Extremely low frequency electromagnetic energy in the air

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Abstract

The present paper reveals that the air contains electromagnetic energy of extremely low frequency, low amplitude as well as of a low phase speed. The energy is of great interest because of its impact on certain biological processes. It is created by the interaction of two well known phenomena. The rotation of the earth generates 24-hour periods currents in the magnetosphere, known as the Birkeland currents. The currents generate transverse electromagnetic waves (EM waves) propagating parallel to the geomagnetic field lines. Furthermore, the air and the earth crust contain electrons caused by the global electric circuit. The electric field vectors of the EM waves exert a force on these electrons, causing them to oscillate and thus generate currents of extremely low frequency both in the air and in the earth crust. A theoretical model of the system is presented and measurement techniques are described. Measurements have been performed during a six year period. The results of the performed measurements verified the theoretical model. Impact on biological processes is discussed.

Keywords: ELF; ELF EM waves; Atmospheric electricity; resonance in the air

1. Introduction

Some biological processes in humans, as reported by several authors (Forrester et al., 2007; Funk et al., 2009; Levin, 2007), are influenced by electromagnetic energy of extremely low frequency (ELF), while others are based on the subtle charge of a few elementary charges (MacKinnon et al., 2000; Ashcroft, 2000; Unwin, 1995). Some of these processes occur at extremely low amplitude of the current (≤ 1 pA) and have therefore been impossible to measure using state-of-the-art methods. One reason for this is that these processes are created by a phenomenon, previously considered unlikely to occur, namely: electromagnetic waves of conduction current in the air, i.e. a current. The basic theory of a current in the air, how it is generated and measured, is described in this paper.

The first part of the paper describes how plane transverse electromagnetic waves (EM waves) are created (generally called radio waves). The earth rotates in the sun wind, thus generating currents in the magnetosphere, propagating towards the earth, known as the Birkeland currents, comprising a 24-hour period (Potemra, 1978; Stern, 1993; Tsyganenko et al., 1993). The currents in turn generate plane transverse EM waves, also displaying a 24-hour period according to Maxwell's equation (Bleaney, 1965) and propagating along the geomagnetic field lines. In the present paper, the EM waves were measured using a novel method, based on the force exerted on a charge and the back reaction force on the EM waves (Melrose and McPhedran, 1991).

The second part of the paper describes how the EM waves create electromagnetic waves of conduction current, i.e. currents, in the air. Air contains approximately 500 pC/m^3 electrons originating from lightning; this is described by a process called the global electric circuit (Adlerman and Williams, 1996; Israel, 1973; Rycroft et al., 2000). Charge conditions close to ground have previously been reported by Israelsson (1994) and Israelsson et al. (1994). EM waves propagating through a medium having charge density exert a force on the medium (Bostrom and Fahleson, 1974; Melrose and McPhedran, 1991), making electrons drift horizontally in 24-hour periods of oscillating motions. Air is an adaptive medium (i.e. its charge is able to change position), resulting in electrons accumulating ($-q$), depleting (q) and electrons (i.e. a current) propagating between the charges forming oscillating electric dipoles (forced damped oscillators) (Stratton, 1941). The resonance period is equal to the dipole time constant (Bleaney, 1965). An adaptive medium strives to attain resonance and the absorbed energy in the medium is maximized. The electric dipoles are supplied with electrons (charge) from the global electric circuit, a process that continues until the dipoles are in resonance with the applied energy. From that point, surplus charge drifts towards the atmosphere, known as the vertical current density in the global electric circuit model (Israel, 1973). Magnetic induction, according to the Biot-Savart law, causes currents to propagate in a stable way in the air.

The third part of the paper describes how a current in the air is measured using a novel technique, based on the force, according to Coulomb's law, acting on the charge in a probe.

2. Theoretical model

The phenomena described in the present paper are, on a theoretical level, identical to the principles of radio transmission, although frequency and medium are different. Radio transmission works as follows. The transmitter generates a current in the transmitter antenna. This current generates plane transverse EM waves in the air (radio waves) consisting of oscillating electric and magnetic field vectors. The electric field vectors exert a force on electrons in the receiver antenna, thus generating a current. This current acts on a forced damped oscillator, creating resonance when the natural (resonance) frequency of the oscillator equals the frequency of the applied energy.

Air conducts at a very low current density. Consequently, the conductors (antennas) in the above example can be substituted using another medium: air. Forced damped oscillators can be implemented in numerous ways, e.g. as LC circuits in radios or as oscillating dipoles in the air. The electric equivalent of the dipoles in the air is a serial LC circuit having low impedance at its natural frequency. The theoretical model then becomes as follows:

The rotating earth generates currents (i.e. Birkeland currents) in the magnetosphere. These currents generate plane transverse EM waves in the air. The electric field vectors exert a force on electrons in the air, generating currents in the air. These currents act on forced damped oscillators in the air (i.e. oscillating dipoles) creating resonance in the air. At resonance the impedance of the air (i.e. the oscillating dipoles) is low and consequently the absorbed energy or current is maximized and at the same time the internal loss within the oscillating dipoles is minimized, following the principles of forced oscillations as described by Bleaney (1965).

3. Plane transverse EM waves

This part describes plane transverse electromagnetic waves, called EM waves, having a 24-hour period. The sun wind contains, among other things, electrons creating a current density in the magnetosphere, which in turn creates current density **J** propagating along the geomagnetic field lines. **J** is influenced by the earth's rotation and thus **J** has a 24-hour period. It is called the Birkeland currents and was described and modeled by Potemra (1978), Stern (1993) and Tsyganenko et al. (1993). According to Maxwell's equation, the relationship between the current density **J**, the electric induction **D** and the magnetic field strength **H** (Bleaney, 1965) is:

$$\text{curl } \mathbf{H} = \mathbf{J} + \partial\mathbf{D}/\partial t \quad (1)$$

The solution to curl **H** = ∂**D**/∂t is plane transverse EM waves having a 24-hour period. The EM waves consist of orthogonal electric field vectors $\mathbf{E_{FV}}$ and magnetic field vectors $\mathbf{B_{FV}}$ as illustrated in Fig. 1. The EM waves are almost static and therefore there is an almost static force **F** between $\mathbf{B_{FV}}$ and the geomagnetic field $\mathbf{B_{GM}}$:

$$\mathbf{F} = c \cdot \mathbf{B_{GM}} \cdot \mathbf{B_{FV}} \quad (2)$$

This force makes the EM waves propagate parallel to the geomagnetic field lines, while $\mathbf{B_{FV}}$ is directed perpendicular to $\mathbf{B_{GM}}$ and directed towards north (on the northern hemisphere). The electric field vectors $\mathbf{E_{FV}}$ are directed horizontally east-west, since $\mathbf{E_{FV}}$ is orthogonal to $\mathbf{B_{FV}}$ (Bleaney, 1965).

A novel technique was developed and used when measuring the EM waves. Plane transverse EM waves, having electric field vectors $\mathbf{E_{FV}}$ passing a medium with charge density ρ, exert a force **F** on the medium as described by Melrose and McPhedran (1991):

$$\mathbf{F} = \rho \mathbf{E_{FV}} \quad (3)$$

The force exerts an equally large back reaction force on $\mathbf{E_{FV}}$ and the EM waves and this gives the EM waves a change of impulse. This impulse acts in the same direction during 12 hours; thus the EM waves change direction.

An electrode, connected to a voltage source U, was positioned in the air, creating a negative charge $-q$ as illustrated in Fig. 2. The force on $-q$ generated a back reaction force and change of impulse on the electric field vectors $\mathbf{E_{FV}}$. Many EM waves were diverted towards $-q$. The EM waves were coherent (synchronized to the rotation of the earth) and polarized (according to Eq. (2)) and as a result, the EM waves were super positioned (Chen, 1985) and their field vectors, $\mathbf{E_{FV}}$ respectively $\mathbf{B_{FV}}$, added linearly and formed amplified field vectors **E** and **B** close to $-q$ which were measured with the instrument described in chapter 5. However, they may also be measured with E- and B-field probes. Achieved data were as follows: at U = 10 V, $-q \approx$ 300 pC and $\mathbf{E} \approx 10 \cdot \mathbf{E_{FV}}$ and $\mathbf{B} \approx 10 \cdot \mathbf{B_{FV}}$. $\mathbf{E_{FV}}$ and $\mathbf{B_{FV}}$ could be amplified about 50 times (at U = 50 - 100 V). When calculating $-q$, the charge density of the air must be considered.

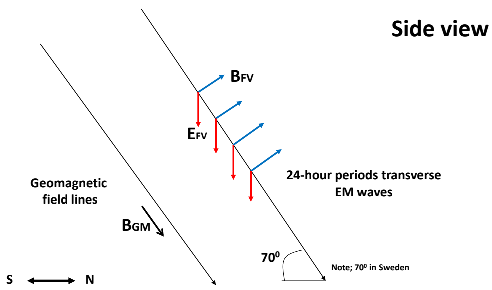

Figure 1. *The 24-hour periods transverse EM waves propagate parallel to the geomagnetic field lines.*

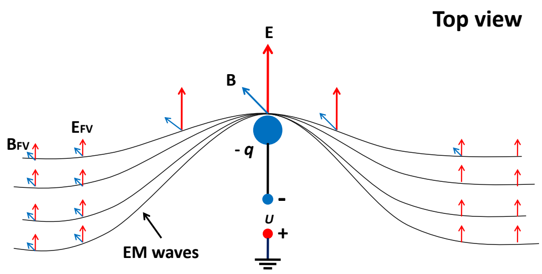

Figure 2. *The back reaction force on the electric field vectors* $\mathbf{E_{FV}}$, *created by the charge -q, diverted a large number of EM waves towards the charge and the field vectors added to high amplitude electric field vectors* ***E*** *and magnetic field vectors* ***B***.

Measured values in Stockholm, Sweden were E_{FV} = 3-10 V/m (i.e. measured with the instrument described in chapter 5) and from this, B_{FV} was calculated to 10-30 nT using the well known relationship B=E/c where c is the speed of light (Bleaney, 1965). The nodes occurred at exactly 00^{13} and 12^{13} (GMT + 1 h). The EM waves were almost square wave shaped, as illustrated in Fig. 3, disclosing that the EM waves contained harmonics (see Melrose and McPhedran, 1991). The EM waves furthermore contained non-periodic fluctuations, illustrated in Fig. 3, probably caused by fluctuations in the magnetosphere or ionosphere currents. The EM waves were also correlated with the position of the moon. It was assumed that during full moon the magnetosphere was disturbed, creating disturbances in the EM waves, causing complete loss during some hours. Stern (2007, *pers. com*) confirms that the Birkeland currents are disturbed during full moon.

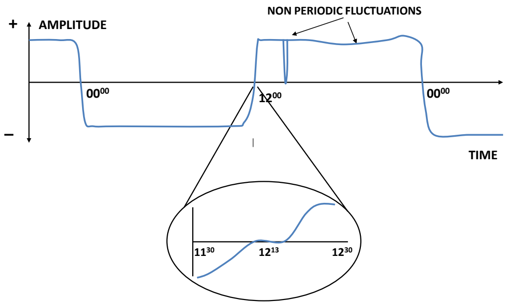

Figure 3. *The amplitude of the 24-hour periods transverse EM waves.*

One interesting phenomenon is illustrated in Fig. 4. Two electrodes, connected to a voltage source (e.g. 9 V) were positioned vertically in the air, comprising an electric dipole *-q*/*q*. Electrons drifted from the negative charge to the positive charge creating a current I (5). EM waves (1) diverted towards the negative charge, *-q*, according to Eq. 3 with the positive side of **E** close to the charge, as illustrated in Fig. 2, followed by a diversion towards the positive charge, *q*, with the negative side of **E** close to the positive charge. After that, they resumed their original direction (4). The current I (5) and the current element **ds** exerted a force **dF** on the magnetic field vectors **B** (Bleaney, 1965):

$$\mathbf{dF} = I\mathbf{ds}\times\mathbf{B} \quad (4)$$

The force **F** was directed perpendicular to **B** making the field vectors propagate in a bow (3) and where the distance was proportional to I (5) and B. In addition, **B** was influenced by the geomagnetic field and thus the bow was always directed towards north (on the northern hemisphere). The two charges, distanced by the vector length **s**, created an electric dipole moment (Bleaney, 1965):

$$\mathbf{p} = q\mathbf{s} \quad (5)$$

An electric dipole **p** in a homogenous electric field **E** was influenced by a force pair $\mathbf{m_F}$ (Bleaney, 1965):

$$\mathbf{m_F} = \mathbf{p}\times\mathbf{E} \quad (6)$$

Equations (4) and (6) were not correct for in-homogenous electric **E** and magnetic **B** field vectors**;** however, they may be used for approximate calculations. The force pair $\mathbf{m_F}$ thus exerted a force on **E,** perpendicular to the dipole **p** and **E** and combined with their momentum, making the field vectors propagate in many one turn helixes (2) around the dipole **p,** as illustrated in Fig. 4 (only one helix is illustrated).

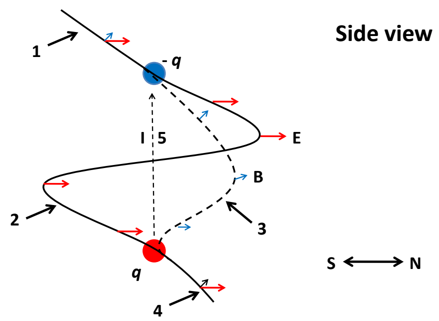

Figure 4. *Two charges, - q and q, diverted EM waves (1) and the EM waves were split into their electric field vectors propagating in a helix (2) and their magnetic field vectors propagating in a bow (3) towards north.*

The radius of each helix was approximately proportional to the amplitude of the EM waves (1) and to the charges *-q*/*q*. Thus, extremely small currents (≥10 fA) and dipole charges (≥ 50 pC) in the air could be measured by measuring the deviation of **E** (2) and **B** (3). The 24-hour period EM waves could be measured with high accuracy (≤ +/- 5%) using a fixed dipole in the air.

In consequence, it was possible to measure the transverse EM waves using two non-correlated techniques.

4. Current in the air

The global electric circuit describes how lightning transfers electrons to the earth crust and the 250 kV potential between the ionosphere and earth crust transfers charge back to the atmosphere, resulting in the air containing approximately 500 pC/m^3 electrons. This process was described and modeled by Adlerman and Williams (1996), Israel (1973), Israelsson (1994), Israelsson et al. (1994) and Rycroft et al. (2000). According to Eq. (3), EM waves having electric field vectors $\mathbf{E}_{\mathbf{FV}}$, exert a force $\rho\mathbf{E}_{\mathbf{FV}}$ on charge density ρ (electrons) in the air, thereby making electrons drift in oscillating motions, creating current density **J** as well as a current in the air. From now on a current in the air is called I_{Air}. Electrons in the air may accumulate (-*q*) and deplete (*q*) and drift (I_{Air}). Two charges -*q*/*q* at some distance from each other and with I_{Air} in between comprise a forced damped oscillator having the time constant q/I_{Air}. Note that period and time constant is used throughout the paper instead of frequency (which is equivalent), the reason being that the phenomena described are synchronized to the earth's rotation having a 24 hour period. Forced damped oscillators oscillate (are in resonance) when the time constant q/I_{Air} equals the period of the applied transverse EM waves (or harmonics). Air is an adaptive medium and as a consequence, rather free of its charge distribution. An adaptive medium strives to minimize the amount of absorbed energy, i.e. the oscillators adapt their charge until they establish resonance with the applied energy. The global electric circuit supplies the air as well as the oscillators with charge until the oscillators acquire time constants, q/I_{Air}, and thereby creating resonance and from that point on surplus charge is transferred to the atmosphere. This surplus charge has previously been measured as vertical current density (1-3 pA/m^2) in the global electric circuit (Israel, 1973). Thus, the resonance mechanism is self-regulating.

The measurements performed in the present study confirmed that the resonance mechanism consisted of oscillators that were organized into a 3D matrix of mutually coupled oscillators. The 3D matrix exhibited a logical structure and consisted of a single repetitive basic element: four charges organized into a horizontal quadrant as illustrated in Fig. 5; two charges, -*q* and *q* (6), and the current I_{Air} (7) between the charges comprised one oscillator; four charges comprised four oscillators (mutually coupled and oscillating in two dimensions). The starting point of the 3D matrix was one quadrant oscillating at 24-hour periods, consisting of a quadrant of four oscillators having 24-hour periods, each denoted 24_0 in Fig. 6. This quadrant was divided into four new quadrants, each containing four oscillators, denoted 24_1, and oscillating at $24/2^1$ = 12-hour periods. Each of these quadrants was divided into four new quadrants, each containing four oscillators, denoted 24_2, oscillating at $24/2^2$ = 6-hour periods. This pattern continued until a fine meshed grid was created. The process was non-linear, producing large amount of harmonics.

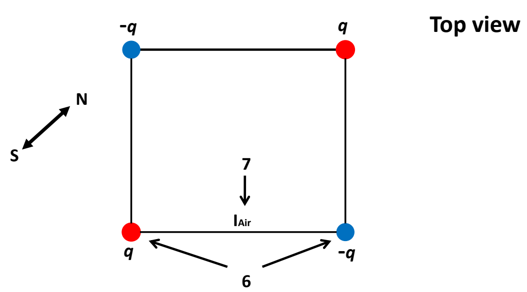

Figure 5. *Two charges (6) and current I_{Air} (7) formed one oscillator. Four charges and four I_{Air} formed a quadrant of four coupled oscillators that oscillated in two dimensions.*

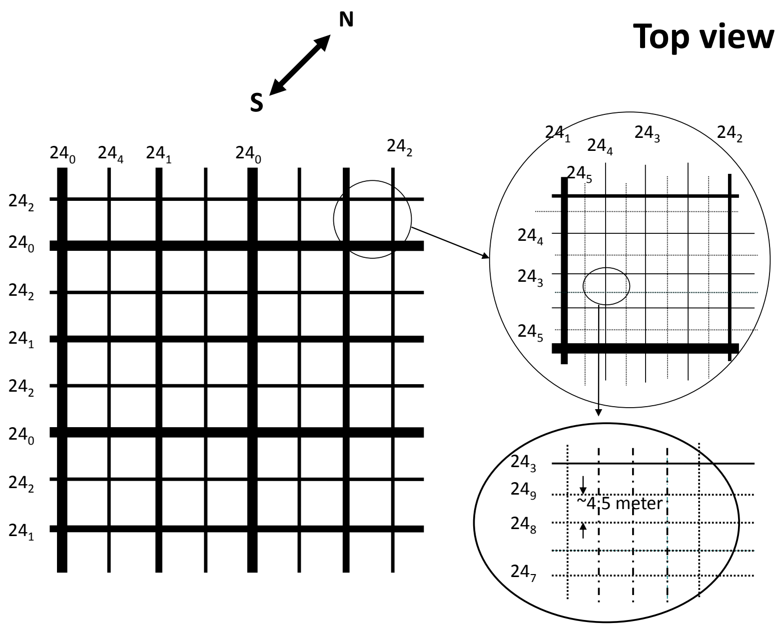

Figure 6. *The 24-hour periods 2D grid.*

The pattern was, furthermore, repeated in four directions forming a large 2D grid as illustrated in Fig. 6. Fig. 6 should be interpreted in the following way. The "line" denoted 24_0 consisted of a long chain of oscillators (*q*, *-q*, *q*, *-q*, *q* etc.) having $24/2^0$ hour periods and oscillators having $24/2^1$, $24/2^2$ etc. -hour periods were super positioned there. Altogether 24_0 consisted of a chain of super positioned oscillators and super positioned currents, I_{Air}, having $\sum 24/2^n$, n = 0, 1, 2, 3, 4, ... -hour periods. The 24_1 consisted of a chain of super positioned oscillators and super positioned currents, I_{Air}, having $\sum 24/2^n$, n = 1, 2, 3, 4, ... -hour periods and so it continued. Thus, electrons in the I_{Air} had to bridge only the distance of the shortest oscillator/dipole in the chain (i.e. approximately 4.5 m), which explains the stability with which a current, exhibiting extremely long periods, was transported in air.

According to the Biot-Savart law the magnetic induction **B** at the distance **r** from a current I (i.e. I_{Air}) and the current element **ds** is (Bleaney, 1965):

$$\mathbf{B} = (\mu_0/4\pi) \int I\mathbf{ds}\times\mathbf{r}/r^3 \qquad (7)$$

The generalized Eq. (7) uses the current density **J,** integrating over the volume *v*:

$$\mathbf{B} = (\mu_0/4\pi) \iiint (\mathbf{J}\times\mathbf{r}/r^3)\,dv \qquad (8)$$

The current density **J** induced a magnetic field **B** and according to Eq. (8), the magnetic field **B** increased with volume *v*. The normal state is where **B** was minimized causing the electrons and a current I_{Air} (or current density **J**) to propagate in a narrow flow or a narrow "current tube". In the present study, the measured diameter of the electron flow, using the method described in chapter 5, was ≤ 1 cm. The electron drift velocity in air is approximately 20 m/s (Israel, 1973), implying that collisions between electrons and air molecules created little scattering and minor loss.

The air contained one horizontally positioned 2D grid approximately 1 meter above ground and then (vertically) every 3 meters was another (phase shifted) horizontal 2D grid. Fig. 7 illustrates how layers of 2D grids (8) formed a 3D matrix (9). Some nodes showed resonance in the vertical direction. This resulted in the horizontal 2D grids being connected (and mutually stabilized) by vertical oscillators and vertical currents I_{Air} (10). The 3D matrix oscillated in 3 dimensions.

The first odd harmonic having 24/3 = 8-hour periods created similar 2D grids, oriented east-west (i.e. 45 degrees to the 24-hour 2D grids) having oscillators at $24/3{\cdot}2^n$ hour periods. The two grids emanated from the same 24-hour periods EM waves and were therefore in phase in some nodes. Theses nodes contained a vertical I_{Air} (10) and vertical oscillators, oscillating at $24/2^n$ and $24/3{\cdot}2^n$ hour periods. Therefore, the two grids were linked by mutual resonance, creating a common 3D matrix. Consequently, the 3D matrix oscillated in three dimensions and in many modes. The structure was complex but logical. The 3D matrix contained harmonics with periods $24/m{\cdot}2^n$ hour, m = 1, 3, 5, 7, 9, 11, 13 and n = 0-18, i.e. harmonics in the 0-10 Hz range.

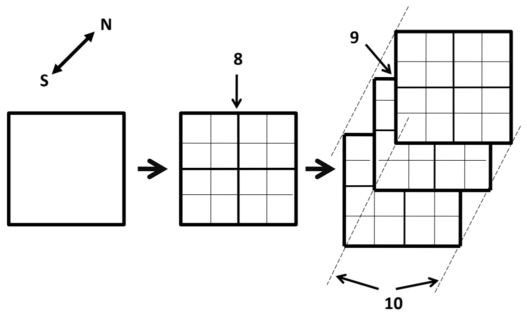

Figure 7. *Quadrants of current and oscillators created 2D grids. Horizontal layers of 2D grids (8) formed a 3D matrix (9). The 3D matrix was stabilized by current and oscillators in the vertical plane (10).*

I_{Air} was measured as described in chapter 5. The I_{Air} amplitude (approximately 0.1 – 1 pA) depended on its position within the 3D matrix, as well as where 24_0 had high amplitude and 24_9 had low amplitude. Fig. 8 shows the measured I_{Air} amplitude, denoted 24_7 in Fig. 6, which contained $\Sigma 24/2^n$ hour periods, n = 7, 8, 9 … The shape of the wave, illustrated in Fig. 8, was caused by harmonics in I_{Air}. It was measured using the method and instrument described in chapter 5 and the measurement (amplitude) precision was ≤ +/- 5 %.

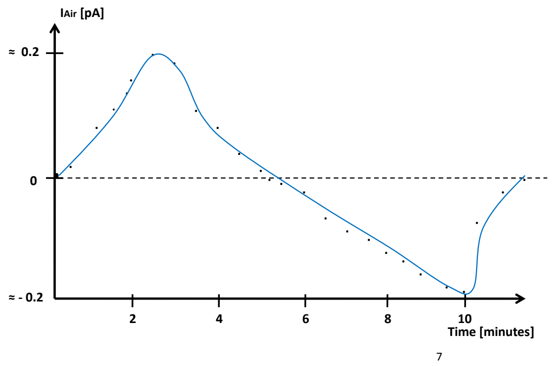

Figure 8. *The amplitude of I_{Air} as a function of the time. I_{Air} had $24/2^7$ hour periods = 11.25 minutes (24^7 in Fig. 6).*

Vertical currents I_{Air} (10) propagated from the earth crust into the air and the resonance mechanism in the earth crust was studied in underground garages and pits. The 24-hour periods transverse EM waves had extremely long wavelength and thus they propagated far into the earth crust. The earth crust contains electrons and the transverse EM waves created a force on the electrons making them oscillate with 24-hour periods and harmonics. The measured electron drift velocity in stone was approximately 6 cm/s in the present study. At an extremely low current (current density) the wave velocity was equal to the drift velocity (*v*) of the electrons and the current may be described as wave propagation in one dimension creating standing waves with node distances:

$$\lambda/2 = v{\cdot}24{\cdot}60{\cdot}60/2^n,\ n = 1, 2, 3, 4\ldots \qquad (9)$$

It was concluded that this created a 3D resonance mechanism in the earth crust, similar to the 3D matrix in the air and displaying the same dimensions. However, the wave propagations and the resonance mechanisms differed. The resonance mechanism in the earth crust was stabilized by a memory mechanism created by the orientation of the atom's electron spin (similar to magnetic memory as described by Bleaney (1965)). This was confirmed in the present study, by positioning a stone in the air, whereby a current I_{Air} propagated through the stone. The current probably changed the electron spin of the atoms and the electron spin persisted. The position of the stone was then changed and the I_{Air} changed direction accordingly, continuing to propagate through the stone in the previous direction. This was a consequence of the force, according to Eq. (2), between the magnetic field created by the electron spin and the induced magnetic field created by the current according to Eq. (7). The 3D matrix in the earth crust and in the air were measured over a six year period and found extremely stable; it was "hard wired" in the sense that the electron spin determined the resonance in the earth crust and the resonance in the air was synchronized into resonance in the earth crust (i.e. by the vertical I_{Air} (10)), creating a similar 3D matrix. Consequently, the dimensions and node distances of the 3D matrix in the air was determined by Eq. (9).

Measurements performed in the present study showed that the 3D matrix in the air vanished in heavy rain. However, resonance persisted in the earth crust and the vertical currents (10) dissolved approximately 2 m above ground. Rain with its ions changed the subtle equilibrium of charge in the air and disabled the formation of dipoles. High content of ions (e.g. at thunder storms) had a similar effect. The 3D matrix in the air recovered amazingly fast, within approximately 0.5-1 hour, depending on type and severity of the disturbance. The following was observed: the resonance started in the vicinity of the vertical currents (10) and then oscillators and I_{Air} slowly spread in three dimensions. Thus, the driving force was the stable resonance in the earth crust and resonance in the air was consequently initiated and stabilized by the resonance in the earth crust. In the present study, measurements of the 24-hour periods EM waves, the I_{Air} and the 3D matrix were performed more than hundred times over a six year period, mainly in Stockholm, Sweden but also on the country side 60 km south of Stockholm in an area having little electromagnetic disturbance (e.g. power lines, radio transmitters). Continuous measurements were repeatedly made, at daytime, in one hour intervals during one week and sometimes at night during full moon. In the present study, measurements were also made in North and South America, north, south, east and west Europe, in the Middle East and in Asia, confirming the presence of the 24-hour periods EM waves, the I_{Air} and the 3D-matrix. The 3D matrix in the air and in the earth crust probably spans over all continents. In the earth crust, the 3D matrix was probably created, fine tuned and maintained during hundreds of millions of years. The process of creating such a complicated resonance mechanism was probably slow. However, once created it should be stable, automatically repairing itself when disturbed, as long as it continuously is supplied with energy having constant period, i.e. the rotation of the earth.

5. Measurement techniques

The behavior of a current in the air is illustrated in Fig. 9. Two electrodes (16) and (17) were positioned in the air spaced some distance (e.g. 2 m) from each other and connected, via wires, to a low frequency signal generator (18). This created an electric field **E** between the electrodes. Air had conductivity σ and the electric field **E** created current density **J** according to Ohm's law, (Bleaney, 1965):

$$\mathbf{J} = \sigma \mathbf{E} \qquad (10)$$

According to Eq. (7) and Eq. (8) the current density **J** propagated as a "current tube" in the air, i.e. as I_{Air}. This was confirmed by measurements carried out using the instrument described in Fig. 10.

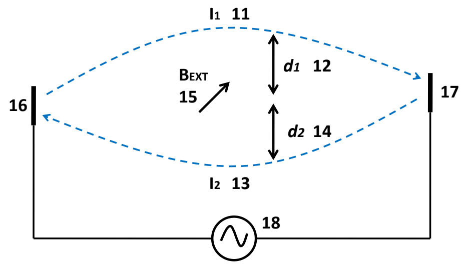

Figure 9. *Two electrodes connected to a generator created a current which was split into its two components I_1 (11) and I_2 (13) propagating at the distance d_1 (12) respectively d_2 (14) caused by the magnetic field $\mathbf{B}_{EXT}$ (15).*

According to Eq. (4) the force **dF** exerted on an element of "wire" **ds**, carrying a current I (i.e. I_{Air}) in an external magnetic field, $\mathbf{B}_{Ext}$, may be expressed as $\mathbf{dF} = I(\mathbf{ds} \times \mathbf{B}_{Ext})$. This is illustrated in Fig. 9. In the following experiment an external magnetic field $\mathbf{B}_{Ext}$ (15) was created using a permanent magnet.

It exerted a force on the current which made electrons, i.e. the current component I_1 (11) propagating in one direction, divert the distance d_1 (12) to one side. It made electrons, i.e. the current component I_2 (13) propagating in the opposite direction, divert the distance d_2 (14) to the opposite side. It was found that d_1 and d_2 were proportional to the currents and to the magnetic field $\mathbf{B}_{\mathbf{Ext}}$. Precise measurement of parameters such as amplitude, period and phase were made by measuring the deviation d_1 (12) of I_1 (11) and d_2 (14) of I_2 (13). Hence, only the presence of charge in the air and its position as function of the time was of interest and from that information the instant amplitude, phase and period could be obtained. This facilitated measurement of an extremely low amplitude current (≥ 10 fA) at arbitrary speed with precision ≤ +/- 5 %.

A magnetic field $\mathbf{B}_{\mathbf{Ext}}$ (e.g. a permanent magnet) was inserted within the I_{Air} in the 3D matrix and it created the same phenomenon. The I_{Air} contained harmonics, comprising very long periods and the instant amplitude was measured as the distances d_1 and d_2 enabling precise measurements of the I_{Air}. Thus, the instant amplitude of the I_{Air} was measured by simply determining the position of its current components as function of the time and from this information phase, periods and content of harmonics could be deducted.

The current I_{Air} and its components I_1 and I_2 were measured using the following method: I_1 (and I_2) consisted of electrons and the charge density ρ was significantly higher within I_1 compared to the surrounding air. Thus, the I_1 represented an abrupt change of charge. The I_1 may be described as distributed charges q_k. The force $\mathbf{F}$ between charges q_p and charges q_k in I_1 having the distance $\mathbf{r}$ followed Coulomb's law (Bleaney, 1965):

$$\mathbf{F} = q_p q_k \mathbf{r} / 4\boldsymbol{\pi}\varepsilon_0 r^3 \quad (11)$$

Modified for many charges:

$$\mathbf{F} = \Sigma\Sigma q_p q_k \mathbf{r_k} / 4\boldsymbol{\pi}\varepsilon_0 r_k^3 \quad (12)$$

Fig. 10 illustrates how a current in the air was measured. A short wire, called a probe (19), was utilized. The probe contained the charges Σq_p and the probe was moved through I, I_1 or I_2. This created an impulse on the charges Σq_p, resulting in a current pulse. The probe was connected to a high gain JFET amplifier (20), the pulse was band pass filtered (21) to remove AC and DC noise and further amplified (22), while the pulse was A/D converted and the digitized pulse was stored and displayed (23).

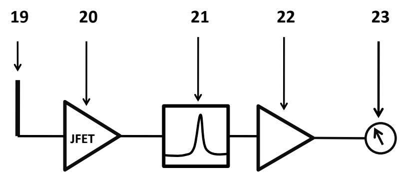

Figure 10. *Charge meter consisted of a probe (19), a high gain amplifier (20), a band pass filter (21), an amplifier (22) and a display (23).*

Fig. 11 shows how the input stage (20) was implemented. Fig. 12 shows the measurement accuracy using this instrument. The position of I, I_1 and I_2 was measured within +/- 5 mm. The peak deviation of d_1 and d_2 was approximately 1-2 m (depending on arrangement) and thus the measurement precision was ≤ +/- 5 % and at high current amplitudes ≤ +/- 1 %.

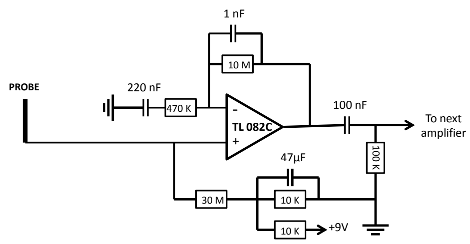

Figure 11. *The input stage in Fig. 10 consisted of probe, JFET amplifier and band pass filter.*

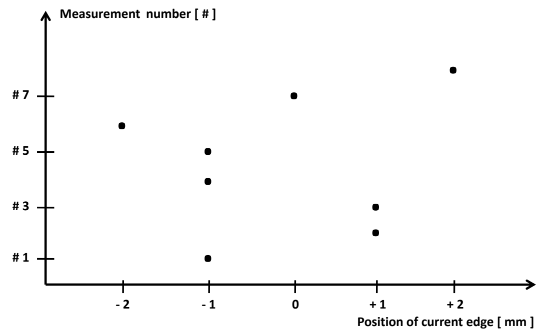

Figure 12. *Eight measured positions of the edge of the current I_1 or I_2 in Fig. 9. The probe was moved sideways into the current.*

Measurements may also be made without using a magnetic field $\mathbf{B_{Ext}}$ (15) and the amplitude of the generated current pulse is measured. However, this method is significantly less accurate (i.e. estimated ≤ +/- 25 %) and was not used in the present study.

The force **F** acting on a charge *q* having the speed **v** in an electric field **E** and a magnetic field **B** (Bleaney, 1965) is:

$$\mathbf{F} = q(\mathbf{E} + \mathbf{v}\times\mathbf{B}) \quad (13)$$

This implies that the charge *q* in the probe (19) was influenced by external electric and magnetic fields. This relationship was exploited and the electric field vectors $\mathbf{E_{FV}}$ and magnetic field vectors $\mathbf{B_{FV}}$ in Fig. 2 and Fig. 4 were measured using the instrument described in Fig. 10. The positions (and amplitudes) of **E** (2) and **B** (3) in Fig. 4 were determined with a precision ≤ +/- 5 %. The amplitude of the EM waves in Fig. 3 was measured in this way.

Trying to measure the I_{Air} with conventional methods is pointless. The speed of the current is 10^7 times slower than the speed of light and its electrons "tunnel" through almost any matter including capacitors and semiconductors. This may be the reason why the phenomena described in this paper have not been reported previously.

6. Discussion and conclusions

The electromagnetic processes described in this paper displayed extremely low frequency and amplitude. Furthermore, the speed of the current, I_{Air}, was extremely low (i.e. 20 m/s). It is far from obvious how such processes may be described and measured and it is not obvious that such processes may have scientific value. This may explain the total absence of scientific reports in this area.

However, the fact that these processes are quasi-stationary enabled development of novel measurement techniques, which in turn enabled measurements of plane transverse EM waves as well as current in the air.

These new techniques provide tools for better understanding of electromagnetic processes in the atmosphere, the magnetosphere and perhaps the ionosphere. EM waves, originating from the magnetosphere may now be monitored in a novel way and the influence of magnetosphere and perhaps ionosphere fluctuations may now be measured using a new technique. The model described in this paper suggests that a large part of the charge (i.e. electrons in the I_{Air}) in the air close to ground is locked into the 3D resonance system. This charge cannot be registered by the methods presently used in geophysics. This discovery may lead to improvements of the model used in the global electric circuit.

At some locations, the I_{Air} amplitude was high. This occurred in particular where the I_{Air} propagated vertically from the ground (10). The I_{Air} contained charges in its nodes (i.e. dipoles) and therefore the EM waves were diverted according to Fig. 4. In the present study experiments were performed on a number of persons: the palm of the hand was moved through the I_{Air}, **E** and **B**. Many persons were able to perceive the I_{Air}, **E** and **B** as tickling feelings in the hand and all three energies (i.e. I_{Air}, **E** and **B**), were perceived in a similar way. The common denominator was probably the force **F**, according to Eq. (12) and Eq. (13), acting on electrons in the hand, creating a current pulse. And it is a well known fact that a current can be perceived. Thus, the I_{Air} may influence at least one biological process.

Some biological processes in human beings, as reported by Forrester et al. (2007), Funk et al. (2009) and Levin (2007) are influenced by extremely low frequency electromagnetic energy and some processes are based on the subtle charge of a few electrons as reported by MacKinnon et al. (2001), Ashcroft (2000) and Unwin (1995). The methods described in this paper enables for the very first time measurements of extremely low amplitude current, using air as conductor. Moreover, it enables measurements of biological processes exhibiting amplitudes far below (i.e. one to two magnitudes below) state-of-the-art techniques. A parallel study has been performed which will be presented elsewhere. The measurements carried out in that study, unveiled that the I_{Air} had a significant impact on biological processes in a number of organisms (i.e. trees/plants and animals including insects, reptiles, birds and mammals). It was possible to measure the response of biological processes as function of the I_{Air} parameters such as period and amplitude. This facilitated a theoretical model of the biological processes which was then verified using achieved data. It was also possible to selectively induce changes in biological processes by injecting I_{Air}, comprising specific periods, facilitating a better understanding of the impact of I_{Air}, and low frequency electromagnetic energy in general, on human beings and other organisms.

Enhanced understanding of atmospheric electricity close to ground evidently has a significant scientific value and will most probably have an impact on biology and medicine.

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