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"Richtfunk" (radio relay) and radar waves are not causing forest damage

Statement of the German Commission on Radiological Protection

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Stellungnahme der Strahlenschutzkommission

**In the event of any doubts about the meaning,
the German original as published shall prevail.**

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For some time the speculation has been repeatedly expressed by the media that high frequency electromagnetic fields produced by "Richtfunk-" (radio relay-) and radar waves (microwaves) may be the cause of widespread damage observed in forests. The committee on "non-ionizing radiation" has examined this topic and arrived at the following conclusion:

1 Interaction between high frequency radiation and biological matter

Every damage to plant- or animal tissue from high frequency radiation is based on the absorption of energy. The energy absorption depends on numerous factors. The most important factors are intensity and frequency of high frequency radiation. Of further significance are size, form and internal structure (especially the water content) of the object as well as the latter's position in the irradiated field.

On the molecular and cellular level, the energy absorbed per unit of time depends on the dielectric characteristics of the material and its inherent electromagnetic field strengths. The energy transfer is governed by various mechanisms, mainly by the polarisation of bound charges, oscillations in the orientation of permanent dipoles, particularly those of water molecules, by oscillating- and rotating movements within molecules or by a shift of unbound charge carriers. The occurrence of these events is consistent with the radiated frequency. Accordingly, the absorbed energy strongly depends on the frequency of the effective electromagnetic radiation.

In a frequency range between 1 GHz and 30 GHz, orientation movements of polar molecules are the predominant absorption mechanism. In biological tissue, mainly water is responsible for the energy transfer in this frequency range. In general, it is assumed that the orientation movements released in water molecules are not resulting in permanent changes of the macromolecules in the cell but that all of the absorbed energy is transformed into heat due to friction losses.

The dose unit by which the absorption of high frequency radiation in matter, also in plant tissue, is quantitatively described, is the specific absorption rate (SAR). This dose unit can be correlated with biological effects and is the absorbed energy averaged per unit of time over the entire object mass, or partial mass (e.g. 1 g); it is described as watt per kilogram (W/kg).

The absorption of high frequency energy by plants or other biological objects depends on size, form and position of the object in relation to the external field. Resonance-like excessive absorptions may here occur and amount for needles and leaves of trees, for instance, to a maximum factor 3 in the frequency range between 2 GHz and 20 GHz. This, of course, requires for needles or leaves to be optimally adjusted in the field, comparable to the adjustment of a television antenna to improve the image reception. In nature, such an optimal adjustment always applies to only a very small portion of needles or leaves. Additionally, an excessive absorption by a factor 3 is of little significance for the considerations discussed within this context.

Also for trees, such resonance-like excessive SAR-values apply in similar magnitude. They are within a frequency range from several MHz up to 10 MHz and depend on the height of the tree. Considering all of these influencing factors, in the most unfavourable case and at an external flow rate density of 10 W/m^2, the result is an estimated maximum SAR-value of

2 W/kg for the microwave range. The subsequent increase in temperature amounts to less than 1 - 2 °C for the long-term effect, taking the loss of heat from heat conduction and heat radiation into account.

Since, due to the low density rate (see paragraph 2), it can safely be excluded that thermic effects from microwaves are one of the causes for forest destruction, various non-thermic effects are also subject to discussion. The various non-thermic effects and their possible plant damaging relevance are examined below:

a) of interest are resonance-type oscillating movements in the macromolecules of the photosynthesis apparatus or in the DNA. So far, no resonance effects have been observed since, due to the relatively high water concentration, resonances are strongly attenuated in plant as well as in animal tissue. This should essentially also be the reason for animal tests not having shown any evidence of effects on genetic material.

b) Field-produced energy effects on cells or field-produced potential differences in boundary layers are primarily of impact at deeper frequencies below some MHz; they are without significance for the microwave range.

c) Cell membrane effects from pulsed microwave radiation which may, for instance, destroy membranes due to dielectric breakthrough, require very high peak pulse rates (field strengths of over 100 kV/m). Such high peak pulse rates can be achieved only in the immediate vicinity of radar facilities with high power rates and, therefore, are without significance outside the near field range (up to some 100 m).

d) Changes in the substance transport through cell membranes have been seen to occur when modulating high frequency fields of 16 or 22 Hz to lower frequency. However, the test conditions were very specific, so that in reality changes of this kind are not expected to be induced by high frequency electromagnetic fields that are presently caused by radio and television transmitters as well as by "Richtfunk-" (radio relay-) and radar waves.

e) Some research groups reported on resonance-like growth changes to occur in specific yeast cells due to microwave exposure in the Giga-Hertz range (40 - 50 GHz) and at specific laboratory conditions. However, these changes were so insignificant as to be within the natural range of deviation; they were not proven to occur in other cell types.

So far, there is no scientific evidence of other non-thermic effect mechanisms.

2 Assessment of the flow rate density caused by radar and "Richtfunk-" (radio relay) devices

The various transmitting devices result in different exposures within the range of the transmitted high frequency fields and, in the following, are described as flow rate densities. The flow rate densities occurring in forest areas are usually derived with sufficient accuracy from theoretical considerations that are based on available data, e.g. on transmission rate and geometric conditions.

a) Standard "Richtfunk-" (radio relay-) devices mostly operate over relatively short distances. They work with transmission rates ranging from mW up to several Watt. The hereby produced flow rate densities are in a range between 1 and 100 $\mu W/m^2$.

b) For covering greater distances, so called scatter facilities are employed. They utilise the reflection in the ionosphere and subsequently radiate at a climbing angle, depending on the distance to be covered. Of main interest is therefore the exposure in the area of the receiver where the transmitted beam meets the earth again. However, at that point the transmitted beam is so strongly expanded that here only very low flow rate densities occur.

c) Satellite communication systems are operating at top rates of up to several hundred kW because of the large distance to be covered. In the transmitting beam, which is strongly focussed and usually has a reflected ray angle of more than 7^o, flow rate densities of 10 W/m^2 may still occur at distances as far as 50 km. Because of the reflected ray angle, the expected exposure on the earth surface is already below 100 mW/m^2 at a distance of several 100 m from the transmitter.

d) Air traffic control and military radar facilities are mostly operated by pulse rates in the MW-range. The mean transmission rate is in the kW-range because of the low probe ratio. Directly in the transmitting beam, flow rate densities of more than 10 W/m^2 may occur at a distance as far as several 100 m. As of a distance of about 1 km from the aerial, the flow rate density has usually decreased to values below 100 mW/m^2. Here, taking the reflected ray angle and the aerial rotation into account, considerably lower mean exposure values can be expected.

e) Radar equipment installed in aircraft operates at transmitting rates of some 10 W. Already at a distance of about 100 m, the exposure values are here markedly below 0.1 mW/m^2.

f) Radio- and television transmitters operate primarily in a radio frequency range below the microwave range. Only some television channels (UHF) are transmitting in the lower microwave range. For this range, there are several very powerful transmitters in the Federal Republic of Germany (mainly in the East) with transmitting rates of up to 1 MW. Since the aerial for the transmission of television programs is usually installed in high television towers, the flow rate densities on the ground or in wooded areas are low. Assuming a minimum height of 150 m for such towers, the flow density rate near the ground (100 m distant from the tower) is about 40 mW/m^2 at a maximum transmission rate of 1 MW. At a distance of about 1 km, the flow rate density is lower by about one order of magnitude.

3 Assessment of forest damage

For the assessment of forest damage, three essential methods are currently used:

a) Damage assessment from the ground: This is done by experienced forest experts determining the condition of each single tree at the site. For an assessment of the condition of the tree top, the essential criteria are: loss of needles and leaves in the tree top and yellowing of the assimilation apparatus. A field assessment can be done purely visually, classifying the damage in 20 stages (0-5%, 5-10%, etc.) which are frequently compiled into 5 damage stages for less differentiated assessments. Best known is the so far annually performed forest damage inventory. This is coordinated between the Federal Government and the Federal States and is based on a uniform, systematic and permanent sample area net with a 4 x 4 km^2 ground space grid. Further additional inventories are done, e.g. by individual forestry stations, using similar methods but a considerably tighter sample area net.

b) Forest damage assessment via aerial photography: this long distance assessment of forest damage is either based on the visual interpretation of infrared aerial colour photos or on an analysis of data from electronic line scanning. This is possible because there are either clear differences in the shape of the tree tops, positioning of the branches or density of leaves between damaged and undamaged trees or reflection differences that occur in one or more spectral areas. Structural tree top changes, which are typical for the present types of forest damage, can be well recognized in stereoscopically analysed aerial photos at near scales of 1:5,000 due to the two- or three-dimensional contour characteristics. This allows for a classification of single trees into 5 stages of treetop condition. For this purpose, interpretation keys for the major tree types may be used, as published by the Association of German Engineers (1990). These largely standardized keys, when used expertly by qualified interpreters, allow for an exact assessment of the tree top condition.

c) Incremental growth analysis: this analysis based on the assessment of annual growth increments from measuring the width of single annual rings. Such increments are essentially suitable for series of observation over longer periods of time, e.g. for an analysis of the effect on growth from climatic changes.

The results from damage analysis are with regard to a determination of the source of damage suitable only for comparative assessments. Therefore, it is especially important that all other parameters (e.g. altitude, topography, weather- and soil conditions) are comparable apart from the assumed damaging agent. Individual observations are not suitable for source finding.

From comparative assessments of forest damage due to high frequency electromagnetic fields, as performed in Switzerland, mean damage values were derived for various investigated zones and coded according to site and tree type (spruce, pine, Scotch fir, beech). A correlation could not be established between forest damage and high frequency electromagnetic fields from installed radio- and television transmitters and radar- and radio relay facilities.

4 Conclusions

The exposure values to be expected in the vicinity of "Richtfunk-" (radio relay-) and radar devices range in the immediate vicinity of the near field area clearly below 100 mW/m, usually however markedly below 1 mW/m. In comparison, the value for solar radiation in the optical range (ultraviolet to infrared) is about 800 W/m^2 (daily maximum).

For thermic effects on plants, 10 W/m^2 are at least necessary. However, these can only be reached or exceeded in the immediate near field range (usually several 100 m) of powerful radar facilities and generally by solar radiation in the optic range.

No indications of damages to plants in our environment can be derived from the analysis of non-thermic effects.

These conclusions, based on the data derived from an analysis of thermic and non-thermic effects, are fully substantiated by the forest damage assessments in Switzerland.

Accordingly, neither biophysical analyses nor direct forest damage assessments, as compared to available electromagnetic fields, establish a causal relationship between installed radar- and radio relay devices and the observed extensive forest damage.