

# **Melatonin:**

## **Fundamental Non-Ionizing Electromagnetic Settings for Optimal Human Performance**

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## Introduction

It has been a fast-paced revolution since Edison installed the first electric power plant in New York back in 1882. Already in 1896 Marconi established the first wireless connection. Though the non-ionizing portion of the electromagnetic spectrum is huge, it took only a century to fill it all up with human activities. The last available frequencies are auctioned off these days for cellular phone communication and digital television. Electricity is a hallmark of industrialized societies, especially in the Western world. We cannot and will not imagine life today without electricity.

After scientists had learned their lessons about health risks associated with ionizing radiation, the International Radiation Protection Agency (IRPA) formed an IRPA Working Group for non-ionizing radiation in 1974. The current guidelines of the now International Non-Ionizing Radiation Committee (INIRC) (Bailey et al. 1997) are based on established thermal bioeffects caused by induced electric fields/currents of a respective field strength. Occupationally exposed and the general public are protected from short-term, immediate health consequences. Official Canadian guidelines have adopted most of those recommended exposure limits (Safety Code 6).

Another hallmark of modern societies is cancer. In Western countries a particularly high incidence of breast cancer is alarming (Howe et al. 2001). Causal relations in cancer etiology are hard to come by because cancer is known not to develop over night, but rather over a long period of time, up to 15 or 45 years from initiation to tumor development. Therefore any ubiquitous environmental factor should be examined closely. Given the pervasive nature of anthropogenic electric and magnetic fields, Wertheimer (1979) was the first epidemiologist to explore the relation between cancer and low-level non-ionizing EMR exposure.

Ever since the debate goes on. Inconclusive findings, which are common fare for non-linear bioeffects, and a lack of plausible biological mechanisms, which is part of any initial research into unknown areas, make such research efforts quite challenging.

When Wilson (1981, 1983) and his colleagues reported that rats exposed to uniform 60-Hz electric fields had a suppression of the normal nocturnal rise in melatonin, a first plausible biological mechanism for the interaction between low-level non-ionizing EMR and living creatures began to emerge. At about the same time it was demonstrated by Tamarin (1981) that melatonin inhibits the development of DMBA-induced mammary tumors in rats. Thus the Melatonin Hypothesis was born as put forth by Stevens in 1987. Though the evidence is sparse, it is definitely provocative.

It is the objective of this paper first to review the current state of knowledge with respect to melatonin, low-level non-ionizing EMR and breast cancer, and second to propose a Melatonin-EMR Information Network monitoring non-ionizing EMR exposures worldwide and in real life, residential settings in relation to the melatonin rhythm and cancer incidences. The research findings will allow occupational and health care professionals, architects and manufacturers of electric equipment including the general public to create a built environment at work and at home, which is designed for long-term health.

## Breast Cancer Incidence and Etiology

According to the Annual Report to the Nation on the Status of Cancer (Howe 2001), total death rates declined in males and females during 1992 through 1998. Incidence rates in females, however, increased slightly, »largely because of breast cancer increases«. The Atlas of Cancer Mortality in the United States shows an interesting geographic pattern for breast cancer. Breast cancer clusters have persisted across the northeast of the US, especially in urban centers, for over four decades (Kulldorff et al. 1997). In the sunny south we find a much lower incidence. And in less developed countries, the female breast cancer incidence is amazingly low.

| Country | Deaths     | Population  | Rate | ASR (W)* |
|---------|------------|-------------|------|----------|
| Canada  | 4,946      | 15,148,900  | 32.6 | 20.0     |
| USA     | 41,943     | 136,618,400 | 30.7 | 18.9     |
| Korea   | <b>976</b> | 23,130,800  | 4.2  | 3.8      |
| Kuwait  | 37         | 697,300     | 5.3  | 12.6     |

Table 1: Breast cancer incidence in developed and developing countries

\*Age Standardized Rate (world population) per 100,000

Source: WHO Mortality Database (Breast 1997) at [http://www-dep.iarc.fr/cgi-bin/cgisql/who2\\_country.idc](http://www-dep.iarc.fr/cgi-bin/cgisql/who2_country.idc)

Already in 1981 Doll and Peto (1981) reviewed life-style and other environmental factors contributing to common types of cancer in the modern world. Air pollution, smoking, diet, alcohol (Blot 1992), and stress among others have been linked to cancer. In the case of breast cancer, experts agree that early age at onset of menarche, late age at onset of menopause, first full-term pregnancy after age 30, a history of pre-menopausal breast cancer for mother and a sister, and obesity are associated with an increased risk of breast cancer (CancerNet 2001). In addition, urban residence is again quoted as a risk factor.

In contrast to Doll and Peto, Schmahl (1989) from the Cancer Research Center in Germany emphasizes that only one-third of the cancer deaths registered in Germany can be assigned to known exogenous carcinogenic agents or lifestyle.

What is it then beside unhealthy lifestyles and polluted air that causes so much trouble in urban areas? According to the National Cancer Institute (NCI 2001), »a female born today has a 1 in 8 chance of developing breast cancer sometime during her life«. This is unacceptable. Modern life ought not to take such a high toll.

Kerenyi (1990) from the University of Toronto points his finger at the change of light exposure, which occurred during the last 100 years in modern society to account for the rapid growth rate of cancer. His postulated »light pollution« is very much in line with the observations of the many researchers dedicated to substantiate the Melatonin Hypothesis (1997), which extends the exogenous agent of visible electromagnetic energy across the whole non-ionizing portion of the spectrum including e.g. power frequencies.

## Melatonin

Melatonin is a universal substance, having been found in every animal and plant studied to date. The human pineal gland, a pea-size organ at the exact center of the skull, was thought to be superfluous for a long time. The persistent research effort of Lerner (1958) and his associates let them discover a new hormone in 1958, which finally made this inconspicuous organ to become known as a master gland.

The release of melatonin follows a strong diurnal pattern, with high melatonin levels at night (ca. 30 - 120 pg/ml) and low melatonin levels during the day (ca. 10 pg/ml). There is also a distinct pattern throughout a human life cycle. It begins with a minimal melatonin production in newborns, goes into a huge peak in early childhood, and starts to decline with puberty, which continues through middle age down to negligible amounts in older people above 60. (Reiter et al. 1995)

Reiter, one of the pioneering medical researchers into the effects of melatonin, summarizes the myriad of its essential functions as follows (Reiter et al. 1995):

- Antioxidant
- Antidepressant
- Immune System Enhancing
- Sleep Promoting
- Heart Supporting
- Free Radical Scavenger

## Melatonin - Its Antitumor Properties

There are many biological pathways by which melatonin is able to protect against cancer.

One is its ability to neutralize free radicals involved in many cancers, protecting nuclear DNA from oxidative damage because it is able to enter the cell nucleus. This was, for example, demonstrated when Reiter and associates injected rats with safrole, a known carcinogen, and half of them also with melatonin. A robust effect could be observed because the melatonin-treated rats had sustained only 1% as much damage as the controls, whose DNA had been severely damaged (Tan et al. 1993). Melatonin is 5 times more effective than glutathione and 15 times more effective than mannitol (Reiter 1994).

Interestingly, Lai (1997) and coworkers observed that radiofrequency-radiation-induced increases in single and double strand DNA breaks in rat brain cells could be blocked by treating the rats with melatonin. This finding, too, suggests in their opinion that RF exposure causes an increase in free radicals, which can then be neutralized by melatonin.

Another pathway is its inhibitory effect on estrogen. Or put another way, when melatonin levels drop, reproductively active hormones such as estrogen and prolactin rise as a consequence. The growth of breast cancer, for example, is stimulated in the presence of excessive levels of prolactin and estrogen. The Melatonin Hypothesis (1997) by Stevens is based on this pathway.

## **Low-Level EMR Exposure and Breast Cancer**

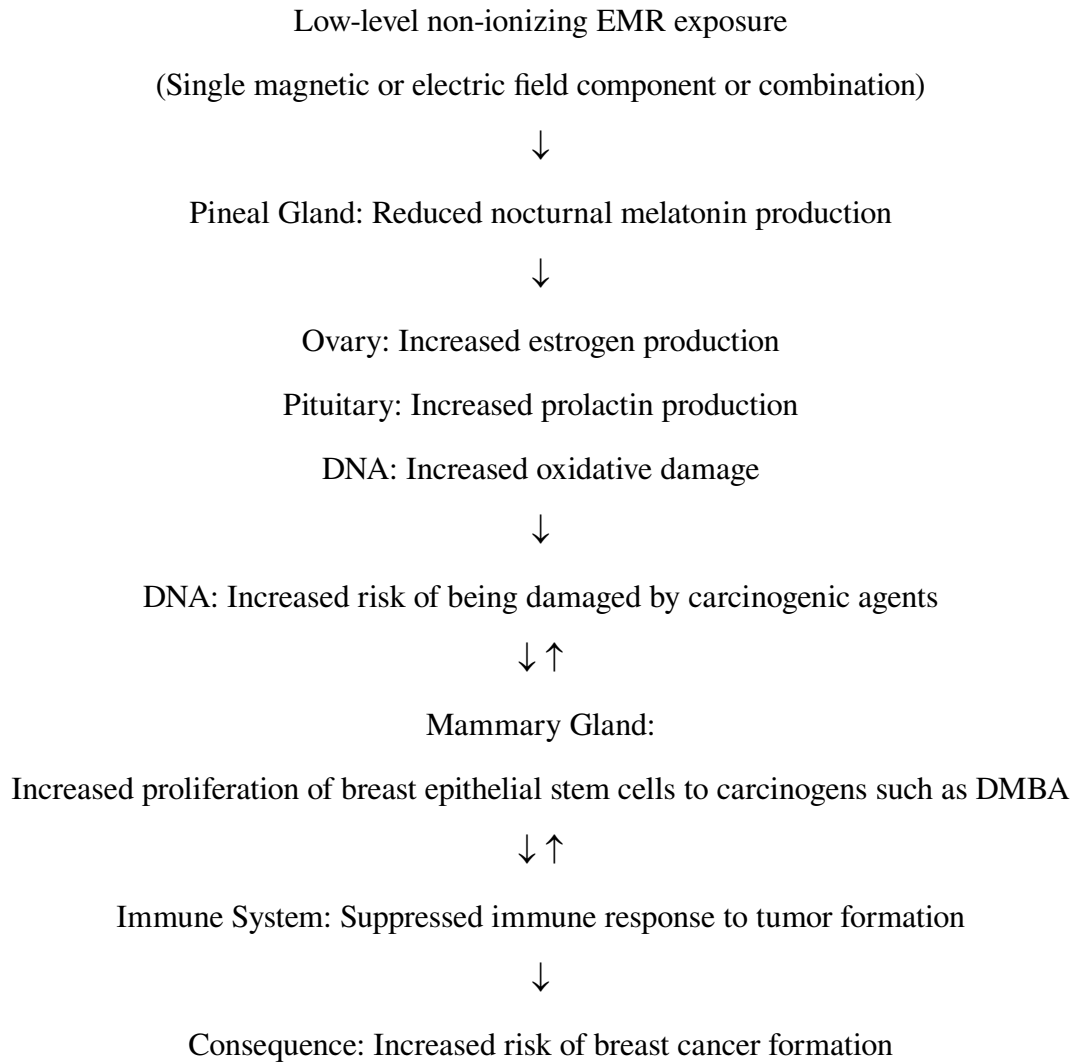


Table 2: Proposed mechanism by which chronic exposure to low-level non-ionizing EMR may increase development and growth of breast cancer.

Modified from the following sources: Stevens et al. 1987, Reiter 1994, Löscher et al. 1997.

Many in vivo and in vitro studies demonstrate significant antiproliferative effects of melatonin: Hill et al. 1992, Cos et al. 1991, Cos et al. 1994, Blask et al. 1991. The cell proliferation in human breast cancer cells (MCF-7) in culture can be inhibited as much as 60 - 78% by the addition of physiological concentrations of melatonin as found during the evening hours (Hill et al.1988).

However, it could also be demonstrated that its oncostatic effect on breast cancer cell proliferation is blocked by 60-Hz magnetic fields (Liburdy et al.1993). Those results could be replicated recently by Blackman (2001).

## Primary Factor: Light - Visible Non-Ionizing EMR

Beyond any doubt, visible light between 700 nm and 400 nm or rather its absence notifies the pineal gland mainly via ocular pathways to know when melatonin is to be released. Ocular light is the major determinant of the circadian rhythm (Skene et al. 1999). The time and amount of melatonin to be released at night depends on many factors (e.g. alcohol and drug consumption, exercise, food intake) but the light intensity, its spectral distribution, and duration of light exposure seem to be the primary factors. First, it was thought that only bright light (2500 lux) at night would have an adverse effect on the pineal gland. Subsequent research, however, revealed that dim light as low as 250 lux can already reduce melatonin to below detectable levels (Trinder et al. 1996). Even single pulses of bright light can shift the timing of the melatonin rhythm (Shanahan et al. 1997).

Minimum intensities of light at night (LAN) found to suppress nocturnal melatonin levels could be related to the duration of light exposure (Aoki 1998).

| Light Intensity | Exposure Duration |
|-----------------|-------------------|
| 393 lux         | 30 min            |
| 366 lux         | 60 min            |
| 339 lux         | 90 min            |
| 285 lux         | 120 min           |

Table 3: Minimum light intensity in relation to exposure duration

On the other hand, the brighter one's day (e.g. 5000 lux and up) the higher the nocturnal melatonin release (Park SJ et al. 1999).

Interestingly enough, the key role of visible light in a healthy melatonin cycle is not debated anymore: the exposure to sufficient bright natural or full-spectrum artificial lighting during the day and avoidance of bright as well as dim light at night promotes favorable melatonin levels. This part of the research already offers practical implications in the form of light treatment for night shift-workers to reset their circadian rhythm (Van Reeth O 1998), or for people suffering from depression and/or Seasonal Affective Disorder (SAD) to shed off their depression and fatigue (Terman JS et al. 2001, Wetterberg L 1990).

## Secondary Factor: Invisible Non-Ionizing EMR

The role of invisible non-ionizing EMR with respect to melatonin is much less obvious and conclusive. It was in 1980 when for the first time Semm (1980) reported that the pineal gland can respond to electromagnetic stimuli other than visible light. He and his associates had depressed the melatonin activity in guinea pig pineal organs by an induced magnetic field. Some researchers cannot find any effect, others keep report positive findings. Though Moulder (1998), a well-known radiation oncologist, main-

tains that the »weak to non-existent« link between ELF EMR and cancer and the »biochemical plausibility« of its effect »is not only unproven, but rather unlikely,« there is more and more data accumulating, which should not be ignored.

The whole situation is quite complicated because small differences in experiment protocols can have a huge effect on the reported observations: temperature of tissue during exposure (Blackman 1991), geomagnetic densities at a given laboratory (Blackman 1985b), lighting conditions (Aoki et al. 1998). The following tables list studies with positive findings to date. They are classified according to the applied electric, magnetic or electromagnetic field.

## **Exposure Characteristics of Non-Ionizing Electromagnetic Radiation and Occurrence of Melatonin Reduction Effect**

Earth's Magnetic Field and Melatonin Effects I - II

Power Frequency (60 Hz) Electric Field and Melatonin Effects I - III

Power Frequency (50/60 Hz) Magnetic Field and Melatonin Effects

Power Frequency - Electric and Magnetic Field and Melatonin Effects

Magnetic Field and Melatonin Effects

Radiofrequency Radiation and Melatonin Effects

## **Abbreviations in the Tables**

|                                               |                                    |
|-----------------------------------------------|------------------------------------|
| 6-OHMS - 6-hydroxymelatonin sulfate . . . . . | MEL - Melatonin                    |
| CPW - Continuous Polymer Wire . . . . .       |                                    |
| MF - Magnetic Field                           |                                    |
| DMBA - Dimethylbenz(a)anthracene. . . . .     | NAT - N-acetyl-5-methoxytryptamine |
| EF - Electric Field . . . . .                 |                                    |
| SD - Sprague-Dawley                           |                                    |
| EMF - Electromagnetic Field . . . . .         |                                    |
| WK - Wistar King                              |                                    |
| EMR - Electromagnetic Radiation               |                                    |



**Table 4: Earth's Magnetic Field and Melatonin Effects I**

| Authors (et al.) | Year of Pub. | Exposure Characteristics               | Exposure Duration            | Melatonin Effect                           | Note                                                                                  |
|------------------|--------------|----------------------------------------|------------------------------|--------------------------------------------|---------------------------------------------------------------------------------------|
| Welker           | 1983         | inversion of horizontal component      | at night during day          | suppressed NAT less conspicuous            | in SD rats any time the degree of inclination was changed - > significant suppression |
| Demaine          | 1986         | inversion of vertical component        | 1 hour at 21:00              | cancellation of day/night rhythm responses | Purkinje cells in the cerebellum of anaesthetized pigeons                             |
| Olecese          | 1986         | 50° rotation of horizontal component   | 30 min                       | suppressed NAT                             | in rats                                                                               |
| Stehle           | 1988         | 60° rotation of horizontal component   |                              | suppressed NAT                             | in albino gerbils and SD rats                                                         |
| Lerchl           | 1991         | inversion of horizontal component      | repeatedly changed inversion | suppressed NAT                             | in rats automatically activated field with rapid on/off transients                    |
| Bartsch          | 1994         | natural change in horizontal component | 1 year                       | solstitial peaks                           | in female rats coincide with high strength of horizontal component                    |

**Table 5: Earth's Magnetic Field and Melatonin Effects II**

| <b>Authors<br/>(et al.)</b> | <b>Year<br/>of Pub.</b> | <b>Exposure<br/>Characteristics</b>                                                          | <b>Exposure<br/>Duration</b> | <b>Melatonin<br/>Effect</b>                                              | <b>Note</b>                                                                                                                                       |
|-----------------------------|-------------------------|----------------------------------------------------------------------------------------------|------------------------------|--------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| Bergia-<br>nnaki            | 1996                    | natural geomagnetic<br>field                                                                 | 1 year                       | peak values<br>June/November<br><br>trough values<br>April/<br>September | in 16 healthy humans<br>high daylength stability + low<br>vertical component values<br>low daylength stability + high<br>vertical component value |
| O'Connor                    | 1996                    | natural geomagnetic<br>disturbances                                                          | 19 succes-<br>sive days      | suppressed<br>MEL                                                        | single limbic epileptic patient                                                                                                                   |
| Persinger                   | 1996                    | incremental chan-<br>ges in intensity over<br>time +<br>ripple frequencies<br>(7 Hz , 45 Hz) | 3 successive<br>nights       | suppressed<br>MEL                                                        | chronic epileptic rats                                                                                                                            |
| Rapoport                    | 1998                    | geomagnetic storms                                                                           |                              | suppressed<br>MEL                                                        | healthy humans, heart patients,<br>cosmonauts                                                                                                     |
| Burch                       | 1999                    | geomagnetic storms<br>> 30 nT                                                                |                              | suppressed<br>6-OHMS                                                     | 132 utility workers<br>greatest suppression observed<br>if combined with elevated<br>60 Hz MF or reduced ambient<br>light exposure                |

**Table 6: Power Frequency (60 Hz) - Electric Field and Melatonin Effects**

| Authors (et al.) | Year of Pub. | Exposure Characteristics     | Exposure Duration | Melatonin Effect           | Note                                                                                           |
|------------------|--------------|------------------------------|-------------------|----------------------------|------------------------------------------------------------------------------------------------|
| Wilson           | 1981         | 60 Hz<br>65 kV/m             | 30 days           | suppressed NAT             | in rats statistically significant differences in 2 replicate exp.                              |
| Wilson           | 1986         | 60 Hz<br>39 kV/m             | 3 weeks           | disturbed MEL rhythm       | in rats recovery of normal melatonin rhythm after ca. 3 days after cessation of field exposure |
| Reiter           | 1988         | 60 Hz<br>10, 65, or 130 kV/m | 23 days           | suppressed MEL phase delay | in rats no clear dose-response relationship                                                    |
| Grota            | 1994         | 60 Hz<br>65 kV/m             | 30 days           | reduced serum MEL          | in SD male rats                                                                                |

**Table 7: Power Frequency (50/60 Hz) - Magnetic Field and Melatonin Effects I**

| Authors (et al.) | Year of Pub. | Exposure Characteristics                                                                                                               | Exposure Duration                     | Melatonin Effect                                                  | Note                                                                                               |
|------------------|--------------|----------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------|-------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|
| Kato             | 1993         | 50 Hz<br>circularly polarized MF<br>1, 5, 50, 250 $\mu$ T                                                                              | 6 weeks<br>(2 h break per day)        | suppressed MEL                                                    | WK albino rats                                                                                     |
| Kato             | 1994         | 50 Hz<br>circularly polarized MF<br>1 $\mu$ T                                                                                          | 6 weeks                               | suppressed MEL                                                    | rats normal melatonin levels 1 week after cessation of field exposure                              |
| Kato             | 1994         | 50 Hz<br>1 $\mu$ T<br>0.02 $\mu$ T (controls)                                                                                          | 6 weeks                               | suppressed MEL                                                    | LE rats (albino + pigmented) slight MEL suppression also occurred in controls                      |
| Yellon           | 1994         | 60 Hz<br>1 mG                                                                                                                          | 15 min<br>(2 hours before lights off) | suppressed MEL                                                    | hamsters experiment was repeated 6 months later                                                    |
| Baum             | 1995         | 50 Hz<br>100 $\mu$ T                                                                                                                   | 24 h/day for 91 days                  | increased mammary tumor growth                                    | 216 DMBA rats                                                                                      |
| Löscher          | 1995         | <b>50 Hz</b><br><b>0.3 - 1 <math>\mu</math>T</b><br><b>10 <math>\mu</math>T</b><br><b>50 <math>\mu</math>T + 100 <math>\mu</math>T</b> | 24 h/day for 13 weeks                 | no increase non-significant significant increase in mammary tumor | ca. 200 DMBA rats significant linear relation between flux density and increase in tumor incidence |

**Table 8: Power Frequency (50/60 Hz) - Magnetic Field and Melatonin Effects II**

| Authors (et al.) | Year of Pub. | Exposure Characteristics                                        | Exposure Duration             | Melatonin Effect                                   | Note                                                                                                                                                                   |
|------------------|--------------|-----------------------------------------------------------------|-------------------------------|----------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Selmaoui         | 1995         | 50 Hz sinusoidal MF<br>100 $\mu$ T<br>10 $\mu$ T<br>100 $\mu$ T | 12 days<br>30 days<br>30 days | suppressed NAT<br>suppressed NAT<br>suppressed NAT | rats                                                                                                                                                                   |
| Mevisen          | 1996         | 50 Hz<br>100 $\mu$ T                                            | 91 days                       | suppressed serum MEL                               | 216 SD rats                                                                                                                                                            |
| Burch            | 1998         | 60 Hz ambient MF at home and at work                            |                               | reduced 6-OHMS                                     | electric utility workers greatest reductions if exposures at work and at home were combined                                                                            |
| Wood             | 1998         | 50 Hz<br>20 $\mu$ T (200 mG)                                    | night exposure                | delay in onset time<br>suppressed MEL              | 30 adult human males marginally significant                                                                                                                            |
| Burch            | 1999         | 60 Hz ambient MF at home and at work                            | 3 consecutive days            | suppressed MEL                                     | 142 male utility workers subjects with low workplace light exposures - high decrease (office workers!) subjects with high ambient light exposure - negligible decrease |

**Table 9: Power Frequency (50/60 Hz) - Magnetic Field and Melatonin Effects III**

| Authors (et al.) | Year of Pub. | Exposure Characteristics                  | Exposure Duration   | Melatonin Effect  | Note                                                                              |
|------------------|--------------|-------------------------------------------|---------------------|-------------------|-----------------------------------------------------------------------------------|
| Selmaoui         | 1999         | 50 Hz<br>100 $\mu$ T<br>sinusoidal MF     | 8 weeks<br>18 h/day | suppressed NAT    | Wistar male rats only in young rats (9 weeks) no decrease in old rats (23 months) |
| Brendel          | 2000         | 50 Hz and 16 2/3 Hz<br>at 86 $\mu$ T      | 8 hours             | suppressed MEL    | isolated pineal glands of Djungarian hamsters                                     |
| Burch            | 2000         | 60 Hz<br>3 phase conductors in substation | more than 2 hours   | suppressed 6-OHMS | electric utility workers                                                          |

|        |      |                                      |                     |                                                                 |             |
|--------|------|--------------------------------------|---------------------|-----------------------------------------------------------------|-------------|
| Ishido | 2001 | 50 Hz<br>1.2 $\mu$ T and 100 $\mu$ T | 3, 5, and 7<br>days | melatonin-induced<br>inhibition of cAMP<br>accumulation blocked | MCF-7 cells |
|--------|------|--------------------------------------|---------------------|-----------------------------------------------------------------|-------------|

**Table 10:  
Power Frequency - Electric and Magnetic Field and Melatonin Effects**

| Authors<br>(et al.) | Year of<br>Pub. | Exposure<br>Characteristics                                | Exposure<br>Duration | Melatonin<br>Effect               | Note                                             |
|---------------------|-----------------|------------------------------------------------------------|----------------------|-----------------------------------|--------------------------------------------------|
| Wilson              | 1990            | 60 Hz EMF<br>ca. 2 - 7 mG                                  | ca. 8 weeks          | suppressed 6-OHMS<br>excretion    | 32 women/10 men<br>CPW electric blanket<br>users |
| Rogers              | 1995            | 60 Hz<br>rapid on/off changes<br>electric field transients |                      | suppressed nocturnal<br>serum MEL | two baboons                                      |

**Table 11: Magnetic Field and Melatonin Effects**

| Authors<br>(et al.) | Year of<br>Pub. | Exposure<br>Characteristics                   | Exposure<br>Duration | Melatonin<br>Effect              | Note                       |
|---------------------|-----------------|-----------------------------------------------|----------------------|----------------------------------|----------------------------|
| Richardson          | 1992            | pulsed<br>0.4 G<br>static magnetic field      | 1 hour               | suppressed NAT                   | in vitro rat pineal glands |
| Lerchl              | 1998            | 1 Hz<br>40 $\mu$ T<br>200 ms on<br>800 ms off |                      | increased nocturnal<br>serum MEL | brook trout                |

**Table 12: Radiofrequency Radiation and Melatonin Effects**

| Authors<br>(et al.) | Year<br>of<br>Pub. | Exposure<br>Characteristics                                              | Exposure<br>Duration                                           | Melatonin<br>Effect  | Note                                                                                                                                                                    |
|---------------------|--------------------|--------------------------------------------------------------------------|----------------------------------------------------------------|----------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Altpeter            | 1995               | Shortwave Transmitter<br>Schwarzenburg<br>150 kW - 550 kW<br>10 - 20 MHz | sample taking<br>after 20 years<br>of operating<br>transmitter | suppressed<br>MEL    | local residents<br>after shut-down of radio station<br>in 1998 MEL increased<br>(Abelin T)<br><br>as low as 0.4 V/m + 1 mA/<br>m health effects in local re-<br>sidents |
| Burch               | 1997               | cellular telephones                                                      | usage more<br>than once per<br>day                             | suppressed<br>6-OHMS | 142 electric utility workers<br>preliminary observations                                                                                                                |

Just because plausible biological mechanisms are difficult to elucidate, the observations of actual bio-effects do not go away. Harvey and French (1999) were puzzled to see that the lower the microwave power levels tended to be, with which they exposed a human mast cell line (HMC-1), the larger the induced stress response genes were upregulated. Back in the 80s it had already been observed that bio-effects caused by ELF electromagnetic radiation in the non-thermal range follow a »window« pattern (Adey 1980). This mystery remains until today: at one specific frequency a large response can be seen and only a little further up or down hardly any (Berg 1999).

Since the calculations by King and Wu (1998), we now know that spherical cells are effectively shielded by their membrane against incoming exogenous fields. However, in cylindrical cells, which are long compared to their radius such as muscle or nerve cells, this shielding effect does not seem to take place. Therefore non-thermal effects of induced electrical fields appear to be possible in those cells at much lower levels.

Brainard (1999) from the Department of Neurology in Philadelphia argues that »given the ubiquitous nature of EMR and artificial light exposure along with the high incidence of breast cancer, even a small risk would have a substantial public health impact.«

## **Melatonin-EMR Information Network**

As can be seen by looking through table 4 to 12, there are various non-ionizing frequency bands in which nocturnal melatonin suppression occurs in addition to too much visible light at night (LAN) and too little light during the day. Though the evidence is just beginning to emerge, one thing becomes clear: melatonin activity in humans, rodents and other mammals can be influenced by various measures of non-ionizing electromagnetic energy, regardless of being visible or not.

The significance of field strengths and modulations and combinations thereof are much less clear. Because a myriad of possibilities for the promotion of an adverse melatonin effect exist, it is of utmost importance to take precise measurements in the real world. »Everything« should be captured according to Hansen (1997), including high-band-width, high-dynamic range, and long-duration data logging. At first glance, this suggestion looks cost prohibitive. However, that is the only way to find out.

So far mostly occupational and residential studies have observed significant changes in melatonin activity (Graham et al 2000). This does not take wonder because in the real world there is no control over relative orientation of the fields, the waveforms are not sinusoidal, sources turn off and on at random, transients are everywhere, artificial lighting conditions prevail. I, hereby, propose a network of data collection sites around the globe to monitor the change throughout the entire non-ionizing portion of the non-ionizing spectrum. Just like scientific institutions worldwide take the »pulse« of the earth by monitoring the geomagnetic activity (Geological Survey of Canada).

## Siting and Measuring Capacity of Data Collection Sites

Since the geographic distribution of breast cancer incidence follows a specific pattern as shown above, the stationary data collection sites should be placed accordingly: one in an urban center of Northeastern US with the highest incidence, one in a rural area in the same state with the lowest incidence; one in a southern US state with the lowest incidence, one in a southern US state with an increasing trend; one in an urban area of Korea with the highest incidence, one in a rural area of Korea with the lowest incidence. The data collection site should be stationed where people live, one also close to a power line and/or cell phone tower. Testing probes should be attached at ground level and at the highest floor level inhabited in a particular city.

The following frequency bands should be monitored 24 hours a day, most of them have been shown to influence melatonin rhythm (see tables 4 - 12).

| EMR                             | Frequency                    | Field Characteristics                                                                                                                                                                                                         |
|---------------------------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Static Magnetic Field           | 0                            | <ul style="list-style-type: none"> <li>• all geomagnetic disturbances &gt; 30 nT from the nearest geological survey site</li> <li>• locating magnetostatic disturbances in bed (e.g. metal springs, steel trusses)</li> </ul> |
| Electrostatic Field             | 0                            | <ul style="list-style-type: none"> <li>• atmospheric electricity from the nearest meteorological survey site</li> <li>• atmospheric activity, if possible</li> </ul>                                                          |
| AC Magnetic Field<br>ELF<br>VLF | 20 Hz - 2 kHz<br>2 - 400 kHz | <ul style="list-style-type: none"> <li>• intensity, temporal stability, energy spikes</li> </ul>                                                                                                                              |
| AC Electric Field<br>ELF<br>VLF | 20 Hz - 2 kHz<br>2 - 300 kHz | <ul style="list-style-type: none"> <li>• intensity, temporal stability, transients</li> </ul>                                                                                                                                 |
| RF Radiation                    | 300 kHz -<br>300 GHz         | <ul style="list-style-type: none"> <li>• intensity, modulation characteristic (amplitude, phase, frequency)</li> </ul>                                                                                                        |

Table 13: A total approach to EMR testing in relation to the occurrence of melatonin effects

Each frequency band would have to be covered with two sets of equipment: one being able to detect the original natural background radiation, if still possible, and one being able to register human-made background radiation. The testing equipment should also be able to keep track of maximum energy spikes, transients and modulation characteristics and store them as such. Mean values are of little value with respect to bioeffects. The superposition of a static field to an alternating one can cause dramatic changes in the response of intracellular signal transduction pathways (Kaiser 1992).

## Real World Measurements in Residential Settings at Night

The natural background radiation occurs in the nano and pico range whereas exposure from human-made sources in the residential setting can often range somewhere from micro to milli or higher. In order to determine whether it is advisable to stick closer to the natural range for long term well-being or if it is possible to change those settings without any co-promoting cancer effect in the future, it is suggested here to start monitoring exposures in residential bedrooms.

Since the field characteristics of each frequency band are different, there are two sets of measurements necessary. First, women suffering from breast cancer and healthy matched controls in the same high-risk age group 35 -45 are equipped with portable meters. Those portable meters should be able to monitor the ELF, VLF and RF range plus a light sensor because visible light exposure during the day or at night has a significant effect on the nocturnal melatonin serum level (Burch 1999). In addition, actual field measurements (Hansen 1997) covering all the frequency bands listed in table 13 should also be taken in the bedroom (8 hour data logging to detect energy spikes + spot measurements to capture transients), at best once a month or at least once each season. Due to electric heating, for example, the exposure in the ELF magnetic field range is usually higher during winter compared to summer.

Void morning urine samples can be used to perform a radioimmunoassay for 6-OHMS, a melatonin metabolite. Creatine-adjusted concentrations give reliable data to determine nocturnal melatonin serum level. To determine phase delays, samples would have to be taken throughout the night, which is reserved for laboratory studies.

Self-administered questionnaire surveys should ask for known risk factors and melatonin-relevant parameters: alcohol, stimulant & drug consumption; time, type and duration of exercise; time of last meal every day; essential fatty acid consumption; type of bed and mattress (with or without metal).

The stationary data collection sites should continue to monitor the background radiation as an ongoing business. So that this type of data will always be available. The measurements in the bedroom would ideally be taken every day. To cut costs but being able to cover a whole year, measurements could be taken once a week. It should be alternated between weekdays and weekend.

## Multivariate Analysis

Each field should be analyzed for the intensity (geometric time weighted average), temporal stability (standardized rate of change metric), and any unusual field characteristic such as transients in relation to 6-OHMS concentrations. The parameters of each field should also be analyzed for the relation between external, ambient measurements from the stationary sites and the mostly indoor measurements from the portable readings.

First, each single field analysis in combination with the melatonin metabolite levels should be related to light intensity during the day and light at night (LAN). After that each of the fields can be paired and correlated to see which field parameters seem to produce the highest effect when combined.

Finally, all the related data will have to be adjusted for age, known risk factors, and seasonal fluctuations in the melatonin level.



## Conclusions

Given the drastic change in the energy level of the non-ionizing portion of the electromagnetic spectrum in industrialized societies over the past 100 years, we as users of this natural resource share the responsibility to find out what consequences our applications have in the long term. In addition to laboratory work, the practical approach to monitor the »unpleasantries« (Hansen 1997) of electromagnetic exposure in everyday life with focus on the vulnerable sleep phase will reveal much needed data. Key is the exact field measurement across as many frequency bands as possible. Even if the numbers do not strike us particularly significant at the moment, they are indispensable to settle the EMR issue some day. Fundamental science is always about keeping good records.

If it turns out that breast cancer sufferers compared to healthy females in the same age group are exposed significantly more frequently to a higher field strength or combination of fields and modulations occurring in their bedroom, we would have a starting point to redesign our built electromagnetic environment based on health. However, the task is daunting because the overall exposure in an urban area is similar to all inhabitants. There are no real controls! That notwithstanding, the actual exposure can vary greatly in an individual case depending on their lifestyle, computer use, cell phone use, etc.

It became obvious that exogenous non-ionizing electromagnetic stimuli exert an influence on human melatonin cycle, be it subtle or great. Given the importance of melatonin as an oncostatic agent in the human body, anything contributing to an optimization of its rhythm and amount should be given appropriate attention.

The proposed Melatonin-EMR Information Network including its data collection sites, analytical tools and focus on real life situations, will serve this purpose.

Occupational health officers will have new data to support occupations susceptible to disrupted melatonin rhythms including shift workers, flight attendants and office workers by optimizing work schedules and adjusting the electromagnetic work environment accordingly. Professional health care providers will be able to practice preventive medicine with regard to optimal visible and non-visible »light« settings. Architects, builders and electrical contractors can begin to create spaces that are most beneficial to their inhabitants. Manufacturers of electric and electronic equipment already follow guidelines for electromagnetic compatibility with regards to electronic equipment and appliances, finally this will also include human parameters of tolerance. Subgroups with low melatonin levels such as is common in depression, SAD, sleep disorders, cancer, diabetes, arthritis will also benefit tremendously from preventive optimal settings of EMR.

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### **Melatonin Research Update with regards to Electromagnetic Field Exposure (2005)**

Over the past 4 years melatonin research has continued. The picture is still the same. As always there are studies that do not support the melatonin hypothesis (e.g. Travis 2004) , other observations, however, confirm that electromagnetic fields and waves have the potential of suppressing nocturnal melatonin levels. Please find a selection of recent studies with positive findings listed below:

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