. |  |
| 12 Damage on different sides: The trees show damages on different sides. |  |
| 13 No damage: The tree shows the typical habitus of its species. With the naked eye no damage can be seen. |  |

Table 3
144 selected points in Bamberg and Hallstadt with their measurements and UTM coordinates.

| Number | Streets and parks in Bamberg and Hallstadt | Measurement $\mu\text{W}/\text{m}^2$ | X | Y | Number | Streets and parks in Bamberg and Hallstadt | Measurement $\mu\text{W}/\text{m}^2$ | X | Y |
|--------|---|--------------------------------------|--------|---------|--------|---|--------------------------------------|--------|---------|
| 1 | Wassermannpark | 2300 | 637395 | 5530345 | 73 | Ludwigstraße/Zollnerstraße | 50 | 636228 | 5529444 |
| 2 | Memmeldorfer Str. 209 | 1830 | 637581 | 5531113 | 74 | Landratsamt, Ludwigstraße, Einfahrt | 670 | 636422 | 5529044 |
| 3 | Holunderweg | 10 | 638125 | 5530967 | 75 | Wilhelmsplatz, Mitte | 460 | 636250 | 5528263 |
| 4 | Hauptsmoorstraße/Seehofstraße | 3600 | 638039 | 5530857 | 76 | Amalienstr. 16 | 16570 | 636303 | 5528086 |
| 5 | Greiffenbergstr. 79 | 4210 | 638349 | 5530855 | 77 | Otttostr. 7a | 120 | 636133 | 5527878 |
| 6 | Heimfriedweg 16 | 870 | 638393 | 5530621 | 78 | Schönbornstr. 3 | 3640 | 636251 | 5527696 |
| 7 | AWO, Innenhof, Parkplatz | 3920 | 638223 | 5530584 | 79 | Hainspielplatz | 1530 | 636229 | 5527403 |
| 8 | Ferdinand-Tietz-Str. 40 | 2600 | 637883 | 5530616 | 80 | P&R Heinrichsdamm, Parkplatz bei Kirschen | 3400 | 636706 | 5527667 |
| 9 | Ferdinand-Tietz-Str. 38 | 80 | 637889 | 5530601 | 81 | P&R Heinrichsdamm, südöstlich des Senders, Eichen | 1690 | 636755 | 5527504 |
| 10 | Petrinistr. 20 | 1340 | 637797 | 5530514 | 82 | Luisenhain, Höhe Wasserwerk | 260 | 636895 | 5526482 |
| 11 | Petrinistr. 32 | 4700 | 637891 | 5530449 | 83 | Kapellenstraße | 2120 | 637050 | 5528148 |
| 12 | Zollnerstraße 181 | 9300 | 637773 | 5530102 | 84 | Geisfelder Str. 9, Gärtnerei | 740 | 637410 | 5528164 |
| 13 | Wassermannstr. 14 | 540 | 637424 | 5530125 | 85 | Geruthstr. 8 | 30 | 637621 | 5527424 |
| 14 | Feldkirchenstraße/Kantstraße | 2620 | 636803 | 5530069 | 86 | Distelweg, Innenhof | 15 | 637881 | 5527160 |
| 15 | Breslaustr. 20 | 3890 | 637392 | 5530431 | 87 | Am Sendelbach BSC 1920 | 30 | 637331 | 5526877 |
| 16 | Berliner Ring | 16920 | 637188 | 5530786 | 88 | Am Sendelbach, Kleingartenanlage | 10 | 637542 | 5526222 |
| 17 | Rodezstr. 3 | 3780 | 637044 | 5530765 | 89 | Robert-Bosch-Straße | 2060 | 637504 | 5528200 |
| 18 | Am Spinnseyer 3 | 880 | 637545 | 5530764 | 90 | Ludwigstraße/Memmeldorfer Straße | 1000 | 635974 | 5529708 |
| 19 | Kirschäckerstr. 24 | 4290 | 636655 | 5530857 | 91 | Coburger Straße, Neubau Studentenwohnheim | 3460 | 635867 | 5529878 |
| 20 | Kammermeisterweg | 810 | 636283 | 5530282 | 92 | Coburger Straße, junge Platane | 3400 | 635835 | 5529941 |
| 21 | Eichendorff-Gymnasium, Hof | 6340 | 637194 | 5529084 | 93 | Gundelsheimer Str. 2 | 9000 | 635783 | 5529680 |
| 22 | Starkenfeldstraße/Pfarrfeldstraße | 3660 | 637092 | 5529138 | 94 | Hallstadter Straße | 12 | 635232 | 5530212 |
| 23 | Parkplatz auf der Westseite der Polizei | 9020 | 636921 | 5528970 | 95 | Gerberstraße/Benzstraße | 1280 | 635108 | 5530546 |
| 24 | Starkenfeldstraße, Höhe Polizei | 1120 | 636975 | 5529061 | 96 | Coburger Straße, Einfahrt Fitnesszentrum | 2000 | 635326 | 5530508 |
| 25 | Starkenfeldstr. 2 | 860 | 637527 | 5529216 | 97 | Kleintierzuchtanlage | 890 | 635380 | 5530622 |
| 26 | Pöeldorf Str., Haltestelle | 2180 | 636965 | 5529217 | 98 | Margaretendamm, Eingang ehemaliges Hallenbad | 1300 | 635455 | 5529178 |
| 27 | Kindergarten St. Heinrich, Eingang | 6450 | 637712 | 5529364 | 99 | Margaretendamm/Europabrücke | 1890 | 635200 | 5529365 |
| 28 | Pöeldorf Str. 142, Nordseite | 1620 | 637654 | 5529433 | 100 | Margaretendamm 38, nahe Sendeanlage | 5560 | 635003 | 5529497 |
| 29 | Pöeldorf Str. 142, Südseite | 30 | 637840 | 5529437 | 101 | Hafenstraße/Regnitzstraße | 7610 | 634719 | 5529740 |
| 30 | Pöeldorf Str. 142, Südseite | 17060 | 637824 | 5529410 | 102 | Lagerhausstraße | 210 | 634556 | 5530102 |
| 31 | Berliner Ring, Höhe Pöeldorf Str. 144 | 4480 | 637900 | 5529380 | 103 | Hafenstr. 28, Bayerischer Hafen | 3200 | 634192 | 5530370 |
| 32 | Schwimmbad Bambados, Vorgarten mit Bambus | 1620 | 638074 | 5529315 | 104 | Laubanger 29 | 160 | 634202 | 5530561 |
| 33 | Schwimmbad Bambados, Parkplatz, Feldahorn | 2540 | 638202 | 5529346 | 105 | Heganger | 1400 | 634341 | 5530812 |
| 34 | Carl-Meinelt-Str. | 5360 | 638043 | 5529094 | 106 | Emil-Kemmer-Str. 2 | 5000 | 633822 | 5530863 |
| 35 | Volkspark, FC Eintracht, Ostseite | 120 | 638343 | 5529065 | 107 | Emil-Kemmer-Str. 14 | 2500 | 634342 | 5531099 |
| 36 | Michelsberger Garten, Teil Streuobst | 5450 | 634831 | 5528673 | 108 | Dr. Robert-Pfleger-Straße 60 | 90 | 634448 | 5530978 |
| 37 | Michelsberger Garten, Terrassengarten, bei Eibe | 2500 | 634988 | 5528508 | 109 | Friedhof Gaustadt, Haupteingang | 13100 | 632981 | 5529677 |
| 38 | Michelsberger Garten, Südostecke, bei Holunder | 910 | 635036 | 5528455 | 110 | Friedhof Gaustadt, Ahornpaar | 1400 | 632929 | 5529728 |
| 39 | Michelsberg, Aussichtsterrasse, oberhalb Weinberg | 1260 | 634924 | 5528463 | 111 | Herzog-Max-Str. 21 | 1600 | 636245 | 5528071 |
| 40 | Michelsberg, Aussichtsterrasse, Aussichtspunkt | 780 | 634911 | 5528537 | 112 | Gaustadter Hauptstr. 116 | 10 | 634042 | 5529457 |
| 41 | Michelsberg, Nordostecke, bei jungen Linden | 390 | 634874 | 5528565 | 113 | Landesgartenschauelände, Hafenerlebnispfad | 2000 | 633789 | 5529894 |
| 42 | Storchsgasse/Michelsberg | 200 | 634725 | 5528415 | 114 | Landesgartenschau, junge Baumgruppe | 1270 | 633949 | 5529718 |
| 43 | St. Getreu-Kirche, Südseite | 55 | 634518 | 5528405 | 115 | Würzburger Str. | 340 | 635283 | 5527151 |
| 44 | Villa Remeis, Garten | 390 | 634295 | 5528203 | 116 | Würzburger Straße/Arthur-Landgraf-Straße | 1380 | 635355 | 5526862 |
| 45 | Villa Remeis, Treppe | 300 | 634400 | 5528237 | 117 | Hohe-Kreuz-Straße/Würzburger Straße, Haltestelle | 590 | 635383 | 5526733 |
| 46 | Maienbrunnen 2 | 3920 | 634744 | 5528838 | 118 | Hohe-Kreuz-Straße | 10950 | 635469 | 5526729 |
| 47 | Am Leinritt | 2140 | 635071 | 5528617 | 119 | Am Hahnenweg 6 | 3420 | 635332 | 5526729 |
| 48 | Abtsberg 27 | 130 | 634526 | 5528935 | 120 | Am Hahnenweg/Viktor-von-Scheffel-Straße | 640 | 635307 | 5526710 |
| 49 | Welcome Hotel, Garten | 3200 | 634788 | 5529012 | 121 | Am Hahnenweg 28 a | 145 | 635028 | 5526654 |
| 50 | Mußstraße, eingang Kindergarten | 1670 | 634864 | 5529011 | 122 | Schlüsselberger Straße | 200 | 634712 | 5526534 |
| 51 | Mußstraße/Schlüsselstraße | 710 | 634846 | 5529034 | 123 | Schlüsselberger Str./Haltestelle Hezilostr., Parkdeck | 460 | 634749 | 5526549 |
| 52 | Nebingerhof | 2040 | 635069 | 5528901 | 124 | Hezilostr. 13 | 70 | 634604 | 5526563 |
| 53 | Graf-Stauffenberg-Platz | 100 | 635120 | 5529009 | 125 | Stückleinsweg, junge Hainbuchenhecke | 75 | 634512 | 5526654 |
| 54 | Don-Bosdo-Straße, Innenhof | 10 | 635176 | 5529056 | 126 | Rößleinsweg, oberes Ende | 300 | 634708 | 5526789 |
| 55 | Pfeuferstraße/Weide | 1100 | 635222 | 5528820 | 127 | Große Wiese | 1500 | 634874 | 5526810 |

Table 3 (continued)

| Number | Streets and parks in Bamberg and Hallstadt | Measurement $\mu\text{W}/\text{m}^2$ | X | Y | Number | Streets and parks in Bamberg and Hallstadt | Measurement $\mu\text{W}/\text{m}^2$ | X | Y |
|--------|---|--------------------------------------|--------|---------|--------|---|--------------------------------------|--------|---------|
| 56 | Weidendamm/Don-Bosco-Straße | 1860 | 635166 | 5529195 | 128 | Suidgerstraße | 195 | 634508 | 5526409 |
| 57 | Katzenberg/Karolinenstraße | 1720 | 635316 | 5528239 | 129 | Waizendorfer Straße | 280 | 635317 | 5525864 |
| 58 | Vorderer Bach | 450 | 635305 | 5528141 | 130 | Waizendorfer Straße, Einfahrt Gärtnerei | 210 | 635326 | 5525582 |
| 59 | Obere Brücke | 8000 | 635565 | 5528289 | 131 | Klinikum, Nähe Spielplatz | 175 | 635732 | 5525672 |
| 60 | Judenstraße | 6 | 635479 | 5528040 | 132 | Klinikum Weiher | 100 | 635759 | 5525520 |
| 61 | Tourist Information | 4920 | 635674 | 5528172 | 133 | Buger Straße/Bamberger Straße | 2730 | 635829 | 5526082 |
| 62 | Universität, Am Kranen 14, Innenhof | 10 | 635501 | 5528535 | 134 | Dunantstraße | 470 | 635848 | 5526176 |
| 63 | Fleischstraße | 10 | 635703 | 5528683 | 135 | Buger Straße/Paradiesweg | 90 | 635743 | 5526286 |
| 64 | ZOB | 600 | 635882 | 5528541 | 136 | Buger Straße/Abzweigung Münchner Ring | 470 | 635528 | 5526499 |
| 65 | Schönleinsplatz, Ostseite | 900 | 636004 | 5528300 | 137 | Hallstadt, Markplatz, bei Linde | 2000 | 634582 | 5532426 |
| 66 | Friedrichstraße, Parkplatz | 165 | 635984 | 5528360 | 138 | Hallstadt, Markplatz 21, Innenhof | 8 | 634632 | 5532488 |
| 67 | Franz-Ludwig-Straße/Luisenstraße | 1720 | 636158 | 5528410 | 139 | Hallstadt, Lichtenfelser Str. 12 | 4000 | 634659 | 5532474 |
| 68 | Franz-Ludwig-Str, Strassenbauamt | 90 | 636246 | 5528408 | 140 | Hallstadt, Lichtenfelser Str. 8 | 9000 | 634720 | 5532516 |
| 69 | Heiliggrabstraße, Nähe Sender | 4740 | 636072 | 5529245 | 141 | Hallstadt, Am Gründleinsbach/Kemmerner Weg | 200 | 634743 | 5532784 |
| 70 | Heiliggrabstr. 29, Landesjustizkasse | 20 | 636063 | 5529399 | 142 | Hallstadt, Valentinstraße/Seebachstraße | 2200 | 634232 | 5532237 |
| 71 | Heiliggrabstr. 57, Aussichtspunkt Schiefer Turm | 4500 | 635797 | 5529410 | 143 | Hallstadt, Johannisstr. 6 | 5000 | 634805 | 5532078 |
| 72 | Bahnhof, ParkplatzWestseite | 1600 | 636300 | 5529374 | 144 | Hallstadt, Bamberger Straße/Michael-Bienlein-Straße | 1860 | 634805 | 5531969 |

For each selected tree, the types of damage and the Universal Transversal Mercator (UTM) coordinates were recorded. In addition, two measurements were recorded: on the side showing damage and on the side without damage, generally corresponding to opposite sides of each tree. On both sides, the measurements were carried out at a variable height of 1–6 m (depending on the height of the tree), using a telescopic rod, a ladder, and the broadband radiofrequency meter.

Most measurements were done in the afternoon or in the evening on different days between April and October 2015. But the measurements on the two sides of each single tree were done one after another immediately on the same day and at the same time. The measurements took about 5 min on each side. When we stood on the ground or on a ladder

we measured the peak values. When we used the telescopic rod we measured the peak hold values. Using the telescopic rod and measuring peak hold values it took longer, because the measurements had to be repeated often in cases where RF-EMF emitting cars or passengers disturbed the results. At each single tree the two measurements were done in the height where the damage had appeared. Because the height of the 120 trees differed, it was necessary to do the measurements at different heights.

In theory, although measurements are changing continuously there is no evidence about significant changes in power densities of electromagnetic radiation produced by phone masts over time. One study carried over one year in the city of Madrid showed no changes in terms of radiation intensity between the three rounds of measurements

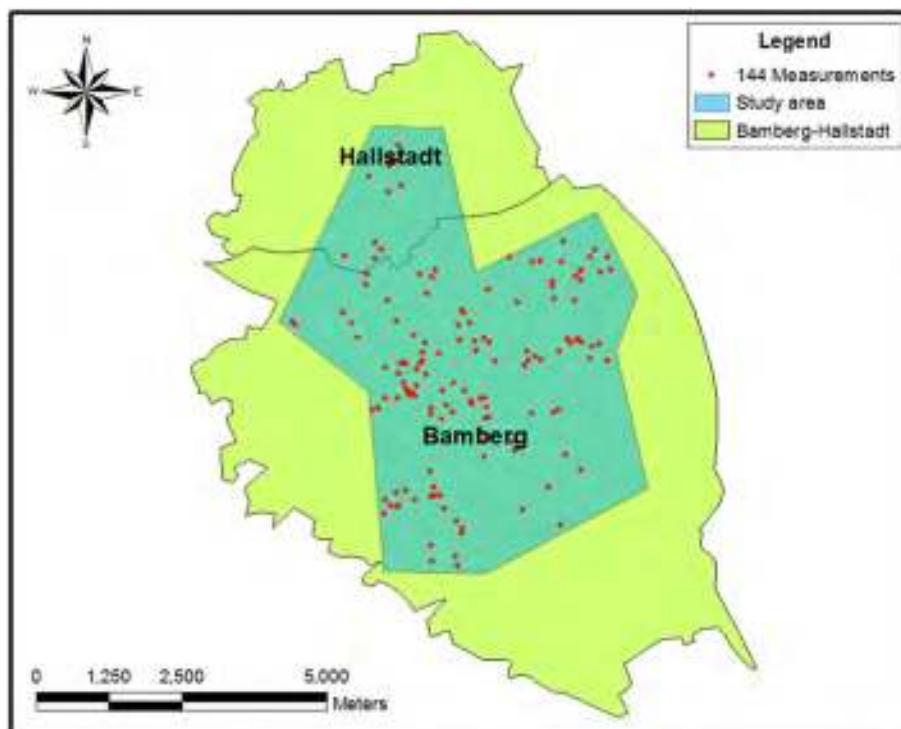


Fig. 2. Location of the 144 measurements points in Bamberg and Hallstadt in the study area.

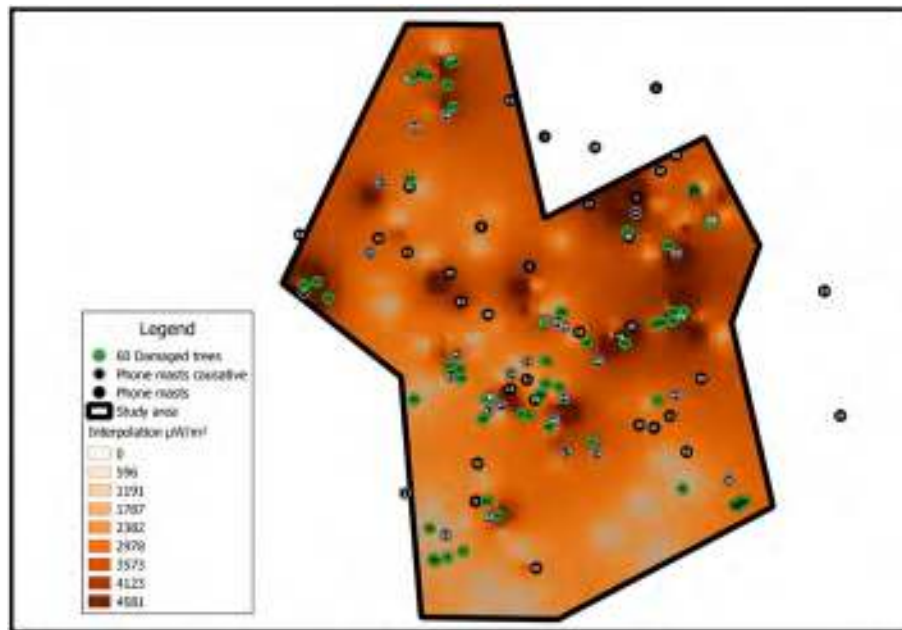


Fig. 3. Map showing the 60 damaged trees and phone masts (both with code numbers) over the interpolation electromagnetic map of the 144 measurement points.

performed in about 200 sampling points (own data). Repeatability analysis checked this. Despite the fact that the increase in sector antennas (observed between 2011 and 2015) would have probably increased the radiation in the environment of the study area, measurements used in this study were mostly done in 2015.

In an attempt to link the electromagnetic radiation measured at every tree to specific phone masts, the distances to the three nearest antennas that could be mainly responsible for the radiation measurements at each tree were calculated in meters with Geographical Information System (GIS) programs, following the general approach criteria of proximity. However, it must be taken into account that buildings and vegetation diminish radiation intensity and, in many cases, the nearest phone mast or masts may be obscured by obstacles. In other cases, the phone mast is in direct line of sight from the tree and the radiation can reach the tree directly.

Additionally, 30 random points were generated inside the polygonal study area and outside a layer of buildings, downloaded from: <http://www.mapcruzin.com/free-germany-arcgis-maps-shapefiles.htm> using a Random Points tool of QGIS 2.6.0-Brighton (QGIS Development Team, 2014) allowing create random points inside a specific layer. Therefore the points were randomly situated in specific places in the study area outside buildings but not frequently concur with the location of trees. That is why measurements were taken from the nearest tree for each random point, generating a random tree group. Measurements and damage characteristics were scored in the same way as with 60 damaged trees explained above, measuring the maximum value of radiation corresponding to opposite sides of each tree.

In areas of the city with low measurements of electromagnetic radiation (no visual contact to any phone mast and power flux density $<50 \mu\text{W}/\text{m}^2$), we scored another 30 trees in the same way as with 60 damaged trees and 30 random points. The UTM coordinates and the three nearest phone masts of each tree in these last two groups (random and low radiation trees) were also recorded.

To generate electromagnetic maps, we used ArcGis 9.3 (ESRI, 2008) and QGIS 2.6.0-Brighton (QGIS Development Team, 2014). To check possible differences between groups of data and taking into account that there were two measures made in each tree, repeated measures analysis of variance were applied, considering a repeated measures factor (within-subjects) and another between-subjects. The post hoc

Bonferroni test was used in all cases to elucidate significant differences. Statistics were performed using STATISTICA 7 program (StatSoft, Inc, 2004).

3. Results

The results of radiation measurements obtained at 144 points in Bamberg and Hallstadt at a height of 1.5 m were between $6 \mu\text{W}/\text{m}^2$ ($0.047 \text{ V}/\text{m}$) and $17,060 \mu\text{W}/\text{m}^2$ ($2.53 \text{ V}/\text{m}$) (for measurements and UTM coordinates, see Table 3). The measured values are far below the current limit values ($41 \text{ V}/\text{m}$ for GSM system and $61 \text{ V}/\text{m}$ for UMTS; ICNIRP, 1998).

The locations of these points in the study area are shown in Fig. 2. By interpolation of the 144 measurements points (Table 3), we prepared a map of the power flux density in Bamberg and Hallstadt (Fig. 3). This map is theoretical and approximate, since many factors affect the true electromagnetic values. However, the map is useful to provide approximate differences in exposure (electromagnetic pollution) throughout the city.

The 60 selected trees showing damage patterns not attributable to diseases, pests or other environmental factors are presented in Table 4. In this Table, we added the tree code number, the scientific name, the UTM coordinates, the measurements (power flux density) on both sides of each tree, and the distances (meters) and code numbers to the three nearest antennas for each tree, which may be mainly responsible for the electromagnetic radiation measured. We also included the orientation of the tree damage and the number of main (nearest) phone mast(s) in direct line of sight, whose lobe of radiation most directly affected each tree. Finally, we included the codes of damage observed in the 60 trees.

From all 60 selected trees, one or more phone mast(s) could be seen, with no obstacles between the phone mast and damaged tree. In many cases, one of the three closest antennas caused the main radiation on the tree surface. In ten trees (codes: 4, 7, 9, 10, 15, 26, 27, 31, 35, and 50), another antenna in direct line of sight caused the measured radiofrequency exposure. This was determined using topography and existing buildings (Table 4 and Fig. 3).

The 60 damaged trees (with their code number) and the phone masts are overlaid on the electromagnetic map prepared by interpolation of the 144 measurements points (Fig. 3). The likely antenna or

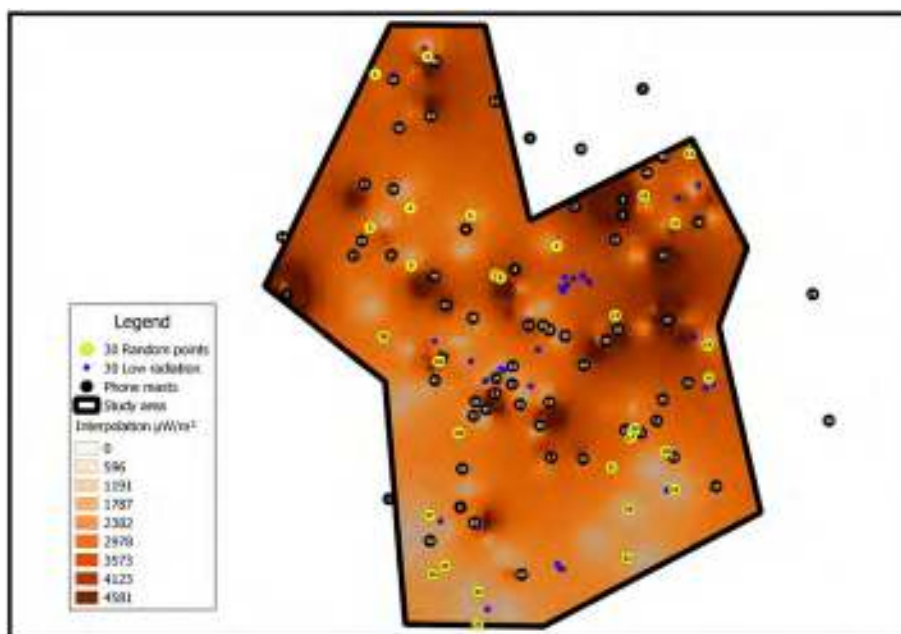


Fig. 4. Map showing the 30 trees at random points and the 30 trees in areas of low radiation (both with code numbers) over the interpolation electromagnetic map of the 144 measurement points. Phone masts (with code numbers) are also represented.

there were no unilateral damages. The measured values were below $50 \mu\text{W}/\text{m}^2$ ($0.137 \text{ V}/\text{m}$) and there was no difference between opposite sides. These results in the three groups point to a connection between unilateral tree damage and RF exposure.

In the electromagnetic field of all mobile phone base stations visited numerous tree damages were observed. The damage occurred in temporal relation with the putting into operation of new mobile phone base stations. Woody plants of all species are affected (deciduous and coniferous trees as well as shrubs).

In the five most represented species ($n \geq 4$) among the 60 damaged trees (*Acer platanoides*, *Carpinus betulus*, *Tilia* sp., *Taxus baccata* and *Thuja occidentalis*), most trees showed damage only on one side (Damage code 1, Tables 2 and 4). Most of these trees were characterized with sparse leaves or needles (crown transparency) (Damage code 2, Tables 2 and 4). In many of the trees with the one-sided damage, the leaves turned prematurely yellow or brown in June – this always began at

the leaf margins (Damage code 3, Tables 2 and 4). In many trees leaves fall prematurely (Damage code 5, Tables 2 and 4) or had dead branches (Peak branches dried) (Damage code 6, Tables 2 and 4). Some trees stopped growing in height while, in others, the main guide died (see Tables 2 and 4).

The differences in susceptibility of different species could be related to radiofrequency energy absorption properties of the trees (e.g., dielectric property). Perhaps this study cannot answer questions about these differences, however it is quite possible that differences are related to the electrical conductivity, related also with the density of the wood (species of fast or slow growth) and particularly with the percentage of water in the tissues. Poplars and aspen that grow near rivers and water bodies in Spain seem to be particularly sensitive to the effects of radiation. But the waves reflection in the water could also influence.

The results presented here lead us to conclude that damage found in the selected trees is caused by electromagnetic radiation from phone

Table 7

Repeated measures ANOVA analysis and Bonferroni post hoc comparisons ($p < 0.01$ values with *) in the three types of trees (damaged, random, and low radiation). Measurement Side 1/2 correspond to the maximum/minimum value of radiation respectively for the opposite sides of each tree.

| | | SS | Degr. of | MS | F | p | | |
|-----------------|---------------|-------------------|-----------|-----------|-----------|-----------|-----------|-----------|
| Intercept | | 62663309 | 1 | 62663309 | 25.81460 | 0.000001* | | |
| Type of tree | | 52931692 | 2 | 26465846 | 10.90280 | 0.000046* | | |
| Error | | 284010086 | 117 | 2427437 | | | | |
| R1 | | 33197069 | 1 | 33197069 | 18.28694 | 0.000039* | | |
| R1*Type of tree | | 44608664 | 2 | 22304332 | 12.28656 | 0.000014* | | |
| Error | | 212395158 | 117 | 1815343 | | | | |
| Type of tree | R1 | | {1} | {2} | {3} | {4} | {5} | {6} |
| 1 | Damaged | Measurement Side1 | | 0.000000* | 0.001829* | 0.000001* | 0.000000* | 0.000000* |
| 2 | Damaged | Measurement Side2 | 0.000000* | | 1.000000 | 1.000000 | 1.000000 | 1.000000 |
| 3 | Random | Measurement Side1 | 0.001829* | 1.000000 | | 1.000000 | 1.000000 | 1.000000 |
| 4 | Random | Measurement Side2 | 0.000001* | 1.000000 | 1.000000 | | 1.000000 | 1.000000 |
| 5 | Low radiation | Measurement Side1 | 0.000000* | 1.000000 | 1.000000 | 1.000000 | | 1.000000 |
| 6 | Low radiation | Measurement Side2 | 0.000000* | 1.000000 | 1.000000 | 1.000000 | 1.000000 | |

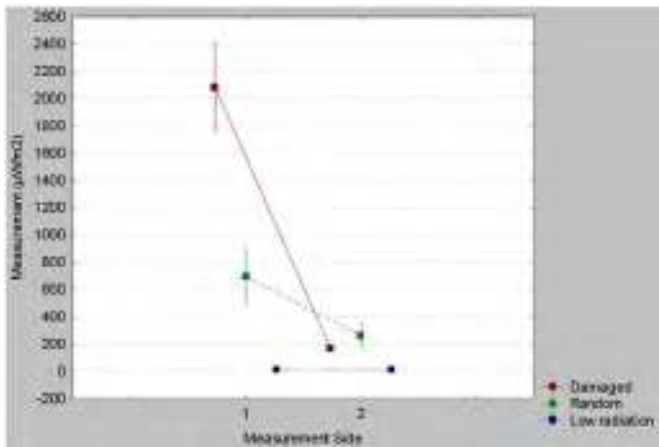


Fig. 5. Differences between measurements in both sides for the three different tree groups: damaged, random, and low radiation. Measurement Side 1/2 correspond to the maximum/minimum value of radiation respectively for the opposite sides of each tree. The bars represent means \pm standard errors. The central point represents the mean and the straight line \pm 0.95*SE.

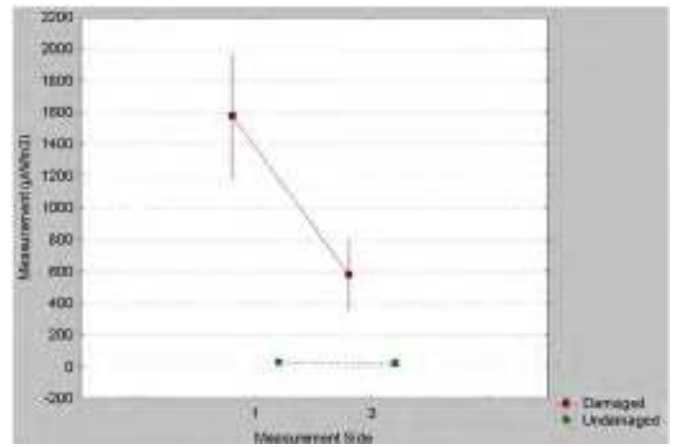


Fig. 6. Differences between measurements in both sides for the damaged and undamaged trees within the random trees group. Measurement side 1/2 correspond to the maximum/minimum value of radiation respectively for the opposite sides of each tree. The bars represent means \pm standard errors. The central point represents the mean and the straight line \pm 0.95*SE.

masts, as we proposed in previous studies (Balmori, 2004; Waldmann-Selsam, 2007; Waldmann-Selsam and Eger, 2013; Balmori, 2014). Interested parties are able to locate the damaged trees found in this work in Bamberg and Hallstadt with their UTM coordinates. However, trees with code numbers 20, 38 and 48 (Table 4) have been cut down and removed.

Research on the effects of radiation from phone masts is advancing rapidly. In February 2011 the first symposium on the effects of electromagnetic radiation on trees took place in Baarn, Netherlands (Schorpp, 2011 - <http://www.boomaantastingen.nl/>), where similar effects and results to those found in the current paper were presented.

Although there are some related experiments that show no effect of long-term exposure (3,5 years), 2450-MHz (continuous wave) and power flux densities from 0.007 to 300 W/m² on crown transparency, height growth and photosynthesis of young spruce and beech trees (Schmutz et al., 1996), this result may not be transferred to modulated 2450-MHz or to other pulsed and modulated frequencies. In addition, an increasing number of studies have highlighted biological responses and modifications at the molecular and whole plant level after exposure to high frequency electromagnetic fields (Vian et al., 2016). Plants can perceive and respond to various kinds of electromagnetic radiation over a wide range of frequencies. Moreover, a low electric field intensity (5 V/m) was sufficient to evoke morphological responses (Grémiaux et al., 2016). Electromagnetic radiation impacts at physiological and

ecological levels (Cammaerts and Johansson, 2015), and evokes a multitude of responses in plants. The effects of high frequency electromagnetic fields can also take place at the subcellular level: it can alter the activity of several enzymes, including those of reactive oxygen species (ROS) metabolism, a well-known marker of plant responses to various kinds of environmental factors; it evokes the expression of specific genes previously implicated in plant responses to wounding (gene expression modifications), and modifies the growth of the whole plants (Vian et al., 2016). It could be hypothesized that membrane potential variations in response to electromagnetic radiation exposure may initiate electrical waves of depolarization (AP and/or VP) that could initiate immediate or delayed growth responses (Grémiaux et al., 2016). It has been proposed that electromagnetic fields act similarly in plants and in animals, with the probable activation of calcium channels via their voltage sensor (Pall, 2016).

Electromagnetic radiation (1800 MHz) interferes with carbohydrate metabolism and inhibits the growth of *Zea mays* (Kumar et al., 2015). Furthermore, cell phone electromagnetic radiation inhibits root growth of the mung bean (*Vigna radiata*) by inducing ROS-generated oxidative stress despite increased activities of antioxidant enzymes (Sharma et al., 2009). Germination rate and embryonic stem length of *Triticum aestivum* was also affected by cell phone radiation (Hussein and El-Maghraby, 2014). After soybeans were exposed to weak microwave radiation from the GSM 900 mobile phone and base station, growth of

Table 8
Repeated measures ANOVA analysis and Bonferroni post hoc comparisons ($p < 0.01$ values with *) in the random trees group. Measurement Side 1/2 correspond to the maximum/minimum value of radiation respectively for the opposite sides of each tree.

| | SS | Degr. of | MS | F | p | |
|------------|-----------|--------------------|-----------|-----------|-----------|-----------|
| Intercept | 17829607 | 1 | 17829607 | 16.60985 | 0.000343* | |
| 13 code | 16391606 | 1 | 16391606 | 15.27023 | 0.000538* | |
| Error | 30056202 | 28 | 1073436 | | | |
| R1 | 3701923 | 1 | 3701923 | 16.73250 | 0.000329* | |
| R1*13 code | 3627579 | 1 | 3627579 | 16.39647 | 0.000368* | |
| Error | 6194761 | 28 | 221241 | | | |
| | 13 code | R1 | {1} | {2} | {3} | {4} |
| 1 | Undamaged | Measurement Side 1 | | 1.000000 | 0.002129* | 0.416303 |
| 2 | Undamaged | Measurement Side 2 | 1.000000 | | 0.000034* | 0.927155 |
| 3 | Damaged | Measurement Side 1 | 0.002129* | 0.000034* | | 0.000055* |
| 4 | Damaged | Measurement Side 2 | 0.416303 | 0.927155 | 0.000055* | |

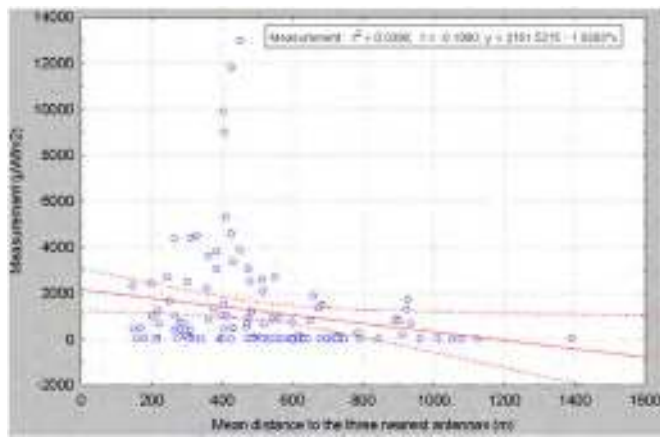


Fig. 7. Scatterplot showing the correlation between measurements from each of the 120 trees and the mean distance to the three nearest antennas. Dashed lines represent the 0.95 confidence interval.

epicotyl and hypocotyl was reduced, whereas the outgrowth of roots was stimulated. These findings indicate that the observed effects were significantly dependent on field strength as well as amplitude modulation of the applied field (Halgamuge et al., 2015). Phone mast radiation also affects common cress (*Lepidium sativum*) seed germination (Cammaerts and Johansson, 2015). In *Arabidopsis thaliana*, the long term exposure to non ionizing radiation causes a reduction in the number of chloroplasts as well as the decrease of stroma thylakoids and the photosynthetic pigments (Stefi et al., 2016). Finally, low-intensity exposure to radiofrequency fields can induce mitotic aberrations in root meristematic cells of *Allium cepa*; the observed effects were markedly dependent on the frequencies applied as well as on field strength and modulation (Tkalec et al., 2009).

In general, polarization from man-made electromagnetic radiation appears to have a greater bioactive effect than natural radiation, and significantly increases the probability for initiation of biological or health effects (Panagopoulos et al., 2015).

Tree damages as in Bamberg and Hallstadt were documented by the authors in several countries: Spain (Valladolid, Salamanca, Madrid, Palencia, León), Germany (Munich, Nürnberg, Erlangen, Bayreuth, Neuburg/Donau, Garmisch-Partenkirchen, Murnau, Stuttgart, Kassel, Fulda, Göttingen, biosphere reserve Rhön, Tegernsee Valley and in several small towns), Austria (Graz), Belgium (Brussels) and Luxemburg.

Each phone mast can harm many trees and each tree can be affected by several phone masts belonging to the same or different base stations. Damaged trees seem to exist around each antenna and the several million phone masts in the world could potentially be damaging the growth and health of millions of trees. This can occur not only in cities, but also in well-preserved forests, and in natural and national parks, where base stations are being installed without the necessary prior environmental impact studies, due to a lack of knowledge of the problem. For this reason, it is essential for an assessment on the environmental impact of any new base station prior to implementation.

Additionally, phone masts can cause a drop in timber productivity in plantations of pine, poplar, etc., as well as fruits, nuts, etc. Thus, the industry must be required to pay damages to plantation owners. Similarly, as trees are a common social good, the industry should compensate for damaged and dead trees around the world due to radiation. Further, the money spent by municipalities to repair or replace damaged trees should enter into the computation of costs/benefits of this technology. For installation of any new technology, the burden of proof should be to the industry that requires demonstration of safety prior to deployment.

Electromagnetic radiation from telecommunication antennas affect the abundance and composition of wild pollinators in natural habitats and these changes in the composition of pollinator communities

associated with electromagnetic smog may have important ecological and economic impacts on the pollination service that could significantly affect the maintenance of wild plant diversity, crop production and human welfare (Lázaro et al., 2016).

Evidence for plant damage due to high frequency electromagnetic radiation was not taken into account in determining the current statutory regulations (the limit values). Once the problem becomes evident, the guidelines of radiation emitted by the antennas should be reviewed. Proper risk assessment of electromagnetic radiation should be undertaken to develop management strategies for reducing this pollution in the natural environment (Kumar et al., 2015).

Moreover, due to the lack of recognition, certain modern projects with interesting ideas for decreasing environmental pollution could have opposite effects than expected. For example, in the Netherlands, the TreeWiFi project (<http://treewifi.org/>), which aims to motivate people to use bikes and public transport in order to reduce the [NO₂] pollution providing free WiFi when air quality improves, could be favoring electromagnetic pollution with even more harmful effects as it has been demonstrated in this manuscript (see also: <http://www.greenpeace.org/canada/fr/Blog/le-wi-fi-tuerait-les-ar-bres/blog/33569/>).

In addition, the number of sector antennas has increased in Bamberg and this increase appears to be accelerating: 483 sector antennas in 2011 and 779 sector antennas in 2015. Both radiation and damaged trees represent a loss of quality of life for citizens. This study began after finding that patients who claimed to be affected by phone masts, referred to as radiation, live in areas where affected trees and plants are located. Evidence of radiation damage was even found in potted plants inside patient homes (Waldmann-Selsam and Eger, 2013). Thus, this study is certainly complementary to the study by Eger and Jahn (2010) and other research that has shown effects on the health of people by phone masts located in their vicinity (Santini et al., 2002; Eger et al., 2004; Wolf and Wolf, 2004; Abdel-Rassoul et al., 2007; Khurana et al., 2010; Dode et al., 2011; Gómez-Perretta et al., 2013; Shahbazi-Gahrouei et al., 2014; Belyaev et al., 2015).

In the introduction to the International Seminar on “Effects of Electromagnetic Fields on the Living Environment” in 1999 in Ismaning, Germany, organized by WHO, ICNIRP and German Federal Office for Radiation Protection (BfS), M. Repacholi, head of the International EMF Project of the WHO, said: “By comparison, influences of these fields on plants, animals, birds and other living organisms have not been properly examined. Given that any adverse impacts on the environment will ultimately affect human life, it is difficult to understand why more work has not been done. There are many questions that need to be raised: ...” and “...it seems that research should focus on the long-term, low-level EMF exposure for which almost no information is available. Specific topics that need to be addressed include: ... EMF influences on agricultural plants and trees” (Matthes et al., 2000).

5. Conclusions

In this study we found a high-level damage in trees within the vicinity of phone masts. Preliminary laboratory studies have indicated some deleterious effects of radiofrequency radiation. However, these early warnings have had no success and deployment has been continued without consideration of environmental impact.

We observed trees with unilateral damage in the radiation field of phone masts. We excluded the possibility that root injury due to construction work or air pollutants could have caused the unilateral damage. We found out that from the damaged side there was always visual contact to one or more phone mast (s).

Statistical analyses demonstrated that the electromagnetic radiation from cellphone towers is harmful to trees. Results show that the measurements in the most affected sides of damaged trees (i.e. those that withstand higher radiation levels) are different to all other groups. These results are consistent with the fact that damage inflicted on

trees by cellphone towers usually start on one side, extending to the whole tree over time.

The occurrence of unilateral damage is the most important fact in our study and an important argument for a causal relationship with RF-EMF, as it supplies evidence for non-thermal RF-EMF effects. This constitutes a danger for trees worldwide. The further deployment of phone masts has to be stopped. Scientific research on trees under the real radiofrequency field conditions must continue.

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