TEMPORAL VARIATION OF ELECTRICAL SIGNAL 
RECORDED IN A STANDING TREE

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In a geophysically motivated experiment, two pairs of electrodes were deepened in the sapwood of a beech tree (\textit{Fagus sylvatica}), standing in the botanic garden of the Sopron University and the potential differences were recorded for more than one year with a sampling interval of 1 minute. The environmental parameters (such as meteorology, atmospheric electricity, geomagnetic field variation) were simultaneously measured partly at the same location, and partly in the Nagycenk Geophysical Observatory. The records show a complicated response of the tree to the environmental electric effects. The potential difference curves belonging to the two closely-spaced pairs of electrodes are quasi-parallel, but sometimes they seem to be contradictory. In case of a low level of the atmospheric electricity and when there was no precipitation, in springtime, we observed characteristic sinusoidal signals with a period of exactly one day and with a peak-to-peak amplitude of about ten millivolts. According to Morat et al. [1994] they might be connected to the daily variation of the sap flow. In our experiment, the phenomenon appeared with a smaller amplitude (about 10 mV from peak-to-peak) than in the experiment by Morat et al. [1994]. The inflection points of the daily variations were observed at about midnight and at noon; the maximum appears in the morning hours.

**Keywords:** atmospheric electricity; electrical potential difference; \textit{Fagus sylvatica}; sap flow; standing tree

**Introduction**

According to some earlier geophysical field experiences, the natural electromagnetic field of the Earth (having typically a horizontal electric field variation of a few tens of mV/km) is strongly distorted, if one of the electrodes is placed in the vicinity of a standing tree. Since the standing trees, together with other “noise sources” (e.g. man-made electromagnetic noise as reviewed by Szarka 1988) might sometimes create a problem in the field application of the so-called telluric or magnetotelluric methods (Vozoff 1991) (for a brief description of these geophysical methods see the Appendix), we turned our attention to the problem of electrical processes within the tree-trunk itself.

Electric phenomenons in standing trees were widely studied in the sixties, but the technical facilities did not allow to get detailed information (Csanády 1969). Matteucig and Toriyama (1992) discovered some unusual behaviour of biollectric potentials in standing trees before earthquake. The first continuous experiment

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concerning electrical recordings on a standing tree has been carried out by Pierre Morat, at the Institut de Physique du Globe de Paris (Morat et al. 1994). The quiet summertime sections of their four-months long experiment, carried out on a 80 years old horse-chestnut tree in 1992, showed a daily variation, with an amplitude of some ten millivolts. In late fall the sinusoidal variations disappeared. A possible reason for such a phenomenon was found by them in the variation of sap flux density, due to the daily evapotranspiration of the leaves of the tree (Granier 1987). Sap-flow velocities and distribution were also examined by Fenyvesi et al. (1996).

In our first experiment (April 1995–April 1996), an approximately 40 years old beech tree (Fagus sylvatica), having a diameter of appr. 13.5 cm (at a height of 1.50 m) was selected in the botanic garden of Sopron University. The 13 months (an overlapped one year) long data series seemed to be enough to have an independent justification for the existence of daily variations. Due to the long recording time, the special effects of different environmental influences on trees, were also among the objects of the study (Koppán 1996).

The measuring method

The electrodes (having a length of 3.5 cm and a diameter of 3 mm) were made of stainless steel. The threaded electrode ends assured a stable fitting in the material of the tree for a long time. In all other aspects the French suggestions (Morat et al. 1994) were followed: the vertical distance between the corresponding electrodes was 1 m, while the horizontal distance between the two pairs of electrodes was 5 cm.

Fig. 1. The common electrode configuration of the French and of the Hungarian experiments. The potential differences between electrodes AB and CD were recorded for 13 months at a sampling interval of 1 min
The geometry of the applied electrode configuration is shown in Fig. 1. The lower electrodes were placed at a height of 1.70 m from the ground. The penetration depth of the electrodes (through the bark, into the sapwood of the trunk) was 1.0 cm, and — similarly to the French experiment — they were not especially (since they could not be) protected from environmental effects. (The trunk was sheltered from direct solar radiation and by a certain extent from the wind.) The signals (after a very high-impedance preamplification) were transmitted by using an appr. 30 m long cable to a PC, situated in the nearest building to the tree. After an analog-digital conversion (by using a 18 bit A/D converter of the type VF-900, having a resolution of 18 µV) the data were recorded on a hard disk with a 1 minute sampling interval. (Just the instantaneous values were used.) Several times there were interruptions (because of a variety of reasons), lasting up to a few days. All data measured in the whole (nearly 400 days long) period were finally recorded on a compact disk.

The electrical data series were completed with meteorological data from the botanic garden and also with atmospheric electricity and geomagnetic data of the Nagycenk Geophysical Observatory (Bencze 1966, Bencze and Márcz 1981, Wésztergom and Szendrői 1997).

Results

In the following subsections some aspects of the measured data are presented. At first the direct environmental effects (from our point of view the “noises”) and the observed differences between the two channels are discussed, then the daily sinusoidal variations found in springtime are presented.

Environmental effects

Figure 2 shows a two-months long part of the whole data set. The most striking phenomena in this compressed way of presentation are the nearly impulse-like jumps. In this presentation they seem to be noise, but perhaps it is better to call them as the responses of the tree to direct environmental effects. We found that their origin was in most cases a high atmospheric electricity due to thunderstorms or lightning within a distance of tens of kilometers. They remain in the (−500 mV, +500 mV) interval.

The geomagnetic activity, as a possible environmental factor (described in details by Verő and Wésztergom 1992) did not show any correlation with the electrical recordings in the tree, not even during geomagnetic storms.

In Figure 3a effect of a typical thunderstorm is shown, while in Fig. 3b the effect of a simple shower is illustrated. In case of high atmospheric electricity or precipitation, there is no chance to get any information from the interior of the tree.

Parallellity and electrode polarization

There is a further difficulty in detecting internal electric processes in standing trees, because of the non perfect parallellity of the two data series measured with the two closely-spaced pairs of electrodes.
Fig. 2. A part (January 1996 - April 1996) of the whole measured data series. The highest amplitudes are due to increased atmospheric electricity.
On larger scale the changes in the two closely-spaced channels take place simultaneously, but going into details, it can be seen (e.g. in Figure 3a and 3b), that a few hours of delay may easily occur between the two channels, and also the amplitudes are not necessarily the same.

The seasonal variation of the basic level of the signals in the two channels are also partly different, sometimes contradictory.

Based on geophysical experiences we think, that both phenomena are due to slight differences in the polarisation processes around the four (A, B, C and D) electrodes.

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Fig. 4. An eight-days long section of channels AB and CD (April 29 – May 6, 1995), showing characteristic daily sinusoidal variations, especially in channel CD. In channel AB the sinusoidal variations are hidden by some disturbances.

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Fig. 5. The characteristic daily variations of the potential difference, measured by electrodes CD, and its least-squares fitting (by using a third degree polynomial trend and a sine function)
Fig. 6. 24 hours long records and their least-squares fitting sine functions a) the most perfect sinusoidal signal (April 29, 1995) within the eight-days long record b) the most disturbed sinusoidal signal (May 2, 1995) within the eight-days long record

Daily variations

Figure 4 shows an eight-days long section of the two channels dominated by nearly perfect sinusoidal variations with a period of exactly one day. Before and after this period the records did not contain such clear sinusoidal variations. They appeared again only in the next spring. In Fig. 5 the zoomed version of channel CD (which proved to be less noisy than channel AB) is shown together with its least-square fitting curve, containing a polynomial trend and a trigonometric function (Pelt 1992).
In Figure 6a and 6b two 24 hours long data series examples: the least noisy and the most noisy days are shown. Figure 7 illustrates the day-to-day variation of the amplitude by using two different (zeroth degree trend and second degree trend) fitting techniques. The average amplitude in both approaches is about 4 mV, which means more than 10 mV in terms of peak-to-peak amplitude.

In Figure 8 the day-to-day variation of the minimum and that of the maximum sites of the best fitting sine function with zeroth-order polynomial trend is shown. The maximum value of the potential difference can be measured after 6 a.m., the minimum takes place after 6 p.m. (in local winter time). The inflexion points can be found a few minutes after midnight and noon.

**Discussions**

The main conclusions of this 13 month-long experiment are as follows.

1. The electric response of the tree to environmental effects never exceeded ±0.5 V. The best correlation of the highest peaks was found with the atmospheric electricity. The precipitation has also some effects lasting for several hours. At the same time, even the strongest geomagnetic activity has not any influence on electrical signals in the standing tree.

2. The quasi-parallel nature of records measured in the two parallel pairs of electrodes refers to very local phenomena, most probably to slight differences in polarization of the electrodes. In the differences of the two channels perhaps the inhomogeneity of the trunk may also play some role.

3. We found similar daily variations as detected by Morat et al. (1994) on a different tree. In the paper we have given the amplitude- and phase parameters of the observed daily variations, obtained by using least-squares fitting.
trigonometric polynomials. The time series (measured in local winter time, when the starting time is at midnight) can be very well approximated by a zero-phase sine curve. The peak-to-peak amplitude of the daily variations (measured by using electrodes at 1 m distance) was found to be more than 10 mV.

As far as the data by Morat et al. (1994) can be compared with our ones, the observed phase relationships in the two experiments seem to be nearly the same.

4. The tree-electrical processes of internal origin, producing signals in the range of ten millivolts, mean realistic danger to long-period telluric or magnetotel-luric measurements.

![Graph showing daily variations](image)

Fig. 8. The day-to-day time shift of the minimum [a] and maximum [b] of the daily variations

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This first experiment taught us that electric signals recorded in a standing tree cannot be separated into those of internal and of external origin, since all internal processes are pure reactions to the variations in the outer world. In understanding of standing trees there is no other way than to continue the observation with more channels. Such an experiment based on experiences of this first one has already started at the Nagycenk Geophysical Observatory.

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Appendix

Within and around the Earth — due to solar emissions, producing variations in the magnetosphere and generating charge flows in the ionosphere, and also due to the lightning activity — as a part of the Earth’s geomagnetic field, there exists a varying magnetic field. The time variation of the magnetic field induces natural electric fields which drive currents within the Earth, known as telluric currents. In the telluric method telluric potential gradients using orthogonal electrode pairs on the Earth’s surface are measured. In the magnetotelluric method besides the telluric field the two horizontal components of the magnetic field are measured, too. From the ratio of the electric and the corresponding magnetic components apparent resistivity values as functions of the period of the field variations are computed. This technique — based on the so called skin-effect concept — allows to get information about the subsurface electrical resistivity structure of the Earth. The magnetotelluric method is used mainly in investigation of the Earth’s crust and upper mantle. (A recent review about magnetotellurics has been given by Vozoff (1991). One of the first monographies about magnetotellurics was edited at the Geodetic and Geophysical Research Institute of the Hungarian Academy of Sciences (Ádám 1976). For some geological applications in Hungary see Ádám et al. (1992)).

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